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STUDY OF BIOLOGICAL PROCESSES ON THE U.S. SOUTH ATLANTIC SLOPE AND RISE

PHASE 2

by

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16. Abstract (Limit: 200 words) A total of 16 stations were sampled during a 2-year field program designed to characterize the biological, chemical, and sedimentary processes on the slope and rise off North and South Carolina. Box cores were taken along 4 transects at depths of 600-3500 m. The infauna yielded a total of 1202 species, 520 of which were new to science. Annelids were the dominant taxa in terms of density and numbers of species. Species diversity was highest at an 800 m site off Charleston. Infaunal densities were highest on the upper slope (600 m) and lowest on the rise (3000 m). Life history analysis yielded evidence of seasonality for two polychaete species. Two stations off Cape Hatteras in depths of 600 m and 2000 m had higher infaunal density, lower species diversity, and higher biomass than elsewhere on the Atlantic slope and rise. Higher than normal lead and hydrocarbon inventories suggest enhanced scavenging processes in this area. Faunal patterns on the Cape Lookout transect were generally typical for other localities on the Atlantic Slope and Rise. Faunal changes were detected off Cape Fear and Charleston that may be related to the enfluence of the Gulf Stream and associated sediment changes. Epifauna were most unusual on the Charleston Bump, where a hard bottom fauna dominated by filter feeding corals and sponges thrives in an area strongly swept by the Gulf Stream. Consistent faunal differences were found between the upstream and downstream sides of the bump. Data generated in the infaunal and epifaunal surveys supported the view that a partial zoogeographic barrier exists on the slope off North Carolina. This break was most evident between Cape Lookout and Cape Fear.

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

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LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF APPENDICES

CHAPTER 1. INTRODUCTION

OBJECTIVES

This is the final report on the "Study of Biological Resources on the U.S. South Atlantic Continental Slope and Rise" performed by Battelle New England Marine Research Laboratory, Woods Hole Oceanographic Institution (WHOI) and Lamont-Doherty Geological Observatory (L-DGO) for the U.S. Department of the Interior, Minerals Management Service (MMS). This report presents new data collected during Phase 2, or the second year, of the Program and includes some data developed in Phase 1. Phase 1 was initiated in October 1983 and included three seasonal oceanographic cruises during 1983-1984. The results of that effort were reported by Blake et al. (1985). The present report includes a presentation of results and synthesis of data generated from three seasonal oceanographic cruises during 1985. In addition, this report includes, where appropriate, a synthesis of the Phase 1 and Phase 2 results and the development of an overall characterization of the biological communities present off North and South Carolina. This multidisciplinary study has the following specific objectives:

1. To characterize biological, geological, and chemical properties of benthic environments at a limited number of stations within areas of potential oil and gas development on the U.S. South Atlantic Slope and Rise;

2. To monitor potential changes in these properties with time in order to determine the extent of natural temporal variation;

3. To determine the background distribution of materials (such as trace metals and hydrocarbons) that may accumulate at elevated levels due to future drilling operations;

The parameters measured as part of this study included benthic infaunal community structure, including determination of ash-free dry weight of infauna at two selected 2000-

m stations and size class data on five dominant polychaete species; megafaunal (epifaunal) population densities; hydrocarbon levels in sediments and faunal tissues; trace metal levels in faunal tissues; sediment grain size composition; levels of total organic carbon, hydrogen, and nitrogen (CHN) in sediments; and a limited collection of near-bottom temperature, salinity, and dissolved oxygen measurements. In addition, the U.S. Geological Survey (USGS) analyzed trace metals in sediments (Bothner et al., 1987).

The major components or tasks of the program are shown in Figure 1. Personnel from Battelle, WHOI, and L-DGO participated in the field program. For this report, Principal Investigators indicated in Figure 1 prepared the chapters associated with their special tasks.

BACKGROUND OF THE STUDY

This study was developed by the Minerals Management Service in response to concerns about exploratory drilling on the U.S. Atlantic Continental Slope and Rise (ACSAR). Prior to this program, there was little information available on deep-sea benthic communities in the U.S. South Atlantic region. Phase 1 was initiated, therefore, in order to provide a limited benthic characterization of the biological processes on the continental slope and rise off North Carolina. Phase 2 was to have been a two-year rig monitoring study in the same region. When drilling activities in the region were postponed, Phase 2 was modified to continue the characterization of the U.S. South ACSAR by sampling sites to the north and south of the Phase 1 stations. The final sampling design for Phase 2 was approved at a Scientific Review Board Meeting consisting of the Principal Investigators and three consultants: Dr. Jim Henry, University of Georgia (Marine Geology); Dr. Thomas Lee, University of Miami (Physical Oceanography); and Dr. Eugene Gallagher, University of Massachusetts, Boston (Marine Ecology).

The rationale for selection of the Phase 1 stations off Cape Lookout, N.C. and Cape Hatteras, N.C. was discussed in the previous report (Blake et al., 1985). The Phase 2 stations were selected on the basis of characterizing additional areas of potential oil industry interest off Cape Fear, N.C. and Charleston, S.C. and at another location off Cape Hatteras. The combined study designs of Phase 1 and 2 provide a broad regional coverage of the slope and rise from the northern limits of Cape Hatteras, N.C. south to

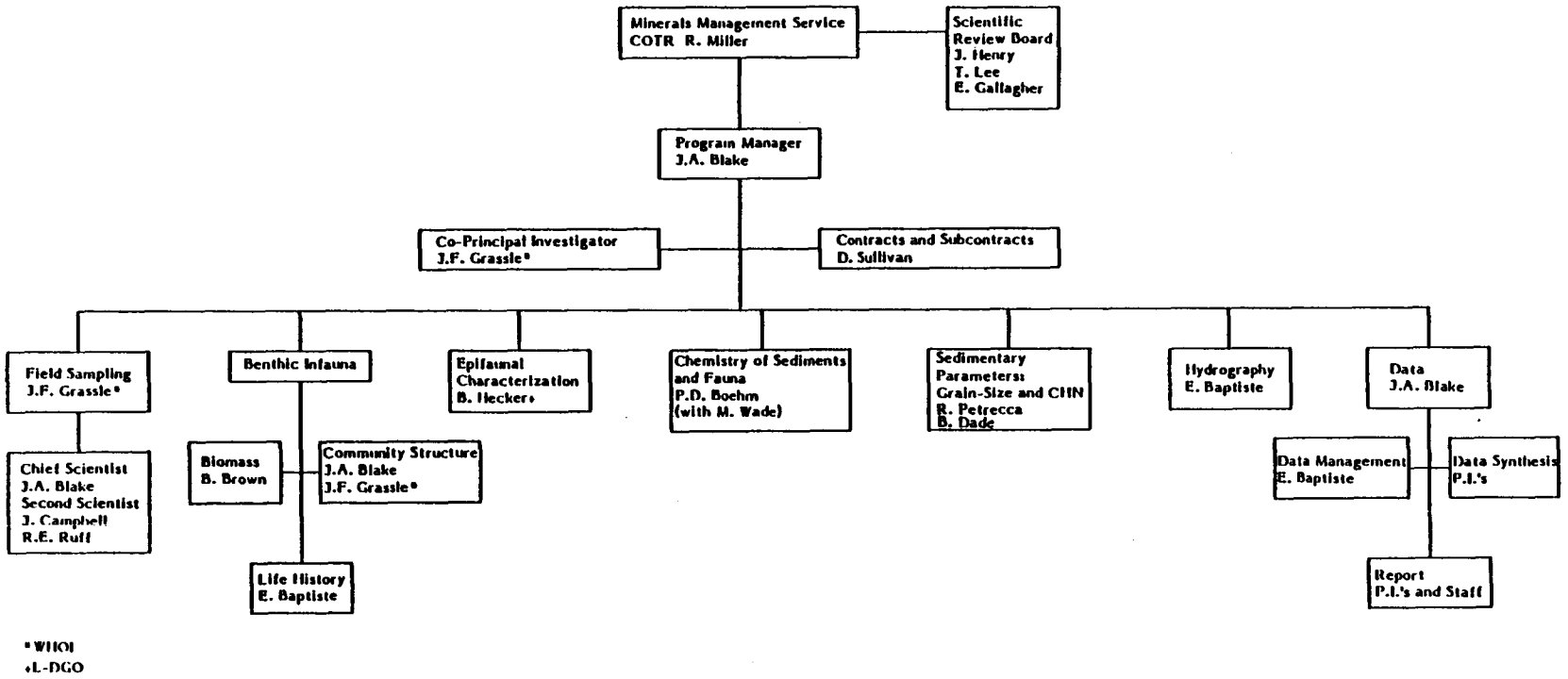


Figure 1. Program Organization Chart.

Charleston, S.C. Potentially unusual deep-sea environments in the area off Charleston where a gyre is formed as the Gulf Stream is deflected by the Charleston Bump are included.

Literature pertaining to the oceanographic environment of the U.S. South ACSAR has been reviewed as part of a larger environmental ACSAR summary (MGAI, 1984; Milliman and Wright, 1987). In addition, a major compilation of research on the Physical Oceanography of the Southeast U.S. Continental Shelf and Adjacent Gulf Stream was published as a special issue of the Journal of Geophysical Research (AGU, 1983), and more recently, the final results of the Blake Plateau Current Measurement Study have appeared (Han et al., 1986). Prior to the present program, the only previous biological studies in the U.S. South ACSAR included epifaunal studies, largely limited to the Hatteras Canyon (Rowe and Menzies, 1969; Rowe, 1971), and a limited infaunal characterization of the upper slope off North Carolina in depths of 400-600 m (Grassle 1967). Since Grassle used fine-mesh screens (0.297 μm), his results provide data comparable to that of present ACSAR program. Extensive surveys by Menzies in the 1960's have never been published as ecological reports, although several important taxonomic works have appeared (Southward and Brattegard, 1968; Southward, 1971; Cutler, 1973; 1975; Menzies et al., 1973). This limited regional biological database has been cited in the ACSAR summary (MGAI, 1984; Milliman and Wright, 1987) and in the Phase 1 report of the present program (Blake et al., 1985).

Due to the limited nature of previous studies in the region, the infauna inhabiting the slope and rise off North and South Carolina was essentially unknown prior to the U.S. South ACSAR program. As reported in the Phase 1 report, a rich and highly diverse benthic infauna was discovered along a five-station transect off Cape Lookout in depths ranging from 600 m on the upper slope to 3000 m on the continental rise (Blake et al., 1985). The infauna was found to be zoned or clustered into separate assemblages according to depth. Faunal breaks were also noted in the results of the epifaunal studies and supported previous work in the region. Nearly 900 species of benthic infaunal invertebrates were encountered, more than one third of which were determined to be new to science.

As the Phase 2 sampling program developed and the laboratory analyses proceeded, it became apparent that the new stations to the north and south of the Phase 1 stations were heterogeneous and markedly different from one another and the Phase 1 stations. For this reason, the present report includes more of a synthesis of the Phase 1 and Phase 2

data than originally conceived. This report thus presents a broad picture of biological communities on the slope and rise from Cape Hatteras, N.C. to Charleston, S.C. Where practical, we have also included comparisons with the results from the companion U.S. Mid- and North ACSAR Studies.

CHAPTER 2. FIELD SAMPLING PROGRAM

INTRODUCTION

The sampling plan for Phase 2 of the U.S. South Atlantic Slope and Rise Study was designed by Battelle, Woods Hole Oceanographic Institution (WHOI), and Lamont-Doherty Geological Observatory (L-DGO) personnel, and approved by the U.S. Minerals Management Service (MMS) following a Scientific Review Board Meeting on March 28, 1985. Nine primary stations were established to meet the objectives of the program (Figure 2). Two stations were located in the vicinity of Block 510 off Cape Hatteras, N.C., an area of interest to the oil industry, in depths of 600 m (Station 9) and 2000 m (Station 10). Station 9 was first sampled on Cruise SA-3 of Phase 1. One station at a depth of 2000 m off Cape Lookout, N.C. (Station 4) was retained from Phase 1 of the program for collection of long-term seasonal data. A cross-slope transect was established off Cape Fear, N.C. in depths of 800 m (Station 11), 2000 m (Station 12), and 3000 m (Station 13). A second transect was established on the northern Blake Plateau off Charleston, S.C. in depths of 800 m (Station 14), 2000 m (Station 15), and 3000 m (Station 16). The southern transect was established with reference to the Charleston Gyre, created by the deflection of the Gulf Stream off a topographic high known as the Charleston Bump (Brooks and Bane, 1978). It was anticipated that distinct areas of scour and deposition might be identified by this transect of stations. Stations 11 and 14 were originally located at a depth of 600 m, however, sandy sediments encountered at these locations during the first cruise of Phase 2 (SA-4) could not be retained by the box core. The structure of the box core is such that coarse or loose sediments may be lost through the space between the box and the spade. Stations 11 and 14 were relocated to an area at 800 m where the sediments were compact and therefore more easily sampled. The box core was later modified by attaching a coarse-textured mat to the spade, thereby sealing the space between the box and the spade. This modification resulted in the ability to sample a tenth station (Station 14A) at 600 m along the Charleston transect during the second cruise of Phase 2 (SA-5). Station reference coordinates and depths are given in Table 1.

The sampling plan for Phase 1 of the U.S. South Atlantic Slope and Rise Study consisted of a transect of five stations located off Cape Lookout, N.C. (Stations 1-5) and

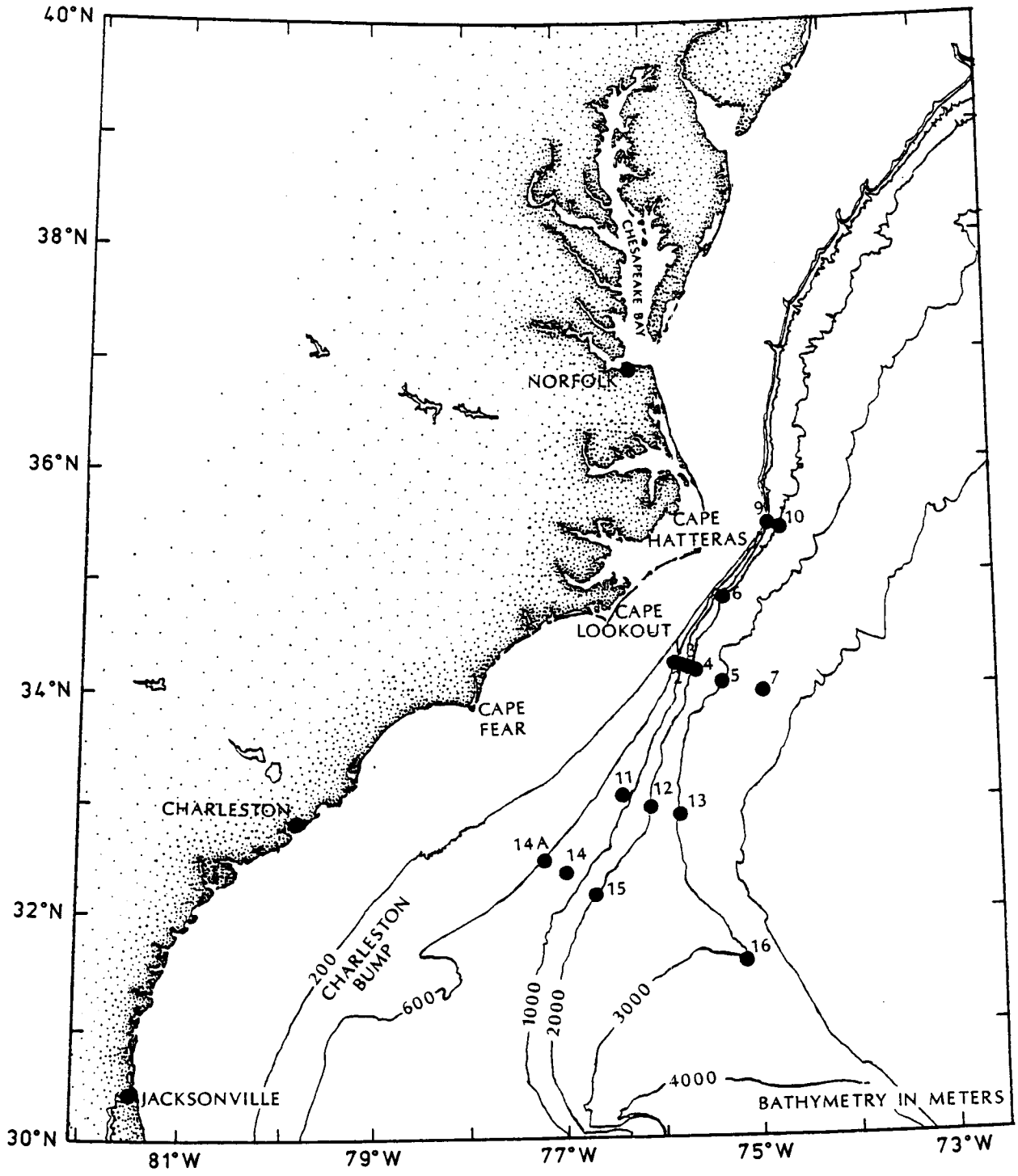


Figure 2. **Map of Study Area Showing Target Locations of Benthic Stations for Phases 1 and 2.**

TABLE 1. SOUTH ATLANTIC SLOPE & RISE STUDY, PHASES 1 AND 2 STATION REFERENCE COORDINATES.

Station	Latitude/Longitude*	Time Delays	Depth (m)
1	34°16.2'N 75°45.8'W	26917.4 39742.2	583
2	34°14.9'N 75°43.6'W	26909.2 39741.4	1000
3	34°14.8'N 75°40.1'W	26898.2 39757.1	1500
4	34°11.4'N 75°38.8'W	26891.0 39741.0	2000
5	34°06.0'N 75°19.0'W	26824.0 39797.0	3006
6	34°49.5'N 75°13.4'W	26840.0 40131.1	2004
7	33°57.9'N 74°56.3'W	26747.3 39848.0	3494
9	35°28.3'N 74°47.6'W	26780.2 40558.8	604
10	35°26.27'N 74°41.43'W	26756.1 40561.9	2003
11	33°04.86'N 76°25.13'W	44869.6 59265.0	800
12	33°00.31'N 76°07.39'W	44807.6 59271.5	1996
13	32°55.19'N 75°49.78'W	44746.5 59281.2	3015
14	32°23.64'N 77°01.13'W	44790.7 59588.2	805
14A	32°32.24'N 77°15.23'W	44869.1 59574.9	600
15	32°12.02'N 76°42.18'W	44688.4 59608.2	1993
16	31°35.23'N 75°10.62'W	44340.0 59610.9	3008

*Station positions based on time delays.

a sixth station at 2000 m located off Cape Hatteras, N.C. in the vicinity of Hatteras Canyon (Station 6). The transect stations were located at approximate target depths of 600 m (Station 1), 1000 m (Station 2), 1500 m (Station 3), 2000 m (Station 4), and 3000 m (Station 5) (Figure 2). Station 7 was established at 3500 m during the second cruise (SA-2) as an extension of the Cape Lookout transect.

In order to distinguish readily between the various transects in the U.S. South Atlantic Region, a code has been developed:

HA = Cape Hatteras transect (Block 510); Stations 9 (600 m), 10 (2000 m)

HC = Hatteras Canyon; Station 6 (2000 m)

LO = Cape Lookout transect; Stations 1 (600 m), 2 (1000 m), 3 (1500 m), 4 (2000 m), 5 (3000 m), 7 (3500 m)

FE = Cape Fear transect; Stations 11 (800 m), 12 (2000 m), 13 (3000 m)

CH = Charleston transect; Stations 14A (600 m), 14 (800 m), 15 (2000 m), 16 (3000 m)

METHODS

General Methods

Sampling procedures were consistent for all cruises and stations sampled during Phases 1 and 2. A box core was used to collect sediment samples for analysis of benthic infauna (macrofauna, meiofauna, and biomass), CHN, sediment grain size, trace metal chemistry, and hydrocarbon chemistry. Camera-sled transects were occupied to record microtopography and visible macro- and megafauna. An otter trawl was used to collect specimens for tissue analysis for background body burdens of trace metals and hydrocarbons. An otter trawl and a Day dredge were used to collect voucher specimens for correlation with film footage. Hydrocasts were conducted at each station using a Niskin bottle and three reversing thermometers to collect data on temperature, salinity, and dissolved oxygen characteristics of near-bottom waters. The Niskin bottle was used in conjunction with a conductivity-temperature-depth probe (CTD) during the second cruise of Phase 2 (SA-5) to provide a continuous profile from surface to bottom.

Box Core Sampling

A Hessler-Sandia MK III box core (0.25 m^2) was used to collect three replicate sediment samples at all stations (Figure 3). The procedures for use of the box core were patterned after Hessler and Jumars (1974) and followed modifications developed during Phase 1 of this program (Blake et al., 1985). The core box was partitioned into 25 "vegematic" aluminum subcores, each wth a surface area of 0.01 m^2. Each individual subcore was fitted with a removable 0.3-mm mesh screen to cover the top opening. The screens allowed water to escape as the box core entered the sediment, while trapping those animals present in the overlying water. Individual subcores were designated for various analyses as represented in Figure 4. A total of nine subcores were designated for benthic infaunal analysis, constituting a surface area of 0.09 m^2. Chemistry, sediment grain size, meiofauna, and CHN samples were collected from separate undisturbed subcores. Subcores designated for trace metals were coated with Teflon.

After collection of a replicate sample, the box core was retrieved and the sample box was disassembled by removing the front plate, exposing the 25 subcores which could then be removed individually. One CHN and two sediment grain-size samples of 15 cm^3 each were removed, placed in Whirlpak bags, and frozen. The subcore designated for meiofauna had two plexiglass core tubes, each 36 cm long and with an inner diameter of 19 mm, attached to its inner surface. The meiofauna subsamples were removed from the subcore, and 2 cm of the sediment, along with approximately 1 cm of overlying water, was extruded from the tube into glass jars and preserved with 5 percent formalin. Meiofauna samples were archived at Battelle.

Two subcores from each replicate were designated for trace metal analysis. An acid-cleaned, round plastic tube with an inside diameter of 8.2 cm was inserted into the center of the subcore to remove the sample, and then capped at both ends and frozen. These samples were transferred to the U.S. Geological Survey (USGS) in Woods Hole at the completion of each cruise. One subcore from each replicate was designated for hydrocarbon analysis. The top 2 cm of the subcore was extruded and sectioned into a prelabeled 250-ml Teflon jar. Frozen samples were transferred to Battelle for analysis.

Biology subcores were removed individually from the sample box and placed on top of a wooden extruding post that exactly fit the inside dimensions of the subcores (10 cm x

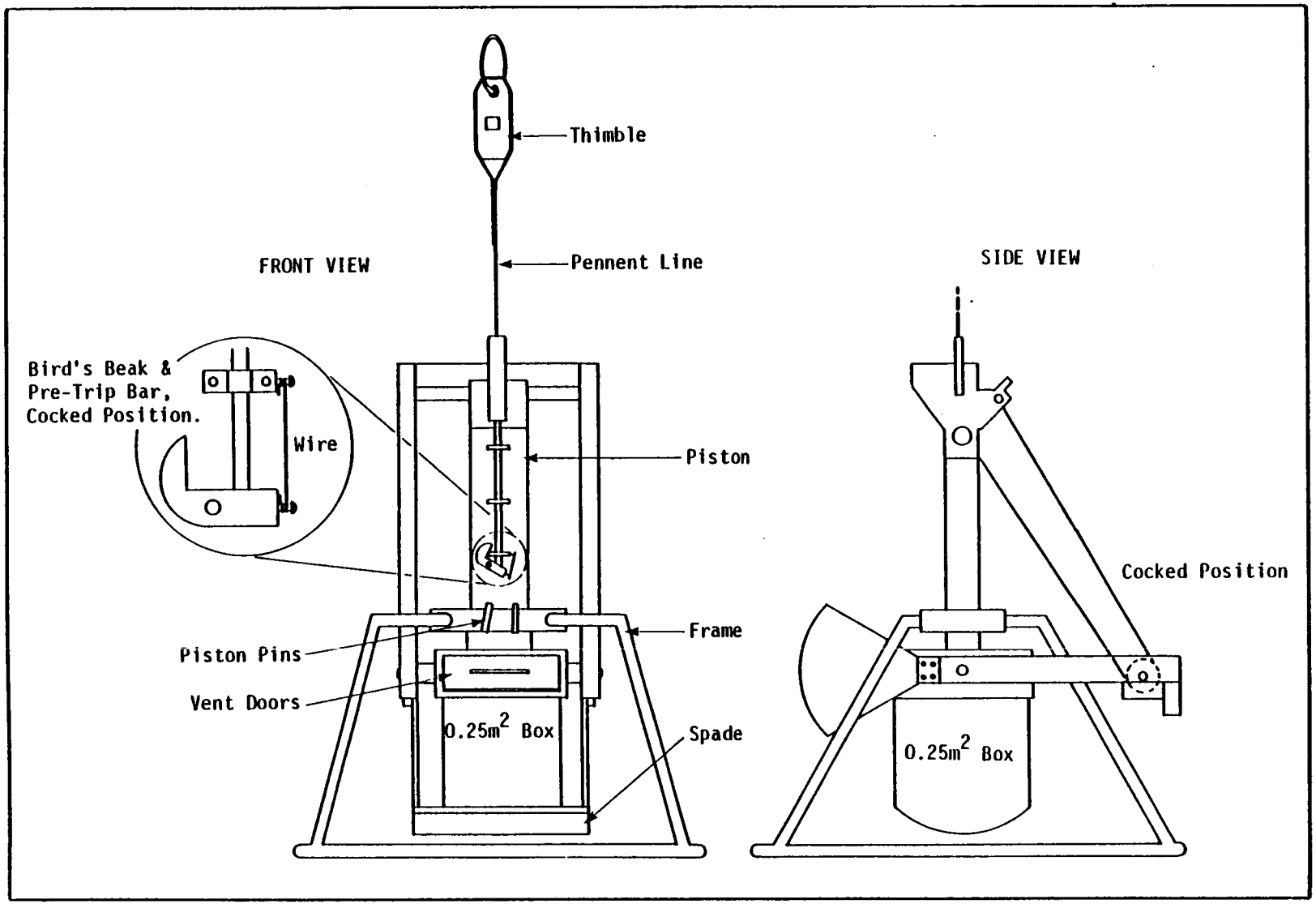


Figure 3. **The MK-III Box Core: Front View With Spade in Closed Position; Side Views With Spade in Cocked Position.**

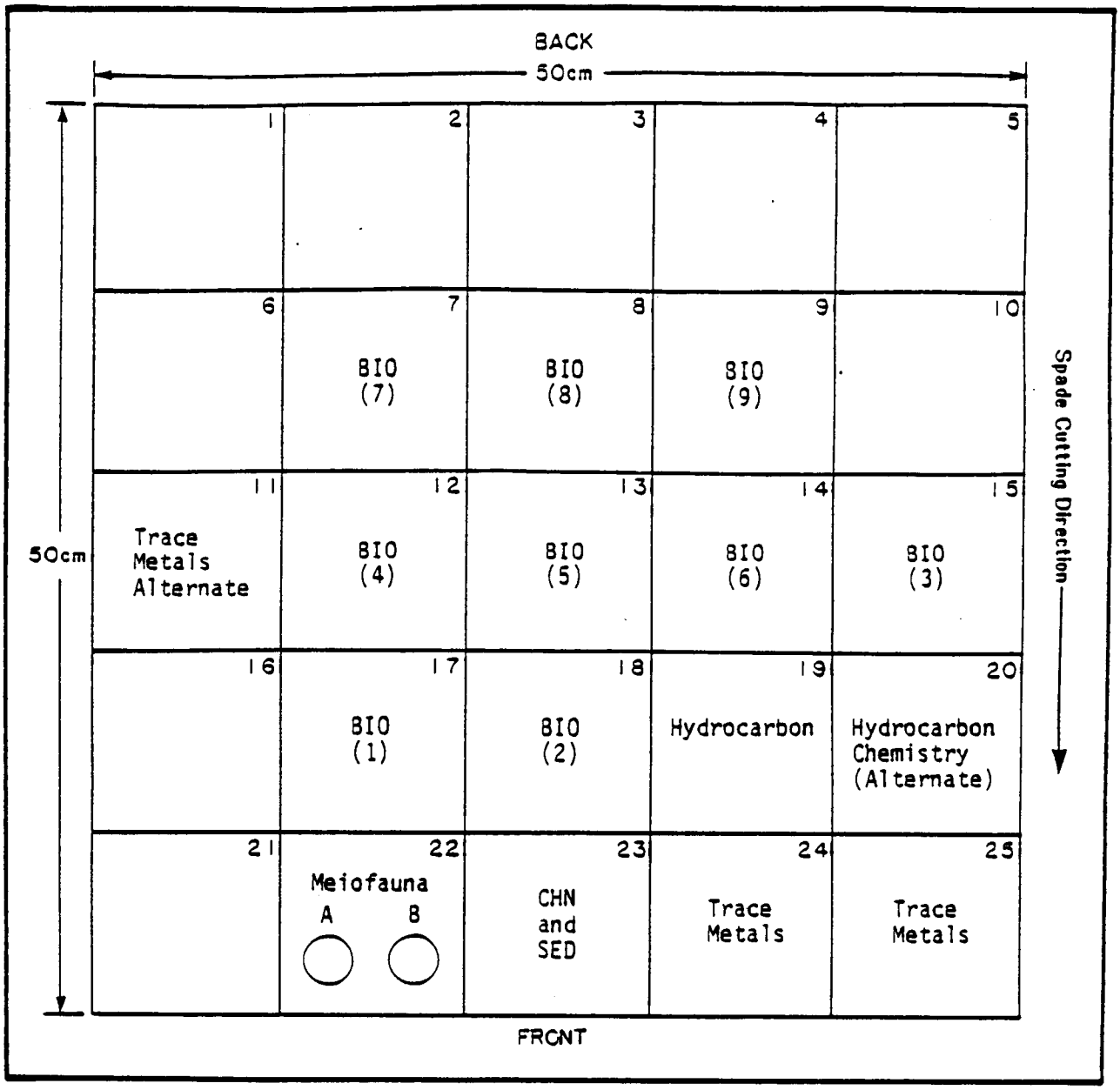


Figure 4. "Vegematic" Partitioning of the 0.25-m^2 Box Core for Phase 2. A Block of 9 Constitutes a 0.09-m^2 Biology Sample. Samples for CHN, Sediment Grain Size, Trace Metal Chemistry, Hydrocarbon Chemistry, and Meiofauna are Taken from the Subcores Indicated.

10 cm). The screen was removed from the top of the subcore and rinsed into a 0.3-mm sieve. The water overlying the sediment was siphoned into the same sieve. The sediment inside the subcore was extruded by pushing the subcore down over the wooden post. The top 10 cm of the subcore were removed by slicing the sediment with a stainless steel cutting blade. The upper flocculent portion was then rinsed directly into a glass jar to avoid excess damage to the animals and preserved in 10 percent buffered formalin. The lower compacted portion was sieved on a 0.3-mm mesh sieve and preserved in 10 percent buffered formalin.

Camera-Sled Transects

The camera sleds BERNEI (Benthic Equipment for Reptant and Natant Epifaunal Imaging) and BABS (Benthic Apparatus for Biological Surveys), both equipped with a Benthos Survey Camera, were utilized to photograph and characterize the epifauna in the study area. Techniques for the use of the camera sleds were developed as part of the MMS-sponsored project "Epifaunal Zonation and Community Structure in Three Mid- and North Atlantic Canyons" (Hecker et al., 1980). Dates, starting and ending positions, and depths of camera-transect surveys conducted during Phase 2 are presented in Table 2.

Epifaunal Collection

A steel-frame Day dredge and a 40-ft Gulf of Mexico otter trawl equipped with steel "V" doors for bottom trawling were used to collect epifaunal specimens for tissue analysis and correlation with bottom photography. The Day dredge was used primarily for the collection of voucher specimens in areas where substrate types were not conducive to sampling with the otter trawl (coral rock and boulders). Samples for tissue analysis were placed in prelabeled Teflon jars and frozen for storage. Most voucher specimens were preserved in 10 percent buffered formalin. Echinoderms were preserved in 70 percent alcohol.

TABLE 2. STARTING AND ENDING DATES, POSITIONS, AND DEPTHS OF CAMERA-SLED TRANSECTS SURVEYED DURING U.S. SOUTH ATLANTIC STUDY, PHASE 2.

Tow	Date	Position	Depth (m)
11	17 May 85	31°29.78'N 78°51.04'W	473
	18 May 85	31°16.66'N 79°00.99'W	610
12	18 May 85	31°49.83'N 78°18.26'W	628
	19 May 85	31°42.33'N 78°23.68'W	643
13	24 May 85	35°28.97'N 74°38.20'W	2013
	25 May 85	35°28.18'N 74°48.25'W	558
14	17 Sep 85	32°11.03'N 76°41.67'W	2052
	17 Sep 85	32°21.18'N 76°56.38'W	863
15	19 Sep 85	32°20.98'N 76°55.53'W	877
	19 Sep 85	32°28.66'N 77°08.55'W	692
16	20 Sep 85	32°28.32'N 77°08.03'W	705
	21 Sep 85	32°35.02'N 77°15.51'W	560
17	28 Sep 85	35°28.17'N 74°39.60'W	1895
	28 Sep 85	35°28.30'N 74°49.47'W	300

TABLE 2. (Continued).

Tow	Date	Position	Depth (m)
18	16 Nov 85	31°43.94'N 78°22.11'W	665
	16 Nov 85	31°37.12'N 78°34.42'W	461
19	17 Nov 85	31°37.38'N 78°42.17'W	433
	17 Nov 85	31°34.77'N 78°46.88'W	449
20	21 Nov 85	33°00.15'N 76°05.87'W	2132
	22 Nov 85	33°01.44'N 74°13.77'W	1580
21	25 Nov 85	35°30.39'N 74°43.67'W	1375
	25 Nov 85	35°27.43'N 74°49.74'W	311

Hydrographic Measurements

Hydrocasts were performed at all stations. A 5-l Niskin bottle equipped with three reversing thermometers was used to collect near-bottom water samples for dissolved oxygen, salinity, and temperature measurements. Dissolved oxygen measurements were performed on board ship in triplicate, using the Winkler titration method. Triplicate salinity samples were drawn and stored for transfer to WHOI where they were analyzed using a conductivity probe. On Cruise SA-5, a Neil Brown Mark III CTD unit was used in conjunction with the Niskin bottle. The CTD was mounted below the Niskin bottle and the unit was integrated with the R/V Gyre's Hewlett Packard computer system to give a continuous graphic profile of temperature and salinity from surface to bottom.

Navigation

A computerized navigation/data logging system was used during Phase 2. This system provided continuous updates on navigation data being input by a Northstar 7000 LORAN-C receiver. The ship's positon was displayed graphically on an EPSCO Plotter and digitally on a monitor, while it was simultaneously recorded on disk and hardcopy printout. The system provided information on the ship's real-time position as well as navigation tracks to and from various waypoints during transit. In addition, the system recorded station-related data and general comments were also recorded. An Apple IIE microcomputer, coupled with an InFax hard-disk drive (Bernoulli Box) equipped with an Iomega 10-megabyte removable cartridge comprised the system. At the end of each cruise the station data was printed to provide a hardcopy record.

Technical problems experienced during SA-4 made it necessary to utilize a simplified navigation system consisting of a Northstar 7000 LORAN-C receiver and a SAIL system provided by Duke University Marine Laboratory. The SAIL system consisted of a Hewlett Packard HP-85 microcomputer that provided a continuous printout of the ship's position. Actual station positions were obtained by storing the data in the memory of the Northstar 7000 and recovering the data for entry into hand-written station logs. These positions were then compared with similar data recorded on the ship's bridge.

RESULTS

Three sampling cruises, requiring 42 days at sea, were conducted during Phase 2 of this program (Table 3). Research vessels included the 137-ft. R/V Cape Hatteras (Duke University) and the 180-ft. RV Gyre (Texas A&M University). A total of 76 box cores for infauna, six box cores for biomass, eight otter trawls, 5 Day dredge hauls, 11 camera transects, and 78 hydrocasts were completed (Table 4). A general overview of each of the three cruises is contained in Appendix A. Included in that review is a summary of sampling positions, depths, and dates for each cruise (Table A.1). Positions of each replicate box core and hydrocast are plotted in Figures B.1 through B.10 (Appendix B).

TABLE 3. SCHEDULE OF CRUISES IN THE U.S. SOUTH ATLANTIC STUDY AREA, PHASES 1 AND 2.

Cruise	Date	Ship Used	Stations Sampled
Phase-1			
South-1	Nov 1983	R/V Columbus Iselin	1, 2, 3, 4, 5, 6
South-2 leg 1	Mar 1984	R/V Cape Hatteras	1, 2, 3 (Reps. 1-2)
South-2 leg 2	May 1984	R/V Gyre	3 (Rep. 3), 4, 5, 6, 7+
South-3	July 1984	R/V Gyre	1, 2, 3, 4, 5, 6, 9
Phase-2			
South-4	May 1985	R/V Cape Hatteras	4, 9, 10, 11, 12, 13 14, 15, 16
South-5	Sep 1985	R/V Gyre	4, 9, 11, 12*, 13 14, 14A, 15, 16
South-6	Nov 1985	R/V Cape Hatteras	4, 10, 11, 12, 13, 14, 15*, 16

*Only one replicate box core taken.
+Only two replicate box cores taken.

TABLE 4. SUMMARY OF SAMPLES COLLECTED AND ANALYZED FOR THE SOUTH ATLANTIC PHASE 2 STUDY.

Sample Type	Number of Stations or Transects	Number of Replicates per Station	Number of Cruises	Total Collected	Total Analyzed
Infaunal Box Cores	7-9[e]	3	3	73	76[d]
Meiofauna	7-9[e]	6	3	146	0
Sediment Grain Size	7-9[e]	3	3	73	76[d]
Sediment CHN	7-9[e]	3	3	73	76[d]
Sediment Hydrocarbons	7-9[e]	3	3	73	76[d]
Sediment Trace Metals[a]	7-9[e]	7[b]	3	189	192[d]
Camera Sled Tows	3-4[e]	1	3	11	11
Biomass Box Core	2	3	1	6	6
Hydrography					
Dissolved Oxygen	7-9[e]	3	3	75	78[d]
Salinity	7-9[e]	3	3	75	78[d]
Temperature	7-9[e]	3	3	75	78[d]
Day Dredge[c]	5	1	1	5	5
Otter Trawls[c]	1-4[e]	1	3	8	8
CTD Casts	9	1	1	9	9

[a] Sediment trace metal samples are analyzed at USGS, Woods Hole.
[b] One extra trace metal core per station for M. Bothner (USGS).
[c] Day dredges and otter trawl samples are analyzed at Lamont-Doherty Geological Observatory.
[d] Total includes analysis of three replicates from SA-3 Station 9.
[e] Number of stations varied by cruise.

CHAPTER 3. BENTHIC INFAUNAL COMMUNITY STRUCTURE

INTRODUCTION

The analysis of the infaunal samples taken from the box cores was one of the major efforts of this program. This effort has been directed toward characterizing the benthic infaunal communities on the continental slope and rise off the Carolinas. During the course of this program, from the initial cruise during Phase 1 in November 1983 to the completion of the sixth cruise in Phase 2 in 1986, a total of 130 0.09-m^2 samples were processed. Seventy-three box cores were processed in Phase 2 and are the focus of the present report. Because of the faunal differences encountered in the Phase 2 stations, we have enlarged the scope of this report to include a synthesis of Phase 2 community data with that of Phase 1. This allows us to better assess the differences encountered among all of the stations sampled, and to provide a more complete characterization of the continental slope and rise off North and South Carolina. This synthesis also provides the basis for a larger synthesis with the now completed U.S. Mid-Atlantic Study and the soon-to-be-completed U.S. North Atlantic Study.

In general, the deep-sea benthos and the processes that affect it are poorly known. Through the pioneering works of Sanders and Hessler in the 1960s, we know the deep-sea environment supports a high diversity of infaunal organisms (Hessler and Sanders, 1967; Sanders, 1968). This concept was developed through the use of fine-mesh screens (0.3 mm) and large samples obtained with the semi-quantitative epibenthic sled. Several major taxonomic studies based on these samples (Hartman, 1965, Hartman and Fauchald, 1971: polychaetes; Rex, 1973: gastropods; Hessler, 1970: isopods; Allen and Sanders, 1973, Sanders and Allen, 1973: bivalves) have confirmed the concept of high diversity in the deep sea. In the past, few efforts have been directed toward characterizing the entire benthic community of deep-sea environments. Although many samples have been taken, most of these have only been analyzed for a portion of the fauna, e.g., polychaetes, isopods, or bivalves. Prior to the present efforts, fewer than 100 box cores had been fully analyzed for macroinfauna. The 130 box cores analyzed in entirety in the U.S. South Atlantic program thus exceed the previous worldwide total of fully analyzed box cores. When taken together with the U.S. Mid- and North Atlantic companion programs, the

present ACSAR program is by far the most extensive effort to characterize and understand the processes regulating deep-sea benthic communities ever attempted anywhere in the world.

In the pages which follow, the details of species richness, infaunal density, species diversity, and patterns in community structure are presented. In addition, some limited data on life history parameters of selected dominant polychaete species is discussed and the question of a zoogeographic boundary off the Carolinas is addressed. These results are discussed and compared with the pertinent literature as well as the U.S. South Atlantic Phase 1 report (Blake et al., 1985), the U.S. Mid-Atlantic Final Report (Maciolek et al., 1987), and the U.S. North Atlantic Interim Report (Maciolek et al., 1986b).

METHODS

Methods for the field collection and handling of samples are presented in Chapter 2. Laboratory methods involved in processing the samples and statistical methods used for data analysis are discussed in this chapter.

Sample Processing

Each sample was logged into a Battelle laboratory record book by sample code number, number of containers per sample, and date received. Each subcore was resieved on a 0.3-mm mesh screen and transferred from formalin to 70 percent ethanol. All samples were labeled both inside and outside the container. Technicians responsible for these procedures signed the appropriate sample tracking sheet.

All sample sorting was conducted at Battelle. In order to maintain sample integrity, each set of nine subcores constituting a replicate sample was assigned to one technician for sorting. Samples were stained with a saturated solution of Rose Bengal at least four hours prior to sorting. Because overstaining impairs the identification process, the Rose Bengal was not allowed to remain in the sample for more than one day. The excess stain was removed by rinsing the sample with water and transferring it to clean 70 percent ethanol. The 0.3-mm screen was used for this procedure.

Samples were examined under a dissecting microscope and each organism removed. Organisms were sorted to major taxonomic groups or lower, depending on the experience of the technician. Major taxonomic groups found in the samples included polychaetes, oligochaetes, bivalves, scaphopods, gastropods, echinoderms, amphipods, isopods, tanaids, and miscellaneous categories such as anemones, nemerteans, hemichordates, tunicates, sipunculids, and pogonophorans.

Each organism was identified to the lowest practicable taxon, usually to the species level. In some cases, designations including "spp. juvenile" or "spp. indeterminate" were used when the stage of development or condition of the specimen precluded further identification.

Counts of the individuals of each species were originally recorded separately for each subcore for the first set of samples collected during Phase 1. Although this procedure provided data on microspatial distribution of the infauna, it proved to be very time consuming, and beginning with the second set of Phase 1 samples and continuing for all Phase 2 samples, the specimens from the nine separate subcores were pooled, resulting in one set of counts for each box core.

Certain taxonomic groups, i.e., amphipods, isopods, tanaids, bivalves, and scaphopods, were transferred to WHOI for identification. All sample transfers were accompanied by the appropriate tracking and data sheets.

All other taxonomic groups, including polychaetes, oligochaetes, echinoderms, decapod crustaceans, gastropods, aplacophorans, pogonophorans, and sipunculids, were identified at Battelle. Dr. Leslie G. Watling, University of Maine, identified all cumaceans.

Life History Analysis

In order to develop additional data on seasonality and recruitment in deep-sea benthic communities and to learn more about the reproduction and life history characteristics of the benthic infauna, a limited analysis of life history parameters was performed on five dominant species of polychaetes. Specimens were selected from two U.S. South Atlantic stations: Station 4 from 2000 m off Cape Lookout and Station 9 from 600 m off Cape Hatteras. The species were chosen on the basis of their overall

importance in slope and rise benthic communities and dominance at either Station 4 or Station 9. Polychaetes from Station 4 included Pholoe anoculata, Aurospio dibranchiata, and Microrbinia linea. Species from Station 9 included Scalibregma inflatum and Cossura longocirrata.

A series of measurements of morphological characters were made for each species studied. Such measurements included thoracic width, prostomial length, length of the branchial bearing region, and number of branchial pairs. These measurements were regressed against the total number of setigers in order to determine the best fit. This proved to be a valuable technique for those species that fragment easily and for which it was not possible to determine the total number of setigers.

In addition to determining size class frequency of each species, all specimens were examined under the compound microscope for evidence of reproductive characteristics. The presence of eggs (or oocytes), their size and location in or on the body, the presence, location and arrangement of sperm or spermatophores, the presence and degree of development of brooded young, and the presence of any obvious or unusual reproductive structures were recorded. Thin sections were cut of selected specimens in order to interpret reproductive structures. Specimens were embedded in formalin-agar (Baldorac, 1979), cut at 5 μm, and stained with hematoxylin and eosin, using standard histological procedures.

Quality Control

Quality control procedures included resorting a minimum of 10 percent of all samples sorted by each experienced technician and 100 percent of samples sorted by each new technician. If the percentage of organisms missed exceeded 5 percent, the sample failed the quality control check. Additional samples sorted both prior and subsequent to the failed sample were then also checked until the percentage of organisms missed was below 5 percent in five consecutive samples. When this requirement was met, the number of samples checked was reduced to one in ten.

Species identifications were confirmed by several consultants, including Dr. Michael Rex, University of Massachusetts, gastropods; Dr. John Allen, Dove Marine Laboratory,

Scotland, thyasirid bivalves; Dr. Leslie G. Watling, University of Maine, amphipods; Dr. George D.F. Wilson, Scripps Institution of Oceanography, isopods; Dr. Kenneth Sebens, Northeastern University, anthozoans; Dr. Edward Cutler, Union College, sipunculids; Dr. Christer Erseus, University of Goteburg; and Ms. Amalie Scheltema, WHOI, aplacophorans.

Data Reduction and Analysis

Infaunal Data

Completed data sheets were coded at Battelle, keypunched at the University of Rhode Island (URI) and entered into the VAX 11/780 computer at WHOI. Most keypunching errors were corrected at URI using a two-operator, double keypunch system. Verification of hard copy printout and correction of errors was conducted jointly by Battelle and WHOI. The individuals for which the species identification was uncertain (juveniles, anterior fragments, etc.) were not used for calculation of similarity or diversity indices, but were included for tabulation of density. Animals attached to hard surfaces such as rocks and shells, and parasitic and planktonic species were excluded from all analyses. The excluded species are indicated by an asterisk on the species list in Appendix C.

Statistical treatment of the infaunal data set included an agglomerative clustering technique (Williams, 1971) to determine similarity between samples. The first step in this classification involves measuring similarity between all pairwise combinations of samples, beginning with the most similar pairs, and subsequently combining samples until they all form one large group. The similarity measure used was NESS, the Normalized Expected Species Shared (Grassle and Smith, 1976), in which the comparison of expected species shared is between random samples of a set number of individuals from the initial collection of individuals in each replicate. Since two equal subsamples, drawn from within each of the original samples, are required for normalization, samples with less than twice the specified number of individuals are excluded from the analysis. For the present analyses, the number of individuals (m) usually was set at 50 and 200. However, for replicates compared separately rather than combined, m was set at 20. The clustering

strategy used was group average (Boesch, 1977). NESS similarity, followed by group average clustering, was also used with polychaete data alone, with m set at 20 individuals. The Bray-Curtis coefficient (Boesch, 1977), with group averaging sorting, was also used as a similarity measure. This test was performed on both untransformed data and on a square root transformation of the entire data set. Analyses were performed on replicates combined for each station on each sampling date; additional analyses were performed on individual replicates.

NESS (m=200) and Bray-Curtis similarity coefficients were calculated for the entire data set (Phases 1 and 2) with cruises and replicates combined. The similarity matrices are presented as trellis diagrams. The same procedure was applied to the polychaetes, bivalves, and peracarids separately using Bray-Curtis.

An inverse classification was performed on data from both Phases 1 and 2 with Bray-Curtis (R-mode) (Boesch, 1977). Species with a total abundance of less than one hundred were eliminated from this analysis. A nodal analysis was performed utilizing these results (Boesch, 1977). The species were separated into groups and used to construct a two-way table that shows stations on the vertical side and species groups on the horizontal side. This technique is used to measure constancy: a proportion derived from the number of occurrences of a species group in a replicate group as compared with the total possible occurrences.

Species abundances were ordinated by the method of reciprocal averaging (Hill, 1973; 1974) using the Cornell program DECORANA (Hill, 1979). Ordination analysis was performed on individual replicates after a two-step truncation process. First, species were excluded from the analysis if they had a total abundance of less than 10 when abundances in all replicates, stations, and sampling dates were summed. Second, species were deleted from a replicate if only one individual was present in that replicate.

Benthic community parameters, including Shannon-Wiener diversity (H') and its associated evenness value (E), were calculated for each replicate of the six sample sets, and also for replicates combined for each station/cruise combination. Shannon-Wiener diversity (H') was calculated:

$$H'(s) = -\sum p_j \log p_j$$

where s is the total number of species and p_j is the observed proportion of individuals belonging to the j^{th} species (j = 1, 2,....., s).

Hurlbert's modification (1971) of the rarefaction method (Sanders, 1968) was used to predict the number of species in a random sample, given a population N:

$$E\left[S_m \middle| N\right] = \sum_{i=1}^{k} 1 - \frac{(N_m - N_i)}{\binom{N}{m}}$$

where N is the finite population of species i; N is $(N_1, N_2, ...N_k)$, a vector representing the entire finite population, N is the total number of individuals in the finite population:

$$\sum_{i=1}^{k} N_i \quad ;$$

and S_m is the random variable denoting the number of species in a sample size m (Smith and Grassle, 1977). For the rarefaction analyses, the number of individuals was set at 32 points ranging between 25 and 25,000. Increments between points were as follows: 25 individuals between 25 and 100; 100 individuals between 200 and 1000; 500 individuals between 1000 and 2000; 1000 individuals between 2000 and 10,000; 2000 individuals between 10,000 and 20,000; and 5000 individuals between 20,000 and 25,000.

The average number of new species contributed by the k replicate from a set of samples drawn from a total number of n replicates was computed using the method of Gaufin et al. (1956). The increase in the number of new species added as the number of replicates is increased was plotted for each station separately.

Hypotheses comparing species densities between selected stations and cruises were tested with the Student t-test, one-way ANOVA, or two-way ANOVA, depending on the number of cruises or stations involved. The Student-Newman-Keuls (SNK) multiple

comparison tests (Sokal and Rohlf, 1969) was used to identify significantly different stations or cruises when ANOVA main effect terms were significant ($p>.05$). If the station and cruise interaction term was significant in the two-way ANOVA, a SNK test was performed on each individual cruise. In all tests, $p > .05$ was considered statistically significant.

Transformed data was used in the analysis if the maximum to minimum variance ratio between any station and cruise used to test a hypothesis was reduced by transformation.

Life History Data

All data were coded and entered into the VAX 11-780 computer at Woods Hole Oceanographic Institution. Analysis was either run on the WHOI VAX or transferred to the VAX 11-750 at Battelle. At WHOI, the subprogram NEW REGRESSION of SPSS (Statistical Package for the Social Sciences; Hull and Nie, 1981) was used to fit the "best" regression equation relating setiger count to the measured variables, the natural $\log_e (X)$, square (X^2) and cube (X^3) of each variable were calculated and also entered into the analysis. The same calculations were run at Battelle using the MINITAB Statistical Package. The resulting equations and their associated coefficients of determination (R^2) were used to calculate the number of setigers for those specimens for which direct setiger counts were lacking. Subprogram FREQUENCIES of the SPSS package (Nie et al., 1975) was used to generate frequency distribution for each species by cruise at five-setiger intervals. A full range of statistics was also generated, including means and standard deviations for each set of measurements. It was not possible to fit a regression to Microrbinia linea due to an insufficient number of entire specimens that could be used for for counts of total setigers. As an alternative, the thoracic width was used directly for the frequency distribution.

RESULTS

Taxonomy

A total of 1202 benthic invertebrate species from 16 phyla have been identified from the box core samples from the U.S. South Atlantic Slope and Rise Study (Table 5; Appendix C). This represents a net increase of 325 species over the total reported for the Phase 1 study, and reflects the results of sampling in the region to the south of Cape Lookout.

Of the 1202 species recorded in this study, over 40 percent are new to science (Table 5). Approximately 288 species of polychaetes (53 percent) are undescribed, including more than 75 percent of the species within the families Cirratulidae, Dorvilleidae, and Spionidae. One hundred and forty-five species of arthropods (53 percent) are new, including nearly two-thirds of the tanaids and cumaceans (64 and 18 species, respectively), half of the isopods (30 species), and over 43 percent of the amphipods (32 species). Fifty-three species of molluscs (29 percent) are undescribed, including a third of the bivalves (32 species). New species were also noted in the Oligochaeta (8 species), Nemertea (4 species), Pogonophora (4 species), and Sipuncula (2 species).

The percent representation of each phylum is similar to that reported for the Phase 1 study, and is listed in Table 5. The annelids accounted for 46.9 percent of the total number of species and include 542 species of polychaetes in 50 families, along with 22 species of oligochaetes in two families. The Spionidae was the best represented polychaete family with a total of 62 species. The Paraonidae, Ampharetidae, Cirratulidae, Phyllodocidae, and Dorvilleidae were also well represented, with 35, 33, 31, 29, and 28 species, respectively.

The phylum Arthropoda was the next most important component of the fauna, accounting for 22.5 percent of the recorded invertebrate species. The order Tanaidacea (100 species) was the dominant arthropod group, followed by the Amphipoda (74 species), Isopoda (59 species), and Cumacea (29 species).

Nearly 15 percent of the species were molluscs, including bivalves (83 species), gastropods (46 species), aplacophorans (36 species), and scaphopods (15 species). The

TABLE 5. SUMMARY OF MAJOR TAXONOMIC GROUPS RECORDED IN U.S. SOUTH ATLANTIC SAMPLES.

Taxonomic Group	Named Species	Undescribed Species	Genus* and Species Undetermined	Total Species Recorded	Percent Entire Fauna
Porifera		1	10	11	0.9
Cnidaria					3.9
Hydrozoa	10	1	18	29	2.4
Anthozoa	6	2	9	17	1.4
Scyphozoa			1	1	0.1
Platyhelminthes			1	1	0.1
Nemertea		4	16	20	1.7
Priapulida	2	1		3	0.2
Annelida					46.9
Polychaeta	183	288	71	542	45.1
Oligochaeta	12	8	2	22	1.8
Echiura			5	5	0.4
Sipuncula	15	2	2	19	1.6
Pogonophora	10	4		.14	1.2
Mollusca					15.0
Gastropoda	33	10	3	46	3.8
Aplacophora	3	9	24	36	3.0
Bivalvia	44	31	8	83	6.9
Scaphopoda	11	3	1	15	1.3
Arthropoda					22.5
Pycnogonida		1		1	0.1
Arachnida			1	1	0.1
Cephalocarida	1			1	0.1
Ostracoda			1	1	0.1
Cumacea	8	18	3	29	2.4
Decapoda	1	1	2	4	0.3
Isopoda	29	30		59	4.9
Tanaidacea	26	64	10	100	8.3
Amphipoda	11	32	31	74	6.2
Bryozoa	6	7	3	16	1.4
Brachiopoda	2		1	3	0.2
Echinodermata					3.5
Crinoidea			1	1	0.1
Echinoidea		2	9	11	0.9
Ophiuroidea	6	2	9	17	1.4
Asteroidea	2			2	0.2
Holothuroidea	6		5	11	0.9
Hemichordata			4	4	0.3
Chordata	1		2	3	0.2
Total	428	520	254	1202	100.0

* Generic identification in some cases not yet worked out due to insufficient, poorly preserved, damaged, or juvenile material.

remaining phyla were relatively less common. The cnidarians and the echinoderms each accounted for less than 4 percent of the total number of species (47 and 42 species, respectively). Twenty species of nemerteans and 19 species of sipunculans were recorded. The pogonophorans, an animal group typically found in deep-sea environments, were represented by 14 species.

A comparison of the occurrence of the 1202 taxa found in the U.S. South Atlantic stations with their occurrence in the U.S. Mid- and North Atlantic regions is shown in Table 6. A total of 485 species representing 40.3 percent of the total of 1202 species occur only in the south: 145 species (12.1 percent) are shared with the U.S. Mid-Atlantic region; 99 species (8.2 percent) are shared with the U.S. North Atlantic region; and 473 (39.4 percent) occur in all three regions.

Diversity

Community parameters are presented in Table 7 for all replicates combined for each station. Community parameters calculated separately for each replicate and sampling date are given in Appendix E, and the same parameters calculated for replicates combined at each station on each sampling date are presented in Appendix F.

Shannon-Wiener diversities taken from Table 7 indicate that most stations were highly diverse, with 10 of the 16 stations represented having diversity indices (H') of approximately 6.0 or higher. Station 14 (800 m) off Charleston, with 436 species in nine replicate box cores and a Shannon-Wiener value of 6.93, was one of the most diverse deep-sea stations encountered. In contrast, Stations 9 (600 m) and 10 (2000 m) off Cape Hatteras were among the lowest diversity stations encountered in the entire ACSAR Program. Station 9 had an H' value of only 2.89, while Station 10 had a value of 4.37. At both of these stations, faunal densities were very high, while the total number of species was low when compared to other slope and rise stations at similar depths. Diversity at Station 14A (600 m) on the Charleston Transect was also low, with a Shannon-Wiener value of 4.45.

The calculated expected number of species in successively smaller samples is currently considered the best way to illustrate deep-sea diversity (Sanders, 1968; Smith

TABLE 6. REGIONAL AFFINITIES OF THE 1202 INVERTEBRATE SPECIES FOUND IN THE U.S. SOUTH ATLANTIC SLOPE AND RISE STUDY.

Taxon	South Only	South/ Mid	South/ North	South/ Mid/ North
Porifera	5	1	1	4
Cnidaria				
Hydrozoa	15	5	0	10
Anthozoa	5	1	0	10
Scyphozoa	0	1	0	0
Platyhelminthes	0	0	0	1
Nemertinea	2	2	1	15
Priapulida	1	0	0	2
Annelida				
Polychaeta	204	66	44	228
Oligochaeta	4	2	3	13
Echiurida	2	0	0	3
Sipuncula	3	2	0	14
Pogonophora	1	2	2	9
Mollusca				
Bivalvia	34	9	9	31
Gastropoda	24	8	6	8
Scaphopoda	3	2	3	7
Aplacophora	10	7	3	16
Arthropoda				
Arachnida	0	0	0	1
Ostracoda	0	0	0	1
Cephalocarida	0	0	0	1
Decapoda	2	1	0	1
Cumacea	23	0	2	4
Tanaidacea	60	8	2	30
Isopoda	23	9	5	22
Amphipoda	36	12	10	16
Pycnogonida	0	0	0	1
Bryozoa	9	2	4	1
Brachiopoda	3	0	0	0

TABLE 6. (Continued).

Taxon	South Only	South/ Mid	South/ North	South/ Mid/ North
Echinodermata				
Echinoidea	2	2	0	7
Crinoidea	1	0	0	0
Ophiuroidea	9	2	1	5
Asteroidea	1	0	0	1
Holothuroidea	2	1	2	6
Hemichordata	0	0	0	4
Chordata	1	0	1	1
Total	485	145	99	473
Percent of Total	(40.3)	(12.1)	(8.2)	(39.4)

TABLE 7. BENTHIC COMMUNITY PARAMETERS FOR EACH U.S. SOUTH ATLANTIC STATION, PHASES I AND 2, ALL REPLICATES COMBINED.

Station	Total Reps	Depth (m)	Density per m^2	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 500 Indiv.	Species per 1000 Indiv.	Species per 2000 Indiv.	Species per 3000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
1	9	583	16,337	361	30.3	48.2	114.9	155.6	204.4	236.3	6.01	0.708
2	9	1000	9,130	325	31.7	49.7	116.3	159.2	212.2	246.9	6.18	0.740
3	9	1500	5,017	354	35.0	57.9	149.1	207.3	278.5	325.0	6.67	0.787
4 (Phase 1)	9	2000	5,622	286	29.7	48.1	122.0	167.9	221.7	255.3	5.93	0.727
4 (Phase 2)	9	2000	4,774	263	30.0	48.5	123.9	168.1	216.7	247.1	6.00	0.747
4 (Phase 1 & 2)	18	2000	5,202	363	30.0	40.1	127.6	176.7	233.4	269.6	6.06	0.713
5	9	3006	870	175	37.9	63.2	157.7	*	*	*	6.67	0.895
6	9	2004	6,209	286	33.1	52.7	125.7	169.2	218.6	249.8	6.34	0.776
7	2	3494	1,000	74	34.7	56.4	*	*	*	*	5.70	0.918
9	9	604	46,255	145	10.4	14.7	32.3	43.9	58.1	67.9	2.89	0.403
10	6	2003	8,950	139	18.6	26.9	59.3	80.3	105.9	122.7	4.37	0.613
11	9	800	10,188	385	33.5	54.1	133.0	183.5	245.6	286.9	6.46	0.753
12	7	1996	2,465	225	36.2	59.6	149.4	198.8	*	*	6.65	0.851
13	9	3015	1,309	174	30.9	50.9	131.1	*	*	*	5.91	0.794
14A	3	600	2,351	64	20.9	30.6	61.0	*	*	*	4.45	0.743
14	9	805	9,033	436	36.8	61.9	161.4	223.1	296.7	345.2	6.93	0.791
15	6	1993	1,311	123	26.8	42.6	110.7	*	*	*	5.18	0.746
16	9	3008	734	140	30.0	50.9	135.6	*	*	*	5.53	0.776

*Sample size was too small to allow calculation of this parameter.

and Grassle, 1977; Hessler and Jumars, 1974; Jumars and Gallagher, 1982). In addition to this rarefaction approach, species accumulation curves using combinations of actual box core samples were used to generate a species-area plot.

Rarefaction Curves

Based upon rarefaction curves plotted for all of the stations for Phases 1 and 2 (Figure 5), Station 14 (CH, 800 m) is clearly the most diverse, followed by Station 5 (LO, 3000 m), Station 3 (LO, 1500 m), and Station 12 (FE, 2000 m). These four stations are followed closely by a large group of 2000- to 3000-m stations, which are slightly more diverse than Station 2 (LO, 1000 m), Station 1 (LO, 600 m) and Station 15 (CH, 2000 m). As in the Shannon-Wiener indices, Stations 14A, 9, and 10 are considerably less diverse than all of the other stations in the study area. Figure 6 is a more expanded version of the rarefaction plots, with the 3000-m stations excluded. The same diversity trends are apparent.

The 1500- to 2000-m stations have been plotted separately to show diversity relationships on the lower slope of the U.S. South Atlantic region (Figure 7). Station 3 off Cape Lookout (1500 m) is the most diverse station, followed by the 2000-m Stations 12 (FE), 4 (LO), 6 (HC), and 15 (CH). Station 10 off Cape Hatteras is the least diverse station.

The 3000-m stations have been plotted separately to show their relationships as well (Figure 8). Station 5 on Cape Lookout is the most diverse of the three, with Stations 13 and 16 on Cape Fear and Charleston being nearly identical.

Station 4 is the only site in the U.S. South Atlantic region for which there are data for six sampling occasions. For this reason, rarefaction curves have been prepared showing the entire fauna and polychaetes, peracarids, and molluscs separately (Figure 9). Polychaete diversity is highest of any of the major faunal groups, followed by peracarids and molluscs.

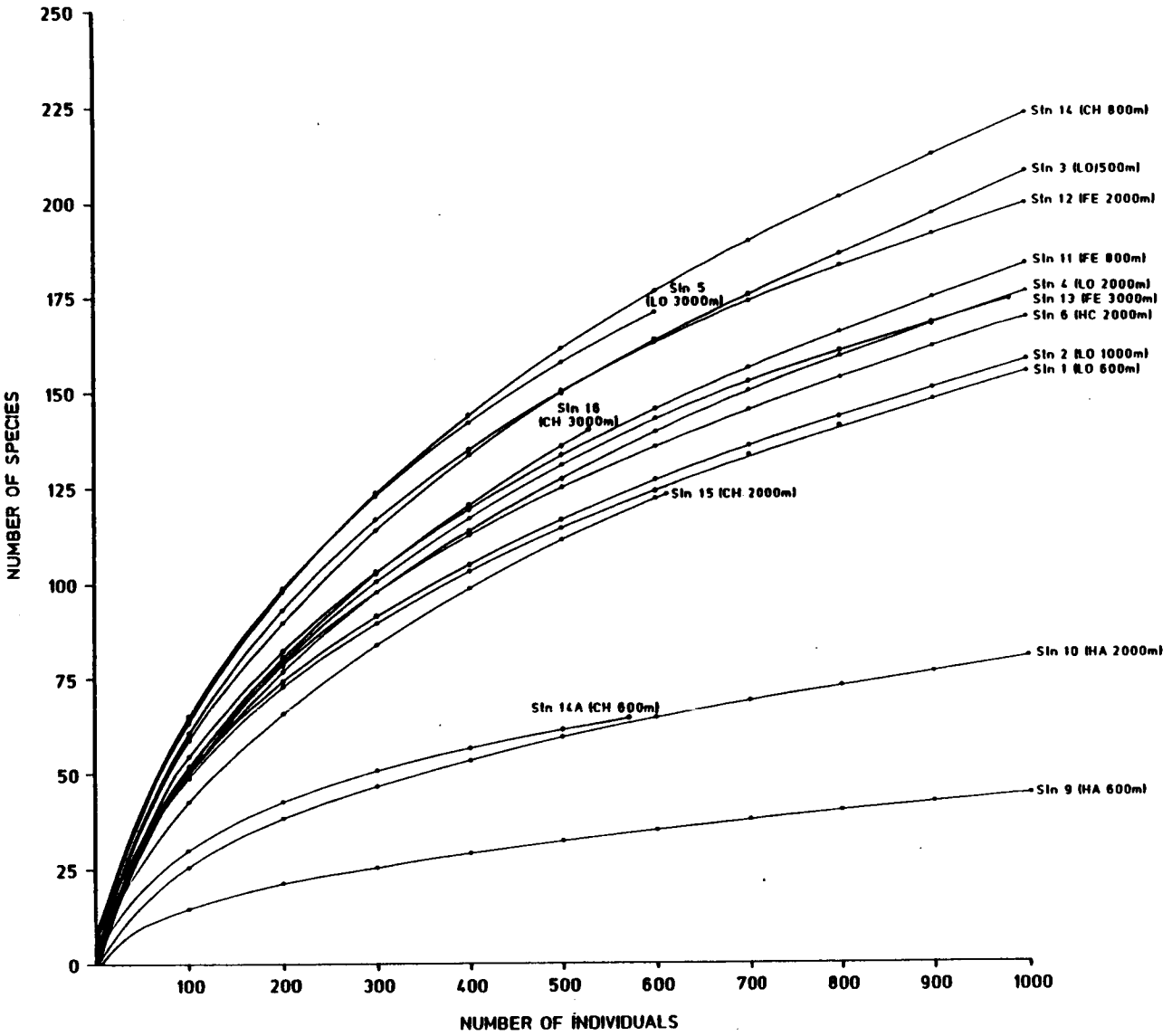


Figure 5. Hurlbert Rarefaction Curves for Total Fauna of 15 U.S. South Atlantic Stations from Phases 1 and 2. Number of Individuals Limited to 1000. Station 7 not Included.

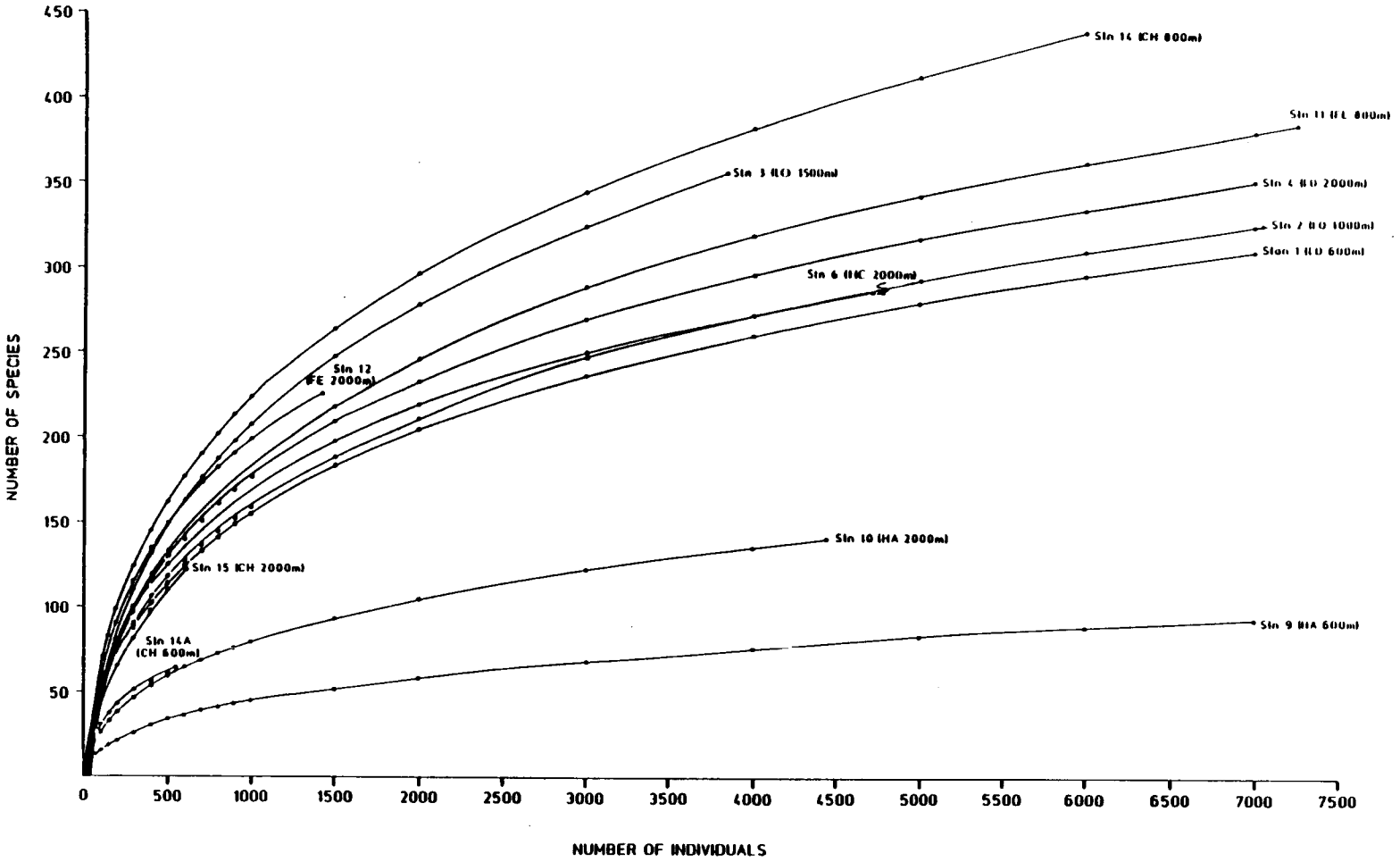


Figure 6. **Hurlbert Rarefaction Curves for Total Fauna of 12 U.S. South Atlantic Stations from Phases 1 and 2. Number of Individuals Extended to Maximum Numbers Collected per Station. Stations 5, 7, 13, and 16 not Included.**

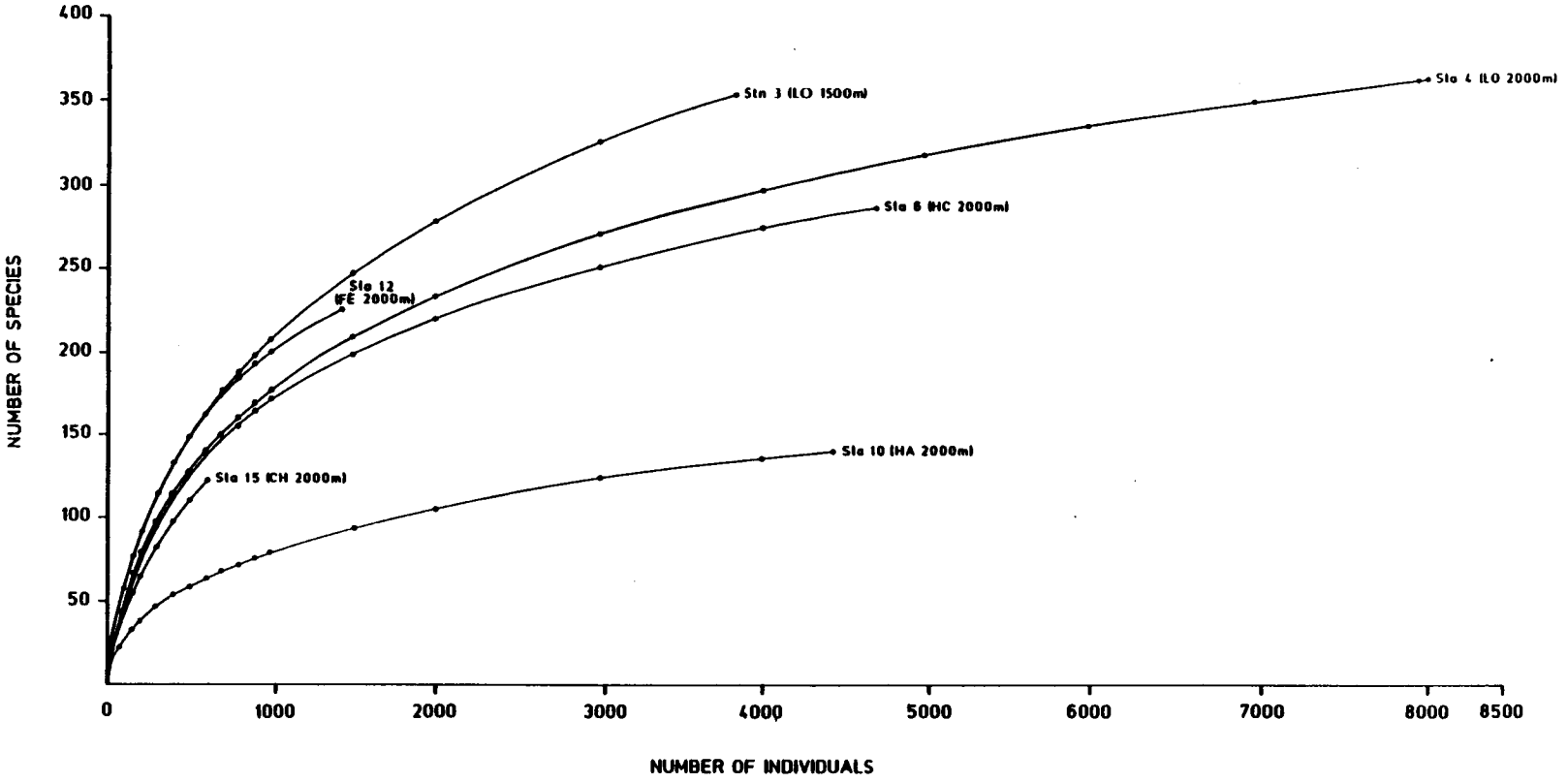


Figure 7. **Hurlbert Rarefaction Curves for Six Stations in the 1500-2000 m Depth Range in the U.S. South Atlantic Region.**

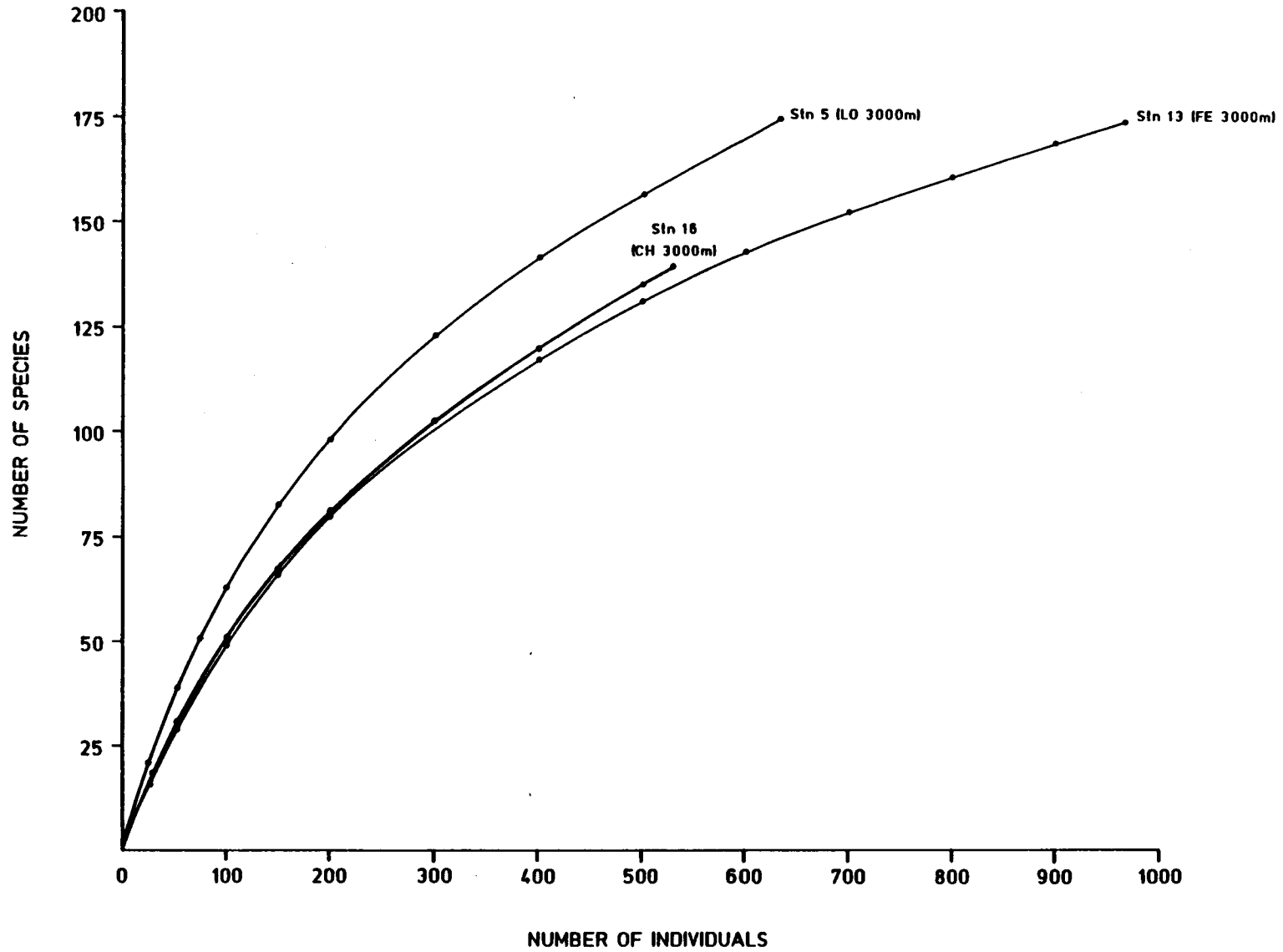


Figure 8. Hurlbert Rarefaction Curves for Three Stations in the 3000 m Depth Range From the U.S. South Atlantic Region.

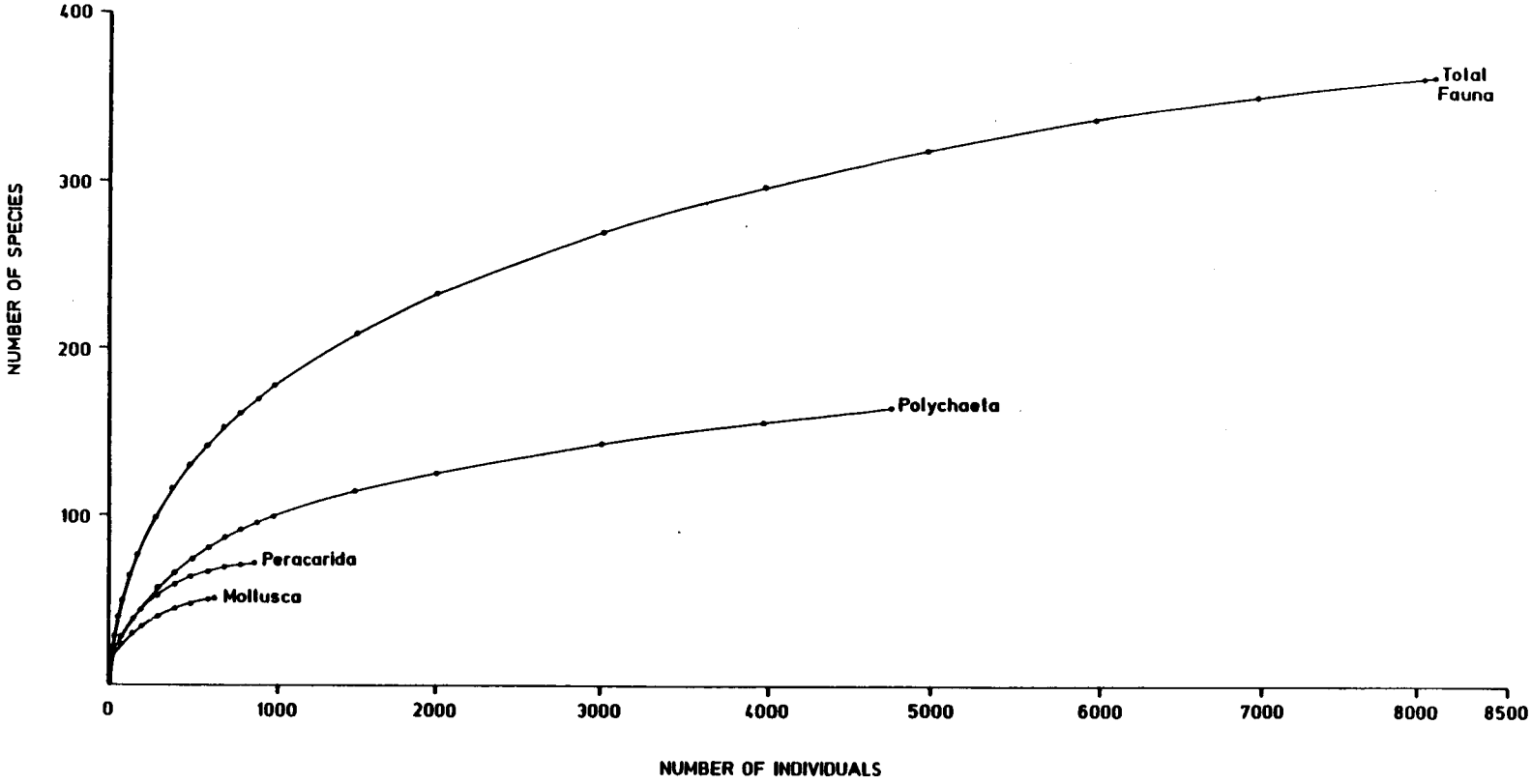


Figure 9. **Hurlbert Rarefaction Curves for Total Fauna, Polychaeta, Peracarida, and Mollusca at Station 4.**

Species Accumulation Plots

All species accumulation curves have been combined on a single plot for comparative purposes (Figure 10). Station 4 is plotted twice, with the nine box cores from Phase 1 plotted separately from those of Phase 2. A separate figure depicts the plot for all 18 box cores taken at Station 4 combined (Figure 11). The greatest rate of species accumulation and, by inference, diversity occurs at the shallower stations between 600 and 1500 m between Cape Lookout and Charleston. Thus, Stations 14 (Charleston) and 11 (Cape Fear) at 800 m are the highest in rate of species accumulation, followed by Station 1 (600 m), Station 3 (1500 m), and Station 2 (1000 m) on the Cape Lookout transect. However, Stations 9 (Cape Hatteras) and 14A (Charleston), both at 600 m, are among the lowest in rate of species accumulation. Stations 4, 6, and 12, all at 2000 m between Hatteras Canyon and Cape Fear, are next in rate of species accumulation and form a distinct group about mid-way down the plot. The 3000-m stations (5, 13, and 16) are in the lowest group. It is interesting that Stations 10 (Cape Hatteras) and 15 (Charleston), both at 2000 m, are similar to the 3000-m stations in rate of species accumulation. Station 10 is similar to Station 9, confirming the distinctness of the Cape Hatteras Transect from all other South Atlantic localities.

Cluster Analysis

Analysis of patterns in the data included use of both cluster analysis and ordination techniques. Ordination is treated separately (see below). Cluster analysis included the use of two techniques: NESS, the number of expected species shared, which was used to determine patterns among stations, and Bray-Curtis, which was also used to determine patterns among stations (Q mode) and also between species groups (R mode).

NESS - Entire Community Analysis

We were unable to run NESS at 200 individuals due to the very low faunal densities encountered at the deepest stations. Instead, NESS was run at 20 and 50 individuals for replicates combined, with different results being obtained in the two calculations (Figures

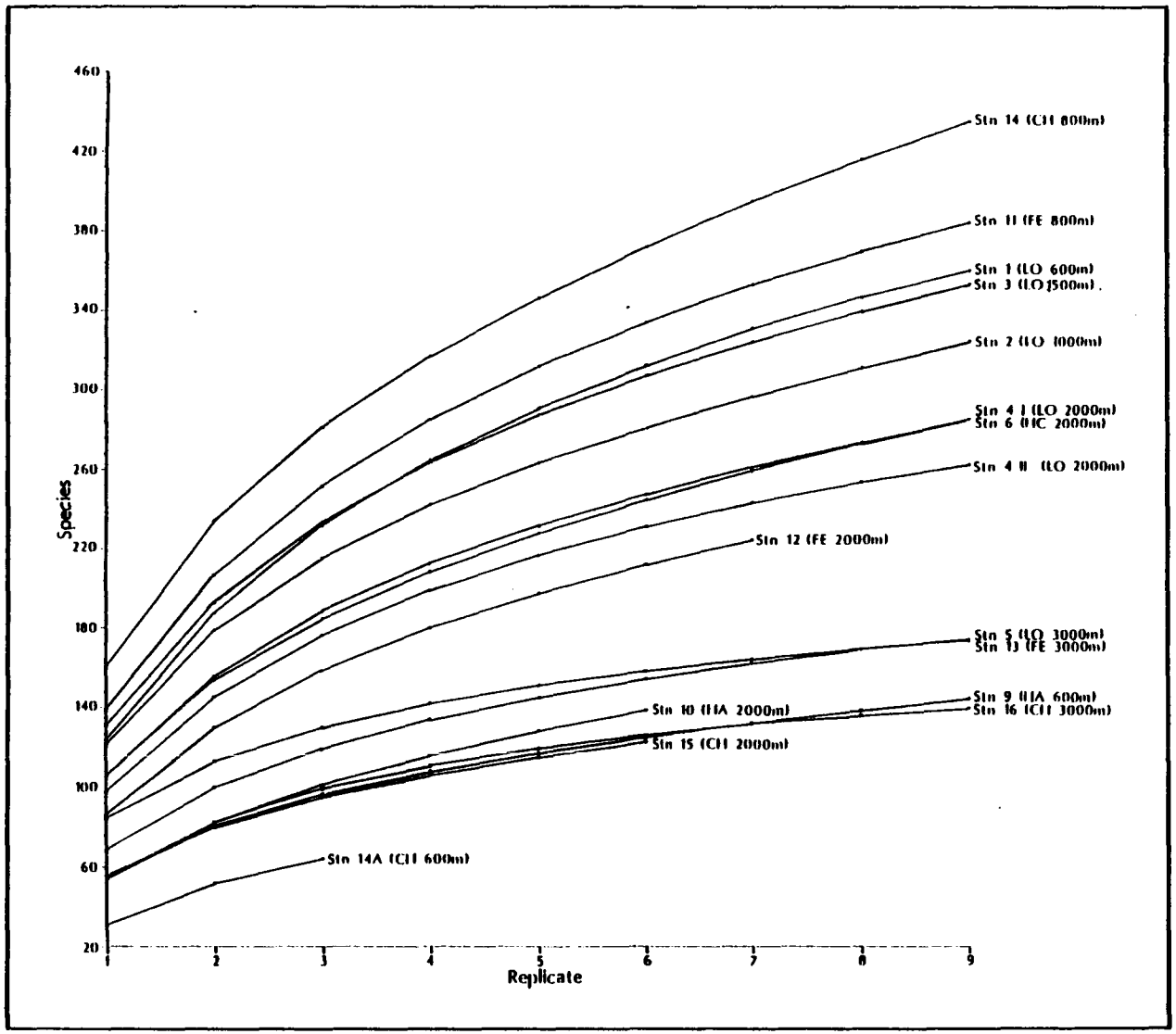


Figure 10. **Species Accumulation Curves for 15 U.S. South Atlantic Stations from Phases 1 and 2. Station 4 is Plotted Separately for Phases 1 and 2. Station 7 is not Included.**

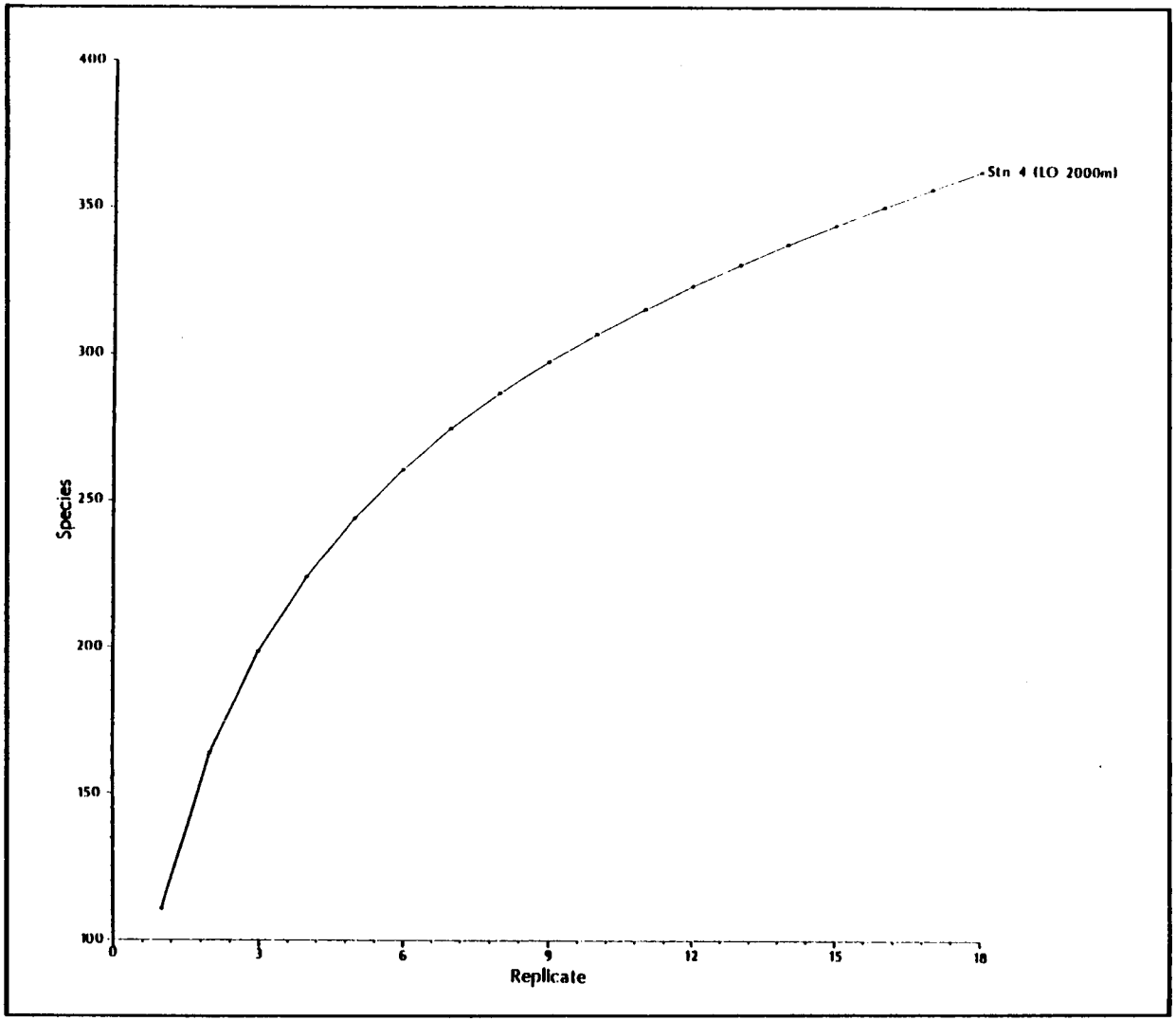


Figure 11. Species Accumulation Curve for Station 4, with all 18 Samples from Phases 1 and 2 Combined.

12 and 14). For replicates separate, NESS was run at 20 individuals. Each station clustered separately, with each cruise of any one station clustering together, rather than with samples from any other stations (Figure 13).

With NESS at m=20, the station having the least affinity with any other station is Station 14A, located at 600 m on the Charleston Transect (Figure 12). All of the other stations clustered very tightly together, with a high degree of similarity among the different cruises. Similarity between stations was apparent as well, with Stations 1 (600 m) and 2 (1000 m) on the Cape Lookout Transect forming a distinct cluster at a similarity level of 0.52. In contrast, Stations 9 (600 m) and 10 (2000 m) on the Cape Hatteras Transect are more similar to each other than to the remaining stations, but are linked only at the 0.32 and 0.17 NESS similarity levels. Station 3 at 1500 m off Cape Lookout, and Stations 4 (2000 m, Cape Lookout), 12 (2000 m, Cape Fear), and 6 (2000 m, Hatteras Canyon) are all clustered at the 0.52 NESS similarity level, with each cruise of each individual station clustering at very high levels of similarity. Another distinct cluster of stations includes Station 13 (3000 m off Cape Fear) and Stations 15 and 16 (2000 m and 3000 m) off Charleston. Although the similarity of Station 15 to Stations 13 and 16 is only 0.48, it is more similar to these 3000-m stations than to the other 2000-m stations. Station 5, the 3000-m station off Cape Lookout, clusters separately from the 3000-m stations off Cape Fear and Charleston and is closer to Station 7 (3500 m, Cape Lookout) at a 0.35 NESS similarity. Both 800-m stations (11, Cape Fear and 14, Charleston) cluster very closely to one another with a 0.75 NESS similarity. To summarize these NESS results, it appears that although stations tend to cluster by depth, these patterns are strongly influenced by latitude. For example, the 2000-m stations tend to separate by latitude. Station 10 (Cape Hatteras) is separate from Stations 6, 4, and 12 (Hatteras Canyon to Cape Fear), and these are separate from Station 15 (Charleston). Likewise, the two more southerly 3000-m stations have only a low level of similarity to Stations 1 and 2 off Cape Lookout. There is an even lower level of similarity of any of these stations with their counterparts off Cape Fear (Station 11) and Charleston (Station 14). Station 14A, at 600 m off Charleston, is unlike any other station.

An analysis of the same data with replicates analyzed separately is presented in Figure 13. The overall pattern described above is repeated, except for Station 3, Replicate 2, Cruise SA-1, which clusters with Station 4, and Station 12, Replicate 2,

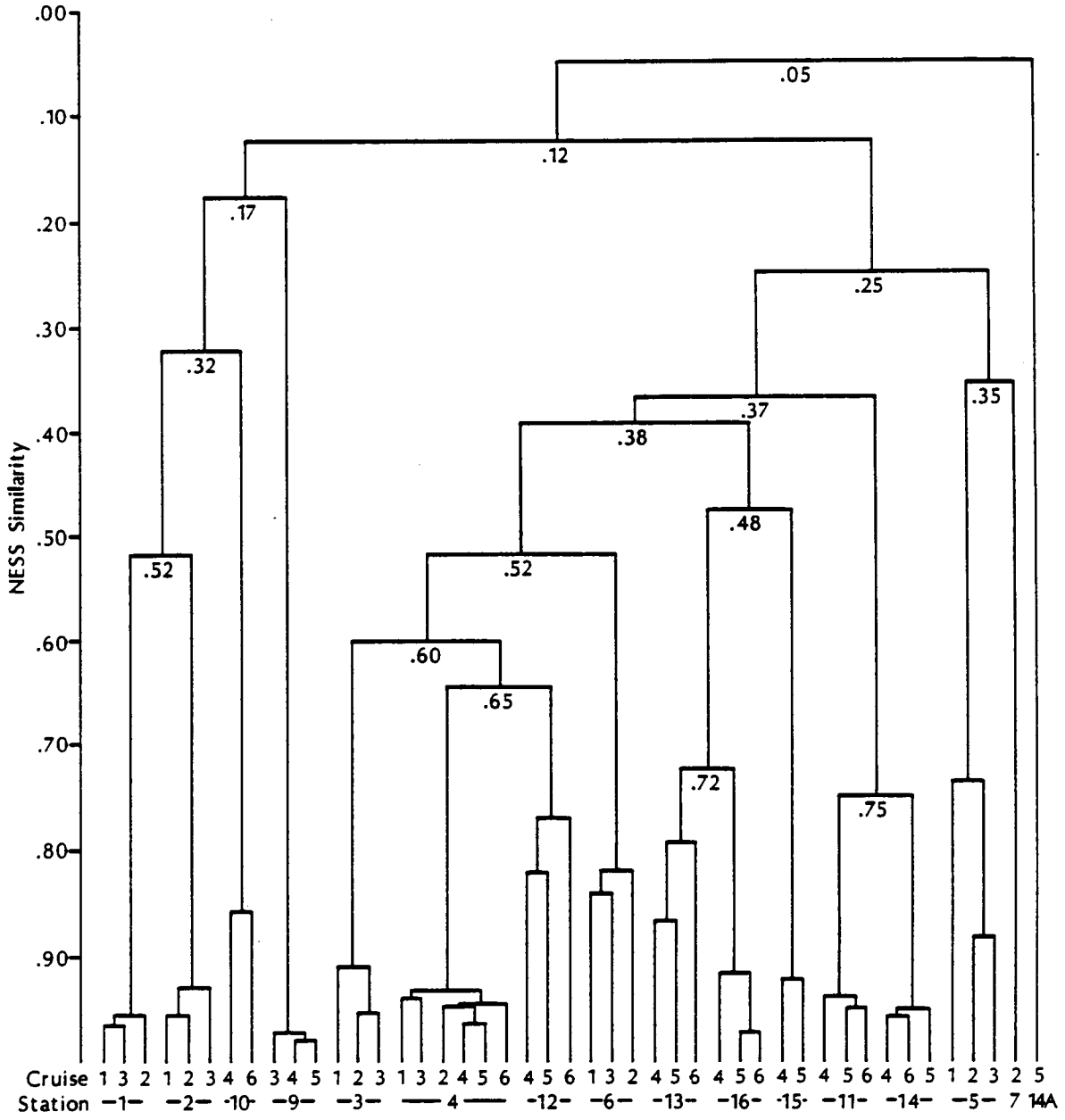


Figure 12. Dendrogram of Summed Replicates Collected at Each Station During Phases 1 and 2 in the U.S. South Atlantic Region Clustered by NESS at 20 Individuals and Group Average Sorting.

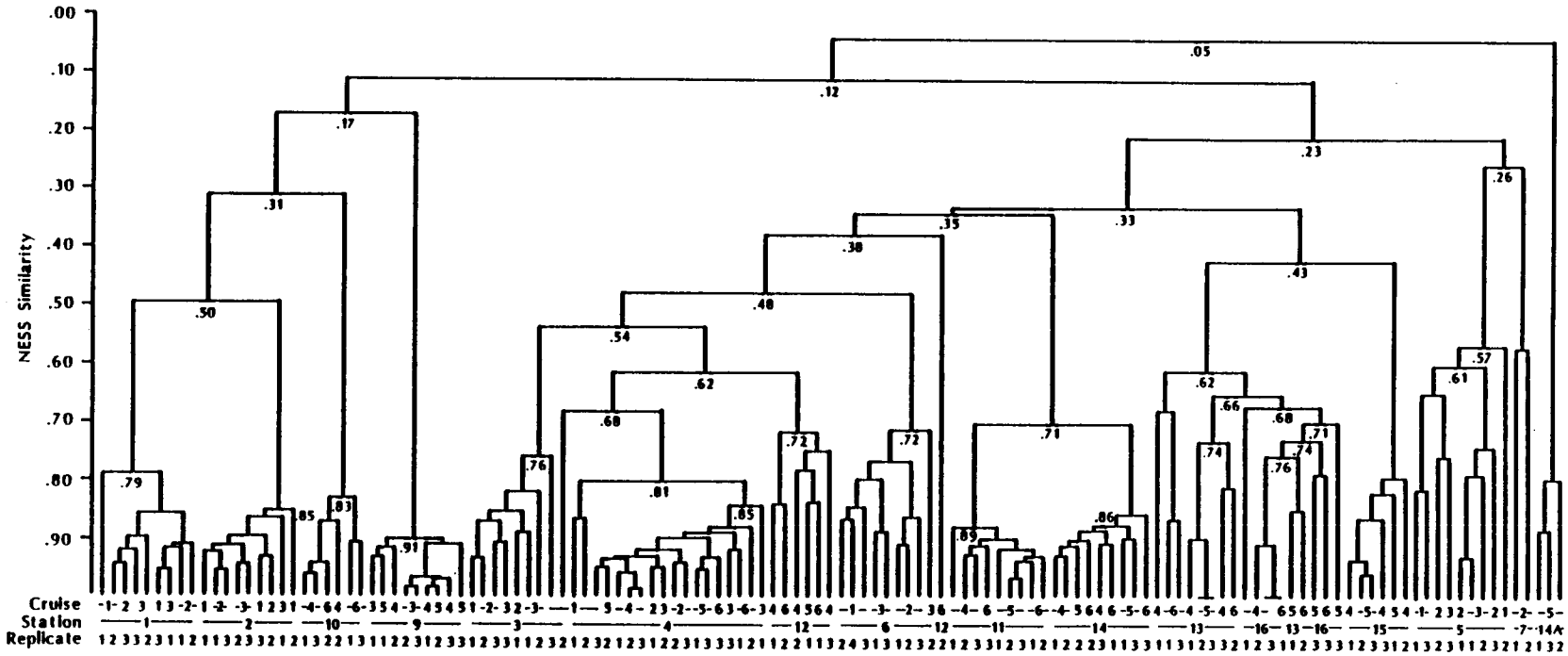


Figure 13. Dendrogram of Individual Replicates Collected at Each Station on Each Cruise during Phases 1 and 2 in the U.S. South Atlantic Region Clustered by NESS at 20 Individuals and Group Average Sorting.

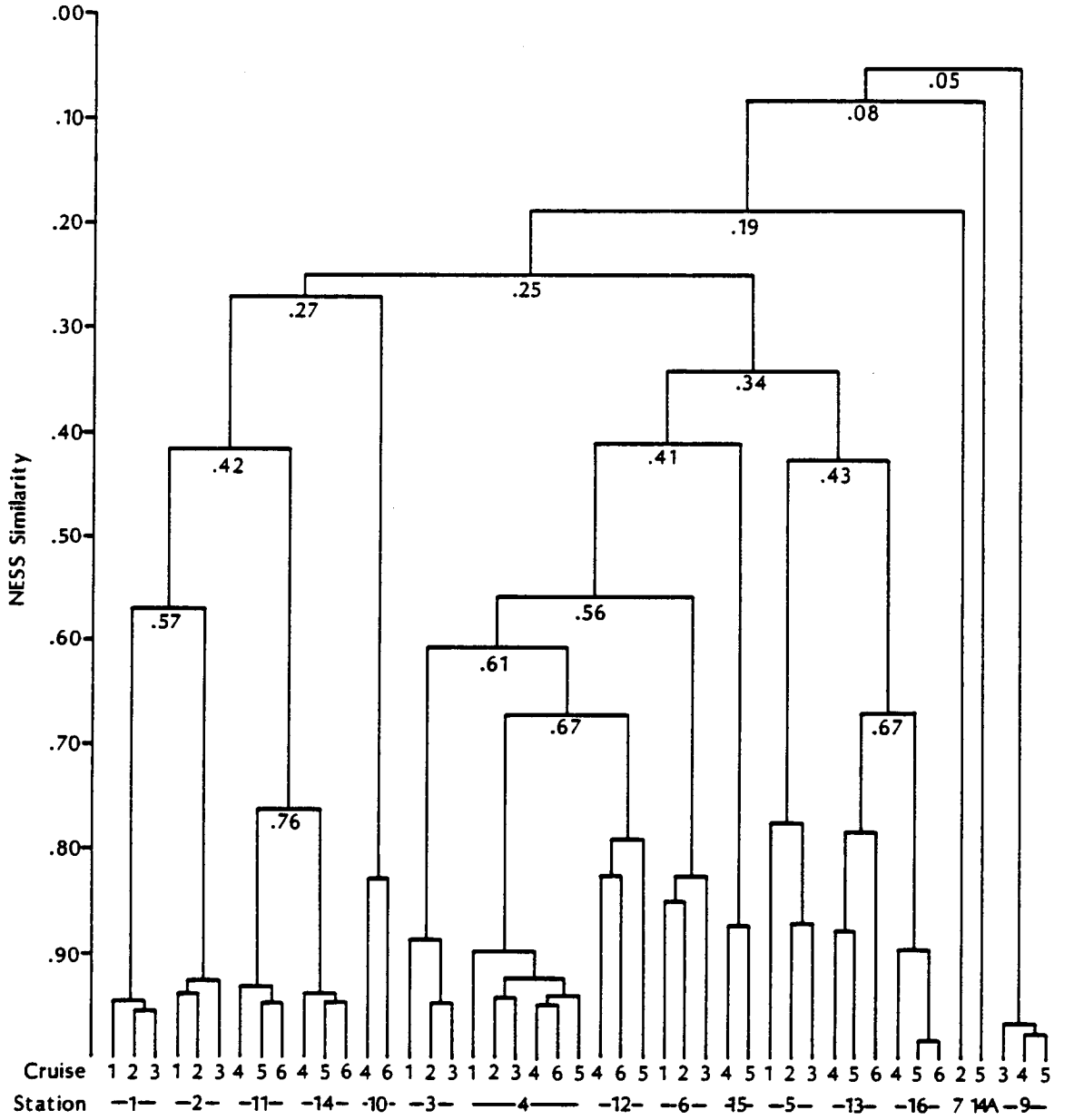


Figure 14. Dendrogram of Summed Replicates Collected at Each Station During Phases 1 and 2 in the U.S. South Atlantic Region Clustered by NESS at 50 Individuals and Group Average Sorting.

Cruise SA-6, which has only a 0.38 level of similarity with all of the Station 3, 4, 6 and 12 replicates. The position of the Station 3 replicate is easily explained. This sample, taken on the first cruise of the program, was collected at a depth of 1690 m instead of the target depth of 1500 m. A similar anomaly was observed with Station 1, Replicate 1, taken on Cruise SA-1. That replicate was taken from a depth of 720 m instead of 600 m. This type of depth anomaly does not explain the pattern displacement of the Station 12, Replicate 2, however. This sample was taken well within the appropriate depth range and in good proximity to other replicates taken on the same and other cruises.

With NESS at m=50, a noticeable rearrangement of some stations is evident (Figure 14). Station 9 is now the station with the least similarity to any other station. Stations 11 and 14 shift to a position closer to Stations 1 and 2. Station 5 is closer in similarity to the other 3000-m stations. The 2000-m stations more or less maintain the same relationships as in the results obtained with NESS set at 20 individuals.

Bray-Curtis - Entire Community Analysis

The cluster patterns resulting from the Bray-Curtis analyses differ in several respects from those based on NESS at m=20, but are similar to those for NESS with m=50. The results are presented in Figures 15 through 18. The first two dendrograms represent the Bray-Curtis analysis of the entire community with replicates combined, with and without square-root transformation, while the last two represent analyses of the entire community with replicates kept separate. The patterns revealed by square-root transformation are quite clear, with most of the replicates from any one station clustering closest to replicates from the same station. The same replicates that depart from this sequence with NESS (see above) also exhibit a similar pattern, but to a lesser degree, with Bray-Curtis.

With Bray-Curtis, as with NESS at m=50, the upper slope Stations 14A (Charleston, 600 m) and 9 (Cape Hatteras, 600 m) tend to be less similar to all other stations, but Stations 1 and 2 (Cape Lookout, 600 m and 1000 m) are more similar to each other (0.46 level) and to Stations 11 (Cape Fear, 800 m) and 14 (Charleston, 800 m) (at the 0.36 level) than to all other stations (Figure 16). Interestingly, with NESS at m=20, Station 9 was most similar to the deeper station on the transect, Station 10 (2000 m), than to any other

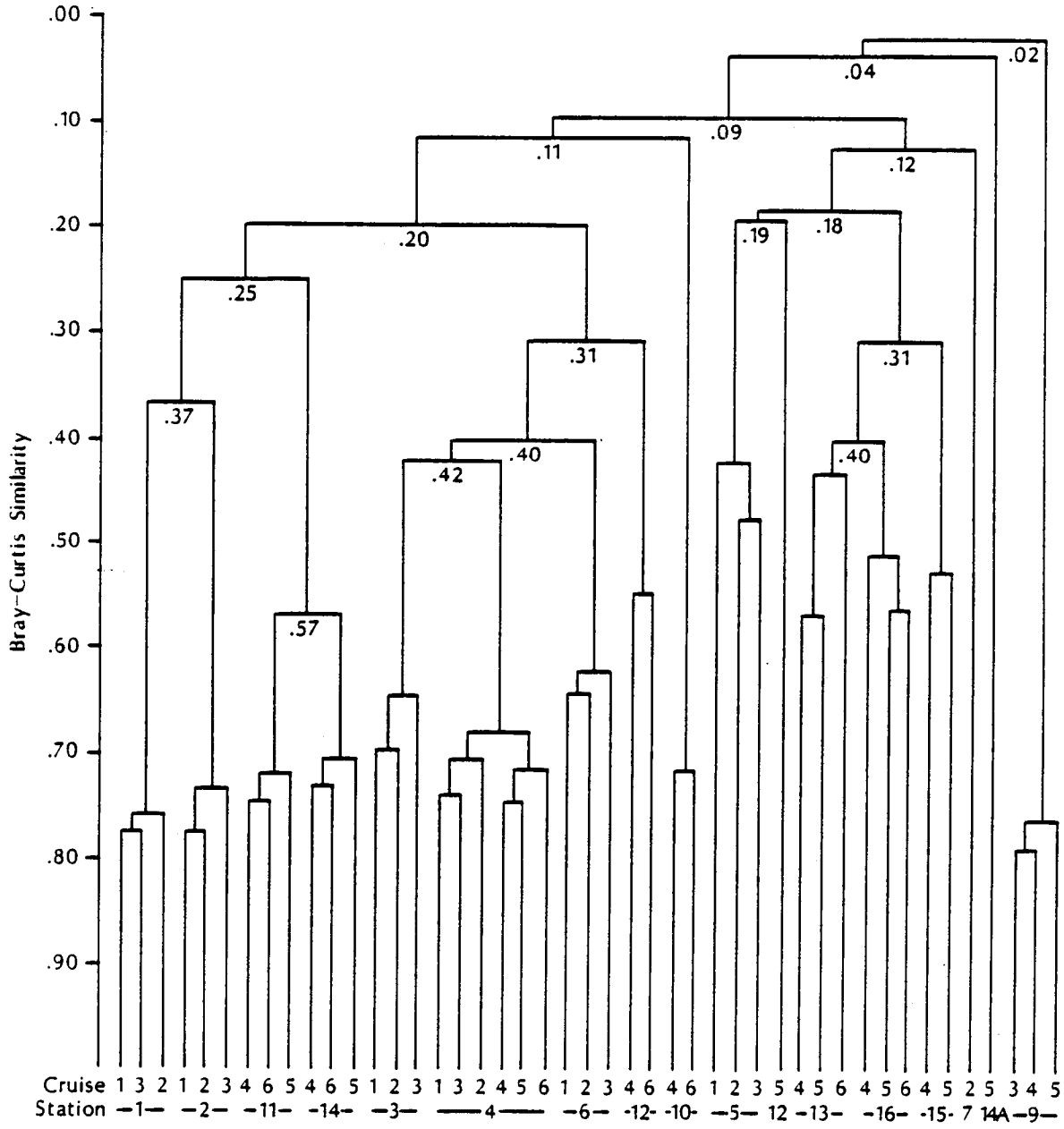


Figure 15. Dendrogram of Summed Replicates Collected at Each Station During Phases 1 and 2 in the U.S. South Atlantic Region Clustered by Bray-Curtis and Group Average Sorting.

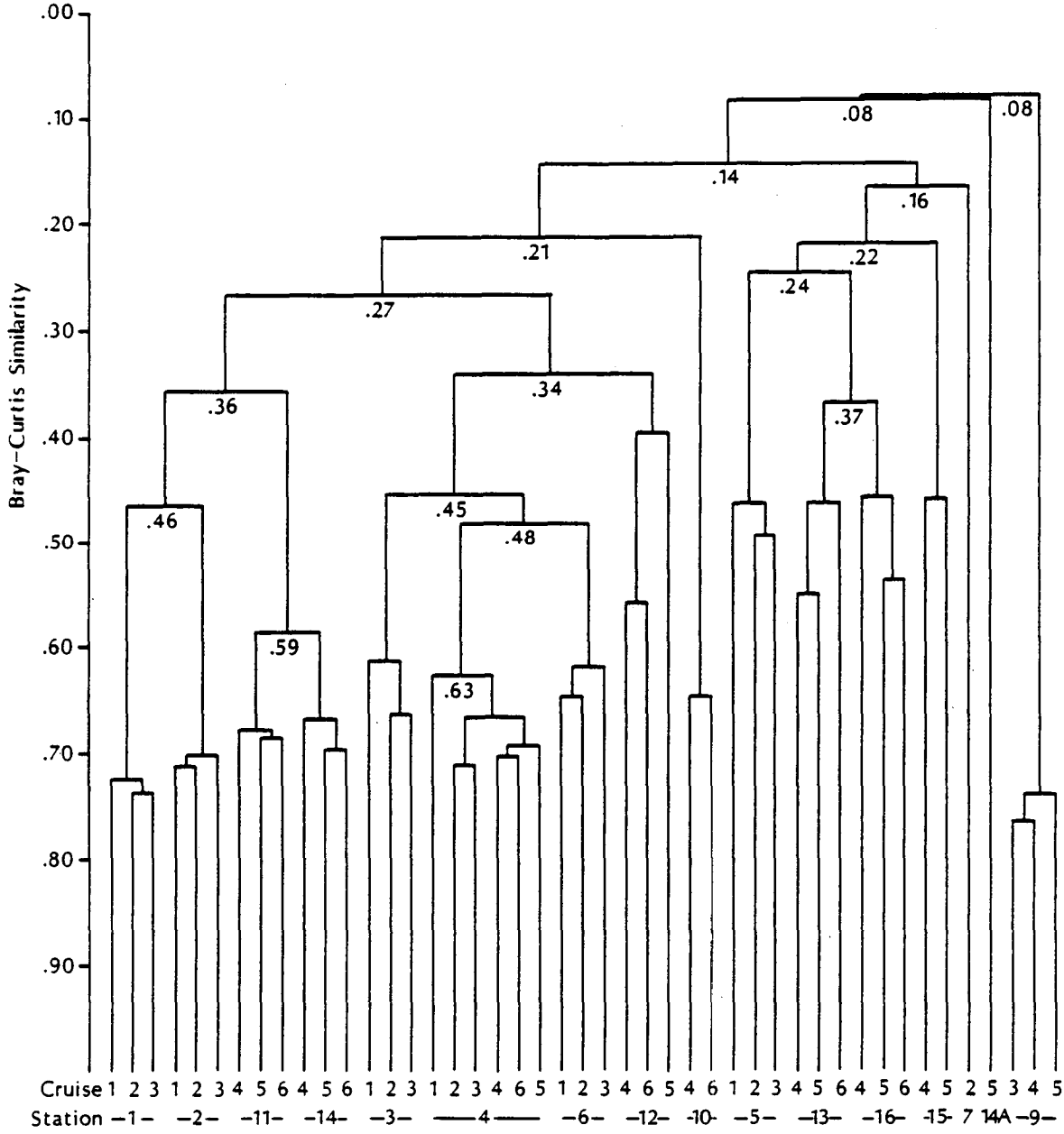


Figure 16. Dendrogram of Summed Replicates Collected at Each Station during Phases 1 and 2 in the U.S. South Atlantic Region Clustered by Bray-Curtis After Square-Root Transformation of the Data and Using Group Average Sorting.

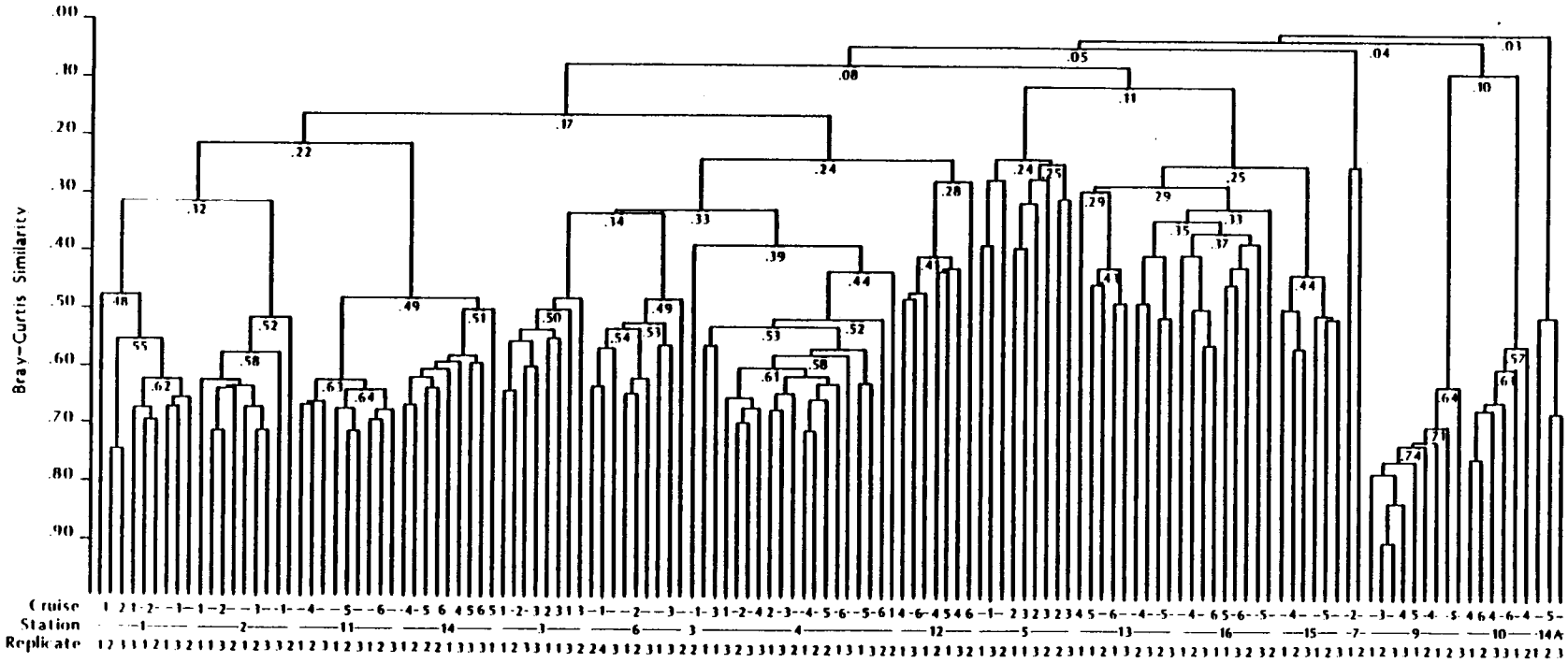


Figure 17. **Dendrogram of Individual Replicates Collected at Each Station on Each Cruise During Phases 1 and 2 in the U.S. South Atlantic Region Clustered by Bray-Curtis and Group Average Sorting.**

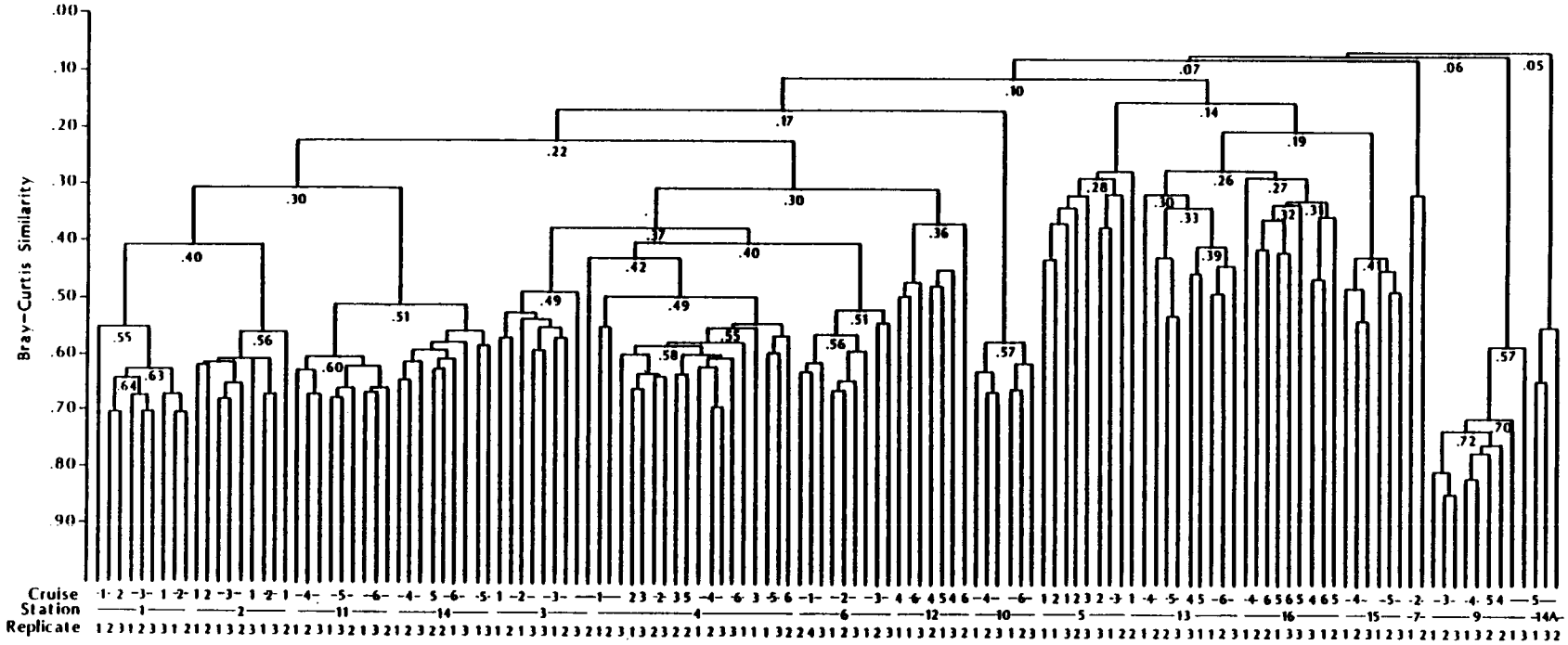


Figure 18. Dendrogram of Individual Replicates Collected at Each Station on Each Cruise During Phases 1 and 2 in the U.S. South Atlantic Region Clustered by Bray-Curtis After Square-Root Transformation of the Data and Using Group Average Sorting.

station, while with NESS at m=50 and Bray-Curtis, Station 10 is distinct, but more similar to the large shallow-water cluster of Stations 1, 2, 11, and 14 just described and to a lower slope cluster of Stations 3, 4, 6, and 12 (1500-2000 m). Of these latter stations, Stations 3 and 4 (Cape Lookout) are more similar to Station 6 (Hatteras Canyon) than to Station 12 (Cape Fear). Station 15, also at 2000 m, but located off Charleston, clusters more closely to the three 3000-m stations than to any of the 2000-m stations. Of the 3000-m stations, Stations 13 (Cape Fear) and 16 (Charleston) are more similar to one another than to Station 5 (Cape Lookout). Station 7 (3500 m off Cape Lookout) clusters more or less by itself, but is closest to the 3000-m cluster of stations and Station 15.

The results based on NESS at m=50 and on Bray-Curtis tend to emphasize similarities along isobaths more than the NESS at m=20 analysis does. Major faunal breaks among the upper slope stations are obvious are at the 600-m site off Cape Hatteras and the 600-m site off Charleston; among the 2000-m stations at Station 15 off Charleston and to some extent at the 2000-m station off Cape Hatteras; and on the 3000-m isobath between Station 5 off Cape Lookout and Stations 13 and 16 off Cape Fear and Charleston.

Bray-Curtis--Polychaetes Only

Bray-Curtis was run on polychaete fauna only, after a square-root transformation of the data (Figure 19). Except for a shift in Station 12, Cruise SA-5, to a position closer to the 3000-m stations and Station 15, the patterns are identical to those just described for the entire community. This result reflects the numerical dominance and importance of the polychaete fauna in the entire community.

Bray-Curtis--Peracarids Only

Bray-Curtis was run on the peracarid fauna only, after a square-root transformation of the data (Figure 20). A major departure from the entire community analysis is seen using this subset of the fauna, with a clearer division of the stations into depth zones. With the exception of the most unusual stations (Station 14A, 9, 10) and one sample set (cruise) of Station 15, all of the upper slope stations (1, 2, 11, and 14) cluster together, as

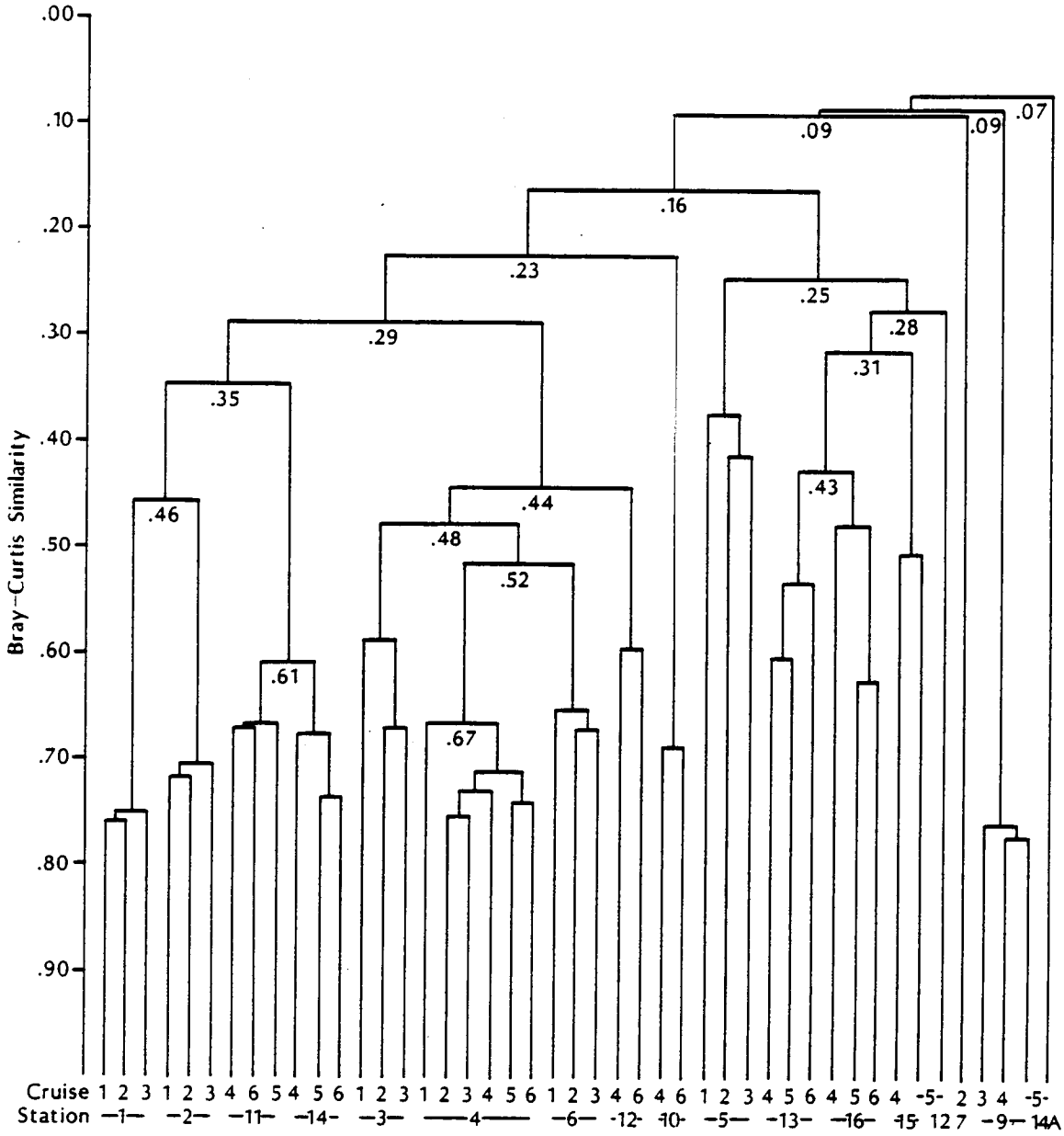


Figure 19. Dendrogram of Summed Replicates of Polychaete Fauna Only Collected at Each Station During Phases 1 and 2 in the U.S. South Atlantic Region Clustered by Bray-Curtis After Square-Root Transformation of the Data and Using Group Average Sorting.

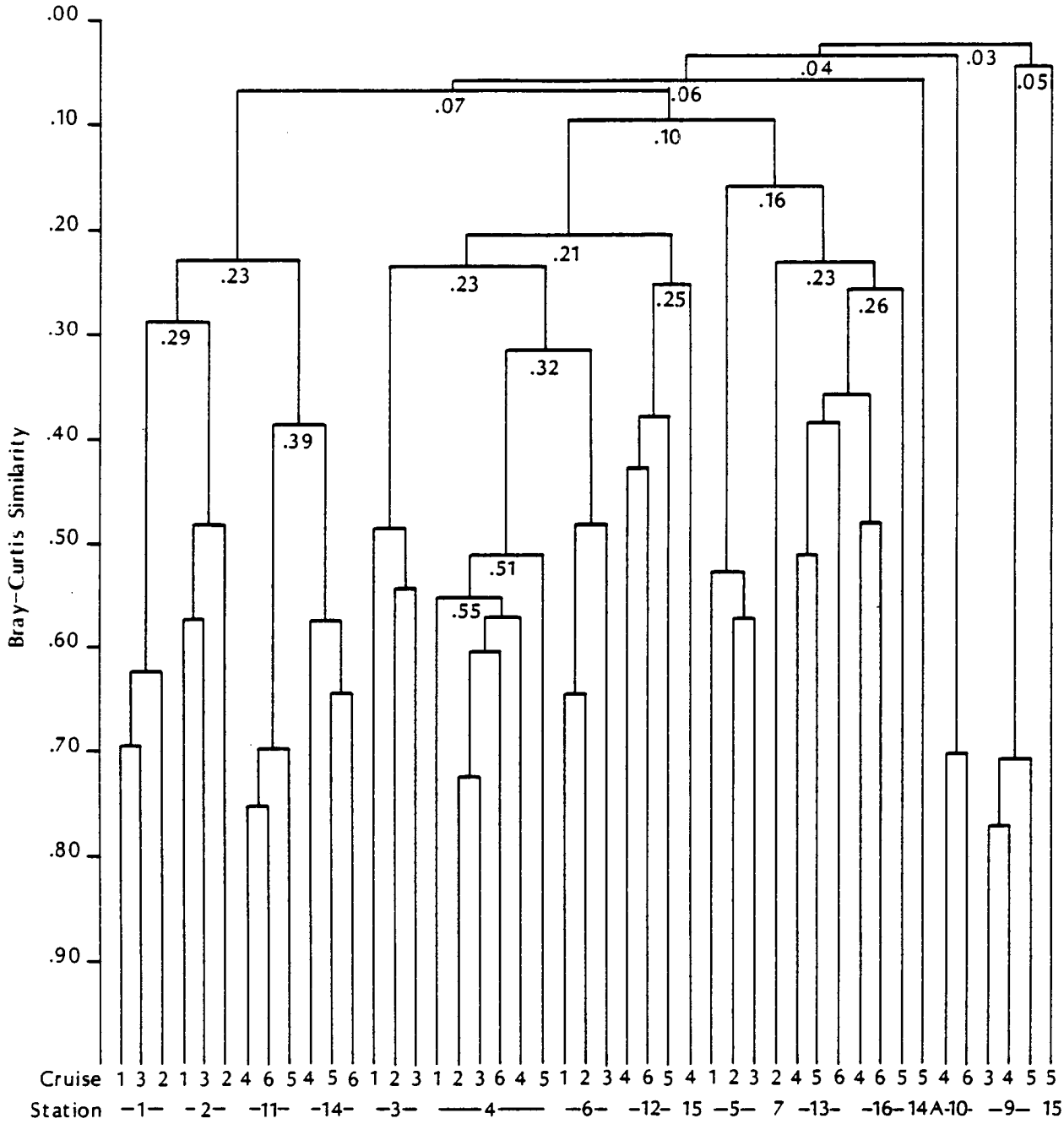


Figure 20. Dendrogram of Summed Replicates of Peracarids Only Collected at Each Station during Phases 1 and 2 in the U.S. South Atlantic Region Clustered by Bray-Curtis after Square-Root Transformation of the Data and Using Group Average Sorting.

do all of the 1500- to 2000-m stations (3, 4, 6, 12), and all of the 3000- to 3500-m stations (5, 7, 13, and 16). The uniqueness of Stations 9 and 10 off Cape Hatteras and Station 14A off Charleston are also evident in this analysis.

Bray-Curtis—Bivalves Only

When only the bivalve fauna is analyzed using Bray-Curtis, many differences compared to the entire community analysis are seen (Figure 21). Station 10 off Cape Hatteras is highly similar to the upper slope stations. The 3000-m stations are more similar to the 2000-m stations than is evident in the entire community analysis, and Stations 15 and 14 show essentially no similarity to any other station. This result implies that bivalves are more distinctly zoned than are the other faunal elements.

Bray-Curtis by Species (R Mode)

Bray-Curtis was run in the R mode in order to distinguish groups of species instead of stations. All species having less than 100 occurrences were eliminated from the analysis, leaving approximately 130 species of the total 1202 recorded. The dendrogram generated from this analysis is shown in Figure 22. Seventeen groups of species were identified and distinguished. Cutoff points for species groups were chosen on the basis of clear separation from other groups rather than by using a predetermined similarity level. In most cases, the various groups selected more clearly separated from the next most similar groups. In a few cases, however, the judgement about where to separate groups was somewhat subjective, and it is possible that 20 groups might be more appropriate. Nevertheless, the species composition of the 17 groups is given in Table 8.

Nodal Analysis

In order to compare the Bray-Curtis R-mode results with the station analyses (Q mode), a nodal analysis was performed. In this analysis, the 17 species groups were directly compared on a group-to-station percent shared basis, with the 16 stations arranged according to latitude and depth (Figure 23). Most of the species groups showed

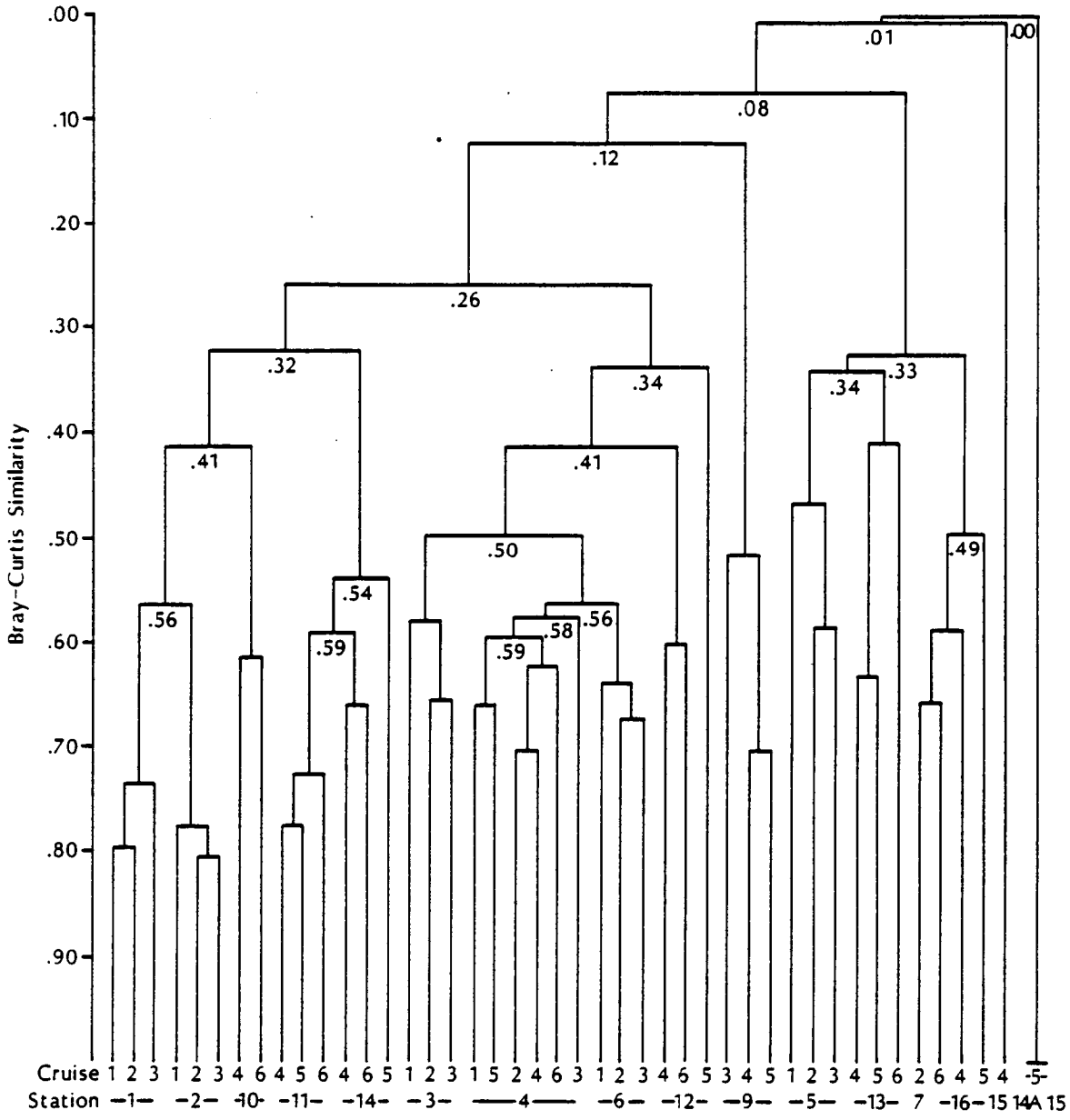


Figure 21. Dendrogram of Summed Replicates of Bivalves Only Collected at Each Station During Phases 1 and 2 in the U.S. South Atlantic Region Clustered by Bray-Curtis after Square-Root Transformation of the Data and Using Group Average Sorting.

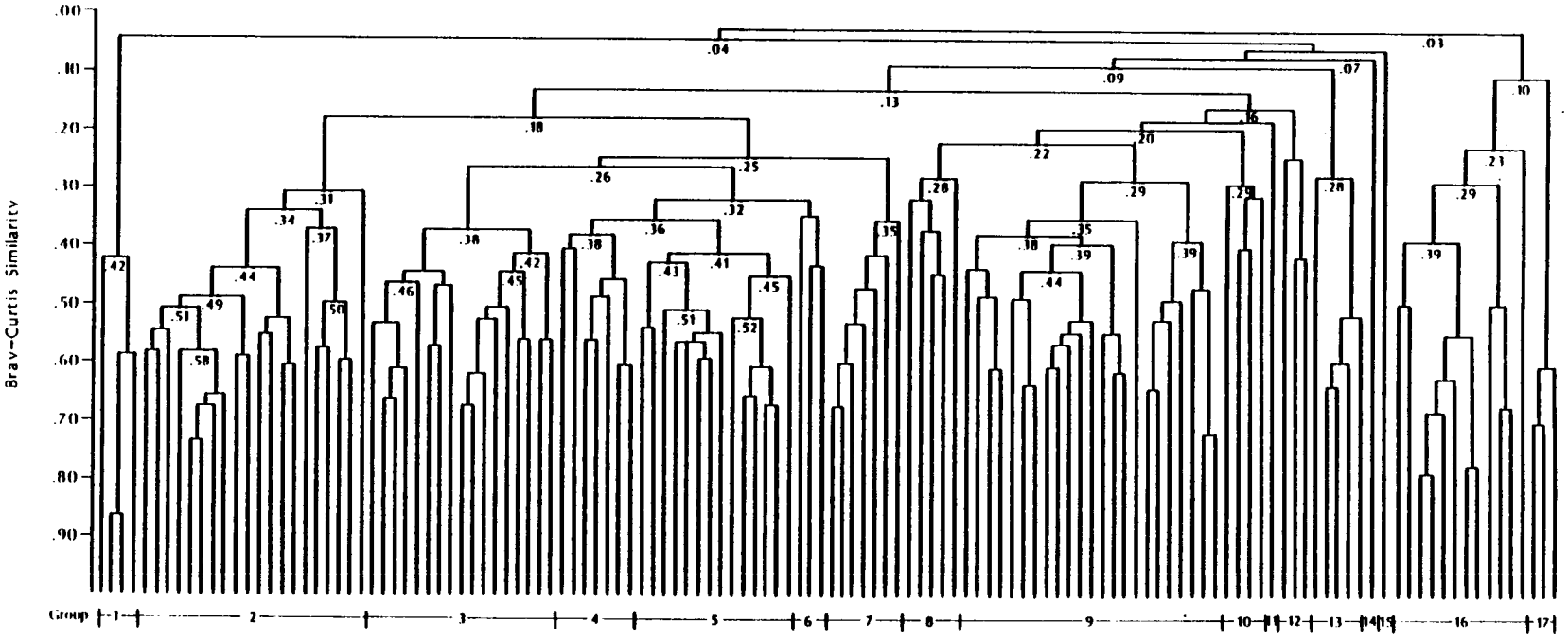


Figure 22. Dendrogram of 130 Species Having a Total Abundance of More than 100 Individuals Collected During Phases 1 and 2 in the U.S. South Atlantic Region. Clustering is by Inverse Classification Using Bray-Curtis.

TABLE 8. SPECIES GROUPS IDENTIFIED BY INVERSE CLUSTER ANALYSIS OF U.S. SOUTH ATLANTIC PHASE 1 AND PHASE 2 DATA.

Group 1

Aricidea catherinae
Prionospio sp. 24
Protodorvillea nr. *kefersteini*
Caulleriella sp. 3

Group 2

Clymenura lankesteri
Leptognathiella sp. 3
Phallodrilus sp. 2
Chone sp. 5
Bathyarca sp. 1
Spionidae n. gen. n. sp. 11
Cossura sp. 2
Jasmineira filiformis
Striopulsellum atlantisae
Nephasoma abyssorum
Trichobranchidae sp. 6
Phallodrilus sp. 4
Chaetozone sp. 10
Nemertea sp. 13
Leptocheliidae sp. 1
Molpadia blakei
Bathydrilus asymmetricus
Kelliella sp. 1
Tubificoides sp. 3
Myriochele sp. 4

Group 3

Tharyx dorsobranchialis
Aricidea nr. *claudiae*
Phascolion strombus
Aricidea sp. 3
Ophelina cylindricaudata
Capitellidae sp. 1
Lepidomeniidae sp. 1
Exogone verugera profunda
Lumbrineris sp. 2
Euchone hancocki
Ninoe nigripes
Tharyx sp. 2
Ophelina abranchiata
Paradoneis brevicirratus
Tubificoides apectinatus
Auchenoplax crinita
Limnodriloides monothecus

Group 4

Prionospio sp. 1
Grania atlantica
Thyasira subovata
Thyasira tortuosa
Prochaetodermatidae sp. 1
Labidoplax buskii

TABLE 8. (Continued).

Group 5

Maldanidae sp. 1
Falcidens sp. 2
Nephasoma diaphanes
Thyasira croulinensis
Levinsenia sp. 1
Nemertea sp. 2
Lumbrineris latreilli
Nemertea sp. A
Braniella nr. palpata
Cossura sp. 1
Levinsenia flava
Flabelligella cirrata
Dysponetus sp. 1
Ceratocephale loveni

Group 6

Myriochele cf. heeri
Thyasira ferruginea
Myriochele sp. 1

Group 7

Barantolla sp. 1
Thyasira (Leptaxinus) minutus
Galathowenia sp. 1
Meiodorvilla minuta
Paradoneis lyra
Tharyx sp. 1
Fabricia sp. 1

Group 8

Paranarthrura cf. insignis
Maldanidae sp. 3
Micrura sp. 1
Paramphinome jeffreysii
Siboglinum angstum

Group 9

Augeneria bidens
Siphonolabrum sp. 2
Falcidens sp. 4
Ninoe nr. brevipes
Ophiura sp. 1 juv.
Trochochaeta watsoni
Kesun gravieri
Dysponetus sp. 4
Aglaophamus sp. 1
Glycera capitata
Prionospio sp. 11
Notomastus latericeus
Prochaetoderma yongei
Spathoderma clenchi
Tubificoides apectinatus
Nemertea sp. 6
Sabidius cornatus
Siboglinum pholidotum
Anarthruridae sp. 1
Prionospio sp. 2
Aspidosiphon zinni
Aurospio dibranchiata
Pholoe anoculata

TABLE 8. (Continued).

Group 10

Exogone sp. 1
Phallodrilus grasslei
Dysponetus sp. 3
Paradoneis abranchiata

Group 11

Haploops setosa

Group 12

Tubificoides maureri
Tubificoides sp. 4
Leptognathia sp. 10

Group 13

Ophryotrocha sp. 1
Aricidea sp. 6
Thyasira equalis
Barantolla sp. 3
Harpinia clivicola

Group 14

Microrbinia linea

Group 15

Gnathia sp. 2

Group 16

Athecata sp. A
Thyasira rotunda
Pleurogonium nr. spinosissimum
Terebellides sp. 4
Dorvilleidae sp. 2
Chaetozone sp. 11
Leitoscoloplos acutus
Schistomeringos caeca
Pseudotanais sp. 5
Aricidea quadrilobata
Tubificoides intermedius
Nicolea sp. 1

Group 17

Limnodriloides medioporus
Scalibregma inflatum
Cossura longocirrata

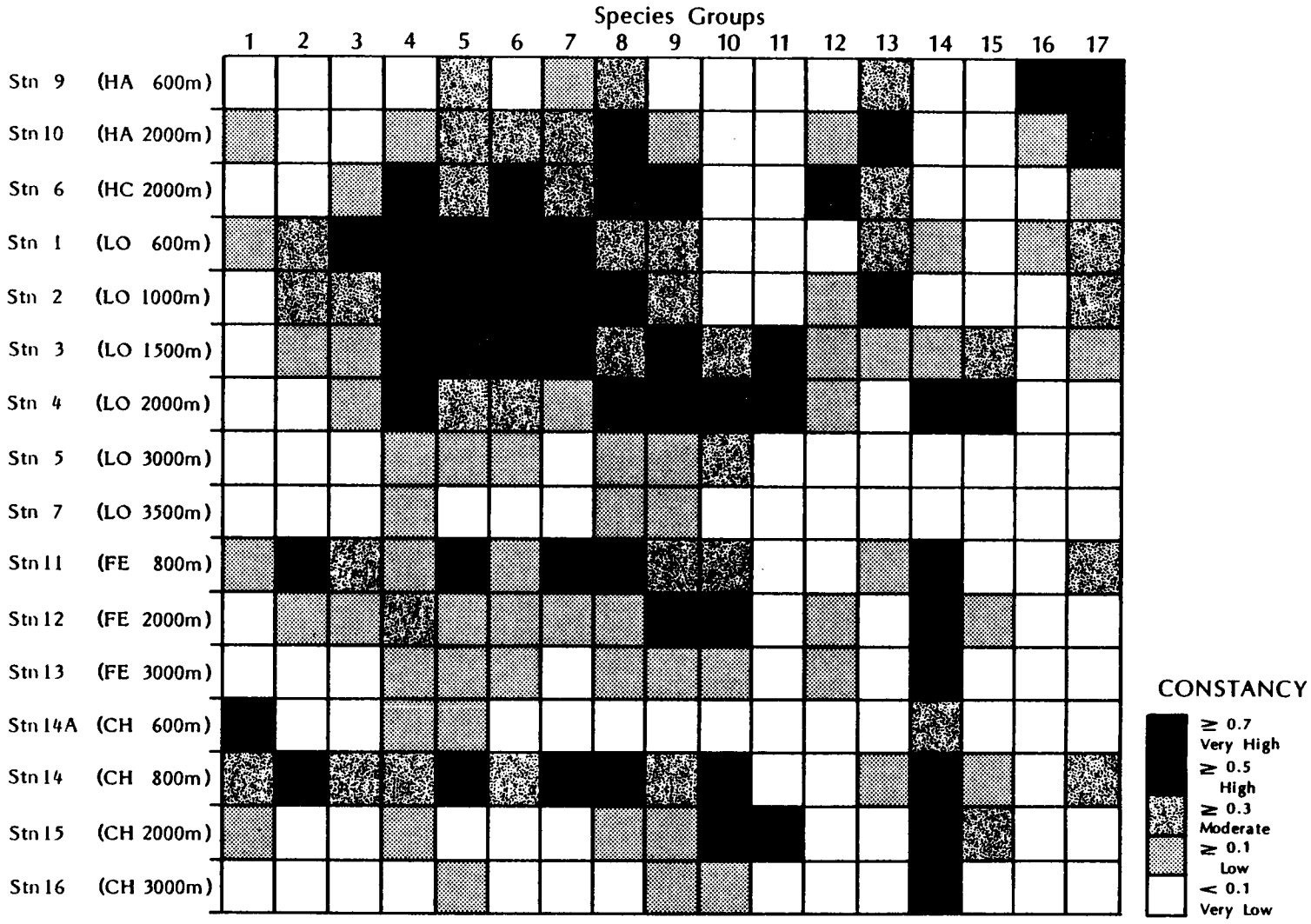


Figure 23. **Nodal Analysis of Constancy for Species Groups and Stations for U.S. South Atlantic Phases 1 and 2 Data.**

clear affinities to individual stations or to groups of stations. Species Group 1 showed strong affinities with Stations 14A and 14 off Charleston (600 m, 800 m). Group 2 represents a large group of species typical of upper slope depths, but most species are affiliated with Stations 11 or 14 off Cape Fear and Charleston (800 m). Group 3 is also an upper slope assemblage, but with highest affinity to Station 1 off Cape Lookout (600 m). Group 4 has its strongest affinities with Stations 1-4 off Cape Lookout and Station 6 off Hatteras Canyon (2000 m) and lesser similarity with Stations 11 off Cape Fear (2000 m) and 14 (800 m) off Charleston. Group 5 is an assemblage of species having its strongest affinities to stations in the 600- to 1000-m depth range from Cape Lookout to Charleston and weaker affiliations with the Cape Hatteras stations (600, 2000 m) and Station 4 off Cape Lookout (2000 m). Group 6 is very clearly associated with the Hatteras Canyon and Cape Lookout stations (HC 2000 m; LO 600-1500 m). Group 7 has its strongest affinities with Station 1 and 2 (LO 600, 1000 m) and 11 (FE 800 m), with weaker affinities with several other stations, both shallow and deep. Group 8 is widely distributed, mostly between 800 and 2000 m. Its strongest affinities are with Station 14 (CH 800 m). Group 9 is widespread, with its strongest affinities with the 1500- to 2000-m stations (HC 2000 m; LO 1500-2000 m; FE 2000 m). Group 10 appears to be a southern cluster, with strongest ties to Cape Fear and Charleston (FE 2000 m; CH 800-2000 m). Group 11 consists of only a single species, Haploops setosa, an amphipod which seems to show some affinity with Stations 3 and 4 off Cape Lookout (1500-2000 m) and Station 15 off Charleston (2000 m). Group 12 exhibits its closest ties with Station 6 (HC 2000 m). Group 13 is most constant at the northern stations from Cape Hatteras to Cape Lookout, but is closest to Station 10 (HA 2000 m). Group 14 consists of a single species, Microrbinia linea, which is the dominant species at six of the South Atlantic stations, beginning with Station 4 at 2000 m off Cape Lookout and including most of the Cape Fear and Charleston stations (see below). All of these same stations show affinities with this species (as Group 14). Group 15 also consists of a single species, Gnathia sp. 2, which occurs at upper slope localities on the Cape Lookout, Cape Fear, and Charleston transects. Group 16 is a Station 9 assemblage (HA 600 m), with only limited affinity with Station 10 (HA 2000 m) and Station 1 (LO 600 m). Group 17, composed of three of the dominant species is also a Station 9 assemblage. Since Cossura longocirrata is included in this group, there is some affiliation with other stations at which that species occurs.

In general, the R-mode Bray-Curtis analyses proved useful in delimiting certain species groups that are affiliated with particular depths and transects in the U.S. South Atlantic region.

Correspondence Analysis

The results of the correspondence analysis are shown in Figures 24 and 25. In Figure 24, Stations 9 (600 m) and 10 (2000 m) separate far out along axis 1. Stations 2 (1000 m) and 1 (600 m) separate somewhat along axis 1, while Stations 14 (800 m), 15 (2000 m) and 16 (3000 m) are separated only slighty from a cloud of closely clustered 2000-m stations on axis 2. These are only partial separations, with the remaining stations not being resolved from one another. Station 14A separates well out along axis 2. In Figure 25, a more significant resolution of stations is apparent relative to axis 3 and axis 1. Stations 1 (600 m), 2 (1000 m), 9 (600 m), 10 (2000 m), and 14A (600 m) exhibit the greatest separation from the central cloud of stations. Stations 11 (800 m), 14 (800 m), and 3 (1500 m) exhibit well-defined separations along axis 3; whereas Stations 6 (2000 m), 15 (2000 m), and 4 (2000 m) are only partially separated from a central cloud of 2000- and 3000-m stations.

The results in Figure 24 clearly emphasize the wide divergence of Stations 9, 10, and 14A from the central cloud of stations, and Figure 25 indicates the wide divergence of Stations 9, 10, 1, 2, and 14A from the central cluster. Stations 1, 2, 9, and 14A are all located on the upper slope and have unique faunal assemblages, but Station 10 is an unusual 2000-m station, having close faunal affinities with Station 9. Except for the 800-m Stations 11 and 14, which diverge along axis 3, the stations at 1500 m, the remaining 2000-m stations, and the 3000-m stations tend to be grouped close together.

In Figure 24, the data indicate a depth gradient, in that Stations 1, 2, and 9 separate along axis 1. The presence of a 2000-m station (10) along that same axis reflects its close faunal similarity with the shallower Station 9, rather than with the other 2000-m stations.

The results of the correspondence analysis for Phase 1 stations (1-7) and Phase 2 stations (4, 9-16) analyzed separately are presented in Appendix G. The results indicate that Phase 1 stations tend to cluster together according to depth (Figures G-1 and G-2). Results of the Phase 2 analysis more closely follow the results of analyzing all stations

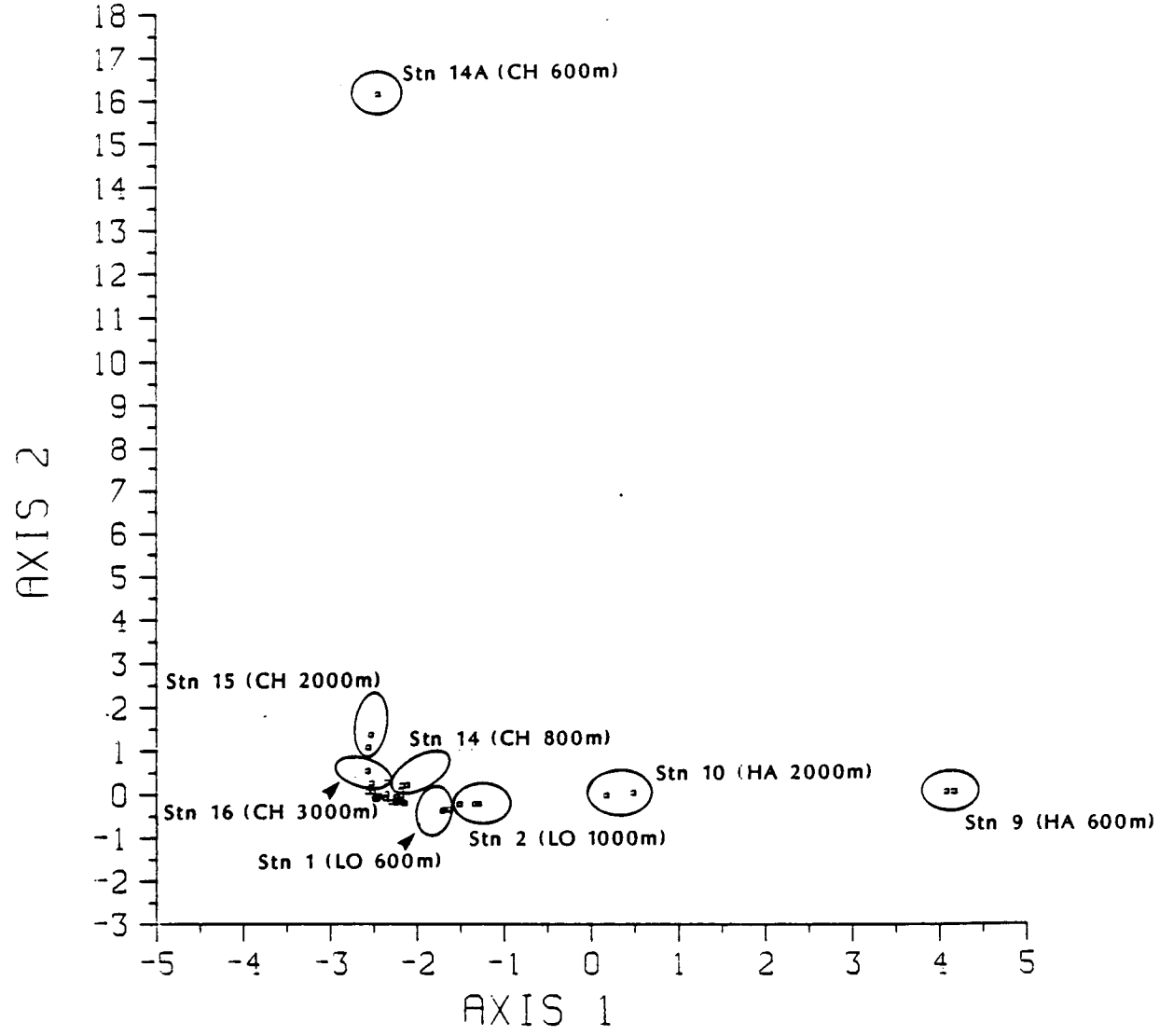


Figure 24. Reciprocal Averaging Ordination of Phases 1 and 2 U.S. South Atlantic Samples. Stations 9, 10, and 14A Separate Along Axes 1 and 2.

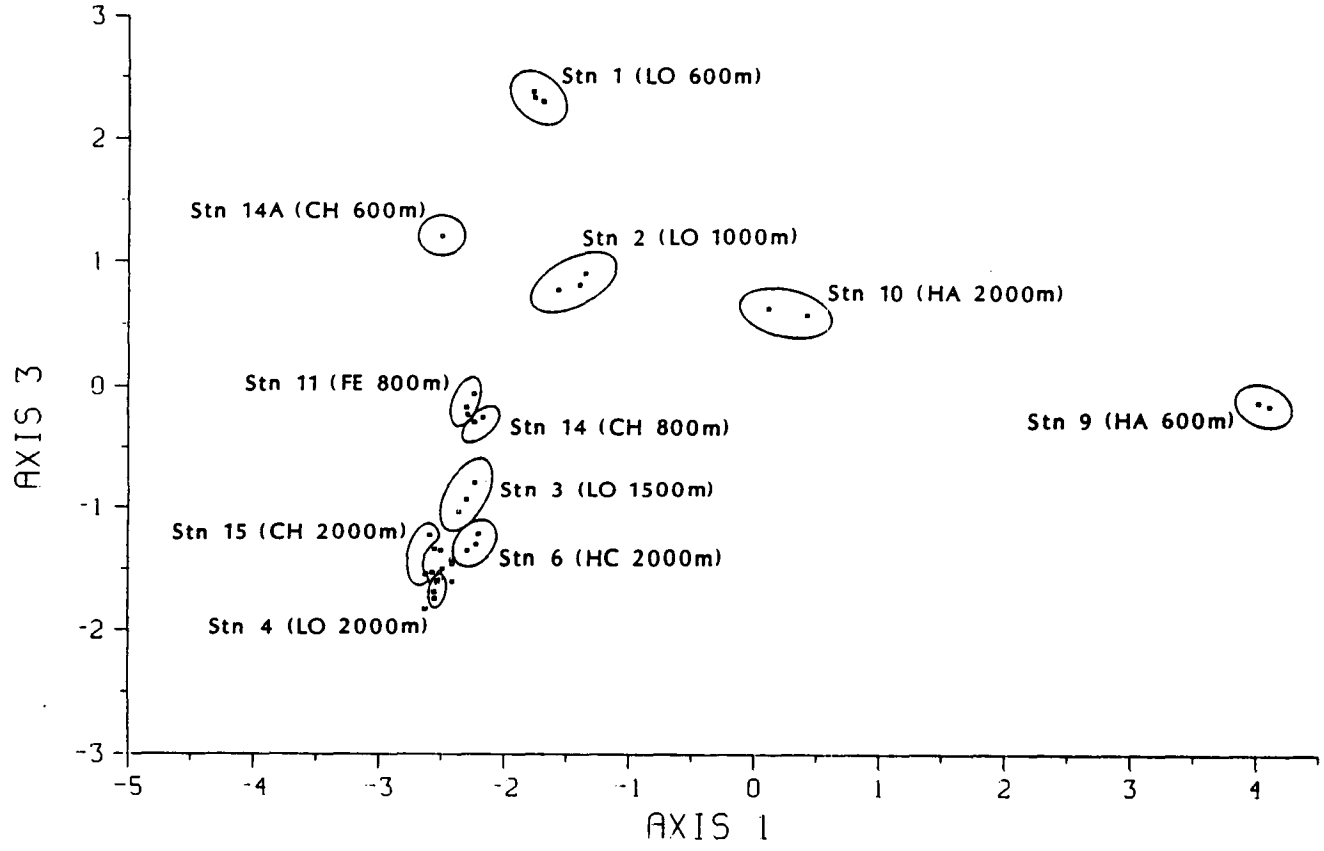


Figure 25. Reciprocal Averaging Ordination of Phases 1 and 2 U.S. South Atlantic Stations 1, 2, 9, 10, and 14A Separate Along Axes 1 and 3.

combined, in that Stations 9, 10, and 14A are widely separated from a central cloud of stations (Figures G.3 and G.4).

Dominant Species

The dominant species and their contribution to the fauna at each station, summed over the seasonal cruises for which they were sampled, are presented in Tables 9 through 24. The tables are arranged with the stations grouped by depth, so that comparisons along isobaths can be made latitudinally. In some cases, indeterminate or juvenile taxa made up significant percentages of the fauna at a given station. These taxa are listed in the tables, and the percentage contribution of identified species has been calculated both including and excluding the indeterminate taxa. The dominant species recorded at each station for each season are given in Appendix D.

Stations on the 600-m isobath. Three stations were sampled at 600 m: Station 9 on the Cape Hatteras Transect, Station 1 off Cape Lookout, and Station 14A off Charleston. Of the three, Station 1 is the most diverse, with 361 species recorded from nine box cores. Station 9 had 145 species in nine box cores; Station 14A had only 64 species, but only three box cores were collected at this station.

At Station 9, five annelid species account for 66.1 percent of the fauna (Table 9). Cossura longocirrata is the dominant species, with 27.8 percent of the total fauna, followed closely by Scalibregma inflatum with 19.6 percent. On Cruise SA-5, S. inflatum was the top-ranked species (Appendix E, Table E-1). Two oligochaetes, Limnodriloides medioporus and Tubificoides intermedius, were next in rank, followed by a paraonid polychaete, Aricidea quadrilobata. The next 15 species in the rank order account for only 7.5 percent of the fauna. These include 10 polychaetes, one tanaid, one isopod, one bivalve, one amphipod, and a nemertean. Included in this list of 20 dominants are some forms that are more typical of shallower continental shelf environments, such as Cossura longocirrata, Limnodriloides medioporus, Aricidea quadrilobata, Leitoscoloplos acutus, and Lumbrineris fragilis. The density of S. inflatum at this station is among the highest ever recorded, and has provided a unique opportunity to collect population data on a widespread and cosmopolitan species. A total of 27 species, including five of the top dominants, occur only at Station 9 off Cape Hatteras.

TABLE 9. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 9 (HA 600 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Cossura longocirrata (Polychaeta)	10,417	27.8	36.5
-	(Tubificidae spp. juv.) (Oligochaeta)	7,971	21.3	-
2.	Scalibregma inflatum (Polychaeta)	7,332	19.6	25.7
3.	Limnodriloides medioporus (Oligochaeta)	4,410	11.8	15.4
4.	Tubificoides intermedius (Oligochaeta)	1,561	4.2	5.5
5.	Aricidea quadrilobata (Polychaeta)	1,005	3.5	3.5
6.	Pseudotanais sp. 5 (Tanaidacea)	600	1.6	2.1
7.	Schistomeringos caeca (Polychaeta)	465	1.2	1.6
8.	Leitoscoloplos acutus (Polychaeta)	361	1.0	1.3
-	(Turbellaria) (Platyhelminthes)	287	0.8	-
9.	Terebellides sp. 4 (Polychaeta)	228	0.6	0.8
10.	Chaetozone sp. 11 (Polychaeta)	200	0.5	0.7
11.	Pleurogonium nr. spinosissimum (Isopoda)	162	0.4	0.6
12.	Dorvilleidae sp. 2 (Polychaeta)	158	0.4	0.6
-	(Terebellides spp. juv) (Polychaeta)	140	0.4	-
-	(Cirratulidae spp. indet.) (Polychaeta)	118	0.3	-
-	(Hesionidae spp. indet.) (Polychaeta)	118	0.3	-
13.	Nicolea sp. 1 (Polychaeta)	103	0.3	0.4
14.	Ceratocephale loveni (Polychaeta)	101	0.3	0.4
15.	Thyasira rotunda (Bivalvia)	94	0.3	0.3
16.	Lumbrineris fragilis (Polychaeta)	93	0.2	0.3
17.	Melinna cristata (Polychaeta)	83	0.2	0.3
18.	Nemertea sp. A (Nemertea)	78	0.2	0.3
-	(Cylichna spp. juv.) (Gastropoda)	78	0.2	-
19.	Erichthonius sp. 3 (Amphipoda)	77	0.2	0.3
20.	Levinsenia sp. 1 (Polychaeta)	56	0.1	0.2
		Total Cumulative Percent	97.7	96.8

None of the top 20 species present at Station 9 are in the top 20 list at Station 1 (Table 10). The five top dominant species at Station 1 include four polychaetes and one bivalve. Fabricia sp. 1, a small filter-feeding sabellid known only from this site, dominates this community with 12.4 percent of the total fauna. Meiodorvillea minuta, the second ranked species at 8.2 percent, is a small omnivorous polychaete, and is the top-ranked species at Station 2 (LO 1000 m) (see below). Many of the remaining dominants are deposit feeders. A total of 48 species occur at Station 1 and nowhere else in the study area.

Station 14A, off Charleston, South Carolina, is the most unusual station in the entire study area (Table 11). The first five species make up 51.6 percent of the fauna. Fourteen of the top 20 species are polychaetes, of which some like Novaquesta trifurcata are here recorded in their southernmost, and deepest, locality. This species was previously known only from the continental shelf off the northeastern U.S. The top-ranked species, Caulleriella sp. 3 with 14 percent, is elsewhere recorded only from Station 15, at 2000 m on the same transect off Charleston. Protodorvillea nr. kefersteini, the second-ranked species with 13.9 percent of the individuals, was found at other shallow stations, including Stations 1, 11, and 14, but was generally rare. This species is more typical of continental shelf localities. Prionospio sp. 24, the third-ranked species, also occurred at Station 14 (800 m) on the Charleston transect and one specimen was identified from 800 m off Cape Fear (Station 11), but it has not been recorded further north. Aricidea catherinae is more widely known from shallower continental shelf habitats. A total of 15 species, including four of the top dominants, occur at Station 14A and nowhere else in the study area.

Stations on the 800- to 1000-m Isobaths. Three stations, Station 2 (1000 m) off Cape Lookout, Station 11 (800 m) off Cape Fear, and Station 14 (800 m) off Charleston, are compared. All three stations are highly diverse, with 325, 385, and 436 species, respectively. Some species occur at only one of these stations and nowhere else: 34 species at Station 2, 31 species at Station 11, and 43 species at Station 14. None of these station-specific species is among the top-ranked dominants. Forty-five species are shared between Stations 11 and 14, and this station pair consistently clusters together using NESS and Bray-Curtis (see above).

Station 2 is dominated by five annelids composing 29.6 percent of the total fauna (Table 12). Meiodorvillea minuta is the species ranked number one with 7.5 percent. It

TABLE 10. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 1 (LO 600 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Fabricia sp. 1 (Polychaeta)	1,635	12.4	13.7
2.	Meiodorvillea minuta (Polychaeta)	1,081	8.2	9.0
3.	Galathowenia sp. 1 (Polychaeta)	689	5.2	5.8
-	(Tubificidae spp. juv.) (Oligochaeta)	552	4.2	-
4.	Thyasira (Leptaxinus) minutus (Bivalvia)	520	3.9	4.3
5.	Barantolla sp. 1 (Polychaeta)	396	3.0	3.3
6.	Auchenoplax crinita (Polychaeta)	339	2.6	2.8
7.	Tharyx sp. 1 (Polychaeta)	303	2.3	2.5
8	Paradoneis lyra (Polychaeta)	281	2.1	2.3
9.	Limnodriloides monothecus (Oligochaeta)	256	1.9	2.1
10.	Tharyx sp. 2 (Polychaeta)	251	1.9	2.1
11.	Ophelina abranchiata (Polychaeta)	250	1.9	2.1
12.	Cossura longocirrata (Polychaeta)	204	1.4	1.7
13.	Ninoe nigripes (Polychaeta)	191	1.4	1.6
14.	Euchone hancocki (Polychaeta)	184	1.4	1.5
15.	Levinsenia sp. 1 (Polychaeta)	153	1.2	1.3
16.	Paradoneis brevicirratus (Polychaeta)	143	1.1	1.2
17.	Flabelligella brevicirratus (Polychaeta)	139	1.1	1.2
18.	Dysponetus sp. 1 (Polychaeta)	137	1.0	1.1
19.	Thyasira croulinensis (Bivalvia)	134	1.0	1.1
20.	Tubificoides apectinatus (Oligochaeta)	129	1.0	1.1
		Total Cumulative Percent	60.2	61.8

TABLE 11. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN THREE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 14A (CH 600 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Caulleriella sp. 3 (Polychaeta)	89	14.0	15.7
2.	Protodorvillea nr. kefersteini (Polychaeta)	88	13.9	15.5
3.	Prionospio sp. 24 (Polychaeta)	87	13.7	15.3
4.	Aricidea catherinae (Polychaeta)	44	6.9	7.7
5.	Novaquesta trifurcata (Polychaeta)	20	3.1	3.5
6.	Ceratocephale loveni (Polychaeta)	17	2.7	3.0
-	(Turbellaria) (Platyhelminthes)	14	2.2	-
7.	Glycera capitata (Polychaeta)	13	2.0	2.3
-	(Tubificidae spp. juv.) (Oligochaeta)	13	2.0	-
8.	Leptognathia cf. armata (Tanaidacea)	12	1.9	2.1
9.	Nereimyra sp. 2 (Polychaeta)	12	1.9	2.1
10.	Ophelia sp. 2 (Polychaeta)	11	1.7	1.9
11.	Notomastus cf. tenuis (Polychaeta)	11	1.7	1.9
12.	Phallodrilus sp. 5 (Oligochaeta)	11	1.7	1.9
13.	Tanaissus sp. 1 (Tanaidacea)	10	1.6	1.7
14.	Scoloplos (Leodamas) sp. 3 (Polychaeta)	10	1.6	1.7
15.	Aonides paucibranchiata (Polychaeta)	9	1.4	1.6
16.	Exogone verugera profunda (Polychaeta)	9	1.4	1.6
17.	Thambema sp. 1 (Isopoda)	8	1.3	1.4
18.	Polycirrus sp. 3 (Polychaeta)	8	1.3	1.4
19.	Enteropneusta sp. 2 (Hemichordata)	7	1.1	1.2
20.	Phoxocephalidae sp. 1 (Amphipoda)	7	1.1	1.2
		Total Cumulative Percent	80.2	84.7

TABLE 12. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 2 (LO 1000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Meiodorvillea minuta (Polychaeta)	552	7.5	7.8
2.	Cossura longocirrata (Polychaeta)	523	7.1	7.4
3.	Tubificoides sp. 3 (Oligochaeta)	505	6.8	7.2
4.	Paradoneis lyra (Polychaeta)	371	5.0	5.3
5.	Levinsenia flava (Polychaeta)	228	3.1	3.2
6.	Dysponetus sp. 1 (Polychaeta)	224	3.0	3.2
7.	Cossura sp. 1 (Polychaeta)	184	2.5	2.6
8.	Nemertea sp. A (Nemertea)	177	2.4	2.5
9.	Kelliella sp. 1 (Bivalvia)	170	2.3	2.4
10.	Braniella nr. palpata (Polychaeta)	162	2.2	2.3
11.	Thyasira (Leptaxinus) minutus (Bivalvia)	146	2.0	2.1
12.	Flabelligella cirrata (Polychaeta)	145	2.0	2.1
13.	Tharyx sp. 1 (Polychaeta)	124	1.7	1.8
14.	Grania atlantica (Oligochaeta)	121	1.6	1.7
15.	Labidoplax buskii (Holothuroidea)	116	1.6	1.6
16.	Thyasira subovata (Bivalvia)	107	1.4	1.5
17.	Pholoe anoculata (Polychaeta)	99	1.3	1.4
18.	Thyasira croulinensis (Bivalvia)	94	1.3	1.3
19.	Prochaetodermatidae sp. 1 (Aplacophora)	92	1.2	1.3
20.	Nemertea sp. 3 (Nemertea)	90	1.2	1.3
	Total Cumulative Percent		57.2	60.0

ranks second at the slightly shallower Station 1 on the same Cape Lookout transect, and is therefore one of the most important benthic polychaetes on the upper slope off North Carolina. Maciolek et al. (1986b) also found M. minuta to be an important component in the shallower communities on the U.S. North Atlantic slope off Georges Bank in depths of 255 to 550 m. Cossura longocirrata is the second-ranked species at 7.1 percent and another important upper slope polychaete. Its dominance at Station 9 (600 m) off Cape Hatteras has already been mentioned. The oligochaete Tubificoides sp. 3 is the third-ranked species at Station 2 with 6.8 percent of the total fauna, and is a high-ranking species at Stations 11 and 14 as well.

Stations 11 and 14 (Tables 13, 14) are both dominated by the small orbiniid polychaete Microrbinia linea, which accounts for 9.0 and 9.5 percent of the total fauna, respectively. Although the list of dominants at both stations includes several shared species such as Cossura sp. 2 and Spionidae sp. 11, there are important differences as well. Forty-three species that occur at Station 14 and 31 species that occur at Station 11 were found nowhere else in this study. None of these species is in the list of top dominants. Meiodorvillea minuta is ranked number 15 at Station 11, but is rare at Station 14, suggesting that it is replaced by M. linea as an upper slope dominant in the area between Cape Fear and Charleston.

Middle to Lower Slope Stations on the 1500- to 2000-m Isobaths. Six stations are included here: starting in the north, Station 10 off Cape Hatteras (2000 m), Station 6 near the Hatteras Canyon (2000 m), Station 3 off Cape Lookout (1500 m), Station 4 off Cape Lookout (2000 m), Station 12 off Cape Fear (2000 m), and Station 15 off Charleston (2000 m). Stations 10 and 15 are the most northern and southern locations of these stations and differ the most from the Hatteras Canyon, Cape Lookout, and Cape Fear stations.

Station 10 is more similar to its shallower counterpart, Station 9, on the Cape Hatteras Transect than to the other 2000-m stations in terms of shared dominant species (Table 15). Cossura longocirrata, which ranked number one at Station 9, is also the most abundant species at Station 10 with 18.6 percent of the total fauna. Scalibregma inflatum, which was the second-ranked species at Station 9, is also important at Station 10. Neither of these species is among the top 20 dominants at the other 1500- to 2000-m stations, but both are important at other upper slope stations. The second-ranked species is Tharyx sp. 1, a cirratulid polychaete, which is fairly common at many stations.

TABLE 13. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 11 (FE 800 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Microrbinia linea (Polychaeta)	739	9.0	10.2
-	(Tubificidae spp. juv.) (Oligochaeta)	508	6.2	-
2.	Leptocheliidae sp. 1 (Tanaidacea)	484	5.9	6.7
3.	Aspidosiphon zinni (Sipuncula)	319	3.9	4.4
4.	Bathydrilus asymmetricus (Oligochaeta)	256	3.1	3.5
5.	Tubificoides sp. 3 (Oligochaeta)	229	2.8	3.2
6.	Kelliella sp. 1 (Bivalvia)	205	2.5	2.8
7.	Chone sp. 5 (Polychaeta)	194	2.4	2.7
8.	Jasmineira filiformis (Polychaeta)	167	2.0	2.3
9.	Myriotrochinae sp. 1 juv. (Holothuroidea)	161	2.0	2.2
10.	pionidae n. gen. n. sp. 11 (Polychaeta)	155	1.9	2.1
11.	athyarca sp. 1 (Bivalvia)	146	1.8	2.0
12.	Tharyx sp. 1 (Polychaeta)	131	1.6	1.8
13.	Cossura sp. 2 (Polychaeta)	117	1.4	1.6
14.	Lumbrineris latreilli (Polychaeta)	113	1.4	1.6
15.	Meiodorvillea minuta (Polychaeta)	106	1.3	1.5
16.	Nephasoma abyssorum (Sipuncula)	106	1.3	1.5
17.	Limnodriloides monothecus (Oligochaeta)	101	1.2	1.4
18.	Nephasoma diaphanes (Sipuncula)	98	1.2	1.3
19.	Thyasira croulinensis (Bivalvia)	89	1.1	1.2
20.	Nemertea sp. 2 (Nemertea)	86	1.0	1.2
	Total Cumulative Percent		55.0	55.1

TABLE 14. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 14 (CH 800 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
-	(Tubificidae spp. juv.) (Oligochaeta)	771	10.5	-
1.	Microrbinia linea (Polychaeta)	693	9.5	11.6
2.	Bathydrilus asymmetricus (Oligochaeta)	212	2.9	3.5
3.	Tubificoides sp. 3 (Oligochaeta)	166	2.3	2.8
4.	Pholoe anoculata (Polychaeta)	159	2.2	2.7
5.	Kelliella sp. 1 (Bivalvia)	135	1.8	2.3
6.	Tharyx sp. 1 (Polychaeta)	123	1.7	2.1
7.	Spionidae n. gen. n. sp. 11 (Polychaeta)	115	1.6	1.9
8.	Myriotrochinae sp. 1 juv. (Holothuroidea)	110	1.5	1.8
9.	Cossura sp. 2 (Polychaeta)	107	1.5	1.8
10.	Phallodrilus sp. 4 (Oligochaeta)	104	1.4	1.7
-	(Cirratulidae spp. indet.) (Polychaeta)	96	1.3	-
11.	Phallodrilus grasslei (Oligochaeta)	85	1.2	1.4
12.	Aricidea sp. 3 (Polychaeta)	79	1.1	1.3
13.	Aurospio dibranchiata (Polychaeta)	78	1.1	1.3
14.	Cossura longocirrata (Polychaeta)	77	1.1	1.3
15.	Dysponetus sp. 1 (Polychaeta)	76	1.0	1.3
16.	Myriochele sp. 4 (Polychaeta)	73	1.0	1.2
17.	Ophelina abranchiata (Polychaeta)	72	1.0	1.2
18.	Limnodriloides monothecus (Oligochaeta)	71	1.0	1.2
19.	Nemertea sp. 2 (Nemertea)	69	0.9	1.2
20.	Boguella sp. 1 (Polychaeta)	68	0.9	1.1
		Total Cumulative Percent	48.5	44.7

TABLE 15. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN SIX REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 10 (HA 2000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Cossura longocirrata (Polychaeta)	900	18.6	20.3
2.	Tharyx sp. 1 (Polychaeta)	59	12.4	13.5
3.	Harpinia clivicola (Amphipoda)	589	12.2	13.3
4.	Barantolla sp. 3 (Polychaeta)	296	6.1	6.7
5.	Thyasira equalis (Bivalvia)	266	5.5	6.0
6.	Aricidea sp. 6 (Polychaeta)	247	5.1	5.6
	(Tubificidae spp. juv.) (Oligochaeta)	221	4.6	-
7.	Paradoneis lyra (Polychaeta)	190	3.9	4.3
8.	Myriochele sp. 4 (Polychaeta)	156	3.2	3.5
9.	Thyasira (Leptaxinus) minutus (Bivalvia)	153	3.2	3.4
10.	Thyasira tortuosa (Bivalvia)	67	1.4	1.5
11.	Scalibregma inflatum (Polychaeta)	64	1.3	1.4
12.	Ophryotrocha sp .1 (Polychaeta)	22	1.0	1.4
13.	Levinsenia sp. 1 (Polychaeta)	48	0.9	1.1
14.	Thyasira croulinensis (Bivalvia)	42	0.8	1.0
15.	Myriochele sp. 6 (Polychaeta)	41	0.8	0.9
16.	Ophelina cylindricaudata (Polychaeta)	38	0.8	0.9
17.	Athecata sp. A (Hydrozoa)	38	0.8	0.9
18.	Falcidens sp. 2 (Aplacophora)	37	0.8	0.8
19.	Aricidea catherinae (Polychaeta)	36	0.7	0.8
20.	Aricidea sp. 4 (Polychaeta)	31	0.6	0.7
		Total Cumulative Percent	84.7	88.0

Harpinia clivicola, an amphipod, is the third-ranking species at Station 10, accounting for 12.2 percent of the total fauna. These species, along with Barantolla sp. 3, Thyasira equalis, Aricidea sp. 6, and Ophryotrocha sp. 1, are restricted to Station 10 and are not found at other stations of similar depth in the U.S. South Atlantic region.

Stations 6, 3, 4, and 12, located from the Hatteras Canyon to Cape Fear, share more common dominant species (Tables 16-19) with one another than with Station 15 off Charleston (Table 20). Pholoe anoculata, a small scale-bearing sigalionid polychaete, ranks number one at Station 6 (HC 2000 m) and Station 3 (LO 1500 m), number two at Station 4 (LO 2000 m) and number three at Station 12 (FE 2000 m). Tubificoides aculeatus, an oligochaete, is the second-ranked species at Hatteras Canyon (Station 6, 2000 m). It is present among the top dominants at both of the Cape Lookout stations, but is missing from the Cape Fear station. Aurospio dibranchiata, a spionid polychaete, the top dominant at most of the 2000- to 2100-m stations in the U.S. Mid-Atlantic region, is also near the top of the list at Stations 6, 3, 4, and 12. This species is also among the top dominants at Station 15 off Charleston. Thus, A. dibranchiata continues to be one of the most characteristic polychaetes of the lower slope on the ACSAR. Interestingly, the species is not the top dominant at any U.S. South Atlantic station. Pholoe anoculata predominates off Hatteras Canyon and at 1500 m off Cape Lookout, while Microrbinia linea is the dominant species at Stations 4 and 15. Station 12 is unusual among all 2000-m stations in having Prionospio sp. 2 as the top-ranked species, with Aurospio dibranchiata, Pholoe anoculata, and Microrbinia linea being lower in rank.

Stations on the 3000 to 3500-m Isobaths. Three stations located at depths of 3000 m and one at 3500 m were sampled. Station 5 off Cape Lookout (3000 m) was sampled during Phase 1. Two samples were taken at a slightly deeper site (Station 7, 3500 m) also off Cape Lookout. Stations 13 and 16, also at 3000 m, were off Cape Fear and Charleston, respectively. Station 16 is located on the Blake Spur, nearly 200 miles from shore and on the edge of the U.S. Exclusive Economic Zone.

In comparing the dominant species at these four stations (Tables 21 through 24), it is apparent that there is a difference between the 3000-m station off Cape Lookout and the two 3000-m stations further south. The dominant species at Station 5 are Prionospio fauchaldi, Macrostylis sp. 1, Prionospio sp. 2, Brevincula verrilli, and Siboglinum angustum. Of these five species, only Prionospio sp. 2 is among the five most dominant

TABLE 16. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 6 (HC 2000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Pholoe anoculata (Polychaeta)	408	8.1	8.7
2.	Tubificoides aculeatus (Oligochaeta)	333	6.6	7.1
3.	Aurospio dibranchiata (Polychaeta)	235	4.7	5.0
4.	Spathoderma clenchi (Aplacophora)	202	4.0	4.3
5.	Lumbrineris latreilli (Polychaeta)	135	2.7	2.9
6.	Prochaetoderma yongei (Aplacophora)	133	2.6	2.8
7.	Barantolla sp. 3 (Polychaeta)	132	2.6	2.8
8.	Siphonolabrum sp. 2 (Tanaidacea)	130	2.6	2.8
9.	Tharyx sp. 1 (Polychaeta)	126	2.5	2.7
10.	Tubificoides sp. 4 (Oligochaeta)	114	2.3	2.4
11.	Leptognathia sp. 10 (Tanaidacea)	100	2.0	2.1
-	(Tubificidae spp. juv.) (Oligochaeta)	97	1.9	-
12.	Aglaophamus sp. 1 (Polychaeta)	87	1.7	1.8
13.	Falcidens sp. 4 (Aplacophora)	86	1.7	1.8
-	(Capitellidae spp. juv.) (Polychaeta)	82	1.6	-
14.	Ninoe nr. brevipes (Polychaeta)	76	1.5	1.6
15.	Sabidius cornatus (Polychaeta)	74	1.5	1.6
16.	Glycera capitata (Polychaeta)	74	1.5	1.6
17.	Anarthruridae sp. 1 (Tanaidacea)	66	1.3	1.4
18.	Nemertea sp. 5 (Nemertea)	59	1.2	1.3
19.	Nemertea sp. A (Nemertea)	55	1.1	1.2
20.	Dysponetus sp. 4 (Polychaeta)	55	1.1	1.2
		Total Cumulative Percent	56.8	57.1

TABLE 17. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 3 (LO 1500 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Pholoe anoculata (Polychaeta)	419	10.3	10.9
2.	Aurospio dibranchiata (Polychaeta)	207	5.1	5.4
3.	Aspidosiphon zinni (Sipuncula)	160	3.9	4.2
4.	Bathydrilus asymmetricus (Oligochaeta)	143	3.5	3.7
5.	Labidoplax buskii (Holothuroidea)	117	2.9	3.0
6.	Haploops setosa (Amphipoda)	88	2.2	2.3
7.	Prochaetodermatidae sp. 1 (Aplacophora)	83	2.0	2.2
8.	Prochaetoderma yongei (Aplacophora)	79	1.9	2.1
9.	Tubificoides aculeatus (Oligochaeta)	69	1.7	1.8
10.	Prionospio sp. 11 (Polychaeta)	63	1.5	1.6
11.	Prionospio sp. 2 (Polychaeta)	62	1.5	1.6
12.	Myriotrochinae sp. 1 juv. (Holothuroidea)	61	1.5	1.6
13.	Dysponetus sp. 1 (Polychaeta)	57	1.4	1.5
14.	Levinsenia sp. 1 (Polychaeta)	54	1.3	1.4
15.	Nemertea sp. A (Nemertea)	54	1.3	1.4
16.	Nemertea sp. 2 (Nemertea)	52	1.3	1.4
17.	Nephasoma diaphanes (Sipuncula)	50	1.2	1.3
18.	Siboglinum pholidotum (Pogonophora)	46	1.1	1.2
19.	Tharyx sp. 1 (Polychaeta)	45	1.1	1.2
20.	Falcidens sp. 2 (Aplacophora)	42	1.0	1.1
		Total Cumulative Percent	47.7	50.9

TABLE 18. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 4 (LO 2000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Microrbinia linea (Polychaeta)	1,280	15.2	15.9
2.	Aspidosiphon zinni (Sipuncula)	517	6.1	6.4
3.	Pholoe anoculata (Polychaeta)	476	5.6	5.9
4.	Aurospio dibranchiata (Polychaeta)	432	5.1	5.4
5.	Prionospio sp. 2 (Polychaeta)	406	4.8	5.0
6.	Anarthruridae sp. 1 (Tanaidacea)	285	3.4	3.5
7.	Siboglinum pholidotum (Pogonophora)	277	3.3	3.4
8.	Sabidius cornatus (Polychaeta)	215	2.6	2.7
9.	Spathoderma clenchi (Aplacophora)	132	1.6	1.6
10.	Dysponetus sp. 4 (Polychaeta)	107	1.3	1.3
11.	Glycera capitata (Polychaeta)	100	1.2	1.2
12.	Prochaetoderma yongei (Aplacophora)	99	1.2	1.2
-	(Cirratulidae spp. indet.) (Polychaeta)	99	1.2	-
13.	Notomastus latericeus (Polychaeta)	94	1.1	1.2
14.	Aglaophamus sp. 1 (Polychaeta)	92	1.1	1.1
15.	Kesun gravieri (Polychaeta)	82	1.0	1.0
16.	Nemertea sp. 2 (Nemertea)	77	0.9	1.0
17.	Levinsenia sp. 1 (Polychaeta)	76	0.9	0.9
18.	Tubificoides aculeatus (Oligochaeta)	75	0.9	0.9
19.	Prionospio sp. 11 (Polychaeta)	74	0.9	0.9
20.	Myriotrochinae sp. 1 juv. (Holothuroidea)	70	0.8	0.9
		Total Cumulative Percent	60.2	61.4

TABLE 19. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN SEVEN REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 12 (FE 2000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Prionospio sp. 2 (Polychaeta)	87	5.6	6.1
2.	Aurospio dibranchiata (Polychaeta)	70	4.5	4.9
3.	Pholoe anoculata (Polychaeta)	69	4.4	4.8
4.	Gnathia sp. 2 (Isopoda)	67	4.3	4.7
5.	Paradoneis abranchiata (Polychaeta)	62	4.0	4.3
6.	Rhodine sp. 1 (Polychaeta)	36	2.3	2.5
7.	Microrbinia linea (Polychaeta)	32	2.1	2.2
8.	Prionospio sp. 21 (Polychaeta)	28	1.8	2.0
9.	Sabidius cornatus (Polychaeta)	26	1.7	1.8
10.	Glycera capitata (Polychaeta)	25	1.6	1.8
11.	Grania atlantica (Oligochaeta)	23	1.5	1.6
12.	Aspidosiphon zinni (Sipuncula)	22	1.4	1.5
13.	Labidoplax buskii (Holothuroidea)	21	1.4	1.5
-	(Cirratulidae spp. indet.) (Polychaeta)	21	1.4	-
14.	Phallodrilus grasslei (Oligochaeta)	20	1.3	1.4
15.	Streblosoma sp. 2 (Polychaeta)	19	1.2	1.3
16.	Nemertea sp. 2 (Nemertea)	17	1.1	1.2
17.	Prionospio sp. 11 (Polychaeta)	17	1.1	1.2
18.	Chelator insignis (Isopoda)	17	1.1	1.2
19.	Myriotrochinae sp. 1 juv. (Holothuroidea)	17	1.1	1.2
20.	Thyasira croulinensis (Bivalvia)	17	1.1	1.2
21.	Aglaophamus sp. 1 (Polychaeta)	17	1.1	1.2
22.	Pseudotanais sp. 2 (Tanaidacea)	17	1.1	1.2
		Total Cumulative Percent	48.2	50.8

TABLE 20. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN SIX REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 15 (CH 2000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Microrbinia linea (Polychaeta)	164	23.2	26.8
2.	Grania atlantica (Oligochaeta)	35	4.9	5.7
3.	Glycera capitata (Polychaeta)	25	3.5	4.1
4.	Aonides sp. 1 (Polychaeta)	24	3.4	3.9
-	(Cirratulidae spp. indet.) (Polychaeta)	24	3.4	-
5.	Caulleriella sp. 3 (Polychaeta)	20	2.8	3.3
6.	Paradoneis abranchiata (Polychaeta)	20	2.8	3.3
7.	Euchone scotiarum (Polychaeta)	19	2.7	3.1
8.	Aspidosiphon zinni (Sipuncula)	16	2.3	2.6
9.	Prionospio sp. 2 (Polychaeta)	16	2.3	2.6
-	(Tubificidae spp. juv.)	16	2.3	-
10.	Aurospio dibranchiata (Polychaeta)	15	2.1	2.5
11.	Phallodrilus grasslei (Oligochaeta)	14	2.0	2.3
12.	Anarthruridae sp. 7 (Tanaidacea)	11	1.6	1.8
13.	Exogone sp. 1 (Polychaeta)	10	1.4	1.6
14.	Exogone sp. 2 (Polychaeta)	9	1.3	1.5
15.	Nephasoma cf. capilleforme (Sipuncula)	8	1.1	1.3
16.	Nemertea sp. 5 (Nemertea)	8	1.1	1.3
-	(Prionospio spp. indet.) (Polychaeta)	8	1.1	-
17.	Prionospio sp. 21 (Polychaeta)	7	1.0	1.1
-	(Capitellidae spp. juv.) (Polychaeta)	7	1.0	-
18.	Tharyx sp. 1 (Polychaeta)	6	0.8	1.0
19.	Ophelia profunda (Polychaeta)	6	0.8	1.0
20.	Bathydrilus asymmetricus (Oligochaeta)	6	0.8	1.0
21.	Nemertea sp. 2 (Nemertea)	6	0.8	1.0
-	(Laonice spp. indet.)	6	0.8	-
		Total Cumulative Percent	71.3	72.8

TABLE 21. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 5 (LO 3000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Prionospio fauchaldi (Polychaeta)	38	5.4	6.0
2.	Macrostylis sp. 1 (Isopoda)	32	4.5	5.0
3.	Prionospio sp. 2 (Polychaeta)	24	3.4	3.8
4.	Brevinucula verrilli (Bivalvia)	23	3.3	3.6
5.	Siboglinum angstum (Pogonophora)	19	2.7	3.0
6.	Aspidosiphon zinni (Sipuncula)	18	2.6	2.8
-	(Maldanidae spp. indet.) (Polychaeta)	15	2.1	-
7.	Siphonolabrum sp. 1 (Tanaidacea)	13	1.8	2.0
8.	Thambema sp. 1 (Isopoda)	11	1.6	1.7
9.	Exogone sp. 1 (Polychaeta)	11	1.6	1.7
10.	Ophelina abranchiata (Polychaeta)	10	1.4	1.6
11.	Dacrydium sp. 1 (Bivalvia)	9	1.3	1.4
12.	Enteropneusta sp. 1 (Hemichordata)	9	1.3	1.4
13.	Leptognathia sp. 4 (Tanaidacea)	9	1.3	1.4
14.	Nemertea sp. A (Nemertea)	9	1.3	1.4
15.	Harpinia sp. 2 (Amphipoda)	9	1.3	1.4
		Total Cumulative Percent	36.9	38.2

TABLE 22. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN TWO REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 7 (LO 3500 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Siboglinum angstum (Pogonophora)	16	8.9	9.8
2.	Prionospio fauchaldi (Polychaeta)	15	8.3	9.2
3.	Leptognathia sp. 23 (Tanaidacea)	8	4.4	4.9
4.	Sigambra sp. 2 (Polychaeta)	4	2.2	2.5
5.	Myriochele sp. 8 (Polychaeta)	4	2.2	2.5
6.	Dentaliidae sp. 2 (Scaphopoda)	4	2.2	2.5
7.	Glycinde profunda (Polychaeta)	4	2.2	2.5
8.	Siboglinum sp. 2 (Pogonophora)	4	2.2	2.5
9.	Nemertea sp. 5 (Nemertea)	3	1.7	1.8
10.	Thyasira subovata (Bivalvia)	3	1.7	1.8
11.	Siboglinum fulgens (Pogonophora)	3	1.7	1.8
12.	Siboglinum sp. 15 (Pogonophora)	3	1.7	1.8
13.	Hesionidae sp. 6 (Polychaeta)	3	1.7	1.8
14.	Aglaophamus sp. 1 (Polychaeta)	3	1.7	1.8
15.	Paragathotanais sp. 1 (Tanaidacea)	3	1.7	1.8
-	(Spionidae spp. indet.) (Polychaeta)	3	1.7	-
		Total Cumulative Percent	46.2	49.0

TABLE 23. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 13 (FE 3000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Microrbinia linea (Polychaeta)	174	16.4	18.0
2.	Prionospio sp. 2 (Polychaeta)	66	6.2	6.8
3.	Myriochele sp. 1 (Polychaeta)	47	4.4	4.9
4.	Dacrydium sp. 1 (Bivalvia)	42	4.0	4.3
5.	Pholoe anoculata (Polychaeta)	39	3.7	4.0
6.	Spiophanes sp. 1 (Polychaeta)	28	2.6	2.9
7.	Exogone sp. 1 (Polychaeta)	26	2.5	2.7
8.	Siboglinum sp. 2 (Pogonophora)	19	1.8	2.0
9.	Capitella spp. complex (Polychaeta)	16	1.5	1.7
-	(Cirratulidae spp. indet.) (Polychaeta)	16	1.5	-
10.	Nephasoma diaphanes (Sipuncula)	14	1.3	1.4
11.	Prionospio sp. 20 (Polychaeta)	14	1.3	1.4
12.	Myriochele sp. 4 (Polychaeta)	11	1.0	1.1
13.	Nemertea sp. 5 (Nemertea)	11	1.0	1.1
14.	Myriochele sp. 13 (Polychaeta)	11	1.0	1.1
15.	Nephasoma cf. capilleforme (Sipuncula)	11	1.0	1.1
16.	Siboglinum fulgens (Pogonophora)	10	0.9	1.0
17.	Pristogloma alba (Bivalvia)	10	0.9	1.0
18.	Aspidosiphon zinni (Sipuncula)	10	0.9	1.0
19.	Hesionidae sp. 3 (Polychaeta)	10	0.9	1.0
20.	Sabidius cornatus (Polychaeta)	9	0.8	0.9
21.	Siphonolabrum sp. 2 (Tanaidacea)	9	0.8	0.9
22.	Anarthruridae sp. 2 (Tanaidacea)	9	0.8	0.9
		Total Cumulative Percent	57.2	61.2

TABLE 24. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN NINE REPLICATES TAKEN AT U.S. SOUTH ATLANTIC STATION 16 (CH 3000 m).

	Species	Total Raw Count	Percent Total Individuals	Percent Identified Individuals
1.	Microrbinia linea (Polychaeta)	144	24.2	27.1
2.	Prionspio sp. 2 (Polychaeta)	37	6.2	7.0
3.	Siboglinum sp. 2 (Pogonophora)	13	2.2	2.4
-	(Turbellaria) (Platyhelminthes)	14	2.2	-
-	(Tubificidae spp. juv.) (Oligochaeta)	13	2.0	-
4.	Leptognathiella abyssi (Tanaidacea)	11	1.8	2.1
5.	Macrostylis sp. 1 (Isopoda)	11	1.8	2.1
6.	Hesionidae sp. 3 (Polychaeta)	9	1.5	1.7
7.	Capitella spp. complex (Polychaeta)	8	1.3	1.5
8.	Spiophanes sp. 1 (Polychaeta)	8	1.3	1.5
9.	Nemertea sp. 5 (Nemertea)	8	1.3	1.5
10.	Nemertea sp. 2 (Nemertea)	8	1.3	1.5
11.	Brevinucula verrilli (Bivalvia)	7	1.2	1.3
12.	Heterospio nr. longissima (Polychaeta)	7	1.2	1.3
13.	Exogone sp. 1 (Polychaeta)	7	1.2	1.3
14.	Ammotrypanella arctica (Polychaeta)	6	1.0	1.1
15.	Pristogloma alba (Bivalvia)	6	1.0	1.1
16.	Tubificidae sp. 2 (Oligochaeta)	6	1.0	1.1
17.	Fauveliopsis brevis (Polychaeta)	6	1.0	1.1
18.	Pseudotanais sp. 4 (Tanaidacea)	6	1.0	1.1
19.	Neotanais americanus (Tanaidacea)	6	1.0	1.1
20.	Paragathotanais cf. typicus (Tanaidacea)	6	1.0	1.1
	Total Cumulative Percent		57.7	60.0

species at Stations 13 and 16. Both of these latter stations are dominated by Microrbinia linea, which does not occur at Station 5. Station 7, the 3500-m site off Cape Lookout, is characterized by a variety of species including Siboglinum angustum and Prionospio fauchaldi, thus having more in common with Station 5 than 13 or 16. At least three common other Siboglinum species are present at Station 7.

Summation of Dominant Species. Different depth contours and the different latitudes influence faunal dominance patterns in the U.S. South Atlantic region. Stations 9 and 10, forming a transect off Cape Hatteras, are distinct in the high densities of a few species. The prevalence of Cossura longocirrata and Scalibregma inflatum at these stations is noteworthy. Of equal interest is the absence of species such as Pholoe anoculata and Aurospio dibranchiata, which are dominant at other stations in the region and further north in the U.S. Mid-Atlantic region. Station 9 is reminiscent of shallow continental depositional sites in the prevalence of oligochaetes and polychaetes typically found in such environments.

The stations along the Cape Lookout transect (Stations 1-5, 6) and the single station near the Hatteras Canyon (Station 6) were characterized in the Phase 1 report (Blake et al., 1985). The 600-m site (Station 1) is dominated by small polychaetes, especially filter feeders, giving way to nearly all deposit feeders with increasing depth. Station 4 (2000 m) is the first station where Microrbinia linea is dominant. This species ranks at or near the top at all stations off Cape Fear and Charleston from 800 to 3000 m. In this respect, M. linea assumes the dominant role played by Aurospio dibranchiata at the 2000- to 2100-m depth interval in the U.S. Mid-Atlantic region (Maciolek et al., 1987) and that of Meiodorvillea minuta and Pholoe anoculata in shallower depths.

Density

Total Densities

The mean number of individuals per box core (0.09 m^2) for each station on each sampling date is shown in Figures 26 through 28. The highest densities were recorded at Stations 9, 1, 11, 2, and 14, in that order. All of these stations are from the upper slope between 583 and 1000 m. Stations 3, 4, 6, 10, and 12 in the 1500-2000 m depth range

ranked next in overall mean density. Stations 5, 13, 15, 16, and 7, ranging from 2000 to 3000 m, were lowest in density.

The stations off Cape Hatteras include Stations 9 (6000 m) and 10 (2000 m) (Figure 26). Station 9 has the highest densities of any station in the entire U.S. South Atlantic region, with an overall average of 46,255 individuals per m^2. This total is well over twice that of the next most dense station, Station 1 (600 m) off Cape Lookout (see below). The densities at Station 9 dropped considerably between the spring (SA-4) and summer seasons (SA-5). The standard deviations are large for all three sampling dates. Station 10 has densities that are somewhat higher than those recorded at the other 2000-m stations. The fauna resembles that of Station 9 more than that of the other 2000-m stations. Station 6 is located on the northern side of the Hatteras Canyon in 2000 m (Figure 5). The densities here are lower than at Station 10 further to the north, and more similar to those of Station 4 off Cape Lookout and also the U.S. Mid-Atlantic 2100-m stations further north (Maciolek et al., 1987).

The Cape Lookout transect includes five primary stations: 1 (600 m), 2 (1000 m), 3 (1500 m), 4 (2000 m), and 5 (3000 m). This transect shows a clear sequence of changes in faunal densities with depth. Station 1 has the highest densities and the greatest standard deviations (Figure 27). Densities decline with depth, but there is little difference between 1500 and 2000 m. Densities are lowest at 3000 m, but standard deviations are small, suggesting a homogenous environment in which it is easy to achieve good replication.

The Cape Fear Transect includes three stations: 11 (800 m), 12 (2000 m), and 13 (3000 m). The densities are highest at the 800-m depth, and decline with depth. Standard deviations are small at all of these stations (Figure 28).

The Charleston Transect includes four stations: 14A (600 m), 14 (800 m), 15 (2000 m), and 16 (3000 m). Station 14A is low in density, undoubtedly due to the strong currents and very sandy sediments at the site. Station 14 is faunistically the most diverse and interesting station on the Charleston Transect. Stations 15 and 16 support low densities (Figure 28). In terms of densities, Station 15 resembles the 3000-m stations more than the other 2000-m stations.

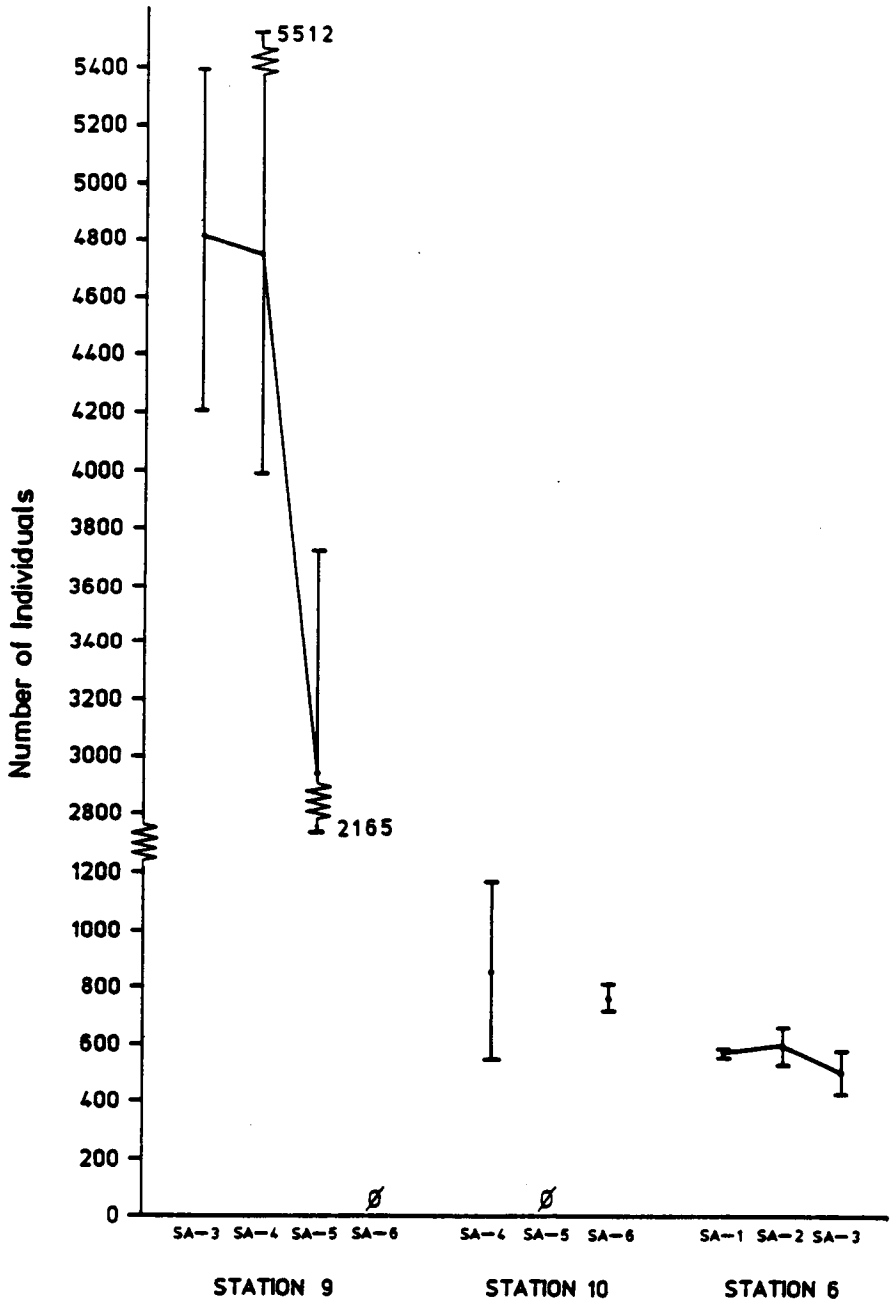


Figure 26. Mean Number of Individuals (No./0.09 m^2 ± 1 SD) at Stations 9 and 10 on the Cape Hatteras Transect and Station 6 at the Hatteras Canyon in the U.S. South Atlantic Region. Ø Indicates No Data.

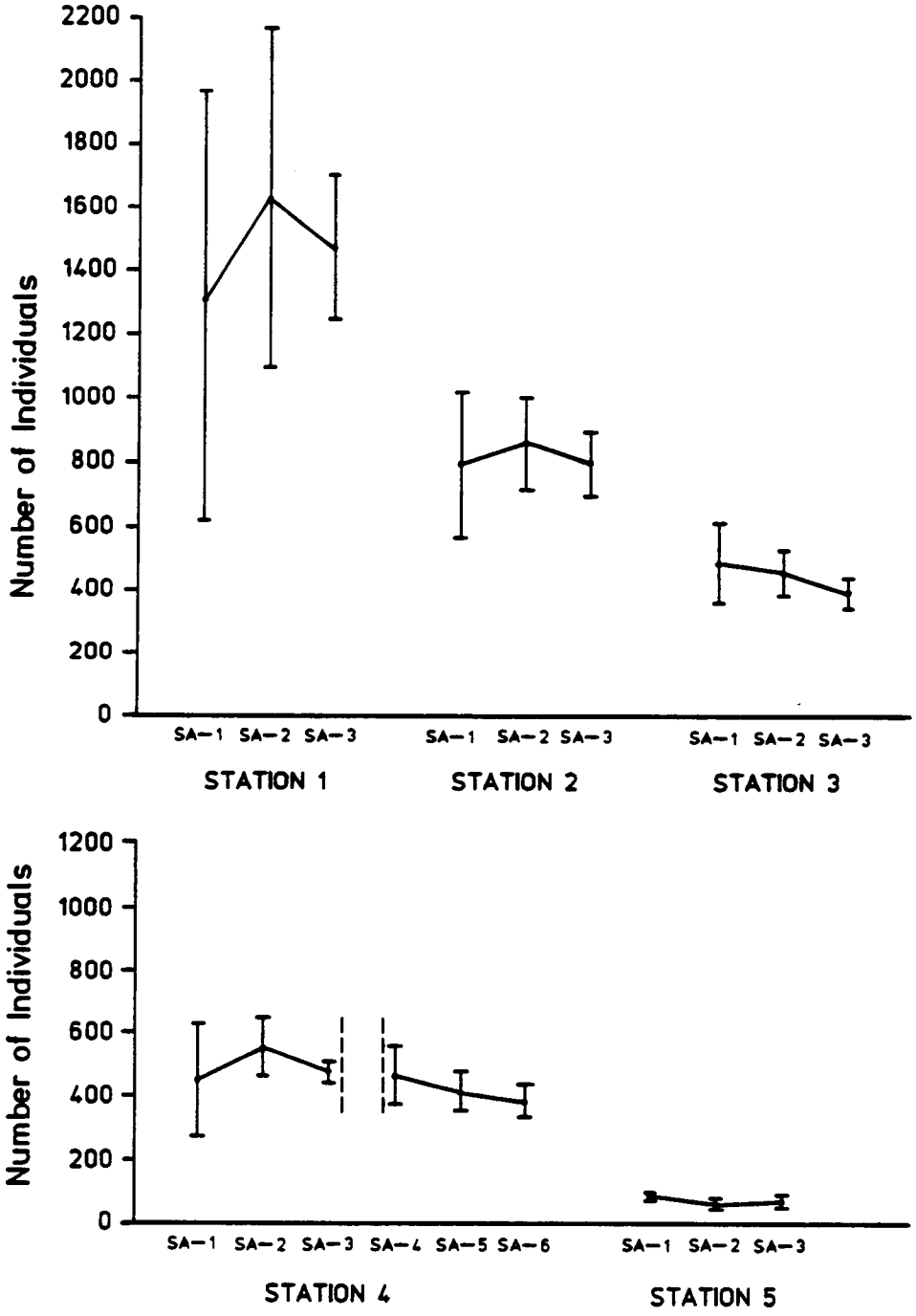


Figure 27. Mean Number of Individuals (No./0.09 m^2 ± 1 SD) at Stations 1-5 on the Cape Lookout Transect in the U.S. South Atlantic Region.

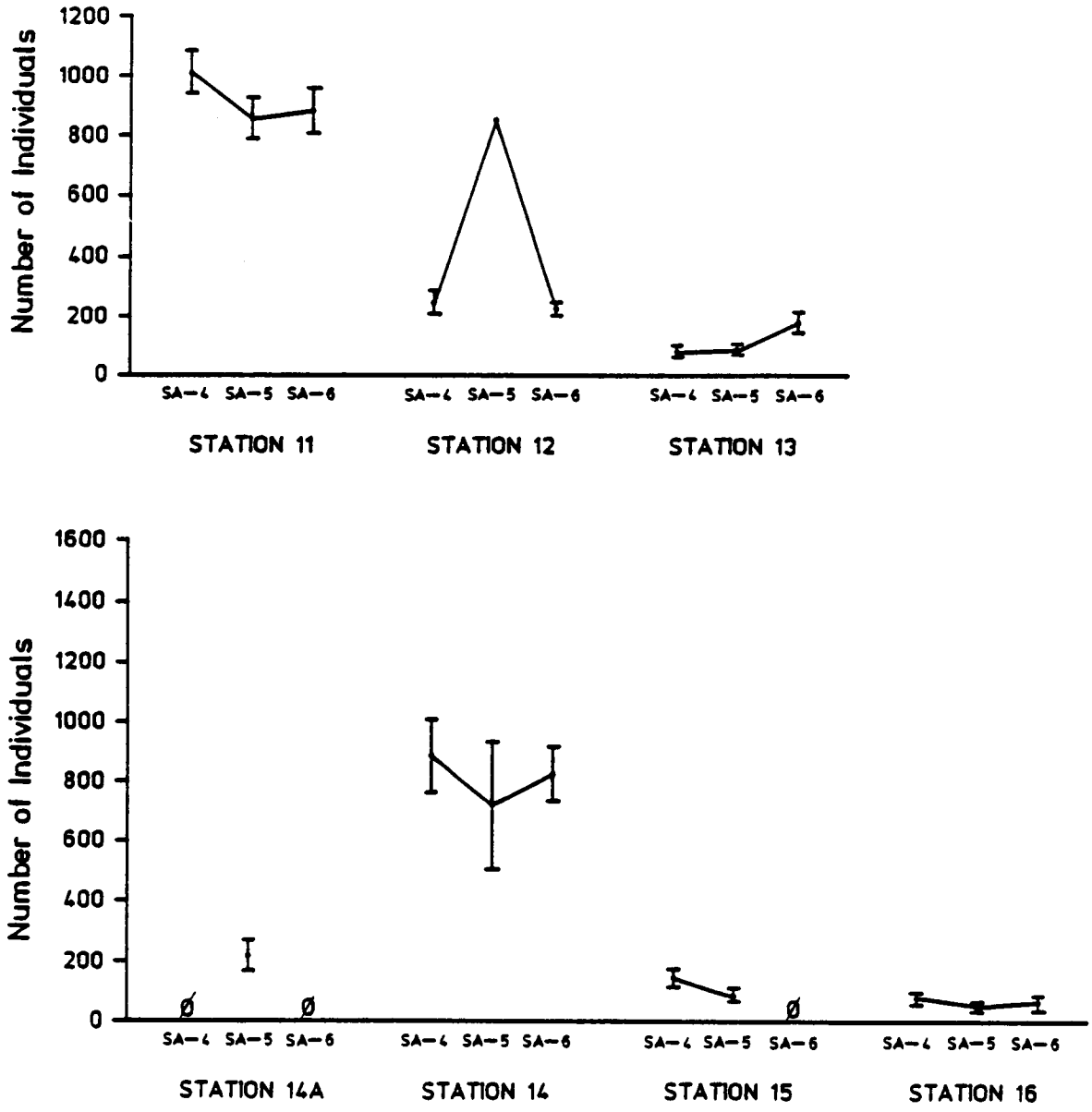


Figure 28. Mean Number of Individuals (No./0.09 m^2 ± 1 SD) at Stations 11-13 on the Cape Fear Transect and 14A-16 on the Charleston Transect in the U.S. South Atlantic Region. Ø Indicates No Data.

Density and Distribution of Some Dominant Species

Species Mostly Limited to the Cape Hatteras Transect. Three polychaetes and two oligochaetes having their distributions primarily at Station 9 (600 m) are plotted.

Aricidea quadrilobata ranks fifth overall at Station 9 over the three cruises. The species is also recorded from Station 1 at the same depth off Cape Lookout (600 m), but in terms of density and overall contribution to the fauna it is numerically important only at Station 9. Mean densities at Station 9 range from a high of 172 individuals per 0.09 m^2 during July 1984 (SA-3) to a low of 47 individuals per 0.09 m^2 during September 1985 (SA-5) (Figure 29).

Leitoscoloplos acutus is more widely known from continental shelf habitats and occurs only at Station 9 in this study. Its importance off Cape Hatteras is another reflection of shallow-water influences on the upper slope. The species is not reported in the U.S. Mid- and North Atlantic Slope and Rise (Maciolek et al., 1986 a-b; 1987), but is present on Georges Bank (Maciolek-Blake et al., 1985). The species has mean densities of 56, 24 and 39 individuals per 0.09 m^2 for July 1984, May 1985, and September 1985, respectively (Figure 30). Standard deviations around the mean are quite large, indicating considerable variability among individual samples.

Scalibregma inflatum is the second-ranked species at Station 9. In May 1985 (SA-4), it was the top-ranked species at this 600-m site. Mean densities were very high, with 595, 1262, and 586 individuals per 0.09 m^2 for July 1984, May 1985, and September 1985, respectively (Figure 31). At Station 10 (HA 2000 m) on the same transect, the species was also among the top-ranked dominant species, but occurred in considerably reduced numbers, with mean densities of only 5 and 10 individuals per 0.09 m^2 for May 1986 and November 1986, respectively. S. inflatum is widely distributed on the continental shelf and also has been reported from deep water. Because of its unusually high density at Station 9, sufficient specimens were available to collect size frequency data which are presented in the Life History section of this chapter. The species is not recorded among the dominants at any station in the U.S. Mid- or North Atlantic regions (Maciolek et al., 1986 a-b; 1987).

Tubificoides intermedius, an oligochaete, is ranked fourth overall at Station 9. It does not occur at any other site in the study area. The densities at Station 9 are high,

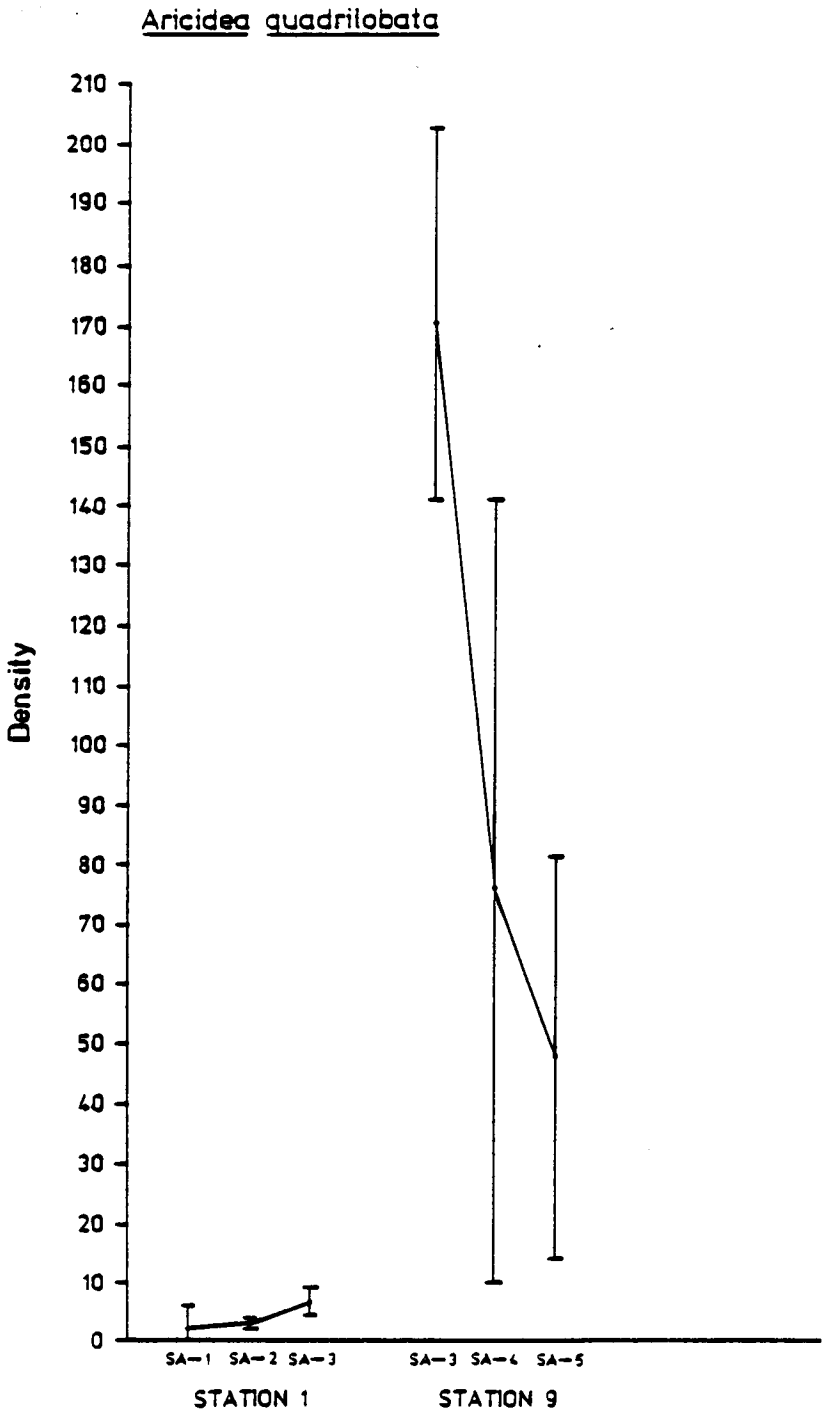


Figure 29. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Aricidea quadrilobata at Station 1 on the Cape Lookout Transect and Station 9 on the Cape Hatteras Transect.

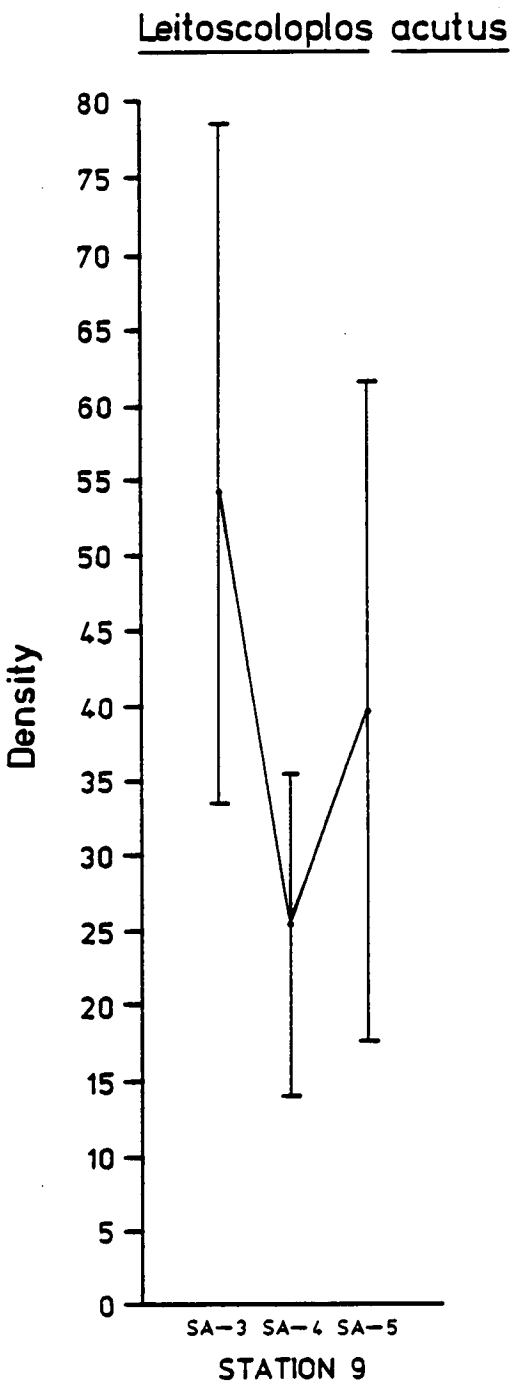


Figure 30. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Leitoscoloplos acutus at Station 9 on the Cape Hatteras Transect.

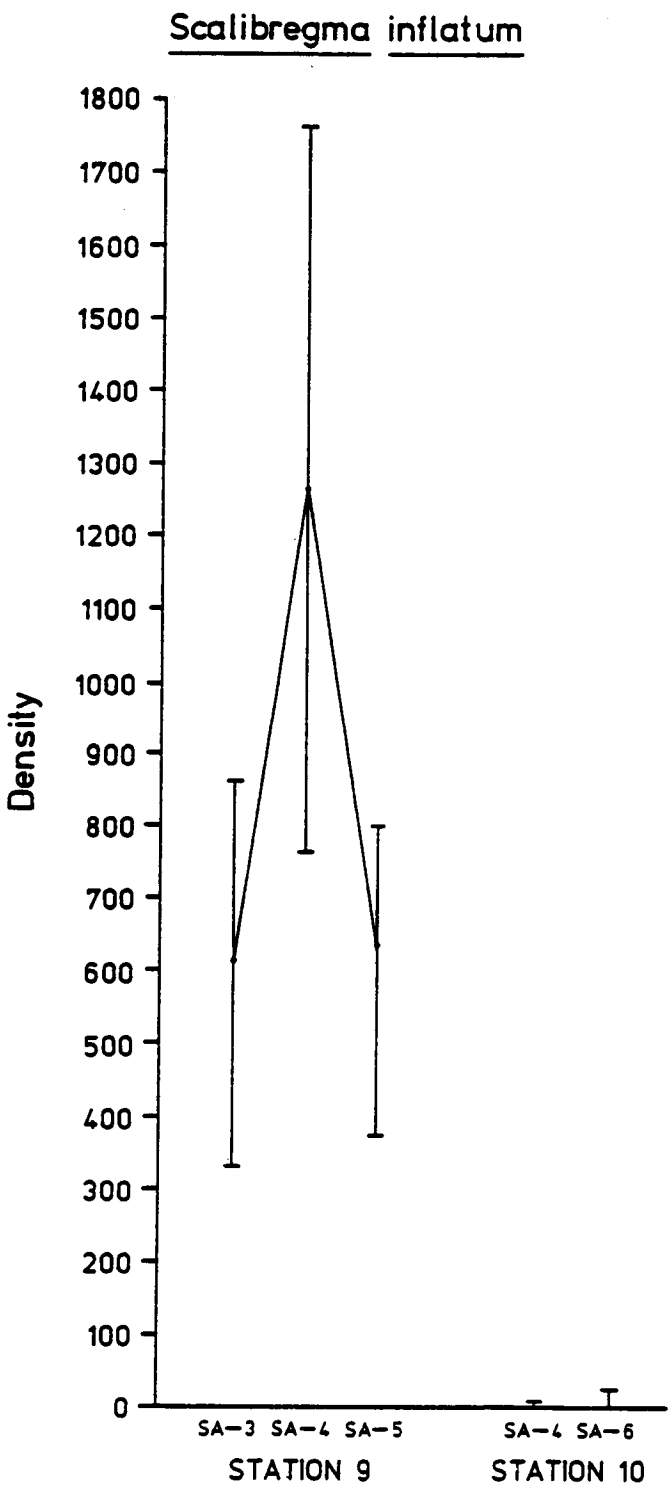


Figure 31. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Scalibregma inflatum at Stations 9 and 10 on the Cape Hatteras Transect.

with means of 206, 142, and 171 individuals per 0.09 m^2 in July 1984, May 1985, and September 1985, respectively (Figure 32). The variability in samples was less during the July 1984 period, but large standard deviations around the mean were evident in subsequent collections.

Limnodriloides medioporus, a widespread continental shelf species, ranks third overall at Station 9. It does not occur at all at the deeper Station 10 on the same transect, but has turned up on rare occasions off Cape Lookout and Cape Fear at 600 to 800 m. At Station 9, mean densities of 606, 675, and 188 individuals per 0.09 m^2 were recorded for July 1984, May 1985, and September 1985, respectively (Figure 33). The decrease in density in the September collection is noteworthy, but there are an insufficient number of sampling occasions to determine if the decreased density is part of an annual cycle or a one-time occurrence. The large standard deviations in these data and that of other species at this station, however, suggest that populations are highly variable.

Densities of Species Having Distributions Largely Limited to Upper Slope Depths (600-1000 m). Seven species of invertebrates with depth distributions largely limited or restricted to the upper slope are plotted. These species include one tanaid, one bivalve, one oligochaete, and four polychaetes.

Leptocheliidae sp. 1 was found at Station 1 (600 m) off Cape Lookout during the Phase 1 program. A total of 10 specimens were identified at that time. During Phase 2, the species was found to be more abundant at Station 11 off Cape Fear (800 m). Mean densities were relatively consistent at this site, with 51, 53, and 57 per 0.09 m^2 for July 1984, May 1985, and September 1985, respectively (Figure 34).

Kelliella sp. 1 is an upper slope bivalve, occurring consistently off Cape Lookout (Stations 1 and 2: 600-1000 m), Cape Fear (Station 11: 800 m), and off Charleston (Station 14: 800 m). During the course of the program, occasional specimens were taken from depths down to 3000 m, but these occurrences were rare. Highest densities were recorded at the 800- to 1000-m depths (Figure 35). Station 11 off Cape Fear had the most consistent densities, with mean densities of 24, 24, and 20 individuals per 0.09 m^2 for July 1984, May 1985, and September 1985, respectively. This species has not been recorded from either the U.S. Mid- or North Atlantic Study regions (Maciolek et al., 1986 a-b; 1987).

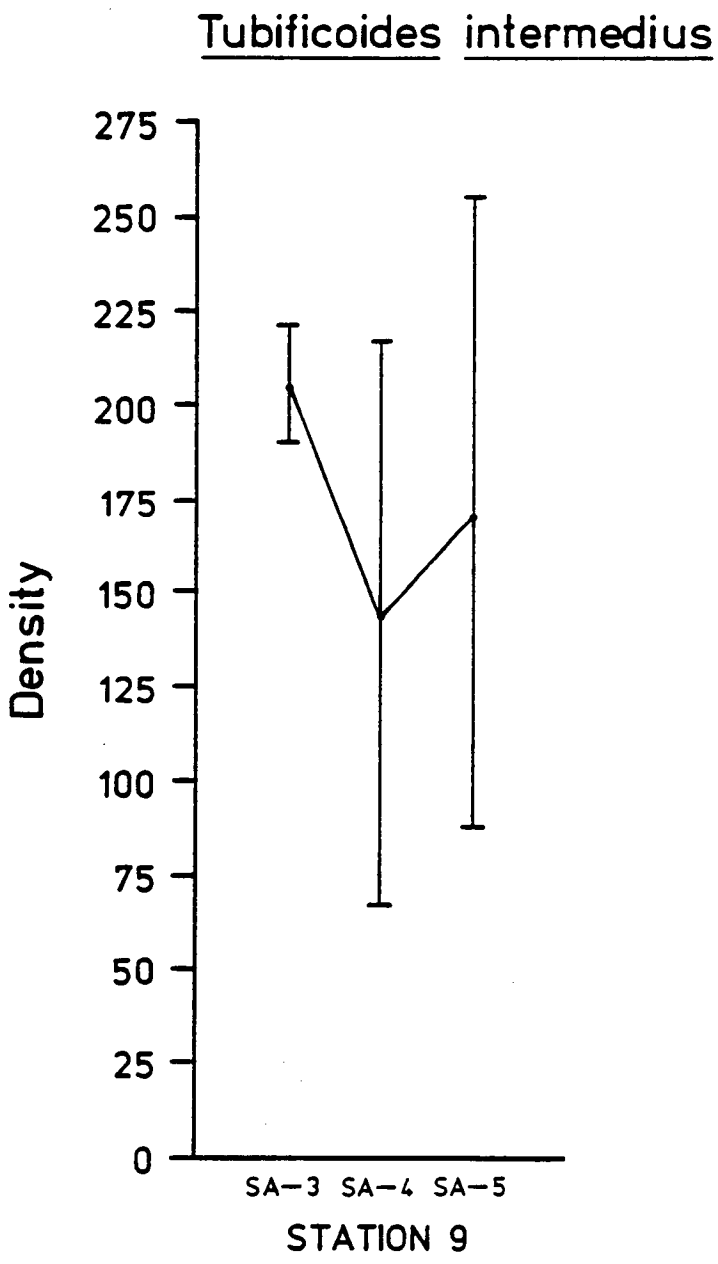


Figure 32. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Oligochaete Tubificoides intermedius at Station 9 on the Cape Hatteras Transect.

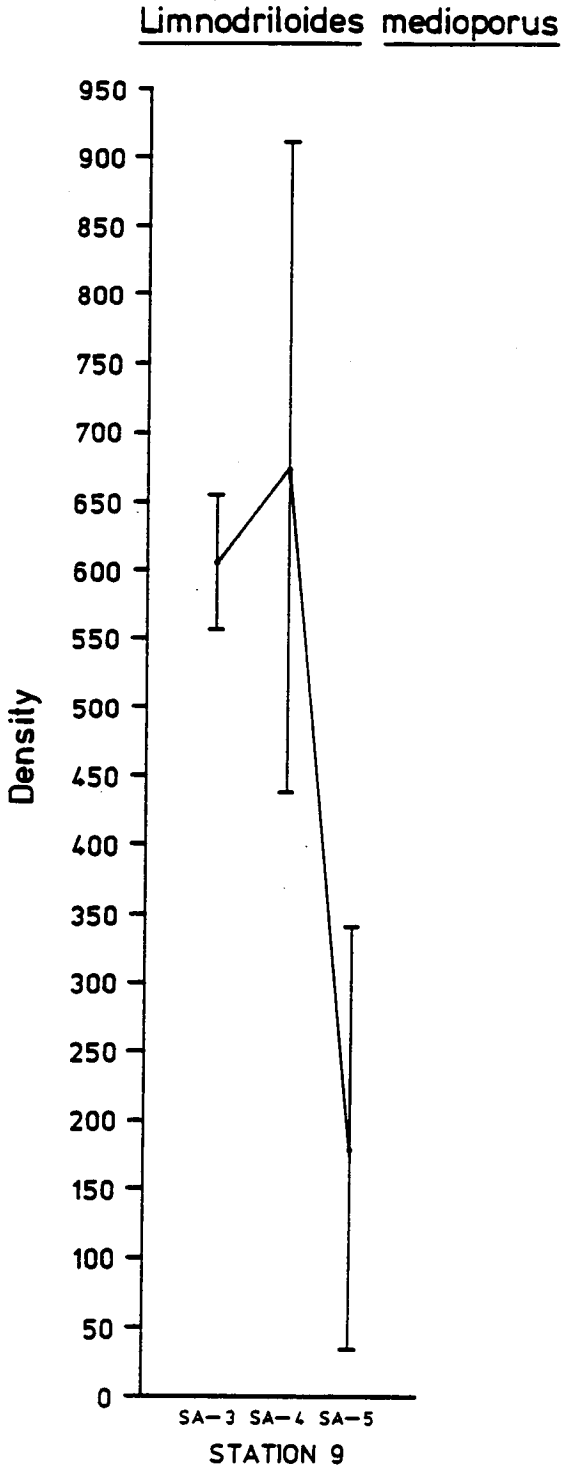


Figure 33. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Oligochaete Limnodriloides medioporus at Station 9 on the Cape Hatteras Transect.

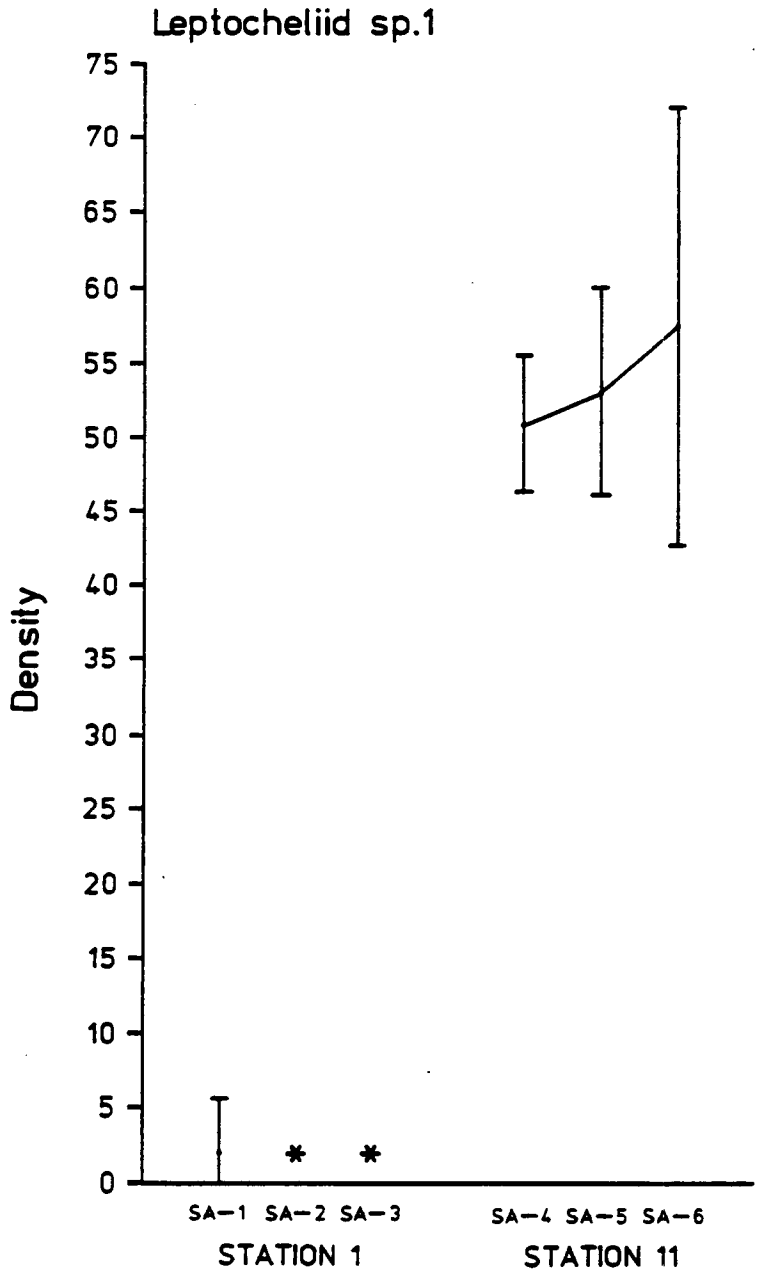


Figure 34. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Tanaid Leptocheliid sp. 1 at Station 1 on the Cape Lookout Transect and Station 11 on the Cape Fear Transect. * Indicates Too Few Individuals to Plot.

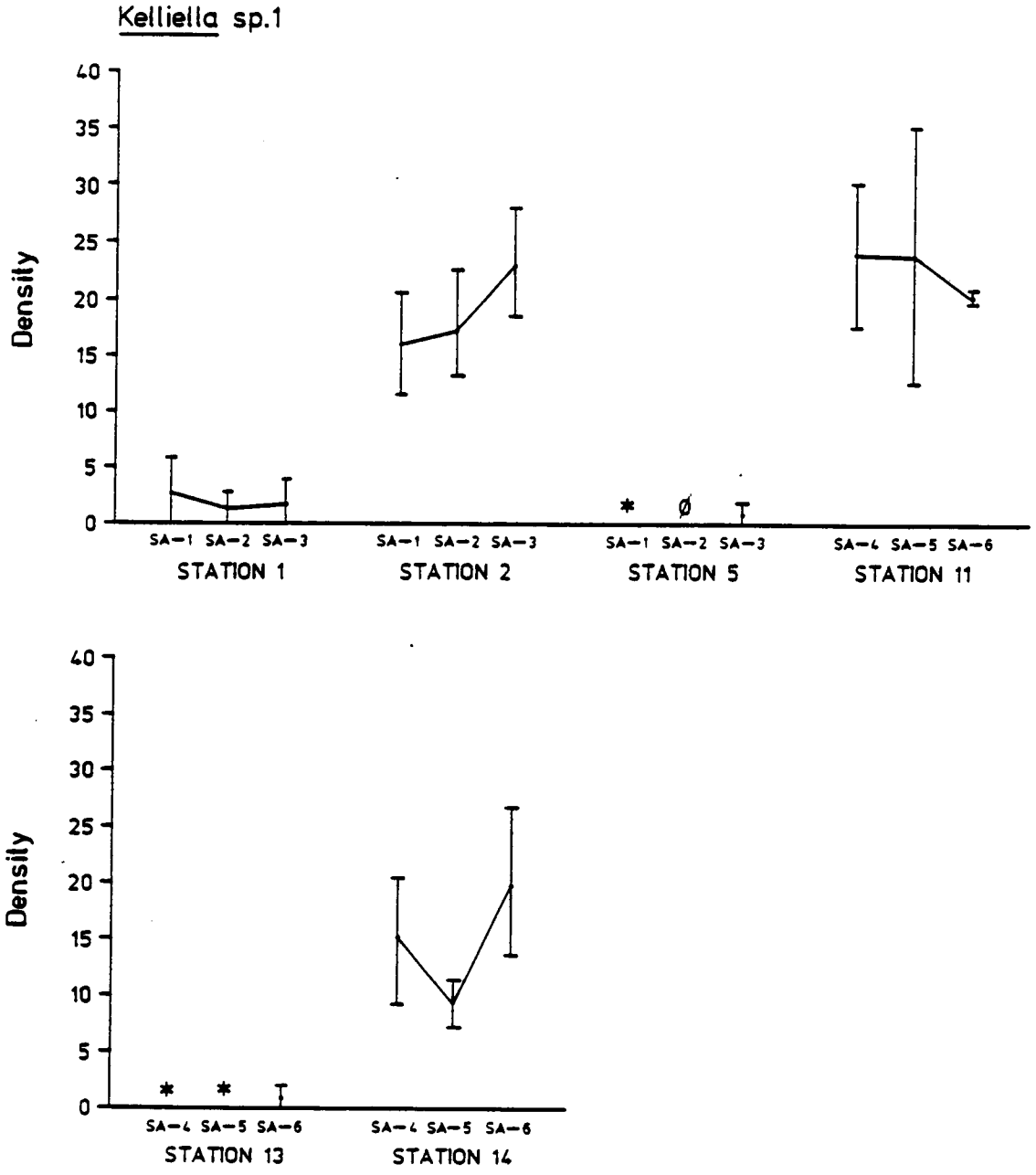


Figure 35. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Bivalve Kelliella sp. 1 at Six Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

Cossura sp. 2 is a characteristic species at Stations 11 and 14 off Cape Fear and Charleston at 800 m, where it appears among the top dominant species. Occasional specimens have been taken from the Cape Lookout transect (600-1500 m), and from Hatteras Canyon (2000 m), but not consistently and never in sufficient densities to influence the dominance patterns. In this regard, C. sp. 2 would appear to replace C. longocirrata as the dominant cossurid south of Cape Lookout. The latter species is a major component of all upper slope stations from Cape Lookout to Cape Hatteras (see below). C. sp. 2 has average mean densities of 13 and 11 individuals per 0.09 m^2 at Stations 11 and 14, respectively (Figure 36). Although low, these densities are sufficient to place the species thirteenth and ninth, respectively, in overall dominance at these stations. C. sp. 2 has been recorded from the U.S. North Atlantic region (Maciolek et al., 1986b), but not from the U.S. Mid-Atlantic (Maciolek et al., 1987), where there were no stations shallower than 1500 m.

Meiodorvillea minuta is one of the most important and characteristic species at Stations 1 and 2 off Cape Lookout (600-1000 m), ranking second and first, respectively, at these stations. The only other station at which this species occurs among the top 20 dominants is Station 11 off Cape Fear (800 m). Specimens do occur regularly at Station 14, but the low densities south of Cape Lookout suggest that there is a break in the distribution of this species. It is not reported as a dominant in the U.S. Mid-Atlantic region by Maciolek et al. (1987), but station depths in that study were not shallower than 1500 m. In contrast, M. minuta was among the dominants at four stations in the U.S. North Atlantic region off Georges Bank in depths of 255 to 550 m (Maciolek et al., 1986b). Off Cape Lookout, the densities of M. minuta were highest at the 600-m site, with mean densities of 102, 122, and 135 individuals per 0.09 m^2 in November 1983, March 1984, and July 1984, respectively. At the 1000-m depth, mean densities of 63, 68, and 52 individuals per 0.09 m^2 were recorded during the same months (Figure 37). These densities are considerably higher than those recorded at the U.S. North Atlantic stations, where densities per of 74 individuals per 0.09 m^2 at 255 m and 10 to 24 individuals per 0.09 m^2 at 550 m were recorded (Maciolek et al., 1986b).

Ophelina abranchiata, a small opheliid polychaete, appeared on the list of top dominants at two upper slope stations: Station 1, off Cape Lookout (600 m) and Station 14 off Charleston (800 m). The species also was taken at the other Cape Lookout stations

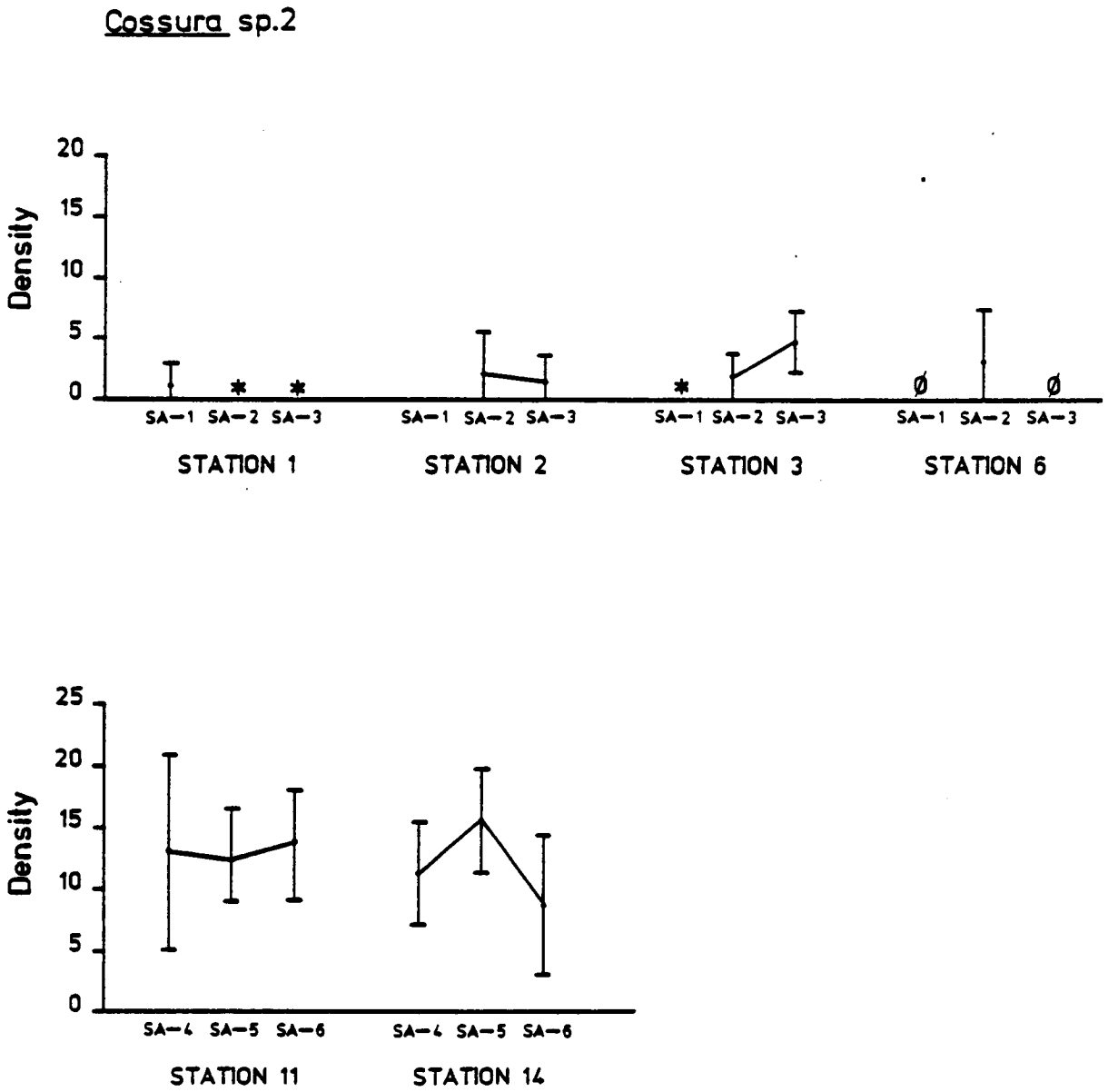


Figure 36. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Cossura sp. 2 at Six U.S. South Atlantic Stations. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

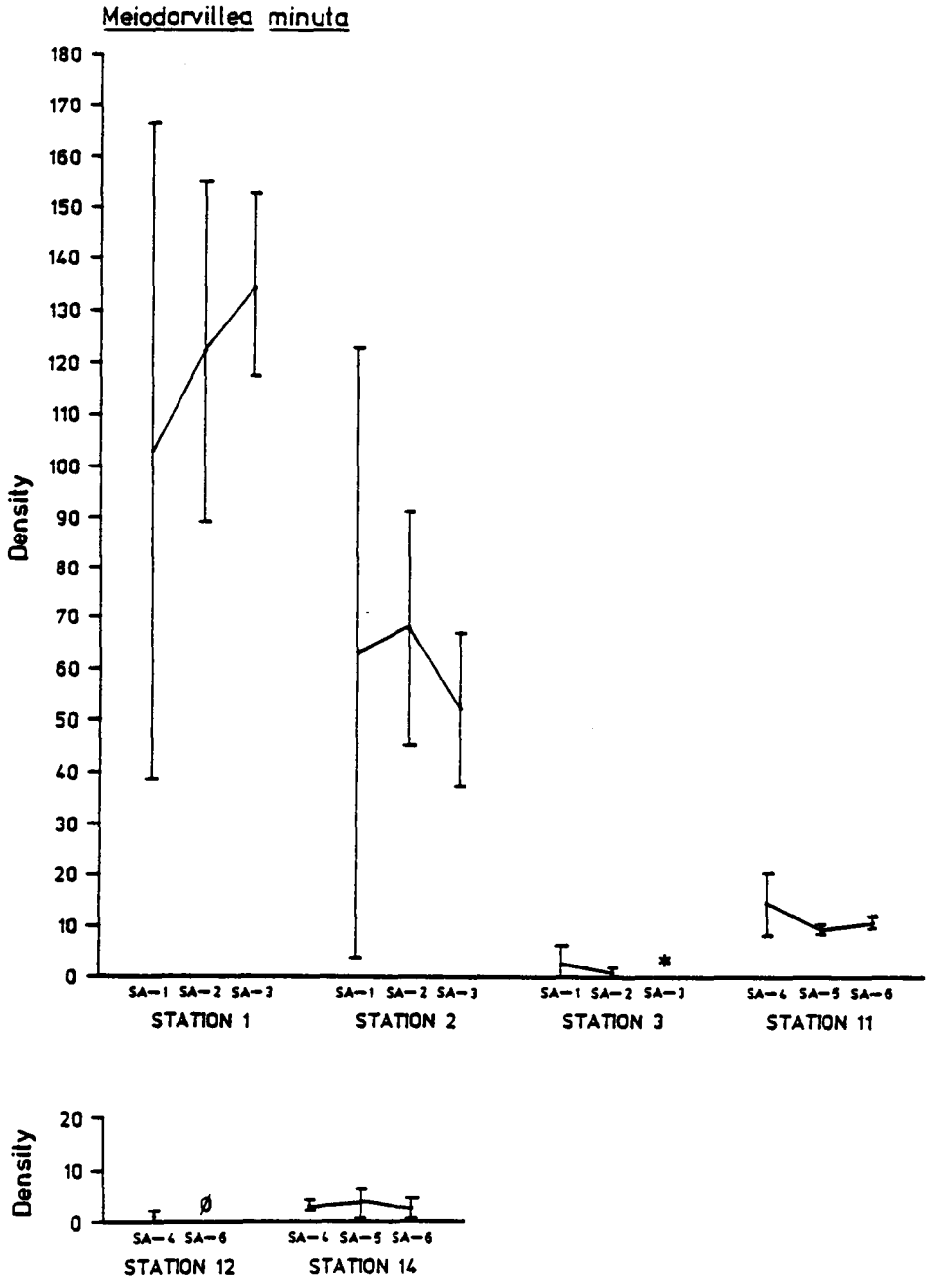


Figure 37. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Meiodorvillea minuta at Six U.S. South Atlantic Stations. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

(1000-3000 m), the Cape Fear Stations (800-3000 m) and off Charleston at 3000 m, but these occurrences were rare and the species was never numerically dominant. At Station 1, average densities were 27, 29, and 26 individuals per 0.09 m^2 during November 1983, March 1984, and July 1984, respectively. Station 14 densities were considerably lower, with average densities of only 10, 7, and 7 individuals per 0.09 m^2 during May 1985, September 1985, and November 1985, respectively (Figure 38). These densities in the U.S. South Atlantic region at 600 m are similar to those recorded at the U.S. North Atlantic 550-m stations (19.3 to 24.1 individuals per 0.09 m^2) by Maciolek et al. (1986b).

Spionidae sp. 11, an undescribed species probably referrable to the genus Prionospio, was limited in its occurrence to Stations 11 and 14 at the 800-m depth off Cape Fear and Charleston. Average densities for May 1985, September 1985, and November 1985, were 15, 12, and 24 individuals per 0.09 m^2, respectively, at Cape Fear, and 13, 10, and 15 individuals per 0.09 m^2, respectively, off Charleston (Figure 39). The absence of this species at any deeper locations and at any site north of Cape Fear is an indication that its range is probably restricted to upper slope stations in the southern study area. Several other spionids are restricted to the U.S. South Atlantic area, but Spionidae sp. 11 is the only one to be a dominant at any station.

Bathydrilus asymmetricus, an oligochaete, is a dominant species at Station 3 (1500 m) off Cape Lookout, and Stations 11 and 14 (800 m) off Cape Fear and Charleston. The species is also present at the 2000-m stations from Hatteras Canyon to off Charleston, but appears to reach its greatest densities in depths between 800 and 1500 m (Figure 40), with the highest densities occurring at the 800-m stations. For example, the overall mean density for three Phase 1 cruises at Station 3 was 16 individuals per 0.09 m^2, while the same value at Stations 11 and 14 for three cruises during Phase 2 was 28 and 21 individuals per 0.09 m^2, respectively. B. asymmetricus was the species ranked number four at Stations 3 and 11 and number two at Station 14. In the U.S. Mid- and North Atlantic regions, this species was dominant at 1220-1500 m, with densities of 8.6 to 15.6 individuals per 0.09 m^2 (Maciolek et al., 1986 a-b; 1987).

The polychaete Cossura longocirrata is the last species to be considered here as an upper slope dominant. This species is the highest ranked species at Stations 9 and 10 off Cape Hatteras (600 and 2000 m). Its dominance at Station 10 appears to be an anomaly, because elsewhere in the U.S. South Atlantic region, it is most abundant at the 600- to

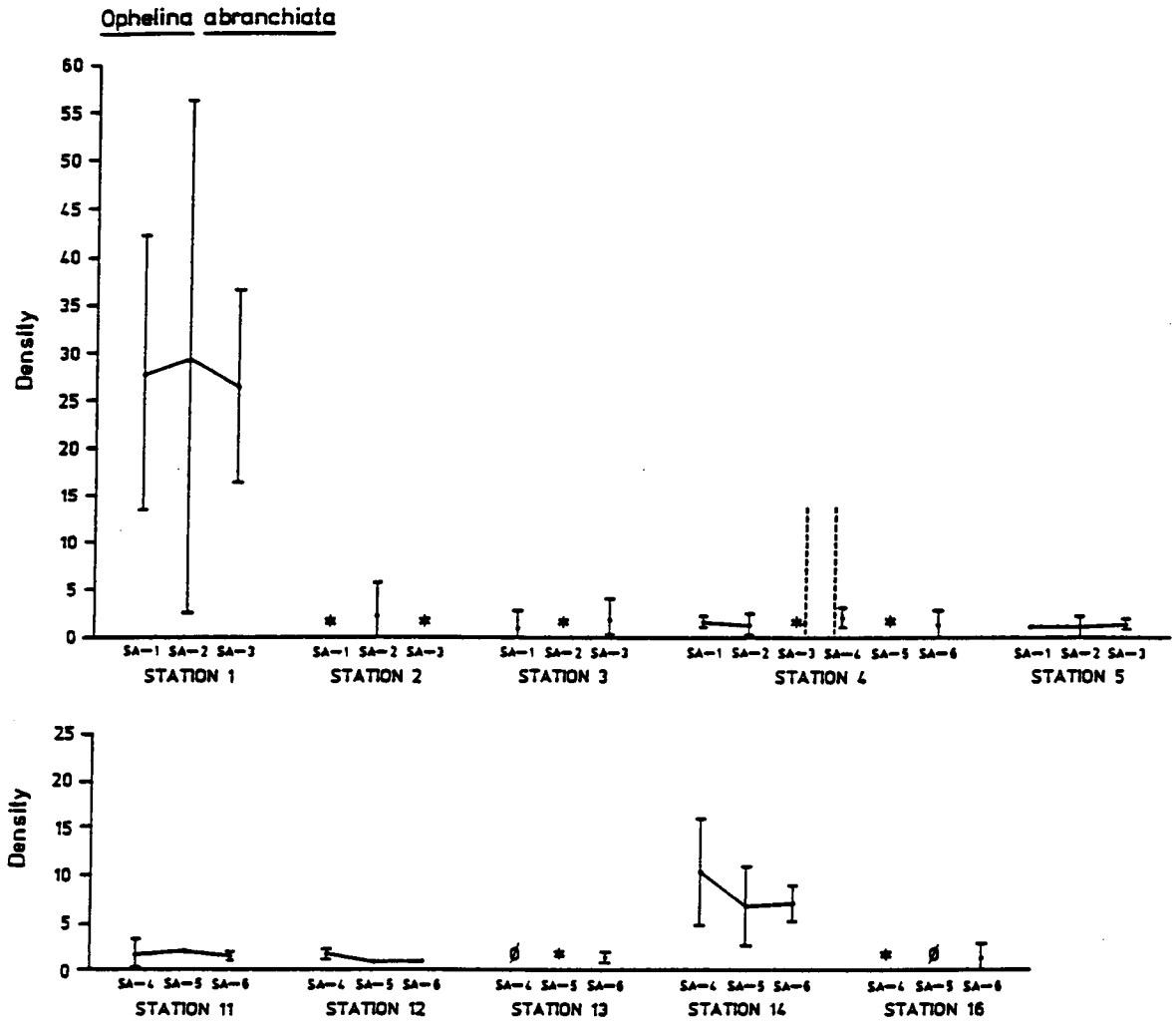


Figure 38. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Ophelina abranchiata at Ten U.S. South Atlantic Stations. * Indicates Too Few Individuals to Plot. ∅ Indicates No Data.

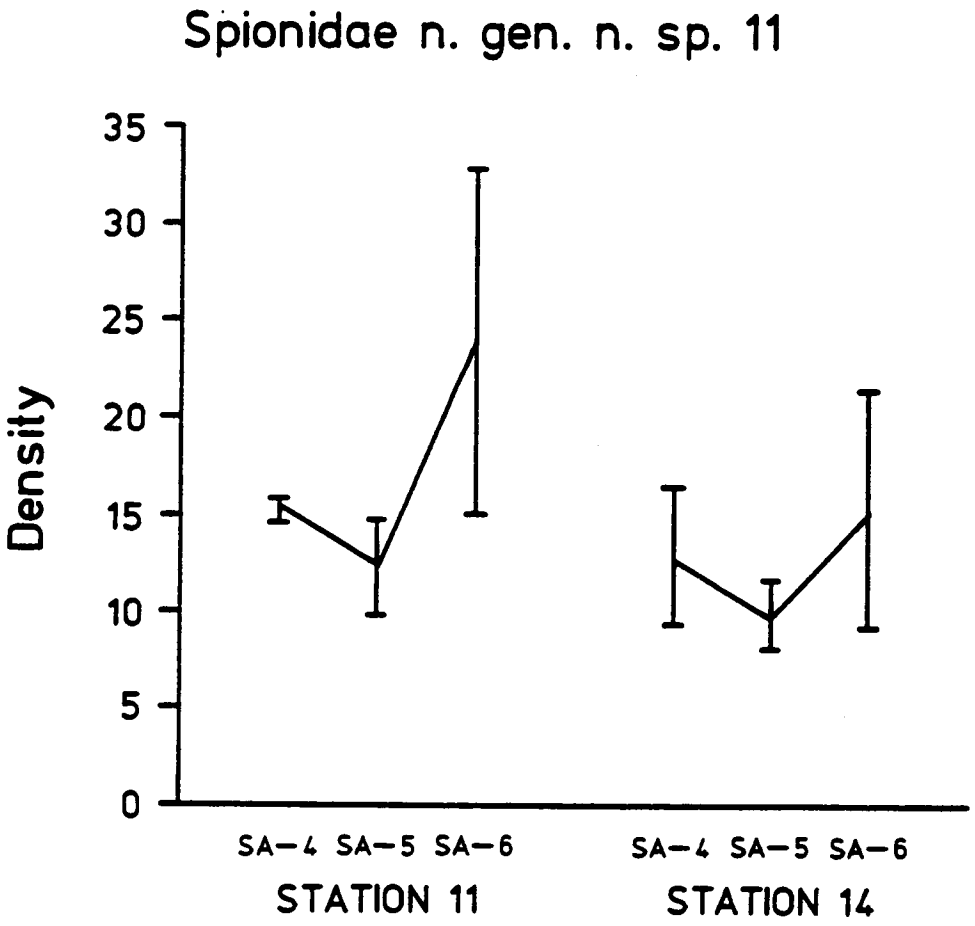


Figure 39. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Spionidae sp. 11 at Stations 11 and 14 in the U.S. South Atlantic Region.

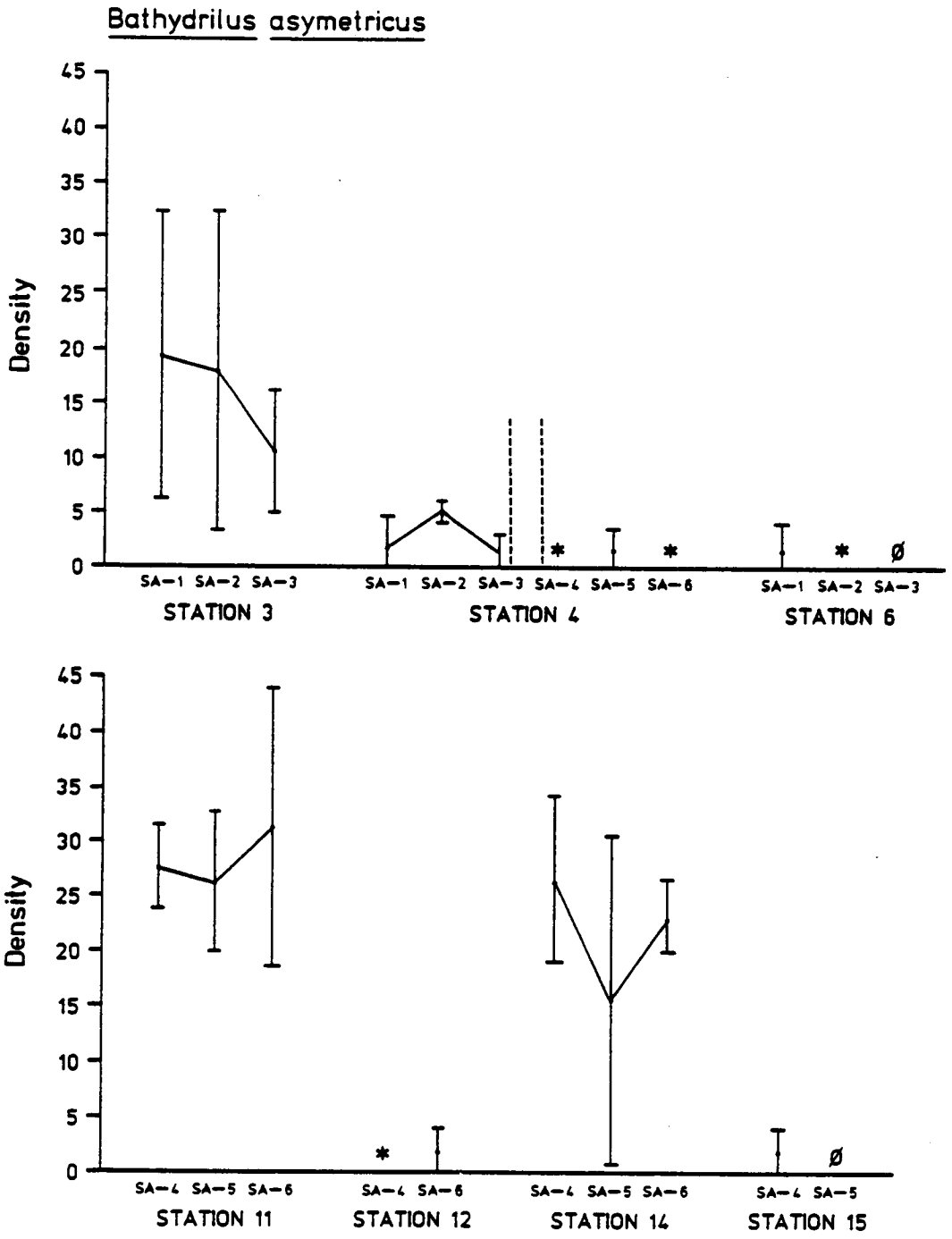


Figure 40. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Oligochaete Bathydrilus asymmetricus at Seven Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

1000-m depths and rare at 2000 m. Off Cape Lookout, for example, C. longocirrata ranks twelfth at Station 1 (600 m) and second at Station 2 (1000 m). The species is rare at 1500 to 2000 m on the same transect. Although replaced by Cossura sp. 2 as a dominant at Stations 11 and 14 (800 m) off Cape Fear and Charleston (see above), C. longocirrata is nevertheless a regular component of the fauna. It is absent from the 2000-m stations along those same transects. Densities of C. longocirrata at Station 9 off Cape Hatteras are by the far the highest recorded in the entire ACSAR Program, including the North, Mid-, and South Atlantic regions (Maciolek et al., 1986 a-b; 1987; Blake et al., 1985; this study). Over a three-cruise program, with samples taken in July 1984, May 1985, and September 1985, the overall mean density of C. longocirrata was 1157 individuals per 0.09 m^2 (Figure 41). The next highest densities for this species in the U.S. South Atlantic region were at Station 10, with 150 individuals per 0.09 m^2. The highest densities recorded for this species in the U.S. North Atlantic region were from the Lydonia Canyon 550-m station, where a mean density of 55.3 individuals per 0.09 m^2 was recorded (Maciolek et al., 1986b). The only other location where this species achieves the high densities recorded from 600 m off Cape Hatteras is a silty depositional site at 70 m on Georges Bank (Maciolek-Blake et al., 1985). Thus, the fauna at Station 9 appears to resemble that found at shallow depositional sites, rather than a typical upper slope station.

Densities of Species Having Wide Geographic and Depth Distributions. Twelve species, including six polychaetes, one oligochaete, one sipunculid, two bivalves, one holothurian, and one nemertean have been selected as representative species having wide latitudinal and depth distributions. In some cases these species are forms having a major impact on benthic communities throughout the entire ACSAR, but a few are dominant only in the southern portion of our study area.

The polychate Microrbinia linea assumes an important role in the U.S. South Atlantic region. Although the species was originally described from off New England (Hartman, 1965), it has only rarely been encountered in either the U.S. North or Mid-Atlantic regions of the ACSAR (Maciolek et al. 1986 a-b; 1987). During the U.S. South Atlantic Phase 1 Study, the species was observed to be the number one dominant species at Station 4 off Cape Lookout in 2000 m (Blake et al., 1985). Although a few specimens were collected at the Cape Lookout 1500-m station during the first cruise of Phase 1,

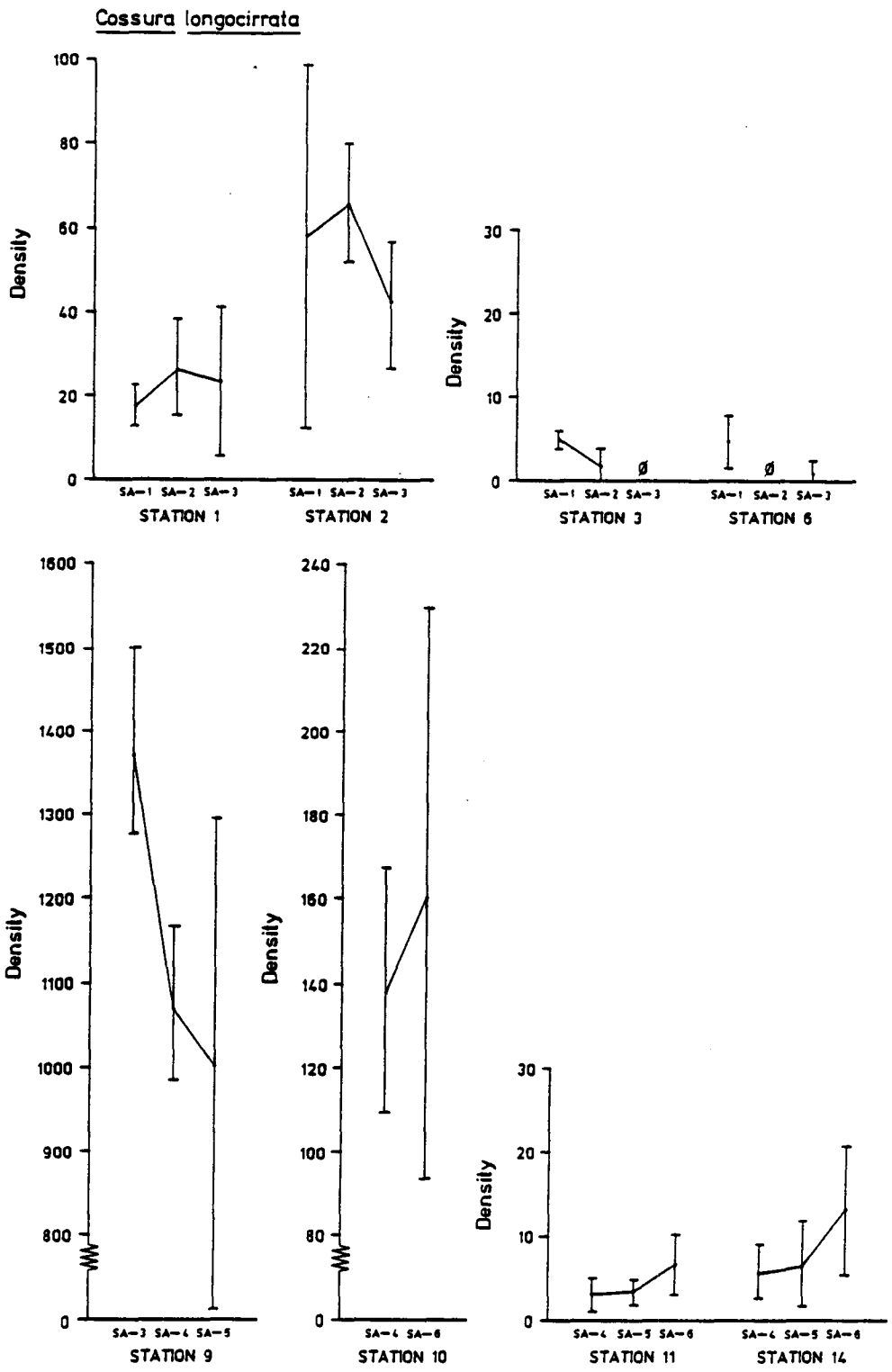


Figure 41. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Cossura longocirrata at Eight Stations in the U.S. South Atlantic Region.

these were from samples taken deeper than the planned target depth. During the Phase 2 program, the species has been recorded in great numbers at the Cape Fear and Charleston transect stations and is the dominant species at five of the six stations in depths of 800 to 3000 m. The total dominance of this species in the middle to lower slope stations beginning at Cape Lookout and proceeding south, its total absence off Cape Hatteras, and the sparse records in the U.S. Mid- and North Atlantic regions strongly suggest that the distribution of M. linea is not random and that conditions favorable to its dominance do not exist at more northern localities. The highest densities per 0.09 m^2 were 71 individuals at Station 4 (LO 2000 m), 82 individuals at Station 11 (FE 800 m), and 69 individuals at Station 14 (CH 800 m). The densities at the 2000-m stations off Cape Fear and Charleston were considerably lower than at stations off Cape Lookout, but the sediment conditions were also very different (See Chapter 7). At Station 12, the sediment was so soft that the box core had to be specially equipped with "snowshoes" in order to collect a sample, while sediments at Station 15 were so compact that it was often difficult to obtain sufficient penetration to obtain samples. For these reasons, the overall densities at both stations are low, and correspondingly, the densities of M. linea and other species are also low. Nevertheless, M. linea was still the top dominant at Station 15 off Charleston at the 2000-m depth. Perhaps equally as remarkable is the dominance of this species at the 3000-m depth off Cape Fear and Charleston and its total absence at that same depth off Cape Lookout.

Seasonal densities of M. linea at seven stations are plotted in Figure 42. At the 800-m depth, a distinct decline in the population occurred during September 1985 at both Cape Fear and Charleston. This same decline was noted at the 2000-m and 3000-m stations on the Charleston Transect, but not at other stations. Life history data collected from the six sampling occasions at the 2000-m site off Cape Lookout do not suggest any obvious trends beyond year-around reproduction (see below). No life history data was developed for samples from shallower depths.

Aurospio dibranchiata is one of the most important polychaete species on the ACSAR. In the U.S. Mid-Atlantic Study, it was the top dominant species at 10 of 14 stations between depths of 1500 and 2500 m. At the other four stations, the species ranked either second, fourth, or eighth (Maciolek et al., 1987). In the U.S. North Atlantic Study located off Georges Bank, A. dibranchiata ranked number one at six stations in the

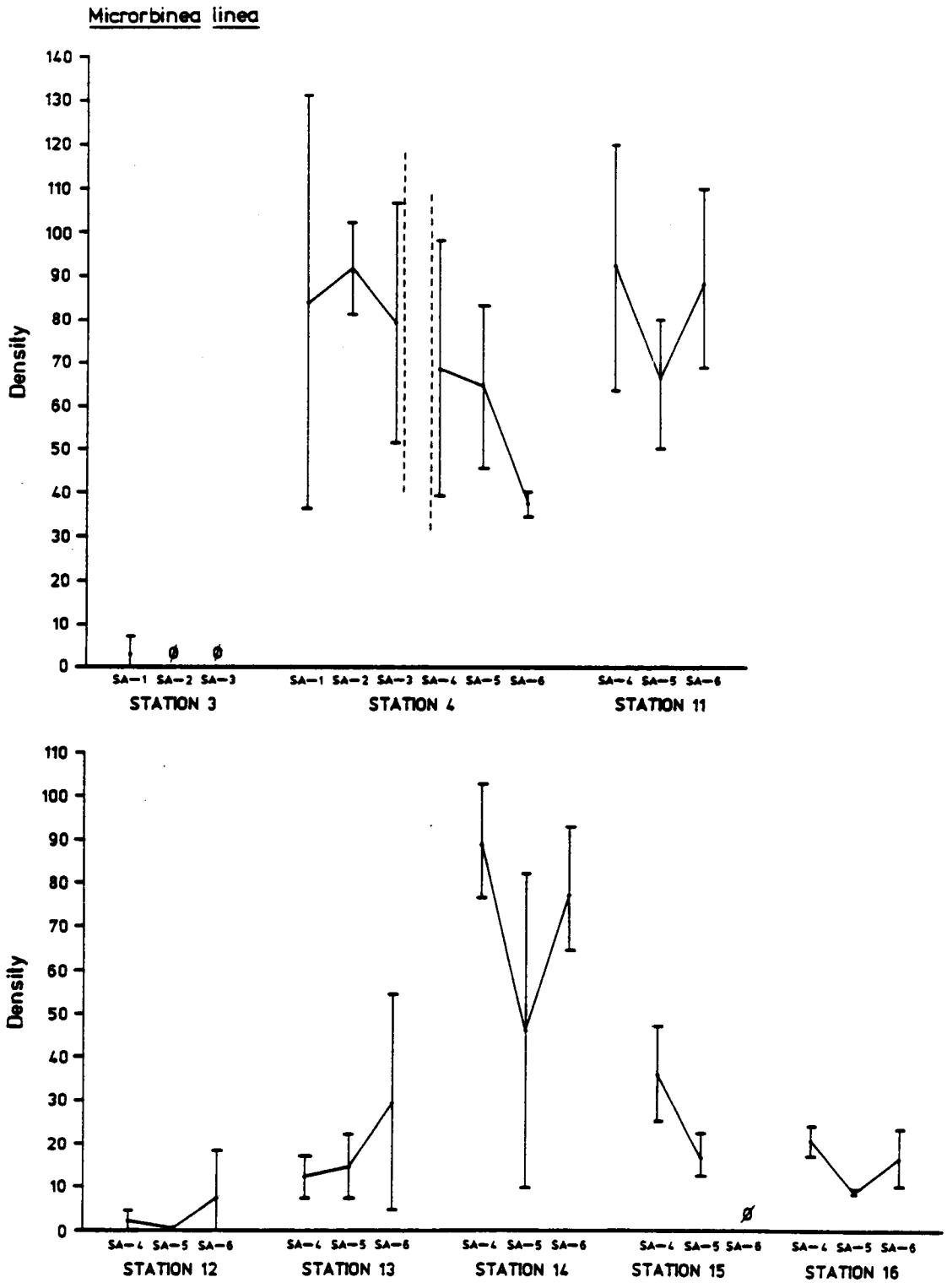


Figure 42. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Microrbinia linea at Eight Stations in the U.S. South Atlantic Region. ∅ Indicates No Data.

2000- to 2100-m depth range and was among the top 10 species at four stations in the 1200 to 1300 m depth range (Maciolek et al., 1986b). In contrast, A. dibranchiata did not rank as the number one species at any of the U.S. South Atlantic stations, but was among the top 20 at six stations. In the U.S. North and Mid-Atlantic regions, mean densities of A. dibranchiata generally ranged between 20 to 33 individuals per 0.09 m^2 box core in the 1500- to 2100-m depth intervals. In the U.S. South Atlantic study, the species achieved comparable densities only at Stations 3 (1500 m) and 4 (2000 m) off Cape Lookout and at Station 6 (2000 m) near the Hatteras Canyon (Figure 43). The densities at these depths declined considerably on the two southern transects. Although it is tempting to suggest a faunal break in A. dibranchiata south of Cape Lookout, this is probably not the case, since the total density of the community declines at Stations 12 and 15 as well. It is obvious, however, that A. dibranchiata is displaced as the dominant species in the 1500- to 2000-m communities in the U.S. South Atlantic region, by Microrbinia linea, Pholoe anoculata, Tubificoides aculeatus, Aspidosiphon zinni, and Prionospio sp. 2. Of all of these species, only M. linea is not important in the more northern slope communities, and it is probable that this one species, more than the others, may be responsible for the alteration in dominance and density patterns seen in the U.S. South Atlantic region.

Pholoe anoculata, a small scaleworm, is an important species throughout depths ranging from 600 to 2000 m. The species is most abundant at Cape Lookout (Stations 3 and 4, 1500-2000 m) and the Hatteras Canyon (Station 6, 2000 m), with mean densities of 46.5, 26.4, and 45.4 individuals per 0.09 m^2, respectively. Densities at other stations, including the 2000-m stations, are considerably lower. At Station 14 off Charleston (800 m), average densities are 17.6 individuals per 0.09 m^2. At most of the stations sampled during Phase 2, there was a decrease in density during September 1985, but this decrease does not appear to be significant. During Phase 1, populations increased during spring 1984 and decreased in summer (Figure 44).

P. anoculata has been the species ranked number one or two at several stations in each of the three ACSAR regions. The mean densities at Stations 3 and 6 in the U.S. South Atlantic are higher than previously recorded for this species in the U.S. Mid- and North Atlantic study areas. The highest mean densities recorded in the U.S. Mid-Atlantic were between 25 and 31 individuals per 0.09 m^2, at three 2100-m stations (Maciolek et al., 1987). In the U.S. North Atlantic, the highest densities were at Stations 3 (1350 m) and 2

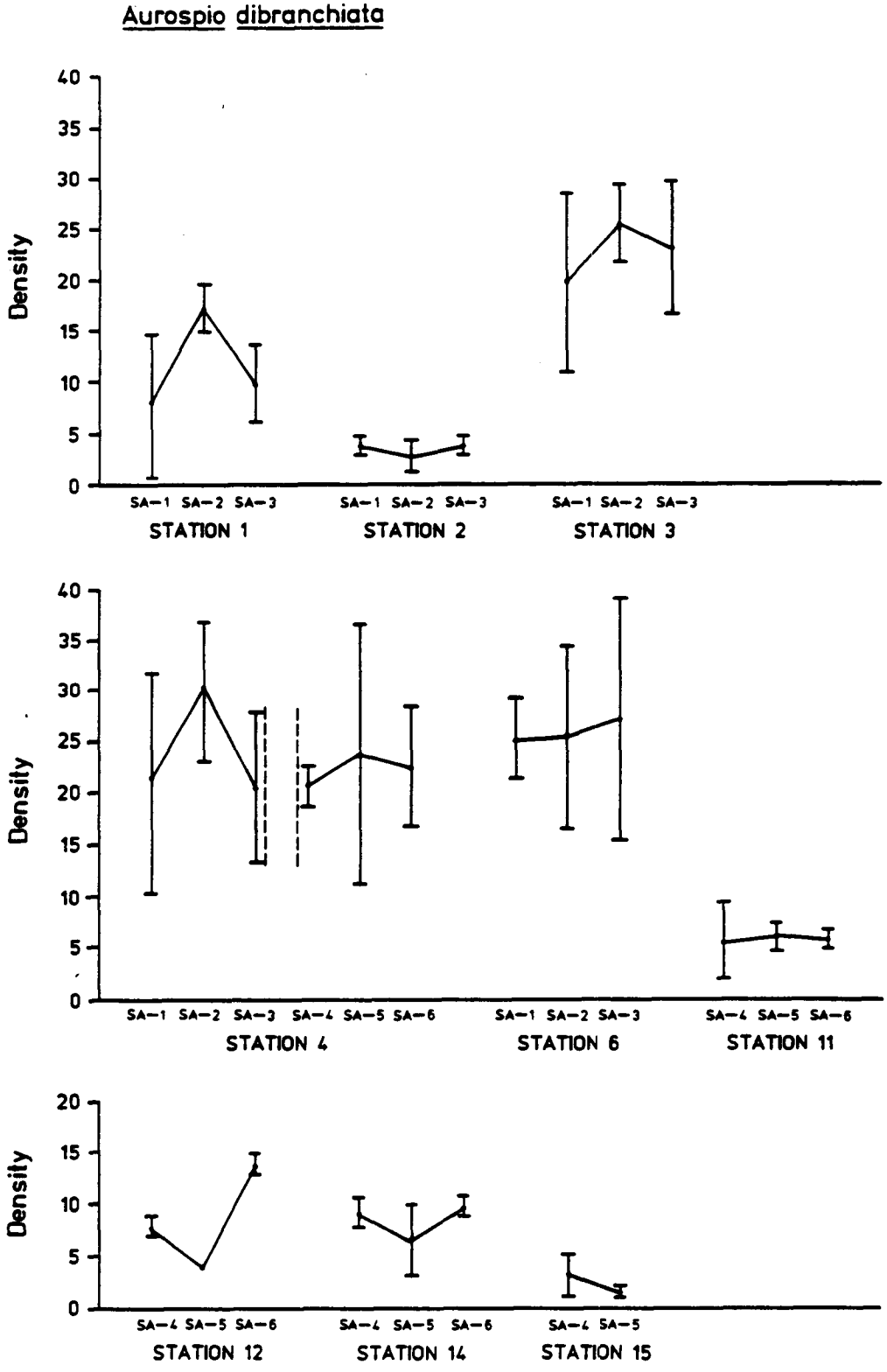


Figure 43. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Aurospio dibranchiata at Nine Stations in the U.S. South Atlantic Region.

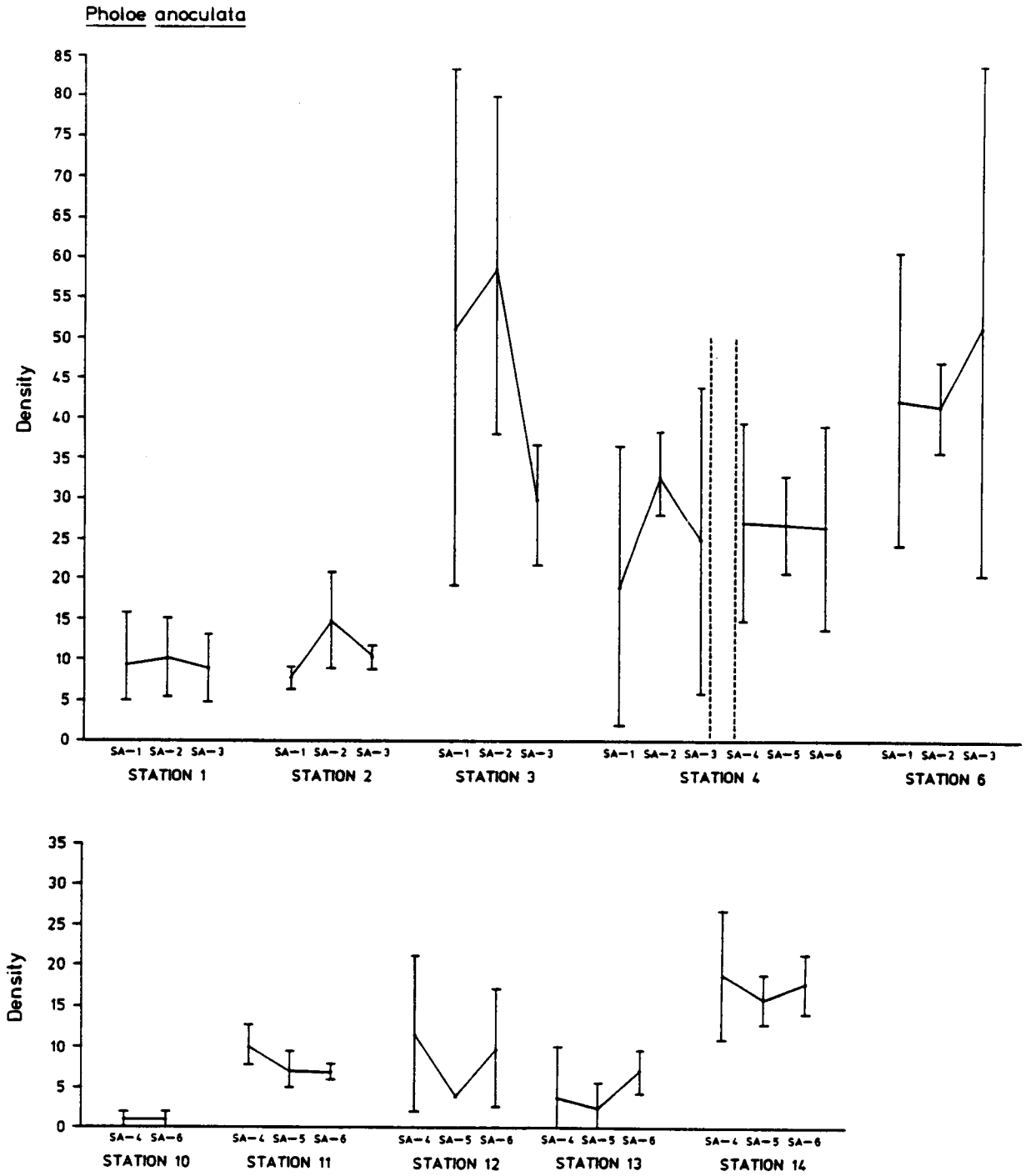


Figure 44. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Pholoe anoculata at Ten Stations in the U.S. South Atlantic Region.

(2100 m) on the Canadian boundary, with mean densities of 22.6 and 11.2 individuals per 0.09 m^2 (Maciolek et al., 1986b).

Tharyx sp. 1 is the most widespread and common of the numerous cirratulid species encountered on the U.S. ACSAR. In the North Atlantic region, the species was rare at the Canadian boundary stations, but ranked between second and sixth at all of the more southern 2000- to 2100-m stations, with average densities of 9.3 to 26.8 individuals per 0.09 m^2 (Maciolek et al., 1986b). In the Mid-Atlantic region, the species is on the dominant list at all stations and ranked between second and sixth at eleven stations in the 2000- to 2500-m depth range, with mean densities from 9.0 to 22.3 individuals per 0.09 m^2 (Maciolek et al., 1987). In the southern study area, Tharyx sp. 1 was widespread over a depth range of 600 to 2000 m. Densities at two sites, however, were especially high. At Station 1 off Cape Lookout (600 m), this species averaged 33.6 individuals per 0.09 m^2 box core; whereas at Station 10 off Cape Hatteras (2000 m), it reached an overall average density of 99.8 individuals per box core. At this site, the species was second only to Cossura longocirrata in overall dominance. Thus, at these two southern stations, densities were higher than at any other location in the entire U.S. ACSAR program. The high densities of Tharyx sp. 1 at Station 10 further contributes to the unusual community structure at stations sampled on the Cape Hatteras transect. No significant trends are evident in the seasonal fluctuations in the densities at the various U.S. South Atlantic stations (Figure 45).

The polychaete Glycera capitata is a well-known and widespread species ranging from shallow continental shelf environments to the deep sea. At the U.S. South Atlantic stations, it appeared on the dominance list at each of the 2000-m stations except Station 10 at Cape Hatteras, where it was rare. Average densities for the species never exceeded 4 to 8 individuals per 0.09 m^2 box core, and no seasonal trends are evident in the seasonal data (Figure 46).

Levinsenia sp. 1, a paraonid polychaete, is widespread across several depth contours from 600 to 2000 m. Densities seem to be highest on the upper slope, especially at Station 1 (Figure 47), but relatively consistent at the other stations. There are no seasonal trends in the data.

Grania atlantica, an oligochaete, occurs at several of the U.S. South Atlantic stations, but is most abundant on the Cape Lookout Transect, where its densities are

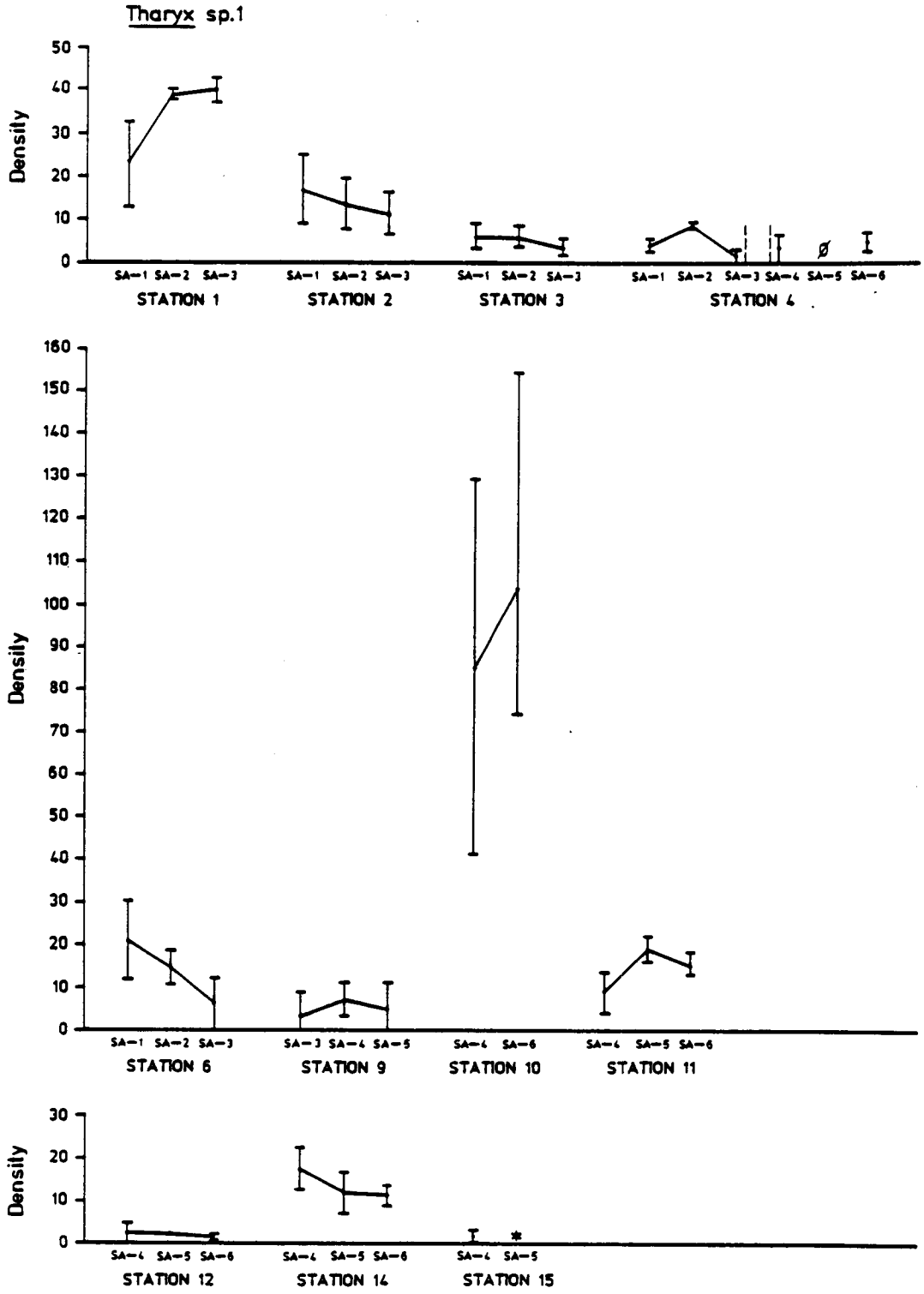


Figure 45. Mean Population Density (No9./0.09 $m^2 \pm 1$ SD) of the Polychaete Tharyx sp. 1 at Eleven Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

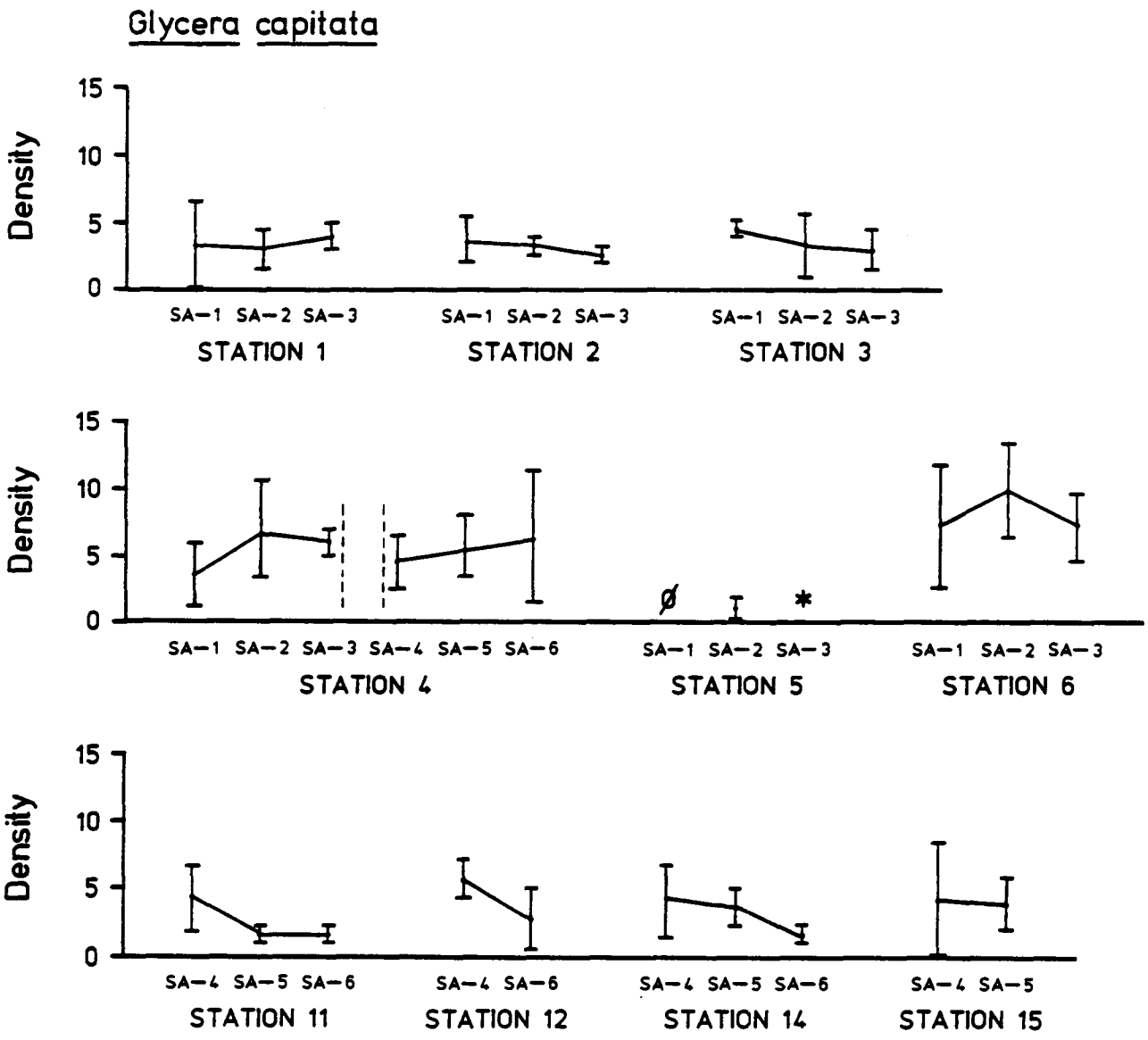


Figure 46. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Glycera capitata at Ten Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

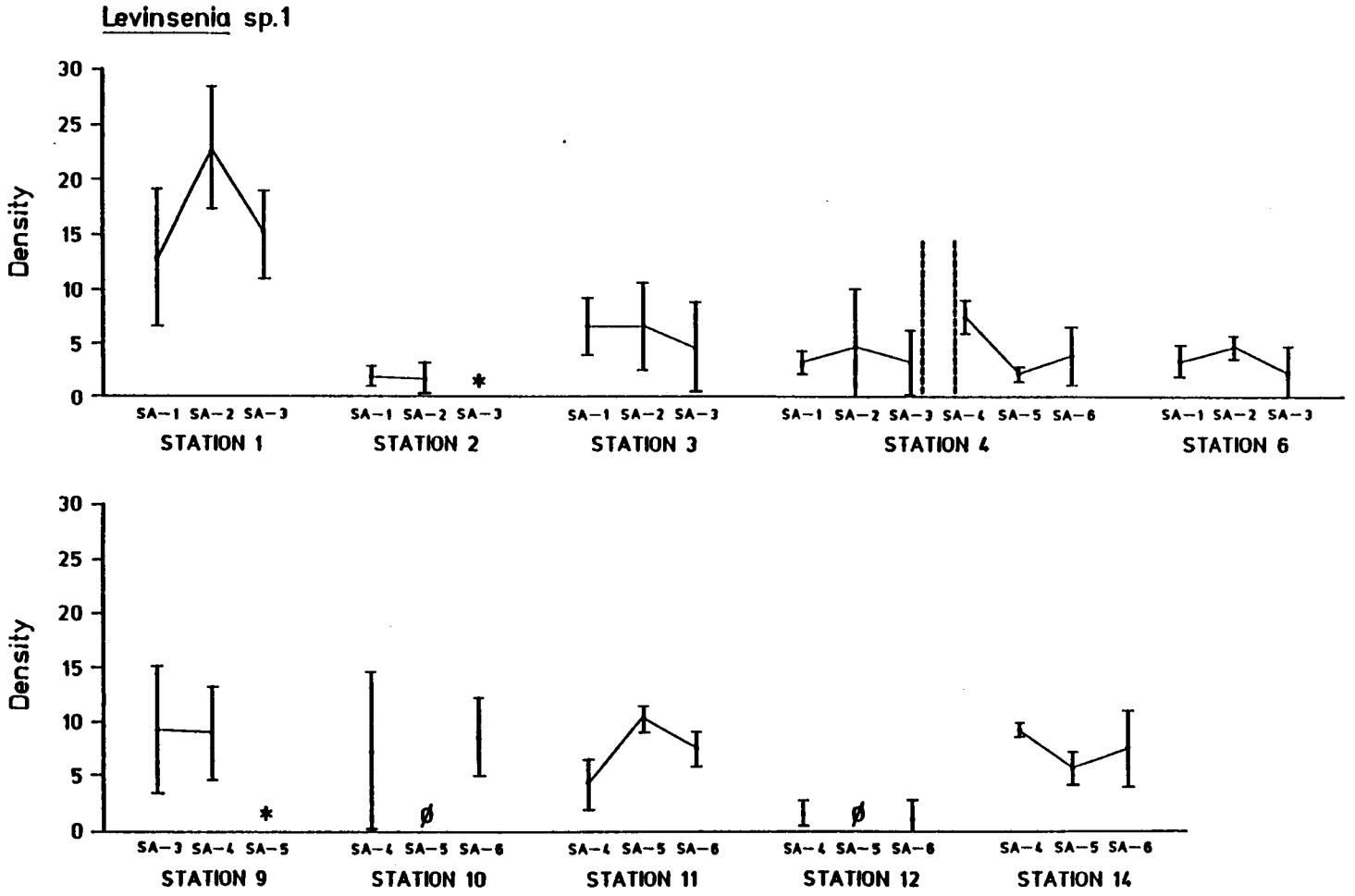


Figure 47. Mean Population Density (No./0.09 m^2 ± SD) of the Polychaete Levinsenia sp. 1 at Ten Stations in the U.S. South Atlantic Region. *Indicates Too Few Individuals to Plot. Ø Indicates No Data.

highest at Station 2 (1000 m). The species is sporadic in its occurrence on the Cape Fear and Charleston Transect and did not occur at all at the Hatteras Canyon station (2000 m). During Phase 1, at Stations 1, 2 and 4, the species underwent a population increase in May 1984 followed by a decline in July 1984 (Figure 48).

Aspidosiphon zinni, a sipunculid, is common all along the U.S. ACSAR. The species seems to be most common in middle slope depths: it is the dominant species at two U.S. North Atlantic stations at 1220 m and two U.S. Mid-Atlantic stations at 1400 to 1600 m. Highest densities at the northern stations are 21.3 to 28.3 individuals per 0.09 m^2 box core, while the highest densities at the U.S. Mid-Atlantic stations are 41.3-59.3 individuals per 0.09 m^2 (Maciolek et al., 1986; 1987). In the south, A. zinni is most common at Stations 3 and 4 off Cape Lookout (1500 m, 2000 m) and at Station 11 off Cape Fear (800 m). At the latter station, the overall mean density is 35.4 individuals per 0.09 m^2. This species did not occur at all at Stations 9 and 10 off Cape Hatteras. Individual seasonal densities show a significant decline at Station 11 during September 1985 (SA-5), but this decline was not seen at the other stations (Figure 49).

Thyasira croulinensis is a deep-sea bivalve that occurs throughout the U.S. North and South Atlantic Ocean in depths of 40 to 3861 m. Its highest densities in the U.S. South Atlantic region are between 600 and 2000 m (Figure 50). The species is most abundant on the Cape Lookout Transect at Stations 1 and 2 (600 m, 1000 m) and at Cape Fear at Station 11 (800 m). At these stations, the mean average densities are 14.8, 10.4, and 9.8 individuals per 0.09 m^2. Mean densities declined in SA-2 (spring 1984) at both Stations 1 and 2 (Figure 50). The species is present in the U.S. Mid- and North ACSAR fauna, and is on the list of dominants at one 550-m station off Georges Bank, where it occurs in densities of 13.1 individuals per 0.09 m^2 (Maciolek et al., 1986b).

Thyasira minutus, another bivalve, was previously known only from a single location off New England in 183 m. The species has been found to co-occur with T. croulinensis, but is usually more abundant. For example, at Stations 1, 2, and 11 the mean densities are 57.7, 16.2, and 8.8 individuals per 0.09 m^2, respectively. There does not appear to be any seasonal trend in the data (Figure 51).

Myriotrochinae sp. 1 is an undescribed species of holothuroid. It is present at most stations from 800 to 2000 m from Cape Lookout to Charleston. It is rare at the 2000-m stations off Cape Hatteras and Charleston. Highest densities occur at the two 800-m

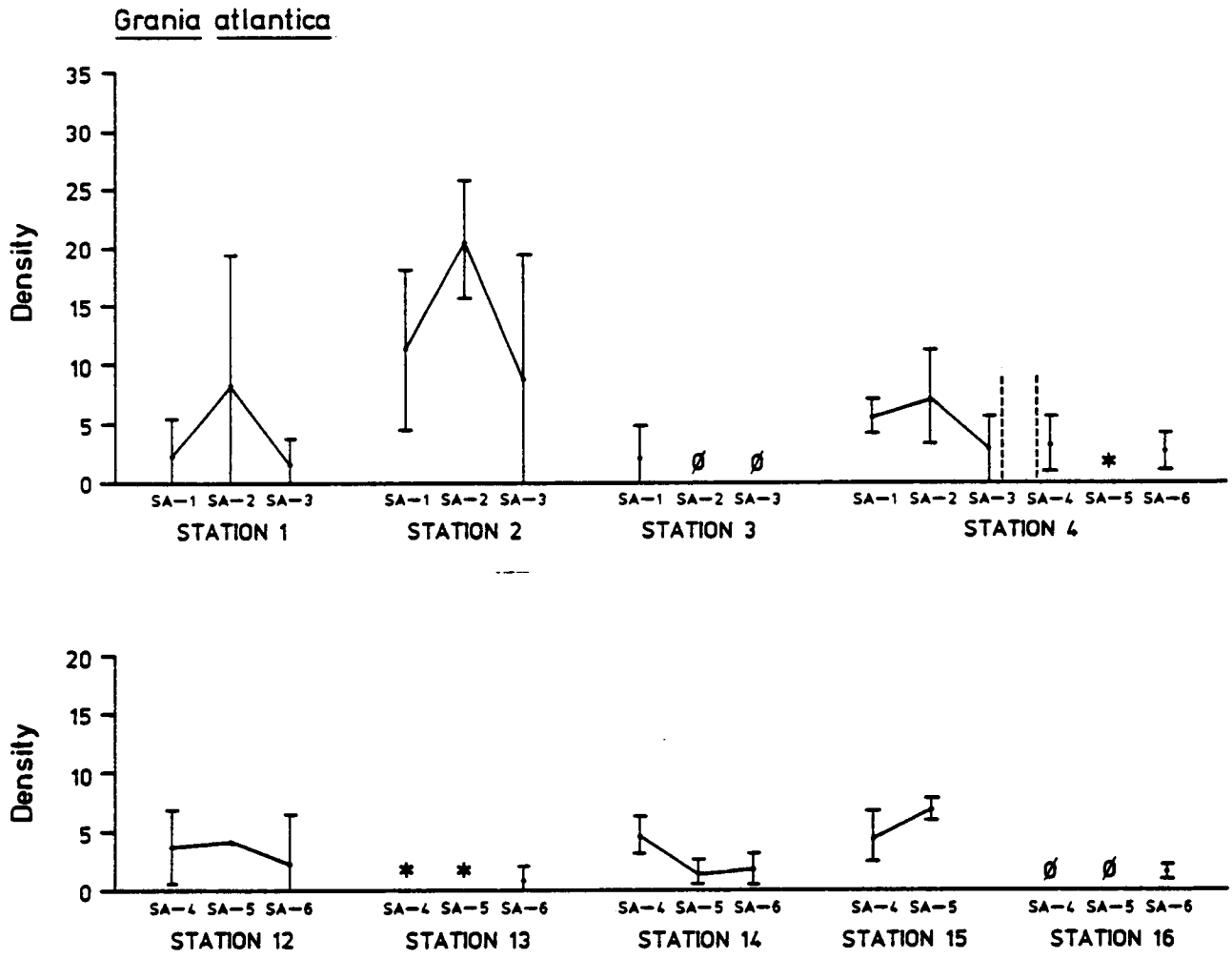


Figure 48. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Oligochaete Grania atlantica at Nine Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

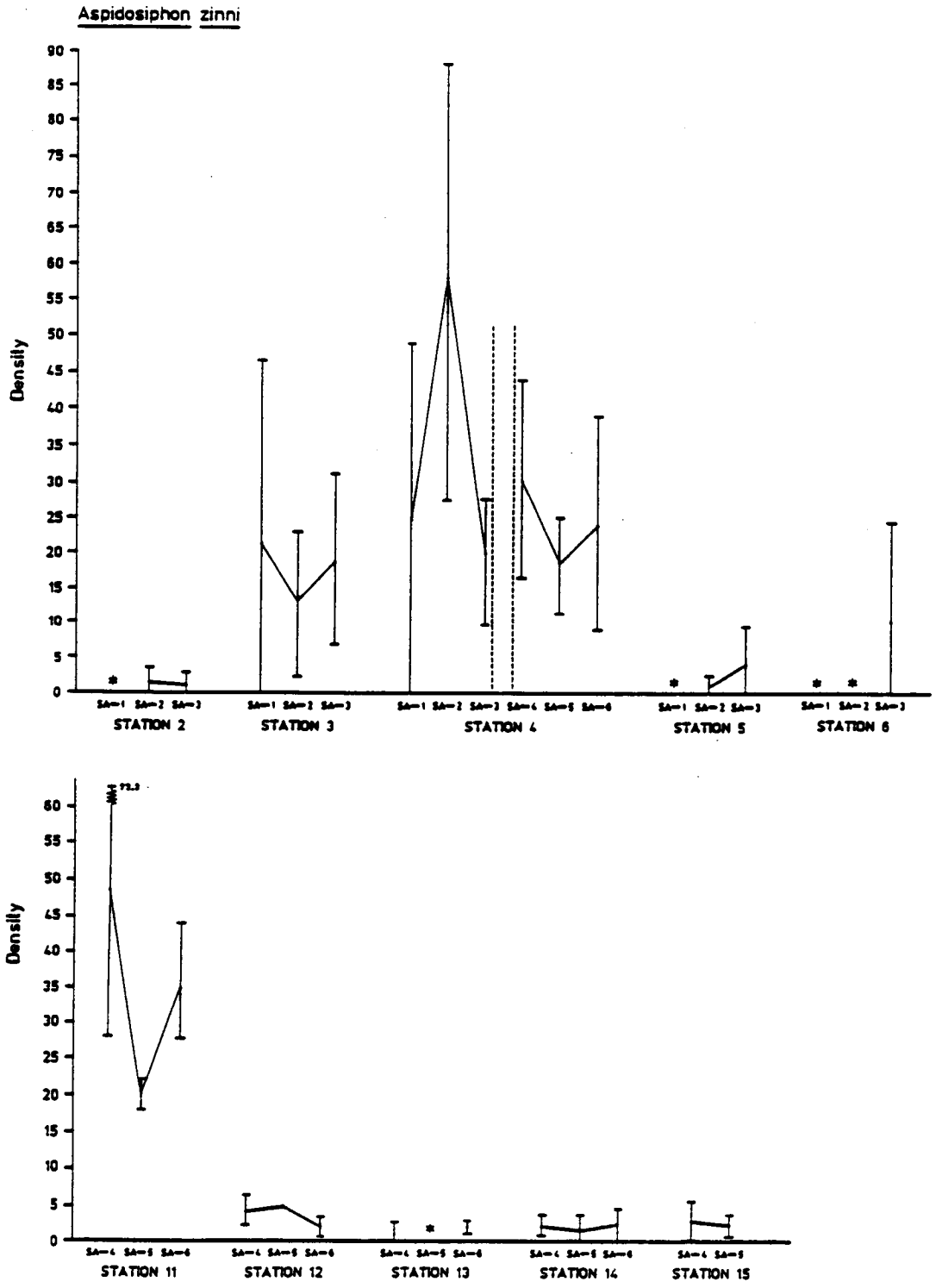


Figure 49. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Sipunculid Aspidosiphon zinni at Ten Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot.

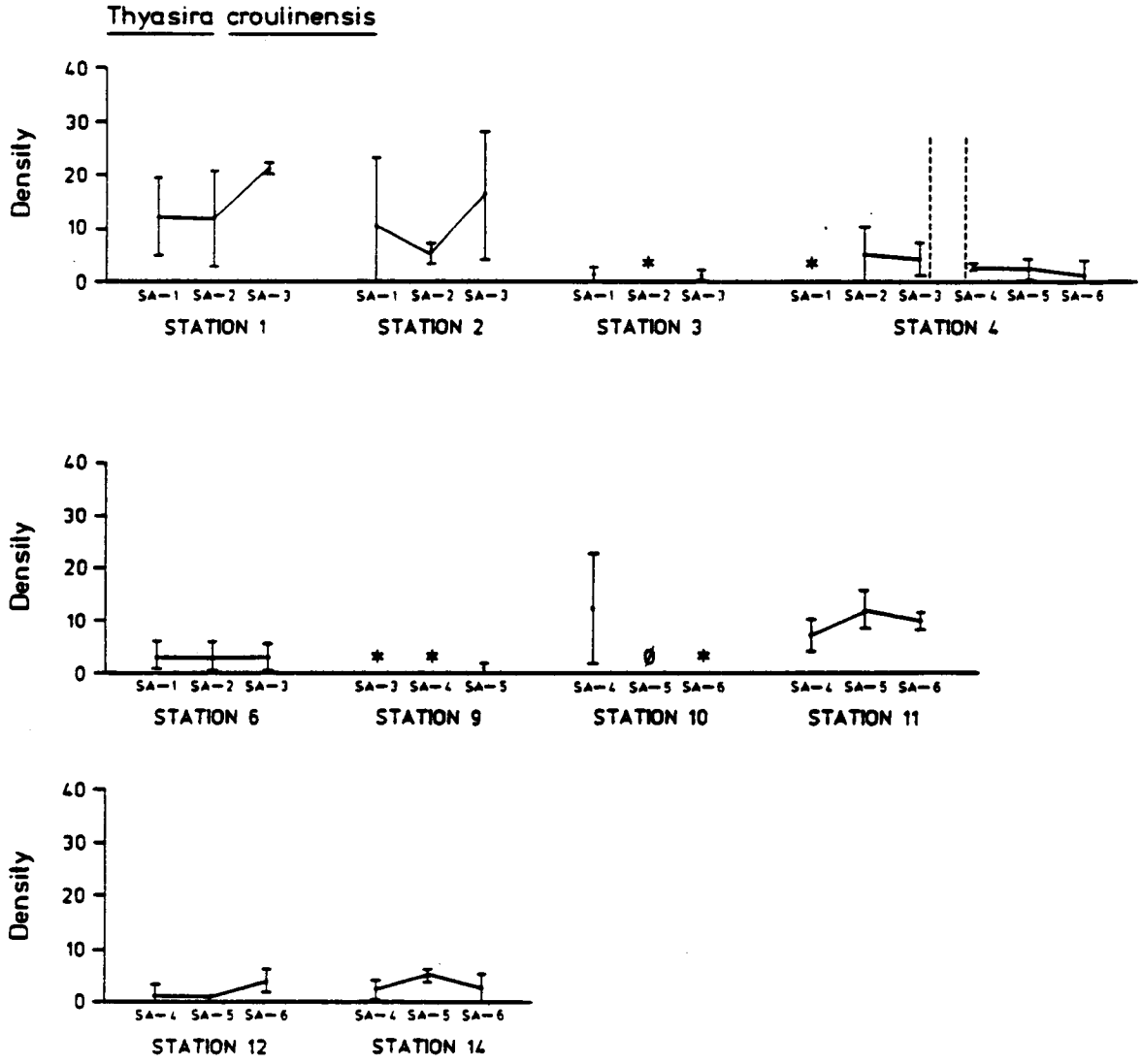


Figure 50. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Bivalve Thyasira croulinensis at Ten Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. ∅ Indicates No Data.

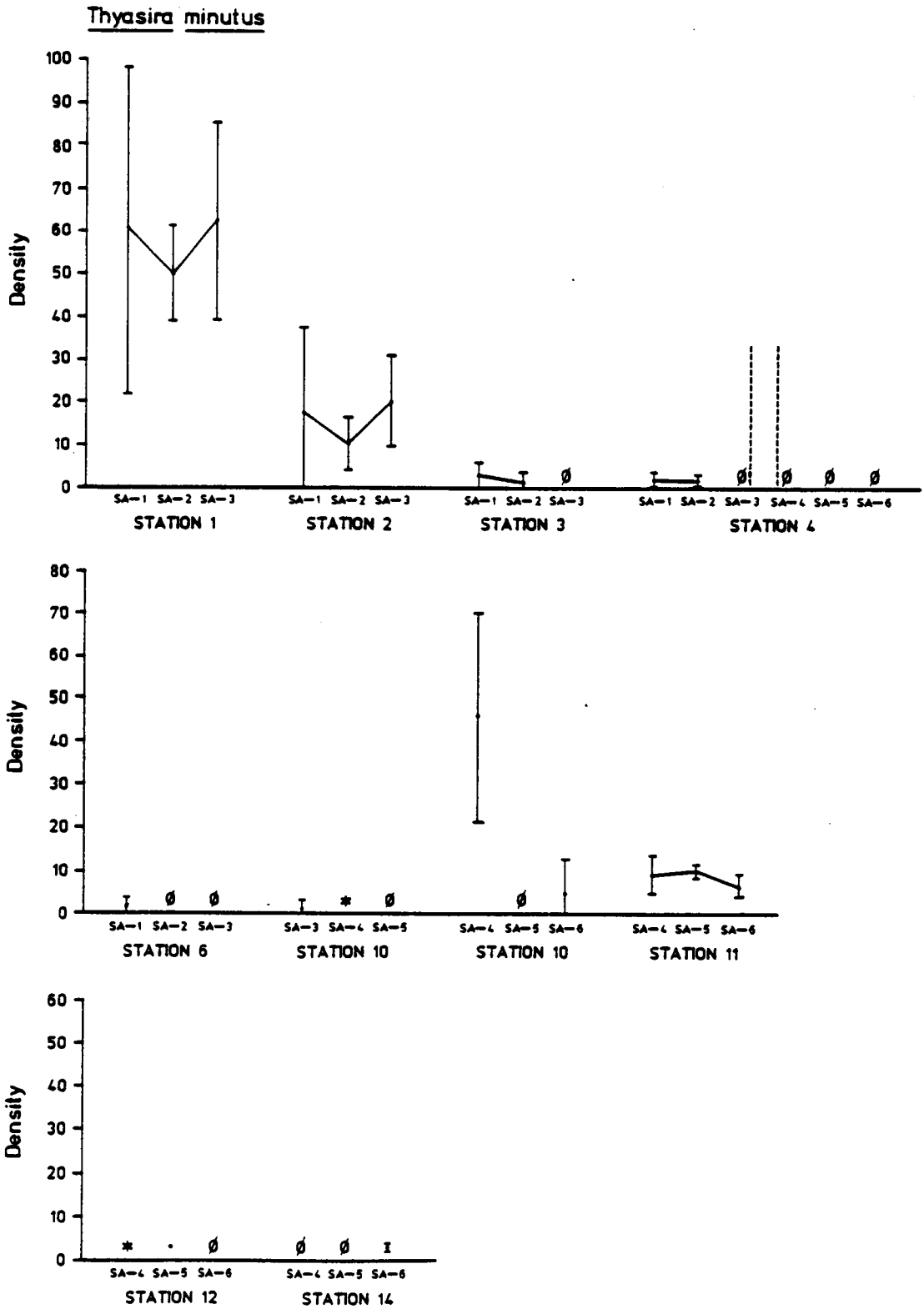


Figure 51. Mean Population Density (No./0.09 m^2 ± 1 SD) of Bivalve Thyasira minutus at Ten Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

stations (FE, CH). There does not appear to be any seasonal trend in the data (Figure 52).

Nemertea sp. 2 has been found in moderate abundance at most of the U.S. South Atlantic stations except for Stations 9 and 10 off Cape Hatteras, where it is rare. Densities are never very high, but the species has appeared on the dominance list at six of the stations in depths ranging from 800 to 3000 m. There do not appear to be any obvious seasonal trends in the data (Figure 53).

Species having a Wide Distribution but Largely Restricted to the Lower Slope and Rise. The following group of species are largely limited to depths of 1500 to 2000 m, or sometimes 3000 m. Included are two polychaetes, one oligochaete, two aplacophorans, and one pogonophoran.

The spionid polychaete Prionospio sp. 2 is most abundant at Station 4 off Cape Lookout (2000 m). At Station 12 off Cape Fear (2000 m), it is the top-ranked dominant species. It ranks second at Station 4 and also at Station 13 (FE 3000 m). In the U.S. Mid-Atlantic region, this species is on the dominance list at 13 of 14 stations at depths of 1500 to 2500 m. At the 2000- to 2100-m stations, the species ranks between third and eighth. Mean densities at those depths are from 8.4 to 15.1 individuals per 0.09 m^2, while at the 2500-m station the species ranks third and has a mean density of 18.2 individuals per 0.09 m^2 (Maciolek et al., 1987). In the U.S. North Atlantic study area, P. sp. 2 is among the dominants at five stations in the 2000- to 2150-m depth range with mean densities of 6.1 to 15.2 individual per 0.09 m^2 (Maciolek et al., 1986b). At South Station 4, the mean density for 18 box cores is 22.5 individuals per 0.09 m^2. This is the highest overall density yet recorded for this species. Trends in the data are difficult to interpret, but a distinct decline in the mean density at Station 4 is evident during the Phase 2 program (SA-4 through SA-6) (Figure 54).

Sabidius cornatus is a widespread deep-sea paraonid first described from the Gay Head-Bermuda Transect and since reported from the Pacific Ocean. The species is known to range from 400 to 2900 m in the Atlantic and to depths of 3388 m in the Pacific (Streltsov, 1973). In the present study, S. cornatus has been found throughout the depth range from 600 to 3000 m. The species has been recorded from both the U.S. Mid- and North Atlantic regions and is usually a dominant at the 2000- to 2100-m depth interval in both areas. It reaches its highest recorded average densities of 31.3 individuals per 0.09 m^2 at Station 15 (2105 m) in the north, where it ranked second (Maciolek et al., 1986b). In

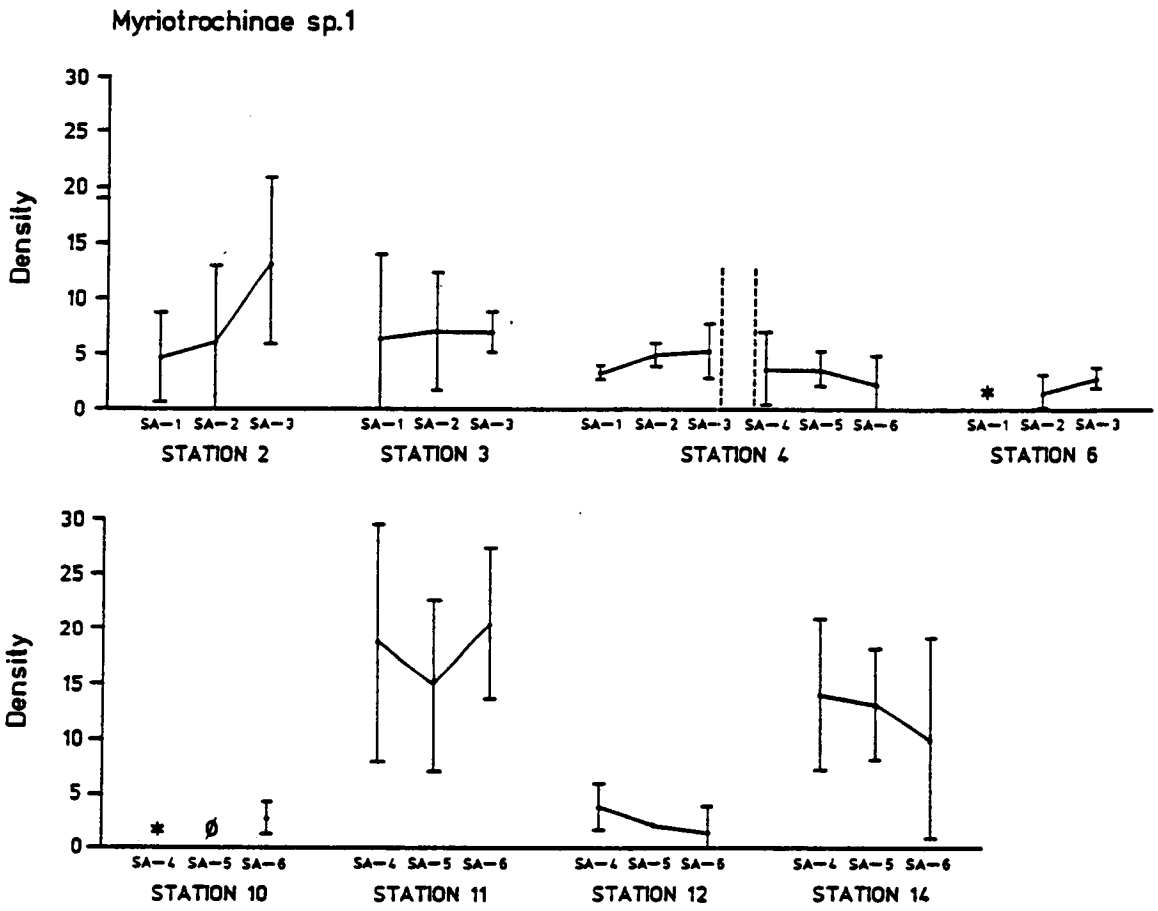


Figure 52. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Holothuroidean Myriotrochinae sp. 1 at Eight Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

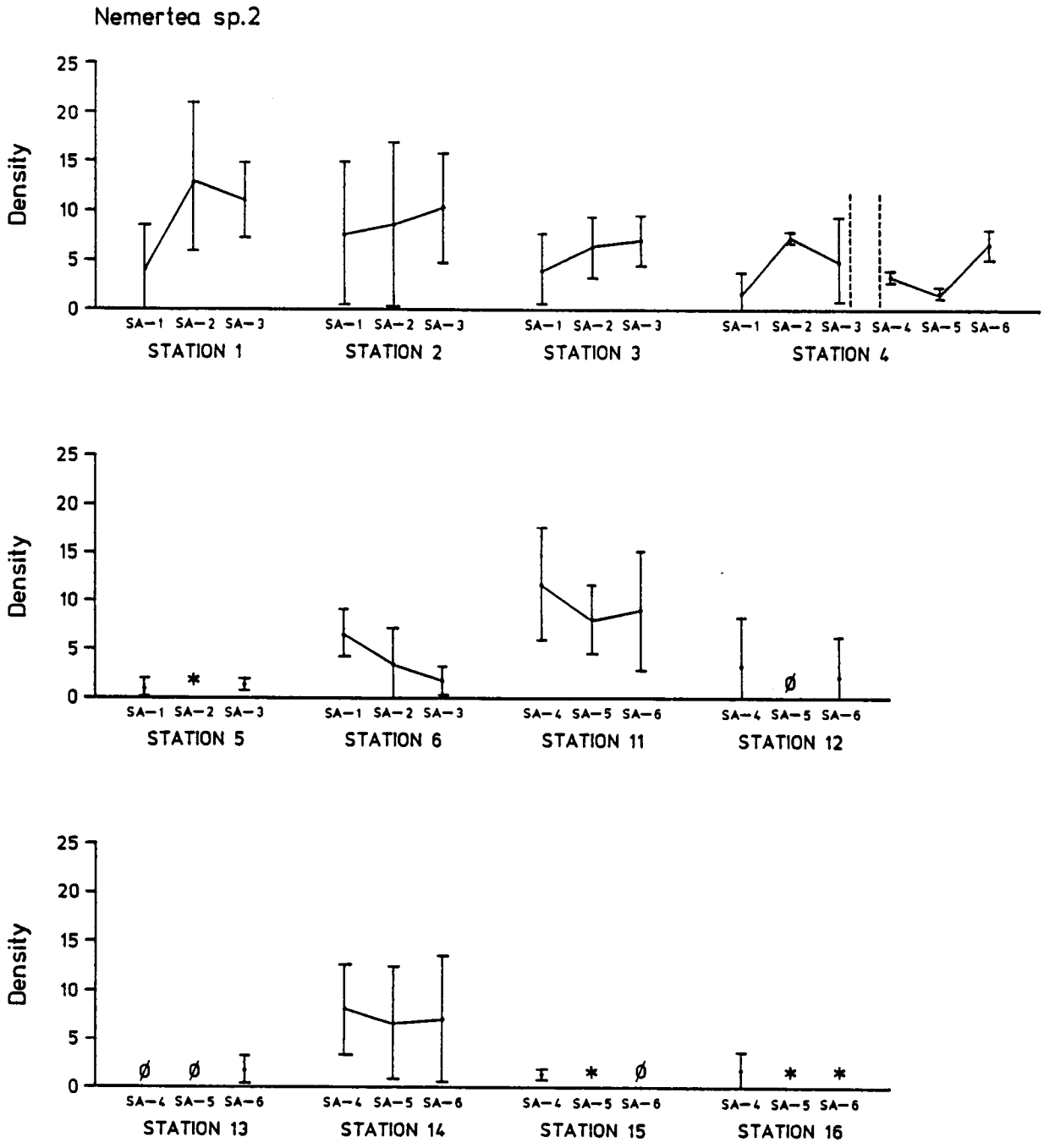


Figure 53. Mean Population Density (No./0.09 m^2 $\pm$ 1 SD) of the Nemertean Nemertea sp. 2 at Twelve Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

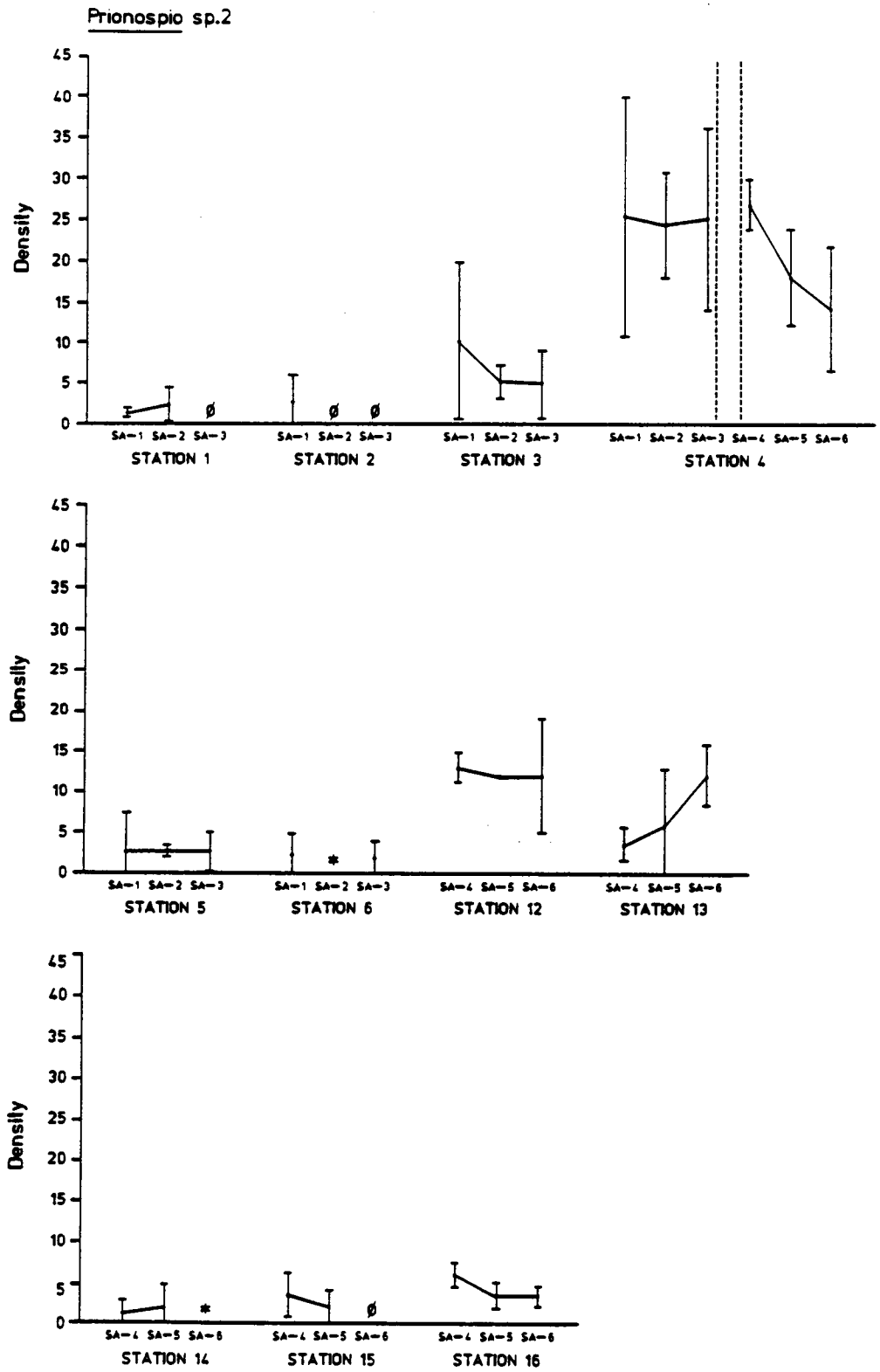


Figure 54. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Prionospio sp. 2 at Eleven Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

the U.S. Mid-Atlantic region, the species has densities from 5.7 to 10.6 individuals per 0.09 m^2 at those 2000-2100 m stations where it is among the top 20 dominants (Maciolek et al. 1987). In the south, the species occurs among the top dominants at the 2000-m stations, with the highest densities of 11.9 individuals per 0.09 m^2 recorded at Station 4 (LO 2000). The species was entirely absent from Station 10 at the 2000-m depth, further emphasizing the unique nature of that transect. There do not appear to be any obvious seasonal trends in the data (Figure 55).

Tubificoides aculeatus, an oligochaete, is widely distributed at the 1500- to 2000-m stations of the U.S. ACSAR. In the Mid-Atlantic region, the species is among the top 20 dominants at 13 out of 14 stations, and is dominant at four out of six 2000- to 2100-m stations in the northern study area (Maciolek et al., 1986 a-b). In the South Atlantic, however, the distribution is limited to only three stations in the entire study area: Stations 3 and 4 off Cape Lookout (1500 m, 2000 m) and the Hatteras Canyon Station 6 (2000 m). The species is totally absent south of Cape Lookout. The highest mean densities are reached at Station 6, with 37.0 individuals per 0.09 m^2. The species was ranked number two at that station. There are no obvious seasonal trends in the data (Figure 56). After being so widespread and prevalent northward on the U.S. ACSAR, the complete absence of this species off Cape Fear and Charleston is noteworthy, suggesting a complete break in its distribution.

Siboglinum pholidotum is widespread on the U.S. ACSAR and is present in both the North and Mid-Atlantic regions as well as in the South Atlantic. It is only at stations on the U.S. South Atlantic slope, however, that the species is among the top 20 dominant species. At Stations 3 and 4 off Cape Lookout (1500 m, 2000 m) the species ranks 18 and 7, respectively. At Stations 3 and 4 and also at Station 6 off the Hatteras Canyon (2000 m) the species has mean densities of 5.1, 15.4, and 5.1 individuals per 0.09 m^2. There are no obvious seasonal trends in the data (Figure 57).

Prochaetoderma yongei is a common aplacophoran on the U.S. ACSAR. It is on the dominants list at 12 out of 14 stations in the Mid-Atlantic region, where it ranks first or second at the 1500-m stations (Maciolek et al., 1987). In the north, the species is also dominant, especially at stations at 1220 to 1350 m (Maciolek et al., 1986b). In the south, the species was limited to Station 6 on the Hatteras Canyon (2000 m) and the Cape Lookout Transect stations, especially Stations 3 and 4 (1500 m, 2000 m). Although a few

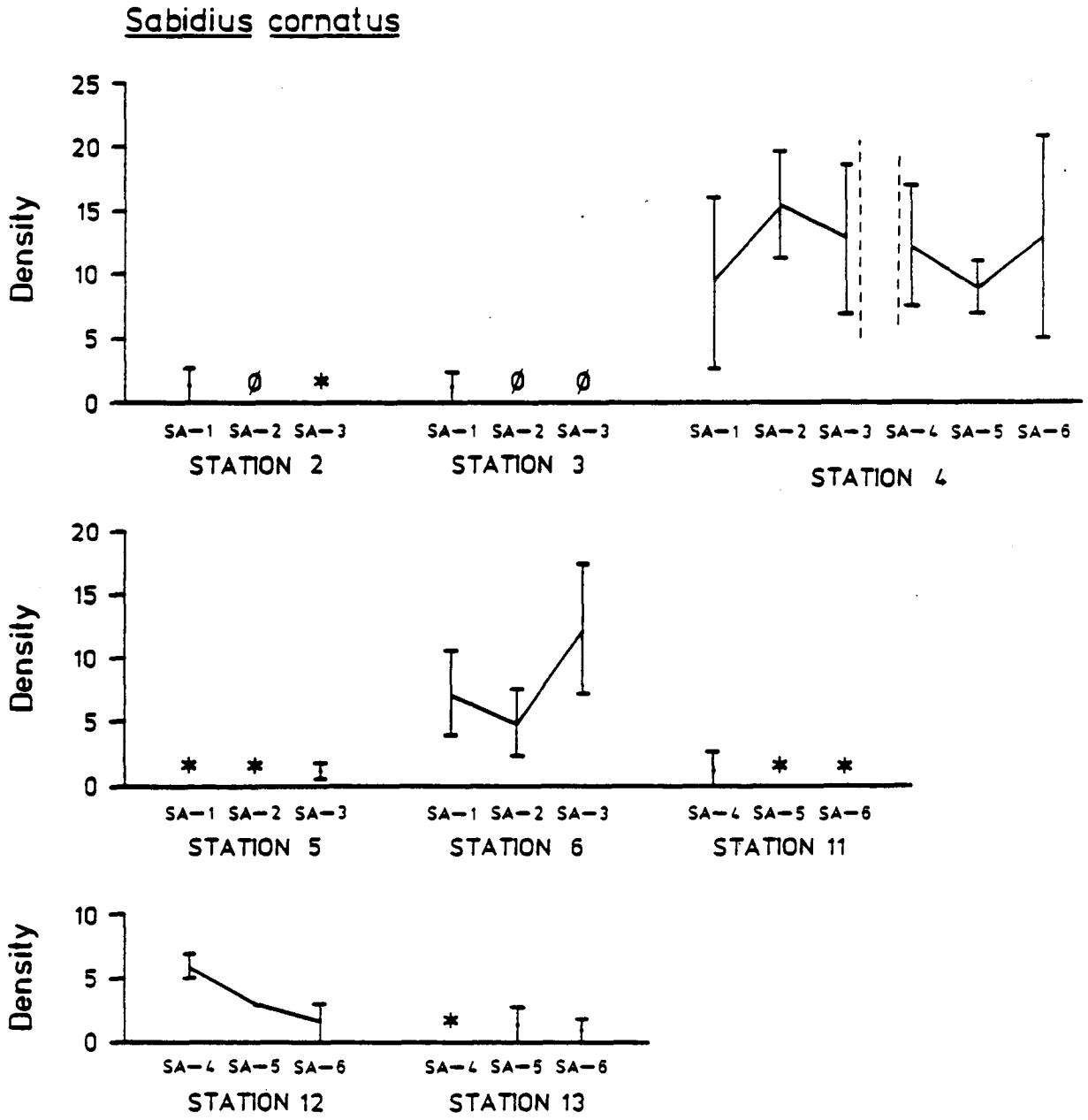


Figure 55. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Sabidius cornatus at Eight Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

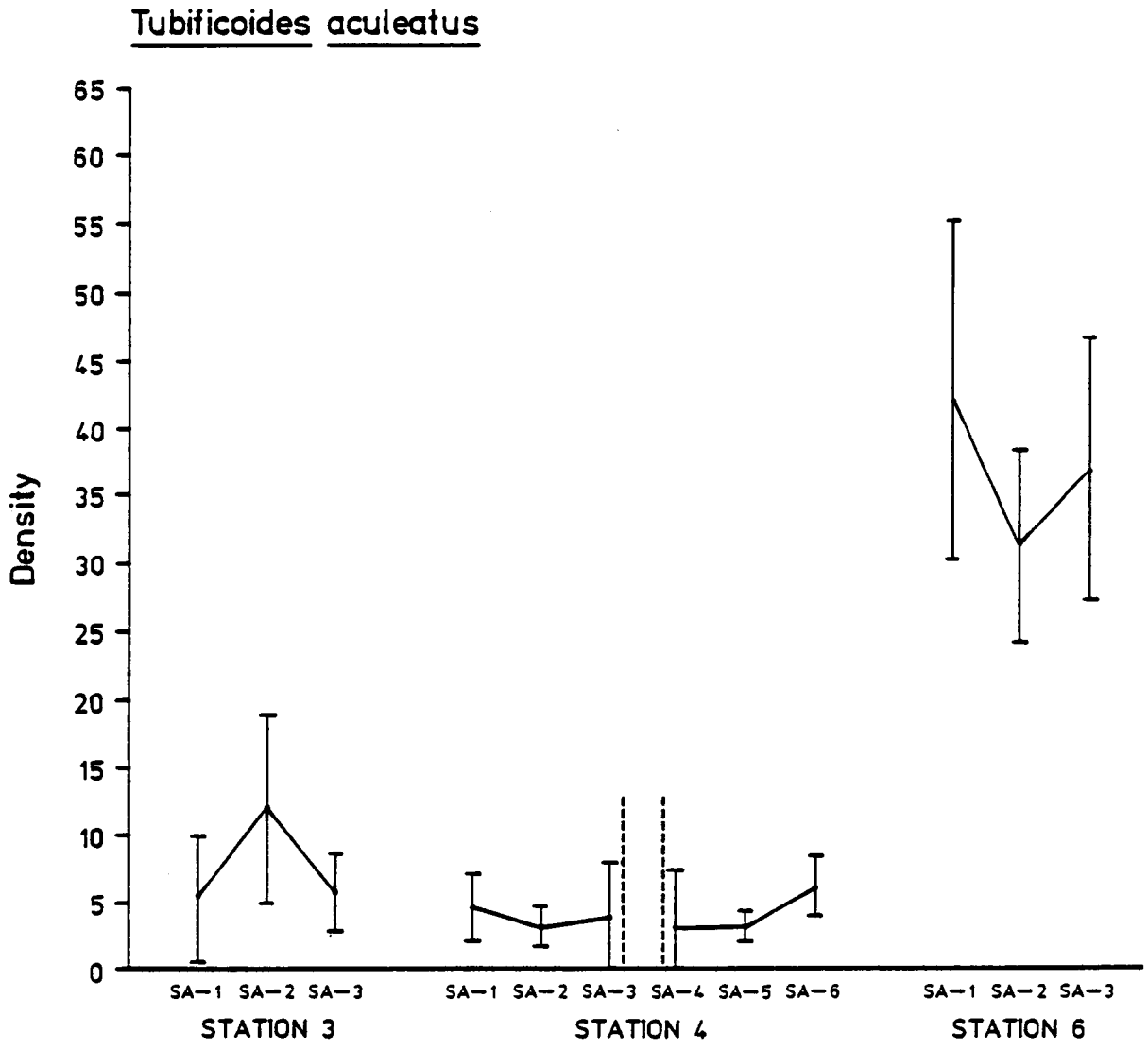


Figure 56. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Oligochaete Tubificoides aculeatus at Three Stations in the U.S. South Atlantic Region.

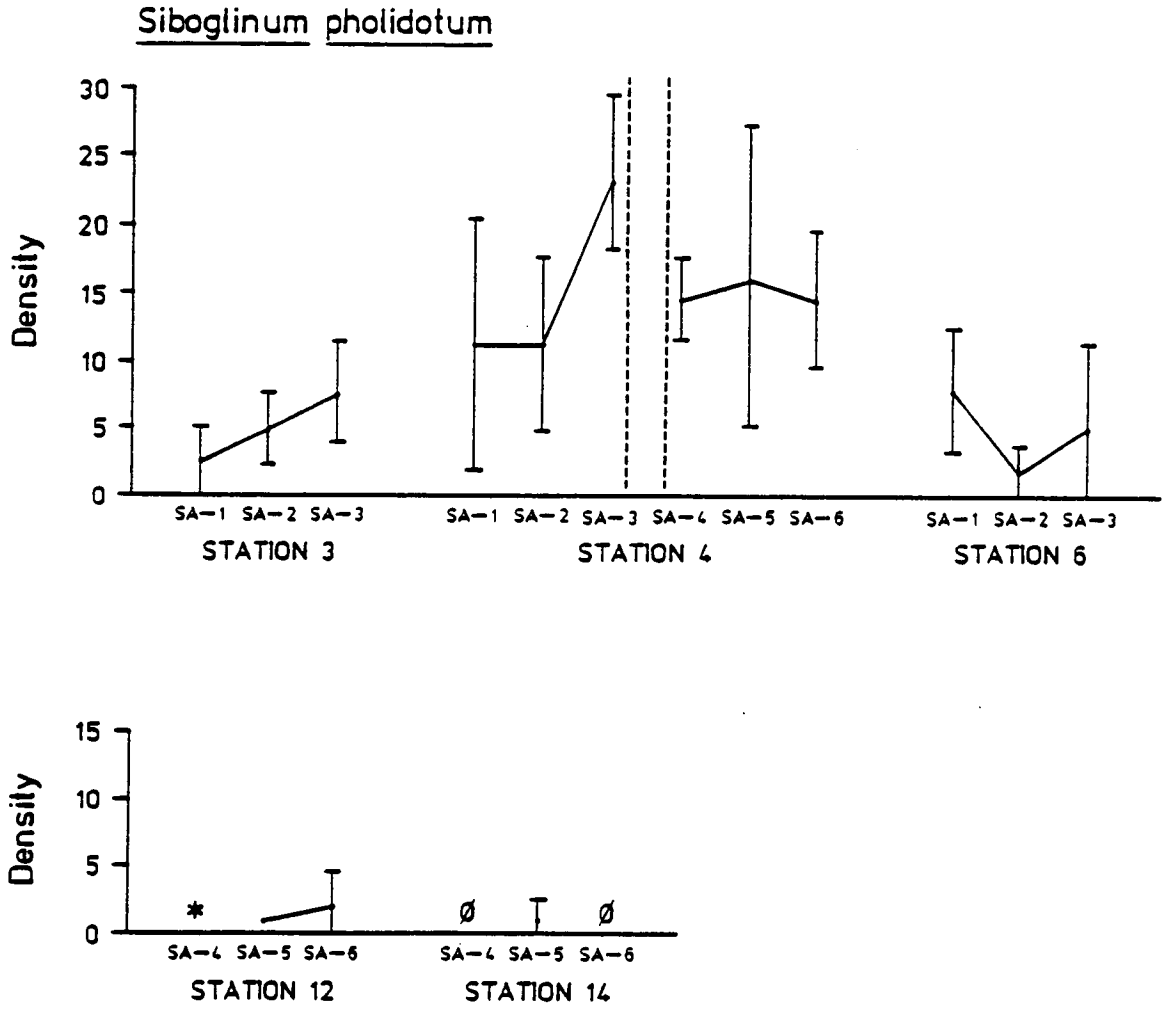


Figure 57. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Pogonophoran Siboglinum pholidotum at Five Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

specimens were taken at Station 11 off Cape Fear (800 m), there appears to be a definite break in the distribution of P. yongei south of Cape Lookout. The highest densities in the south were at Station 6. Mean densities at that station were 14.7 individuals per 0.09 m^2, which are similar to densities at the 2000-m station in the Mid-Atlantic region. Densities at the Mid-Atlantic 1500-m stations, however, are 29 to 31 individuals per 0.09 m^2. One North Atlantic 1220-m station had a density of 34.2 individuals per 0.09 m^2. Thus, densities of P. yongei appear to be lower in the south and the species all but disappears south of Cape Lookout. There are no obvious seasonal trends in the data (Figure 58).

Spathoderma clenchi, another common aplacophoran in the U.S. Mid- and North ACSAR regions, follows the same pattern as Prochaeteoderma yongei. It is mostly limited to the Hatteras Canyon station (2000 m) and off Cape Lookout (2000 m). Although an occasional specimen is recorded south of Cape Lookout, there appears to be a distinct break in the distribution of this species. Mean densities are highest at Station 6 with 22.4 individuals per 0.09 m^2. This is slightly higher than the highest mean densities recorded from a Mid-Atlantic 2100-m station (21.6 individuals per 0.09 m^2) (Maciolek et al., 1987). North Atlantic densities were lower. S. clenchi is more common at the 2000-m depth interval than is P. yongei, which is more prevalent at 1500 m. There are no consistent seasonal trends in the data for the species (Figure 59).

Tests for Differences in Species Density On Transects, Isobaths, and Between Seasons

To determine if breaks in the distribution of common species were evident between the Cape Lookout, Cape Fear, and Charleston Transects, a series of tests were conducted based on the densities of individual species occurring at selected stations collected during the same cruises. These tests were also used to elucidate seasonal trends at Station 4, where six cruises were conducted from 1983 to 1985.

Two basic questions were addressed: 1) Did densities of each species vary over time? 2) Did the mean density of individual species differ from one station to the next when sampled on the same cruise? Specifically, the hypotheses tested were as follows:

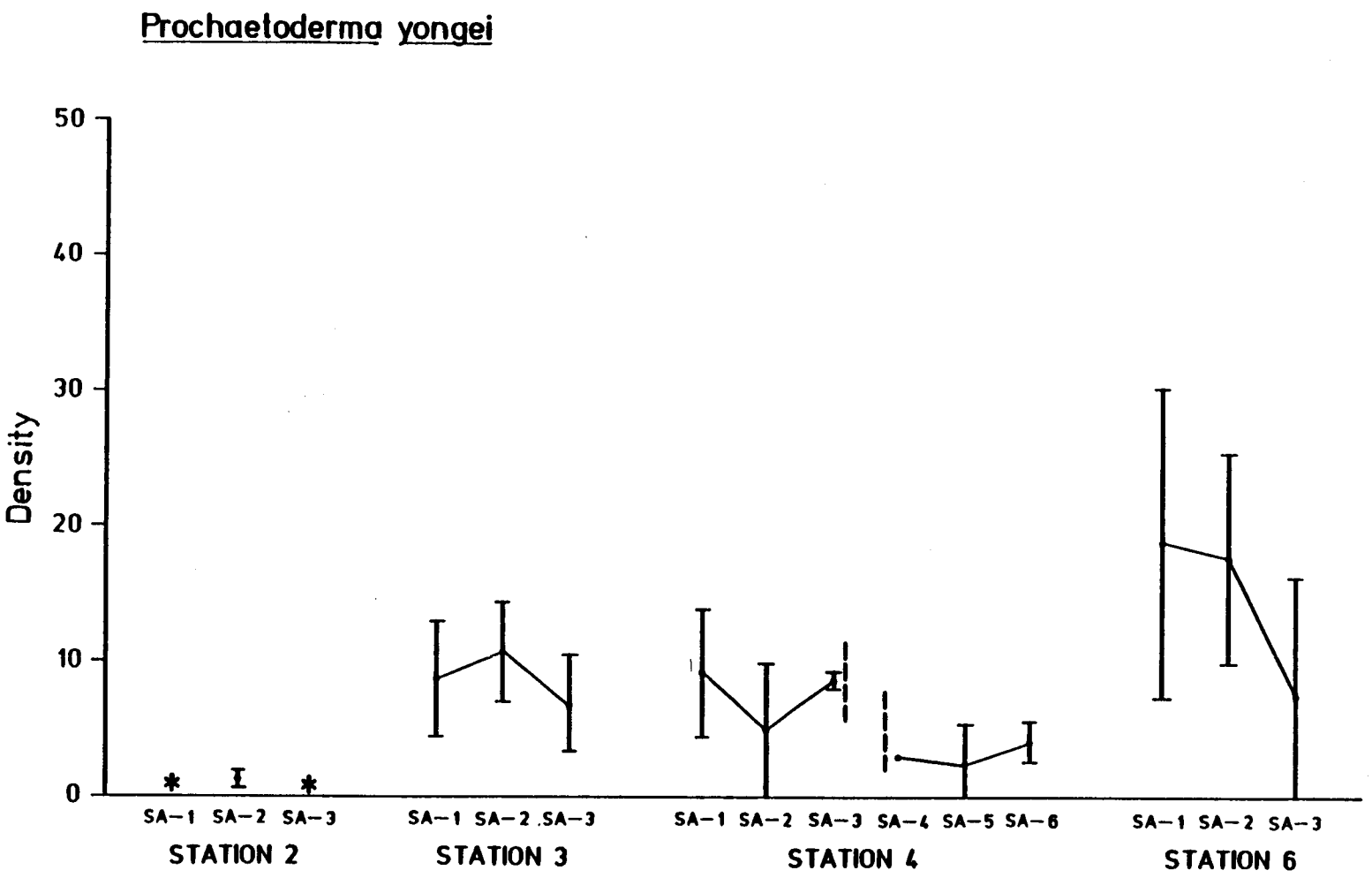


Figure 58. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Aplacophoran Prochaetoderma yongei at Four Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot.

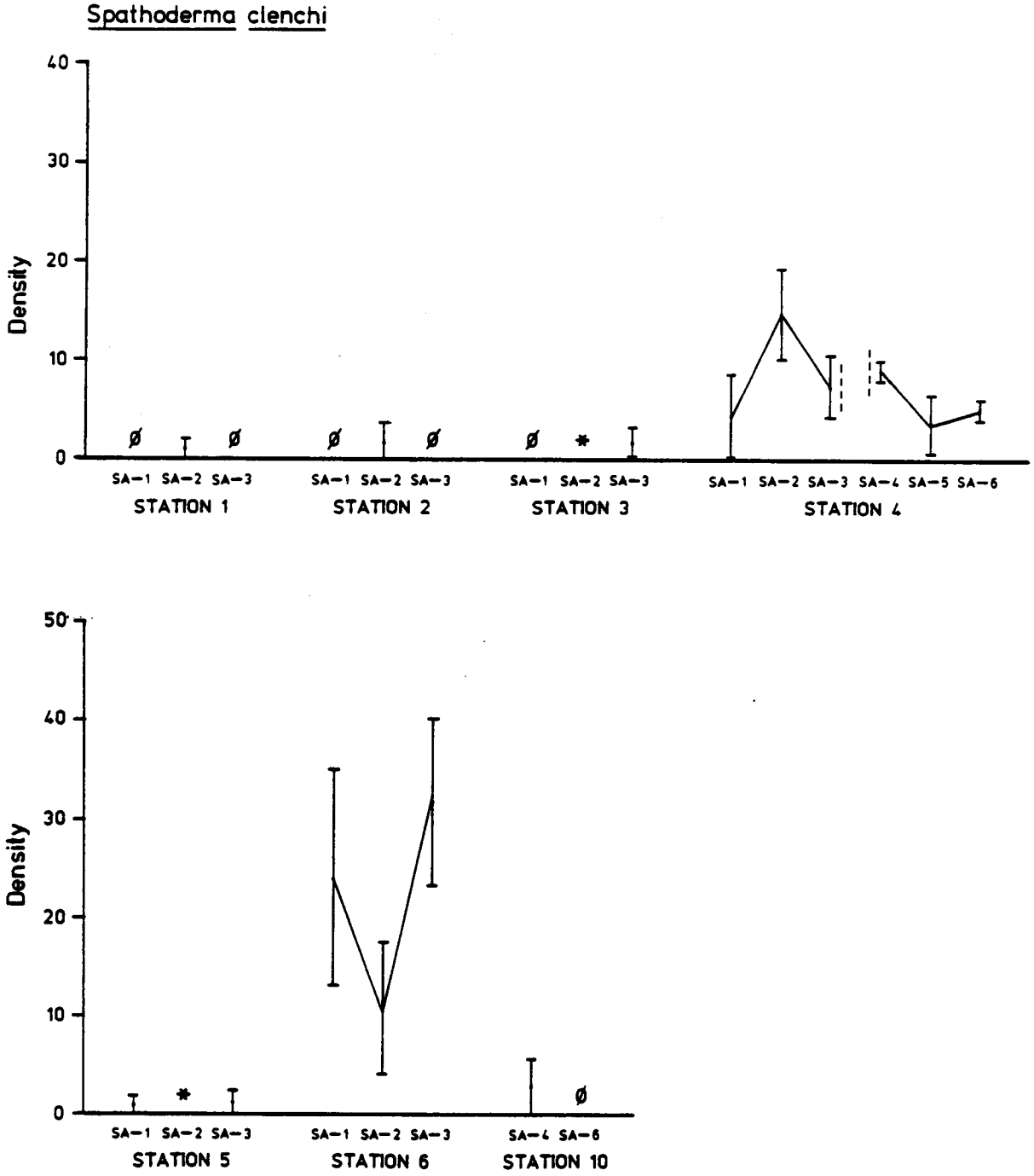


Figure 59. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Aplacophoran Spathoderma clenchi at Seven Stations in the U.S. South Atlantic Region. * Indicates Too Few Individuals to Plot. Ø Indicates No Data.

Hypothesis 1: Does the mean density of Microrbinia linea differ for the three stations along the Charleston Transect (CH, 800 m, 2000 m, 3000 m) sampled during Cruises SA-4, SA-5, and SA-6?

Hypothesis 2: Does the mean density of Microrbinia linea differ for the three stations along the Cape Fear Transect (FE, 800 m, 2000 m, 3000 m) sampled during Cruises SA-4, SA-5, and SA-6?

Hypothesis 3: Does the mean density of 13 species differ between Stations 11 and 14 along the 800 m isobath sampled during Cruises SA-4, SA-5, and SA-6?

Hypothesis 4: Does the mean density of eight species differ between Stations 4 and 6 along the 2000-m isobath sampled during Cruises SA-1, SA-2, and SA-3?

Hypothesis 5: Does the mean density of 10 species differ between Stations 4, 12, and 15 along the 2000-m isobath sampled during Cruises SA-4, SA-5, and SA-6?

Hypotheis 6: Does the mean density of six species differ between Stations 13 and 16 along the 3000-m isobaths sampled during Cruises SA-4, SA-5, and SA-6?

Hypothesis 7: Does the mean density of 20 numerically dominant species differ at Station 4 (LO, 2000 m) when sampled seasonally during Cruises SA-1, SA-2, SA-3, SA-4, SA-5, and SA-6?

To test Hypotheses 1 and 2, the abundance of Microrbinia linea was compared at stations on the Charleston Transect (CH 800 m, 2000 m, and 3000 m) and the Cape Fear

Transect (FE 800 m, 2000 m, and 3000 m). Station 15 was not sampled on Cruise SA-6. Consequently, the differences in abundance along the Charleston Transect were tested separately for each cruise.

The results are shown in Table 25 for the Charleston Transect and Table 26 for the Cape Fear Transect. On the Charleston Transect (Hypothesis 1) , the abundances of M. linea were highest at Station 14 (800 m) and decreased with increasing depth on Cruise SA-4 (May 1985). On Cruise SA-5, the pattern was similar, except that the two deeper stations (15 and 16) were not different from one another. On Cruise SA-6, Station 14 again had a higher abundance of M. linea that did Station 16. On the Cape Fear Transect (Hypothesis 2), the 800-m Station 11 had higher abundances of M. linea than did either of the deeper stations. The 3000-m Station 13 had higher abundances than did Station 12 at 2000 m.

To test Hypothesis 3, 13 species having total abundances greater than 200 at Stations 11 and 14 were tested. Six species (Bathyarca sp. 1, Kelliella sp. 1, Paratanaid sp. 1, Jasmineria filiformis, Aurospio dibranchiata, and Spionidae sp. 11) had significantly higher abundances at Station 11 than at Station 14 (Table 27). Pholoe anoculata had higher abundances at Station 14 than at Station 11. The density of Spionidae sp. 11 was higher at Station 11 than at Station 14 on all cruises (Figure 60). Significantly higher densities were found at both stations on Cruises SA-6 and SA-4 than on Cruise SA-5, but Cruises SA-5 and SA-4 did not differ in density. However, when differences between stations were tested for each cruise, there was no signficant difference found between stations for any cruise. There was a tendency for densities at Station 11 and 14 to vary differently for Tharyx sp. 1 (Figure 60), but neither cruise nor station main effects were significant (Table 27). No other species showed between-cruise differences in densities at these stations.

Eight species were used to test Hypothesis 4 (Table 28). Spathoderma clenchi, an aplacophoran, had signficantly higher densities at Station 6 than at Station 4 for Cruises SA-1 and SA-3, but densities at these stations did not differ on Cruise SA-2 (Figure 61). Densities of S. clenchi did not differ between cruises at either station. Pholoe anoculata had significantly higher densities at Station 6 than at Station 4 and this result was consistent over all cruises (Figure 61). No other species tested had any significantly different densities at Stations 4 or 6 on Cruises SA-1 through SA-3.

TABLE 25. RESULTS OF ANALYSES TO COMPARE ABUNDANCES OF MICRORBINIA LINEA AT STATIONS ALONG THE CHARLESTON TRANSECT (HYPOTHESIS 1).

Cruise	Analysis	Probability	SNK[1,2]
SA-4	1-way ANOVA 14=15=16	.0006***	14 15 16
SA-5	1-way ANOVA 14=15=16	.0011**	14 15 16
SA-6	t-test 14=16	.0029**	14 16

[1]Stations arranged highest to lowest densities.

[2]Underlined stations are not significantly different.

* = 0.05 >p> 0.01
** = 0.01 >p> 0.001
*** = p < 0.001

TABLE 26. RESULTS OF 2-WAY ANOVA TO COMPARE ABUNDANCES OF MICRORBINIA LINEA ALONG THE CAPE FEAR TRANSECT (HYPOTHESIS 2).

Source	Probability	Significance	SNK
Station	.0001	***	11-13-12
Cruise	.3114	NS	11-13-12
Station and Cruise	.9149	NS	11-13-12

NS =Not significant.
* = 0.05 >p> 0.01.
** = 0.01 >p> 0.001.
*** = p < 0.001.

TABLE 27. RESULTS OF ANOVA AND SNK TEST OF DENSITIES OF ABUNDANT SPECIES BETWEEN STATIONS 11 (FE 800 m) AND 14 (CH 800 m) (HYPOTHESIS 3).

Species	Transformation	Probability			
		Main Effects		Interaction	
		Station	Cruise	Station by Cruise	SNK
Bathyarca sp. 1	Raw	.0032*	.329	.460	11>14
Kelliella sp. 1	Raw	.0239*	.584	.178	11>14
Paratanaid sp. 1	Log	.0001***	.842	.750	11>14
Myriotrochinae sp. 1	Raw	.155	.863	.617	
Jasminera filiformis	Log	.0012**	.754	.705	11>14
Aspidosiphon zinni	Log	.0001**	.064	.669	11>14
Bathydrilus asymmetricus	Raw	.262	.703	.786	
Tubificoides sp. 3	Raw	.217	.358	.091	
Tharyx sp. 1	Raw	.660	.620	.015*	(See Fig. 9)
Cossura sp. 2	Raw	.662	.649	.412	
Microrbinia linea	Raw	.599	.082	.934	
Pholoe anoculata	Log	.0001***	.367	.574	14>11
Spionidae sp. 11	Log	.0424*	.019*	.610	(See Fig. 9)

* = 0.05 >p> 0.01
** = 0.01 >p> 0.001
*** = p< 0.001

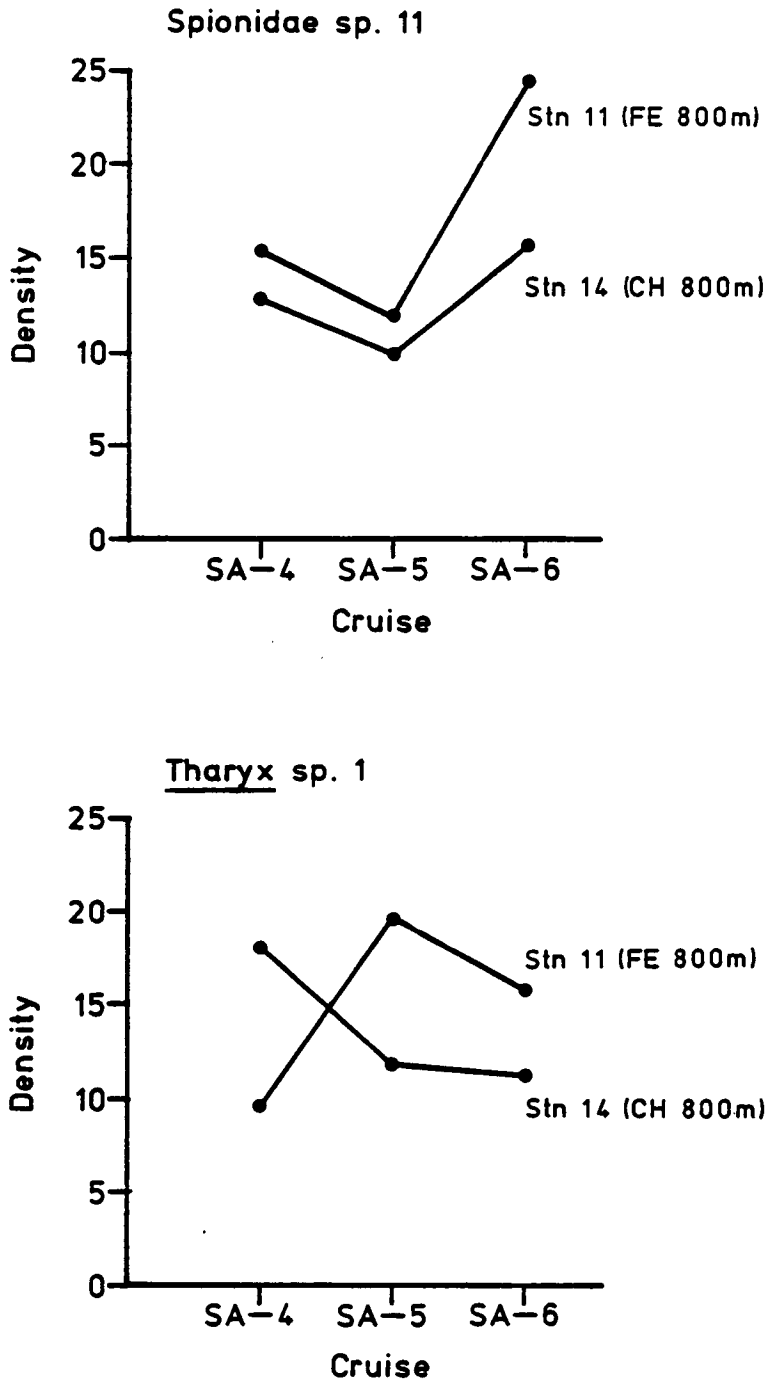


Figure 60. Comparison of Mean Densities per 0.09 m^2 of Spionidae sp. 11 and Tharyx sp. 1 at Stations 11 and 14.

TABLE 28. RESULTS OF 2-WAY ANOVA TO COMPARE ABUNDANCES OF EIGHT DOMINANT SPECIES AT STATIONS 4 (LO 2000 m) AND 6 (HC 2000 m) (HYPOTHESIS 4).

		Probability			
		Main Effects		Interaction	
Species	Transformation	Station	Cruise	Station by Cruise	SNK
Spathoderma clenchi	Log	.003**	.348	.0133*	6>4
Prochaetoderma yongei	Raw	.066	.385	.258	
Glycera capitata	Raw	.101	.296	.811	
Tubificoides aculeatus	Log	.0001	.654	.880	
Aurospio dibranchiata	Raw	.600	.627	.536	
Sabidius cornatus	Raw	.088	.357	.199	
Pholoe anoculata	Raw	.045*	.742	.663	6>4
Nemertea sp. 2	Raw	.721	.628	.039*	(See Fig. 70)

* = 0.05 >p> 0.01
** = 0.01 >p> 0.001
*** = p< 0.001

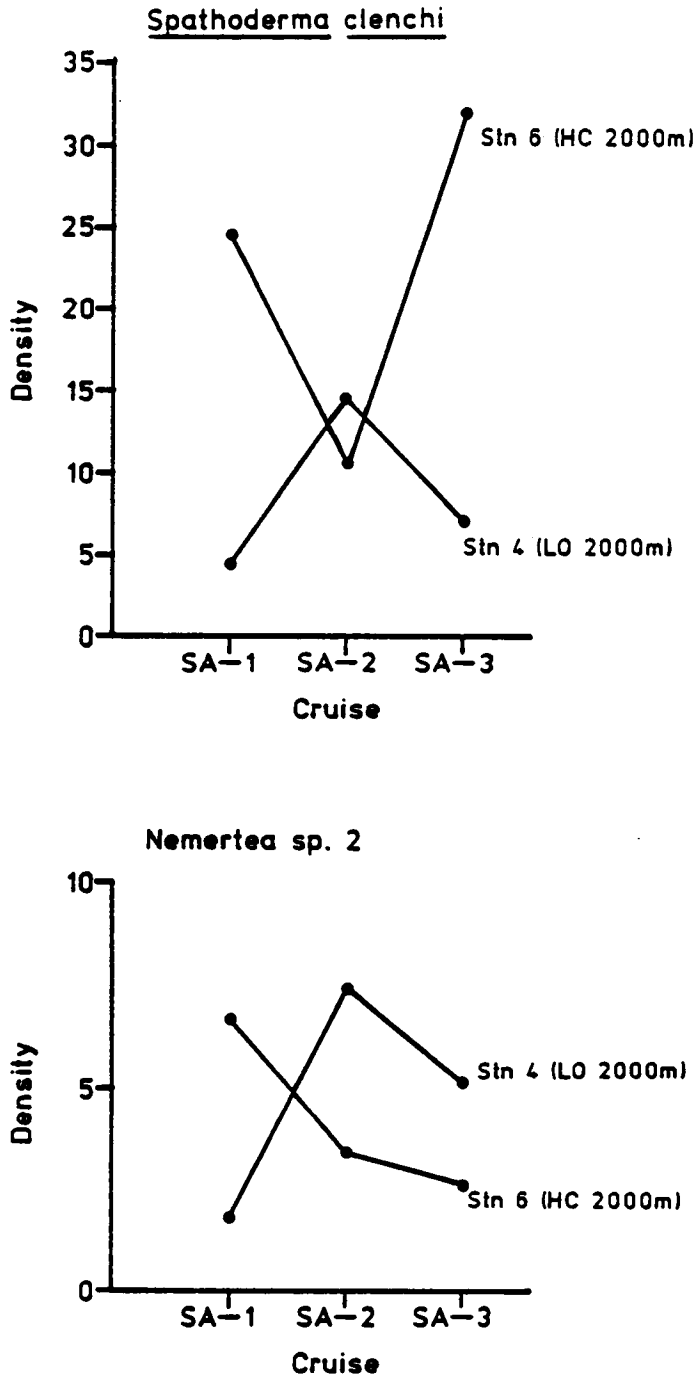


Figure 61. Comparison of Mean Densities per 0.09 m^2 of Spathoderma clenchi and Nemertea sp. 2 from Stations 4 and 6.

Differences between stations at 2000 m sampled on three cruises (Hypothesis 5) were tested for each cruise separately because not all stations were sampled on each cruise. Ten species with densities greater than 50 were present at Stations 4, 12, and 15 (2000 m) on Cruise SA-4. These species were used to test Hypothesis 5 for Cruise SA-4.

On Cruise SA-4, Aspidosiphon zinni, Aurospio dibranchiata and Prionspio sp. 2 had significantly higher densities at Station 4 than at Station 15 (Table 29). Microrbinia linea had equal densities at Stations 4 and 15 and significantly higher densities at those stations than at Station 12.

Six additional species with total abundances greater than 50 were present at Stations 4 and 12, but not at Station 15, on Cruise SA-4. T-tests were used to determine if densities of these six species differed at Stations 4 and 12. These results are shown in Table 30 and indicate that Anarthruid sp. 1 ($p>.001$), Notomastus latericeus ($p>.003$), and Siboglinum pholidotum ($p>.001$) were significantly more abundant at Station 4 than at Station 12 on Cruise SA-4.

One species, Gnathia sp. 2, was present at Stations 4 and 15 on Cruise SA-4, but not at Station 12. There was no difference in its abundance at Stations 4 and 15 on this cruise ($p>.001$).

Eight species had abundances greater than 50 at 2000-m Stations 4, 12, and 15 on Cruises SA-4 to SA-6 and were present at Stations 4 and 15 on Cruise SA-5. These species were used to test Hypothesis 5 for Cruise SA-5. Four species had higher abundances at Station 4 than at Station 15 on Cruise SA-5: Aspidosiphon zinni ($p>.0067$); Aurospio dibranchiata ($p>.003$); Microrbinia linea ($p>.005$); and Paradoneis abranchiata ($p>.001$). One species, Grania atlantica ($p>.002$), had significantly higher densities at Station 15 than at Station 4.

Fifteen species were tested to determine if their abundances differed between the 2000-m Stations 4 and 12 on Cruise SA-6. Station 15 was not sampled on this cruise. T-tests were used to compare densities. Five species had significantly higher densities at Station 4 than at Station 12 (Table 30). These species were Notomastus latericeus, Aspidosiphon zinni, Microrbinia linea, Sabidius cornatus, and Prionospio sp. 11. A. zinni also had higher densities at Station 4 on Cruise SA-4. One species from Cruise SA-6, Paradoneis abranchiata, had significantly higher densities at Station 12. However, this species did not have higher densities at Stations 12 on Cruise SA-4.

TABLE 29. RESULTS OF 1-WAY ANOVA TO COMPARE ABUNDANCES OF NINE DOMINANT SPECIES AT STATIONS 4 (LO 2000 M), 12 (FE 2000 M), AND 15 (CH 2000 M) (HYPOTHESIS 5).

Species	Transformation	Probability	SNK[1]
Glycera capitata	Raw	.839	
Aspidosiphon zinni	Log	.004**	4 12 15
Grania atlantica	Raw	.803	
Aurospio dibranchiata	Raw	.0001***	4 12 15
Microrbina linea	Log	.0012**	4 15 12
Paradoneis abranchiata	Log	.087	
Prionospio sp. 2	Raw	.0001***	4 12 15
Prionospio sp. 11	Raw	.070	
Nemertea sp. 2	Raw	.641	

[1]Underlined stations are not significantly different.
* = 0.05 >p> 0.01
** = 0.01 >p> 0.001
*** = p< 0.001

TABLE 30. RESULTS OF t-TEST TO COMPARE ABUNDANCES OF FIFTEEN DOMINANT SPECIES AT STATIONS 4 (LO 2000 m) AND 12 (FE 2000 m) ON CRUISE SA-6 (HYPOTHESIS 5).

Species	Transformation	Probability	SNK
Gnathia sp. 2	Log	.845	
Glycera capitata	Log	.305	
Notomastus latericeus	Raw	.001**	4>12
Siboglinum pholidotum	Raw	.054	
Aspidosiphon zinni	Log	.025*	4>12
Grania atlantica	Log	.672	
Aurospio dibranchiata	Log	.053	
Aglaophamus sp. 1	Raw	.051	
Microrbinia linea	Raw	.0096**	4>12
Paradoneis abranchiata	Raw	.003**	12>4
Sabidius cornatus	Log	.032*	4>12
Pholoe anoculata	Raw	.116	
Prionospio sp. 2	Raw	.713	
Prionospio sp. 11	Log	.035*	4>12
Nemertea sp. 2	Raw	.157	

* = 0.05 >p> 0.01
** = 0.01 >p> 0.001
*** = p< 0.001

Hypothesis 6 was tested with six species with densities greater than 30 at the 3000-m Stations 13 and 16 from Cruises SA-4 to SA-6.

Three species, Pholoe anoculata, Spiophanes sp. 1, and Exogone sp. 1 had higher abundances at Station 13 than at Station 16. No other species showed any difference in density between cruises or between stations (Table 31).

Hypothesis 7 was designed to test if species densities differed at Station 4 over all six sampling cruises. This was the only Phase 1 station to be sampled again in Phase 2 and the only site in the U.S. South Atlantic region where a longer seasonal data base was available. Twenty numerically dominant species at Station 4 were used to test whether abundances changed over time at this station.

The results indicate that only two species, Myriotrochinae sp. 1 ($p>.0097$) and Prionospio sp. 11 ($p>.042$) were significantly more abundant on Cruise SA-2 than on the other cruises. The ANOVA indicated that densities of another species, Nemertea sp. 2, was signficantly different over time ($p>.022$). The SNK test, however, did not indicate that any times differed. This result may be due to the high variance in Cruise SA-3 relative to the other cruises.

Zoogeography

Biologists have suggested that a distinct zoogeographic barrier exists off Cape Hatteras. Although Cutler (1975) found evidence that sipunculids and pogonophorans were separated latitudinally on the continental slope off Cape Hatteras and Scheltema (1985) presented similar evidence for aplacophorans, there is little actual data to prove or disprove this hypothesis.

In an effort to determine if zoogeographic boundaries are reflected in the slope and rise faunas off the Carolinas, the U.S. South Atlantic data were examined in two ways:

1) Calculation of similarities of fauna by depth and latitude using cluster analysis (NESS and Bray-Curtis) with all replicates taken at any one station combined and compared with other stations. These analyses are presented as trellis diagrams instead of cluster

TABLE 31. RESULTS OF 2-WAY ANOVA TO COMPARE DENSITIES OF SIX SPECIES AT STATIONS 13 (FE 3000 m) AND 16 (CH 3000 m) OVER CRUISES SA 4-6 (HYPOTHESIS 6).

Species	Transformation	Probability			SNK
		Main Effects		Interaction	
		Station	Cruise	Station by Cruise	
Siboglinum sp. 2	Raw	.603	.614	.178	
Microrbinia linea	Log	.763	.1512	.170	
Pholoe anoculata	Log	.0286*	.323	.423	13>16
Prionospio sp. 2	Log	.189	.250	.049	
Spiophanes sp. 1	Log	.004***	.682	.344	13>16
Exogone sp. 1	Log	.003**	.629	.707	13>16

* = 0.05 >p> 0.01
** = 0.01 >p> 0.001
*** = p< 0.001

dendrograms in order to present the actual similarity values as well as graphical relationships. The analyses were run on the entire fauna with NESS and Bray-Curtis and on the Polychaeta, Bivalvia, and Peracarida separately using Bray-Curtis. The intent of this set of analyses was to determine if the entire fauna or major faunal components showed any distinct latitudinal or depth patterns.

2) Examination of species lists generated for the U.S. Mid-, North, and South ACSAR programs for obvious differences in occurrences of species and inspection of the known ranges of selected taxa in order to identify species having known range limits which might provide evidence to support the zoogeographic barrier hypothesis.

These observations also draw upon the taxonomic, diversity, community similarity, dominance, and density data already presented elsewhere in this chapter.

Similarities of the Fauna by Depth and Latitude

The Bray-Curtis and NESS similarity analyses of the entire fauna with all replicates from all cruises combined are generally in agreement with the cluster analyses presented earlier in this chapter. The Cape Hatteras stations are clearly distinct; there is an upper-slope assemblage, a 1500- to 2000-m lower-slope assemblage, and a 3000-m upper-rise assemblage. Station 14A was not included in the trellis diagrams, but exhibited little similarity to any other stations.

The Cape Hatteras Transect. The stations on the Cape Hatteras Transect are different from all other transects. Station 9 at 600 m differs from all other stations, but is more similar to Station 10 at 2000 m on the same transect than to any other station. Similarity levels between Stations 9 and 10 are 21.5 (Bray-Curtis) (Figure 62) and 22.8 (NESS) (Figure 63). In this respect, Station 9 more closely resembles a 2000-m station than the other 600- to 1000-m stations. This same relationship is true when polychaetes (Figure 64) and bivalves (Figure 65) are analyzed separately, but not with the peracarids (Figure 66). Less than 10 percent of the peracarids found at Station 9 are found at any

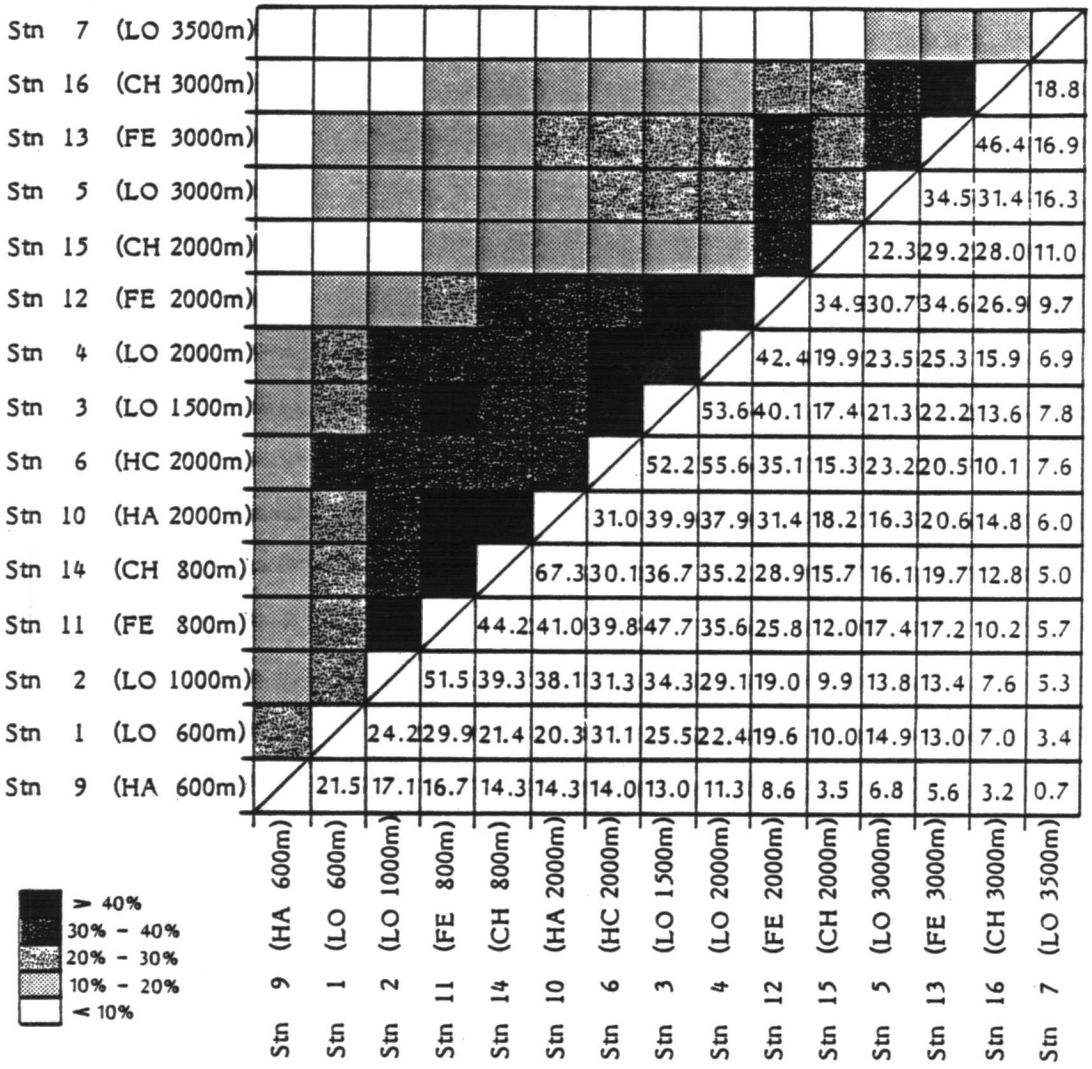


Figure 62. Trellis Diagram Based on Bray-Curtis Similarity, Entire Community Analysis. Station 14A Excluded.

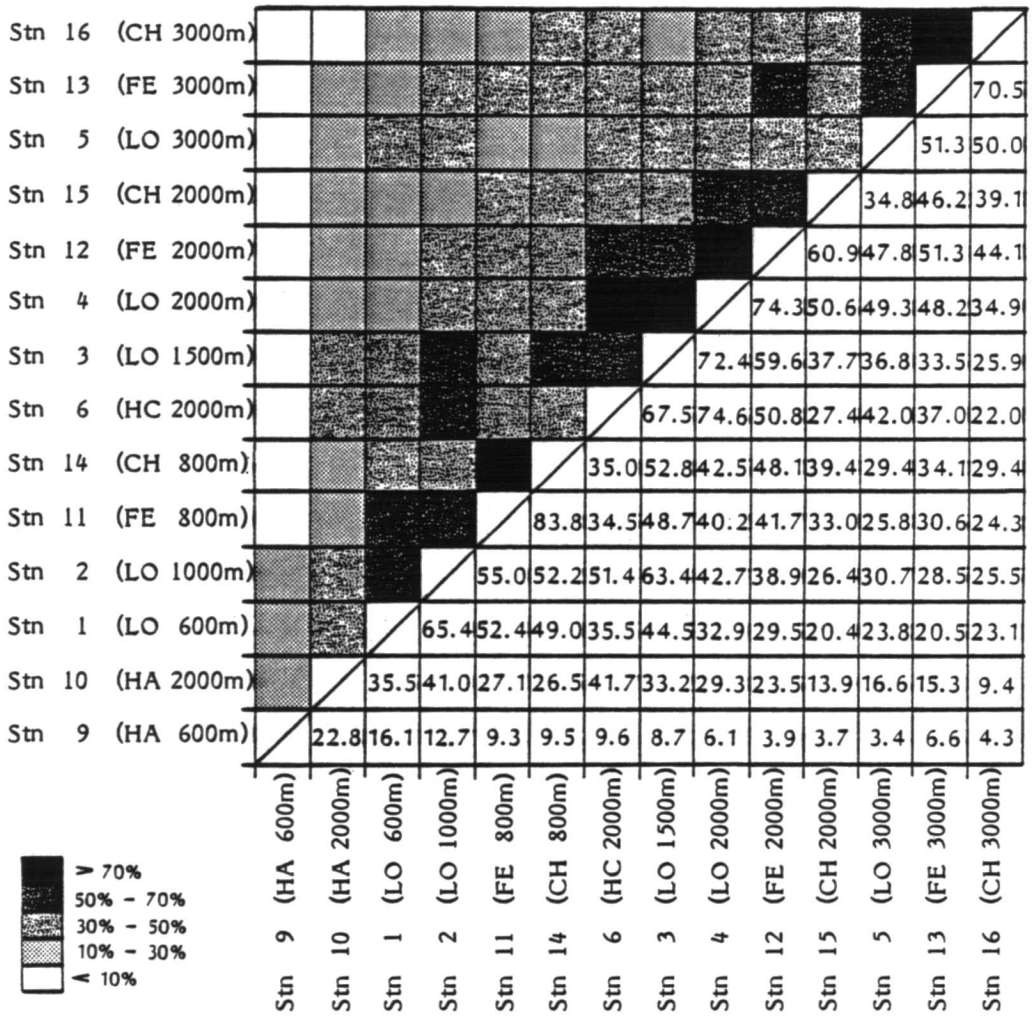


Figure 63. Trellis Diagram Based on NESS Similarity, (m=200), Entire Community Analysis. Stations 7 and 14A Excluded.

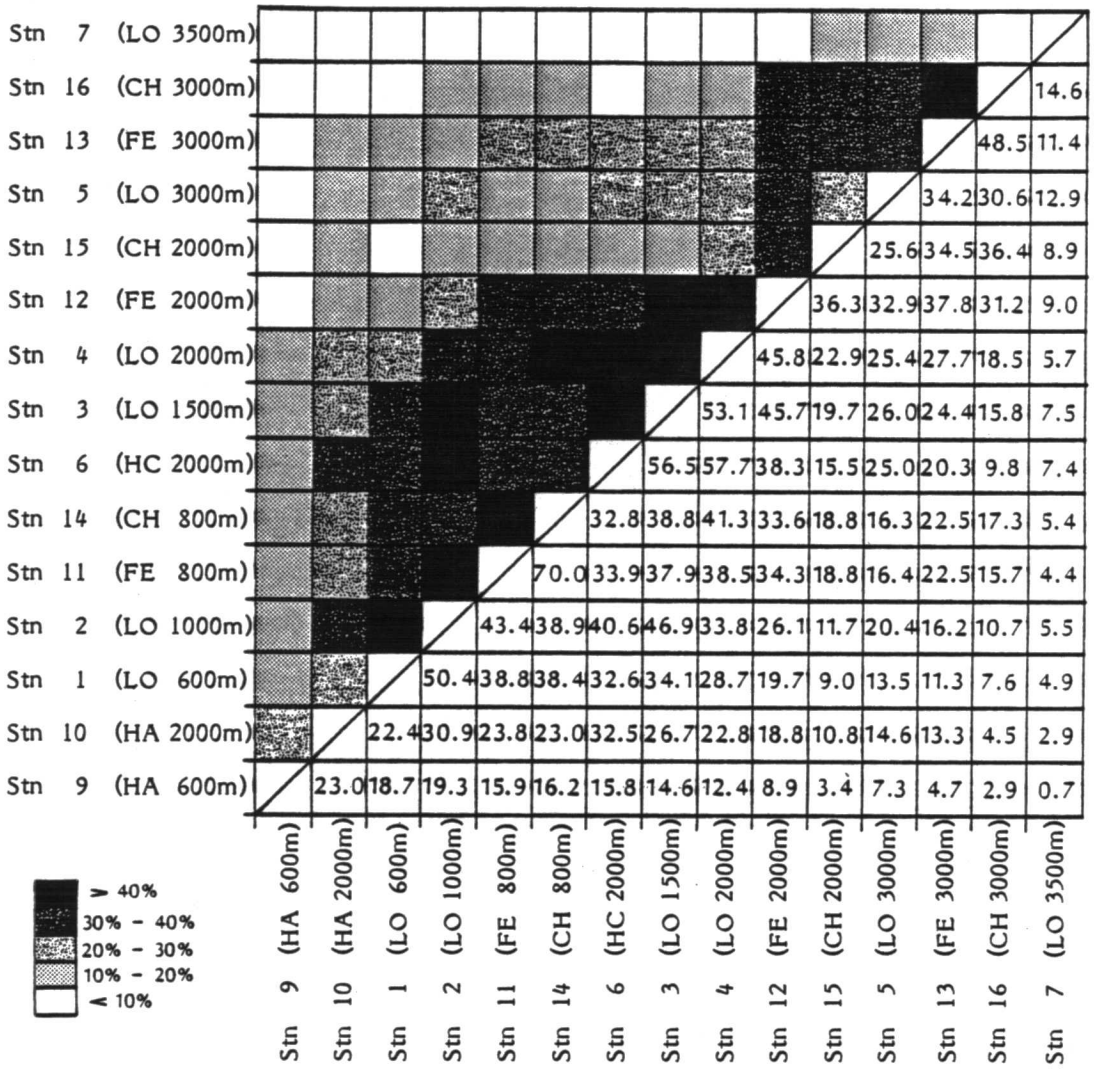


Figure 64. **Trellis Diagram Based on Bray-Curtis Similarity, Polychaeta. Station 14A Excluded.**

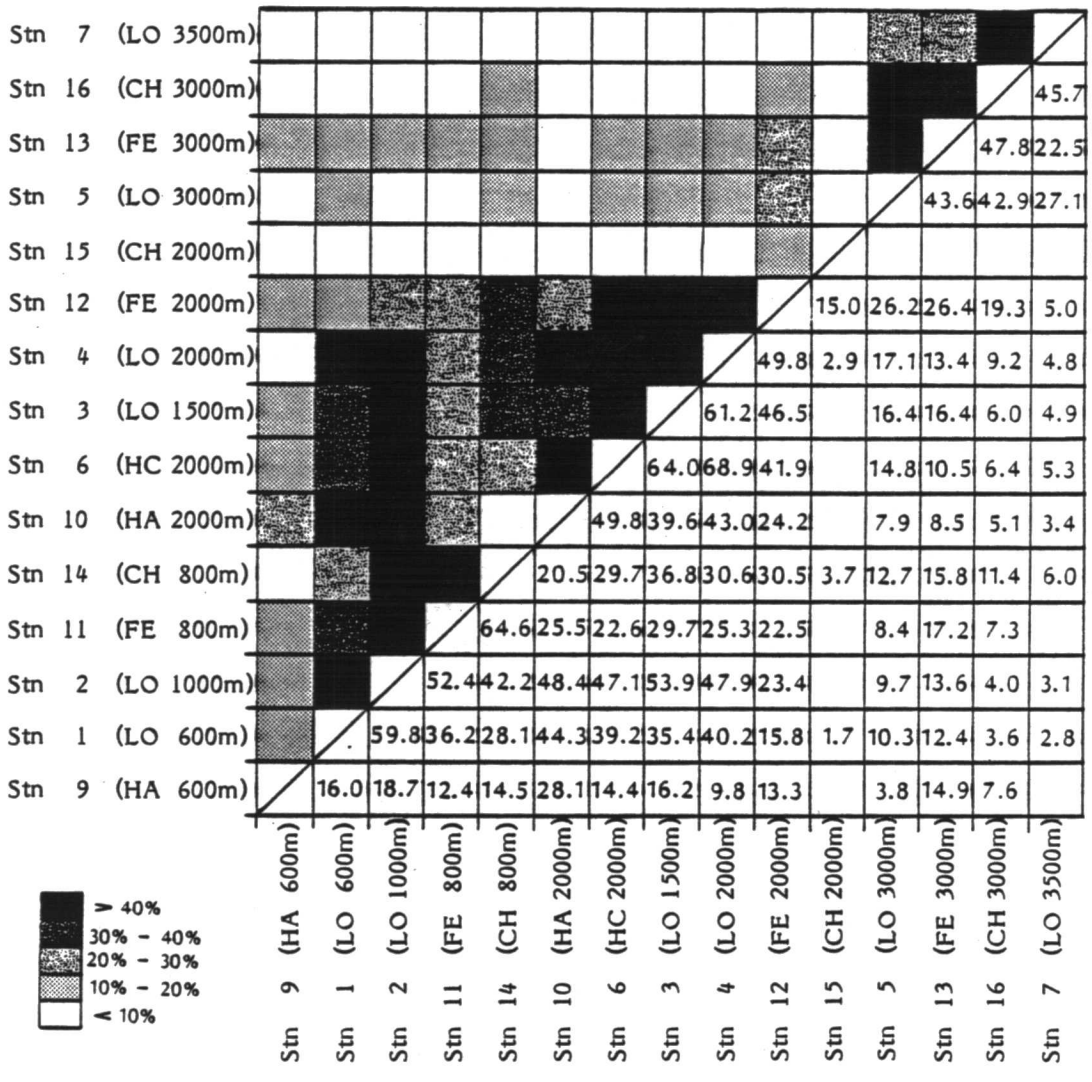


Figure 65. Trellis Diagram Based on Bray-Curtis Similarity, Bivalvia. Station 14A Excluded.

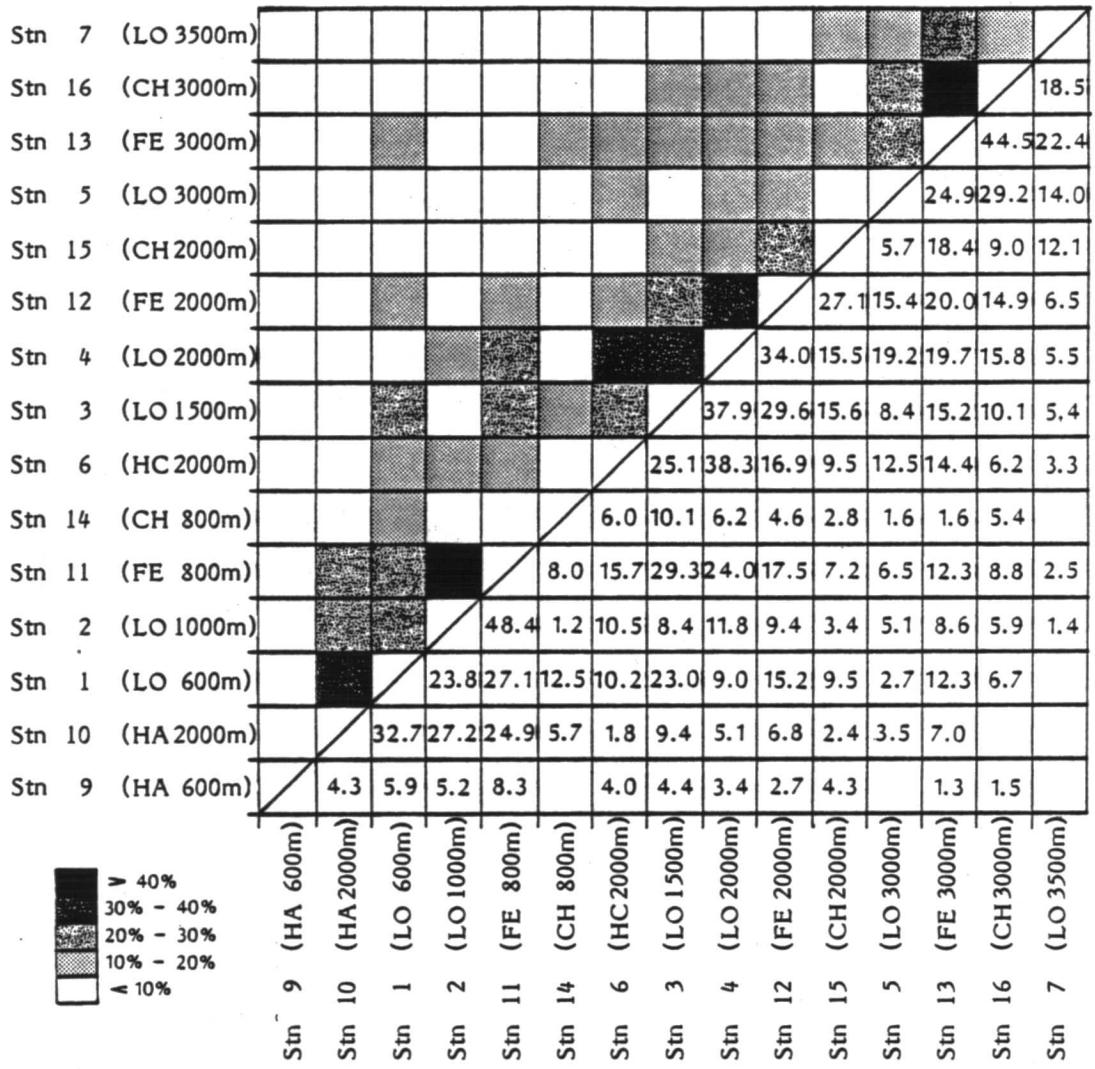


Figure 66. Trellis Diagram Based on Bray-Curtis Similarity, Peracarida. Station 14A Excluded.

other station in the U.S. South Atlantic region. The highest percentages are from the upper slope stations (1, 2, 11 and 14 at 600-800 m). Station 10 (CH, 2000 m) is closest in overall similarity to Stations 2 (LO 1000 m) and 6 (HC 2000 m) with 21.9 and 31.1 Bray-Curtis similarity levels, respectively (Figure 62) and 41.0 and 41.7 NESS similarity levels, respectively (Figure 63). This relationship also holds for polychaetes and bivalves analyzed separately (Figures 64 and 65). For the peracarids, however, the relationships differ slightly, with Stations 2 and 3 (LO, 1000-1500 m) being the most similar to Station 10 (Figure 66).

The Upper Slope Assemblage (600-1000 m). Upper slope Stations 1 and 2 off Cape Lookout (600-1000 m) and Stations 11 and 14 (800 m) off Cape Fear and Charleston are grouped here. With one exception, the Bray-Curtis and NESS similarities for the entire fauna and the Bray-Curtis similarities for polychaetes, bivalves, and peracarids are more similar among these stations than among any other stations in the study area (Figures 62 through 66). The one exception is Station 2, which is more similar to Station 3 (LO, 1500 m) than to either Stations 11 or 14. The highest similarity among all of these stations is between Stations 11 and 14, with a 67.3 Bray-Curtis similarity value and a 83.8 NESS similarity value. This relationship also holds for polychaetes, bivalves, and peracarids considered separately.

The Lower Slope Assemblage (1500-2000 m). The 2000-m assemblage includes Stations 3 and 4 (LO 1500-2000 m), 6 (HC 2000 m), 12 (FE 2000 m), and 15 (2000 m), but not Station 10 off Cape Hatteras, which has been shown to be distinct (see above). The Hatteras Canyon, Cape Lookout, and Cape Fear stations are most similar in the Bray-Curtis and NESS analyses based on the entire fauna (Figures 62-63). Station 15 is more similar to Station 12 off Cape Fear than to any of the more northern stations, suggesting subtle faunal differences between Cape Fear and Charleston at this depth. The highest NESS similarities among these stations are between Stations 4 and 12 (74.3), Stations 4 and 3 (72.4), and Stations 4 and 6 (74.6). Station 3 on the Cape Lookout Transect serves as a bridge between the upper slope stations and the lower slope, since it has a 63.4 NESS similarity with Station 2 at 1000 m on the same transect. These same relationships hold up well for polychaetes only, in that Stations 3 and 6, 4 and 6, 3 and 4, 3 and 12, and 4 and 12 exhibit the highest levels of similarity (Figure 64). As in the entire faunal analysis, the polychaete fauna at Station 15 is more similar to that found at Station 12 than to that

found at the Cape Lookout and Hatteras Canyon stations. The bivalves also generally follow this pattern (Figure 65). One interesting variant is that the bivalve fauna at Cape Hatteras Station 10 exhibits a relatively high similarity with that of Station 6 on the Hatteras Canyon and Station 4 off Cape Lookout. This relationship is not observed when the entire fauna or other higher taxonomic categories are analyzed. Station 15 continues to be the most different of these 2000-m stations, with a low level of Bray-Curtis similarity to Station 12 in terms of shared bivalve species. Station 15 did not share any bivalve species with Stations 3, 6, or 10. Only 2.9 percent were shared with Station 4. Thus, for bivalves considered separately there appears to be some evidence of faunal discontinuity south of Cape Fear. The peracarids generally follow the pattern established by the analysis of the entire fauna in that Stations 4 and 6, 4 and 3, and 4 and 12 are most similar to one another and Station 15 is more similar to Station 12 than to stations further north (Figure 66).

The Upper Rise (3000 m) Assemblage. Four stations, Stations 5 (LO 3000 m), 7 (LO 3500 m), 13 (FE 3000 m), and 16 (CH 3000 m) are included in this assemblage. Station 7 was only sparsely sampled and was not included in the NESS analysis. The three 3000-m stations exhibit consistent similarities with both NESS and Bray-Curtis. Stations 13 and 16 have the highest similarity when the entire fauna is analyzed (46.4 Bray-Curtis similarity; 70.5 NESS similarity) and both share nearly equal similarity to Station 5 (Figures 62-63). This same relationship holds up well with polychaetes (Figure 64) and peracarids (Figure 66), but not with bivalves, where all three stations are very similar (Figure 65). All of the 3000-m stations have closer affinities with the 2000-m station assemblage than with any other station group in the U.S. South Atlantic region. Of these station relationships, there appears to be a closer affinity between the three 3000-m stations and Station 12 than to Stations 4, 6, or 15. This relationship is strongest with the NESS and Bray-Curtis entire fauna analysis, but breaks down when the polychaetes, bivalves, and peracarids are analyzed separately. Polychaetes at the 3000-m stations show mixed results in terms of similarity with Stations 12 and 15. Bivalves, on the other hand, show no similarity between the 3000-m stations and Station 15, but do show similarity with Station 12. The highest peracarid similarities are between Stations 4 and 12.

General Comments. Based on the Bray-Curtis analysis, bivalves appear to show more of a faunal break between the Cape Fear Transect and the Charleston Transect than do polychaetes and peracarids. These same patterns were evident in the results on cluster analysis presented earlier where cruises were analyzed separately. There is essentially no similarity between bivalve species at Station 15 on the Charleston Transect and the other 2000-m stations. There are also only low similarities between the 3000-m stations and the 2000-m stations.

Comparison of Regional Species Lists

Species lists from the recently completed U.S. North Atlantic Interim Report (Maciolek et al., 1986b) were compared with the list compiled for the present report (Appendix C). Five groups were selected: Pogonophora, Sipuncula, Aplacophora (Mollusca), Gastropoda (Mollusca), Cumacea (Crustacea), and Polychaeta (Annelida).

Fifteen species of Pogonophora in six genera are present in the southern region, and 13 species in five genera are present in the north. Eleven of the northern species also occur in the southern region. This result indicates that most of the species occurring in the southern region have wide geographic ranges. Cutler (1975) determined that a geographic faunal break occurred off Cape Hatteras and that several species of Pogonophora and Sipuncula reached their southernmost distributions off Cape Hatteras.

Nineteen species of Sipuncula are present in the south and 15 are present in the north. Of these, 11 of the northern species also occur in the south, indicating that many species have wide geographic ranges. Five species from the South Atlantic list that were not present on the North Atlantic list were present at stations in the U.S. Mid-Atlantic region (Maciolek et al., 1987), leaving only four species limited to the southern region.

Thirty-one species of Aplacophora occur in the south and 21 occur in the north. Twenty of the northern species occur in the south. Scheltema (1985) indicated that Cape Hatteras appeared to be the southern limit of the distribution of two species: Spathoderma clenchi and Prochaetoderma yongei. Our results confirm this observation, in that these species become relatively unimportant south of Cape Lookout, and a distinct break is evident.

Forty-four species of gastropods have been identified in the U.S. North ACSAR (Maciolek et al., 1986b). Fifteen of these species also occur in the south. Forty-five species are recorded on the South Atlantic species list. Most of the non-shared southern species have wider ranges in the North Atlantic, and there is no firm evidence of zoogeographic barrier with the gastropods.

For the Cumacea, 27 species are reported for the U.S. North ACSAR (Maciolek et al., 1986b) and 28 are reported for the south. Only seven species are shared between these two lists. The Cumacea are not generally an abundant taxon, but they usually occur at all sites in low numbers and exhibit high diversity. Of the 28 species recorded in the U.S. South Atlantic, eight were known previously and the remaining 20 are thought at this time to be new to science. Twenty of the species were found at only one station and 16 are known from only a single specimen. This is not unlike the situation for deep-sea cumaceans outlined by Jones (1969).

Half of the cumacean species occurred at stations of less than 1200-m depth (Table 32). Most of these are members of the Family Nannastacidae (only one species from this family was found at depths exceeding 1500 m). The deepwater species are primarily members of the Families Lampropidae and Diastylidae.

The cumacean species at the Cape Hatteras Transect Stations 9 and 10 are species that have been previously recorded from stations north of Cape Hatteras. Those at the central group of stations, Stations 1 to 7 (Hatteras Canyon to Cape Lookout), are almost entirely different from those at Stations 11 - 16 (Cape Fear and Charleston Transects). The southern group of stations also has some species with anomalous distributions. Cyclaspis spectabilis had been recorded previously only from the continental slope off the west coast of South Africa (Day, 1978a). The southern group of species are also primarily members of the Nannastacidae, with the species from the deeper stations belonging to the more typical deep- or cold-water families seen at the northern station group. This suggests that there is a significant biogeographic shift in the composition of the cumacean fauna on the continental slope between 33° and 34° N. Significantly, this is also the latitude at which the Blake Plateau Outer Ridge begins to diverge from the continental slope. North of this line, the cumacean fauna is more typical of colder bottom waters, suggesting that some mixing of the WBUC and Florida Current waters is occurring. This observation also supports the prevous contention that the Nannastacidae are primarily a

TABLE 32. DEPTH DISTRIBUTIONS IN NUMBERS OF INDIVIDUALS OF CUMACEANS COLLECTED DURING THE U.S. SOUTH ATLANTIC SLOPE AND RISE STUDY.

Species	Station and Depth (m)															
	1 600	9 600	14A 600	11 800	14 800	2 1000	3 1500	4 2000	6 2000	10 2000	12 2000	15 2000	5 3000	13 3000	16 3000	7 3500
Campylaspis sp. 4	3		1													
Leptostylis sp. 1				11	13	2							1	2		
Leucon sp. 11				1						1						
Cumella sp. 4				1	1											
Cumella sp. 5				1												
Cumella antipai				1	7											
Cumella sp. 6				4												
Cumella sp. 3				4	1						1					
Leucon serratus					2									4		
Cumella sp. 7					1											
Campylaspis sp. 3					1											
Cyclaspis spectabilis					1											
Cumellopsis sp. 1					19											
Campylaspis vitrea						1										
Paralamprops sp. 2							1									
Eudorella cf. pusilla							1									
Leucon sp. 1							1									
Hemilamprops cristatus								1		1				2	1	
Diastylidae sp. 1								1								
Leuconidae sp. 2 juv.									1							
Leuconidae sp. 1									2							
Vemakylindrus hastata										1						
Leucon sp. 10										7						
Makrokylindrus sp. 4											1					
Bathylamprops motasi												1				
Hemilamprops sp. 1													1			
Paralamprops sp. 1													1			
Atlantocuma benguelae														2		

warm-water family whereas the Lampropidae and Diastylidae are cold-water forms (Day, 1978b).

The polychaete fauna includes species that are known from the southwestern Atlantic, the Caribbean, northeastern Atlantic, West Africa, Antarctica, and the Pacific Ocean. The U.S. South Atlantic stations represent the northern limit for most of the species previously reported from more southern localities. Out of 15 species previously reported from South America, eight are present only off North Carolina, three range from North Carolina to New Jersey and Delaware, and four occur along the entire U.S. ACSAR. Ten species recorded in the present U.S. South Atlantic study area were previously known only from the Antarctic or the Pacific. Four of these species are limited to off North Carolina, two species also occur off New Jersey and Delaware, and four occur along the entire ACSAR (Table 33).

Thirty of the 181 named polychaete species that were identified in both phases of the U.S. South ACSAR program were previously reported from more northern localities, including Europe and West Africa. Sixteen of these species range northward along the entire ACSAR to the Canadian border, five occur in both the South and Mid-Atlantic regions, and nine are limited to North Carolina. Distributional patterns for these more northern species are not as clear as for those of the more southern elements.

The overlapping of southern and northern polychaete faunas is perhaps one of the reasons for the very high diversity of benthic polychaetes in the U.S. South Atlantic region as compared to the U.S. Mid- and North Atlantic regions. A large number of undescribed species are found in the South Atlantic region that are not present in the Mid- or North Atlantic. Some families having high numbers of new species include Spionidae (36), Ampharetidae (16), Phyllodocidae (13), Paraonidae (11), and Syllidae (10) (Table 34). The presence of numerous new species of phyllodocids and their dominance in the U.S. South Atlantic region is in contrast to the Mid- and North Atlantic regions where the family is relatively unimportant in terms of total numbers of species. The overwhelming dominance of spionids in the south is impressive as the total of 65 species is twice the number reported from the Mid- and North Atlantic regions (Maciolek et al., 1986b; 1987).

TABLE 33. PREVIOUSLY KNOWN DISTRIBUTION OF POLYCHAETE SPECIES AND THEIR DISTRIBUTIONS ON THE U.S. ATLANTIC SLOPE AND RISE.

A. Species Previously Reported from South America

1. Species found only on the U.S. South Atlantic Slope and Rise

Aricidea cerruti
Cirrophorus branchiatus
Notomastus americanus
Sarsonuphis fragosa
Sarsonuphis paucibranchis
Scolecolepides carunculatus
Sclerobregma stenocerum
Subadyte pellucida

2. Species found only on the U.S. South and Mid-Atlantic Slope and Rise

Fauveliopsis glabra
Mystides dayi
Paradiopatra glutinatrix

3. Species found on the U.S. South, Mid-, and North Atlantic Slope and Rise

Cirrophorus furcatus
Ephesiopsis guayanae
Flabelligella macrochaeta

B. Species Previously Reported from Northern Regions

1. Species found on the U.S. South, Mid- and North Atlantic Slope and Rise

Aberranta enigmatica
Amphicteis vestis
Asychis biceps
Dysponetus gracilis
Goniada norvegica
Hyalinoecia artifex
Neoleanira tetragona
Praxillella gracilis
Praxillura longissima
Rhodine gracilior
Schistomeringos caeca
Trochochaeta watsoni

TABLE 33. (Continued).

2. Species found only on the U.S. South and Mid-Atlantic Slope and Rise

Nephtys paradoxa
Notoproctus oculatus
Praxillella praetermissa
Trichobranchus roseus

3. Species found only on the U.S. South Atlantic Slope and Rise

Ammotrypanella arctica
Amphitrite cirrata
Ceratocephale loveni
Goniadella gracilis
Melinna elisabethae
Microphthalmus listensis
Nephtys hystricis
Novaquesta trifurcata
Oligobregma aciculatum

C. Species previously reported from Pacific/Antarctic Regions

1. Species found only on the U.S. South Atlantic Slope and Rise

Aricidea facilis
Goniada annulata
Jasmineira pacifica
Tharyx monilaris

2. Species found only on the U.S. South and Mid-Atlantic Slope and Rise

Notomastus tenuis
Onuphis geophiliformis

3. Species found on the U.S. South, Mid-, and North Atlantic Slope and Rise

Euchone hancocki
Euchone scotiarum
Exallopus cropion
Levinsenia flava

TABLE 33. (Continued).

D. Species previously reported from the Eastern Atlantic, including Europe and West Africa.

1. Species found only on the U.S. South Atlantic Slope and Rise

Lumbrinerides carpinei

2. Species found on the U.S. South, Mid-, and North Atlantic Slope and Rise

Eclysippe vanelli
Fauveliopsis olgae
Mugga wahrbergi
Onuphis rullieriana

TABLE 34. NUMBER OF U.S. SOUTH ATLANTIC POLYCHAETE SPECIES THAT HAVE NOT BEEN RECORDED IN THE U.S. NORTH AND MID-ATLANTIC STUDY AREAS.

Polychaete Family	Species
Spionidae	36
Ampharetidae	16
Phyllodocidae	13
Paraonidae	11
Syllidae	10
Cirratulidae	9
Hesionidae	9
Orbiniidae	8
Capitellidae	7
Flabelligeridae	7
Onuphidae	7
Opheliidae	7
Maldanidae	5
Polynoidae	5
Sabellidae	5
Terebellidae	5
Chrysopetalidae	4
Scalibregmatidae	4
Dorvilleidae	3
Goniadidae	3
Nephtyidae	3
Pilargidae	3
Trichobranchidae	3
Unassigned	3
Acrocirridae	2
Pholoididae	2
Aberrantidae	1
Amphinomidae	1
Arabellidae	1
Bogueidae	1
Cossuridae	1
Euphrosynidae	1
Glyceridae	1
Lumbrineridae	1
Nereididae	1
Oweniidae	1
Poecilochaetidae	1
Questidae	1
Sabellariidae	1
Sphaerodoridae	1
Sternaspidae	1

General Comments

These results and others presented in both this chapter and in Chapter 5 for the epifauna suggest the presence of a partial zoogeographic barrier in the region off North Carolina. Results for individual species such as the aplacophorans Prochaetoderma yongei and Spathoderma clenchi and the spionid polychaete Spionidae sp. 11 clearly indicate a change in the distributions of these species between Cape Lookout and Cape Fear. There are three distinct cumacean faunas evident: Cape Hatteras; Cape Lookout; and Cape Fear and Charleston, with essentially no overlap. The presence of numerous species occurring in the U.S. South Atlantic region, but not in the Mid- and North Atlantic regions also lends support to the presence of a partial faunal break in the U.S. South Atlantic region. Some species, such as the polychaete Microrbinia linea, which is the dominant species at five of six stations on the Cape Fear and Charleston Transects and at the 2000-m station off Cape Lookout, are very rare and never appear among the top dominants in the U.S. Mid- and North Atlantic study areas.

The highly unusual faunal assemblages found on the Cape Hatteras Transect include, especially at the 600-m depth, species that are more typical of shallower continental shelf habitats. The 2000-m station does not resemble the more northern Mid-Atlantic 2000-m stations in terms of faunal dominants, nor does it resemble the Cape Lookout or more southern stations. Thus, it is probable that the unusual oceanographic conditions, topography, and sedimentary environment found at the Cape Hatteras Transect may serve as a kind of physical barrier to the settlement, recruitment, and colonization of the faunal elements found more typically south and north of the area. In addition, the entire continental slope off North Carolina is influenced by the Gulf Stream, which impinges on the bottom to at least 600 m.

Life History Analysis

Data on reproduction and population size frequency was developed for five species of polychaetes. The five species were Pholoe anoculata, Microrbinia linea, Aurospio dibranchiata, Cossura longocirrata, and Scalibregma inflatum. These species were dominant at one or more stations and occurred in densities high enough to provide

adequate numbers for evaluation. Summary size data for four species are presented in Table 35.

Pholoe anoculata Hartman

Pholoe anoculata was first described by Hartman (1965) from off New England at depths of 400 to 1500 m and from off northeastern South America at depths of 770 to 805 m. The species has subsequently been reported from other localities in the western North Atlantic by Hartman and Fauchald (1971) and more recently from the eastern North Atlantic by Christie (1982). During the present study, this species has been found at stations from the Canadian border to off South Carolina. At many of these stations, especially at the 2000 m depth, it was among the dominant species. It is the most abundant species at Station 3 (1500 m) off Cape Lookout. The results described below are based on specimens collected during six cruises at Station 4 off Cape Lookout, North Carolina.

Reproductive Characteristics. During the course of taking measurements of specimens from Station 4, an effort was made to identify sexually mature specimens. None were found initially, and it was decided to reexamine the material and also to inspect specimens from other stations on the Cape Lookout transect (Station 1, 583 m; Station 2, 1000 m; and Station 3, 1500 m). Sexually mature male and female specimens werre found at the shallower sites, but not at Station 4, where only a few specimens with immature oocytes were eventually encountered. The sperm of the males are associated with the neuroaciculum and tend to surround this structure throughout the length of the parapodium. The eggs are located in a cluster at the base of each neuroaciculum beginning at about setiger 10. Mature eggs are irregular in outline and have a mean diameter of 141 μm (SD = 18.15). Typically there are about six eggs per cluster which equate to around 160 total eggs per gravid specimen. Only specimens >2.0 mm in length are gravid. In general, the average size decreases with increasing depth, with the specimens from Station 4 (2000 m) being noticeably smaller than those at Stations 1 and 2.

Size Frequency Distribution. The data indicate a relatively stable size distribution in the population over the six seasons sampled (Figure 67) with the majority of specimens always in the 10 to 15 setiger size class. Postlarval specimens in the 5 to 10 setiger size

TABLE 35. AVERAGE NUMBER OF SETIGERS AND ONE STANDARD DEVIATION OF FOUR SPECIES OF POLYCHAETES FROM U.S. SOUTH ATLANTIC STATIONS.

Species	Nov 1983 $\bar{x}$	Nov 1983 SD	May 1984 $\bar{x}$	May 1984 SD	July 1984 $\bar{x}$	July 1984 SD	May 1985 $\bar{x}$	May 1985 SD	Sep 1985 $\bar{x}$	Sep 1985 SD	Nov 1985 $\bar{x}$	Nov 1985 SD
Aurospio dibranchiata	34.09	7.91	37.39	7.40	36.69	7.33	36.79	7.16	37.09	7.77	37.23	6.59
Cossura longocirrata	*		*		37.03	10.12	38.95	8.00	44.06	6.63	*	
Pholoe anoculata	14.77	4.22	15.47	4.23	14.57	3.72	14.57	3.18	13.89	3.23	14.46	3.16
Scalibregma inflatum	*		*		26.41	7.76	30.40	9.11	28.11	7.15	*	

*No specimens measured.

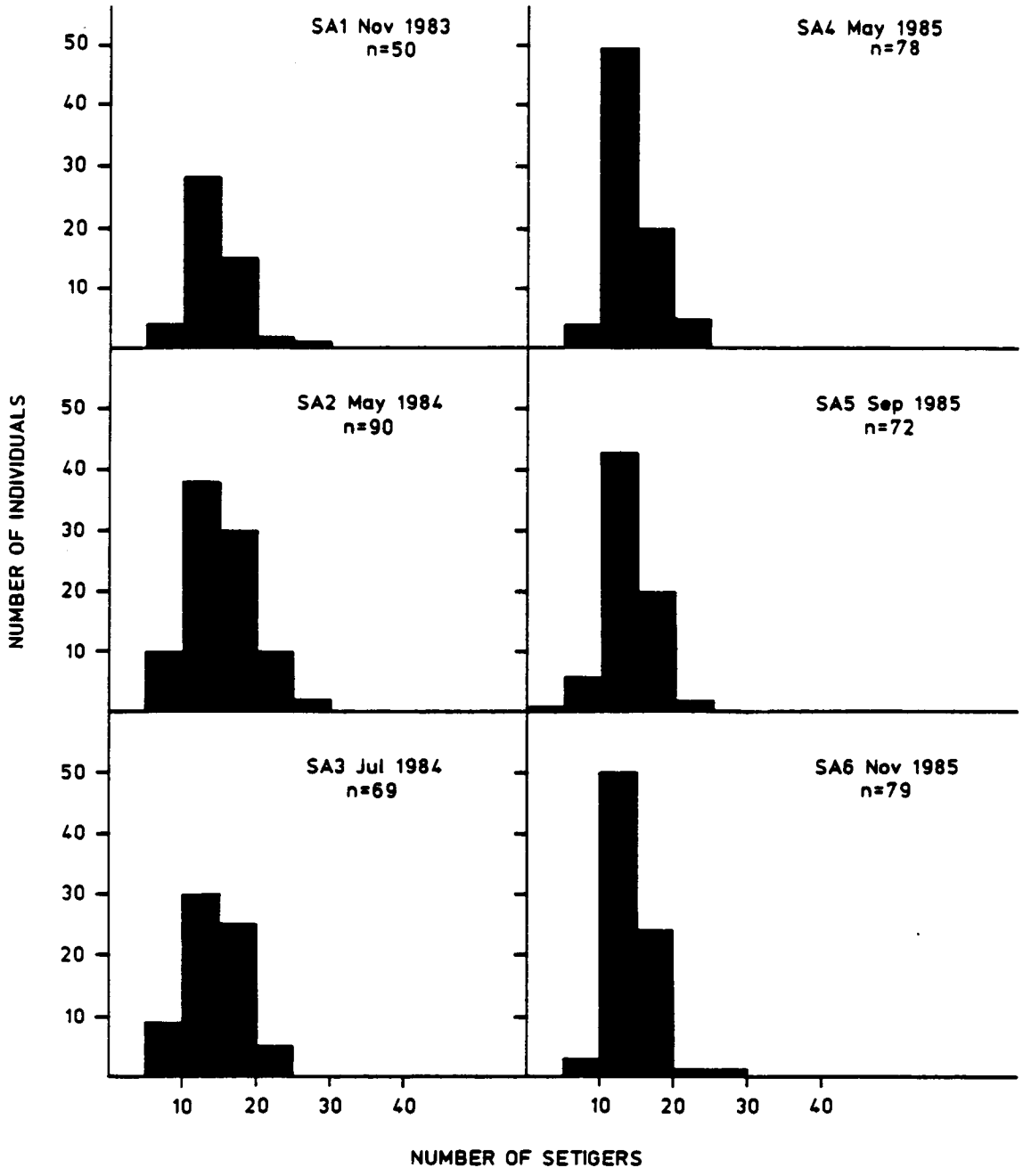


Figure 67. Frequency Distribution of Size Classes of Pholoe anoculata from Station 4 at 2000 m off Cape Hatteras.

class were always present. Average sizes ranged between 13.9 to 15.5 setigers throughout the six cruises. These data suggest year-round recruitment.

Remarks. The only previous data on reproduction in P. anoculata is that of Christie (1982) who reported on a form he called Pholoe cf. anoculata from off the Northumberland coast (U.K.), in relatively shallow depths of 30 to 80 m. While it is possible that Christie's form will eventually prove to be a separate species, some comments on his findings are appropriate. The species retains gametocytes in the gonads until maturity, with gametogenesis in the population synchronized with a restricted breeding season. Females produce large, yolky eggs (180-200 μm), while males bear long-headed, aberrant sperm. Spawning occurs in November, with larvae developing directly.

Seasonality of the type described by Christie from shallower localities in the eastern Atlantic has not been observed from our deeper populations in the western Atlantic. The presence of larger specimens with gravid eggs in the upper slope and smaller immature specimens on the lower slope suggests that the deeper populations may depend upon recruitment from the shallower reproductive populations. Since no size class data was developed at the shallower stations this hypothesis cannot be tested until additional measurements are taken. The data thus far developed do not suggest any seasonality, at least for the 2000 m populations. This does not preclude seasonality eventually being detected in upper slope populations.

Microrbinia linea Hartman

This species was originally described from off New England in 1000 to 2000 m and from off the mouth of the Amazon River in 770 to 1500 m. In the present study, the species is dominant at several stations from Cape Lookout to off Charleston in depths of 800 to 3000 m. The species has also been occasionally found in the North and Mid-Atlantic study areas, but has never been a dominant species in those localities. To date there are no published accounts on the biology of this species. The present observations include data on reproductive characteristics and size frequency for the population at Station 4 (2000 m) off Cape Lookout.

Reproductive Characteristics. Microrbinia linea is a small, threadlike species, having a compact thoracic region that lacks branchiae and a long, thin fragile abdominal

region. An unusual dorsal conical, glandlike structure, was observed on some specimens in posterior thoracic and anterior abdominal setigers (Figure 68A). At first these structures were thought to be porelike structures, perhaps nephridial in origin. A histological examination has revealed them to be glandular (Figure 68D). A distinct pore or opening through the structure was not observed. This structure was rarely observed in females and its prevalence in males suggests some role in copulation.

Females bear large eggs in middle abdominal segments. Eggs occur in one segment (setiger 16) only, with two large eggs per segment (Figure 68B). The eggs are very elongate (200 - 364 μm) and bear a distinct germinal vesicle embedded in a very finely granulated cytoplasm (Figure 68C). Large eggs were found in all seasons, with the largest average diameters found in May 1985 ($\bar{x}$ = 344 μm).

Males have been observed with segments packed with all stages of spermiogenesis. Mature sperm are of the long-headed type termed aberrant by Franzen (1956). Such sperm are associated with modified forms of reproduction including copulation and brooding.

The highest percentages of males were observed in July and September, while females were most prevalent in May, September, and November (Table 36).

Size Frequency Distribution. Size classes are based on thoracic width of the specimens. Only four size classes were present: 5-10 μm, 10-15 μm, 15-20 μm, 20-25 μm (Figure 69). The 10-15 μm size class was most abundant in November 1983, and May and July 1984, while the 15-20 μm size class was most abundant in May, September and November 1985. No seasonal trends are apparent from these data. The presence of the large eggs year round and the relatively uniform size class data suggest that reproduction and recruitment occur year round.

Aurospio dibranchiata Maciolek

Aurospio dibranchiata is a widely distributed deep-sea spionid, occurring over most of the Atlantic Ocean from slope depths of 300 m to abyssal depths of 3600 m (Maciolek, 1981a). The species has also been reported from the Pacific Ocean (Maciolek, 1981b). During the course of the U.S. ACSAR program, the species was commonly encountered in stations from the Canadian Border to off North Carolina. At many of these stations,

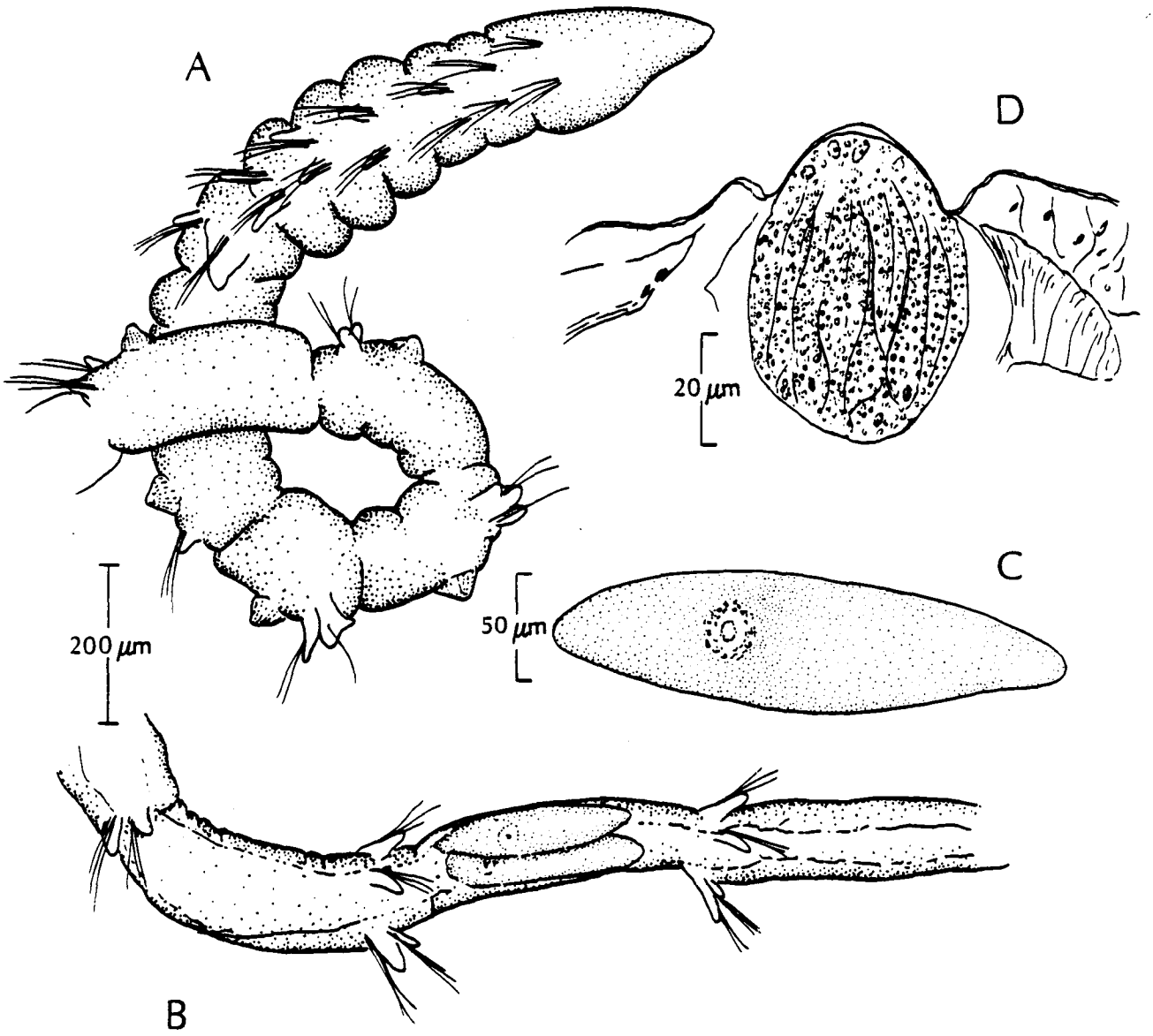


Figure 68. Microrbinia linea. A. Anterior End in Lateral View Showing Position of Glandlike Structures on Anterior Abdominal Setigers; B. Detail of Abdominal Segment with Two Eggs; C. Egg; D. Thin Section of Glandlike Structure from Anterior Abdominal Segment.

TABLE 36. PERCENT MALES AND FEMALES OF MICRORBINIA LINEA.

Cruise	Date	Percent Males	Percent Females	Ave. Egg Diameter (µm)
SA-1	Nov 1983	24.8	6.4	230 x 80
SA-2	May 1984	33.8	12.2	230 x 130
SA-3	Jul 1984	44.8	4.8	360 x 130
SA-4	May 1985	38.2	7.8	320 x 140
SA-5	Sep 1985	42.2	12.0	270 x 110
SA-6	Nov 1985	27.6	12.4	270 x 150

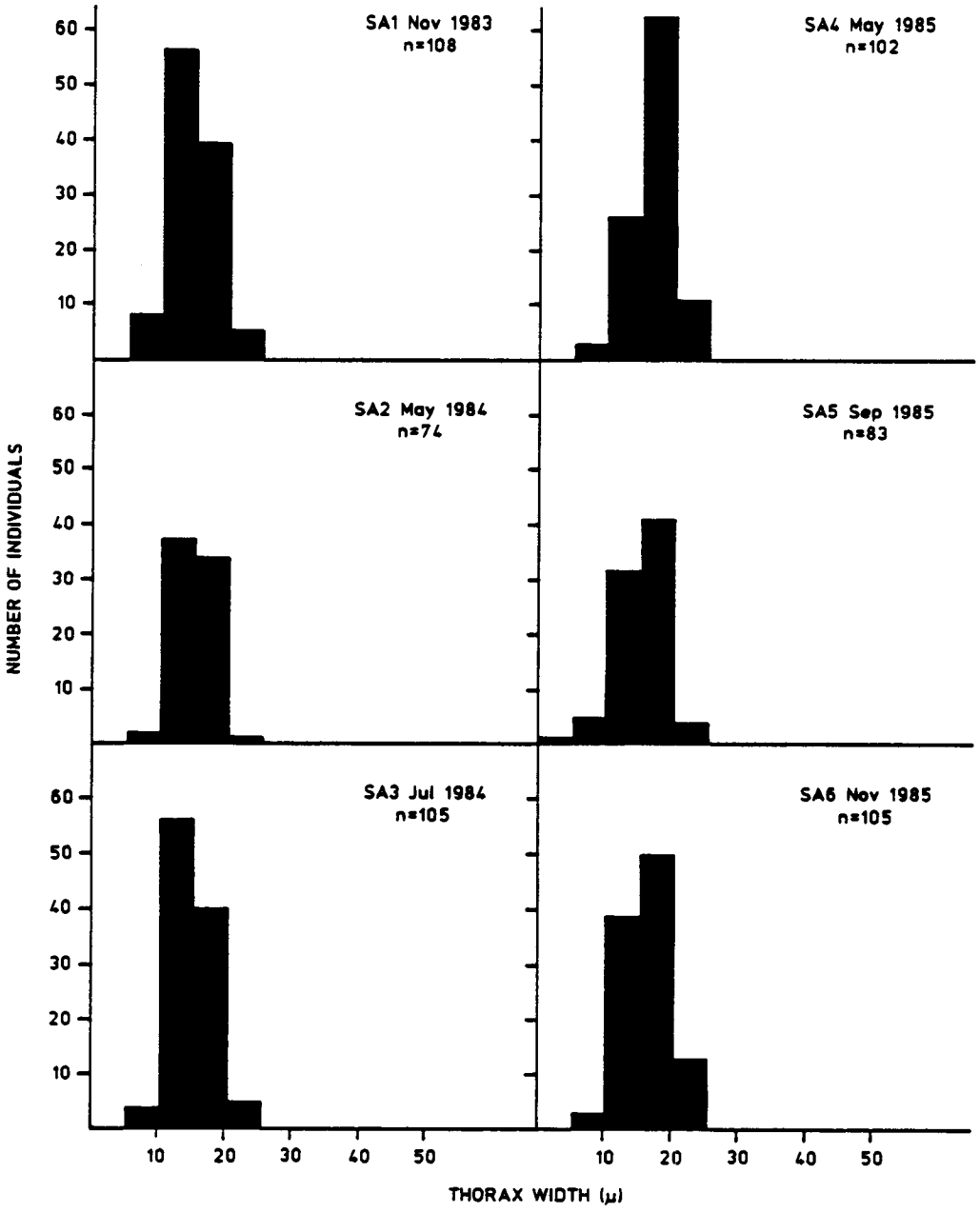


Figure 69. Frequency Distribution of Size Classes of Microrbinia linea from Station 4 at 2000 m off Cape Lookout.

especially in the U.S. Mid-Atlantic region, the species has been found to be the top dominant species in the 2000- to 2100-m depth zone (Maciolek et al., 1986 a-b; 1987). In the U.S. South Atlantic region, it ranks among the top 20 dominants at several 2000-m stations, but never ranks first. It is largely displaced from that role by Microrbinia linea.

Reproductive Characteristics. Maciolek (1981a) found only a few specimens with eggs out of more than 3000 adults she examined. The eggs measured 50-96 µm across their widest dimension. In the present study, a total of 13 specimens out of 425 individuals examined were found to bear eggs or sperm. In all cases, whether male or female, the first segment to bear gametes was setiger 13. The ovaries were found to be attached to the mid-ventral side of the coelom. Eggs in various growth phases were observed in specimens taken during November 1983 ($\bar{x}$ = 41 µm, SD = 12.5), July 1984 ($\bar{x}$ = 57.7 µm, SD = 12.3), September 1985 ($\bar{x}$ = 59.7 µm, SD = 28.0), and November 1985 ($\bar{x}$ = 53.3 µm, SD = 7.8). The largest eggs observed measured 112 µm, although 70-98 µm is probably a more valid upper size limit. These larger eggs were only observed during September 1985. Eggs were not observed during spring collections in 1984 and 1985. These data suggest a possible seasonal pattern whereby reproduction proceeds during the summer and fall months, but ceases during the winter and spring when organic inputs to the lower slope are less important.

Size Frequency Distribution. There is some evidence of seasonality and growth of A. dibranchiata in the 1983-1984 data. In the November 1983 data, the 25- to 30-setiger size class is predominant (Figure 70). Growth of worms in the 25- to 35-setiger range occurred between May and July, such that the 35-setiger size class predominated in July. At the same time, the percentages of larger individuals having 35 to 50 setigers declined. A distinct bimodality is obvious in the data for July 1984. In 1985, the same bimodality appears to be present between the May 1985 and September 1985 cruises. The average size of individuals varied from a low of 34.1 setigers in November 1983 to a high of 37.4 setigers in May 1984. The four collections from July 1984 to November 1985 were all very similar with an average of 36.7 to 37.2 setigers. There is no obvious evidence of recruitment over the six sets of samples examined at this station.

Remarks. There is some evidence of seasonality in the lack of sexually mature specimens in two spring collections and in the very clear bimodality present in the size frequency data for the spring and summer of 1984. In 1985, the smallest size class (20-25

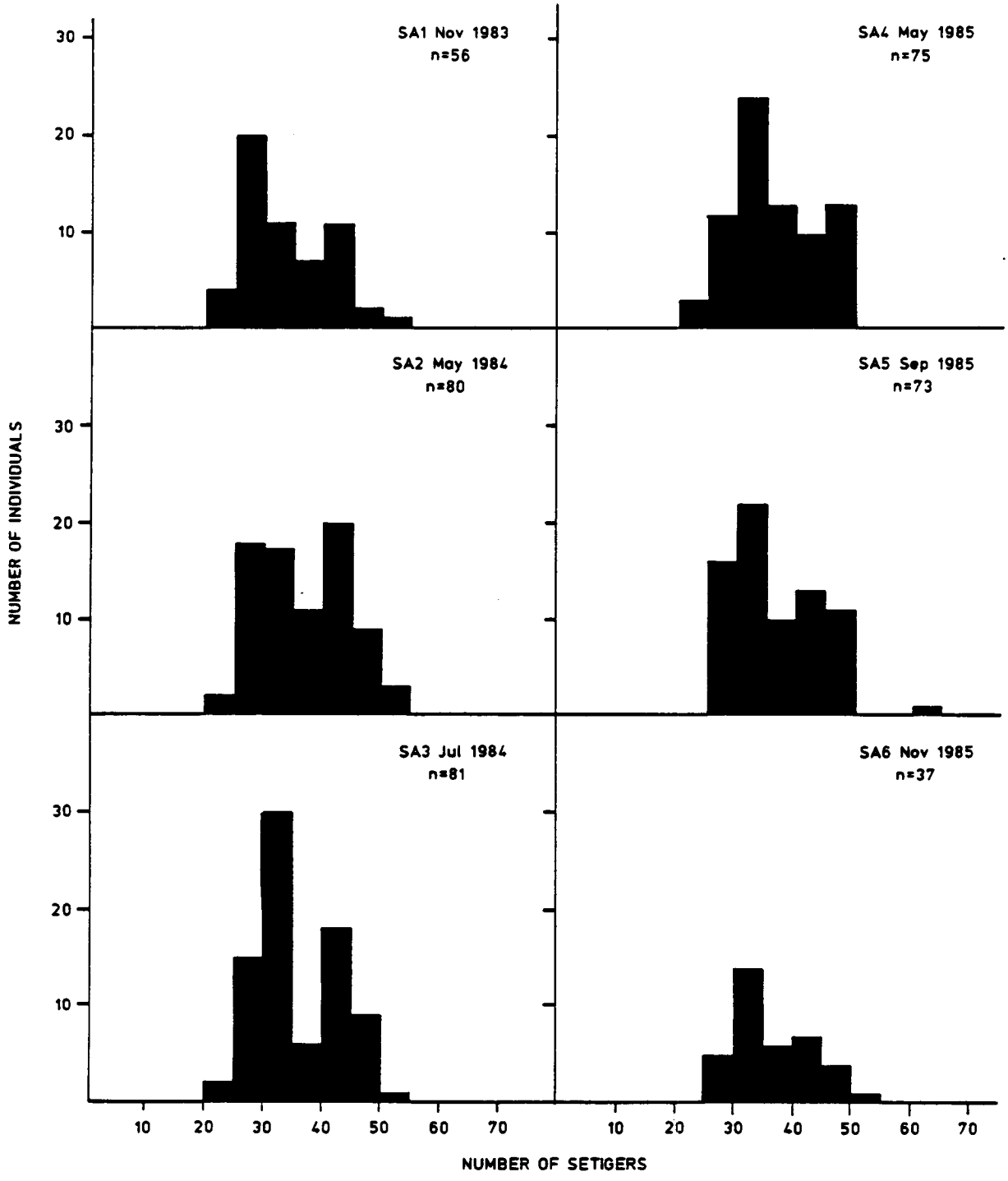


Figure 70. Frequency Distribution of Size Classes of Aurospio dibranchiata from Station 4 at 2000 m off Cape Lookout.

setigers) was present only in the May collection and completely absent in the summer and fall. In 1983 and 1984, however, some specimens of the 20- to 25- setiger size class were present in each of the collections.

Cossura longocirrata (Webster & Benedict)

Cossura longocirrata is one of the most important species in the slope and rise environments. In the present study, it was one of the most predominant species in depths of 600 to 2000 m off Cape Lookout and Cape Hatteras. Off Cape Fear, Cossura sp. 2 becomes the more abundant cossurid, with C. longocirrata ranking lower among the top dominants.

The most important review of the reproductive biology and life history of C. longocirrata was presented by Blake and Baptiste (1985) as part of the Georges Bank Benthic Infauna Monitoring Program. In that study, the species was found to be a dominant in fine silty sediments at a depth of 70 m (the so-called Mud Patch). The authors postulated that with the onset of maturation, the eggs move posteriorly to abdominal beaded segments where they continue development and from which they are eventually spawned. The males do not exhibit a beaded region. Size frequency data presented by Blake and Baptiste (1985) suggest that recruitment takes place in spring and summer on the continental shelf.

There is no additional information available on reproduction of C. longocirrata on the continental shelf or the slope. In the present study, data was developed for a population at a 600-m station off Cape Hatteras where over 10,000 individuals were taken from nine replicate box cores in each of three seasonal cruises: SA-3 (July 1984), SA-4 (May 1985) and SA-5 (September 1985). The site (Station 9) is unique in that species diversity is low, while density is very high. C. longocirrata is the dominant species at this station.

Reproductive Characteristics. The same morphology of beaded and swollen individuals as observed in the Georges Bank samples was observed in the slope specimens from Station 9. Females with swollen anterior abdominal segments bearing eggs were observed. Table 37 presents data on the occurrence of the various reproductive body forms. The most specimens with swollen bodies containing eggs occurred in July 1984

TABLE 37. SUMMARY DATA ON REPRODUCTIVE BODY FORMS IN COSSURA LONGOCIRRATA.

	SA-3		SA-4		SA-5		Total	
	n	%	n	%	n	%	n	%
Swollen with eggs	101	12.4	43	8.0	26	7.6	170	10.0
Beaded with eggs	2	0.2	0		0		2	0.1
Beaded	157	19.3	33	6.1	25	7.3	215	12.7
Swollen	317	38.9	145	27.0	74	21.7	536	31.7
Sperm Present	43	5.3	32	6.0	36	10.6	111	6.6
Normal	195	23.9	284	52.9	180	52.8	659	38.9

TABLE 38. PERCENT MALES AND FEMALES OF COSSURA LONGOCIRRATA.

Cruise	Date	Percent Males	Percent Females	Ave. Egg Diameter (µm)	Max. Egg Diameter (µm)
SA-3	Jul 1984	5.3	12.7	100 x 60	150 x 90
SA-4	May 1985	6.0	8.0	110 x 70	140 x 70
SA-5	Sep 1985	10.6	7.6	110 x 70	180 x 80

(12.4 percent). Eight percent and 7.6 percent of the specimens in May and September 1985, respectively, were also mature. A high number of beaded specimens occurred in July 1984 (19.3 percent), along with more specimens with swollen segments (38.9 percent). The largest egg diameters were observed in September 1985, but averages were not different from one season to the next (Table 38). The highest percentage of males was recorded in July 1984, while the most females occurred in September 1985. These data suggest that C. longocirrata probably reproduces year round, but has peaks of reproductive activity during the summer months.

Size Frequency Measurements. The data suggest that recruitment takes place in the spring and early summer, because the smallest size classes are present in those collections and the large size classes predominate in the September collection (Figure 71). The average size of the population was 37.0 setigers ± 10.1 in July 1984, 39.9 setigers ± 8.0 in May 1985, and 44.1 setigers ± 6.6 in September 1985. In July 1984 and May 1985, 53.7 percent and 52.5 percent of the population, respectively, were less than 40 setigers in size. Two of the smallest size classes (5-10 setigers and 10-15 setigers) occurred only in the May 1984 collection. In contrast, in the September 1985 samples, only 24.9 percent of the population had fewer than 40 setigers, while 75.1 percent had more. These data indicate that the species undergoes a heavy recruitment in the spring, with some additional activity in the summer. The predominance of large size classes in the late summer indicates that a rapid growth with little additional recruitment occurs after July.

Remarks. The size frequency data compare favorably with results from the continental shelf, where spring recruitment was also suggested (Blake and Baptiste, 1985). It is probable, however, that the species reproduces to some extent during the entire year.

Scalibregma inflatum Rathke

Scalibregma inflatum is one of the best known and widespread polychaetes in the world. It is certainly the most familiar and common of the scalibregmatids. Its known range includes both coasts of North and South America, Europe, Australia, New Zealand, South Africa, and Antarctica. Its known depth range extends from the intertidal to abyssal depths (Blake, 1981). It has been suggested that the wide distribution of this species is an artifact, and that several sibling species might be present (Kudenov and

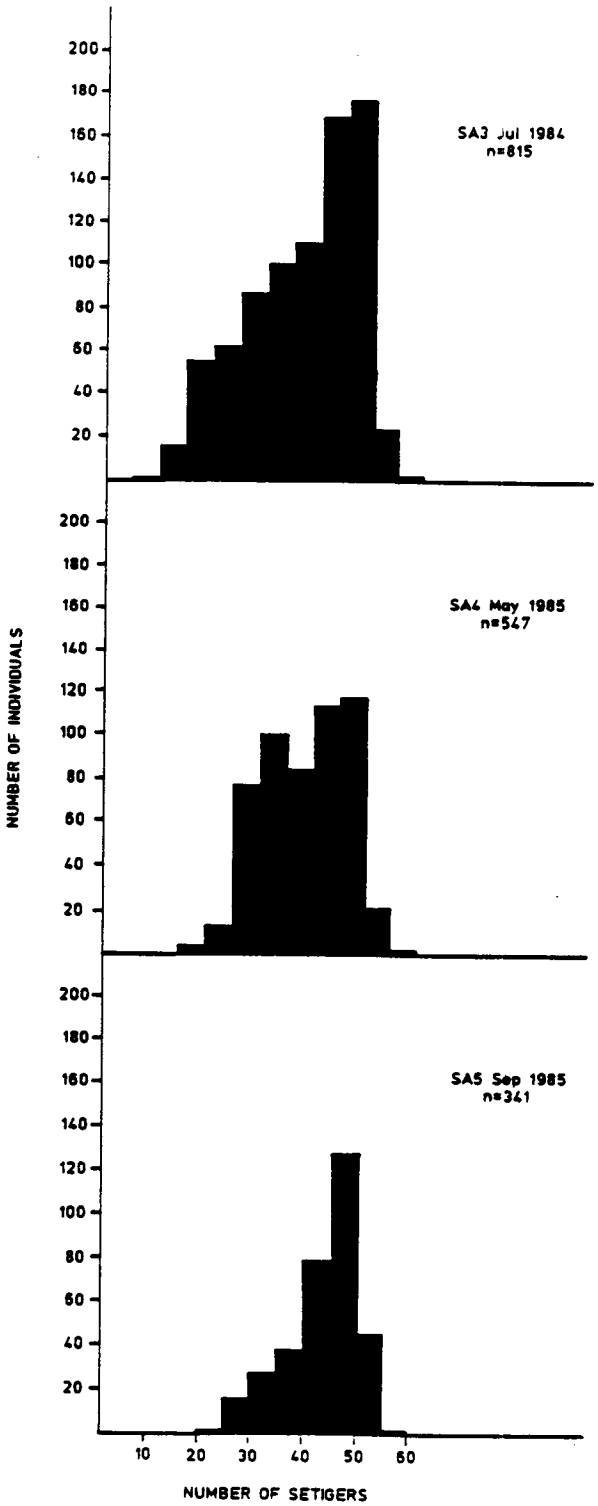


Figure 71. Frequency Distribution of Size Classes of Cossura longocirrata from Station 9 at 600 m off Cape Hatteras.

Blake, 1978). As yet, however, the appropriate studies have not been conducted to test this hypothesis. It is rare that S. inflatum has been numerous enough to collect sufficient population data. It is noteworthy, therefore, that in the present study the species was one of the numerically dominant species at one of the slope stations off Cape Hatteras. In three collections at Station 9 (600 m), S. inflatum ranked second after C. longocirrata. On at least one cruise (SA-4, May 1985) it was the top dominant. More than 7000 specimens were collected over the three seasons. This collection, in addition to providing a basis to conduct size frequency measurements, provides a valuable resource for establishing a database to eventually test the hypothesis that widespread populations include sibling species.

The only previous study to provide any information on the reproduction of S. inflatum is that of Ashworth (1915). The information, however, is so sketchy and confusing that it appears best to ignore it.

Reproductive Characteristics. Females bearing eggs were observed in each of the three collections. Eggs in various growth phases were found: July 1984 ($\bar{x}$ = 150 µm, SD = 20), May 1985 ($\bar{x}$ = 160 µm, SD = 30), and September 1985 ($\bar{x}$ = 130 µm, SD = 10). The largest eggs recorded were 190 µm in September 1985. These data do not suggest any apparent seasonality.

Size Frequency Data. The data do not indicate any seasonality either with regard to average sizes or the size frequency distributions over any of the three seasons observed. However, the largest specimens were observed in May 1985 and the smallest in September 1985 (Figure 72). There appears to be a shift toward smaller specimens in the size classes with fewer than 25 setigers from May to September. This suggest a summer recruitment pattern and some mortality of specimens with 45 to 55 setigers.

DISCUSSION

The present study is one of three companion studies designed to characterize the U.S. Atlantic Continental Slope and Rise (ACSAR). When taken together the U.S. North Atlantic, Mid-Atlantic and South Atlantic Studies provide a comprehensive reconnaisance of the entire slope and rise from the U.S.-Canadian Boundary to off South Carolina. The U.S. South Atlantic Study is focused in the area from Cape Hatteras, N.C. to off

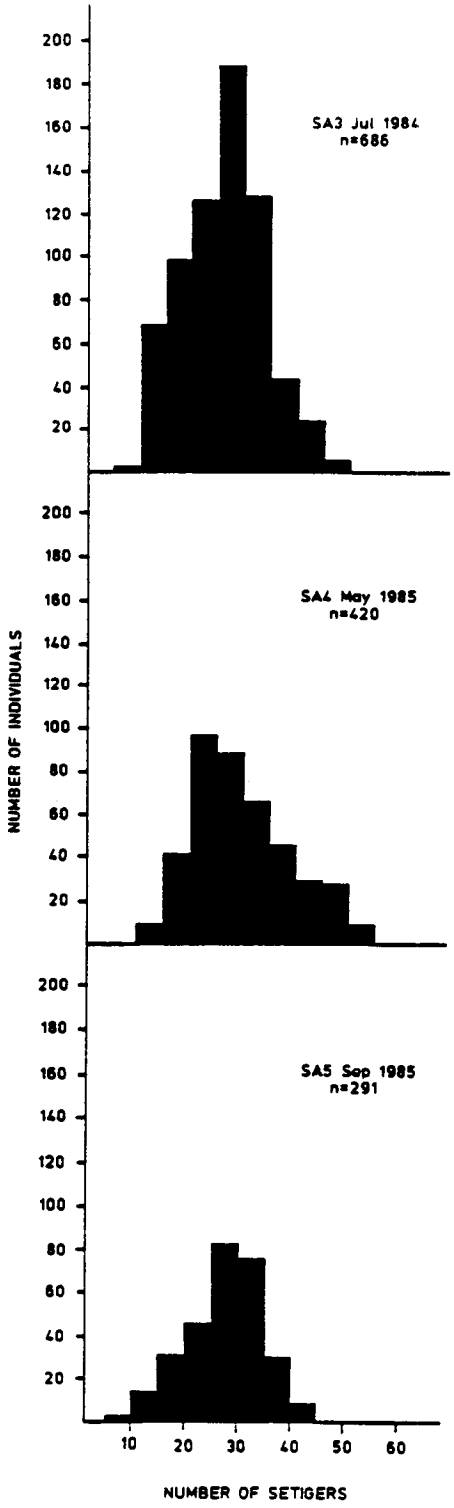


Figure 72. Frequency Distribution of Size Classes of Scalibregma inflatum from Station 9 at 600 m off Cape Hatteras.

Charleston, S.C. and provides benthic infaunal community data from depths ranging from 600 to 3500 m.

During the course of six seasonal cruises, divided into two distinct study phases, a total of 130 quantitative box cores were collected from a total of 16 stations and fully analyzed for infauna. This study has permitted a census of the macroinfauna of the region from Cape Hatteras to off Charleston and an analysis of how this fauna is partitioned into communities or assemblages along transects and depth contours. These data have permitted an assessment of so-called faunal breaks or zoogeographic barriers thought to exist off Cape Hatteras. A limited collection of data on life history parameters during Phase 2 and analysis of microspatial vertical distribution during Phase 1 have allowed some assessment of the ecology of important individual species. The collection of supporting sediment and hydrographic data taken together with available physical and chemical measurements in the same area provides a basis for explaining animal distributions and community patterns with some degree of confidence.

Taxonomy

A total of 1202 species of marine benthic invertebrates has been recorded from the samples analyzed in this study. Of this total, 520 species or 43.3 percent are new to science. Another 254 species or 21.1 percent may also represent undescribed species, but are less well represented in the collections. Only 428 species or 35.6 percent can be referred to a previously named species. The undescribed species include 288 species of polychaetes, 146 species of arthropods, and 53 species of molluscs. The remaining 33 species are from eight other phyla and the Oligochaeta. The Annelida dominate the fauna with 564 species or 46.9 percent of the total; 542 species are polychaetes and 22 are oligochaetes. The dominance of annelids in the fauna follows the pattern recorded for the U.S. North Atlantic and Mid-Atlantic regions, where annelids accounted for 46.5 and 44.1 percent, respectively (Maciolek et al., 1986 b; 1987). Except for Station 7 at 3500 m, all stations from 600 to 3000 m in the U.S. South Atlantic region had a polychaete as the number one ranked species. Station 7 was dominated by a pogonophoran. These results are in contrast with the North and Mid-Atlantic studies where sipunculids and aplacophorans were frequently the top dominant species at upper slope stations (Maciolek et al., 1986 b; 1987).

Diversity

By all measures, Station 14 at 800 m off Charleston is one of the most diverse benthic stations yet encountered in the marine environment. A total of 436 species taken in nine box cores from the site resulted in a Shannon-Wiener Diversity Index (H') of 6.93 and an evenness value (E) of 0.708. This is by far the highest such diversity measurement encountered at any station in the entire ACSAR Program. The high diversity at Station 14 is corroborated by the Hurlbert rarefaction method and by plots of species accumulation. South Atlantic Stations 14, 5 (3000 m off Cape Lookout), 12 (2000 m off Cape Fear), and 3 (1500 m off Cape Lookout) have Hurlbert rarefaction values for species per 500 individuals of 161.4, 157.7, 149.4, and 149.1, respectively, all of which are higher than the value at any Mid- or North Atlantic location. Station 10 (1220 m) off Georges Bank is closest with a Hurlbert rarefaction value of 144.1 species per 500 individuals. Several other North Atlantic stations and some Mid-Atlantic stations have values between 130 and 134.5, but none approach the high values of the southern stations. Most of the higher diversity values encountered at the Mid- and North Atlantic sites are from stations in upper slope depths from 1220 to 1500 m. In contrast, the southern stations with high diversity values are at several depths ranging from 800 to 3000 m. The U.S. North and Mid-Atlantic results strongly suggest that the upper slope is the most diverse site on the U.S. continental margin, while in the U.S. South Atlantic, high diversity sites have been found at several depths, including upper slope, lower slope, and continental rise locations. This heterogeneity of diversity across depth contours is probably the result of a greater diversity of sediment types found in the region (Chapter 7). Gray (1974) argued that mixed sediments in the deep sea may also result in enhanced diversity.

Much of our knowledge of benthic diversity in the deep sea is based on the work of Hessler and Sanders (1967). They used an epibenthic sled, towed over long distances, to collect their samples. Most of the diversity measures presented in their studies are based on the polychaete and bivalve portions of the fauna, rather than the entire fauna. There is little quantitative data from other geographic areas that can be compared with the results from the present program. Most previous studies of deep-sea benthic communities have not included the analysis of the entire community, but utilize only the polychaete or polychaete-bivalve data to calculate diversity.

Gage (1978) reviewed diversity data from his own studies of the Rockall Trough off Ireland, the studies of Hessler and Jumars (1974) from the central Pacific, and the work of Jumars (1976) in some deep basins off southern California. This review compared polychaete-bivalve diversity using Hurlbert rarefaction curves. When polychaete diversity data from the U.S. South Atlantic Station 4 is compared with Gage's polychaete-bivalve values from the eastern Atlantic and Pacific, the Station 4 polychaete diversity is as high, or higher than, the Rockall trough values.

One of the few studies to employ large numbers of replicate box cores is that of Hecker and Paul (1979) who studied abyssal community structure in the central Pacific. Very high diversities were depicted in their rarefaction curves for both the entire fauna and the polychaete fauna alone. For the entire fauna, the rarefaction curves did not begin to reach an asymptote. Projections for total individuals, however, did not exceed 40, owing to the low faunal diversities in the oligotrophic Pacific.

Community Analysis

The analysis of community structure by cluster and ordination analysis has allowed an interpretation of faunal assemblages by depth (600-3000 m) and along depth contours from Cape Hatteras, N.C. to off Charleston, S.C. In addition, these analyses have contributed toward a general analysis of patterns of spatial and temporal community structure. These studies have also contributed toward an understanding of suspected zoogeographic boundaries or faunal breaks in the area off Cape Hatteras.

In nearly all cases, the individual replicate box cores taken at a station were more similar to one another than to those taken at other stations. This clearly indicates that faunal assemblages at particular sites or depths are not random, but the result of heterogeneous community patterns distributed across the U.S. South ACSAR.

In the U.S. Mid- and North Atlantic Studies, major station clusters were identified at 550 m, 1220 to 1500 m, 2100 m, and 2500 m depth intervals (Maciolek et al., 1986b; 1987). This same pattern was present in the Phase 1 results for the U.S. South Atlantic study, where major station clusters along the Cape Lookout Transect were zoned into upper slope (600-1000 m), lower slope (1500-2000 m), upper rise (3000 m), and lower rise (3500 m) components. In the present study, the addition of a transect to the north of

Cape Lookout off Cape Hatteras at Block 510 and two southern transects off Cape Fear and Charleston have revealed patterns which depart from the earlier conclusions of a distinct and predictable zonation of assemblages along the slope.

The stations off Cape Hatteras are unique in comparison to any sites previously characterized in the U.S. ACSAR Studies. The 600-m site is dominated by polychaetes and oligochaetes that are more typically found in shallow depositional sites on the continental shelf. In addition, this site bears essentially no similarity to either of the 600-m sites off Cape Lookout and Charleston. The 2000-m site off Cape Hatteras is more similar to its upslope 600-m counterpart and other upper slope stations and bears little similarity to the other 2000-m stations in the U.S. South Atlantic region.

The upper slope stations off Cape Lookout are more similar to the 800-m stations off Cape Fear and Charleston than to any other stations, although the 1000-m station off Cape Lookout does show a high degree of similarity to the downslope 1500-m station on the same transect. The 600-m station off Charleston is unique and has little similarity to any other station in the region.

The 2000-m stations at Hatteras Canyon, Cape Lookout, and Cape Fear are more similar to one another than to either the Cape Hatteras station or the Charleston station. The two 3000-m stations off Cape Fear and Charleston are more similar to one another than to the 3000-m station off Cape Lookout. The 2000-m station off Charleston appears to have more similarity with the 3000-m stations than to the 2000-m stations.

Correspondence analysis supports the results of the cluster analysis in the wide divergence of the 600- to 1000-m stations and the 2000-m station off Cape Hatteras from one another and from other sites. These stations and the two 800-m stations off Cape Fear and Charleston depart farthest in the ordination space from the remaining 1500- to 3000-m stations.

Interpretation of these patterns must take into account the heterogeneity already noted in diversity patterns, where the stations with the highest diversity occurred at many depths rather than in predictable depth zones as found in the North and Mid-Atlantic study areas (Maciolek et al., 1986 b; 1987). Undoubtedly the faunal diversity and density patterns influence the patterns revealed by the cluster and ordination analysis. A clue to these patterns is revealed by the R-mode or inverse cluster analysis of species group patterns. In many cases the species group clusters were completely interactive with the

station clusters, as demonstrated by nodal analysis (Figure 23). By examining the species lists of these station groups and the density and species richness data, some of the underlying reasons for the heterogeneity are evident. Examination of the physical data suggests some of the basis for the presence or absence of these dominant species.

Dominance Patterns and a Partial Zoogeographic Barrier

Patterns of dominant species corresponded to those elucidated by other statistical analyses in emphasizing the differences between the 600-m and 2000-m stations off Cape Hatteras from others in the U.S. South Atlantic region. The 600-m Cape Hatteras site is highly unusual in being dominated by polychaetes and oligochaetes more typical of continental shelf faunas. Five of these species accounted for over 65 percent of the individuals. Densities of Cossura longocirrata and Scalibregma inflatum are among the highest ever recorded for these species.

Dominant species recorded in the U.S. North and Mid-Atlantic regions, while present at the southern stations, occupy different ranks at these stations. For example, Aurospio dibranchiata is dominant at most of the 2000- to 2100-m stations in the North and Mid-Atlantic, but is never ranked number one in the south. Instead, another species, Microrbinia linea, which is rare in the northern stations, is the top dominant at most of these southern stations. M. linea is also the top dominant at 800-m and 3000-m depths on the Cape Fear and Charleston transects. This major change in dominance is difficult to explain since M. linea is known from more northern latitudes, but is relatively unimportant in community analysis.

Two aplacophorans Prochaetoderma yongei and Spathoderma clenchi and a sipunculid Aspidosiphon zinni that are dominant species in the North and Mid-Atlantic regions at middle and upper slope depths maintain an important role in the southern communities as far south as the Cape Lookout Transect. Thereafter, the aplacophorans virtually disappear and A. zinni, while present, drops much lower in the rank of dominants. These changes in dominance contribute to the suggestion that a partial zoogeographic barrier exists off North Carolina. Explanations for these changes are difficult to develop, since not all species show such abrupt changes. A summation of three categories of some dominant species on the ACSAR are listed below:

Northern Dominants	Southern Dominants	North-South Dominants
Prochaetoderma yongei	Microrbinia linea	Tharyx sp. 1
Spathoderma clenchi	Spionidae sp. 11	Pholoe anoculata
Meiodorvillea minuta	Kelliella sp.	Ophelina abranchiata
Aspidosiphon zinni	Leptocheliidae sp. 1	Cossura longocirrata
Sabidius cornatus	Microrbinia linea	Aurospio dibranchiata
Tharyx annulosus	Levinsenia sp. 1	Tharyx sp. 1
Bathydrilus atlanticus	Glycera capitata	Thyasira croulinensis
Oecidiobranchus plebejum	Thyasira minutus	Prionospio sp. 2
Kesun gravieri	Siboglinum pholidotum	Galathowenia sp. 1
	Caulleriella sp. 2	Bathydrilus asymmetricus
	Fabricia sp. 1	Tubificoides aculeatus
	Tubificoides sp. 3	Grania atlantica
	Cossura sp. 2	
	Gnathia sp. 2	

Density

The most comprehensive data on deep-sea faunal densities in the western North Atlantic prior to the current ACSAR program was provided by Sanders, Hessler, and Hampson (1965) from stations on the Gay-Head Bermuda Transect (75-5001 m) and from a transect off northeastern South America (535-4525 m). Results of the U.S. ACSAR program indicate that the previous density values were underestimates for depths of 550 to 3000 m (Table 39).

For upper slope depths of 550 to 600 m, six stations from the U.S. North and South ACSAR program have a mean density of 16,872 individuals per m^2 ($\pm$ 1 SD of 15,248). The large standard deviation is due to Stations 9 and 14A in the south which have the highest (46,255 individuals per m^2) and lowest (2,355 individuals per m^2) densities, respectively, of

TABLE 39. COMPARISON OF CONTINENTAL SLOPE AND RISE INFAUNAL DENSITY VALUES FOR THE WESTERN NORTH ATLANTIC.

Geographic Area	Depth (m)	Density (m^2)	± 1 SD
U.S. Slope & Rise[1]	550-600	16,872	15,248
Gay-Head Bermuda Transect[2]	487	8669	-
N.E. South America[2]	535	5427	-
U.S. Slope & Rise	800	9610	816
Gay-Head Bermuda	823	2979	-
N.E. South America	790	1883	-
U.S. Slope & Rise	1000	9130	-
U.S. Slope & Rise	1220-1500	5094	1097
Gay-Head Bermuda	1500	1719	-
N.E. South America	1500	519	-
U.S. Slope & Rise	2000-2150	4656	1918
Gay-Head Bermuda	2086	2154	-
U.S. Slope & Rise	2500	3567	-
Gay-Head Bermuda	2870	748	-
U.S. Slope & Rise	3000	971	301
U.S. Slope & Rise	3500	1000	-
Gay-Head Bermuda	3752	1003	-

1 Data from Maciolek et al. (1986 b-c) and this study.
2 Data from Sanders, Hessler, and Hampson (1965).

any of the stations. In contrast, the data from Sanders, Hessler, and Hampson (1965) for two stations at 487 m and 535 m have lower densities (8669 and 5427 individuals per m^2, respectively). Two 800-m stations on the U.S. South Atlantic Slope averaged 9610 animals per m^2 ($\pm$ 1 SD of 816), while two of the stations sampled by Sanders, Hessler and Hampson (1965) at 790 and 823 m had 1883 and 2979 individuals per m^2, respectively.

Eight middle-slope stations at depths ranging from 1220 to 1613 m have been sampled in the ACSAR program. These stations have a mean density of 5094 individuals per m^2. In comparison, two 1500-m stations in the with Gay Head-Bermuda Transect and northeastern South American had values of 1719 and 519 individuals per m^2.

Twenty-one stations at depths of 2000 to 2150 m have been sampled during the ACSAR program. Collectively these stations averaged 4656 individuals per m^2. In contrast, one 2086-m station on the Gay Head-Bermuda Transect had a density of 2154 individuals per m^2. A single U.S. Mid-Atlantic station at 2500 m had a mean density of 3567 individuals per m^2, and three stations in the U.S. South Atlantic region at 3000 m had a mean density of 971 individuals per m^2. One 2870-m station on the Gay Head-Bermuda Transect had a density of 748 individuals per m^2. A U.S. South Atlantic station at 3500 m had 1000 individuals per m^2, which compares well to a Gay Head-Bermuda Transect value of 1003 individuals per m^2 for a 3752-m station.

The values for densities of animals per m^2 at depths ranging from 550 to 2500 m developed during the current ACSAR program are considerably higher than previously recorded values from the Gay-Head Bermuda Transect and from a transect off northeastern South America by Sanders, Hessler, and Hampson (1965). Similar data from the continental rise (3000-3500 m), however are similar to the earlier database.

Of all of the density values developed in the ACSAR program, those of the U.S. South Atlantic are the most variable. For example, three stations in the 600 m depth range have density values ranging from 2351 individuals per m^2 at Station 14A off Charleston to 46,255 individuals per m^2 at Station 9 off Cape Hatteras. In contrast, three stations in the North Atlantic Program in the 550- to 560-m depth interval range from 9300 to 15,489 individuals per m^2. A wide range of values was also recorded at the 2000-m stations, with densities ranging from a low of 1311 individuals per m^2 at Station 15 off Charleston to a high of 8950 individuals per m^2 off Cape Hatteras. Combined North and Mid-Atlantic values ranged from a low of 3978 to a high of 5361 individuals per m^2.

Reproduction and Life History

There have been relatively few studies devoted to the reproduction and life history of deep-sea benthos. Data developed in previous studies includes observations on gametogenesis, fecundity, and size frequency distributions. Speculation has focused on whether deep-sea invertebrates exhibit any form of seasonality or periodicity in their reproduction. Given the relatively constant environmental conditions present in deep-sea environments, continuous reproduction would be expected. The earliest attempts to develop data on reproduction of deep-sea benthos, however, were based upon examination of samples not specifically intended for reproductive studies. Consequently, the irregular nature in which the collections were made provided material which, when examined by biologists, led to speculation that reproductive periodicity or seasonality was present in most cases (George and Menzies, 1967; Schoener, 1968; Sanders and Hessler, 1969; Scheltema, 1972). The validity of these earlier studies was challenged in a series of papers by Rokop (1974; 1977 a-b; 1979) who developed data from a series of samples taken at 13-week intervals for one year at a 1240-m site in the San Diego Trough off southern California. In all, Rokop examined 11 species including three bivalves, two ophiuroids, two isopods, one polychaete, one amphipod, one scaphopod, and one brachiopod. Of these, the first nine species were found to be in a reproductive condition all year long, while the last two spawned seasonally. In a series of studies of invertebrates from the Rockall Trough off Ireland in which samples were taken seasonally for several years, at least seven species of invertebrates including two asteroids, two ophiuroids, one echinoid, and two bivalves have been found to reproduce seasonally (Tyler et al., 1982; Tyler and Gage, 1984a), while for another five echinoids there was no evidence of seasonality (Tyler and Gage, 1984b). These results indicate that both continuous and cyclic reproductive patterns may be expected in deep-sea benthic invertebrates. Recent evidence for a downward flux of surface-derived particulate organic matter indicating a seasonal pulse into the deep sea correlated with a spring phytoplankton bloom (Deuser and Ross, 1980; Deuser et al., 1981) led Tyler and Gage (1980) and Tyler et al. (1982) to the hypothesis that sinking organic matter provided a food source for developing larvae in the water column and a food source for adults of species with seasonal reproduction, providing energy to complete gametogenesis. Direct visual evidence of a possible plankton bloom

settling on the seafloor was observed during two camera tows four days apart in the same location on the U.S. North ACSAR program on the spring 1985 cruise (Maciolek et al., 1986b: Chapter 4: 74). On the first camera tow, suspended particulate material was present in the water column and patches of greenish-tan material were seen on the bottom; four days later, the suspended material was still present, but dense mats of flocculent material were visible on the bottom. This is evidence that a pulse of organic material of the type described by Deuser and Ross (1980) can impinge upon the bottom.

In the present study, observations on reproductive morphology and size class measurements were made on five dominant species of polychaetes. Two species from the 600-m Station 9 were studied. Cossura longocirrata appears to reproduce throughout the year, but undergoes peaks during the summer. Scalibregma inflatum does not exhibit any evidence of seasonality. Of three species studied from Station 4 at 2000-m off Cape Lookout, only Aurospio dibranchiata showed any evidence of seasonality. No seasonality was detected for Pholoe anoculata and Microrbinia linea, the other two species studied.

These data, while limited, provide the first evidence of seasonality in infaunal invertebrates from the ACSAR. Further studies on these same species would be instructive to determine if seasonal patterns are repeated at other stations at similar or different depths. The widespread distribution of A. dibranchiata along the ACSAR means that sufficient material is available to assess this species in detail at some future date. Other species which should be investigated in the future include those dominant polychaetes, crustaceans, aplacophorans, and bivalves that occur in sufficient densities to lend themselves to life history analysis. More detailed investigation of reproductive morphology would also be instructive to determining seasonality of reproduction.

CHAPTER 4. BIOMASS OF BENTHIC INFAUNA

INTRODUCTION

Analyses of benthic infaunal communities most often involve studies in which macrofaunal organisms are removed from a known area of sediments, identified, and counted, followed by statistical testing and data interpretation. These analyses, based on numbers of organisms per unit area, can be supplemented by other studies, e.g., estimation of recolonization rates or measurements of benthic biomass or production. Biomass is defined as the amount of living substance constituting the organisms that are being studied and is alternatively called "standing stock" or "standing crop" (Crisp, 1984). Production is that part of assimilated food or energy that is retained and incorporated in the biomass of the organism, but excluding reproductive bodies released from the organism (Crisp, 1984). While production measures are informative about growth in populations, they are costly and time-consuming to conduct, even in shallow-water environments. Biomass measurements are made frequently, instead of production estimates, to determine standing stock of benthic infauna by obtaining a measure of the weight of the animals present. The "Study of Biological Processes of the U.S. South Atlantic Slope and Rise" provided the opportunity to make standing stock (i.e., wet weight and ash-free dry weight) measurements of preserved specimens from off North Carolina.

Measurements of wet weight and ash-free dry weight (AFDW) of benthic infauna were obtained from six box cores taken expressly for biomass estimates. The samples were collected during Cruise SA-6 in November 1985 at Station 4 off Cape Lookout and Station 10 off Cape Hatteras from depths averaging 2061 and 2004 m, respectively. The sediments were sieved through both 2.0-mm and 0.3-mm screens for extraction of animals and the size fractions were analyzed separately. The data provide comparisons between size fractions within and between samples; among faunal groups; between wet weight and AFDW; and, where station depths are similar, among geographic areas both along the eastern U.S. continental slope and throughout the world.

METHODS

Laboratory Analysis

The six box cores were collected during Cruise SA-6 with a Sandia 0.25-m^2 box core. Three replicate samples were collected at both Stations 4 and 10 (Appendix A). Methods for handling, preserving, and sorting the subcores were identical to those used for processing the infaunal samples, except for the resieving in the laboratory. This sieving process was conducted using both 2.0-mm and 0.3-mm sieves. The fractions were kept separate throughout the analyses. After sieving, the organisms from both fractions were sorted into nine taxonomic categories as follows: Annelida, Bivalvia, Other Mollusca, Arthropoda, Sipuncula, Pogonophora, Ophiuroidea, Other Echinodermata, and All Other Taxa. Counts of animals (whole or anterior sections with heads) were obtained for each category after the sorting had been completed.

Wet weight and AFDW biomass measurements were obtained for each category. To obtain wet weight measurements, the organisms were first rinsed out of the vial with 70 percent alcohol onto a screen. Forceps were used to remove the organisms from the screen and blot them dry on a screen-covered blotting pad for 15 to 30 sec or until all visible alcohol was removed. The organisms were then placed in a preweighed aluminum container. The sample size determined which of two weighing containers would be used: (1) an aluminum pan (57-mm diameter) or (2) a microbalance weighing boat (1 ml). Prior to use, all weighing containers were placed in a muffle furnace at 500°C for 2 hrs to remove any organic material and then were stored in a dessicator until used. All pans were weighed on a Mettler analytical balance that has an accuracy of 0.01 mg, and all boats were weighed on a Cahn 28 automatic electrobalance, which has an accuracy of 1.0 µg. The Cahn balance was calibrated daily with standard weights. The calibration weights for the Cahn and the forceps used to handle the weighing boats were cleaned with dicloromethane prior to use. The Mettler balance was calibrated according to a routine schedule. Both balances were zeroed before weighing and after every fifth sample weighed. A reading was taken 30 sec after placing the container on the balance to obtain the wet weight.

After the wet-weight biomass measurements had been obtained, the AFDW measurements began. First, dry weights were obtained by placing the sample containers into a drying oven at 60°C. The samples were removed from the oven after 24 h and

placed in a dessicator for at least 12 h. The containers were then weighed, with a reading being taken 30 sec after the containers were placed on the balance. Samples were then put in a muffle furnace at 450°C for 4 h. The samples were next removed from the oven and placed in a dessicator for at least 12 h. Then the samples were weighed as above. The container weight was subtracted from the wet, dry, and ash weights, and the AFDW was calculated as follows for each sample:

$$\text{AFDW} = \text{dry weight} - \text{ash weight}$$

Data Reduction and Analyses

Prior to weighing, epibenthic and pelagic species were excluded from the database. When the data were computerized, totals, means, and standard deviations were determined where appropriate. For each station, the coefficient of variation (CV) was determined for wet, dry, and ash-free dry weights and for number of individuals for the two size fractions separately and combined, as follows:

$$CV = SD\ (100/\bar{x})$$

where $\bar{x}$ is the mean of the particular weight and SD is the standard deviation. Data were converted from g/0.09 m^2 to g/m^2 by multiplying by a factor of 11.11.

RESULTS

Average total wet weight, dry weight, and AFDW at Station 10 were approximately 3.5, 3.5, and 2.4 times higher, respectively, than wet weight, dry weight, and AFDW at Station 4 (Tables 40 and 41, Figure 73). However, the mean total number of individuals at Station 10 was only 1.2 times higher than that found at Station 4. At Station 4, total wet weight ranged between 0.9605 and 1.3270 g/m^2, total dry weight ranged between 0.3501 and 0.4814 g/m^2, total AFDW ranged between 0.1920 and 0.2781 g/m^2, and total number of individuals ranged between 6955 and 10132 per m^2. At Station 10, total wet weight ranged between 2.8399 and 5.3632 g/m^2, total dry weight ranged from 0.8962 and 1.8459

TABLE 40. WET, DRY, AND ASH-FREE DRY WEIGHT (g/m^2) FOR SIZE FRACTIONS INDIVIDUALLY SUMMED BY STATION AND REPLICATE.

Station	Rep.	Wet Weight			Dry Weight			Ash-Free Dry Weight			No. of Individuals		
		0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total
4	1	0.9387	0.3883	1.3270	0.3556	0.1257	0.4813	0.2047	0.0734	0.2781	9465	667	10132
	2	0.9676	0.1348	1.1024	0.3356	0.0528	0.3884	0.1799	0.0276	0.2075	6477	478	6955
	3	0.7789	0.1816	0.9605	0.2939	0.0562	0.3501	0.1620	0.0300	0.1920	7199	489	7688
10	1	1.7265	2.0930	3.8195	0.5789	0.9885	1.5674	0.2313	0.2975	0.5288	8510	744	9254
	2	1.7843	3.5790	5.3633	0.6530	1.1929	1.8459	0.2302	0.4195	0.6497	8121	1911	10032
	3	1.4105	1.4294	2.8399	0.3826	0.5136	0.8962	0.2020	0.2151	0.4171	8755	2122	10877

TABLE 41. MEAN (g/m^2), STANDARD DEVIATION (SD) AND COEFFICIENT OF VARIATION (CV) FOR THREE REPLICATES OF WET WEIGHT, DRY WEIGHT, ASH-FREE DRY WEIGHT AND NUMBER OF INDIVIDUALS FOR U.S. SOUTH ATLANTIC STATIONS 4 AND 10. DATA PRESENTED WITH SIZE FRACTIONS SEPARATE AND COMBINED.

	Wet Weight			Dry Weight			Ash-Free Dry Weight			No. of Individuals		
	0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total
Station 4												
Mean	0.89506	0.23486	1.12992	0.32837	0.07824	0.40662	0.18217	0.04366	0.22583	7714	545	8258
SD	0.10161	0.13492	0.18480	0.03150	0.04118	0.06751	0.02143	0.02581	0.04591	1559.1	106.1	1663.5
CV	11.4	57.4	16.4	9.6	52.6	16.6	11.8	59.1	20.3	20.2	19.5	20.1
Station 10												
Mean	1.64043	2.36714	4.00756	0.53820	0.89832	1.43651	0.22117	0.31071	0.53188	8462	1592	10054
SD	0.20119	1.10068	1.27212	0.13974	0.34849	0.48819	0.01662	0.10285	0.11636	319.7	742.2	811.7
CV	12.3	46.5	31.7	26.0	38.8	34.0	7.5	33.1	21.9	3.8	46.6	8.1

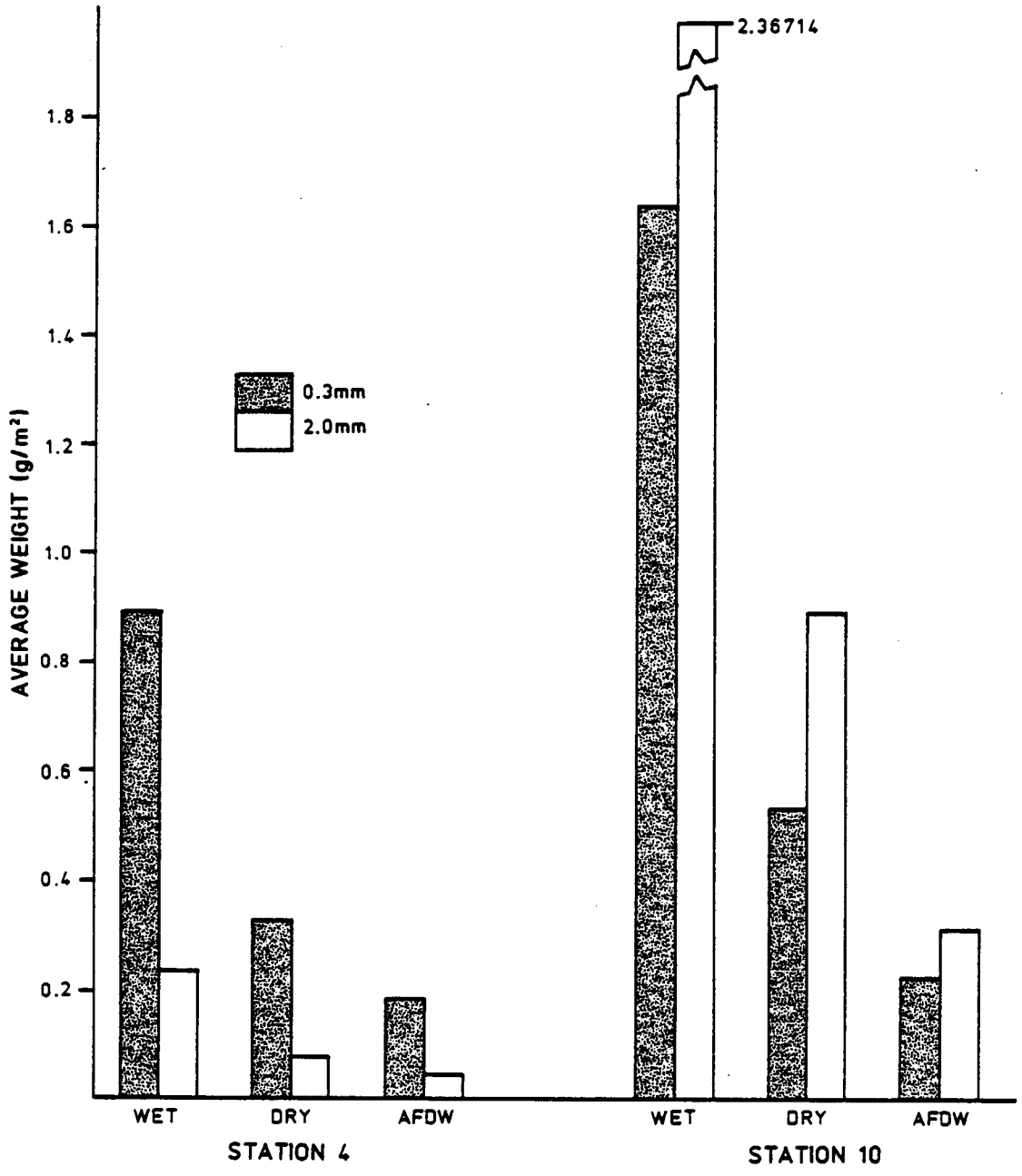


Figure 73. Average Wet, Dry, and Ash-Free Dry Weight (g/m^2) for Stations 4 and 10 with Size Fractions Presented Separately.

g/m^2, total AFDW ranged between 0.4171 and 0.6497 g/m^2, and total number of individuals ranged between 9254 and 10877 per m^2. The coefficient of variation for AFDW was approximately equal at both stations; whereas the coefficient of variation for wet weight and dry weight at Station 10 was approximately twice that of Station 4. The coefficient of variation of numbers of individuals for Station 4 was 2.5 times that of Station 10.

At Station 4, average wet weight, dry weight, and AFDW were approximately four times higher for the 0.3-mm size fraction than for the 2.0-mm size fraction; whereas mean number of individuals in the 0.3-mm size fraction was 14 times higher than in the 2.0-mm size fraction (Tables 40 and 41, Figure 73). At Station 4, the 0.3- and 2.0-mm size fractions made up 80.7 and 19.3 percent, respectively, of the average total AFDW and 93.3 and 6.7 percent, respectively, of the total number of individuals (Tables 42 and 43).

In comparison, at Station 10, the average wet weight, dry weight, and AFDW were approximately 1.5 times higher for the 2.0-mm size fraction than for the 0.3-mm size fraction. The number of individuals in the 0.3-mm size fraction at Station 10 was 5.3 times that in the 2.0-mm size fraction. At Station 10, the 0.3- and 2.0-mm size fractions composed 41.6 and 58.4 percent, respectively, of the average total AFDW and 84.2 and 15.8 percent, respectively, of the total number of individuals at Station 10.

The Annelida were the predominant taxonomic group in terms of biomass at both stations in both size fractions (Tables 42 and 43, Figures 74 and 75). The Annelida occurred most frequently at both stations in the 0.3-mm size fraction. In the 2.0-mm size fraction, the Annelida were the dominant group in terms of numbers of individuals at Station 10. However, at Station 4, the Pogonophora had the highest number of individuals in the 2.0-mm size fraction.

At Station 4, the Annelida constituted 64.4 percent of the mean total AFDW and 44.6 percent of the mean total number of individuals, and the Arthropoda, All Other Taxa, Sipuncula and Pogonophora combined made up 31.4 percent of the mean total AFDW and 48.4 percent of the total number of individuals (Tables 42 and 43, Figure 74). At Station 4, all taxonomic categories in the 0.3-mm size fraction weighed more (AFDW) than in the 2.0-mm size fraction. Similarly, there were more organisms in most of the taxonomic categories in the 0.3-mm size fraction than in the 2.0-mm size fraction.

TABLE 42. PERCENT COMPOSITION OF MEAN TOTAL AFDW (g/m^2) FOR EACH TAXON AND STATION PRESENTED WITH SIZE FRACTIONS SEPARATE AND COMBINED

	0.3 mm	Percent for Taxa	2.0 mm	Percent for Taxa	Screens Combined	Percent of Total
Station 4						
Taxon						
Annelida	0.12591	86.6	0.01952	13.4	0.14543	64.4
Arthropoda	0.01096	65.8	0.00570	34.2	0.01667	7.4
Bivalvia	0.00389	100.0	0.00000	0.0	0.00389	1.7
Other Mollusca	0.00263	100.0	0.00000	0.0	0.00263	1.2
Ophiuroidea	0.00041	100.0	0.00000	0.0	0.00041	0.2
Other Echinodermata	0.00152	59.5	0.00104	40.5	0.00256	1.1
Pogonophora	0.00644	51.3	0.00611	48.7	0.01255	5.6
Sipuncula	0.00782	87.9	0.00107	12.1	0.00889	3.9
All Other Taxa	0.02259	68.9	0.01022	31.1	0.03281	14.5
Total	0.18217	80.7	0.04366	19.3	0.22584	100.0
Station 10						
Taxon						
Annelida	0.13303	43.7	0.17161	56.3	0.30463	57.3
Arthropoda	0.02985	68.2	0.01392	31.8	0.04377	8.2
Bivalvia	0.03144	54.9	0.02581	45.1	0.05726	10.8
Other Mollusca	0.00888	22.0	0.03141	78.0	0.04029	7.6
Ophiuroidea	0.00026	100.0	0.00000	0.0	0.00026	<0.1
Other Echinodermata	0.00122	2.9	0.04055	97.1	0.04177	7.9
Pogonophora	0.00167	19.9	0.00670	80.1	0.00837	1.6
Sipuncula	0.00037	100.0	0.00000	0.0	0.00037	0.1
All Other Taxa	0.01444	41.1	0.02070	58.9	0.03515	6.6
Total	0.22116	41.6	0.31070	58.4	0.53187	100.1

TABLE 43. AVERAGE NUMBER OF INDIVIDUALS PER SQUARE METER EACH TAXON AND STATION PRESENTED WITH SIZE FRACTIONS SEPARATE AND COMBINED FOR U.S. SOUTH ATLANTIC STATIONS 4 AND 10.

	0.3 mm	Percent for Taxa	2.0 mm	Percent for Taxa	Screens Combined	Percent of Total
Station 4						
Taxon						
Annelida	3622	98.2	67	1.8	3689	44.6
Arthropoda	1878	98.3	33	1.7	1911	23.1
Bivalvia	200	100.0	0	0.0	200	2.4
Other Mollusca	222	100.0	0	0.0	222	2.7
Ophiuroidea	33	100.0	0	0.0	33	0.4
Other Echinodermata	111	96.9	11	3.1	122	1.5
Pogonophora	122	27.5	322	72.5	444	5.4
Sipuncula	900	90.0	100	10.0	1000	12.1
All Other Taxa	622	97.1	22	2.9	644	7.8
Total	7710	93.3	555	6.7	8265	100.0
Station 10						
Taxon						
Annelida	5111	79.7	1300	20.3	6411	63.8
Arthropoda	1489	93.3	111	6.7	1600	15.9
Bivalvia	1033	94.3	67	5.7	1100	11.0
Other Mollusca	200	89.8	22	10.2	222	2.2
Ophiuroidea	22	100.0	0	0.0	22	0.2
Other Echinodermata	78	87.5	11	12.5	89	0.9
Pogonophora	11	20.0	56	80.0	67	0.7
Sipuncula	22	100.0	0	0.0	22	0.2
All Other Taxa	489	95.0	22	5.0	511	5.1
Total	8455	84.2	1589	15.8	10044	100.0

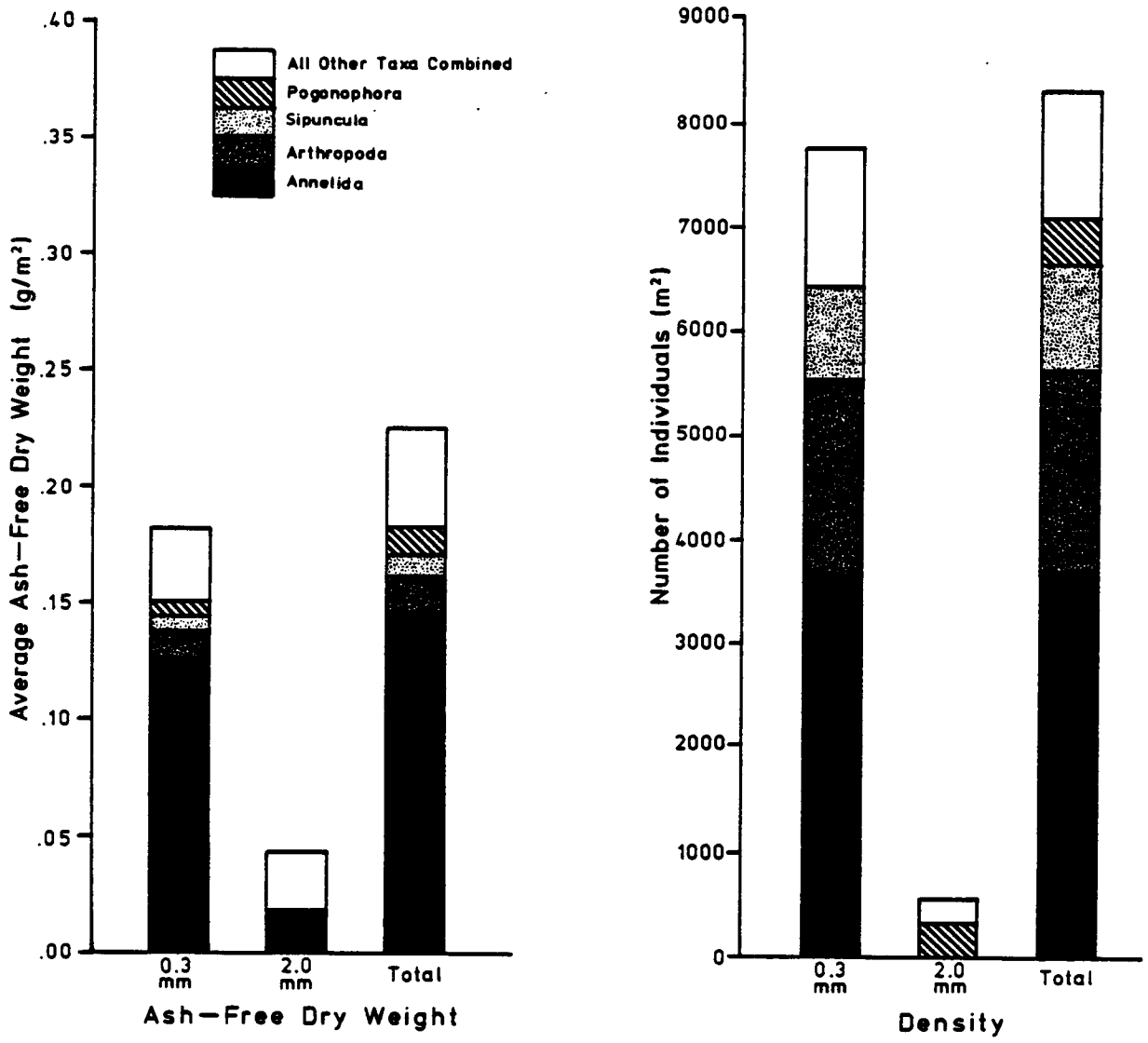


Figure 74. Average Ash-Free Dry Weight (g/m^2) and Number of Individuals (Number/m^2) for Station 4 with Size Fractions Presented Separately and Combined.

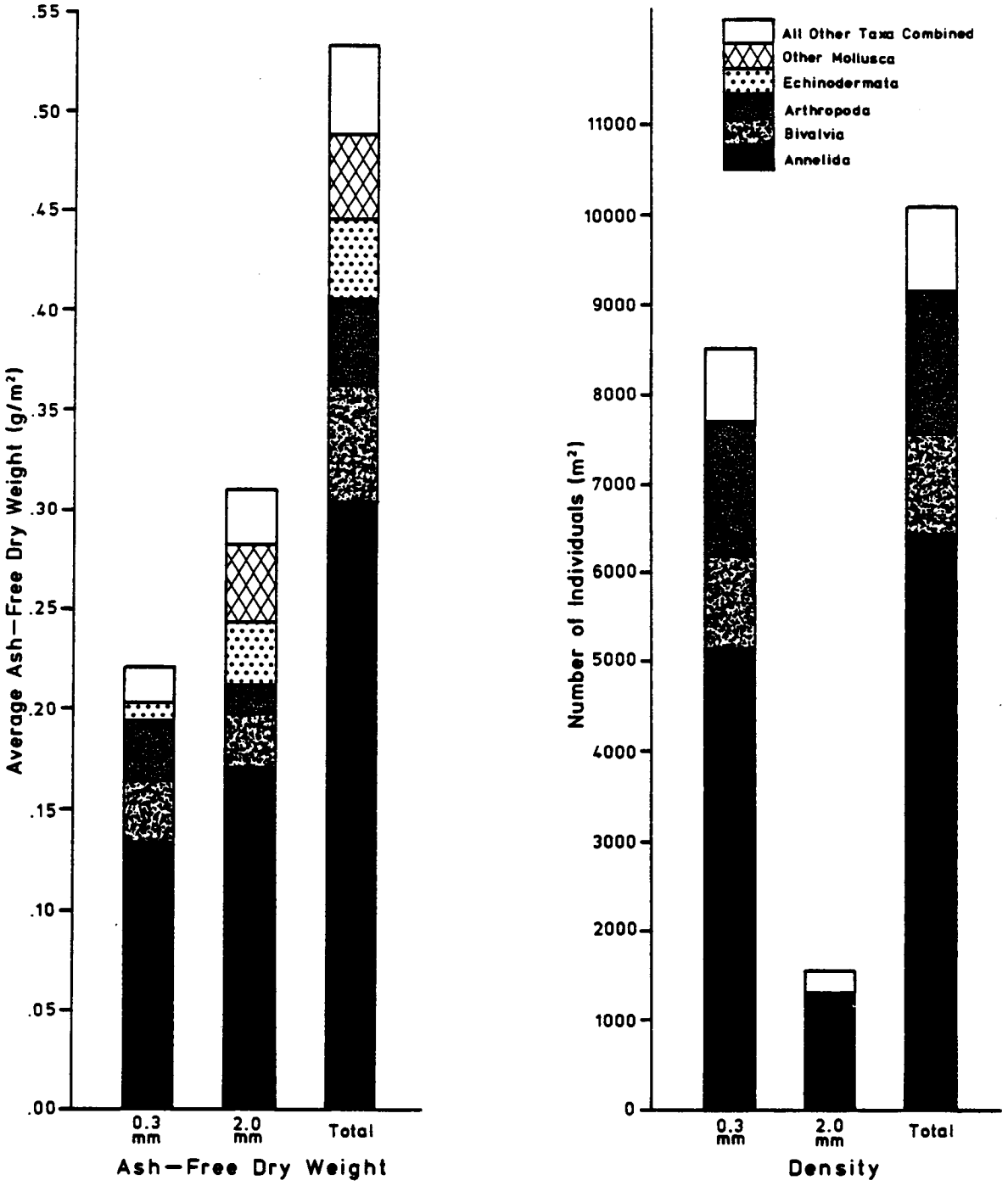


Figure 75. Average Ash-Free Dry Weight (g/m^2) and Number of Individuals (Number/m^2) for Station 10 with Size Fractions Presented Separately and Combined.

At Station 10, the Annelida made up 57.3 percent of the mean total AFDW and 63.8 of the mean total number of individuals, and the Bivalvia, Arthropoda, Other Mollusca, Other Echinodermata combined accounted for 34.5 percent of the mean total AFDW (Tables 42 and 43, Figure 75). Of these taxa, the Other Echinodermata was the only category found predominantly in one size fraction (i.e., the 2.0-mm fraction), and one organism constituted all the biomass in that fraction. As was the case for Station 4, more organisms were found at Station 10 in the 0.3-mm size fraction for most taxa than were found in the 2.0-mm fraction.

DISCUSSION

Biomass data from the two 2000-m stations off Cape Lookout and Cape Hatteras for Cruise SA-6 are generally consistent with results from similar depths (Blake et al., 1985; Maciolek et al., 1987). The considerable variability among replicates noted in other studies (Brown, 1985; Blake et al., 1985; Maciolek et al., 1987) was observed in this study as well, although to a lesser degree. Similarly, biomass was quite different between the two stations sampled during Cruise SA-6.

Except for Maciolek et al. (1987), all previous reports for biomass in deep-sea communities provide data for only wet and/or dry weight. As can be seen in Table 44, results are comparable with most other studies conducted at similar depths (Khripounoff et al., 1980; Dinet et al., 1985; Maciolek et al., 1987). Biomass of Georges Bank on the continental shelf was considerably higher than that of the continental slope and rise. Benthic macrofauna have been noted to decrease in size with increases in depth (Sanders et al., 1965; Thiel, 1975), resulting in a lower biomass with increasing depth. This is consistent with the idea that biomass decreases with increasing water depth (Rowe, 1983). The present results off North Carolina and those of Maciolek et al. (1987) along the U.S. Mid-Atlantic continental slope and rise indicate that biomass is slightly higher off eastern North America than in the Golfe de Gascogne off the coast of France in similar depths. Dinet et al. (1985) do not indicate that they removed or dissolved hardparts such as shells and tests. Therefore, the only other interpretations of biomass differences between the western Atlantic and the Golfe de Gascogne might be differences in (1) sampling dates, (2) productivity at the two sites, or (3) some other, as yet undetermined, factor.

TABLE 44. BIOMASS MEASUREMENTS (g/m^2) FROM SEVERAL STUDIES.

Geographic Area	Depth (m)	Wet Weight	Dry Weight	Ash-Free Dry Weight	Study
Georges Bank	38-168	11.46-426.00	-	1.377-23.861	Brown, 1985
U.S. Mid-Atlantic					
Station 6	2080	1.183	0.486	0.167	Maciolek et al., 1986c
Station 10	2090-2095	6.068	3.211	0.380	
U.S. South Atlantic (Phase 1)					
All Stations	583-3000	0.786-12.514	-	-	Blake et al., 1985
Station 4	2000	11.184	-	-	
U.S. South Atlantic (Phase 2)					This Study
Station 4	2000	1.130	0.407	0.226	
Station 10	2000	4.008	1.437	0.532	
Golfe de Gascogne, France	2100	-	0.157-0.161	-	Khripounoff et al., 1980
Golfe de Gascogne, France	4100	-	0.18	-	Dinet, 1985
Golfe de Gascogne, France	2100	-	0.29	-	

Wet weight biomass measurements for U.S. South Atlantic Study, Phase 1 (Blake et al., 1985) ranged between 0.786 and 12.514 g/m^2 and were considerably higher than those found at similar depths during Cruise SA-6 (present study). The difference in results between Phase 1 cruises and Phase 2 Cruise SA-6 may be attributable to at least two factors: (1) temporal variability may be a factor of considerable importance in these measurements and (2) the slightly different methods used may have resulted in overestimation of biomass in Phase 1. In Blake et al. (1985), individual species rather than major taxa were weighed after counting. Further, a less accurate balance was used in the measurement, followed by estimation of the weights below detection limits of the balance through a subsampling technique. This difference in methods could have led to an overestimation of biomass, but, if so, the difference was not anticipated to be as large as actually obtained. Therefore, we believe that the difference is a result of both factors.

The 0.3- and 2.0-mm size fractions have been studied both here and in Maciolek et al. (1987). The only outstanding trend is that the 2.0-mm size fraction is quite variable; the magnitude of the variability depends on the patchy distribution of larger organisms.

Annelids dominate the macrofaunal biomass of the deep sea (Jumars and Gallagher, 1982; Blake et al., 1985; Maciolek et al., 1987; present study). Other taxonomic groups that predominate are the molluscs and arthropods. Echinoderms were a notable portion of the biomass at Station 10 off Cape Hatteras (this study) and in Maciolek et al. (1987) for the U.S. Mid-Atlantic stations in the 2.0-mm fraction where they represented only a small number of individuals.

These data represent the second set of AFDW measurements from the U.S. ACSAR program with the first being reported in Maciolek et al. (1987) for the U.S. Mid-Atlantic region. The two sets of AFDW values are quite comparable. AFDW data are considered good measures of biomass because water weight, which adds considerable variability to measurements, is excluded and because AFDW measures organic matter with the nonliving parts removed (Crisp, 1984).

When examining the biomass data presented here and in other reports for the deep sea (Blake et al., 1985; Maciolek et al., 1987), the large variability among stations and replicates is apparent. The variability in this study, however, was slightly less than in the other two studies. The work discussed above measured standing stock only and not productivity. Because few species are numerically dominant in deep sea communities

(Sanders and Hessler, 1969), it would be difficult to design a deep sea study centered around productivity of one species. Sufficient material of a single species might be prohibitively expensive to collect. A valuable addition to this type of research would be an analysis of biochemical constituents of the standing stocks similar to the work conducted by Khripounoff et al. (1980) and Khripounoff and Rowe (1985).

CHAPTER 5. EPIFAUNA

INTRODUCTION

This chapter presents the results of Phase 2 of a study of megafaunal assemblages on the U.S. South Atlantic Continental Slope and Rise (ACSAR). The objective of Phase 1 was to assess seasonal stability of megafaunal populations off Cape Lookout and in the Hatteras Canyon area (Blake et al., 1985). The objectives of this second phase of the study were to assess megafaunal distribution patterns over a wider geographic area and in different habitats found within this region. The areas studied included the steep slope north of Cape Hatteras, N.C. in the vicinity of Block 510, the slope off Charleston, S.C. which underlies the Charleston Gyre, the slope off Cape Fear, N.C. and the northern Blake Plateau in the vicinity of the Charleston Bump. To accomplish these objectives, eleven camera-sled tows were conducted during three cruises in 1985 (May, September, and November).

The data presented in this chapter are based on an analysis of 35-mm color slides taken with a towed camera sled. Photographic methods for studying epifaunal populations have advantages over conventional survey techniques. Deep-sea megafauna is generally too sparsely distributed to be adequately sampled by bottom grabs or box cores. Additionally, these bottom samplers are not suitable for studying areas of lithified sediment, such as are found on the Blake Plateau. Trawls cover larger areas, but give questionable quantitative results and do not effectively sample areas of high relief. A comparison of density estimates obtained from trawls versus still photographs shows that trawl samples underestimate abundances by an order of magnitude (Haedrich et al., 1975). Motion picture techniques also tend to underestimate megafaunal abundances (Barham et al., 1967); whereas direct visual observation tends to overestimate abundances (Grassle et al., 1975). Uzmann et al. (1977) found that densities obtained from photographic techniques underestimated benthopelagic species in comparison to densities obtained from trawls. They suggest that this results from a photonegative response of benthopelagic species to the strobe of a photographic system. However, this explanation would account for only some of the observed differences between the two techniques because some

species appear to be attracted to the light or disturbance caused by a vehicle traversing the seafloor (Hecker, personal observations from submersible dives). Burrowing organisms tend to be underestimated by both trawls and photography.

METHODS

Sampling

Field Sampling Design

The areas surveyed for both phases of this study of megafaunal populations in the South Atlantic region are shown in Figure 76. The first phase consisted of seasonal transects on the continental slope and rise off Cape Lookout and on the slope in the Hatteras Canyon area. The second phase covered a wider geographic area and varying geologic and oceanographic habitats. The areas that were chosen to be studied in Phase 2 are 1) the exceptionally steep continental slope north of Cape Hatteras (in the vicinity of Block 510); 2) the flat slope off Charleston which underlies a semi-permanent cyclonic gyre (Charleston Gyre); 3) an area of very soft, silty sediment on the continental slope off Cape Fear; and the Charleston Bump, a ridge projecting seaward on the northern Blake Plateau. The field sampling design was continually updated to fill in data gaps and pursue interesting questions raised by previous sampling.

The steep slope north of Cape Hatteras was surveyed because of high industry interest in the Block 510 area. Because of the steep terrain and strong currents in this area, three camera-sled tows were necessary for adequate photographic coverage. One tow was conducted during each of the three cruises (May, September, and November of 1985). A long transect, consisting of three contiguous camera-sled tows, was positioned across the slope off Charleston. This area underlies a semipermanent cyclonic gyre (Charleston Gyre) produced by the seaward deflection of the Gulf Stream north of the Charleston Bump. In addition to addressing whether the presence of the gyre affected the megafauna inhabiting this region, this transect was also used to evaluate the possible presence of a zoogeographic break south of Cape Lookout (indicated by the results of

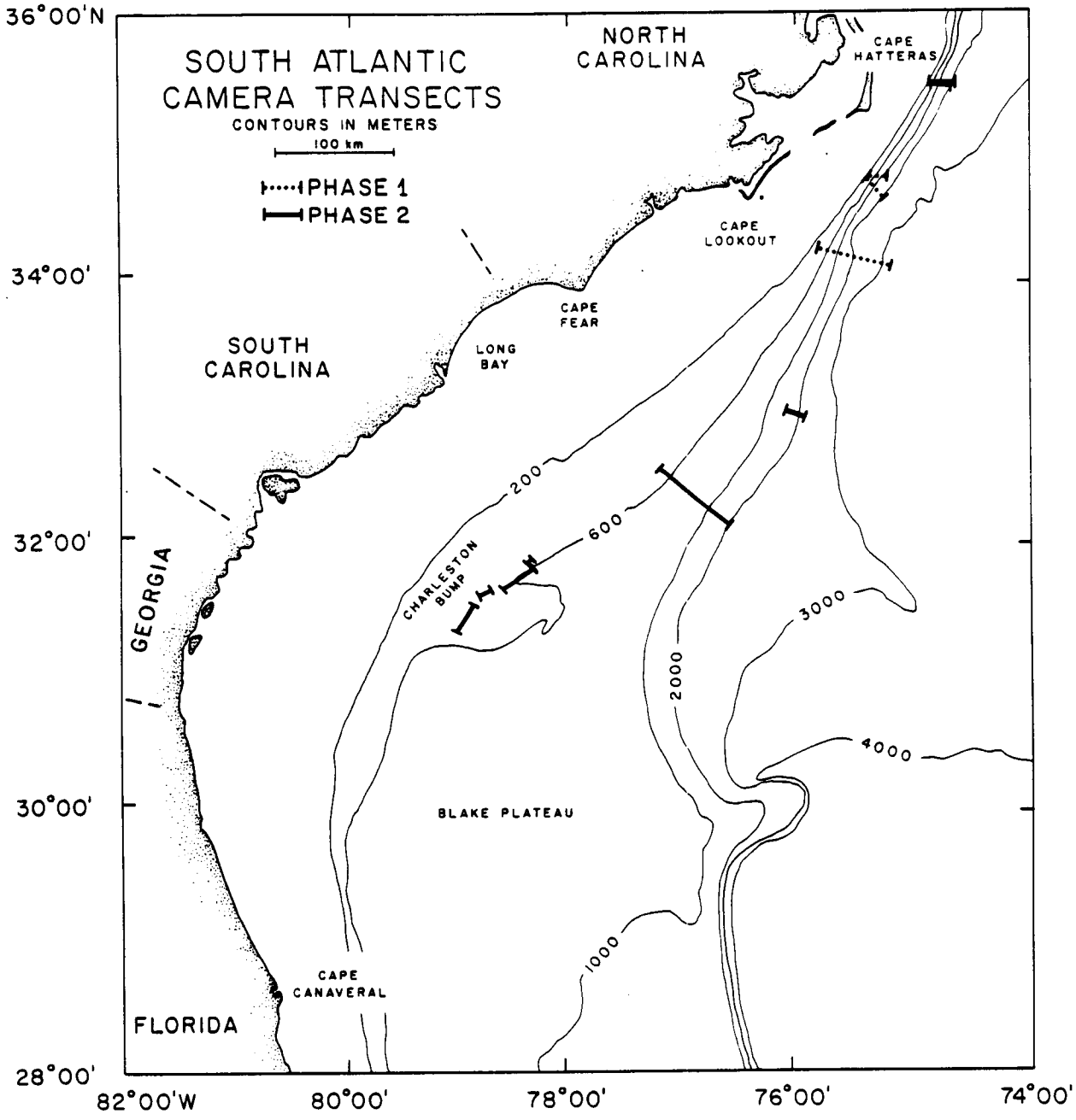


Figure 76. Location of Camera-Sled Tows for the Study of Megafaunal Populations in the South Atlantic.

trawls conducted during the first Phase 2 cruise). A short camera-sled tow was conducted on the continental slope off Cape Fear to further evaluate the presence of a faunal break in this vicinity. Additionally, box core results on previous cruises indicated that this area may be a region of deposition. Finally, four camera-sled tows were conducted in the vicinity of the Charleston Bump on the northern Blake Plateau. This area was chosen to study the effect of the Gulf Stream on the megafauna in this region. One camera-sled tow was taken on the upstream side, one on the top, and two on the downstream side, of the Charleston Bump. The deeper downstream tow was positioned to assess whether the trough behind the Charleston Bump was a region of deposition, and thus a possible site for infaunal sampling.

Photography

The photographs were taken with the towed-camera sleds BERNEI (Benthic Equipment for Reptant and Natant Epifaunal Imaging) and BABS (Benthic Apparatus for Biological Surveys). Although the frame and towing assembly of the two systems differed, they had identical camera angle and illumination configuration. BABS was originally designed as a backup system for BERNEI. In field tests, BABS was more tolerant of changes in towing angle and less prone to hanging up on protruding rock ledges. These characteristics proved valuable during the tows in the Charlestown Bump area of the Blake Plateau, where numerous low-relief ledges caused considerable damage to the skids and towing assembly of BERNEI.

The camera was oriented facing forward at an angle of 13.5^{o} down from horizontal and was mounted to ride 0.43 m above the seafloor. Illumination was provided by a 200-watt-second strobe mounted to the side and slightly above the camera. This configuration resulted in a low viewing-angle and sharp shadows which afforded the following advantages: side views aided in the identification of many taxa by presenting a clear view of features such as fin configuration of fish and polyp arrangement of soft corals; close proximity to the seafloor allowed enumeration of smaller taxa; and shadowing helped discern substrate-colored, transparent, or translucent organisms. The major disadvantage of low-angle views was the large variation in the area photographed (m^2) when the camera

sled traversed rough terrain. In these cases, area viewed was estimated based on the position of the horizon on the photograph, on the size of organisms, and on microtopography.

Exposures were made at automatic 15-sec intervals throughout each tow. At an average towing speed of 1 kn, a picture of approximately 10 m^2 was taken every 7.7 m, covering 52 percent of a 2.5-m-wide swath along the track of the tow. Because of light attenuation and inability to discern smaller organisms further away from the camera, the typical usable area per frame was 5 m^2. This resulted in a maximal quantifiable coverage of 26 percent along the transect line. In practice this coverage was less because the camera sled did not always maintain bottom contact on steep downhill grades, and tended to tilt forward on steep uphill grades. Run number, time, and depth were recorded on each frame.

Slide Examination

Each slide was systematically analyzed for area viewed (m^2), surficial geology, topography, faunal associations, and species occurrence and abundance. The number of square meters viewed was measured by photographing quadrants corrected for the refractive index of sea water. Species identification from photographs is tentative. It was virtually impossible to identify to the species level every organism observed on the slides. Within this constraint, each organism was identified as specifically as possible. With the exception of the fauna in the Charlestown Bump area, more than 95 percent of the organisms observed were assigned to a species category. Some lumping was unavoidable because species differences between congeners could frequently not be discerned in photographs. In the Charlestown Bump area, 36 percent of the organisms seen were juvenile sponges and corals. Because the shape and/or branching pattern of these juveniles were not well developed enough to allow identification to species, they were assigned to general sponge and coral categories.

Assignment of taxonomic names to the species catagories was greatly aided by the collection of voucher specimens. Collections were made by trawl on the slope off Cape Fear and Charleston and by Day dredge on the Charleston Bump. Voucher specimens were

particularly crucial for the latter area, because the fauna inhabiting this area had not been encountered in any of our previous studies. In fact, relatively little is known of the fauna in this region of the Blake Plateau. Of the 53 new species categories that were recognizable in the photographs from this area, we obtained voucher specimens for 33 of the most common ones.

All recognizable taxa were counted, but some were omitted from the statistical analyses of the data. Planktonic organisms were not included in any of the analyses. With the exception of Hyalinoecia sp., worm tubes were not included because it was impossible to determine whether they were inhabited. General taxonomic categories (i.e., sponge, coral, fish) were retained for abundance estimates and trophic pattern analysis, but were excluded from community analysis.

Quality Control

Two-person teams, consisting of one viewer and one keypuncher, viewed the film. After the data were entered for each picture, the keypuncher checked the frame to determine if any organisms had been omitted. During the viewing process, summary statistics were generated at the end of each day and checked for keypunch errors. Following initial viewing, summary statistics were generated for each film and checked for possible identification and typing errors. Notes taken by the viewers during laboratory analysis were then checked by the principal investigator against the film to identify any difficulties in species recognition. Finally, the film was checked against data listings for individual pictures. If inconsistencies were found, the entire film was rechecked and corrected.

Statistical Techniques

Two types of analyses, transect analysis and community analysis, were performed. Continuous transect plots of depth, trophic type, and density of total fauna and selected dominant taxa were generated. The depths were plotted for individual pictures, but the trophic type and density plots were based on 20-picture averages.

Community analysis included hierarchial, agglomerative classification and ordination. For both techniques, each transect was divided into homogeneous sample intervals. The transects were initially divided at temporal breaks in coverage exceeding 5 min and/or depth gaps exceeding 30 m. The remaining intervals were then divided into 30-picture intervals, which were treated as samples in the subsequent analyses. To reduce discrepancies between samples with unequal areal coverage, abundances were standardized to number per 100 m^2. A pairwise comparison of all samples within a transect was performed using the percent similarity coefficient (Whittaker and Fairbanks, 1958):

$$PS = 100\,(1.0-0.5\,\Sigma|p_{ia} - p_{ib}|) = 100\,\min\Sigma(p_{ia} - p_{ib})$$

where p_{ia} is the proportion of sample "a" composed by species "i" and p_{ib} is the same for sample "b." This is equivalent to the sum of the lesser proportion of each species common to both samples. Geographically contiguous samples with greater than 80 percent faunal similarity were pooled into composite samples for subsequent analysis. Only species with absolute abundances of ten or greater were retained for community analysis.

Community analysis consisted of normal (sample) and inverse (species) hierarchial classification. For normal analysis the percent similarity coefficient was used as a measure of faunal similarity between samples, and for inverse analysis the Bray-Curtis coefficient (Boesch, 1977) was used as a measure of distributional similarity between species. Unweighted pair-group clustering (Sokal and Sneath, 1963) was used as the amalgamation strategy in the analysis of samples; flexible clustering (Boesch, 1977) was used in the analysis of species. The inverse analysis was primarily used to reorder the data matrix to aid in interpreting the normal classification. Hierarchial classification clusters samples with similar species composition closer together and samples with dissimilar species composition further apart.

The grouping of samples into clusters tends to impose discontinuities on what may really be a graded series. Additionally, the one-dimensionality of a dendrogram focuses on inter-group resemblances, without adequately retaining the finer inter-sample relationships. To overcome these disadvantages, the data were ordinated by reciprocal

averaging (Hill, 1973; 1974). Ordination simultaneously arranges samples and species in as low-dimensional a space as possible, with similar entities close together and dissimilar entities further apart.

RESULTS

A total of eleven camera-sled tows, five long ones and six short ones, were conducted for the second phase of this study. Analyses of the faunal data collected from these tows are presented in this section. These results will be presented in two parts, one covering the continental slope areas north of the Blake Plateau and one covering the Charleston Bump area.

Slope Areas

Photographic Coverage and Geological Characteristics

The three camera-sled tows in the area off Cape Hatteras were each approximately 15 km long, and together covered a total depth range of 278 to 2003 m (Figure 77). The topography in this region of the continental slope was exceptionally steep and complicated. Depth profiles generated from the depth transducer on the camera sled indicated that the slope between 278 and 1800 m was sporadically interrupted by ridges and valleys that appeared to be oriented parallel to the isobaths. Additionally, numerous outcrops of consolidated sediment interrupted the steep slope above 1400 m. As a result of the steepness of the slope and its complicated topography, photographic coverage above 1400 m was very patchy (Table 45). In an attempt to obtain better coverage on the middle and upper slope, the last camera tow (November, 1985) was oriented to cross isobaths at an oblique angle (Figure 77), however, this approach did not yield satisfactory results. A total of 10,281 m^2 of the seafloor was viewed on the Cape Hatteras slope near Block 510. Most of this area was surveyed by the tows taken during the first two cruises. Representative photographs taken along the Cape Hatteras transect and Block 510 are shown in Figure 78.

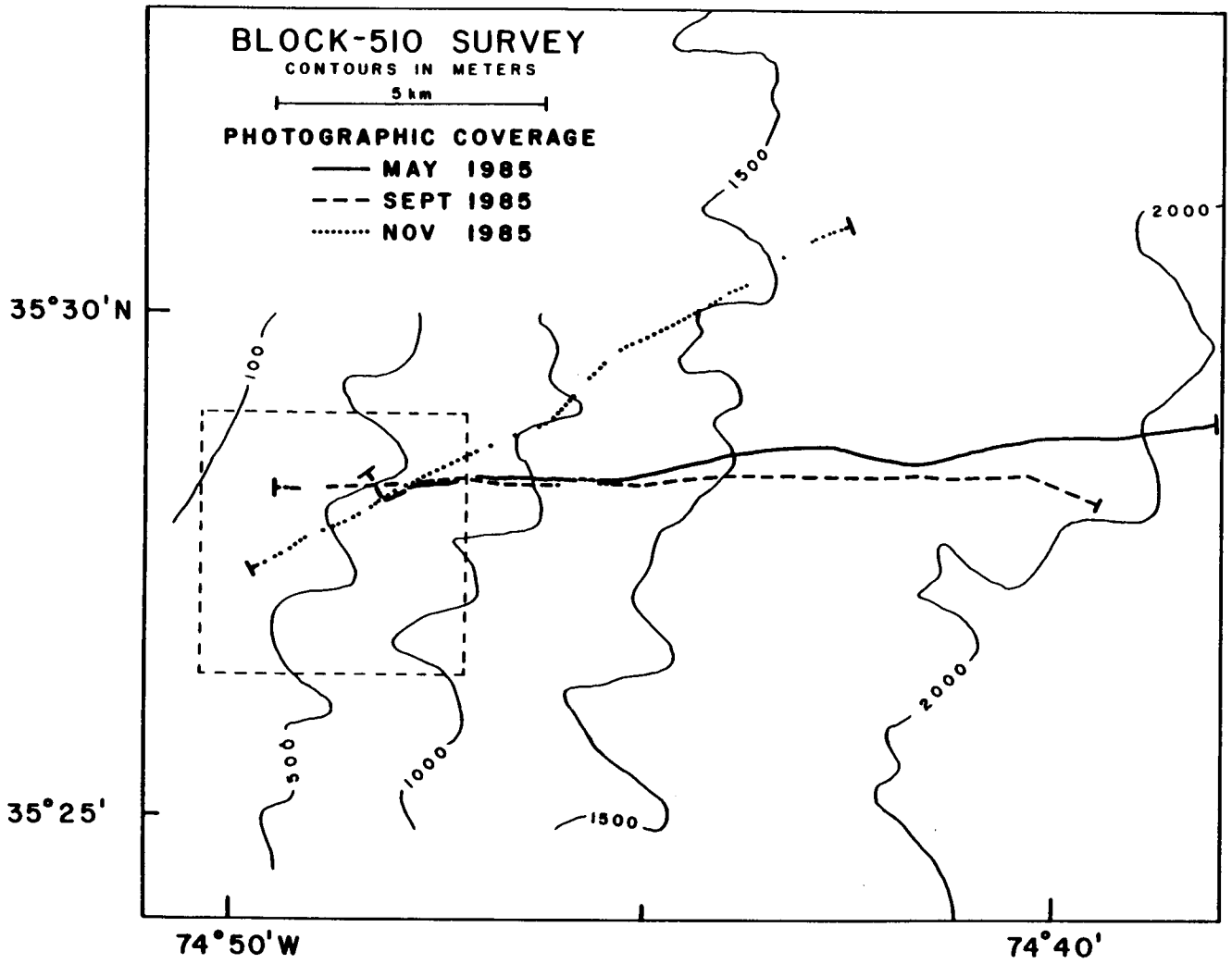


Figure 77. Photographic Coverage of Three Camera-Sled Tows on the Cape Hatteras Transect in Block 510.

TABLE 45. TOTAL AREA VIEWED (m^2) FOR 100-M DEPTH INTERVALS FROM SEASONAL CAMERA-SLED TRANSECTS IN THE CAPE HATTERAS (BLOCK 510) AREA.

Depth Interval (m)	May 1985	Sep 1985	Nov 1985	Total
278-299			15	15
300-399		181	26	207
400-499		69	4	73
500-599	106	86	43	235
600-699	106	195	183	484
700-799	113	173	47	333
800-899	35	150	4	189
900-999	6	62	12	80
1000-1099	33	42	96	171
1100-1199	57	50	21	128
1200-1299	28	105	121	254
1300-1399	141	118	100	359
1400-1499	102	226	303	631
1500-1599	102	509		611
1600-1699	310	235	38	583
1700-1799	393	139	5	537
1800-1899	1420	893		2313
1900-1999	1024	2001		3025
2000-2003	53			53
Total	**4029**	**5234**	**1018**	**10281**

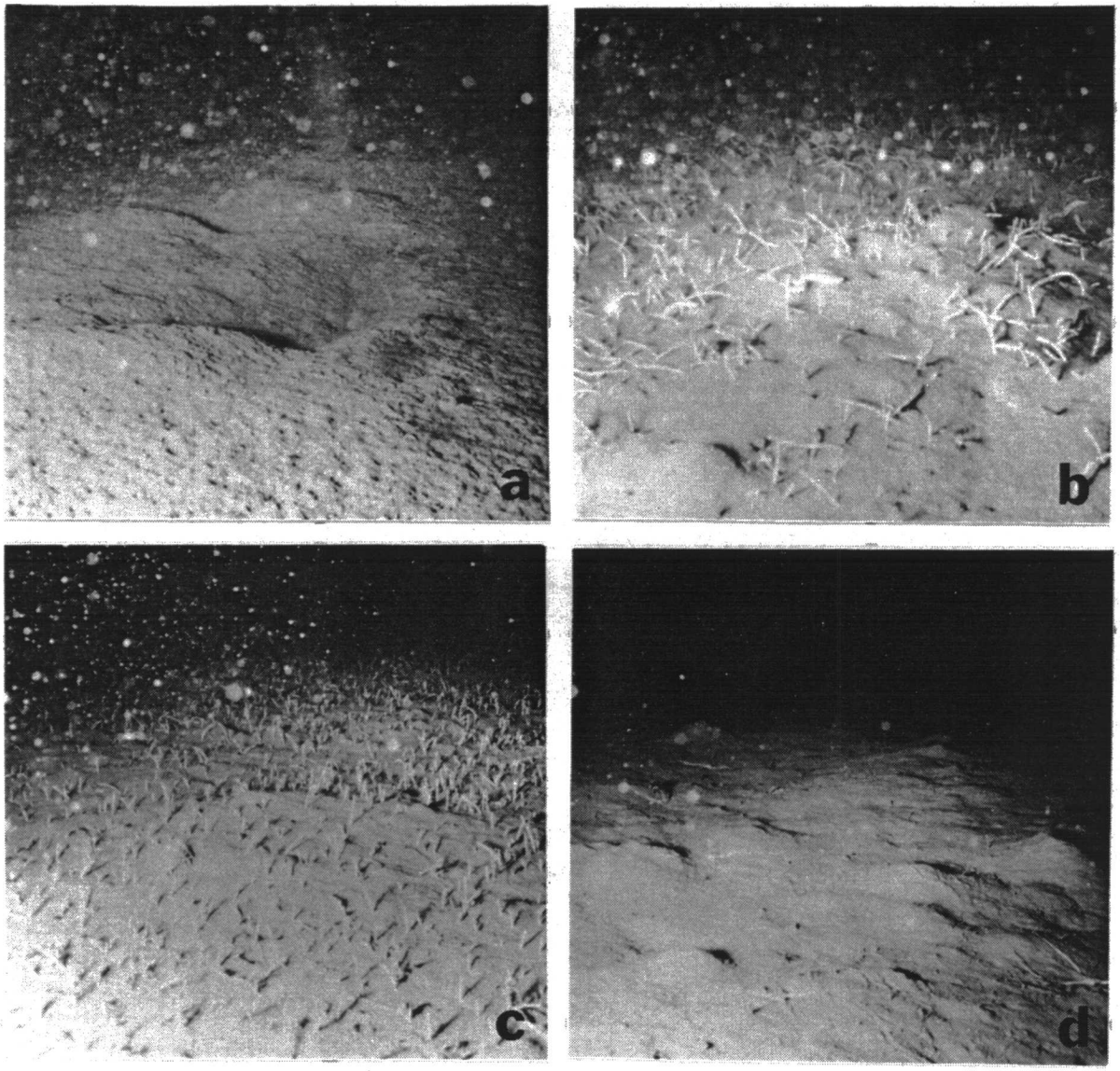


Figure 78. Representative Bottom Photographs from the Cape Hatteras (Block 510) Camera-Sled Transects. Note the High Amount of Suspended Particulate Matter Shown in the First Three Photographs. a. Steep Upper Slope, with Numerous Dimple-like Crustacean Tracks (343 m). b. Middle Slope with High Concentrations of White Tubes (788 m). The Fish is the Eel Pout, Lysencheles verilli. c. Lower Slope (1897 m) with High Concentrations of White Tubes Persisting; Organism Responsible for These Tubes Not Yet Identified. d. Flatter Part of Lower Slope Characterized by Gentle Mounds Caused by Burrowing Activity (1957 m). The Brittle Star, Ophiomusium lymani, is the Dominant Epifaunal Organism in this Region.

The 12.5-km-long transect off Cape Fear covered a depth range of 1534 to 2147 m (Figure 79). The seafloor throughout this area consisted of fine-grained sediment interrupted by a low-relief outcrop of consolidated sediment at 1712 m. A total of 6773 m^2 of the seafloor was viewed along this transect (Table 46).

The 70-km-long transect on the slope off Charleston consisted of three contiguous camera-sled tows and spanned a depth range of 559 to 2126 m (Figure 80). The seafloor between 559 and 640 m was characterized by large sand waves, with steep west faces and gradually sloping east faces. These sand waves appeared to be oriented parallel to the isobaths. Well-developed ripple marks, indicating intermittent, high current activity, were prevalent throughout this area. Between 640 and 715 m the seafloor was characterized by a series of low-relief ridges that also appeared to be parallel to the isobaths. The ridge crests consisted of a thin sandy veneer covering a hard material whereas the sides of the crests had a heavy drape of finer-grained sediment. The seafloor between the ridges consisted of a hard subsurface covered by a thin layer of fine-grained sediment. Toward the shoaller portion of this area, ripple marks occasionally covered the steep landward faces of the ridges. Between 715 and 750 m the seafloor consisted of a fine-grained sediment covering a hard surface. Below 750 m the seafloor consisted of a fine-grained sediment that appeared to reach a maximum in thickness and siltiness at 990 m. Below this depth the sediment gradually became coarser grained again and more compacted. This compactedness reached a maximum around 1750 m. Below 1800 m gravel and cobble-sized fragments of consolidated sediment were frequently seen on the seafloor. The presence of numerous remains of seaweed and fine-scale microstructure between 750 and 1180 m indicates that bottom currents were minimal in this area.

A total of 32,649 m^2 of the seafloor was viewed along this transect (Table 47). Because the camera sled maintained bottom contact throughout this transect, the number of cubic meters viewed within 100-m depth intervals reflects the steepness of the slope. The slope was moderately steep below 1200 m and gradually flattened above that depth. Representative bottom photographs taken along the Charleston and Cape Fear transects are shown in Figure 81.

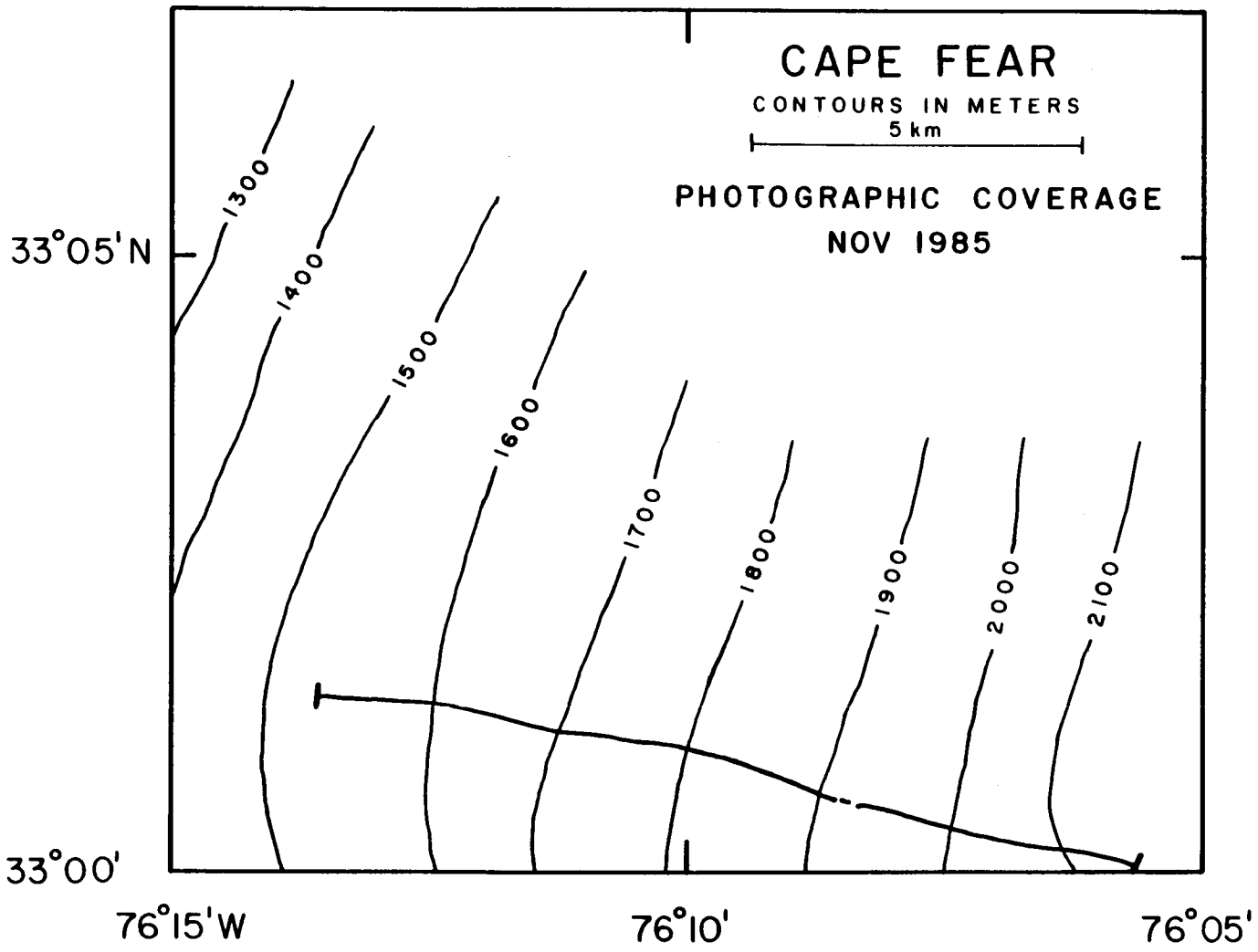


Figure 79. Photographic Coverage of One Camera-Sled Tow on the Cape Fear Transect.

TABLE 46. TOTAL AREA VIEWED (m^2) FOR 100-M DEPTH INTERVALS FROM A CAMERA-SLED TOW ON THE SLOPE OFF CAPE FEAR, N.C.

Depth Interval (m)	Area
1534-1599	991
1600-1699	1113
1700-1799	893
1800-1899	1325
1900-1999	979
2000-2099	935
2100-2147	537
TOTAL	**6773**

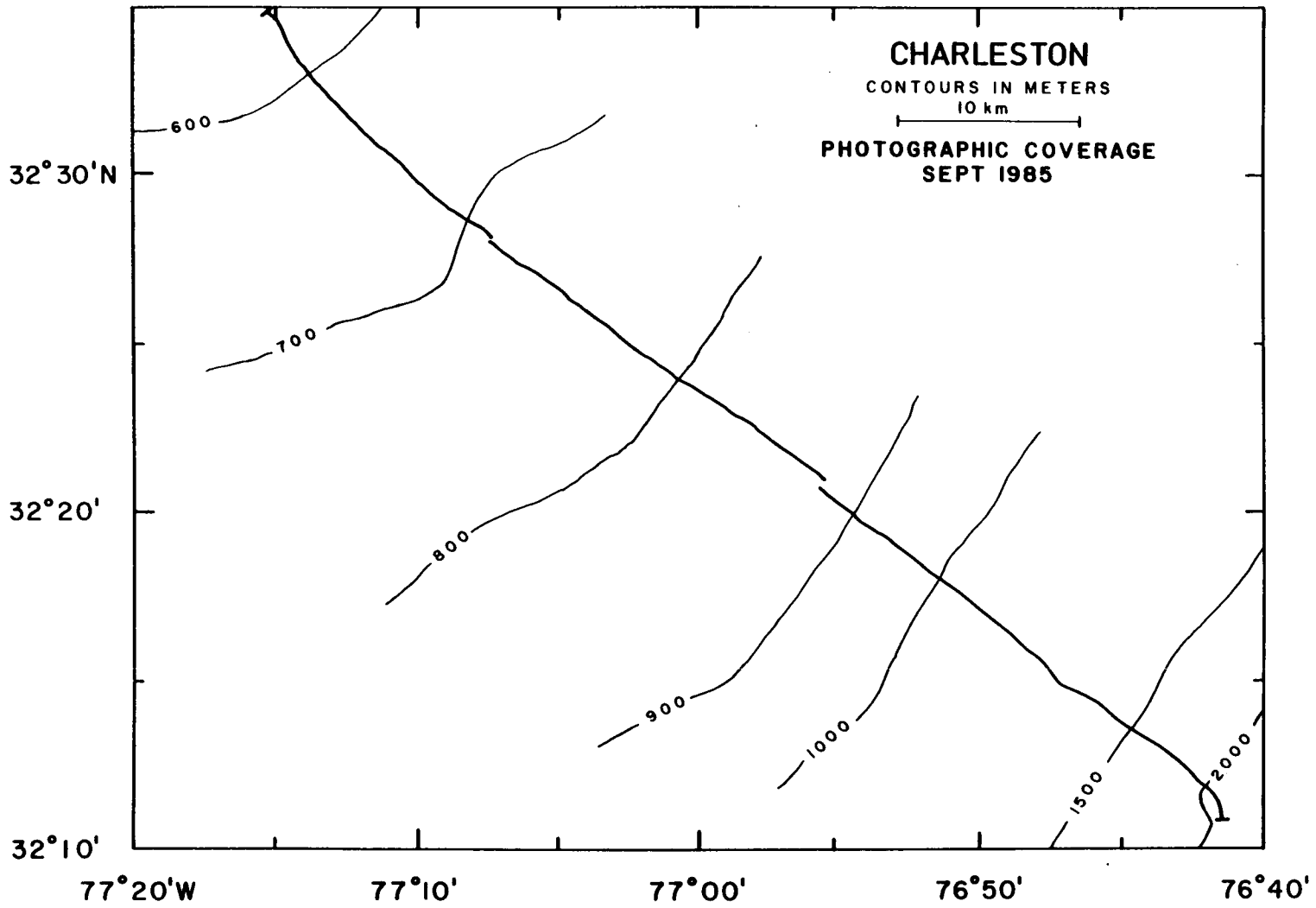


Figure 80. Photographic Coverage of Three Camera-Sled Tows on the Charleston Transect.

TABLE 47. TOTAL AREA VIEWED (m^2) FOR 100-M DEPTH INTERVALS FROM THE CAMERA-SLED TRANSECT ON THE SLOPE OFF CHARLESTON, S.C.

Depth Interval (m)	Area
559-599	1940
600-699	5738
700-799	6916
800-899	6395
900-999	3045
1000-1099	1994
1100-1199	1209
1200-1299	908
1300-1399	541
1400-1499	561
1500-1599	431
1600-1699	404
1700-1799	370
1800-1899	509
1900-1999	439
2000-2099	852
2100-2126	397
TOTAL	**32649**

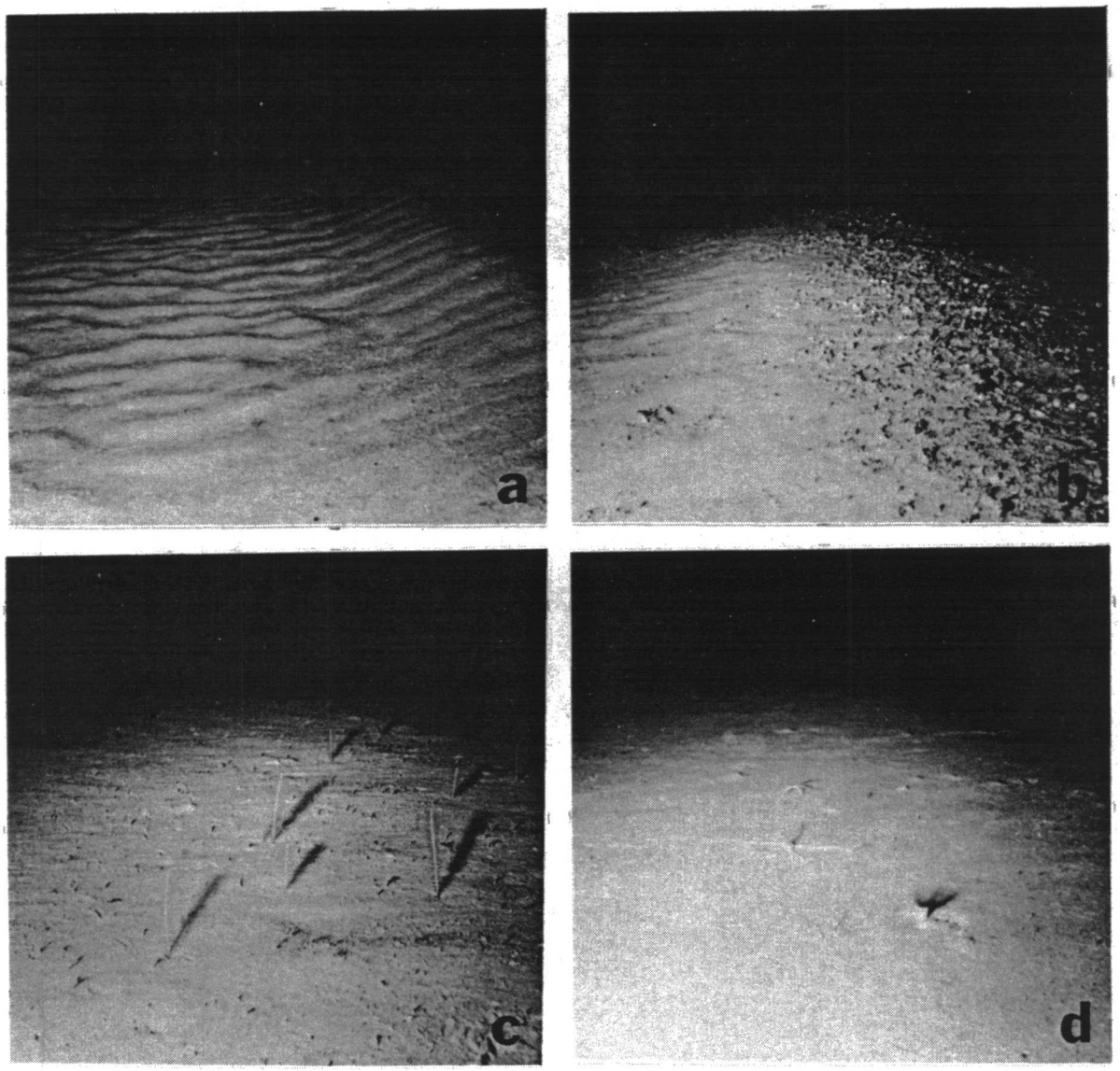


Figure 81. Representative Bottom Photographs from the Charleston Camera-Sled Transect. a. Sand Waves with Well Developed Ripple Marks Characteristize Shallow Portion of this Transect (621 m). b. Slightly Deeper, Ridges Provide Suitable Hard Substrate Attachment Sites for the Solitary Hard Coral Bathypsammia tintinabulum (652 m). c. Flat Middle Slope Inhabited by Dense Population of an Unidentified Sea Pen (1068 m). Fine Scale Microstructure Indicates Weak Currents. d. Flat Lower Slope Inhabited by Two Brittle Star Species, Bathypectinura heros (Center) and Ophiomusium lymani (Center Front and Center Rear), and Cerianthid Anemones (Front Right). Lack of Fine Microstructure and Burrowing Indicates Compacted Sediment Swept by Currents (2121 m).

Faunal Abundance and Depth Distribution

The density of total megafauna with depth in the three slope areas is shown in Figure 82. Megafaunal abundance in the northern slope area off Cape Hatteras at Block 510 was intermediate between 300 and 900 m, uniformly low between 900 and 1600 m, and high below 1600 m, with a peak in density between 1800 and 1900 m. The limited coverage on the slope off Cape Fear shows that megafauna below 1600 m also increased in this area, but that the peak was shifted slightly deeper (to between 2000 and 2100 m). The southern slope area (off Charleston) showed a slightly different pattern of megafaunal abundance with depth. In this region three intermediate peaks in abundance occurred between 559 and 2126 m. Closer examination of the taxa responsible for the observed megafaunal densities revealed differences in the taxa inhabiting these areas.

In all three areas the deeper peak in megafaunal abundance was almost entirely due to dense populations of the brittle star Ophiomusium lymani (Figure 83). Densities of O. lymani (1.8 individuals per m^2) were much lower on the slope off Charleston than on the slope off Cape Fear (5.9 individuals per m^2) or north of Cape Hatteras (5.0 individuals per m^2).

Figure 84 shows the relative proportion of total megafaunal abundance contributed by the five most common species in the Block 510 area off Cape Hatteras. Together, these five species accounted for the majority of the fauna seen on this slope. The large burrowing anemone Cerianthus borealis dominated the fauna above 500 m. Between 500 and 1100 m two species, the eel pout Lysenchelys verilli and the anemone Actinauge verilli, dominated the fauna inhabiting the steep slope. Exceptionally dense concentrations (50 to 150 per m^2) of a large white polychete tube were also seen in this area. Between 1100 and 1600 m the sparse megafauna consisted almost entirely of several fish species. Below 1600 m the megafauna was totally dominated by O. lymani.

The depth distributions of the three common eel pouts on the Cape Hatteras slope in the vicinity of Block 510 are shown in Figure 85. Of these eel pouts, L. verilli was the most abundant and also had the shallowest distribution, with a peak in density of 0.85 individuals per m^2 between 600 and 800 m. The distributions of the two deeper species, an unidentified grey eel pout and Lycodes atlanticus, overlapped considerably, but each

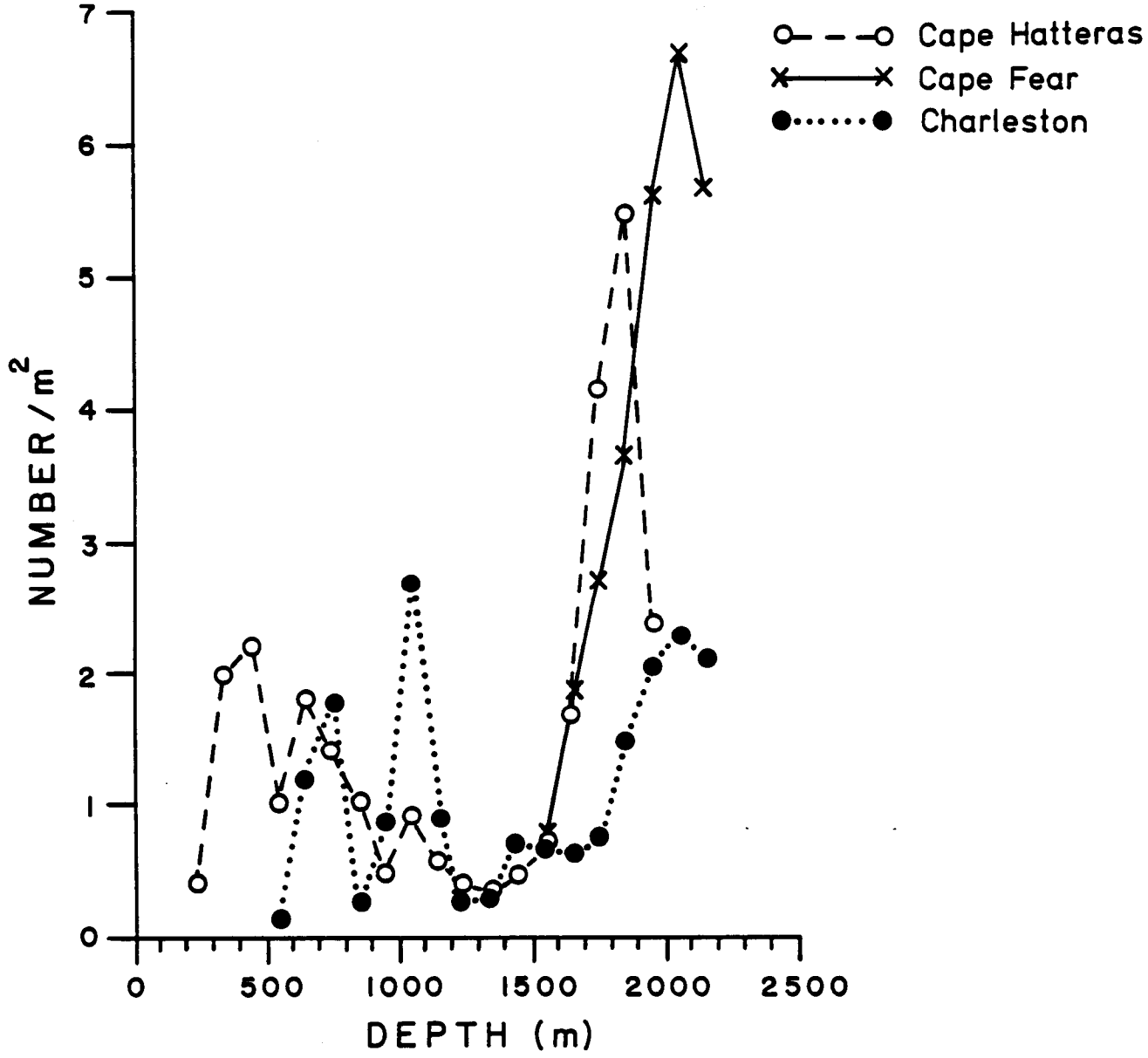


Figure 82. Density of Total Megafauna with Depth on Three U.S. South Atlantic Slope Transects.

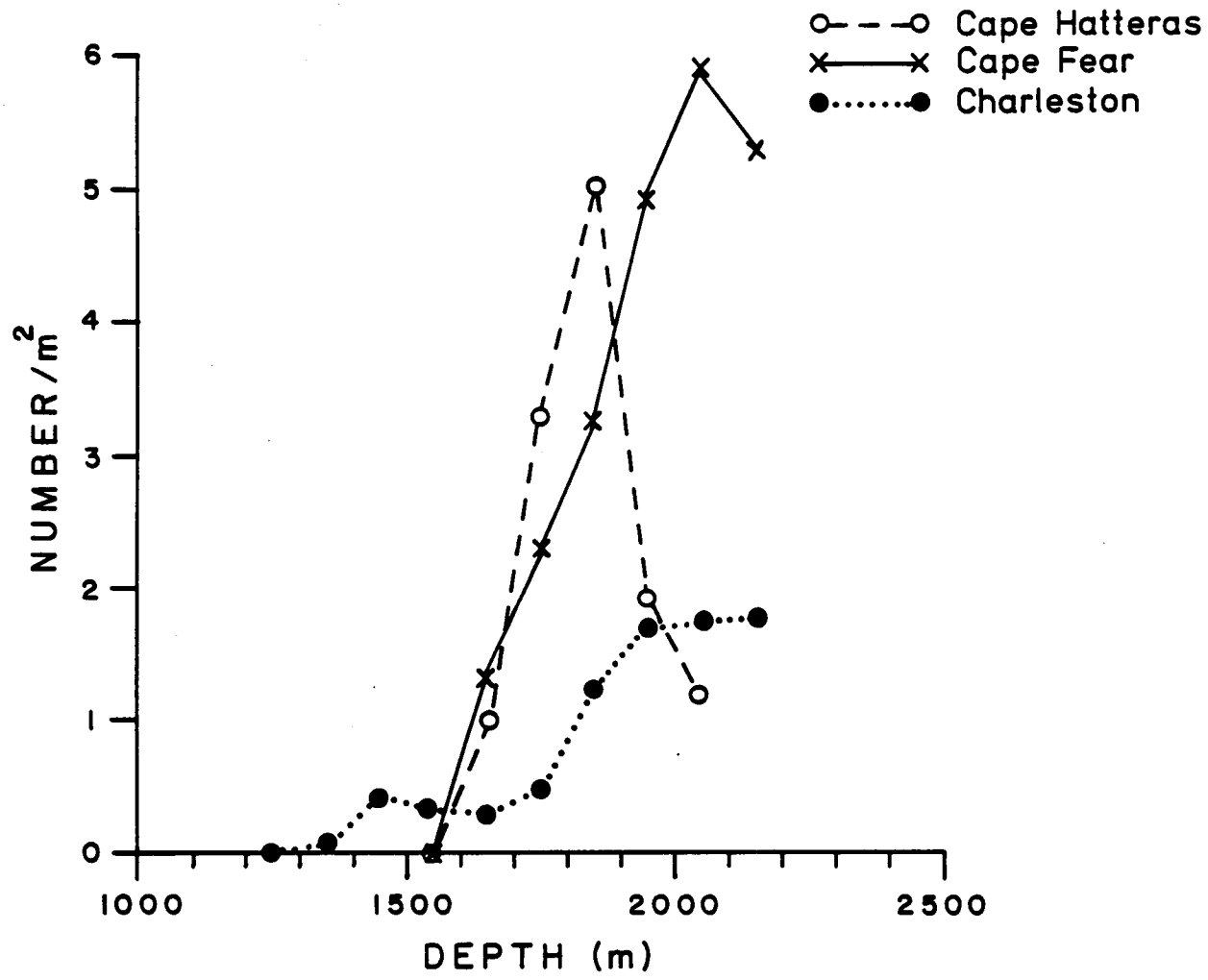


Figure 83. Density of the Brittle Star Ophiomusium lymani with Depth on Three Transects Off North and South Carolina.

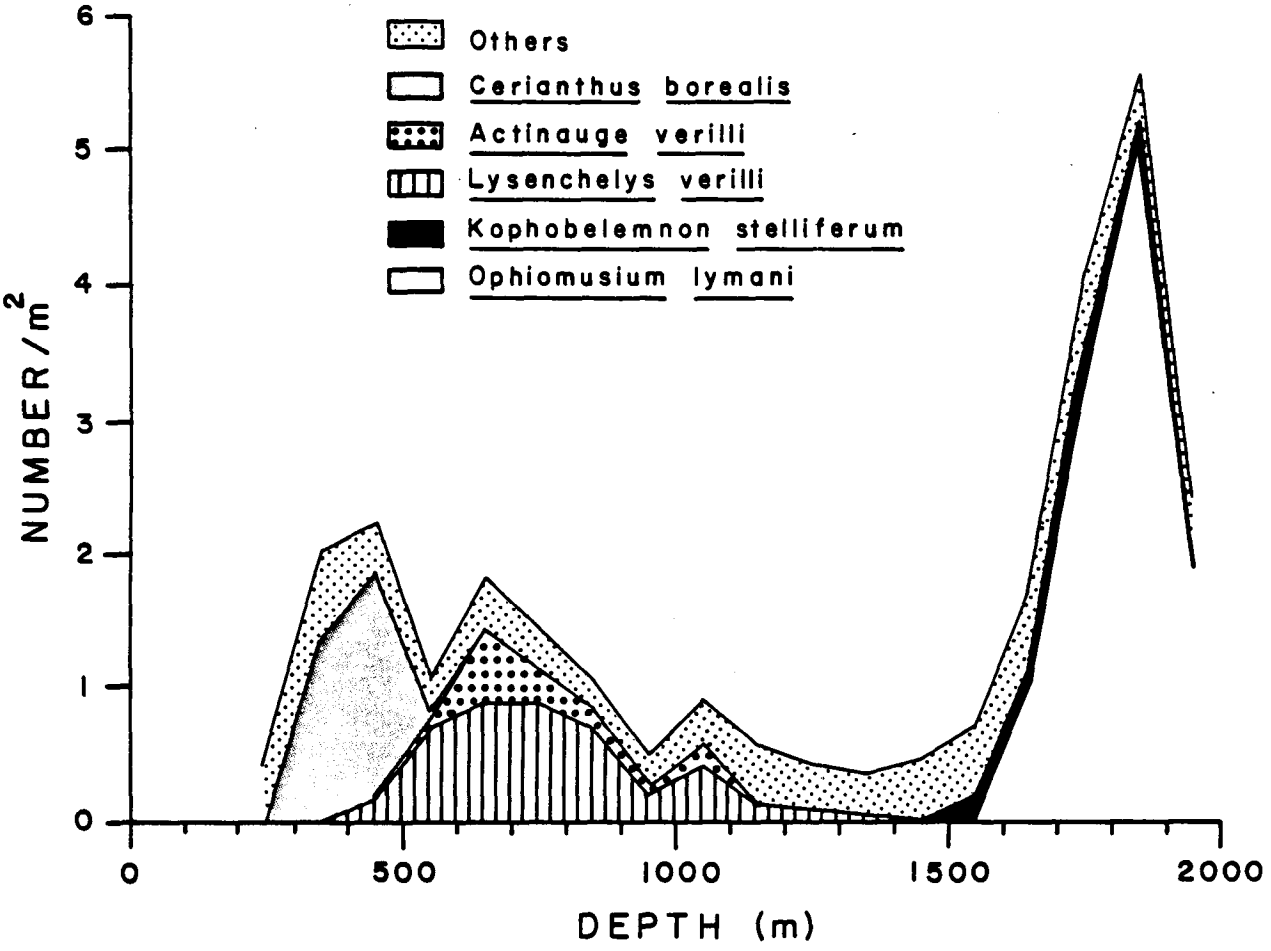


Figure 84. Density of Total Megafauna and the Five Most Common Species with Depth on the Cape Hatteras Transect in the Block 510 Area.

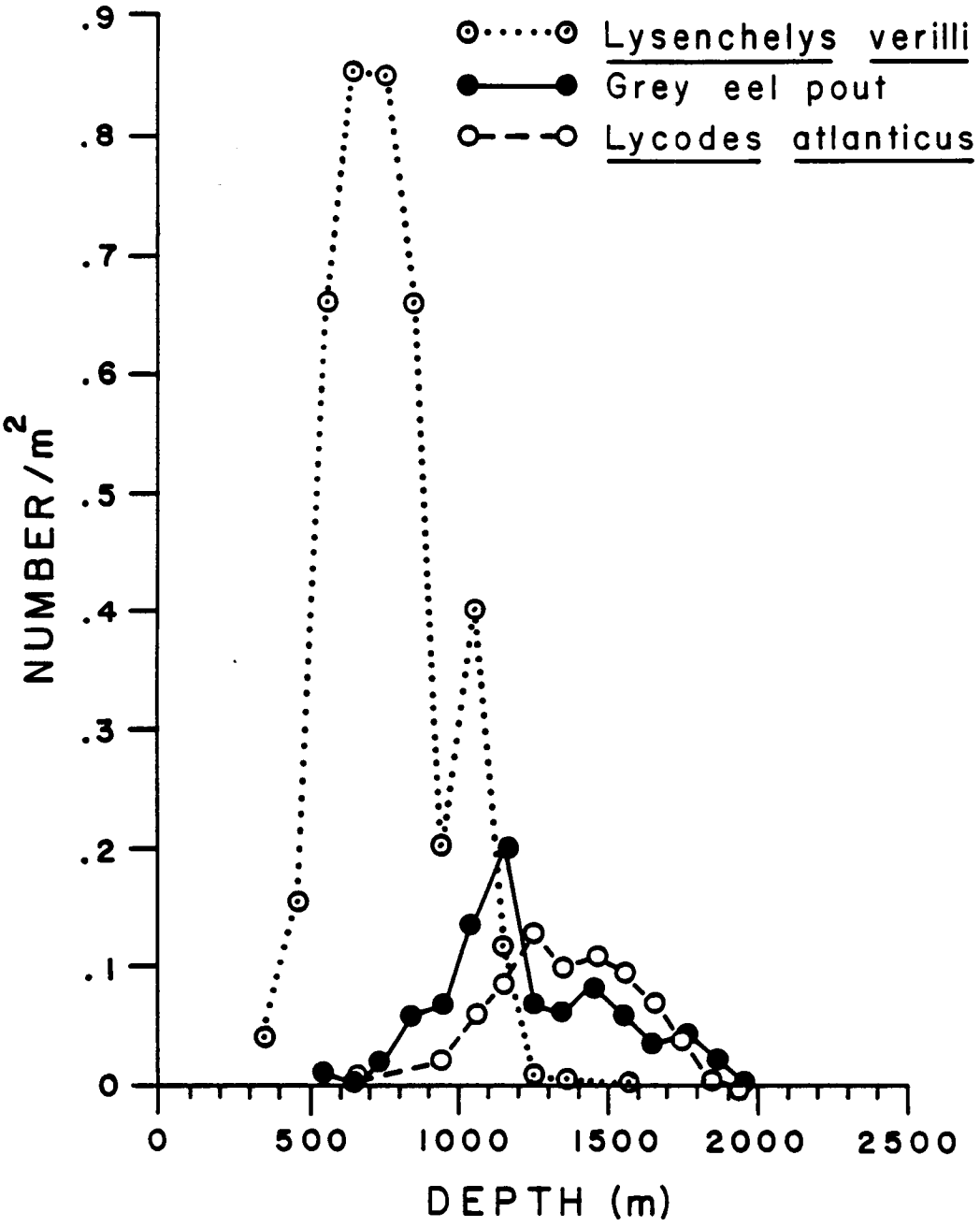


Figure 85. Depth Distributions of Three Eel Pouts on the Cape Hatteras Transect in the Block 510 Area.

showed a slightly different depth optimum. The grey eel pout was present in highest densities (0.20 individuals per m^2) between 1100 and 1200 m; whereas L. atlanticus was present in highest densities (0.10 to 0.13 individuals per m^2) between 1200 and 1500 m.

Figure 86 shows the relative proportion of total megafaunal abundance with depth contributed by the three most common species on the slope off Charleston. The sand waves at the shallow end of the transect were almost devoid of fauna. Between 600 and 800 m dense populations (1.5 individuals per m^2) of the hard coral Bathypsammia tintinnabulum accounted for most of the fauna seen. Slightly deeper, the fauna on the silty slope between 900 and 1200 m was dominated by high densities (2.4 individuals per m^2) of a large unidentified sea pen. Between 1200 and 1800 m several species of fish accounted for approximately half of the fauna. Below 1800 m the fauna was mostly dominated by O. lymani. This region was also inhabited by several species of fish and one crustacean.

The depth distributions of the four most common crustaceans on the slope off Charleston are shown in Figure 87. Each of these species showed a marked habitat preference. A large red and white spider crab, Rochinia sp., inhabited the sand waves found at the shallow end on the transect. A pagurid crab, Parapagurus sp., inhabited an area of low-relief ridges slightly deeper along the transect. The dominant crustacean in the soft sediment region between 800 and 1200 m was a large shrimp, Glyphocrangon sp. Below 1200 m the dominant crustacean was another pagurid crab, Catapagurus sp.

Community Analysis

Cape Hatteras Transect (Block 510). Classification analysis of the 57 pooled sample areas and 38 species from three camera-sled tows on the Cape Hatteras slope defines four major clusters at a faunal similarity level of 20 percent (Figure 88). The mean depths of areas within these clusters clearly show that the clustering structure is a function of depth. Each of the clusters further subdivides, on the basis of depth, into groups of areas with higher faunal similarities. Major faunal breaks occurred at 1200 and 1500 m, and a minor break occurred at 500 m. A plot of the groups formed by cluster analysis along the camera-sled tows is shown in Figure 89, and the fauna indicative of each of the cluster groups are presented in Table 48.

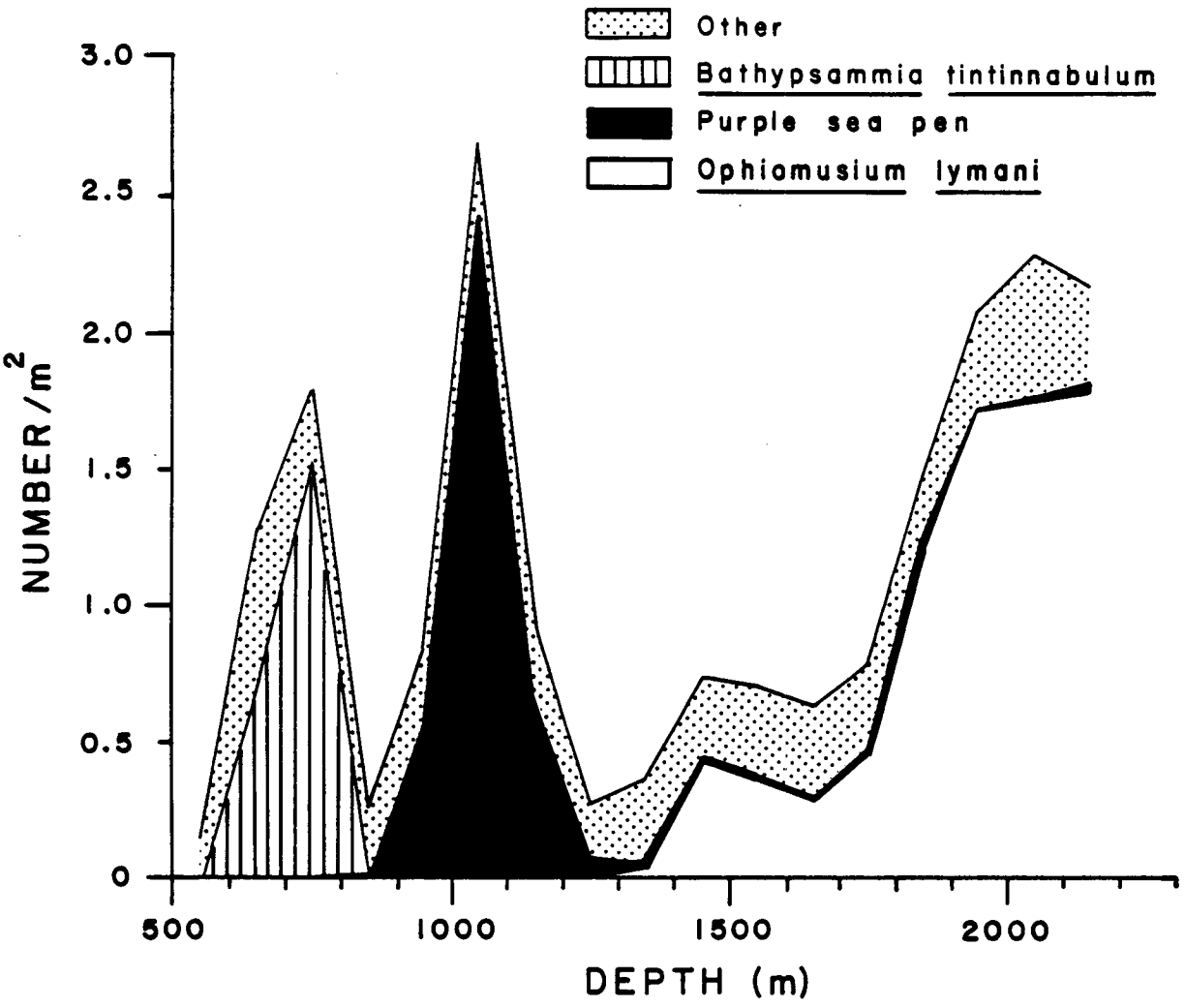


Figure 86. Density of Total Megafauna and the Three Most Common Species with Depth on the Charleston Transect.

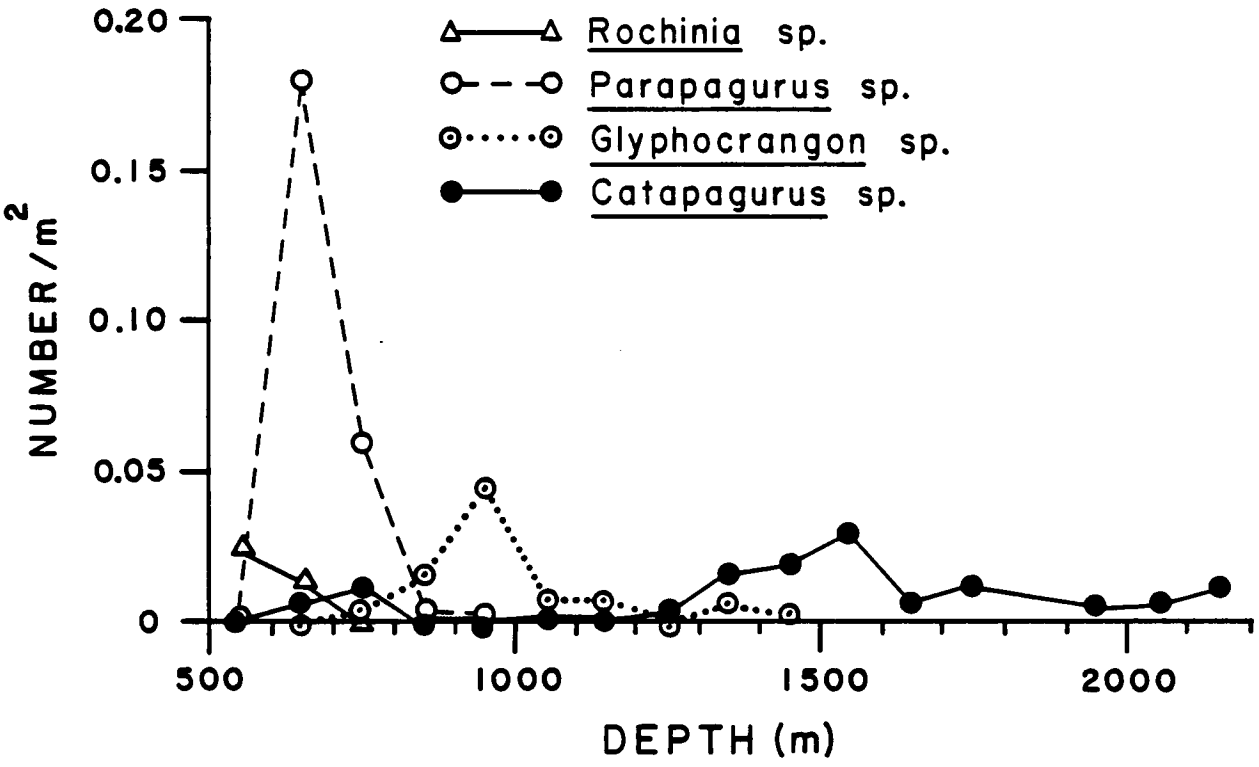


Figure 87. Depth Distributions of Four Crustaceans on the Charleston Transect.

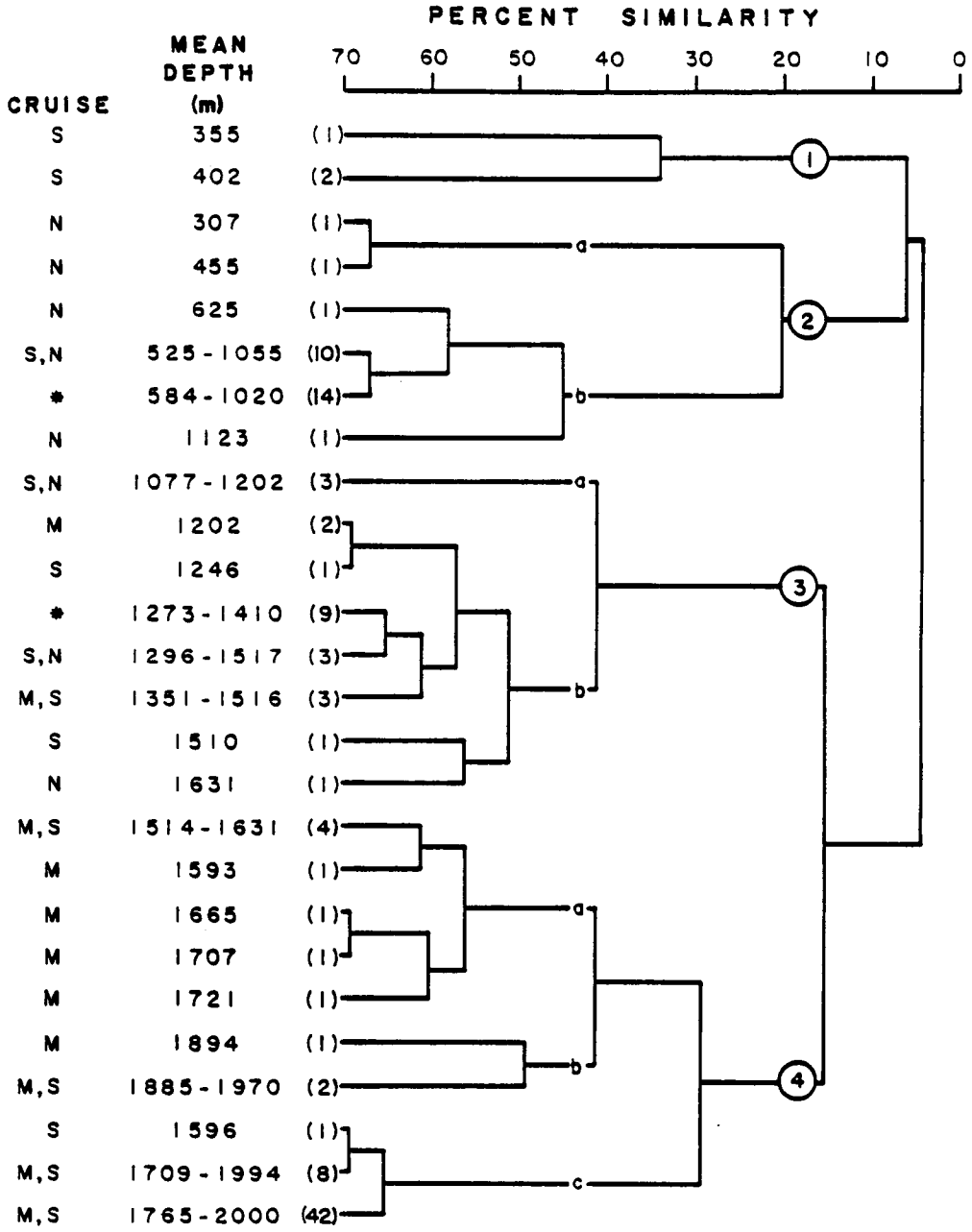


Figure 88. Heirarchial Classification of Sample Areas From Camera-Sled Tows in the Cape Hatteras (Block 510) Area. The Circled Numbers and Letters Represent Major Clusters and Groups of Areas. The Following Information is Presented for the Areas in Each Leg of the Dendrogram: Cruise (M=May 1985, S=September 1985, N=November 1985, and *=All Three Cruises), Depth Refers to the Range of Mean Depths of the Pooled Sample Areas, and the Number in Parantheses Represents the Number of Before Pooling Sample Areas Included in the Leg.

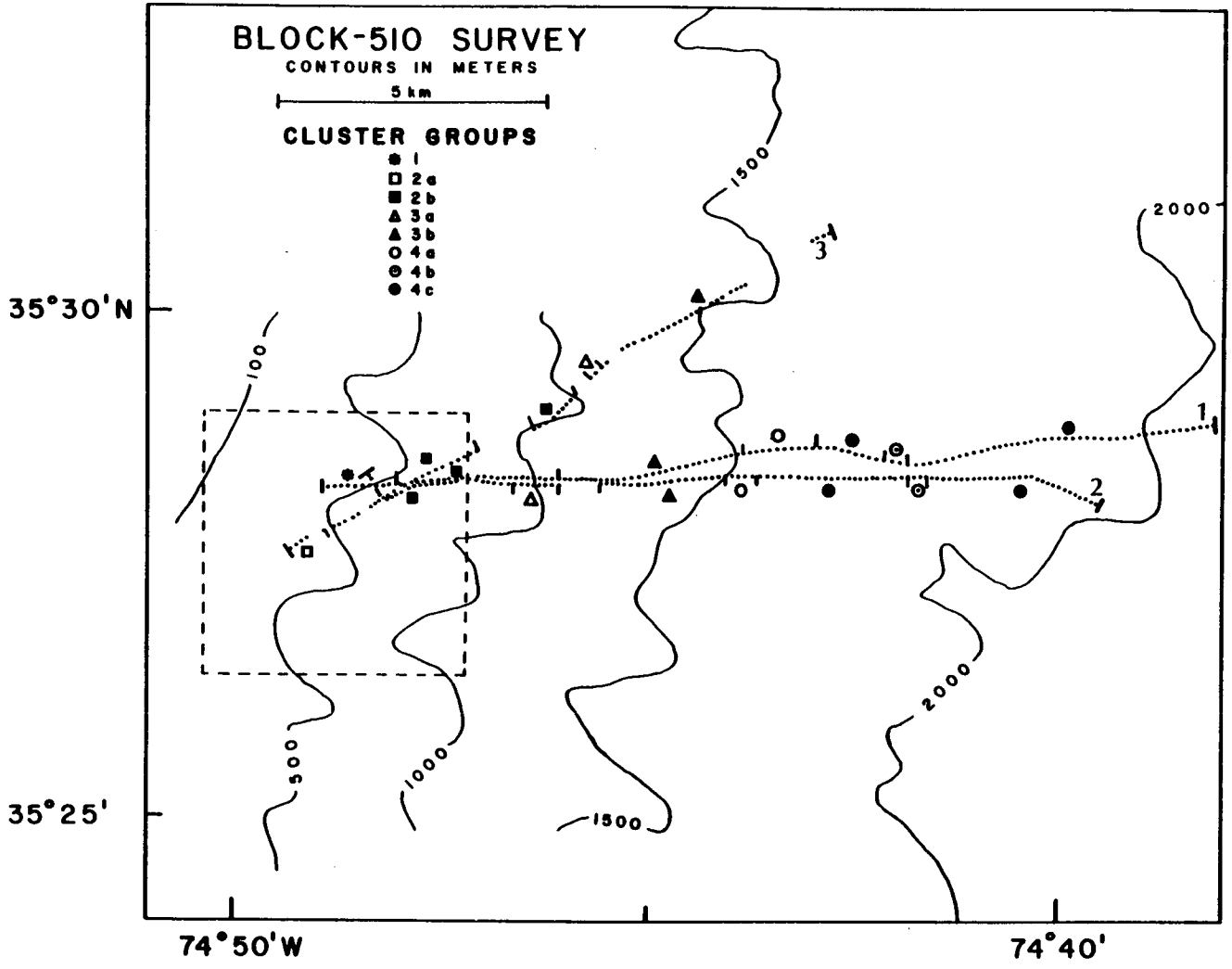


Figure 89. Plot of Cluster Groups Along the Cape Hatteras Transect in the Block 510 Area. Order of Tows: 1 = May 1895, 2 = September 1985, and 3 = November 1985.

TABLE 48. DEPTH AND RELATIVE DENSITY OF DOMINANT EPIFAUNAL SPECIES IN THE CLUSTERS AND GROUPS OF AREAS DEFINED BY CLASSIFICATION ANALYSIS OF THE CAPE HATTERAS TRANSECT (BLOCK 510) CAMERA-SLED TOWS.

Cluster	1	2		3		4		
Group		a	b	a	b	a	b	c
Mean Depths (m)	355-402	307-455	525-1123	1077-1202	1202-1631	1514-1721	1894-1970	1596-2000
Cerianthus borealis*	H	-	-	-	-	-	-	-
Lysenchelys verilli*	L	M	H	L-M	-	-	-	-
Glyptocephalus cynoglossus	L	L	L-H	-	-	-	-	-
Grey eel pout	-	-	L	L-H	L-M	L	L-M	L
Lycodes atlanticus	-	-	L	M	M-H	L-M	L-M	L
Synaphobranchus spp.	-	-	-	M-H	M-H	L-H	L	L
Distichoptilum gracile	-	-	-	-	-	-	H	L
Kophobelemnon stelliferum	-	-	-	-	-	H	M-H	L-H
Ophiomusium lymani*	-	-	-	-	-	L	M	H

* =Very abundant
- =Absent
L =Low density
M =Moderate density
H =High density

The three areas in cluster 1 were located at the shallow end of the September 1985 tow. The fauna in this region were dominated by the burrowing anemone Cerianthus borealis. The shallowest of these areas also supported high concentrations of the sea star Astropectin americanus and the crab Cancer borealis. The mean depths of areas within cluster 2 range from 307 to 1123 m. The shallowest of these are the two areas in group 2a, which were surveyed by the November 1985 tow. Both of these areas had substantial exposures of consolidated sediment and were almost solely inhabited by the eel pout Lysenchelys verilli. Most of the areas in the second cluster belong to group 2b. Approximately half of these areas also had extensive exposures of consolidated sediment; the other half were characterized by steep sediment-covered slopes. The areas with outcrop were almost exclusively inhabited by L. verilli; whereas the steep sediment slopes also supported moderate densities of the flounder Glyptocephalus cynoglossus and the anemone Actinauge verilli. In addition, these steep slopes had exceptionally high densities of large white polychaete tubes protruding from the sediment. Slightly deeper (between 1077 and 1631 m), the areas in cluster 3 also were characterized by steep sediment slopes with high densities of polychaete tubes. The dominant taxa inhabiting these areas were two species of eel pouts, an unidentified grey eel pout and Lycodes atlanticus, and eels belonging to the genus Synaphobranchus. The three shallower areas (group 3a) had slightly higher densities of the grey eel pout; in contrast, the remaining deeper areas (group 3b) had slightly higher densities of L. atlanticus. These three species were also found in reduced abundances in the lower slope areas defined by cluster 4. The faunal differences between the three groups of areas in the fourth cluster were predominantly determined by the relative abundance of the brittle star Ophiomusium lymani. The shallowest region of the lower slope (areas in group 4a) supported low densities of O. lymani and moderate densities of the sea pen K. stelliferum. The deeper region (areas in group 4c) had a dense population of O. lymani. This region was interrupted by a valley (areas in group 4b) with moderate densities of O. lymani and the sea pen Distichoptilum gracile. The plot of cluster groups along the camera-sled tows indicates that the zonation pattern was independent of season (Figure 89). The minor differences between the tows appear to reflect the patchy coverage obtained in this area.

The results of ordination analysis of data from the Block 510 camera-sled tows are presented in Figures 90 and 91. All three axes appear to reflect depth gradients. The first axis clearly represents the depth gradient across the slope, with lower slope areas having low values and upper slope areas having high values. The most pronounced faunal break along the first axis occurs between clusters 2 and 3 (approximately 1100 m). Faunal differences among the shallower areas (clusters 1 and 2) are defined along the second axis, with the shallow mud areas from the September 1985 tow (cluster 1) having high values, the shallow consolidated sediment areas from the November 1985 tow (group 2a) having intermediate values, and the deeper areas from all three tows (group 2b) having low values (Figure 90). Differences among the deeper areas (clusters 3 and 4) are defined along the third axis (Figure 91). The middle slope areas defined by cluster 3 have high values on axis 3; the shallower areas on the lower slope (group 4a) have intermediate values; and the deeper areas (group 4c) have low values. The results obtained by ordination analysis are very similar to those obtained with cluster analysis.

Cape Fear Transect. Classification analysis of the nine pooled sample areas and 28 species from the short camera-sled tow off Cape Fear defines two main clusters (Figure 92). Examination of the mean depths of areas within the clusters indicates that the cluster structure is a function of depth and that a faunal break occurred at 1590 m. The seven areas in the first cluster have mean depths ranging from 1539 to 1585 m. These areas were inhabited by moderate densities of a soft coral, Acanella sp., the hard coral Flabellum alabastrum, eels belonging to the genus Synaphobranchus, and an unidentified sponge that resembled a venus fly-trap, and low densities of O. lymani. The areas in cluster 2 further separate into two groups on the basis of depth. The areas in both of these groups supported low densities of the F. alabastrum, Synaphobranchus spp., and the fly-trap sponge, and moderate densities of Acanella sp. In addition, O. lymani was moderately abundant in shallower areas (group 2a) and more abundant in deeper areas (group 2b).

Charleston Transect. Classification analysis of the 113 pooled sample areas and 37 species from the transect on the slope off Charleston defines five clusters at the 35 percent level of faunal similarity (Figure 93). Examination of the mean depths of areas within each cluster indicates that the clustering structure is again a function of depth.

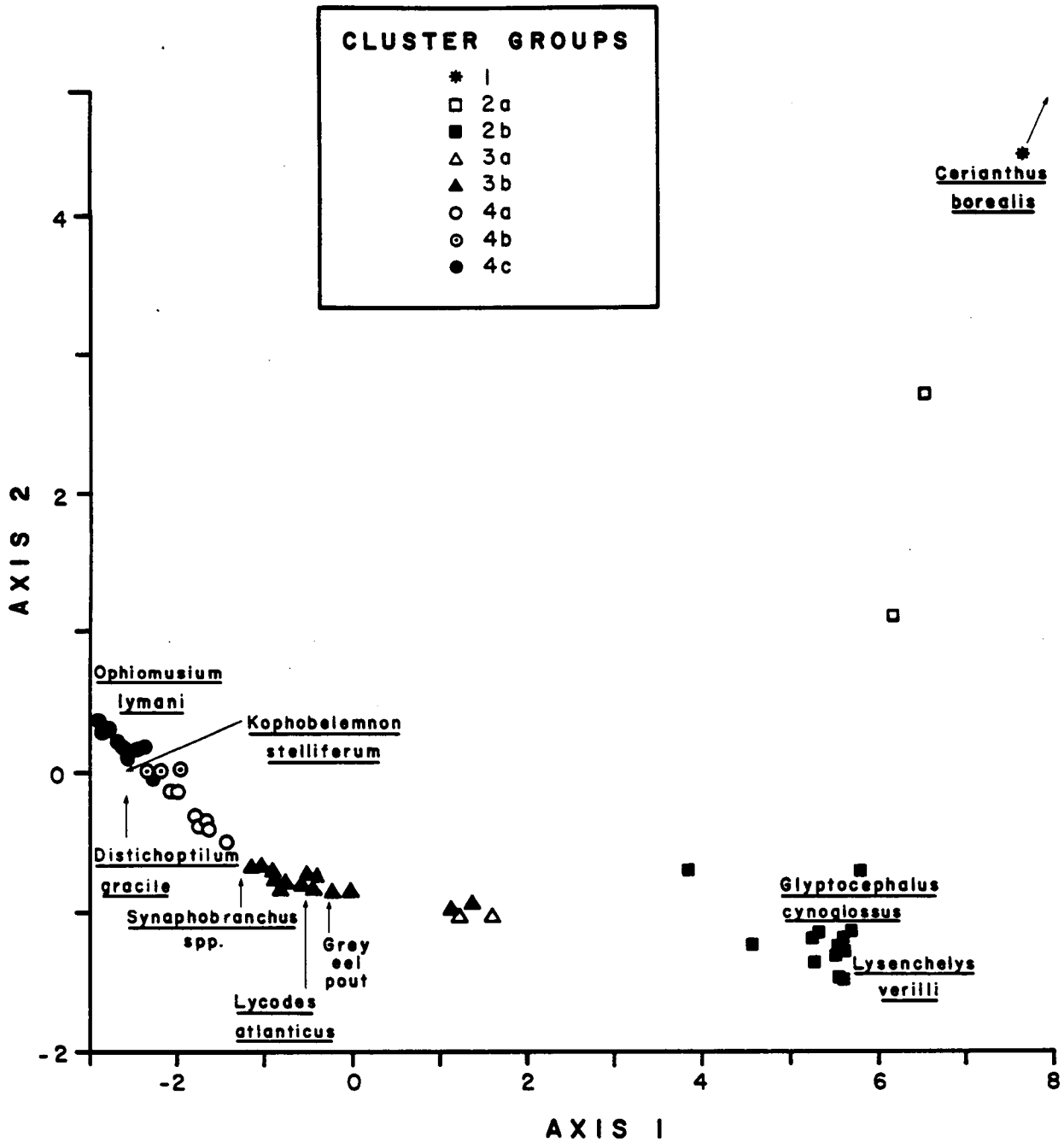


Figure 90. Ordination by Reciprocal Averaging of the Cape Hatteras (Block 510) Sample Areas and Species on Axes 1 and 2. Symbols Represent Cluster Groups Defined by Classification. Dominant Species Responsible for the Ordination Pattern are Also Shown.

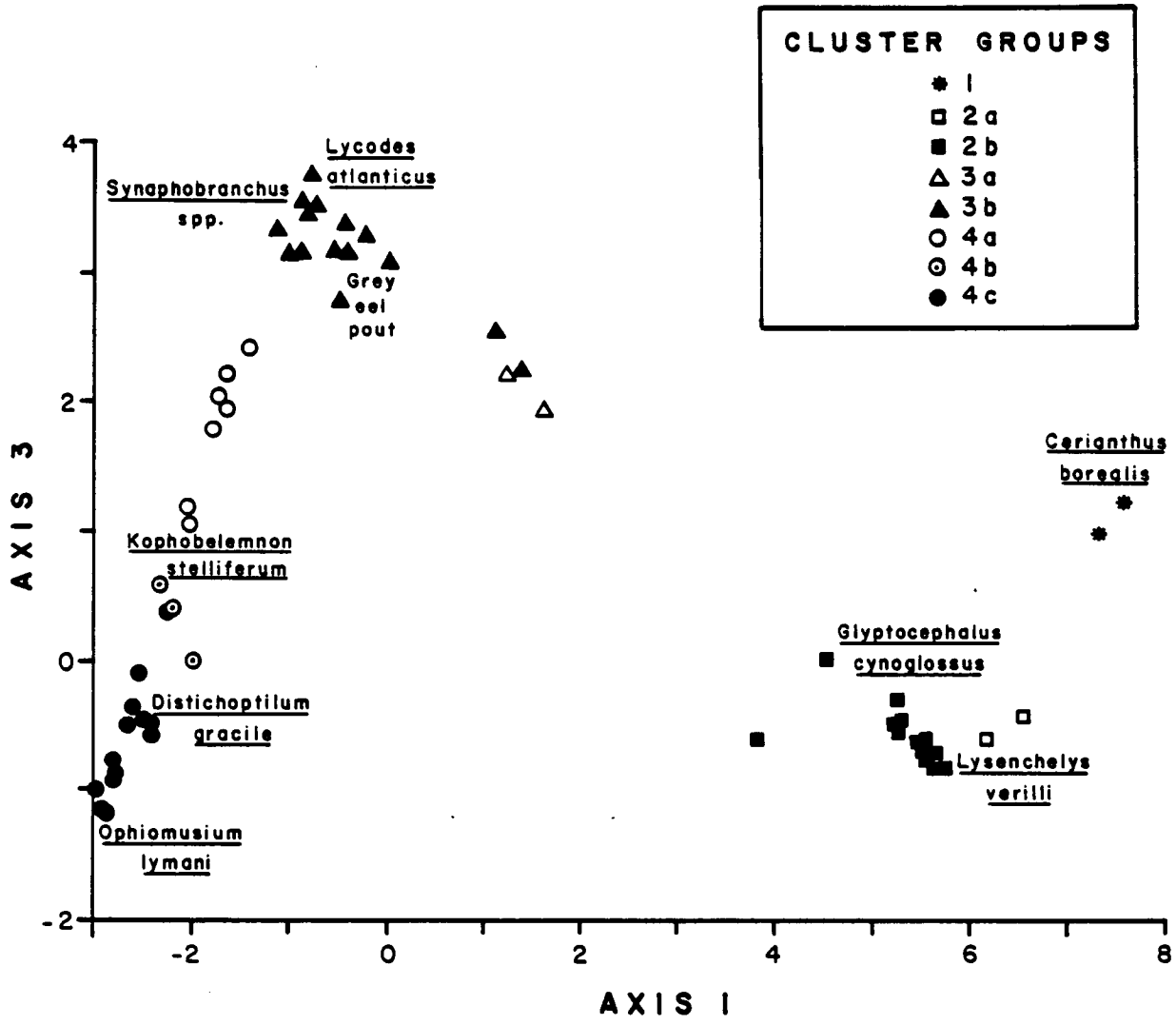


Figure 91. Ordination by Reciprocal Averaging of the Cape Hatteras (Block 510) Sample Areas and Species on Axes 1 and 3. Symbols Represent Cluster Groups Defined by Classification. Dominant Species Responsible for the Ordination Pattern are Also Shown.

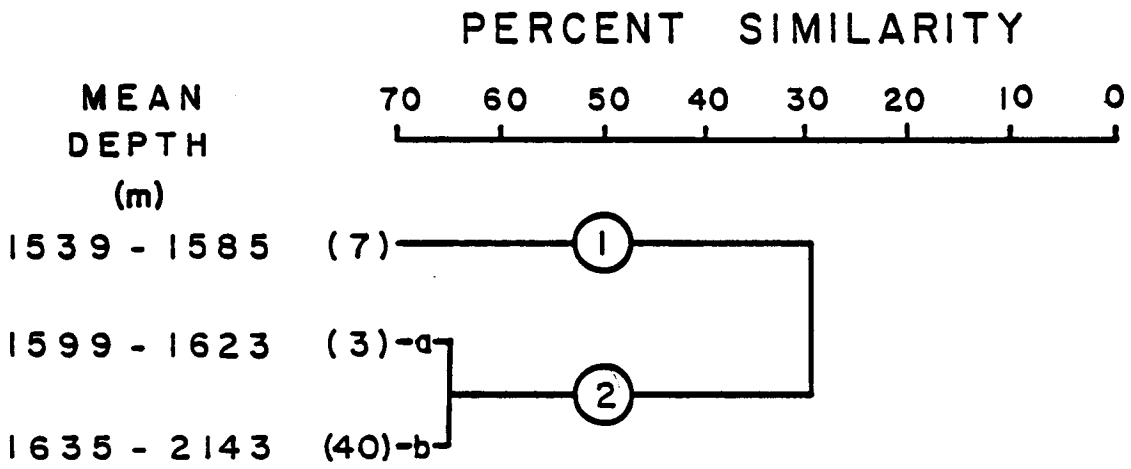


Figure 92. Heirarchial Classification of Sample Areas from the Camera-Sled Tow on the Cape Fear Transect. The Circled Numbers and Letters Represent Major Clusters and Groups of Areas. The Following Information is Presented for the Areas in Each Log of the Dendrogram: Depth Refers to the Mean Depths of the Pooled Sample Areas and the Number in Parentheses Represents the Number of Before Pooling Sample Areas Included in the Leg.

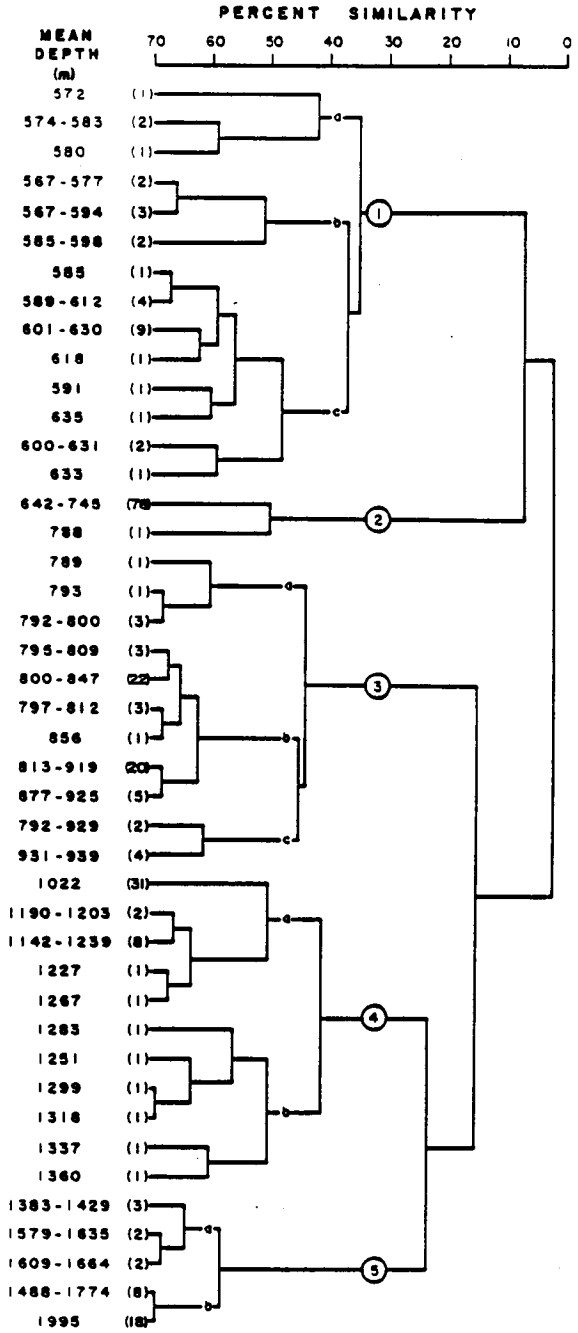


Figure 93. Heirarchial Classification of Sample Areas from Camera-Sled Tows on the Charleston Transect. The Circled Numbers and Letters Represent Major Clusters and Groups of Areas. The Following Information is Presented for the Areas in Each Leg of the Dendrogram: Depth Refers to the Mean Depths of the Pooled Sample Areas and the Number in Parentheses Represents the Number of Before Pooling Sample Areas Included in the Leg.

Each of the clusters further subdivides, with depth, into groups of areas with higher levels of faunal similarity. Major faunal breaks occurred at 640, 790, 950, and 1370 m. Each of these clusters represents a different physical environment. A plot of the cluster groups along the transect is shown in Figure 94, and the fauna and physical characteristcs indicative of each group are presented in Table 49.

The areas in cluster 1 were all located in a region of sand waves at the shallow end of the transect (559 to 640 m). This region was inhabited by sparse populations of a spider crab Rochinia sp., the hagfish Myxine glutinosa, and the anemone Actinauge longicornis. The faunal differences within this cluster were minor and appear to reflect the extreme sparsity of organisms. The shallower areas in cluster 2 were in a region of low-relief ridges (640 to 715 m), but the deeper areas had a silty sediment overlying a hard subsurface (715 to 800 m). The fauna inhabiting both of these regions consisted almost entirely of a dense population of the hard coral Bathypsammia tintinnabulum. The shallower ridges also supported a dense population of pagurid crabs, Parapagurus sp., and the deeper flat areas had a sparse population of cerianthid anemones. The areas in cluster 3 were indicative of the silty slope between 790 and 950 m. This region was inhabited by sparse populations of a large shrimp, Glyphocrangon sp., eels, and a burrowing cerianthid anemone. Differences between the groups of areas within cluster 3 reflect the higher abundance of cerianthids in some areas (group 3b), and the higher abundance of eels in other areas (group 3c). The slope between 950 and 1370 m is represented by the areas in cluster 4. Most of the areas in this cluster were indicative of the silty slope between 950 and 1260 m (group 4a). This region was inhabited by a very dense population of a large sea pen, a moderate population of the hard coral Flabellum alabastrum, and a sparse population of eels. The slightly deeper areas between 1250 and 1370 m (group 4b) lacked the high densities of the sea pen. The lower slope areas in cluster 5 were characterized by a steeper slope and compacted sediment. This region had sparse populations of a soft coral, Acanella sp., the fly-trap sponge, and eels. In addition, O. lymani was abundant in most of the areas in this region (group 5b). The map of cluster groups indicates large areas of relatively homogeneous fauna, separated by narrower areas of rapid faunal change (Figure 94).

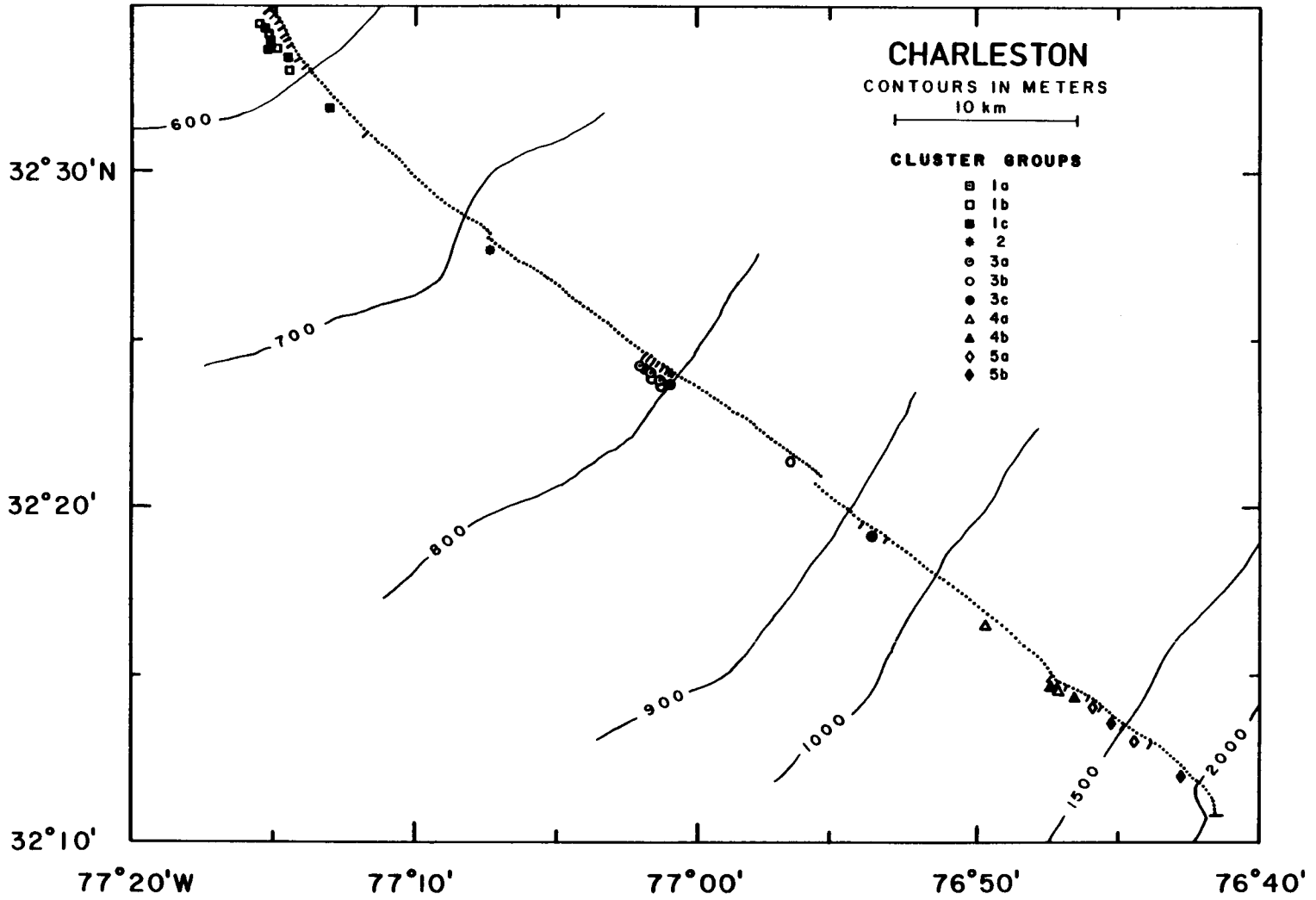


Figure 94. Plot of Cluster Groups Along the Charleston Transect.

TABLE 49. DEPTH AND RELATIVE DENSITY OF DOMINANT EPIFAUNAL SPECIES IN THE CLUSTERS AND GROUPS OF AREAS DEFINED BY CLASSIFICATION ANALYSIS OF THE TOWS ALONG THE CHARLESTON TRANSECT.

Cluster	1			2	3			4		5	
Group	a	b	c		a	b	c	a	b	a	b
Characteristics	Sand Waves			Ridges	Soft Sediment				Compacted Sediment		
Mean Depths (m)	572-580	567-598	585-635	642-788	789-800	795-925	792-939	1022-1267	1251-1360	1383-1664	1488-1995
Myxine glutinosa	H	L	L	L	-	-	-	-	-	-	-
Rochinia sp.	M	M-H	M-H	-	-	-	-	-	-	-	-
Actinauge longicornis	L	-	M-H	M	-	-	-	-	-	-	-
Bathypsammia tintinnabulum*	-	-	-	H	-	-	-	-	-	-	-
Parapagurus sp.*	-	-	-	H	L-M	L	-	-	-	-	-
Glyphocrangon sp.	-	-	-	-	L	M-H	M-H	-	-	-	-
Synaphobranchus spp.	-	-	-	L	M	M	M-H	M-H	M	M	M
Cerianthid anemone	-	-	-	-	L	M-H	L-M	L	L	L	L
Purple sea pen*	-	-	-	-	-	L	L	M-H	L	L	L
Flabellum alabastrum	-	-	-	-	-	-	-	H	M-H	L	-
Fly-trap sponge	-	-	-	-	-	-	-	L	L	H	H
Acanella sp.	-	-	-	-	-	-	-	L	M	M-H	M-H
Ophiomusium lymani*	-	-	-	-	-	-	-	-	-	L	M-H

* =Very abundant
- =Absent
L =Low density
M =Moderate density
H =High density

The results of ordination analysis of the data from the Charleston transect are presented in Figures 95 and 96. The first axis clearly represents the depth gradient across the slope, with deep areas having low values and shallow areas having high values. The only pronounced faunal break defined by the first axis is at 780 m, between the two legs of cluster 2. The second axis may represent a gradient in sediment grain size. The rippled sand-wave areas in cluster 1 have high values, the compacted-sediment areas on the lower slope (cluster 5) have intermediate values, and the ridges and silty areas have low values. An additional faunal break at 640 m, between the regions of sand waves and ridges, is defined by axis 2. The middle and lower slope regions (clusters 3, 4 and 5) separate most clearly along the third axis. The soft-sediment areas in cluster 3 have low values; the compacted-sediment areas in cluster 5 have high values. No pronounced faunal breaks are defined by axis 3. The placement of the cluster groups along this axis indicates gradual faunal replacement across the middle and lower slopes. In contrast to the results obtained with cluster analysis, ordination analysis indicates that the only pronounced faunal breaks occur between the sand waves (cluster 1) and ridges (part of cluster 2), and within cluster group 2.

Transect Analysis

Continuous plots of depth, trophic composition, and faunal density were used to examine changes in feeding type with depth and topography. With few exceptions, all organisms seen in the photographs were assigned to one of three trophic categories. Designations of filter/suspension feeder, deposit feeder, or carnivore/scavenger were based on known life habits or were inferred from morphology. The percent trophic composition is presented as a modified kite diagram with the darkened areas above and below the center line representing the percent of carnivore/scavengers and filter feeders, respectively. The clear envelope surrounding the center line reflects the percent of deposit feeders. The top line on the faunal abundance plots represents total megafaunal abundance. The relative proportion that each of the dominant species contributes to the total fauna is also presented. The depth plots were based on individual pictures, but trophic composition and faunal abundances were averages of 20 pictures.

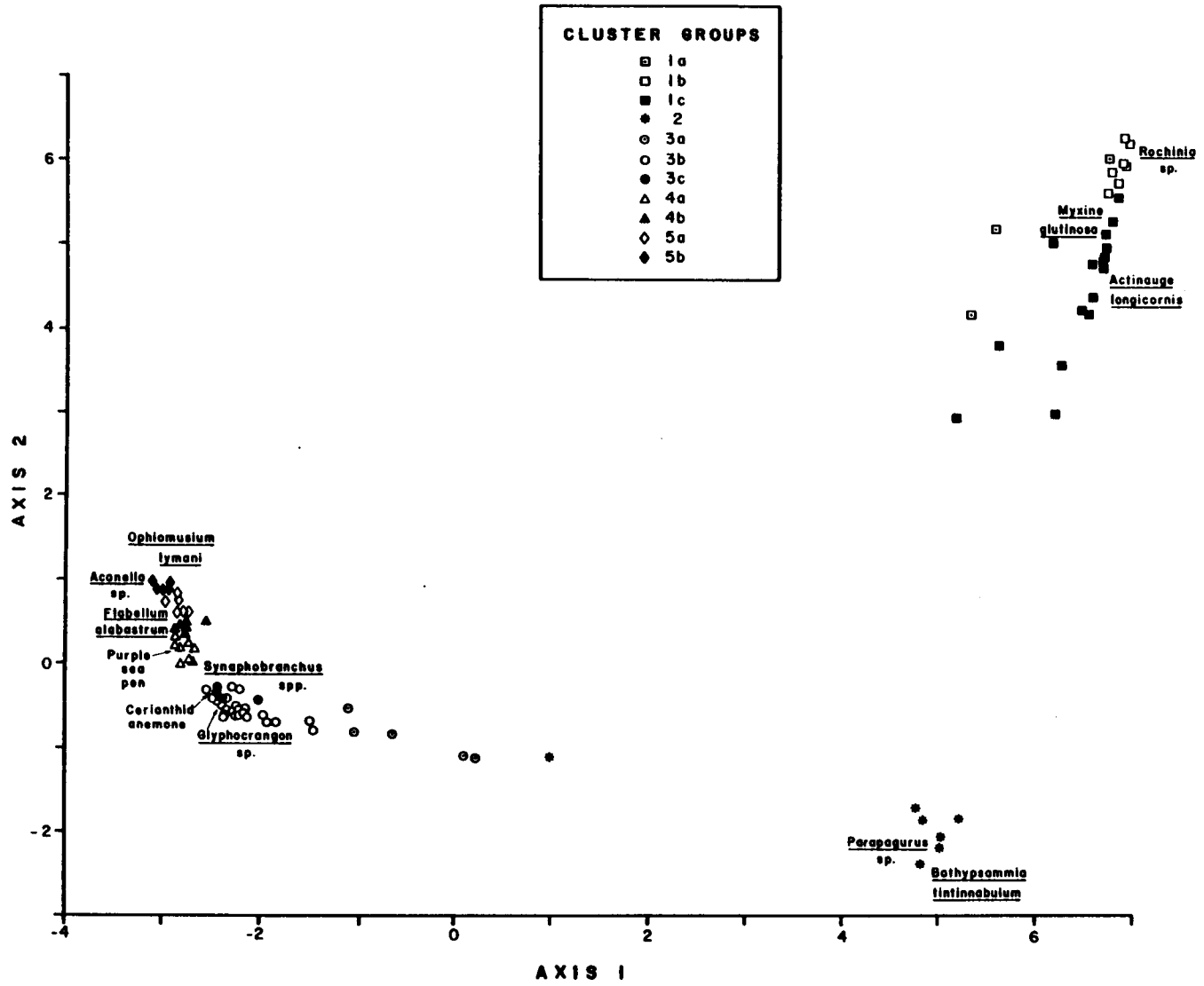


Figure 95. Ordination by Reciprocal Averaging of the Charleston Sample Areas and Species on Axes 1 and 2. Symbols Represent Cluster Groups Defined by Classification. Dominant Species Responsible for the Ordination Pattern are Also Shown.

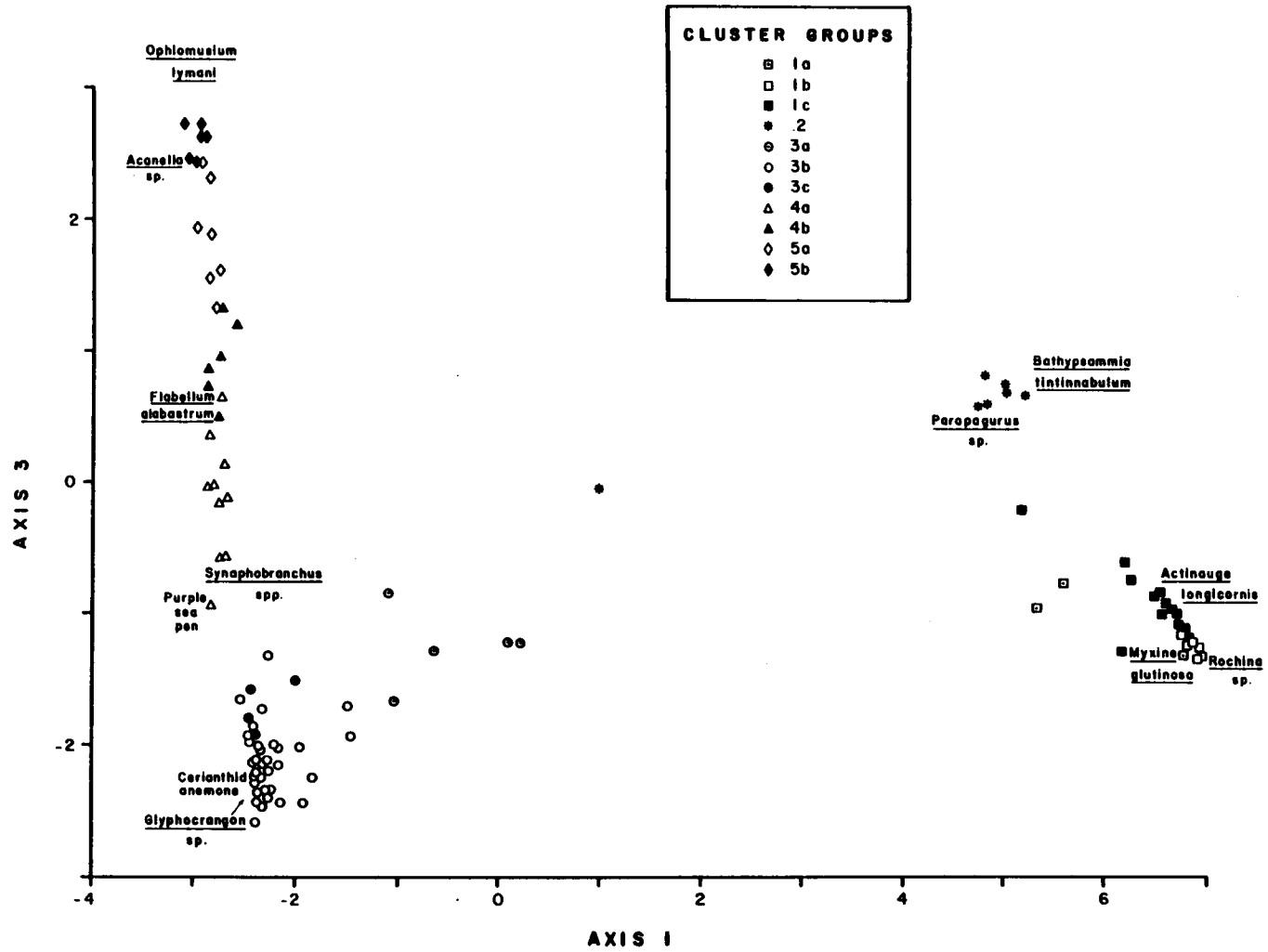


Figure 96. Ordination by Reciprocal Averaging of the Charleston Sample Areas and Species on Axes 1 and 3. Symbols Represent Cluster Groups Defined by Classification. Dominant Species Responsible for the Ordination Pattern are Also Shown.

Cape Hatteras Transect (Block 510). Plots of depth, trophic composition, and faunal density along two camera-sled tows on the slope north of Cape Hatteras are shown in Figures 97 and 98. Only the tows taken in May 1985 and September 1985 are presented. The patchy coverage obtained from the November 1985 tow precluded definition of any pattern. Despite minor differences between the two tows, the similarities in the plots indicate a consistent pattern of change in trophic composition and faunal abundance across the slope.

A mix of filter and deposit feeders dominated the sparse fauna on the deepest portion of the lower slope (Figure 97). This changed to a dense fauna dominated by deposit feeders on most of the remainder of the lower slope. This region was interrupted by a valley at the base of the steepest portion of the lower slope. The sparse fauna in this valley was dominated by filter feeders (Figures 97 and 98). These observed shifts from dominance by deposit feeders were caused by decreases in the densities of Ophiomusium lymani. The steep slope above 1700 m was sparsely populated by megafauna alternately dominated by carnivores and filter feeders. A mix of carnivores and filter feeders predominated between 1550 and 1700 m in the area surveyed by the May 1985 tow, and between 1500 and 1600 m in the area surveyed by the September 1985 tow. This mix of feeding types reflected sparse populations of several fish species and the sea pen Kophobelemnon stelliferum. In both tows, the steep middle slope fauna was dominated by carnivores to a depth of 800 m. Between 600 and 800 m the fauna was again dominated by a mix of carnivores and filter feeders, reflecting intermediate densities of the eel pout Lysenchelyes verilli and the anemone Actinauge verilli. The shallowest area surveyed was dominated by filter feeders, reflecting intermediate densities of the burrowing anemone Cerianthus borealis (Figure 98).

The major difference in the fauna between the two tows is in the abundance of O. lymani. This brittle star was considerably more numerous in the area covered by the May 1985 tow. The most feasible explanation for this difference may be related to topographic differences between the areas covered by each of the tows. Results from a concurrent study in the U.S. Mid-Atlantic region indicates that O. lymani exhibits a preference for topographic highs (Maciolek et al., 1987). The deeper portion of the May 1985 tow was located on the crest of a ridge and had much higher densities of this brittle star than the September 1985 tow which was located on the southern wall of the same ridge.

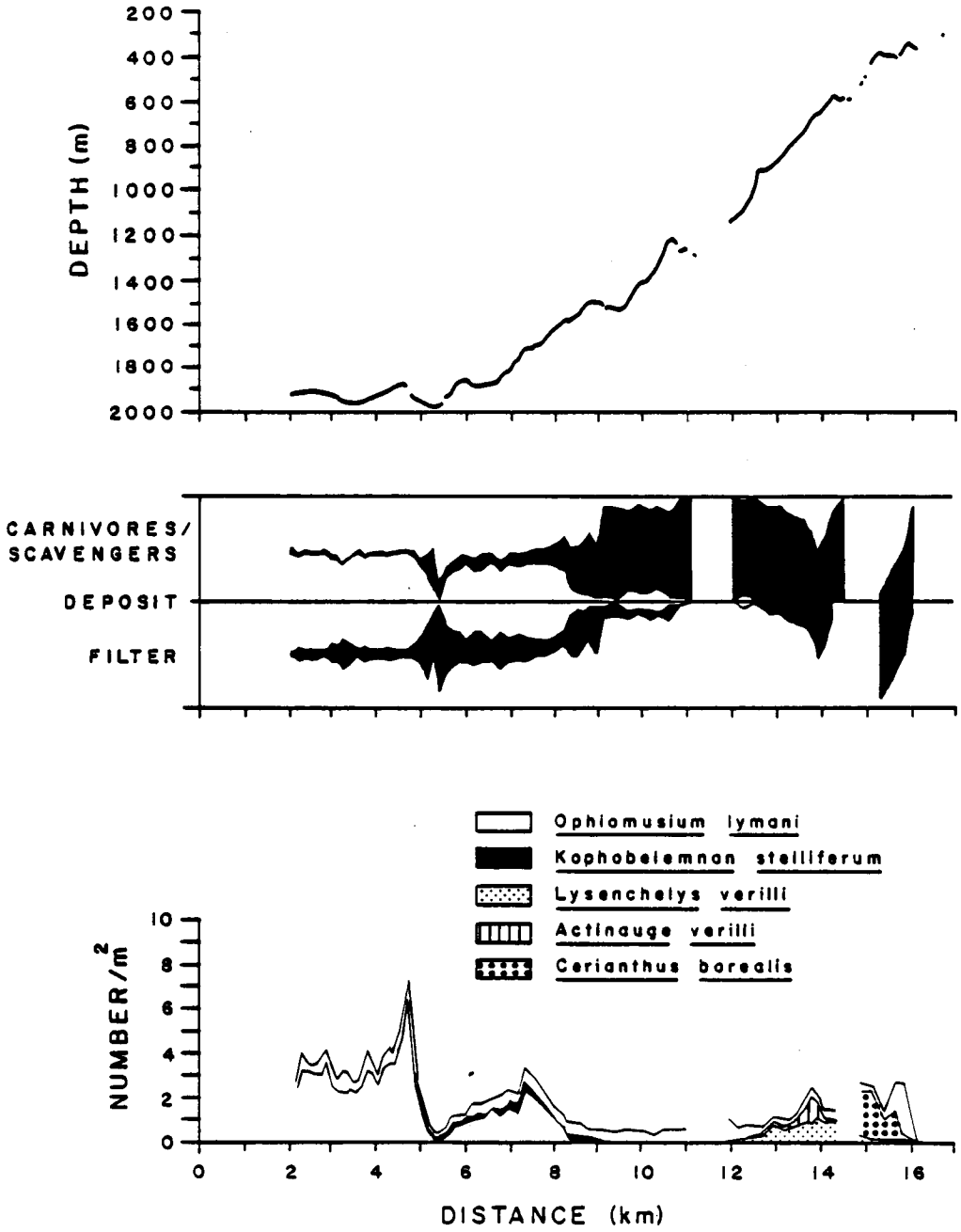


Figure 97. Depth, Trophic Type, and Abundance of Total Megafauna and Five Selected Species from the September 1985 Camera-Sled Tow on the Cape Hatteras Transect in the Block-510 Area. The Relative Proportion of Deposit Feeders is Represented by the Clear Envelope Around the Center Line; the Relative Proportion of Carnivore/Scavengers and Filter Feeders are Respectively Represented by the Shaded Areas Above and Below the Line. The Top Line On the Density Plot Represents Total Megafauna.

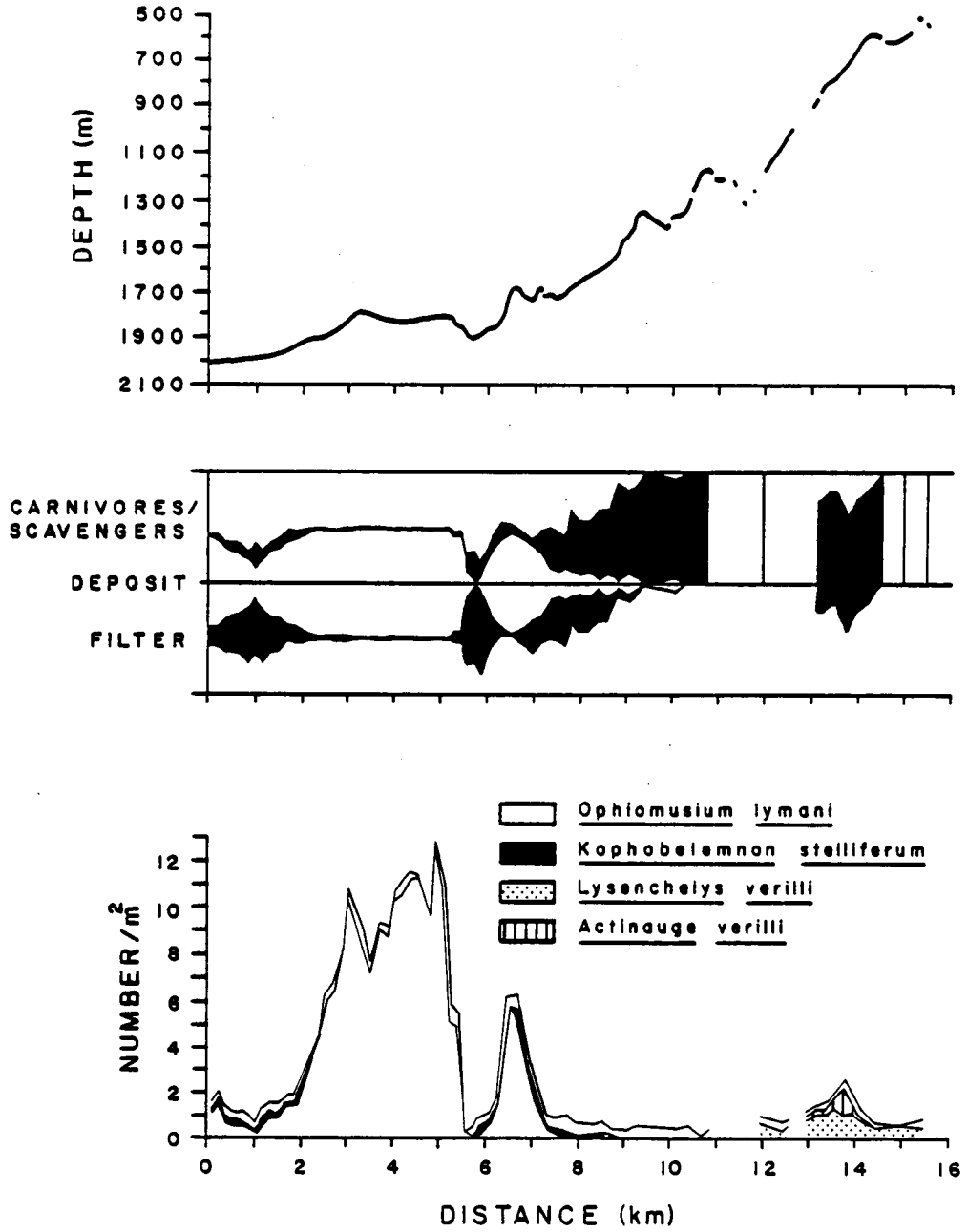


Figure 98. Depth, Trophic Type, and Abundance of Total Megafauna and Four Selected Species from the May 1985 Camera-Sled Tow on the Cape Hatteras Transect in the Block 510 Area. The Relative Proportion of Deposit Feeders is Represented by the Clear Envelope Around the Center Line; the Relative Proportion of Carnivores/Scavengers and Filter Feeders are Respectively Represented by the Shaded Areas Above and Below the Line. The Top Line on the Density Plot Represents Total Megafauna.

Cape Fear Transect. Plots of depth, trophic composition, and faunal abundance for the short tow on the slope off Cape Fear are presented in Figure 99. Deposit feeders dominated the abundant fauna found throughout most of this tow (1600 to 2147 m). A shift to a sparse fauna dominated by filter feeders occurred toward the shallower end of this transect (1534 to 1600 m). The brittle star O. lymani accounted for most of the fauna. The trophic shift and reduced faunal abundance above 1600 m reflects the decrease in numbers of O. lymani in the shallower end of this region. Slight increases in the density of a soft coral, Acanella sp., and the fly-trap sponge accounted for the dominance of filter feeders above 1600 m. This pattern is similar to that observed on the lower slope at Cape Hatteras.

Charleston Transect. Plots of depth, trophic composition, and faunal abundance for the transect off Charleston are presented in Figures 100 and 101. Most of the pronounced shifts in trophic composition across this slope reflect differences in geological characteristics. These shifts also reflect the density distributions of the three most common species found on this slope. The fauna on the slope below 1750 m was dominated by deposit feeders, mainly the abundant O. lymani. Between 1750 and 1150 m the fauna gradually changed from domination by deposit feeders to a mix of filter feeders and carnivores. Faunal densities were quite low throughout this region, reflecting decreasing numbers of O. lymani and slightly increasing numbers of Synaphobranchus spp. and a sea pen. The abundant fauna between 1150 and 950 m was dominated by a large sea pen, accounting for the high proportion of fiter feeders found in this silty region. Between 950 and 800 m the silty slope was very sparsely inhabited by a mix of filter feeders and carnivores. A small cerianthid anemone accounted for most of the filter feeders seen in this area. Between 800 and 715 m the compacted sediment supported high concentrations of the hard coral Bathypsammia tintinnabulum, accounting for the dominance of filter feeders in this region. In addition to being inhabited by moderate densities of B. tintinnabulum, the ridges between 715 and 640 m also had moderate densities of a pagurid crab, Parapagurus sp. The exceptionally sparse fauna inhabiting the sand waves between 640 and 559 m was almost entirely composed of carnivores and was not dominated by any single species. A large spider crab, Rochinia sp., and several species of fish accounted for most of the fauna seen in this region.

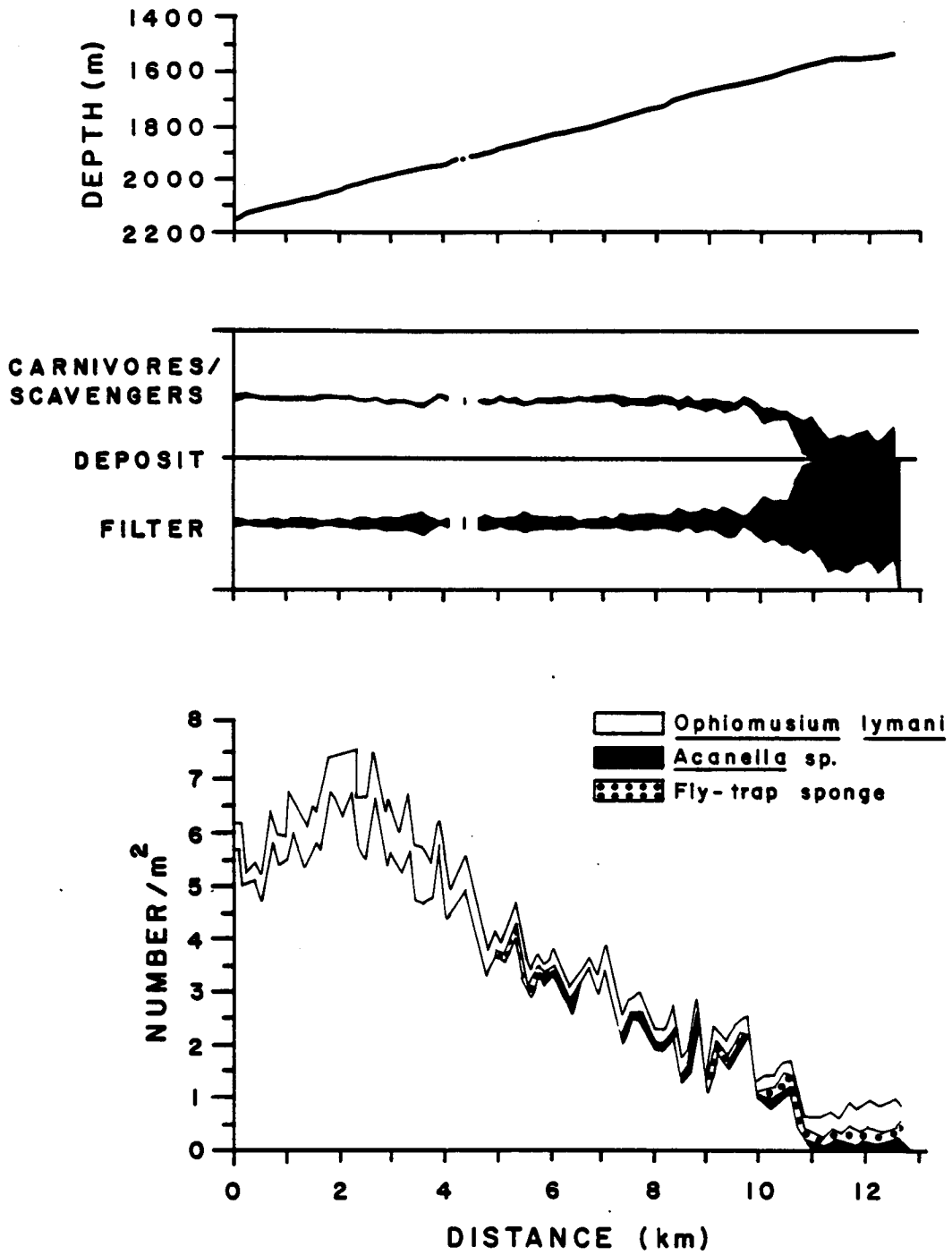


Figure 99. Depth, Trophic Type, and Abundance of Total Megafauna and Three Selected Species from the Camera-Sled Tow on the Cape Fear Transect. The Relative Porportion of Deposit Feeders is Represented by the Clear Envelope Around the Center Line; the Relative Proportion of Carnivore/Scavengers and Filter Feeders are Respectively Represented by the Shaded Areas Above and Below the Line. The Top Line on the Density Plot Represents Total Megafauna.

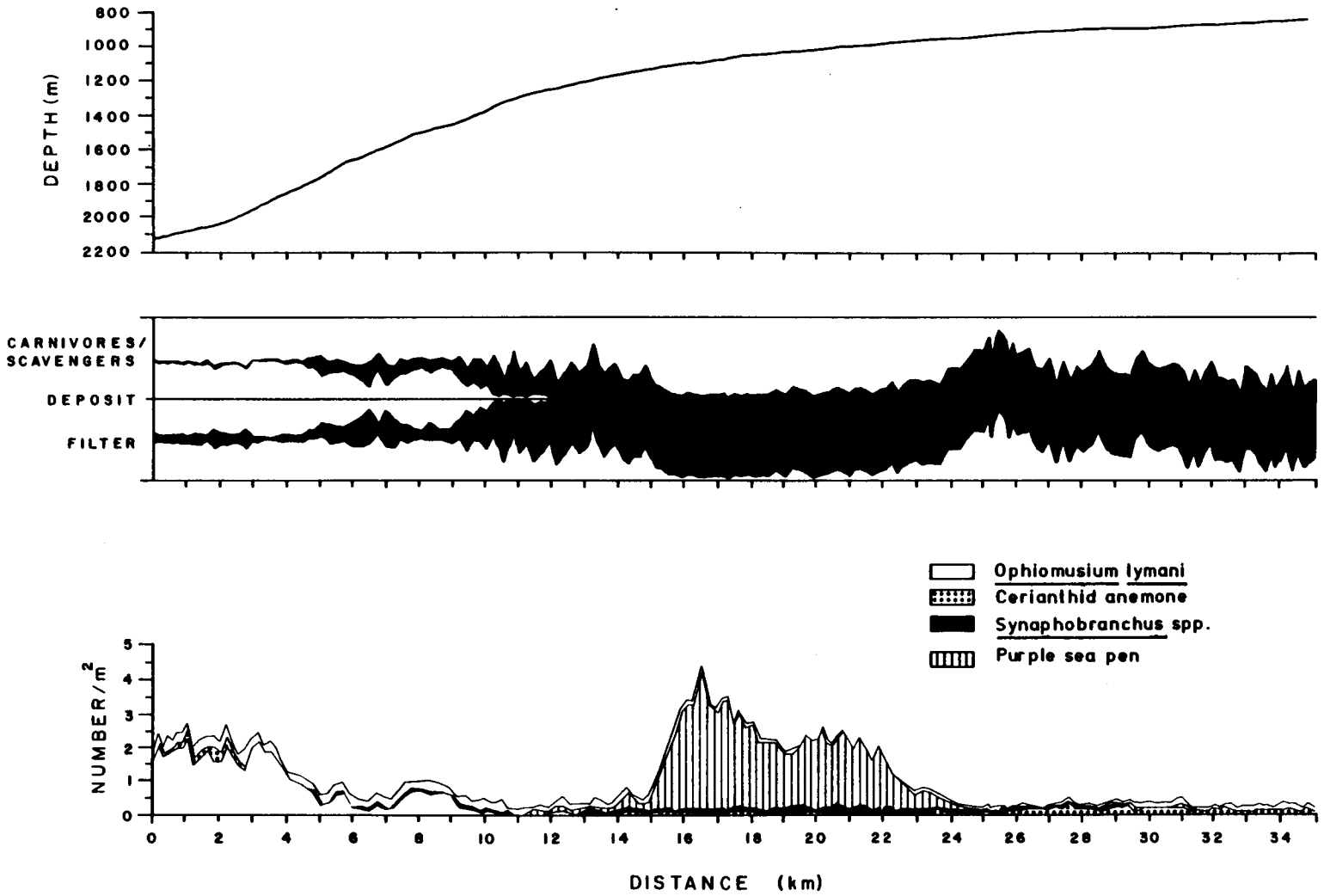


Figure 100. Depth, Trophic Type, and Abundance of Total Megafauna and Four Selected Species in the Deeper Portion of the Camera-Sled Transect off Charleston. The Relative Proportion of Deposit Feeders is Represented by the Clear Envelope Around the Center Line; the Relative Proportion of Carnivores/Scavengers and Filter Feeders are Respectively Represented by the Shaded Areas Above and Below the Line. The Top Line on the Density Plot Represents Total Megafauna.

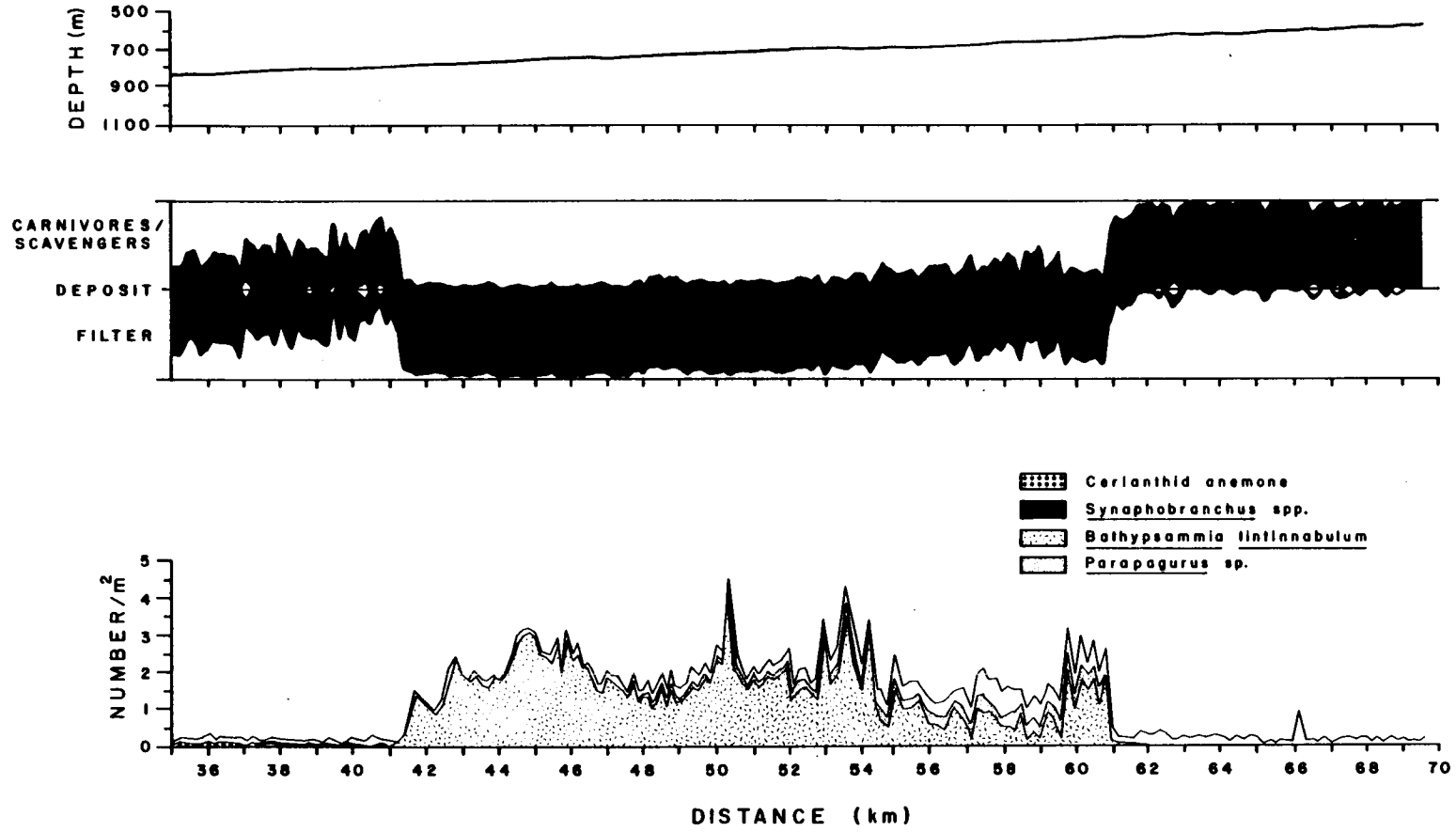


Figure 101. Depth, Trophic Type, and Abundance of Total Megafauna and Four Selected Species in the Deeper Portion of the Camera-Sled Transect off Charleston. The Relative Proportion of Deposit Feeders is Represented by the Clear Envelope Around the Center Line; the Relative Proportion of Carnivores/Scavengers and Filter Feeders are Respectively Represented by the Shaded Areas Above and Below the Line. The Top Line on the Density Plot Represents Total Megafauna.

Charleston Bump

Photographic Coverage and Geological Characteristics

Four camera-sled tows were conducted in the vicinity of the Charleston Bump on the northern end of the Blake Plateau (Figure 102). An 8.5-km-long tow, covering 451 to 473 m depth, was taken on top of the Charleston Bump. Because the camera sled frequently hung up on the many projecting rock ledges in this area, this tow was considerably shorter than originally planned. The upstream side of the bump was surveyed by a 27.5-km-long tow in depths ranging from 461 to 585 m. The downstream side of the bump and the trough behind it were surveyed by two tows along a 35-km-long transect. Numerous low-relief outcrops and overhanging ledges caused several major hang-ups; thus two tows were required to adequately cover this region. The depth range of this transect was from 457 to 684 m. A total of 39,815 m^2 of the seafloor were viewed in the photographs from the four camera-sled tows in the vicinity of the Charleston Bump (Table 50).

The surficial geology of the Charleston Bump varied considerably between the three areas surveyed. The flat top of the bump was characterized by a thin sand veneer overlying a lithified surface and low-relief, overhanging rock ledges. Occasionally, the absence of the sand veneer exposed a smooth crust of cemented sediment. Twenty-five percent of the pictures taken in this area showed a black manganese crust covering the exposed rock surfaces. On the upstream side of the bump the flat seafloor above 500 m was interrupted by a series of 10-m-high ridges. The surficial geology consisted mainly of a sand veneer overlying a hard surface. The surfaces of the ridges did not differ appreciably from the surrounding seafloor. Below 500 m the seafloor was incised by a series of valleys 1-km in width. Manganese-encrusted outcrops were exposed on the lower walls of these valleys; whereas gravel covered the upper downstream walls and sand covered the upper upstream walls. Well-developed ripple marks were seen in 27 percent of the pictures taken on the upstream side of the bump.

The downstream side of the bump consisted of three flat ledges separated by steep slopes. The top two ledges (at 500 and 550 m) were covered by a crust of cemented

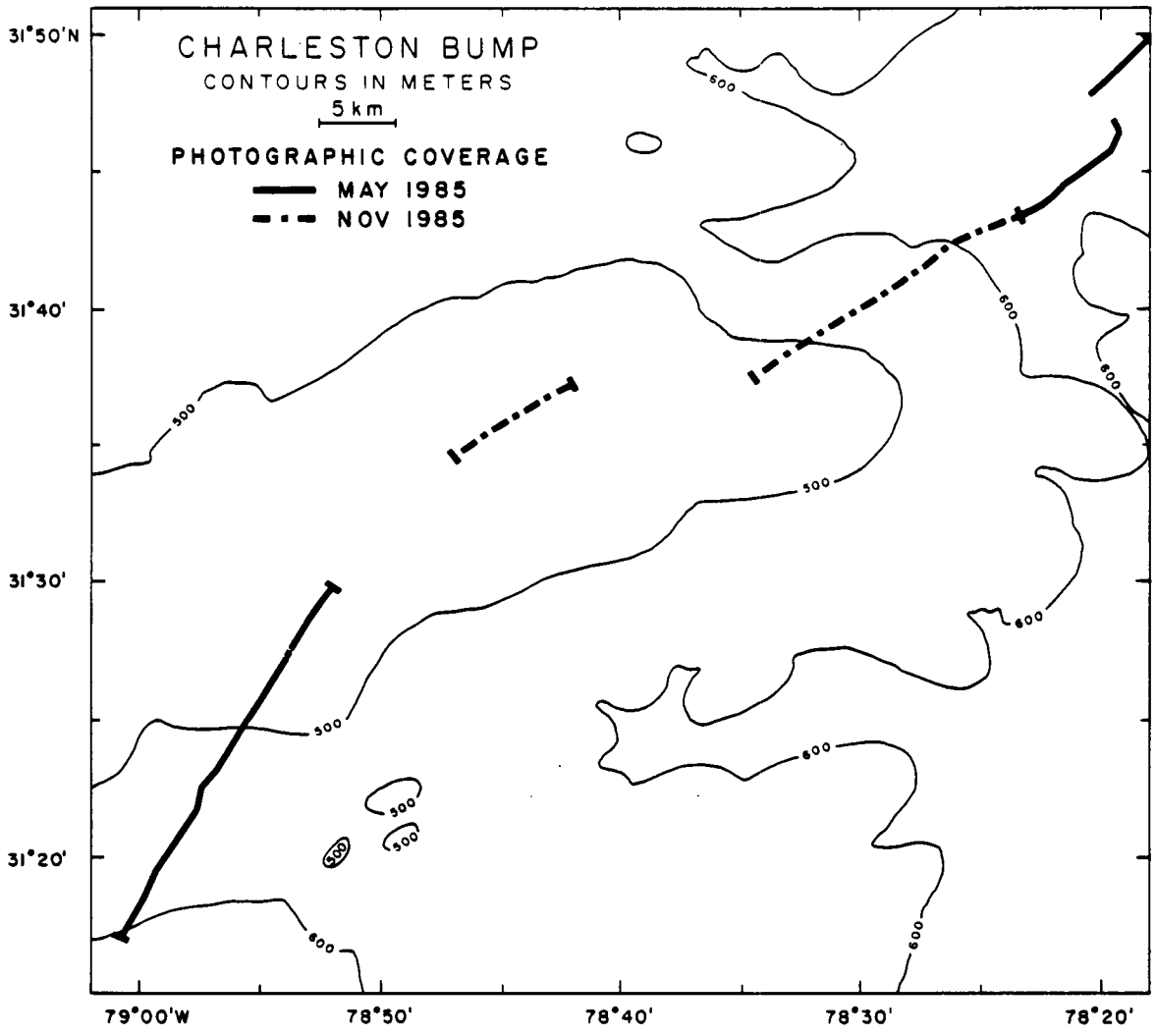


Figure 102. Photographic Coverage from Four Camera-Sled Tows in the Charleston Bump Area.

TABLE 50. TOTAL AREA VIEWED (m^2) FOR 50-M DEPTH INTERVALS FROM CAMERA-SLED TOWS IN THE CHARLESTON BUMP AREA.

Depth Interval (m)	Upstream	Top*	Downstream	Total
451-499	7807	5333	3346	16486
500-549	5838		2706	8544
550-599	1071		3024	4095
600-649			5192	5192
650-684			5498	5498
TOTAL	14716	5333	19766	39815

*Top of Charleston Bump.

sediment that was occasionally broken to reveal either unconsolidated coarse-grained sediment or coral rubble underneath. Occasional patchs of sand and outcrop were also seen on these ledges. The lower ledge (at 650 m) was covered by a manganese-encrusted pavement. The steep slopes separating these ledges had more extensive exposures of outcrop and coral rubble. Most of the exposed rock surfaces were encusted with manganese. The flat trough behind the bump consisted mainly of an exposed crust of cemented sediment with occasional breaks revealing unconsolidated sediment underneath. The trough near the bump also had a fair amount of manganese encrusting the exposed hard surfaces, but the seafloor further away from the bump frequently had a thin sand veneer covering the crust. Extensive areas of coral rubble were also seen in the area further away from the bump. Throughout the area covered by the downstream transect, 5 to 10-m high ridges frequently interrupted the seafloor. Again, the surfaces of these ridges did not differ from the surrounding seafloor. Representative bottom photographs taken from various localities on the Charleston Bump are shown in Figures 103 and 104.

Faunal Abundance and Depth Distributions

The density of total megafauna with depth and the relative proportion contributed by each of the eight most common species in the Charleston Bump area are shown in Figure 105. Together, these eight species account for slightly less than half of the organisms seen in this area. Approximately 36 percent of the remaining fauna consisted of unidentified juvenile sponges and corals. Faunal density was uniformly high (18 to 20 individuals per m^2) between 450 and 600 m, and lower (9.5 to 13 individuals per m^2) between 600 and 700 m. Although most of these taxa were found throughout the covered depth range, each showed a distinct depth preference. The most abundant species between 450 and 500 m was the soft coral Swiftia casta. Slightly deeper, four species, three stylasterin corals and a bryozoan, accounted for most of the identified taxa seen between 500 and 550 m. One of these stylasterids, Stylaster erubescens, dominated the fauna between 550 and 600 m. Three other species, two soft corals, Plumarella pourtalesii and Swiftia sp., and one hard coral, Thecopsammia socialis, dominated the fauna below 600 m.

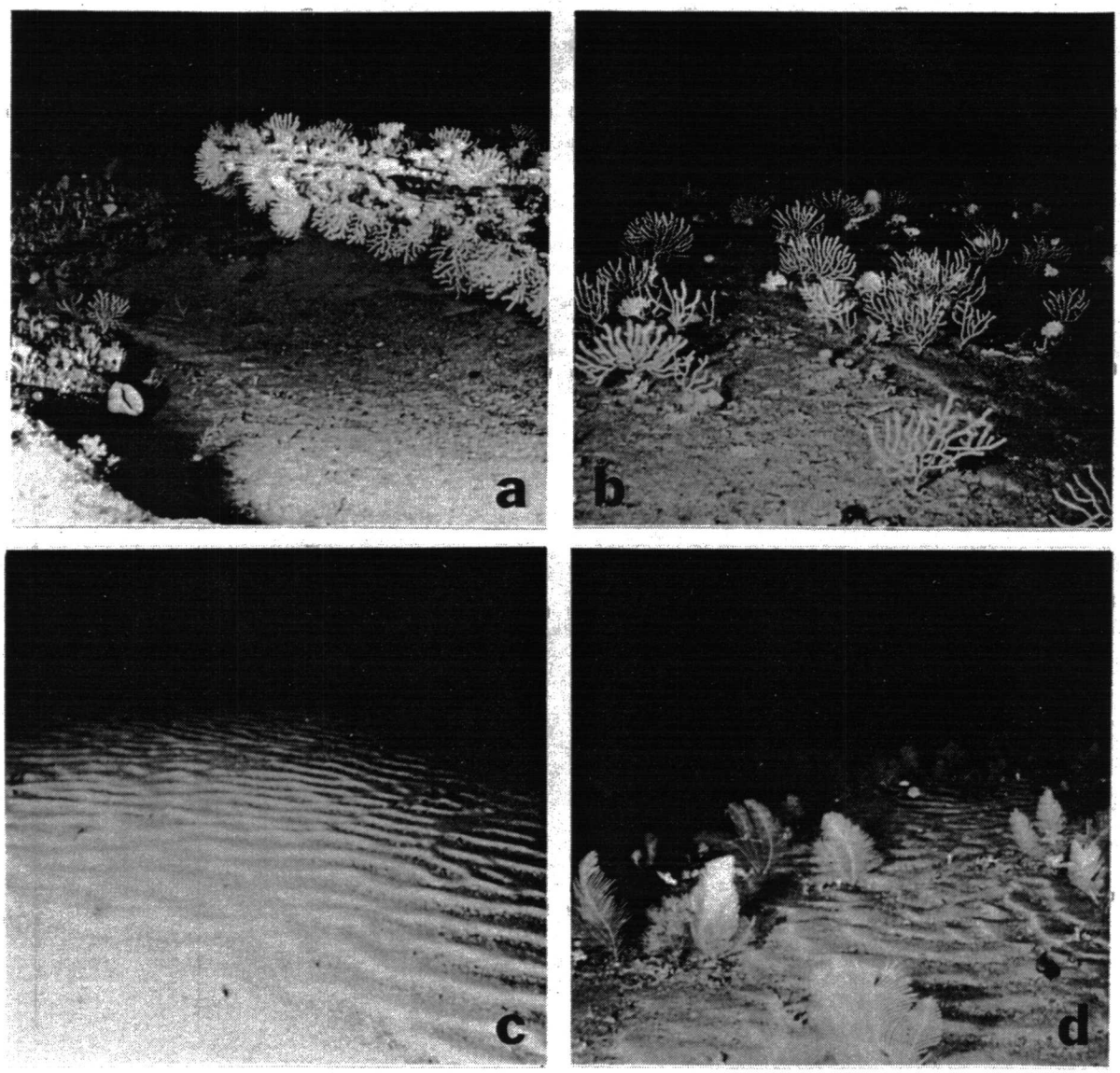


Figure 103. Representative Photographs from Camera-Sled Transects on the Top and Upstream Side of the Charleston Bump. a. Numerous Outcropping Ledges Characteristic of the Seafloor on the Top of Bump (466 m) Provide Suitable Attachment Sites for the Soft Coral Swiftia casta (Upper Right), a Lithistid Sponge (Lower Left), and Numerous Other Sessile Taxa. b. Cemented Sediment Overlain by Thin Sand Veneer Characteristizes the Upper Portion of Upstream Side of Bump (467 m). Large Loosely-Branched Corals are S. casta, Smaller Densely-Branched Corals are Stylasterins. c. Numerous Ripple Marks in Regions of Unconsolidated Sediment Indicate Strong Currents on Upstream Side of Bump (506 m). Low Faunal Densities in These Regions is Related to Lack of Exposed Hard Substrate Required for Attachment. d. Exposed Hard Substrate Provides Suitable Attachment Sites for Soft Corals, Such As these Plumarella pourtalesii (530 m).

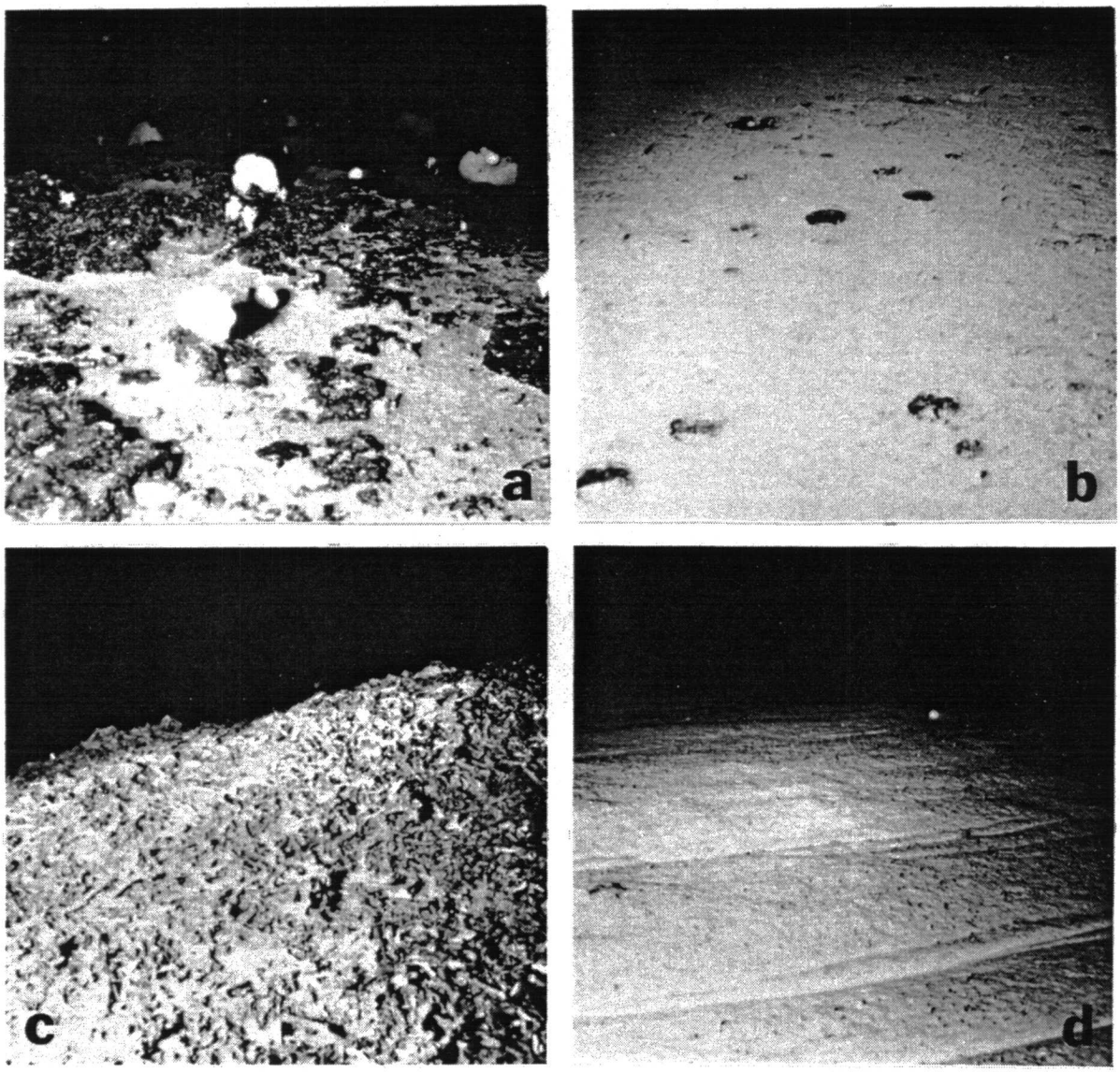


Figure 104. Representative Bottom Pictures from Camera-Sled Transects on the Downstream Side of the Charleston Bump. a. Manganese Encrusted Outcrop Forms Pavement on Lower Portion of the Downstream Side of Bump (652 m), Providing Attachment Sites for Large Fan Sponges and the Stylasterin Coral, Stylaster erubescens. b. Numerous Holes in Crusts of Lithified Sediment, Frequently Exposing Unconsolidated Sediment Underneath (675 m). c. Coral Rubble Frequently Seen Exposed on Steep Slopes Between Ledges on the Downstream Side of Bump (659 m). d. Trough Behind Bump Frequently Covered by Crust of Lithified Sediment (664 m).

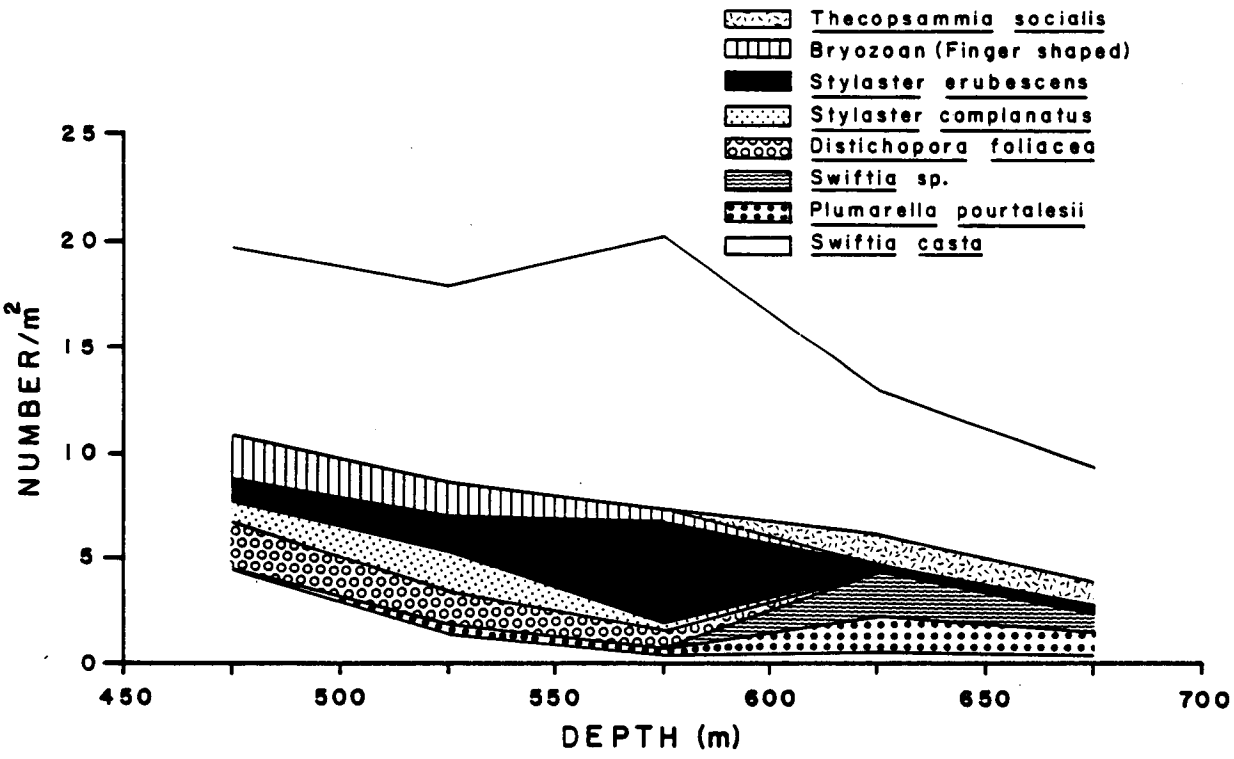


Figure 105. Density of Total Megafauna and Eight Selected Species with Depth in the Charleston Bump Area. The Top Line Represents Total Fauna.

There were also marked differences in the relative abundance of various species between the upstream and downstream sides of the Charleston Bump. Figure 106 shows the density of total megafauna and 15 selected species, with depth, in several locations on the bump. Total faunal densities were highest on the top and between 500 and 600 m on the downstream side (23 to 24 individuals per m^2), and lowest in the trough behind the bump (9 individuals per m^2). Stylasterin corals were found throughout the areas surveyed, but were most abundant between 450 and 600 m on the downstream side. Two of these, S. erubescens and S. complanatus, were only found in high densities on the downstream side. The other stylasterid, Distichopora foliacea, was found in equal abundances on the top, between 450 and 500 m on the upstream side, and between 450 and 550 m on the downstream side. Gorgonian corals dominated the fauna on top of the bump, on the upstream side, and between 600 and 700 m on the downstream side. The most abundant of these was S. casta, which was found in highest densities on top of the bump (6.8 individuals per m^2). This species was also quite common in the shallower portion of the upstream side. Two other gorgonians, P. pourtalesii and Plumarella sp., were common in the deeper portion of the upstream side. One of these soft corals, P. pourtalesii, and another one, Swiftia sp., were common in the trough behind the bump. Of the other common taxa, a finger-shaped bryozoan was most abundant in the shallow portion of the upstream side and on the top; whereas the hard coral T. socialis was only found in the trough.

The six most common sponges also showed marked habitat preferences. A bright-blue encrusting sponge, which was abundant on the upper portion of the downstream side, was found only in low densities on top and on the upstream side of the bump. In contrast, a large semicircular white fan sponge was found in appreciable densities only in the shallow portion of the upstream side, and a large veined fan sponge was found only in the trough behind the bump. Another fan sponge (shaped like a tennis racquet), was most common on top of the bump and was also found in reduced abundances on the downstream side.

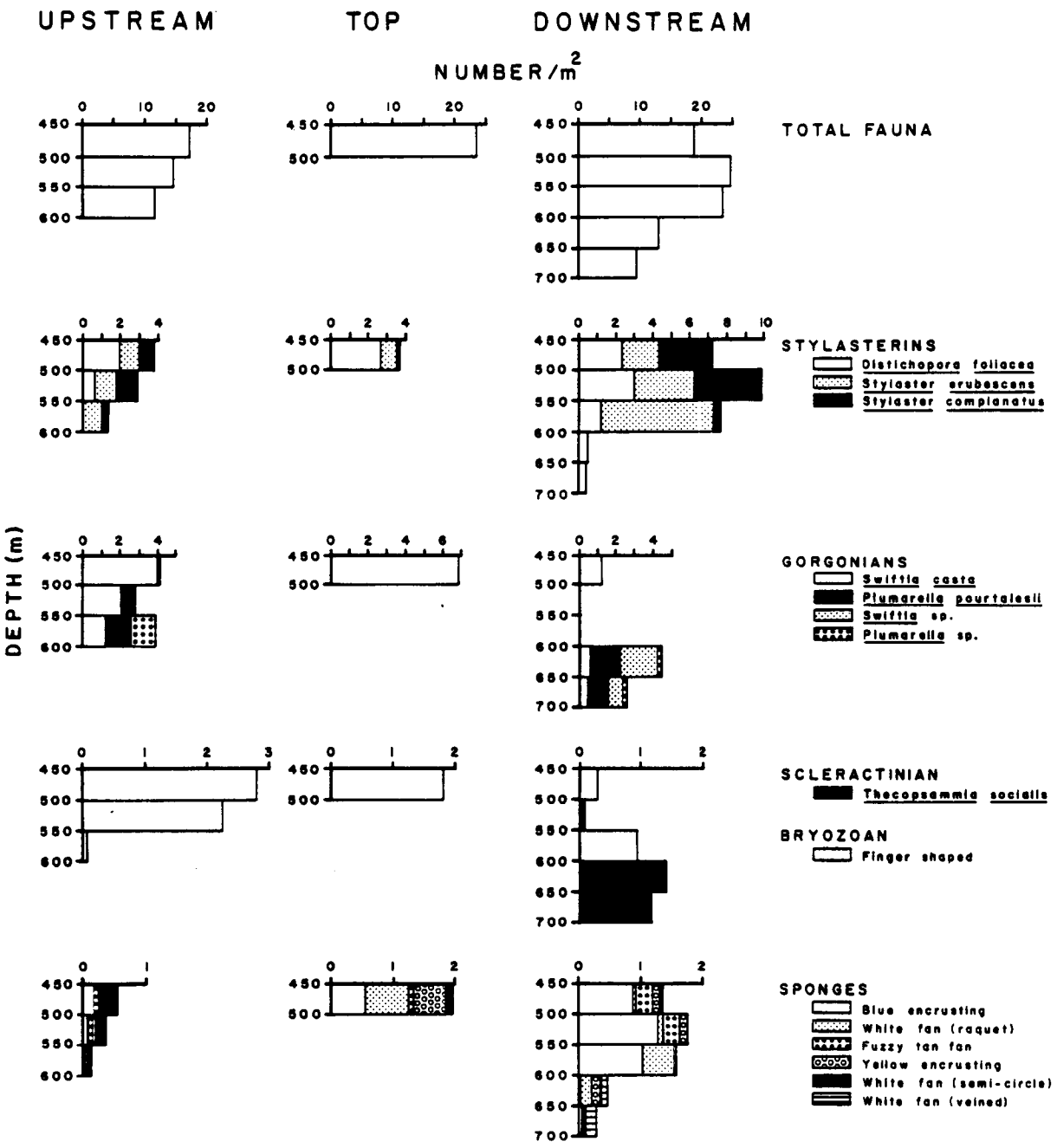


Figure 106. Density of Total Megafauna and Fifteen Selected Species with Depth and Location in the Charleston Bump Area.

Transect Analysis

Details of the faunal difference between the areas surveyed on the Charleston Bump can best be seen on continuous plots of total megafaunal abundance and density of dominant taxa, along the camera-sled tows (Figures 107 and 109). Gorgonians dominated the fauna on the top and most of the upstream side of the bump, as well as the trough behind it. In contrast, stylasterids were dominant on the downcurrent side of the bump. The fauna at intermediate depths on the upcurrent side consisted of a mixture of gorgonians, stylasterids, and a bryozoan. The trophic structure of the fauna is not presented in these plots because filter feeders were totally dominant accounting for more than 99 percent of the fauna seen in the Charleston Bump area.

Figure 107 shows a plot of faunal density along the tow taken on top of the bump. The seafloor throughout this area consisted of a sandy bottom continuously interrupted by manganese-encrusted outcrop. Faunal density was consistently high, ranging from 16 to 32 individuals per m^2. Densities were highest in the outcrop areas and lowest in the sandy areas. The most abundant species was the soft coral Swiftia casta. Two stylasterin corals, Distichopora foliacea and Stylaster erubescens, were present in moderate and low densities, respectively. The finger-shaped bryozoan was also present throughout most of this area.

Figure 108 shows similar plots of faunal density and dominant taxa along the camera-sled tow taken on the upcurrent side of the bump. Faunal densities were relatively high (16 to 24 individuals per m^2) in the flat region near the top of the bump and variable in the deeper portion that was incised by a series of valleys. In general, faunal densities were lowest on the downcurrent side of these valleys and highest on the upcurrent side. S. casta was an important component of the fauna throughout the tow. Along with D. foliacea, it dominated the fauna near the top of the bump. Slightly deeper two other species, the stylasterid Stylaster complanatus and the finger-shaped bryozoan, became increasingly important. Below 500 m the gorgonian Plumarella pourtalesii gradually replaced S. casta. S. erubescens was found in low densities throughout this tow.

Figure 109 shows similar plots of faunal abundance along the transect located on the downcurrent side of the bump. Faunal densities were moderately high on the first two

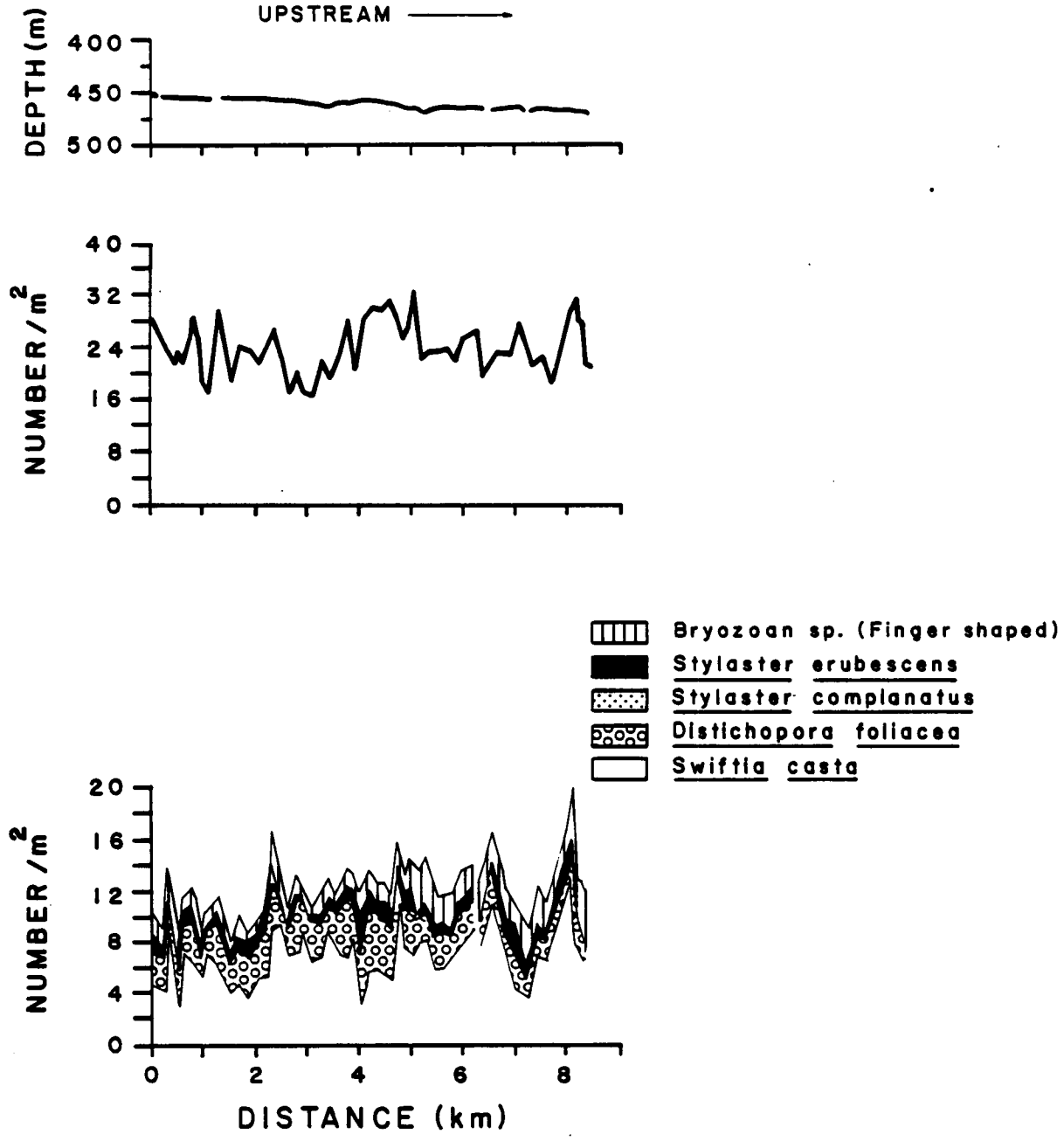


Figure 107. Depth, Abundance of Total Megafauna, and Density of Five Selected Species from the Camera-Sled Tow on Top of the Charleston Bump.

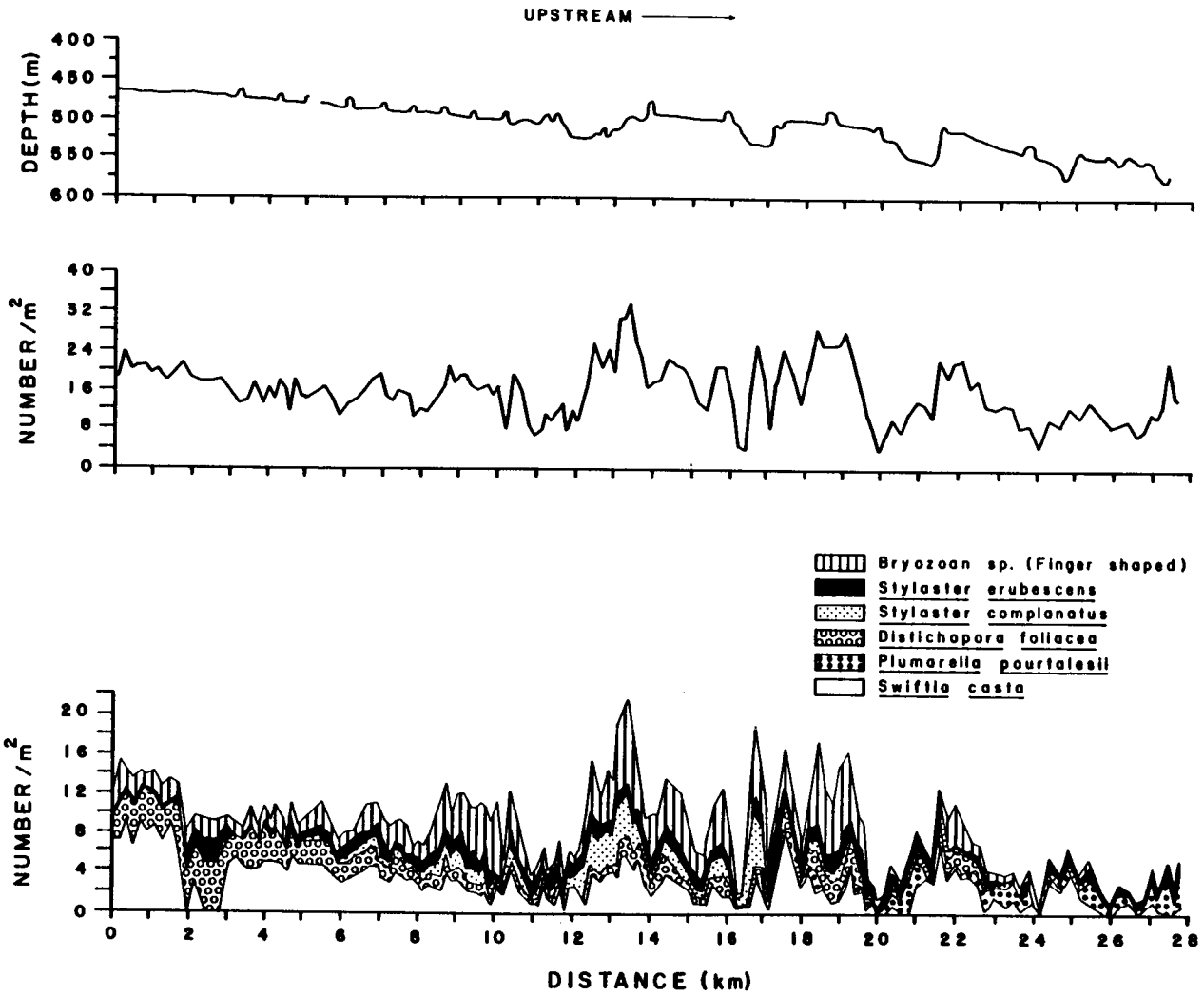


Figure 108. Depth, Abundance of Total Megafauna, and Density of Six Selected Species from the Camera-Sled Tow on the Upstream Side of the Charleston Bump.

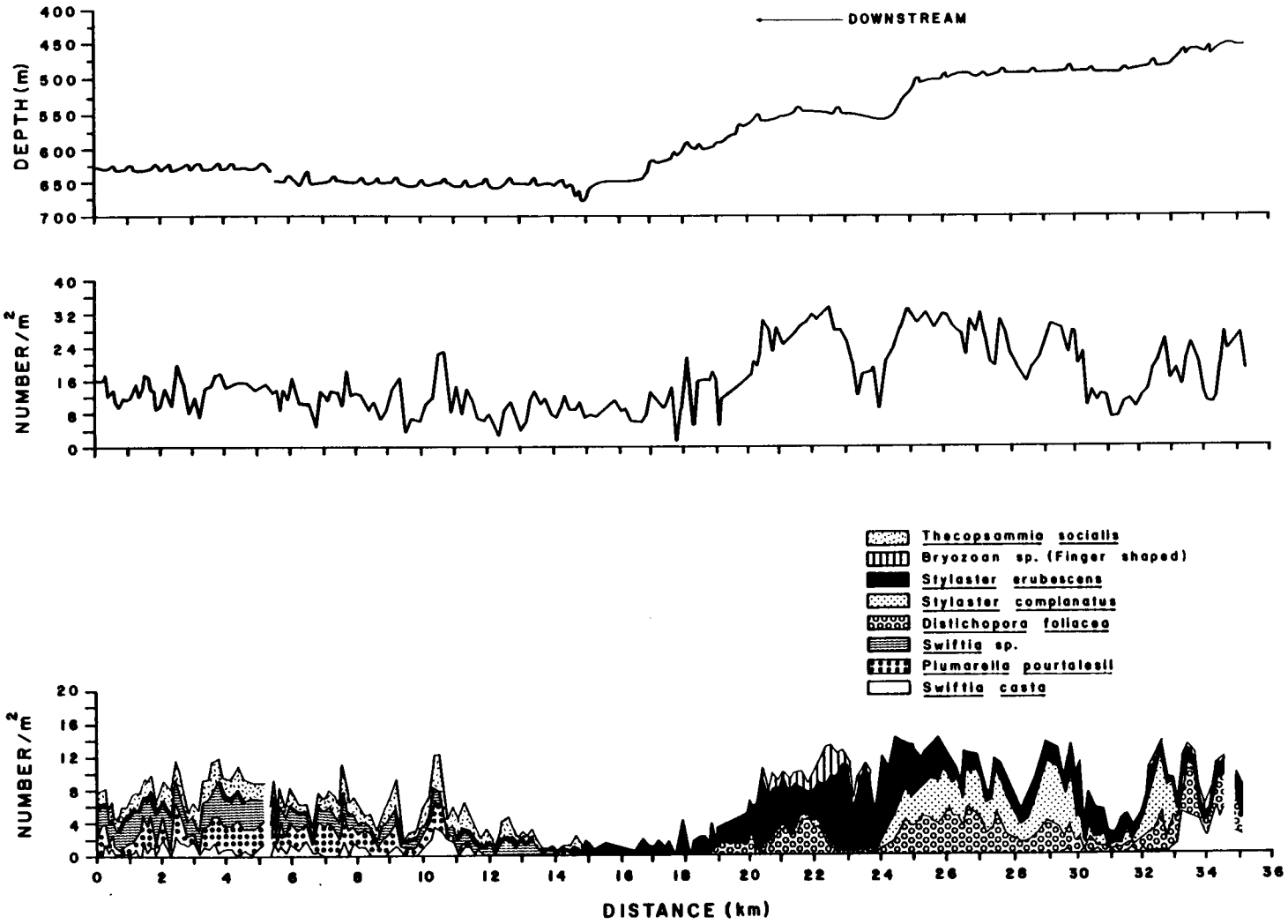


Figure 109. Depth, Abundance of Total Megafauna, and Density of Eight Selected Species from the Camera-Sled Transect on the Downstream Side of the Charleston Bump.

ledges (averaging 24 individuals per m^2), and lower on the third ledge and in the trough (averaging 12 individuals per m^2). In this region, S. casta and D. foliacea again dominated the fauna near the top of the bump. Slightly deeper, the fauna on the three ledges on the downcurrent side was dominated by stylasterids, S. complanatus and D. foliacea on the first ledge, and S. erubescens on the second and third ledges. In contrast, two soft corals, P. pourtalesii and Swiftia sp., and one hard coral, Thecopsammia socialis, dominated the fauna in the trough. The other common soft coral, S. casta, which was dominant near the top, but absent from the ledges, was present in low numbers in the trough.

Community Analysis

Classification analysis of the 135 pooled sample areas and 64 species from the camera-sled tows taken in the Charleston Bump area defines five major clusters (Figure 110). The clustering structure is a function of a combination of location and depth. Each of the clusters further subdivides, on the basis of depth, into groups of areas with greater than 55 percent faunal similarity. A plot of these cluster groups along the camera-sled tows is shown in Figure 111, and the taxa indicative of each group are presented in Table 51.

The first cluster consists of areas located at the deeper end of the upcurrent tow, where valleys incise the gently sloping seafloor. The areas in group 1a were located in the deepest valley; 1b areas were on the ridge just downstream of this valley; and 1c areas were in the slightly shallower valleys and on the ridges between them. The fauna inhabiting these areas was dominated by three species of Plumarella: P. pourtalesii throughout the areas in cluster 1, joined by P. aurea on the deepest ridge (group 1b), and by an unidentified species in the deepest valley (group 1a). The areas in cluster 2 were located on the shallower portion of the upstream side (group 2a) and on top of the bump (group 2b). Most of these areas supported reasonably dense populations of the soft coral Swiftia casta, the stylasterid Distichopora foliacea, and a finger-shaped bryozoan. In addition to these three taxa, the top of the bump (2b areas) was also inhabited by lower densities of the alcyonarian Pseudodrifa nigra and a mushroom-shaped lithistid sponge.

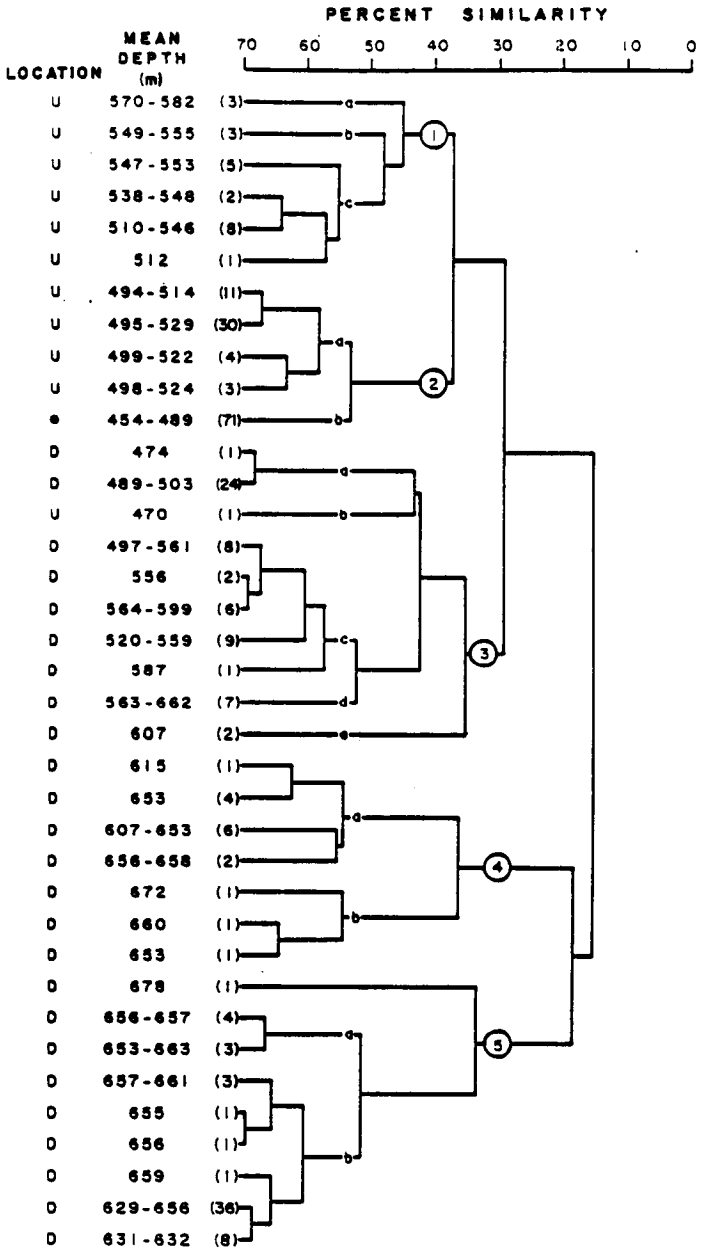


Figure 110. Heirarchial Classification of Sample Areas from Camera-Sled Tows in the Charleston Bump Area. The Circled Numbers and Letters Represent Major Clusters and Groups of Areas. The Following Information is Presented for the Areas in Each Leg of the Dendrogram: Location (U=Upstream Side, D=Downstream Side, and *=Top), Depth Refers to the Mean Depths of the Pooled Sample Areas, and the Number in Parantheses Represents the Number of Before Pooling Sample Areas Included in the Leg.

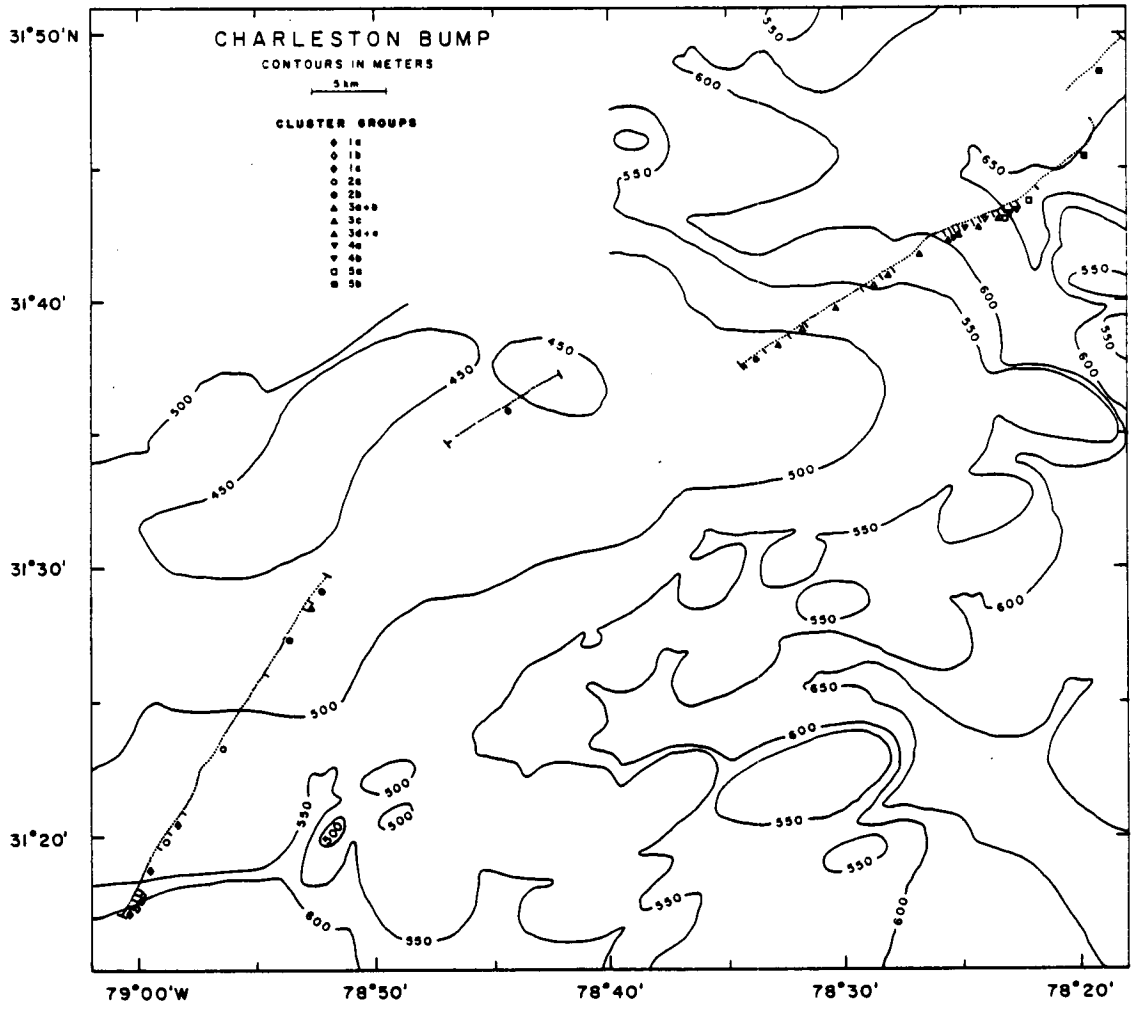


Figure 111. Plot of Cluster Groups Along the Camera-Sled Tows in the Charleston Bump Area.

TABLE 51. DEPTH AND RELATIVE DENSITY OF DOMINANT EPIFAUNAL SPECIES IN THE CLUSTERS AND GROUPS OF AREAS DEFINED BY CLASSIFICATION ANALYSIS OF THE CHARLESTON BUMP CAMERA-SLED TOWS.

Cluster	1			2		3					4		5		
Group	a	b	c	a	b	a	b	c	d	e	a	b	a	b	c
Location	Upstream				Top	D	U	Downstream					Trough		
Mean Depths (m)	570-582	549-555	510-553	494-529	454-489	474-503	470	497-599	563-662	607	607-658	653-672	653-663	629-663	678
Plumarella pourtalesii*	H	H	M-H	L-H	-	-	-	-	-	-	-	L	L	M-H	-
Plumarella sp.	H	L	-	-	-	-	-	-	-	-	-	-	-	L-M	-
Plumarella aurea	L	H	L-M	-	-	-	-	-	-	-	-	M	M	M-H	-
Bryozoan (finger shaped)*	-	L	L-M	M-H	M-H	L	M	L-H	-	L	-	-	-	-	-
Lithistid sponge	-	-	-	L-M	L-H	-	-	-	-	-	-	-	-	-	-
Swiftia casta*	L-M	L-M	L-M	M-H	H	L-M	-	L	-	-	L	-	-	L-M	-
Pseudodrifa nigra	-	-	-	-	H	-	-	L	-	L	L-M	L	L-M	H	L
Districhopora foliacea*	L	L	L	M	M-H	H	H	M-H	-	-	-	-	-	-	-
Stylaster complanatus*	L	L	L	M-H	L-M	H	L	-	L-M	-	-	-	-	-	-
Blue encrusting sponge	L	L	L	L	M	H	M	M-H	L	L	L	L	L	L	L
Stylaster erubescens*	M	M	M	M	M	M-H	H	H	M-H	M	M	M	L	L	L
White fan sponge	-	-	-	-	L-M	L	-	L-M	-	H	-	-	-	-	-
Small round sponge	-	-	-	-	-	-	-	L-M	L	L	M-H	M	L-M	-	-
Swiftia sp.*	-	-	-	-	-	-	-	-	-	-	L	-	H	H	L
Thecopsammia socialis*	-	-	-	-	-	-	-	-	-	-	L	-	M-H	H	H
Callogorgia sp.	-	-	-	-	-	-	-	-	-	-	L	-	-	L-H	-

Top =Top of Charleston Bump
D =Downstream
U =Upstream
* =Very abundant
- =Absent
L =Low density
M =Moderate density
H =High density

With the exception of one small area (3b), the areas in cluster 3 were all on the downstream side of the bump. The areas in groups 3a and 3c were located on the upper two ledges, with the 3a areas on the shallowest ledge and most of the 3c areas on the second ledge. In contrast, the areas in groups 3d and 3e were located on the steep slopes between the ledges. The fauna in this region was dominated by stylasterin corals; with moderate to high densities of Stylaster erubescens in all of the cluster 3 areas, joined by moderate to high densities of D. foliacea in the areas in groups 3a, 3b, and 3c, and by high densities of Stylaster complanatus in the areas in group 3a. In addition to stylasterids, the areas on the ledges (groups 3a and 3c) also had large numbers of a blue encrusting sponge. The areas on the slopes between the ledges (groups 3d and 3e) supported lower densities of S. erubescens and a large fan sponge. The areas in cluster 4 were all located in the deeper portion of the downstream side of the bump, with the 4a areas on the slope between the last two ledges and on the last ledge, and the 4b areas in the trough. The fauna inhabiting these regions was quite sparse and consisted mainly of moderate abundances of S. erubescens. An unidentified small round sponge also was found in moderate to high densities in the 4a areas.

The areas in cluster group 5 were all located in the trough behind the Charleston Bump. The areas in group 5a were located near the base of the bump, and the areas in group 5b were located further away from the bump. One outlier area in this cluster was located in a small valley at the base of the downstream side of the bump. All of the areas in cluster 5 supported moderate to high densities of the hard coral Thecopsammia socialis. In addition to T. socialis, the areas on the flat floor of the trough were inhabited by moderate to high densities of soft corals; Swiftia sp. in all of the areas, joined by P. pourtalesii, P. aurea, and P. nigra in the areas that were further away from the bump (group 5b).

The results of ordination analysis of data from the Charleston Bump camera-sled tows are presented in Figures 112 and 113. Axis 1 appears to represent a depth gradient, with the areas near the top of the bump having low values and the areas in the trough behind the bump having high values (Figure 112). No pronounced faunal breaks can be discerned along this axis. With the exception of the areas in the trough behind the bump (cluster 5), the upstream and downstream sides separate along the second axis. Areas on

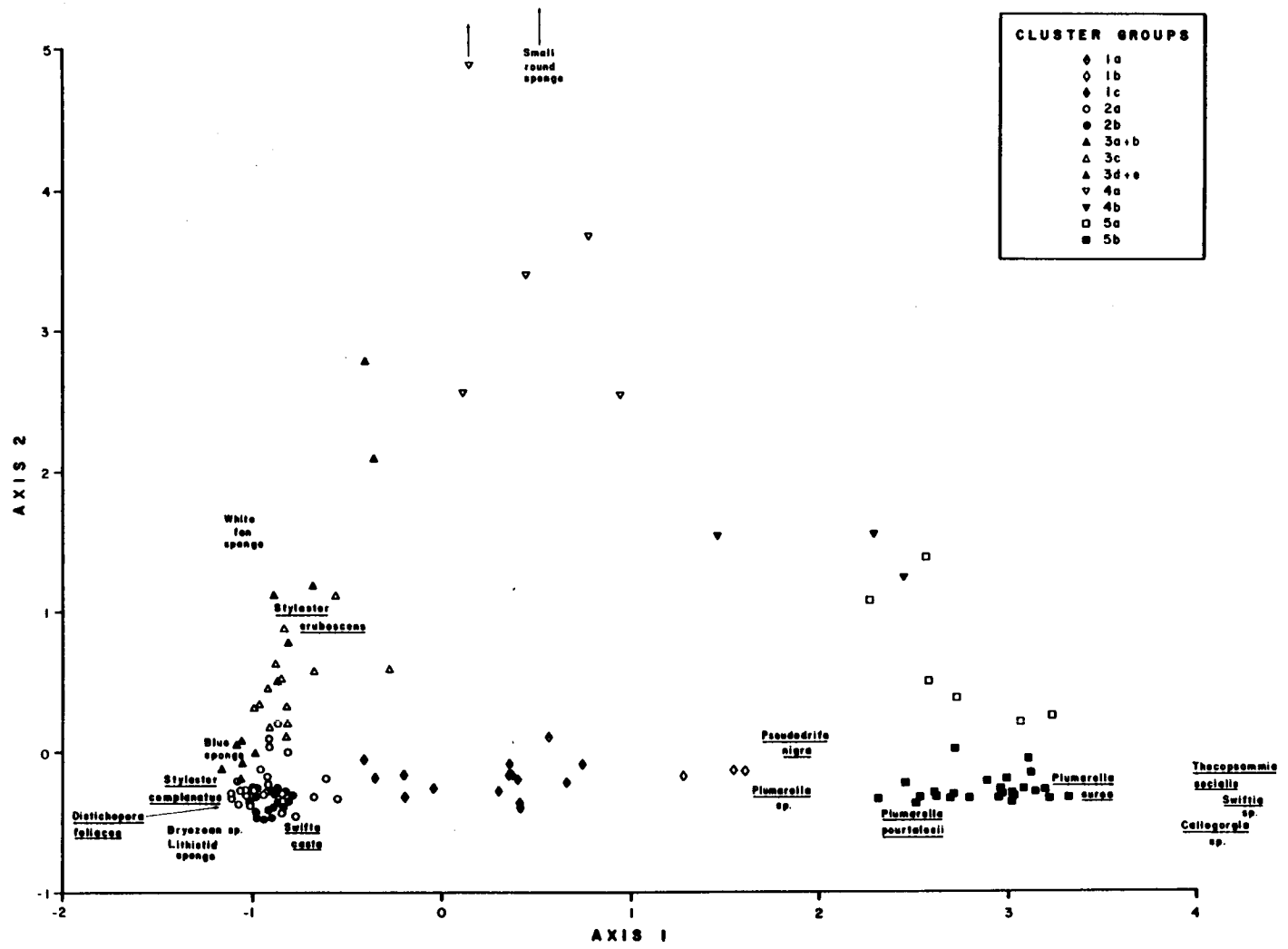


Figure 112. Ordination by Reciprocal Averaging of the Charleston Bump Sample Areas and Species on Axes 1 and 2. Symbols Represent Cluster Groups Defined by Classification. Dominant Species Responsible for the Ordination Pattern are Also Shown.

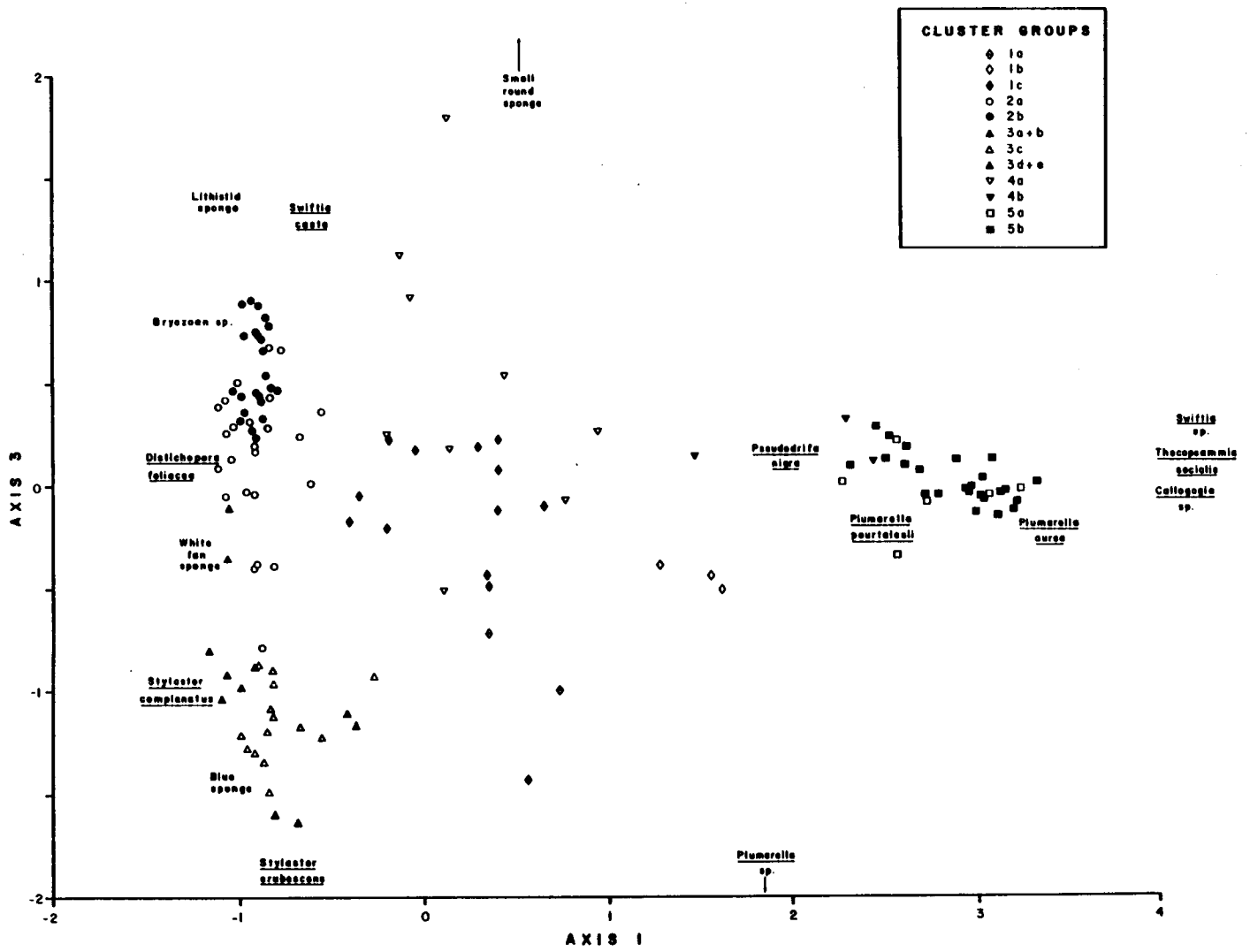


Figure 113. Ordination by Reciprocal Averaging of the Charleston Bump Sample Areas and Species on Axes 1 and 3. Symbols Represent Cluster Groups Defined by Classification. Dominant Species Responsible for the Ordination Pattern are Also Shown.

the top and upstream side of the bump (clusters 1 and 2) have low values on axis 2, and areas on the downstream side (clusters 3 and 4) have higher values. This second axis could represent an exposure, steepness, and/or substrate gradient. The areas on the top and upstream side (clusters 1 and 2) were directly exposed to the Gulf Stream, were flat, and had a fair amount of loose sand. The areas on the downstream side (clusters 3 and 4) would be expected to be more protected from strong bottom currents and were characterized by a cemented crust substrate. Within each of these clusters the steeper areas (groups 3d, 3e, and 4a) had higher values on axis 2 than the areas on the flat ledges (groups 3a and 3c) or in the trough (group 4b). The areas on the floor of the trough (cluster 5) might be expected to be less protected from bottom currents, particularly those further away from the bump (group 5b); they were flat and had some loose sand. Axis 3 best separated the shallower areas, with areas on the top of the bump having high values, the shallower portion of the upstream side having intermediate values, and the shallower portion of the downstream side having low values (Figure 113). No consistent environmental gradient could be discerned for this axis. This inability to identify an environmental gradient represented by axis 3 reflects the physical complexity of the Charleston Bump area, where depth, topography, current regime and geological characteristics differ markedly among the various areas surveyed.

DISCUSSION

The zonation of fauna across continental slopes, which separate shelves from the deep sea, has been the focus of numerous studies (Vinogradova, 1962; Rowe and Menzies, 1969; Menzies et al., 1973; Carney and Carey, 1976; Haedrich et al., 1975, 1980; Rowe et al., 1982; Hecker et al., 1983). The fact that organisms are zoned in bands extending along isobaths has been well established. The results of these investigations differ in the number of zones delimited and their depth boundaries. The observed disparities frequently reflect differences in sampling or statistical techniques, taxa used to define the zones, or physical parameters of the areas studied.

Much less attention has been focused on delineating horizontal faunal changes along the slope. Hecker et al. (1983), studying megafaunal populations on the continental slope

off New Jersey and Georges Bank, found that faunal zones extended for long distances along the continental margin, but were sporadically interrupted by submarine canyons. They attributed the breakdown of these zones to the complex current patterns and varied geological conditions found in submarine canyons. Cutler (1975), studying the distribution of sipunculids and pogonophorans, identified a partial zoogeographic barrier on the slope east of Cape Fear, N.C. Since both of the organisms that he was studying are sedentary, he attributed this barrier to the influence of bottom currents on larval dispersal.

Research on the bottom currents influencing the seafloor off North Carolina indicates that the seasonal effects of the northward-flowing Gulf Stream may occur deeper than 1000 m off Cape Hatteras (Richardson, 1977) and deeper than 700 m off Cape Fear (Levin and Bergin, 1983). On its northward passage along the shelf edge, the Gulf Stream is deflected offshore just downstream of a ridge (Charleston Bump) on the northern Blake Plateau (Brooks and Bane, 1978). This offshore deflection induces upwelling on the upper slope off Charleston, driving a semipermanent cyclonic gyre overlying the slope between the Charleston Bump and Cape Lookout (Singer et al.,1983). This gyre expands and contracts seasonally, and is thought to be particularly prevalent directly off Charleston. Additionally, a western boundary undercurrent flows southward along the isobaths between 1000 and 4000 m (Heezen et al., 1966). Lee and Waddell (1983) found what they interpret as a possible remnant of this countercurrent on the Blake Plateau off Georgia. Studies by Richardson (1977) on the slope northeast of Cape Hatteras indicate that seasonal changes in the undercurrent may be induced by its interaction with the deeper portion of the Gulf Stream. At present, the complex oceanographic processes occuring on the slope off North Carolina are only beginning to be understood.

The photographic survey of megafaunal populations in the U.S. South Atlantic region included a variety of habitats, ranging from the steep slope northeast of Cape Hatteras to the flat slope off Charleston, and south to the ridge projecting seaward (Charleston Bump) on the northern Blake Plateau. The fauna inhabiting the Charleston Bump was completely different from that inhabiting the slope areas. For this reason, the discussion of faunal densities and distribution patterns on the Charleston Bump will be presented separately.

Slope Areas

Patterns of megafaunal density, zonation, and trophic structure in the three slope areas studied for Phase 2 of the U.S. South Atlantic Study were variable, but usually within the range of patterns observed on other portions of the U.S. South Atlantic slope (Blake et al., 1985), and on the U.S. Mid- and North Atlantic slopes (Hecker et al., 1983). These patterns generally reflected the distributions of several dominant taxa. Since many of the dominant species varied between the areas, the resulting density, zonation, and trophic composition patterns differed. The faunal patterns found on the northeastern slope of Cape Hatteras and off Cape Fear closely resembled those found in other slope areas, but the patterns found on the middle slope off Charleston differed substantially.

The slope in the vicinity of Block 510 off Cape Hatteras lacks the major submarine canyons characteristic of the U.S. Mid- and North Atlantic regions. However, this area is dissected by numerous smaller canyons that begin on the slope but do not breach the shelf edge (McGregor, 1984). Using a combination of seismic-reflection profile and sidescan sonar data, McGregor (1984) found average seafloor gradients of 9°, with local gradients of 30° on the canyon walls. As a result of this complex and steep topography our photographic coverage was quite patchy in this area. The geology of this region is also complex in that the relatively coarse grain size of the sediment indicates an erosional environment (Bothner et al., 1987; Chapter 7, this volume); whereas the elevated lead (5-10 times higher than predicted) and aromatic inventories (consistently higher than the other stations) indicate a depositional environment (Bothner et al., 1987; Chapter 6, this volume).

Our photographic coverage indicates that the seafloor in this region is indeed quite complex and does not closely resemble other slope habitats. One striking characteristic was the presence of exceedingly high densities of large white tubes projecting from the sediment on the steep seaward facing slopes between 600 and 1150 m, 1300 and 1500 m, and 1700 and 1950 m. Similar tubes have previously been seen only on the steep walls of submarine canyons in the U.S. Mid-and North Atlantic regions (Hecker et al., 1980; 1983). Faunal densities were intermediate on the upper slope, low on the middle slope, and high on the lower slope. This pattern is similar to that found on slopes north and south of this

area. However, the higher densities of some taxa and absence of others indicate that this area of the continental slope is anomalous. The most striking faunal difference between this area and other slopes is in the abundance of eel pouts. These fish are usually only a minor portion of the fauna inhabiting the gentler slopes north and south of this area, but in the Block 510 area they were a dominant component of the fauna on the upper and middle slope. The elevated densities of infauna found in this region (Chapter 3, this volume) may well explain the higher abundances of eel pouts, since they feed mainly on small bottom-dwelling invertebrates. Other faunal differences between this region and the slopes to the north and south are absence of the quill worm Hyalinoecia artifex and the anemone Bolocera tudiae, reduced abundances of the crustaceans Parapagurus sp. and Munida valida, and increased abundances of the anemone Actinauge verilli, on the upper slope. Faunally, the lower slope in this area resembles other slopes in having high densities of the brittle star Ophiomusium lymani, and low to moderate densities of the sea pens Distichoptilum gracile and Kophobelemnon stelliferum.

The lower slope off Cape Fear appears to be a depositional area; it is characterized by a fine-grained sediment (Bothner et al., 1987; Chapter 7 this volume), and the photographs show no indication of strong bottom currents. The high faunal density in this region agrees well with the results of previous studies. Again, O. lymani was the predominant inhabitant of the lower slope. However, some of the other common lower slope taxa were either absent or found in exceptionally reduced abundances in this area. The sea pens D. gracile and K. stelliferum, which are quite common on the slopes to the north, were very rare in this area. In contrast, an unidentified white sea pen, which is found on the rise off Cape Lookout, was common on the lower slope off Cape Fear. The urchin Echinus affinis, the soft coral Acanella arbuscula, and the holothurian Mesothuria lactea, which are common north of Cape Fear, were absent in this area. These species were replaced by low densities of another holothurian, Mesothuria verilli, a looser branched Acanella, and an unidentified sponge.

The slope off Charleston consisted of several very distinct geological regions. The deeper portion of the upper slope was characterized by sand waves, with well-developed ripple marks covering both the waves and the troughs between them. The coarse-grained sediment and ripple marks both indicate that this is an erosional region. Slightly deeper,

the upper portion of the middle slope was characterized by a series of ridges between 640 and 715 m and a flat seafloor of compacted sediment between 715 and 800 m. The shallower portion of this region also appeared to be erosional. The middle slope between 800 and 1200 m appeared to be largely depositional, in that it was covered by a finer-grained sediment and had numerous remains of seaweed strewn on the seafloor. The remainder of the middle slope gradually graded into the more compacted, coarser-grained sediment found on the lower slope. This area again appeared to be erosional in nature, but to a lesser degree than the upper slope.

Faunal densities on the slope off Charleston differed from those to the north in that they alternated between intermediate and low on the middle slope instead of being consistently low, and were intermediate on the lower slope instead of high. The fauna in the shallower portion of the transect resembled the fauna on the slope off Cape Lookout and in the Hatteras Canyon area in the density of Rochinia sp. and Parapagurus sp., but differed in the exceptionally low densities of M. valida and the absence of B. tudiae. The low densities of M. valida in this region may be related to the erosional regime. This galatheid crab is frequently found in large depressions, which may afford them refuge from predation. The sand waves and compacted sediment characteristic of the shallower portions of the Charleston transect would preclude formation and maintenance of such depressions. No satisfactory explanation for the absence of B. tudiae in this region can be identified at this time. Another striking difference in the fauna was the high abundance of a hard coral, Bathypsammia tintinnabulum, on the middle slope off Charleston. This coral was not found in any of the other areas studied. Deeper on the middle slope, high densities of an unidentified purple sea pen totally dominated the fauna. In previous studies this sea pen had been found only in very low densities. The high abundances of B. tintinnabulum and the purple sea pen are probably related to increased productivity in the vicinity of the Charleston Gyre. O. lymani still dominated the fauna on the lower slope, but was substantially reduced in abundance. The reduced density of this brittle star may be related to the erosion of fine particles from this area. With the exception of the reduced abundances of O. lymani, the fauna on the lower slope resembled that found off Cape Fear.

Faunal breaks defined by classification analysis marked regions of rapid faunal change separating zones of faunal homogeneity. The homogeneous zones frequently reflected the depth distributions of several dominant species. Faunal breaks were identified at 500, 1200, and 1500 m on the slope northeast of Cape Hatteras, at 1590 m on the slope off Cape Fear, and at 640, 790, 950, and 1370 m on the slope off Charleston. The lack of a faunal break between 500 and 1100 m off Cape Hatteras reflects the dominance of the eel pout L. verilli on the steep slope throughout this depth range. The faunal break at 1500 m in this region reflects the upward limit of O. lymani, which dominated the lower slope faunal zone. The faunal zone between 1100 and 1500 m was characterized by low abundances of several species. Not much can be said about faunal zonation on the slope off Cape Fear, because of the limited depth coverage (1534 to 2147 m). However, the lower slope faunal break at 1590 m reflects the upper limit of O. lymani in this area.

The faunal zones on the slope off Charleston parallel the boundaries of different geological provinces and the distributions of three dominant taxa. The shallow break at 640 m marks the seaward extent of sand waves that are inhabited by sparse populations of fish and crustaceans. The faunal zone between 640 and 790 m reflects the very high densities of B. tintinnabulum found on the compacted sediment and ridges characteristic of this area; whereas the faunal zone between 790 and 950 m represents an area inhabited by very sparse populations of several species. The depositional region between 950 and 1370 m marks a faunal zone dominated by a very abundant purple sea pen. The lower faunal break at 1370 m again reflects the upper limit of O. lymani, which dominates the lower slope faunal zone.

All three slope areas were similar in that the lower faunal zone was defined by the distribution of the O. lymani. However, the upper and middle slope faunal zones, differed between the Cape Hatteras and Charleston areas. These differences reflect the pronounced geological and taxonomic differences between the two areas. In comparison to faunal zonation on the slope off Cape Lookout and in the Hatteras Canyon area (Blake et al., 1985), the slope northeast of Cape Hatteras lacks a discrete faunal break between the upper and middle slopes. In this regard the slope in the vicinity of Block 510 most closely resembles the slope off Georges Bank, which also lacks a sharp faunal boundary on the upper to middle slope (Hecker et al.,1983). In contrast, the slope off Charleston has

an additional faunal break on the middle slope, separating the shallower erosional region from the deeper depositional one. These disparities reflect differences in topography, geological provinces, and current regimes between various areas of the U.S. South ACSAR, and hence differences in the fauna inhabiting them.

The observed faunal zonation patterns reflect changes in trophic strategy along a resource gradient. The differences in faunal zonation between the areas studied are also seen in the patterns of trophic composition across the slope. All three areas are dominated by deposit feeders on the lower slope. However, they differ in the relative proportion of filter feeders and carnivores on the middle and upper slopes. Northeast of Cape Hatteras the fauna inhabiting a narrow band on the lower portion of the middle slope consists of a mixture of filter feeders and carnivores, which gives way to a fauna dominated by carnivores on most of the middle slope. This in turn grades into a fauna consisting of a mixture of carnivore and filter feeders near the upper-middle slope boundary, then changes to a fauna dominated by filter feeders on the upper slope. In terms of trophic composition, this slope area resembles the previously studied slope areas to the north (Hecker et al., 1983) and to the south (Blake et al., 1985). In contrast, the fauna inhabiting the middle slope off Charleston is frequently dominated by filter feeders, separated by narrow bands of a mixture of filter feeders and carnivores. This dominance by filter feeders on most of the middle slope is a pattern usually found in submarine canyons, where hard substrates or enhanced current regimes afford a suitable habitat for many corals and sponges.

The observed trophic composition patterns may reflect differences in the physical characteristics of the areas studied and the resulting food-resource gradient. The upper slope northeast of Cape Hatteras is periodically influenced by seasonal fluctuations of the Gulf Stream. This may account for the predominance of filter feeders in this region. Additionally, rapidly sinking larger particles advected off the shelf would preferentially settle out on the upper slope, supplying food resources for large filter feeders and the smaller prey species of carnivores. Most of the middle slope in this area would be comparatively nutrient poor, with the few particles landing in this area possibly being rapidly carried further down the steep slope. This type of environment would favor carnivores, which are capable of rapidly locating and utilizing food items. The lower

slope, receives fine particles that settle out of the water column, as well as those from downslope transport, favoring a fauna dominated by deposit feeders, which can best utilize finer-grained particles.

Similarly, the pattern of trophic structure off Charleston also reflects depositional and erosional regimes. However, this area is further complicated by an intense shallow current regime and an unusual circulation pattern. The semipermanent cyclonic gyre centered off Charleston revolves around a dome of upwelled nutrient-rich cold water (Singer et al., 1983). The horizontal dimensions of this gyre expand and contract seasonally with variations in the flow intensity of the Gulf Stream. The upwelled waters may well enhance the productivity of this region, resulting in an increased flux of particulates to the seafloor. This may explain the higher densities of filter feeders found on the middle slope off Charleston. Alternatively, a shallow arm of the western boundary undercurrent may also be supplying nutrients to this area. The absence of filter feeders in the sand wave area at the shallower end of the Charleston transect may be related to several factors. The seafloor in this area may be relatively nutrient poor because the high current activities evidenced by ripple marks would carry particulates out of the area. Additionally, the substrate instability of continual sediment movement would preclude settlement of most sessile filter feeders. The reduced abundances of deposit feeders on the lower slope may be related to the larger grain size of sediment found in this area, where currents appear to be eroding away the finer particles utilized by deposit feeders.

Zoogeographic Barrier

Our results from photographic transects support Cutler's (1975) premise that the slope off North Carolina represents a partial zoogeographic barrier. Additional evidence for the faunal break was obtained from trawl samples taken on the slopes off Cape Lookout, Cape Fear, and Charleston. Trawl samples from 800 m off Cape Fear were dominated by M. valida and Parapagurus sp., but the 2000-m samples from off Cape Lookout were dominated by O. lymani. In contrast, two other crustaceans, Glyphocrangon sp. and Stereomastis sp., joined Parapagurus sp. in the 800-m trawl samples from off Charleston, while another brittle star, Bathypectinura heros, dominated the 2000-m trawl

samples in the same area. This would indicate that the most pronounced faunal break occurs on the slope between Cape Fear and Cape Lookout. However, data from the camera-sled transects indicates that the transition from a northern faunal province to a southern faunal province is much more gradual and incomplete. While most of the taxa characteristic of U.S. Mid- and North Atlantic slope habitats were found off Cape Lookout, low abundances of several of the southern species were also found in this region. On close examination of the data it appears that the distributional limits of many of the taxa differ.

The pattern that emerges is one of gradual faunal change along the slope between Cape Hatteras and Charleston. The slope between Cape Hatteras and Hatteras Canyon appears to be the southern limit of the rattail Coryphaenoides rupestrus, the brotulid Dicrolene intronigra, and the burrowing anemone Cerianthus borealis. Additionally, much higher concentrations of the hermit crab Parapagurus sp. are found south of Cape Hatteras. The slope between Hatteras Canyon and Cape Lookout marks the southern limit of the holothurian Mesothuria lactea and the urchin Plesiodiadema antillarum (Urchin A in Blake et al., 1985) and the northern limit of the brittle star B. heros and the holothurian Mesothuria verilli. The slope between Cape Lookout and Cape Fear marks the southern limit of the sea pens Distichoptilum gracile and Kophobelemnon stelliferum, and the urchin Echinus affinis, and the northern limit of a small sponge that resembles a venus fly-trap. The slope between Cape Fear and Charleston marks the southern limit of high densities of M. valida and O. lymani, and the northern limit of high densities of the hard coral Bathypsammia tintinnabulum, the crustaceans Glyphocrangon sp. and Stereomastis sp., and the large purple sea pen. In contrast, other species, like the urchins Phormosoma placenta and Hygrosoma petersi, the hard corals Ealbellum alabastrum and Caryophyllia ambrosia, and eels belonging to the genus Synaphobranchus, are found in nearly equal densities from Georges Bank to Charleston.

The faunal differences among the various regions studied indicate faunal responses to differing current and geological parameters. The distribution of taxa that depend on larval dispersal may well be controlled by the complex interaction of the predominant currents in this area of the South Atlantic. However, the distributions of many of the taxa appear to be controlled by the presence or absence of certain geological habitats within a given depth range.

At present, we have identified the slope off North Carolina as being a region of rapid faunal change. Examining this partial zoogeographic barrier in greater detail would require more in-depth data analysis than time has permitted. However, this may be useful in better elucidating some of the factors responsible for the dramatic faunal turnover occurring in this area. Identifying these factors would also require a greater knowledge of the life-habits of many of these organisms and of the near-bottom current regime.

Charleston Bump

In contrast to the slope areas to the north, the Blake Plateau offers an entirely different environment. Instead of the soft sediments characteristic of the continental slope, the seafloor on the northern Blake Plateau consists of a hard pavement of cemented sediments and manganese-encrusted outcrops. Current velocities in this region preclude the build-up of any substantial amounts of sediment. The Charleston Bump is a seaward projecting ridge on the northern Blake Plateau located off the coast of Charleston, South Carolina. Much interest has been afforded this area by physical oceanographers, since the ridge causes a seaward deflection of the Gulf Stream north of the bump (Brooks and Bane, 1978). However, very little is known of the fauna inhabiting this area. Our camera-sled transects on the Charleston Bump revealed a very rich and dense bottom fauna, dominated by filter-feeding corals and sponges. Consistent differences were found between the fauna inhabiting the upstream and downstream sides of the bump.

The topography and surficial geology varied considerably across the Charleston Bump. The top was flat and characterized by a cemented crust that was frequently interrupted by projecting manganese-encrusted rock ledges. The upstream side of the bump consisted of a gentle slope that was interrupted by a series of 10-m high ridges in the shallower region and 1-km wide valleys in the deeper portion. The surficial geology of this area consisted of a sand veneer overlying an irregular hard subsurface. Well-developed ripple marks were frequently observed on the sand throughout this region. Occasionally, manganese encrusted outcrops and gravel deposits were found on the walls of the valleys. The downstream side of the bump consisted of three flat ledges that were separated by steep slopes. The first two ledges consisted mainly of a cemented crust

covering unconsolidated sand and coral rubble. The third ledge consisted of a manganese-encrusted pavement. The slopes separating the ledges had extensive exposures of manganese encrusted outcrop, interrupted by regions of sand and coral rubble. The flat trough behind the bump was interrupted by a series of 5- to 10-m relief ridges, and consisted of a cemented crust that was sporadically interrupted by manganese encrusted outcrop and coral rubble. Further away from the bump the crust was frequently covered by a ripple-marked thin veneer of sand.

The highest faunal densities were found on top of the bump and on the first two ledges on the downstream side, while the lowest densities were found in the trough behind the bump. Since most of the taxa inhabiting the Charleston Bump were sessile filter feeders, the higher densities on the top and downstream side may reflect the higher proportions of exposed hard substrate available in those areas. Also, these areas may be slightly more protected from the direct force of the current, which could easily abrade the thin external tissue of corals. The lower faunal densities in the trough, which is in the lee of the bump, may be related to lower current intensities delivering less nutrients to this area.

The fauna inhabiting the upstream and downstream sides of the bump differed considerably. While most taxa were found throughout the region, they showed marked depth and location preferences. The most noticable faunal difference between the areas surveyed was that stylasterin corals dominated on the downstream side of the bump, while gorgonians dominated on the top, the upstream side, and in the trough. Structural differences between these two groups may explain this distribution. Stylasterids have a rigid, calcified skeleton and a dense branching pattern that results in a large surface area. In contrast, the skeleton of gorgonians is less massive, more flexible, and the branching pattern is sparser. Since filter feeders frequently orient themselves perpendicular to the current, the bases of the rigid stylasterids would be subjected to far greater stress than would the bases of the more flexible gorgonians. Thus, the stylasterids would require harder and stabler attachment sites, and possibly lower current intensities than the gorgonians. The low density of stylasterids in the trough behind the bump indicates that they are also less tolerant of low current intensities.

Individual species within these two groups also displayed habitat and depth preferences. The stylasterid Stylaster complanatus was most common on the crust surface on the shallower portion of the downstream side of the bump, while S. erubescens was most common on the manganese-encrusted surfaces slightly deeper. The other abundant stylasterid, Distichopora foliacea, was found in equal densities on the top and upper sides of the bump. The most common gorgonian found in the Charleston Bump region was Swiftia casta. This species was present in highest densities on top of the bump, but was also found in reduced densities throughout most of the area studied. Species belonging to the genus Plumarella were found in highest densities in the deeper portion of the upstream side and in the trough. P. pourtalesii was found in comparable densities in both regions, while another species, Plumarella sp., preferred the upstream side. An unidentified species of the genus Swiftia was found only in the trough.

Several of the other common taxonomic groups in this area also showed marked habitat and depth preferences. An unidentified bryozoan was confined to the depths above 600 m, and was found in high densities only on the top and upstream side of the bump. In contrast, a small scleractinian, Thecopsammia socialis, was only found in the trough behind the bump. Additionally, the dominant sponges inhabiting the Charleston Bump showed similar preferences.

The results of community analysis reflected the different habitat and depth preferences of the dominant species inhabiting the Charleston Bump. Depth and location appeared to be the dominant factors controlling community structure. Classification and ordination analysis failed to define any pronounced faunal breaks, but rather indicated a pattern of gradual faunal change between the different regions of the bump. The most pronounced faunal change was related to depth, with the fauna inhabiting areas above 600 m differing substantially from the fauna inhabiting deeper areas. Regions of rapid faunal change coincided with the most pronounced changes in topography and surficial geology.

The fauna inhabiting the top of the Charleston Bump was relatively homogeneous, with the areas located at the top of both sides clustering very closely with the areas in the middle. The fauna on both sides of the bump gradually changed with increasing depth. The most pronounced faunal change on the upstream side occurred at 500 m, where the flat seafloor became steeper and was incised by valleys. Three regions of rapid faunal

change were noted on the downstream side of the bump. The first of these regions was at 470 m where the flat top surface of the bump steepened into the slope leading to the first ledge. The second region of rapid faunal change on the downstream side occurred between the second and third ledges, where the cemented sediment crust gave way to a manganese-encrusted pavement. The third region was located on the trough, behind the bump, where the hard sediment crust near the base of the bump gradually became covered with a sand veneer further away. In addition to changes in topography and surficial geology, differences in the bottom currents between these areas probably account for some of these faunal changes.

The Charleston Bump region of the northern Blake Plateau is a particularly interesting area. Its geological heterogeneity and strong currents provided suitable habitats for exceptionally dense populations of filter-feeding taxa. The density and taxonomic composition of this area was very reminiscent of shallower-water reef habitats. How extensive this type of assemblage is on the other portionns of the Blake Plateau is presently not known. However, based on geological and current regime considerations we predict that these types of communities could be widely distributed throughout the region.

Overview

Our photographic coverage of the U.S. South Atlantic continental margin indicates that this is a very heterogeneous region and provides suitable habitats for a wide range of benthic communities. This heterogeneity is a reflection of the complex current regime providing a wide variety of different environmental conditions. The soft sediment slope in the northern portion of this region varies between silty depositional areas and sandy erosional areas. As a result of this heterogeneity, the U.S. South Atlantic margin differs from the U.S. Mid- and North Atlantic margins in that it is a region of marked horizontal faunal change. The dominant gradients controlling the distribution of megafaunal assemblages on the U.S. Mid- and North Atlantic slopes are depth and canyon versus slope habitats (Hecker et al., 1983). The more complex and diffuse zonation pattern found in canyons reflects the greater substrate hetrogeneity and enhanced current regimes found

there. While canyons sporadically interrupt the faunal zones found on the slope, these zones continue for long horizontal distances on either side of a canyon. In contrast, marked faunal changes are noted within short horizontal distances on the U.S. South Atlantic slope. The predominant factors controlling megafaunal distributions in this region are also depth, current regime, and surficial geology. While these controlling factors are similar to those found further north, their spatial scale differs considerably. Thus, it is difficult to characterize the magafaunal assemblages of the U.S. South Atlantic slope on a regional basis, except to note that they change within short horizontal distances.

CHAPTER 6. CHEMICAL ANALYSIS OF SEDIMENTS AND TISSUES

INTRODUCTION

The technical approach of the analytical chemistry segment of the program involved the analysis of bottom sediments for hydrocarbons and selected benthic epifauna for hydrocarbons and trace metals. As part of an overall program to determine the pre-drilling biological, chemical, and geological conditions of offshore areas potentially subject to oil and gas exploration activities, it is important to accurately characterize the levels of organic chemicals, especially hydrocarbons, and metals in the benthic environment. Information on conditions prior to drilling activities will allow comparisons to be made when potential impacts of any subsequent activity on the marine environment are studied. This approach will permit an examination of pollutant pathways through the benthic chemical environment and estimation of recovery in the event that adverse environmental impacts occur due to drilling activities. The study of Bothner et al. (1987) on the trace metal content of bottom sediments complements the work presented in this section.

The objectives of the analytical chemistry program are to establish pre-drilling biogeochemical data sets for sediments and tissues. Methods of sediment and tissue analysis and results from three sets of samples obtained on three cruises are presented in this chapter.

Details of the field collection of samples are presented in Chapter 2 of this report. Sediment samples were collected from one station on Cruise SA-3, from all stations on Cruise SA-4 and, with one exception, on Cruises SA-5 and SA-6 (Table 52). The particular stations were chosen for continuing study because the oil industry has expressed interest in drilling areas in Block 510 near those locations (Stations 9 and 10). Station 4, off Cape Lookout, was retained from the Phase 1 study in order to obtain long-term seasonal biological data and to obtain chemical data not collected in Phase 1. The transects off Cape Fear (Stations 11, 12, and 13) and Charleston (Stations 14A, 14, 15, and 16) were selected in order to provide data in areas of oil industry interest south of Cape Lookout.

TABLE 52. STATIONS SAMPLED FOR SEDIMENT HYDROCARBON ANALYSIS.

Cruise	Stations
South 3 (SA-3)	9
South 4 (SA-4)	4, 9, 10, 11, 12, 13, 14, 15, 16
South 5 (SA-5)	4, 9, 11, 12, 13, 14, 15, 16
South 6 (SA-6)	4, 10, 11, 12, 13, 14, 15*, 16

* Station 15, SA-6, partially processed. Analyzed for sediment hydrocarbons as a single sample.

ANALYTICAL METHODS

General

The analytical strategy adopted for surface sediments involved a two-phased approach, whereby three replicate sediment samples collected at each of the selected stations were extracted and analyzed (Figure 114). The extracts were first screened for petroleum residues by synchronous scanning UV/fluorescence spectrofluorometry (UV/F). The UV/F method provided a semi-quantitative characterization of the fluorescence character, i.e., aromatic hydrocarbon distribution, of the sample extracts, and was used in conjunction with station location to identify those samples that should be selected for further analysis by high resolution gas chromatography (GC) and capillary gas chromatography/mass spectroscopy (GC/MS). A second use of the UV/F technique was to determine relative differences in aromatic content among stations and at the same station over time. A third application of the technique was to provide information on replicate variability prior to pooling the sample extracts for subsequent analyses.

Samples were processed using a method based on the ambient temperature shaking-solvent extraction technique of Brown et al. (1979, 1980). The extracts were analyzed by UV/F. The three extracts from each station were then combined and fractionated by column chromatography to isolate saturated and aromatic hydrocarbons. Individual compounds, indicative of both biogenic and anthropogenic inputs, were quantified using capillary gas chromatography with flame ionization detection (GC/FID) for saturated hydrocarbons and GC/MS for aromatic hydrocarbons.

Faunal samples and sediments were analyzed directly by GC/FID and GC/MS to determine hydrocarbon content and composition and were also analyzed by atomic absorption spectroscopy (AAS) for selected trace metals. The data were interpreted as related to background levels and possible geochemical interactions with the benthos. The details of the analytical methods used are presented below.

Hydrocarbon Analysis

Sediments. A known amount of wet sediment (generally 75 to 100 g dry weight) was sealed in a Teflon jar and processed by shaking sequentially with methanol (three times,

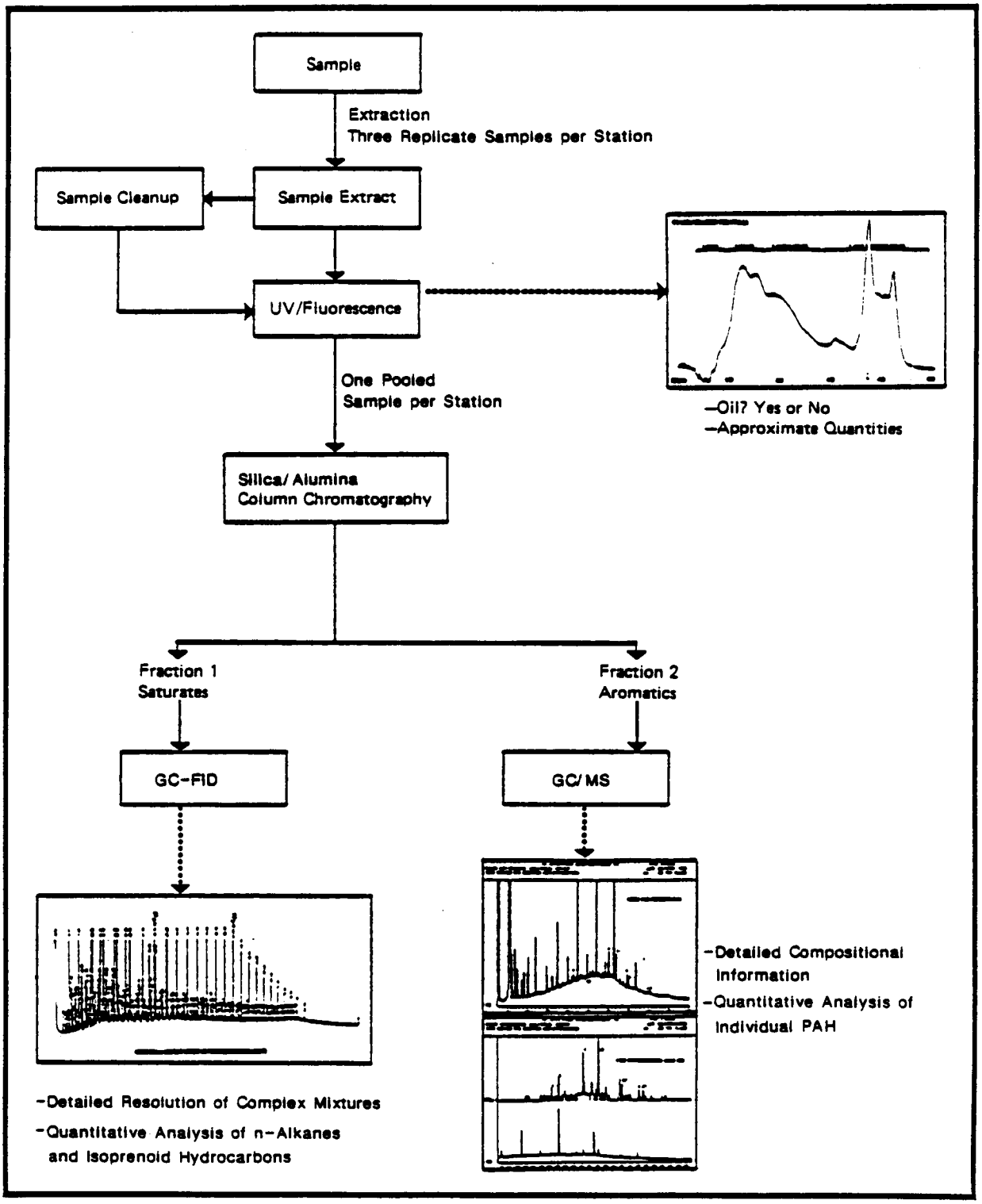


Figure 114. Analytical Scheme for Hydrocarbons in Sediments and Tissues.

30 min each) followed by a 1:9 methanol:methylene chloride (2:1 solvent volume: wet weight) mixture (three times, 8 h each). Solvents used in this study were pesticide grade or equivalent. Internal standards (androstane and o-terphenyl) were added prior to extraction with the methanol:methylene chloride mixture. Following each extraction, the solvent was isolated by centrifugation and decantation. The combined methanol/methylene chloride extracts were diluted with an equal volume of Milli-Q water and partitioned three times versus methylene chloride. The combined methylene chloride extracts were dried over Na_2SO_4 and concentrated to near dryness on a rotary evaporator or in a Kuderna-Danish concentrator, during which time the methylene chloride was displaced with hexane.

Tissues. Several species were targeted for tissue analyses: the brittle star Ophiomusium lymani or Bathypectinura heros and the sea urchin Echinus affinis. When none of these species were obtained, the species selected was Munidia valida, a galatheid crab, or Stereomastis sp., a shrimp. Whole brittle stars, including exoskelton and soft tissues, were analyzed because separation of soft tissue was not possible in this species. Soft tissues and fluids were, however, isolated from the sea urchins. Six to twelve individuals were pooled and homogenized for each analysis. Subsamples of this homogenate (approximately 30 g wet weight) were used for analysis. Tissue samples were cut into small pieces and the chopped tissue added to a Teflon jar or glass centrifuge bottle containing aqueous 5N KOH. Following addition of internal quantification standards, the jar was sealed and the sample completely digested at 35°C for 12 h. The digested mixture was neutralized with 6N HCl; these extractions were performed by adding ether directly to the digestate in the centrifuge bottle. The extracts were collected, dried over Na_2SO_4, and concentrated on a rotary evaporator to near dryness in preparation for alumina precolumn cleanup.

UV/Fluorescence Analysis

The synchronous excitation/emission technique for this analysis was based on Wakeham (1977) and Gordon et al. (1976), and has been extensively described by Boehm et al. (1982). The analytical conditions were as follows: Farrand System-3 spectrofluorometer with corrected excitation feature; synchronous monochronometer scanning excitation wavelengths 225 to 475 nm and emission wavelengths 250 to 500 nm;

scan speed 50 nm/min; emission slit width 2.5 nm, excitation slit width 5.0 nm; 25-nm separation of excitation and emission wavelengths. This technique measures fluorescing compounds including, but not limited to, aromatic hydrocarbons with a 2- to 5-ring aromatic structure (Lloyd, 1971). To ensure that the measurements were free of spectral quenching, the extract was repeatedly diluted by 50 percent with hexane and reanalyzed until a comparison of two consecutive dilutions indicated that the analysis was performed within the linear range of fluorescence response. The intensity of the fluorescence spectra was measured at three emission wavelengths (312, 355, and 425 nm) which corresponded to peak maxima present in an EPA Arabian Light crude oil reference sample. This crude oil was chosen as a reference because it is used as a standard in many international monitoring programs (i.e., International Consortium of Environmental Studies or ICES). The fluorescence spectra were converted to relative concentration units (i.e., oil equivalents) by comparing the peak height at each wavelength to that of a reference oil standard calibration curve that was run daily. All tissue sample extracts and sediment sample extracts were processed through a small chromatography column (4 g) of activated alumina and eluted with 20 ml methylene chloride prior to UV/F analysis.

Liquid Chromatography

The liquid chromatographic procedure outlined in Boehm (1983) was used to isolate saturated and aromatic hydrocarbons from sediment extracts. Chromatographic fractions containing saturated and aromatic hydrocarbons were eluted from a 1-cm i.d. alumina/silica gel/activated copper column (1 g/11 g/2 g); hexane (17 ml) and 1:1 hexane:methylene chloride (21 ml) were used as solvents. The fractions were concentrated to a known volume by rotary and N_2 evaporation. An aliquot of each fraction was weighed on a Cahn-25 electrobalance to determine total gravimetric concentrations of each hydrocarbon type. The sum of these concentrations was the total gravimetric hydrocarbon concentration.

GC/FID and GC/MS Analysis

All saturated hydrocarbon fractions of sediments and tissues were analyzed by GC/FID. Gas chromatographic conditions were as follows: Shimadzu Model GC9A or

Hewlett-Packard 5880A gas chromatograph with a Shimadzu C-R3A chromatographic data processor; splitless injection on a 30-m x 0.25-mm i.d. DB-5 fused silica capillary column, temperature programmed from 60 to 290°C at 4°C/min after an initial 0.1-min isothermal period; He carrier gas (2 ml/min). Specific saturated compounds (n-alkanes over the range n-C_{10} to n-C_{34}, pristane, phytane) were identified by comparing GC/FID retention time versus authentic standards; their concentrations were calculated by comparing integrated peak area versus the androstane internal standard. Response factors relative to the internal standard were calculated daily from analysis of standard mixtures and applied to the final quantitative results. Concentrations of total resolved hydrocarbons were calculated by comparison of total resolved area (i.e., sum of all peaks) in gas chromatograms to that of the internal standard, androstane. Unresolved hydocarbon concentrations (i.e., the unresolved complex mixture described by Farrington and Tripp, 1977, and Boehm, 1984) were calculated by using the chromatographic data processor to integrate the area of the unresolved envelope beneath the peaks in chromatograms and applying the same internal standard technique and a response factor of one.

Concentrations of individual 2- to 5-ring polycyclic aromatic hydrocarbons (PAH) were determined by capillary GC/MS on a Finnigan 4530 quadrupole GC/MS system, equipped with a Data General Nova-4 computer with Incos data system. GC conditions were as follows: splitless injection on a 30-m x 0.25-mm DB-5 fused silica capillary column, temperature programmed from 40 to 290°C at 6°C/min after a 1-min isothermal period; He carrier gas. MS conditions were electron impact mode, ionizing voltage 70 eV; electron multiplier, 1200-2400V; m/e scan range 50 to 450; scan rate, 1 scan/sec. Ion currents were calculated in each aromatic fraction and related to that of the o-terphenyl internal standard. These currents corresponded to the molecular ions of the naphthalene, fluorene, phenanthene and dibenzothiphene alkyl homologue series, as well as fluoranthene, pyrene, benz(a)anthracene, chrysene, benzofluoranthene, benzo(e)pyrene, benzo(a)pyrene and perylene. Response factors relative to the internal standard were calculated from daily analysis of standard mixtures analyzed and applied to the final results to yield concentrations for the individual constituents. Where standards were not available (e.g., for alkylated homologues) response factors were assigned by extrapolation.

Trace Metal Analysis

Sample Preparation and Digestation

Frozen specimens were manually separated, placed in bags and freeze-dried for 24 h. Because of the expected low metal concentrations, all handling of tissue samples was conducted in a laminar flow hood to limit atmospheric contamination. Talc-free plastic gloves were worn when handling samples. Additionally, all equipment was acid-cleaned by soaking for 1 h in concentrated HNO_3 followed by concentrated HCl. All aqueous rinses and dilutions were made using quartz-distilled water. After freeze-drying, samples were ground using a clean ceramic mortar and pestle, and stored in plastic bags in a dessicator.

For the preparation of samples from Cruise SA-4 for all elements except Hg, V, and Ba, a known amount of sample (generally 2 to 8 g) was placed in a quartz beaker and 5 ml G. Frederick Smith doubly-distilled nitric acid (GFS HNO_3) was added slowly. Because of their high $CaCO_3$ content, brittle stars have a tendency to foam excessively upon digestion and care was taken to avoid possible losses of sample due to such foaming. The beakers were covered with a watchglass and allowed to stand overnight. After an additional 5 ml of GFS HNO_3 was added, the solution was heated to near dryness. This procedure was repeated and the resulting solution transferred to a clean polypropylene volumetric flask, diluted with acid, and an aliquot removed for analysis. Samples for Hg analysis were prepared using a nitric-sulfuric acid digestion followed by permanganate oxidation.

For the preparation of Cruise SA-5 samples for all elements except V and Ba, a known amount of sample was placed in a precleaned Teflon digestion vessel and 10 ml G. Frederick Smith doubly-distilled nitric acid (GFS HNO_3) was added slowly. The Teflon vessel was sealed and placed in a CEM Corporation MDS-81 microwave digestion system. Vessels were microwaved for a 5-minute duration at 90 percent full power. After examination for incomplete digestion, the solution was brought to 30 ml volume total with MILLI-Q water. The solution was decanted into pre-cleaned polyethylene bottles for analysis.

Sample Analysis

Tissue samples were analyzed for cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) by atomic absorption spectroscopy (AAS). Because of differing concentrations and instrument sensitivities, samples were analyzed by both flame AAS (FAAS) and graphite furnace AAS (GFAAS) using deuterium background correction. To decrease metal volatility, analyses for Pb and Cd were conducted after addition of $(NH_4)_2NO_3$ to sample solutions. General instrument conditions were as follows:

Metal	Instrument	Wavelength (nm)
Cd	GFAAS	228.8
Cr	GFAAS	357.9
Cu	FAAS	324.8
Fe	FAAS	248.3
Mn	FAAS	279.5
Ni	GFAAS	232.0
Pb	GFAAS	283.3
Zn	FAAS	213.9

Tissue samples were analyzed for mercury (Hg) by the cold vapor technique using a LDC mercury analyzer.

Freeze-dried samples were also analyzed for barium (Ba) and vanadium (V) by instrumental neutron activation analysis (INAA). These analyses were performed by Nuclear Energy Services, Inc., Chapel Hill, North Carolina.

Quality Control

Hydrocarbon Analyses

Analytical quality control procedures covered a wide range of activities including daily calibration of all instruments, verification of instrumental performance through analysis of standard compound mixtures, and verification of the purity of all solvents and reagents.

The precision of each of the instrumental methods used in the study was determined by an initial three-point calibration and repeated analyses of calibration standards representative of the period of time over which each instrument was used. Analytical variability was also determined and controlled as part of laboratory quality assurance. Sediment homogenized in the laboratory was analyzed by UV/F, and an interim reference material or laboratory reference material was analyzed by GC-FID and GC/MS. Both analyses were performed in triplicate. The specific quality control measures described below were used for the analyses performed for this study.

Sediments. One procedural blank was included with every set of 12 samples analyzed. Blanks were processed in exactly the same manner as actual samples and were analyzed by UV/F, GC/FID, and/or GC/MS as appropriate to determine the presence/absence of contaminants. Initially, a fortified blank, consisting of 1 ml of National Bureau of Standards - Standard Reference Material (NBS-SRM)-1647 (PAH in acetonitrile) and a known amount of an alkane standard mixture containing n-alkanes ranging in carbon number from C_{14} to C_{32}, was substituted for the blank every third set of 12 samples analyzed. Concentrations of individual compounds were calculated relative to an external standard and compared to the added amounts in order to evaluate recovery efficiences of the various analytical procedures. To evaluate the accuracy of the UV/F technique, a previously processed sediment was fortified with a known amount of the reference Arabian Light crude oil. The extraction process was repeated, the extracts were reanalyzed and the amount of oil present was quantified and compared to the added amount.

Tissues. One blank and one fortified blank (prepared as described above) were processed with each set of tissue samples analyzed.

Trace Metal Analyses

Tissues. One procedural blank was processed with each set of six samples. Samples of NBS-SRM-1566 (bovine liver) were also analyzed by FAAS and/or GFAAS and INAA for certified constituents. Analytically determined concentrations in these SRMs were

compared to certified concentrations to evaluate accuracy. To obtain an estimate of the precision of the method, all digestions and analyses were performed in duplicate.

RESULTS

Sediment

Hydrocarbon Analysis

UV/F-determined petroleum - equivalent concentrations in Cruises SA-4 through SA-6 sediments are listed in Table 53. The results, expressed in Arabian Light crude oil (ALCO) equivalents, are reported as the mean value ± one standard deviation based on triplicate analyses at each of three emission wavelengths (312, 355 and 425 nm) corresponding to spectral maxima of the ALCO emission spectrum. The three wavelengths selected generally are considered to be the fluorescence maxima of 2-ring, 3-ring, and 4- and 5-ring polynuclear aromatic hydrocarbons (PAH) respectively; although the fluorescence intensity at any given emission wavelength is the combination of multiple fluorescence emissions of petroleum hydrocarbons. The UV/F data for sediment ranged from 3-95 μg/g dry weight; the data, in general, were reproducible over the sampling intervals. Coefficient of variations expressed as a percentage were normally 50% or greater for overall mean values below 16 μg/g, and were in the 10-20% range for mean values above 32 μg/g (Table 54). The large variability observed between sample replicates at Station 4 on cruises SA-4 and SA-5 (Table 53) and Station 16 on Cruise SA-5 are real and do reflect a greater variability between replicates for these particular samples. Concentrations generally increased with increasing emission wavelength owing to the dissimilarity of the spectra of the reference oil, ALCO, and the sediment extracts themselves. This result reflects the lack of similarity of the UV/F spectra of sediment extracts and ALCO, and specifically the greater relative abundance of compounds with higher aromatic ring numbers in the sediments relative to ALCO. The highest values were exhibited at Stations 4, 9, 10, 12 and the lowest values were found at Station 13 and 15. Typical UV/F spectra from a low and a high value station are shown in Figures 115 and 116.

TABLE 53. CONCENTRATIONS OF HYDROCARBONS IN SEDIMENT SAMPLES FROM CRUISES SA-4, SA-5, AND SA-6 AS DETERMINED BY UV/F (μg ARABIAN LIGHT CRUDE OIL EQUIVALENTS /g DRY WEIGHT).

Emission Wavelength (nm)	Station								
	4	9	10	11	12	13	14	15	16
Cruise SA-4									
312	28.30 ± 9.45	35.26 ± 5.17	28.67 ± 4.87	15.34 ± 2.91	26.61 ± 3.50	4.46 ± 0.81	19.20 ± 7.51	8.53 ± 4.26	14.01 ± 4.86
355	60.33 ± 20.92	51.97 ± 6.83	45.04 ± 5.05	28.46 ± 0.06	69.84 ± 10.89	9.92 ± 3.24	38.59 ± 14.10	24.61 ± 19.68	29.09 ± 8.25
425	95.37 ± 40.04	61.22 ± 7.22	49.66 ± 5.13	31.55 ± 0.46	85.13 ± 9.29	12.85 ± 4.29	49.38 ± 22.97	30.85 ± 20.90	44.02 ± 11.79
Cruise SA-5									
312	35.05 ± 28.08	28.99 ± 9.57	NC	15.70 ± 5.13	34.02	6.60 ± 1.91	13.04 ± 2.26	8.88 ± 5.84	21.19 ± 19.36
355	84.31 ± 92.74	41.68 ± 11.72	NC	24.21 ± 4.44	64.25	10.68 ± 2.47	25.06 ± 2.53	12.05 ± 5.74	14.37 ± 10.14
425	81.20 ± 80.87	44.94 ± 12.40	NC	24.77 ± 5.17	72.40	12.35 ± 2.76	27.16 ± 1.99	8.35 ± 2.51	21.33 ± 23.80
Cruise SA-6									
312	18.52 ± 2.32	NC	21.25 ± 3.52	8.86 ± 1.30	18.36 ± 1.79	8.64 ± 4.64	13.41 ± 2.00	2.97	8.28 ± 3.01
355	31.28 ± 4.40	NC	32.86 ± 7.32	16.08 ± 2.40	34.29 ± 2.98	10.11 ± 4.95	26.94 ± 4.89	4.84	13.54 ± 5.14
425	33.35 ± 4.48	NC	43.05 ± 10.68	15.42 ± 1.44	38.71 ± 2.26	10.56 ± 5.37	31.42 ± 8.03	3.52	14.57 ± 5.86

NC - Not collected - see individual cruise reports.

Comments:Normally, results represent triplicate analyses per station.

Cruise SA-4

1. Concentrations at Stations 4 and 9 are based on triplicate analyses of one replicate averaged with two additional analyses of individual replicates.
2. The result of Station 11 at 312 nm is based on the analysis of two replicates only.

Cruise SA-5

1. Results for Station 12 based on single analysis of an individual sample.
2. Concentrations at Station 15 are based on triplicate analyses of one replicate averaged with two additional analyses of individual replicates.

Cruise SA-6

1. Results for Station 15 based on a single analysis of an individual sample.
2. Concentrations at Station 14 are based on triplicate analyses of one replicate averaged with two additional analyses of individual replicates.

TABLE 54. MEAN AND STANDARD DEVIATION (µg/g DRY WEIGHT) AND COEFFICIENT OF VARIATION OF SEDIMENT UV/FLUORESCENCE DATA FOR SAMPLES COLLECTED ON CRUISES SA-4 THROUGH SA-6.

Emission Wavelength (nm)		Station								
		4	9	10	11	12	13	14	15	16
312	$\bar{x}$	27.29	31.13	24.96	13.30	26.33	6.57	15.22	6.79	14.49
	SD	8.31	3.02	5.25	3.85	8.81	3.77	6.40	4.14	6.58
	CV	30	10	21	29	33	57	42	61	45
355	$\bar{x}$	58.64	46.83	38.95	22.92	56.13	10.24	30.20	13.83	18.98
	SD	26.56	7.28	8.61	8.13	13.25	4.91	9.38	7.12	7.69
	CV	45	16	22	35	24	48	31	51	40
425	$\bar{x}$	69.96	53.08	46.36	23.91	65.41	11.92	35.99	14.41	26.64
	SD	32.50	10.33	4.67	8.44	14.42	5.43	10.48	8.25	15.43
	CV	46	19	10	35	22	46	29	57	58

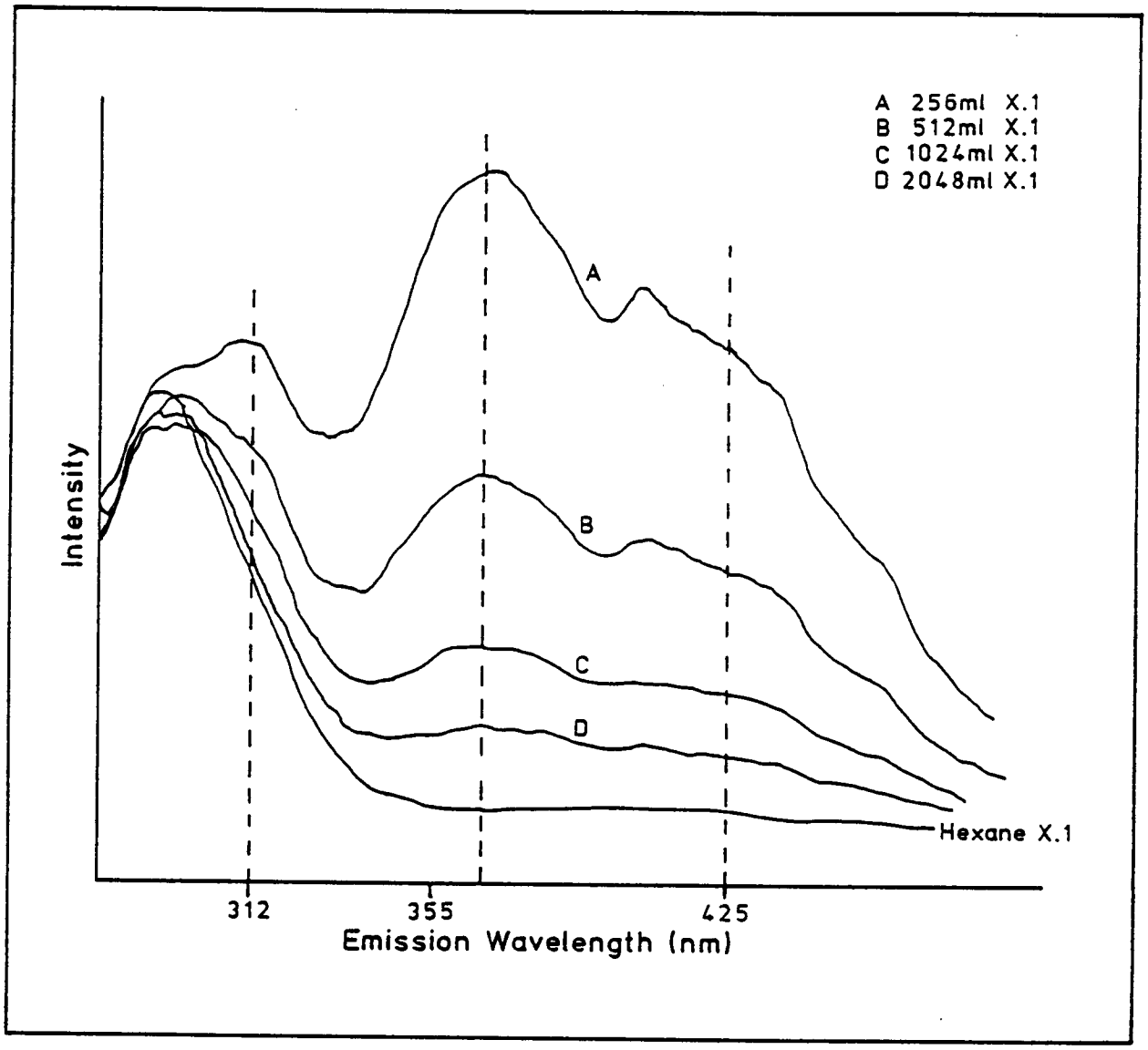


Figure 115. Representative UV/F Emission Spectra of Sediment Hydrocarbons from Station 15, Cruise SA-4 Representing a "Typical Low-Level" Sediment Station. Note Shift in Emission Maximum Away From 355 nm.

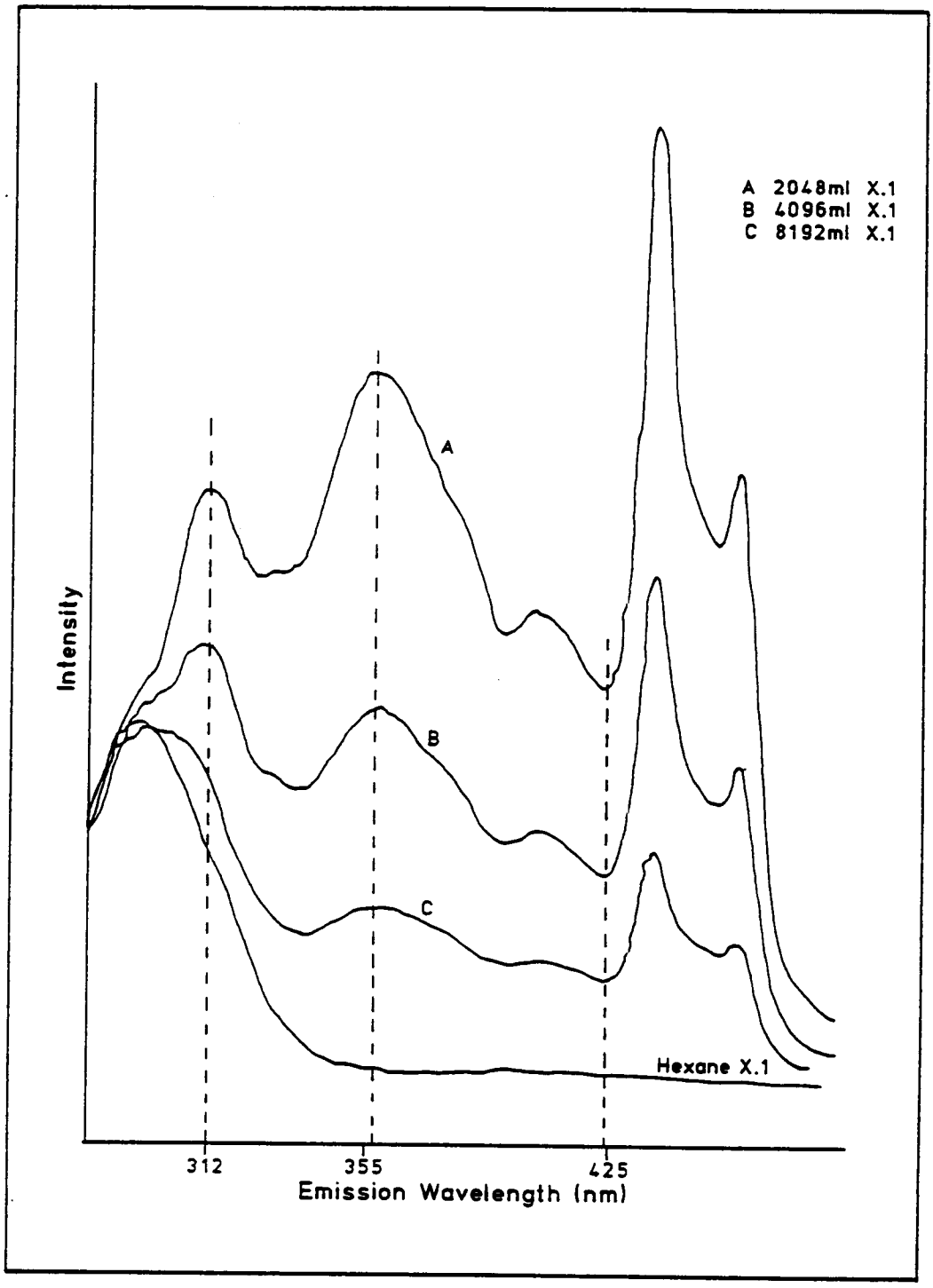


Figure 116. Representative UV/F Emission Spectra of Station 10, Cruise SA-4 Representing Sediment Hydrocarbons From a "Typical Higher-Level" Sediment Station.

Hydrocarbon concentrations and values for selected saturated hydrocarbon parameters determined gravimetrically and by GC/FID in Cruises SA-3 through SA-6 sediments are shown in Tables Appendix H, Tables H.1-H.4. Total hydrocarbon concentrations ranged between 5.7 and 118 µg/g dry weight, with generally comparable contributions from saturated and aromatic hydrocarbons at most stations. The highest concentration (117 µg/g) occurred at Station 12 for one sample. Throughout the data set, Stations 4, 9, 10, and 12 showed the highest hydrocarbon concentrations in a general range of 20-60 µg/g dry weight. The lowest concentrations of hydrocarbons were found at Stations 13 and 15. These trends correspond to the results of the UV/F data, although the UV/F-determined concentrations of ALCO oil equivalents do not, and are not expected to, agree with the absolute concentrations determined gravimetrically. The UV/F technique is a "bulk" measurement of the fluorescence properties of the extracted organic matter. In this technique, an arbitrary reference material, in this case ALCO, is used for quantification. Therefore, a given data set will produce intervally consistent results (i.e., concentrations of ALCO equivalents). As the composition of ALCO and actual extracts of environmental samples are very different, (e.g., the ratio of saturated to aromatic hydrocarbons), any correspondence of actual UV/F determined concentrations to any other data set, e.g., gravimetric results would be accidental at best. General trends in the quantitative data would be expected to be the same between data sets, but absolute agreement between determinations by the two types of techniques will generally not occur (National Academy of Science, 1985).

Representative GC/FID chromatograms for a typical high station (Station 9), a typical intermediate station (Station 16), and a typical low value station (Station 13) all taken from Cruise SA-4 are presented in Figures 117 through 119. The chromatograms from all the stations studied show the same general hydrocarbon compositional patterns with only quantitative differences. There are some differences between station results, however, typically in the C-20 to C-22 region of the chromatogram. The Unresolved Complex Mixture (UCM) generally associated with anthropogenic inputs (Wakeham and Farrington, 1980) could not be found in all chromatograms, but at the stations exhibiting higher concentrations the UCM appeared slightly earlier in the chromatogram typically in the nC-16-to nC-17 range.

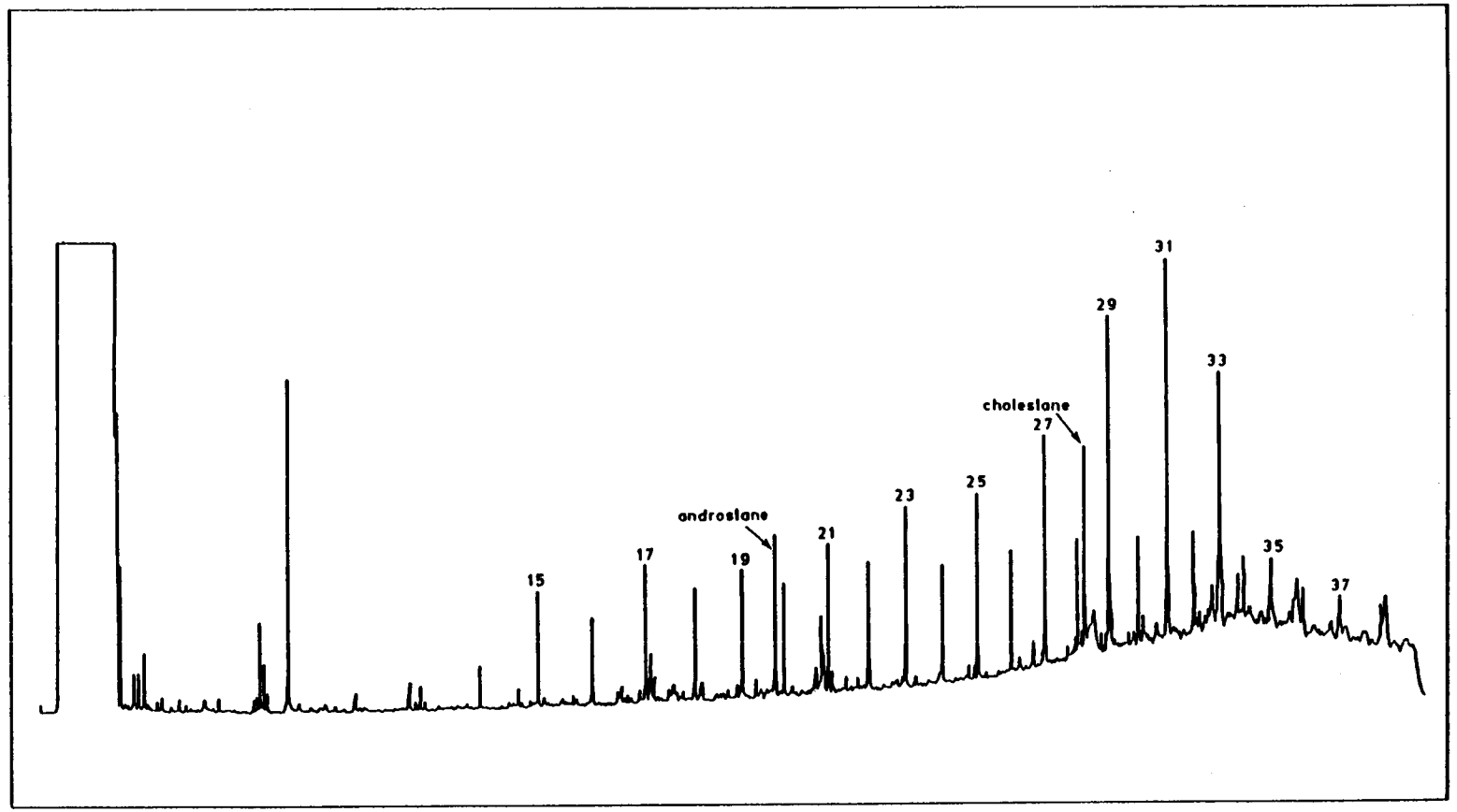


Figure 117. GC/FID Chromatogram of Station 13, Cruise SA-4 Sediment Showing Predominance of Odd-Chain Alkanes from Terrestrial Sources. This Chromatogram Represents a "Typical Low-Level" Sediment Station.

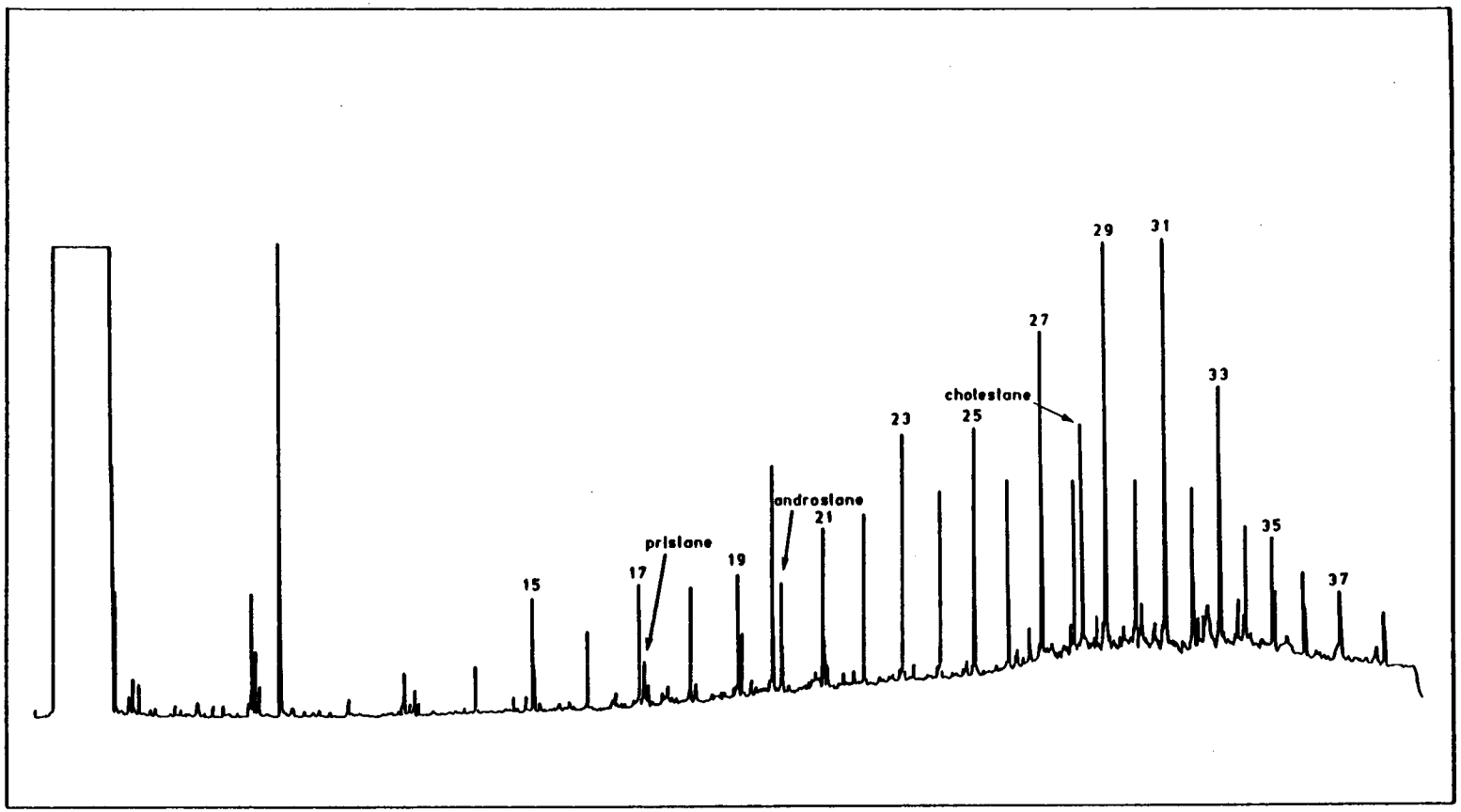


Figure 118. GC/FID Chromatogram of Station 16, Cruise SA-4 Sediment Showing Predominance of Odd-Chain Alkanes from Terrestrial Sources. This Chromatogram Represents a "Typical Mid-Level" Sediment Station.

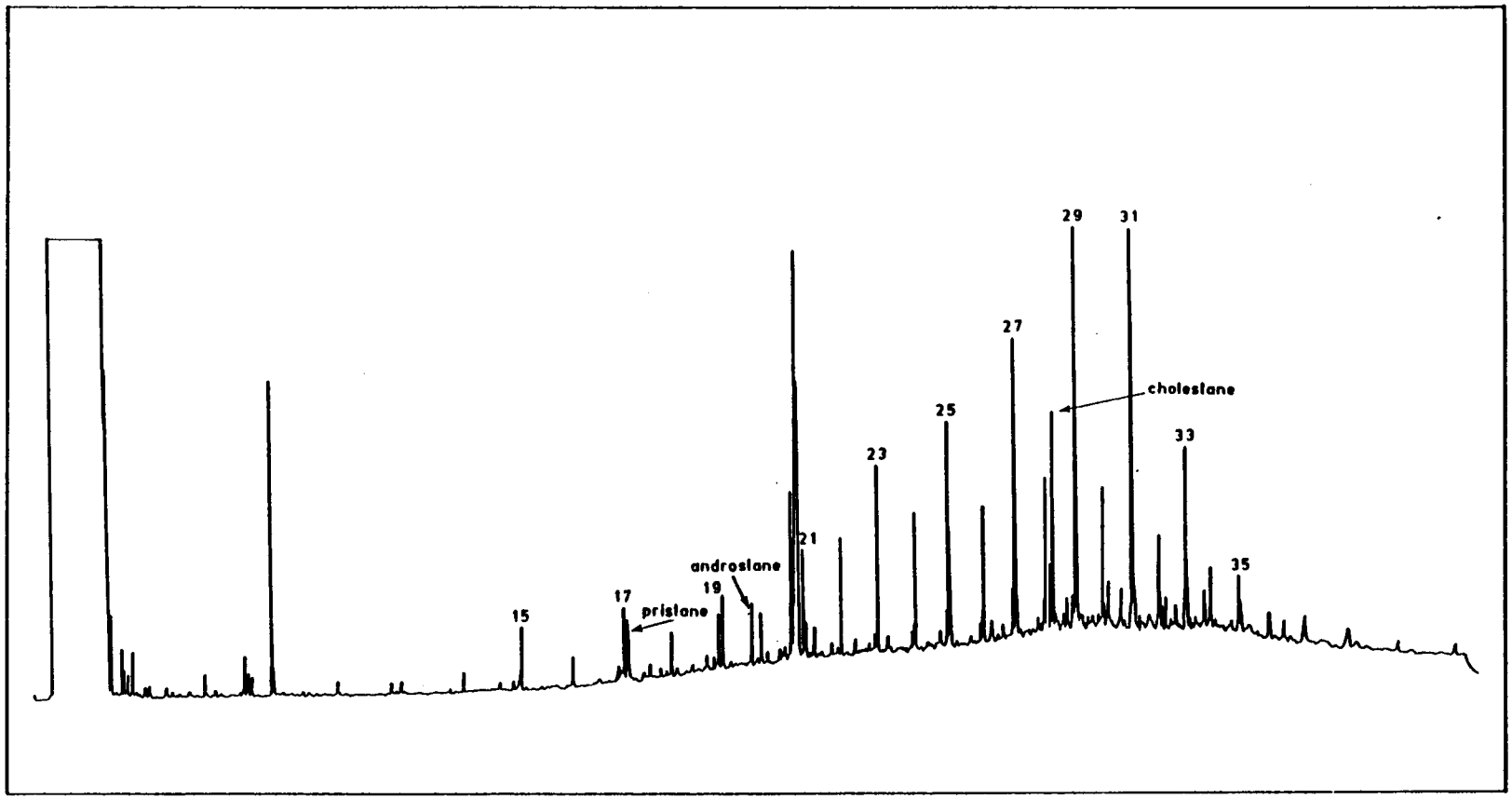


Figure 119. GC/FID Chromatogram of Station 9, Cruise SA-4 Sediment Showing Biogenic Hydrocarbons Plus Input of Odd-Chain Alkanes from Terrestrial Sources. This Chromatogram Represents a "Typical Higher-Level" Sediment Station.

The Odd-Even Preference Index (OEPI), used as an indicator of the relative abundance of odd versus even carbon number alkanes in a sample (Farrington and Tripp, 1977), ranged from 0.5 to a maximum of 4.0. The value of the OEPI typically was in the range of 1.5-2.0. This parameter can range from approximately 1.0 in crude oils to greater than 5.0 where the alkane distribution is dominated by terrigenous, biogenic alkanes. An OEPI value near 1.0 generally indicates a petroleum source. In this study the relatively low OEPI values do not suggest a petroleum source for any of the samples as the other gas chromatographic features suggest biogenic sources for the low hydrocarbon levels observed. The relatively low OEPI values combined with low levels of all hydrocarbons suggest possible diagenetic modification of hydrocarbons present. In addition, in the analysis of the relatively low levels of hydrocarbons as encountered in this study, any calculation such as OEPI is subject to large variability in value with relatively small changes in absolute levels of alkanes. If concentrations of alkanes were higher, for example in an input of petroleum to the sediments, the variability of the concentration of selected alkanes would have a minimal effect due to the large concentrations of all alkanes present. However, in this study where low concentrations of total saturated and specifically the straight and branched chain aliphatic hydrocarbons are observed, the reliability of OEPI or for that matter the reliability of source ratios such as OEPI is diminished. Other saturated hydrocarbon parameters, including diagnostic ratios of the isoprenoid alkanes pristane and phytane to each other and to normal alkanes, are listed with the quantification data in Appendix H, Tables H.1-H.4.

Concentrations of selected 2- to 5-ring polynuclear aromatic hydrocarbons (PAH) as determined by GC/MS are listed in Appendix H, Tables H.5-H.8. Total PAH concentrations (the sum of the 27 compounds or alkyl homologue groups) ranged between 32 and 359 ng/g dry weight. The results paralleled the previous UV/F and GC/FID results in that Stations 13 and 15 showed lowest PAH totals, and Stations 4, 9, 10, and 12 exhibited the highest values.

Compositionally, the phenanthrene series and the 4- and 5-ring compounds accounted for the greatest percentage contribution to the total PAH values. The napthalene, fluorene, and dibenzothiophene groups yielded relatively minor contributions to the PAH totals. This trend was especially evident at those stations of lowest concentration (Stations 13 and 15). Only when total PAH values rose above approximately

100 ng/g could some dibenzothiophenes or fluorenes be detected. Even at highest values, other dibenzothiophene or fluorene homologues could not be detected. Conversely, naphthalene and its alkyl homologs usually could be detected, even at low total PAH values.

The Fossil Fuel Pollution Index (FFPI), using differing PAH distributions to identify sources from fossil fuels to combustion sources (Boehm and Farrington, 1984), was calculated for the sediment samples. Values ranged from 12 to 56 on a scale in which 0 indicates the absence of fossil fuel PAHs (i.e., all PAH due to combustion sources) and 100 indicates that all the PAH found originated from uncombusted fossil fuel. The highest FFPI value were found at Stations 13 and 15, where values of 56.3 and 56 were calculated. The lowest FFPI values were from one replicate at Station 9 taken on Cruise SA-4. Normally, FFPI values of 20-30 were common in this study.

Tissue

Benthic faunal samples for chemical analyses of hydrocarbons and trace metals were collected from selected stations on each cruise (Table 55).

Hydrocarbon Analysis

Total hydrocarbon concentrations of benthic fauna ranged between 5.2 and 322 μg/g wet weight (Appendix H, Tables H.9 and H.10). In all but two samples, the saturated hydrocarbon components were higher than the unsaturated/aromatic compounds. In the faunal tissues analyzed, the saturated hydrocarbon distribution was consistent throughout the sample set. A significant UCM was observed in many of the chromatograms, normally beginning in the higher molecular weight range (n-C_{26}) of the chromatogram. The UCM in the sediments began at somewhat lower molecular weight range (n-C_{22} to n-C_{23} range). When calculable (i.e., when phytane was present), pristane/phytane ratios were very high.

GC/MS analyses of the faunal samples collected on Cruises SA-4 and SA-5 are presented in Appendix H, Tables H.11 and H.12. Generally, total PAH values were low, in the range of 12-55 ng/g wet weight. However, two shrimp samples collected at Station 14

TABLE 55. STATIONS SAMPLED FOR FAUNAL HYDROCARBON AND TRACE METAL ANALYSIS.

Cruise	Station
South 4 (SA-4)	Station 4 (Brittle Star, Ophiomusium lymani)
	Station 11 (Galatheid Crab, Munida valida)
	Station 14 (Shrimp, Stereomastis sp.)
	Station 15 (Brittle Star, Bathypectinura heros)
South 5 (SA-5)	Station 4 (Brittle Star, O. lymani)
	Station 4 (Sea Urchin, Echinus affinis)
	Station 4 (Brittle Star, B. heros)
	Station 11 (Galatheid Crab, Munida valida)

showed total PAH values of 314 and 412 ng/g. The first sample had two major PAHs present --C3 - phenanthrene and C3 dibenzothiophene. The second Station 14 sample had 90 percent presence of 4- and 5-ring PAH's identified.

Trace Metal Analysis

Representative samples of benthic fauna were also analyzed in duplicate for selected trace metals (Appendix H, Tables H.13 and H.14). These analyses represent whole body analyses for all samples. For both cruises, Al and Fe consistently showed the highest levels of any element regardless of species. The lowest elemental concentrations were found for Cr, Hg, and Pb, with concentrations in the range of a few tenths of a part per million. The other elements analyzed had concentrations in the 2 to 30 ppm range, with the exception of Zn which ranged in the 30-50 ppm levels. Organisms collected during SA-4 which were common with SA-5 generally had the same relative ranking of elemental abundance. However, Al, Cr, Fe, Ni, Pb, and V concentrations were consistently higher in SA-5 compared to SA-4. Ba and Zn in brittle stars and Cd in shrimp were lower in the SA-5 specimens relative to SA-4. Comparison of Hg results is different due to the poor agreement with NBS-certified standards. The poor recoveries may be in part due to the methodological difference used to digest the samples between the two cruises.

Quality Control

Hydrocarbons

The results of the tests performed to determine instrumental precision used in this investigation are given in Table 56. Results are given as the coefficient of variation (percent) of multiple measurements of the same analyte. Overall, analytical precision was reassured in triplicate determinations on one sample. These results, given in Tables 57 through 59, are compared with single analyses of a pooled sample collected from the same station.

TABLE 56. PRECISION OF INSTRUMENTAL METHODS.

Method	Analyte	Coefficient of Variation[a] (percent)
UV/Fluorescence Spectroscopy	355 nm[b]	6
Gas Chromatography-Flame Ionization Detection	$n\text{-}C_{10}$	2
	$n\text{-}C_{20}$	1
	$n\text{-}C_{30}$	9
Gas Chromatography/Mass Spectroscopy	naphthalene	8
	phenanthrene	6
	perylene	13

a n=7 for UV/F, n=5 for GC-FID, n=8 for GC/MS.
b Quantified against Arabian Light crude oil standard.

TABLE 57. COMPARISON OF TRIPLICATE ANALYSES OF A SINGLE SAMPLE COLLECTED AT STATION 9 ON CRUISE SA-4 VS. SINGLE ANALYSIS OF THREE REPLICATES POOLED. CONCENTRATIONS ARE GIVEN IN µg/g DRY WEIGHT.

	9A	9B	9C	$\bar{X}$[a]	SD[b]	CV[c]	9 (Pooled)
Total Hydrocarbons	19.22	24.23	21.14	21.53	2.53	12	26.51
Saturated	8.86	8.2	10.86	9.31	1.39	15	11.16
Aromatic	10.36	16.03	10.28	12.22	3.30	27	15.35
Saturated Hydrocarbon Parameters							
Resolved	3.64	3.22	2.32	3.06	0.84	27	4.37
Unresolved	12.08	4.97	6.13	7.73	4.45	59	17.78
OEPI[d]	3.2	3.7	3.7	3.53	1.52	43	4.03
Pristane/ Phytane	0	0.9	0	-	-	-	0
Pristane/ $n\text{-}C_{17}$	0	2.1	0	-	-	-	0.73
Phytane/ $n\text{-}C_{18}$	0	2.3	0	-	-	-	0

[a] $\bar{X}$ = mean

[b] SD = Standard Deviation

[c] CV = Coefficient of Variation

[d] Odd-Even Preference Index = $\dfrac{2(n\text{-}C_{27} + n\text{-}(C_{29})}{n\text{-}C_{26} + 2(n\text{-}C_{28}) + n\text{-}C_{30}}$

TABLE 58. COMPARISON OF TRIPLICATE ANALYSES OF A SINGLE SAMPLE COLLECTED AT STATION 10 CRUISE SA-4 VS. SINGLE ANALYSIS OF THREE REPLICATES POOLED. CONCENTRATIONS ARE GIVEN IN µg/g DRY WEIGHT.

	10A	10B	10C	$\bar{X}$[a]	SD[b]	CV[c]	10 (Pooled)
Total Hydrocarbons	15.73	17.71	17.16	16.87	1.02	6	17.26
Saturated	7.98	8.83	8.41	8.41	0.43	5	8.56
Aromatic	7.75	8.88	8.75	8.46	0.62	7	8.70
Saturated Hydrocarbon Parameters							
Resolved (µg/g)	11.22	2.506	5.51	6.41	4.43	69	
Unresolved (µg/g)	13.2	2.22	4.64	6.69	5.77	86	
OEPI[d]	4.3	1.18	4.16	3.21	1.76	55	
Pristane/ Phytane	8.4	1.6	2.73	4.24	3.64	86	U[e]
Pristane/ n-C_{17}	1.2	1.2	2.67	1.69	0.85	50	0.407
Phytane/ n-C_{18}	0.2	1.1	1.08	0.79	0.51	65	0

[a] $\bar{X}$ = mean

[b] SD = Standard Deviation

[c] CV = Coefficient of Variation

[d] Odd-Even Preference Index = $\frac{2(n\text{-}C_{27} + n\text{-}(C_{29})}{n\text{-}C_{26} + 2(n\text{-}C_{28}) + n\text{-}C_{30}}$

[e] U = Undefined

TABLE 59. COMPARISON OF TRIPLICATE ANALYSES OF A SINGLE SAMPLE COLLECTED AT STATION 15 ON CRUISE SA-5 VS. SINGLE ANALYSIS OF THREE REPLICATES POOLED. CONCENTRATIONS ARE GIVEN IN µg/g DRY WEIGHT.

	15A	15B	15C	$\bar{X}$[a]	SD[b]	CV[c]	15 (Pooled)
Total HC	8.71	37.67	18.16	21.51	14.77	69	14.06
Saturated	4.08	12.89	10.49	9.15	4.55	50	5.83
Aromatic	4.63	37.67	7.67	16.67	18.26	110	8.23
Saturated Hydrocarbon Parameters							
Resolved	6.68	13.22	10.76	10.2	3.3	32	11.99
Unresolved	0	0.88	0		-		6.34
OEPI[d]	1.74	1.21	1.39	1.45	0.27	19	1.63
Pristane/ Phytane	2.01	2.38	2.26	2.22	0.19	8	2.43
Pristane/ n-C_{17}	0.187	0.408	0.330	0.308	0.112	36	0.728
Phytane/ n-C_{18}	0.232	0.289	0.245	0.255	0.030	12	0.357

[a] $\bar{X}$ = mean

[b] SD = Standard Deviation

[c] CV = Coefficient of Variation

[d] Odd-Even Preference Index = $\dfrac{2(n\text{-}C_{27} + n\text{-}(C_{29})}{n\text{-}C_{26} + 2(n\text{-}C_{28}) + n\text{-}C_{30}}$

Routine procedural blanks analyzed by the UV/F technique revealed the absence of significant petroleum contamination. Results of Cruise SA-4 samples ranged from 9.2-27.2 μg ALCO equivalents. Assuming 25 g sample (the average dry weight of the sample set), the blank contributions range from 0.4-1.1 μg/g (325 nm). Compared with the UV/F data from actual samples from SA-4, the blank contribution could contribute less than 1 percent (at Station 4), to 11 percent (at Station 13). Blank values for Cruise SA-5 were somewhat lower, yielding less than 1.54 μg total oil equivalents. This value indicates that blank values are less than 0.1 μg/g. Likewise, blanks for Cruise SA-6 were 0.68-3.38 μg total oil (355 nm), which, assuming 25 g of starting material, results in blanks of less than 1 percent of the sample UV/F results. In the majority of sampling, the procedure blank represented less than 10 percent of the total concentration.

For the GC/FID analysis, saturated and aromatic hydrocarbon fractions corresponding to blanks were not analyzed gravimetrically. The procedural blanks for Cruise SA-5 sediment analyses showed blank contamination present at levels of 66.5 μg-76.8 μg resolved hydrocarbons. No unresolved complex mixture was detected in the hydrocarbon scan. Most of the laboratory contamination was confined to the n-C_9 to n-C_{11} range of the chromatogram and 42-67 percent of the total resolved concentration in the blanks was contained in one peak (n-C_{11}). Minimal hydrocarbon contamination was found beyond n-C_{14} in the chromatogram, with the contribution of the most prominent alkane being only 6 percent of the cholestane internal standard. Other alkanes were at least an order of magnitude less in the blanks, (ranging from 0.3 percent to 1.6 percent of the cholestane deflection) than in the samples themselves. Results from blanks in Cruise SA-6 showed similar results, with one constituent located in the n-C_{10} to n-C_{12} range, contributing more than 50 percent of the total resolved values. Generally, contributions averaged more than 1.0 percent per constituent for laboratory blanks relative to cholestane. In all cases, contributions to the final quantified values from laboratory blanks were minimal.

Blanks performed in the analysis of samples by GC/MS showed similar results. No identified PAH were confirmed for blanks run on Cruise SA-4 and SA-5. The identified PAH constituents in procedure blanks for Cruise SA-6 were phenanthrene, benz(a)anthracene, and chrysene, with values of 0.008-0.02 μg total contribution. In all cases, blank contributions to identified PAH values were insignificant. These blank values are comparable to less than 1 ng/g in total contribution to PAH total concentrations.

TABLE 60. PERCENT RECOVERY OF SELECTED ANALYTES, PROCEDURE BLANKS SPIKED, TISSUE AND SEDIMENT BATCHES.

	$n\text{-}C_{10}$	$n\text{-}C_{11}$	$n\text{-}C_{14}$	$n\text{-}C_{15}$	$n\text{-}C_{24}$	$n\text{-}C_{25}$	$n\text{-}C_{32}$	$n\text{-}C_{34}$
Tissue SA-5	92	101	115	120	138	133	117	109
Sediment SA-5	124	1124	156	155	176	169	149	141

	Naphthalene	C_1-Naphthalene	C_2-Naphthalene	Pyrene	Chrysene	Perylene
Tissue SA-5	102	106	121	141	131	73.4
Sediment SA-5	95.8	97.5	114	146	138	99.1
Sediment SA-6	85	84.4	85.8	101	93.7	73.7

To determine the accuracy of the analyses, spiked blanks were analyzed. Spiked blanks, processed with sediment batches, yielded absolute recoveries generally at or above 100 percent for all spiked compounds (Table 60). Recoveries of n-C_{24}/n-C_{25} were usually highest, with over 170 percent recovered. In general, recoveries were within 85-146 percent for all parameters.

Trace Metals

Results of method blank and replicate standard reference material analysis in support of the QA/QC program for metals analysis are presented in Table 61 for Cruise SA-4. For reporting purposes, the replicate blank analyses assumed a sample with a dry weight of 5 g. Blank concentrations were at or below the detection limits for the method for Zn, Mn, Hg, Fe, Cr, and Cd. Al, Ni, and Pb blanks were up to a factor of 3 greater than the detection limit. Cu was elevated by as much as a factor of 15. With the exception of Cu, contamination from the laboratory procedures did not contribute significantly to observed tissue results. For Cu, blank values were sufficient to account for the observed levels in brittle stars. Values for Fe were somewhat low because acid digestion did not include hydrofluoric acid to break up the mineral matrix. Values of Pb were slightly higher than reported values indicating that some slight laboratory contamination may have contributed to Pb values.

Results of method blank and replicate standard reference material analysis in support of the QA/QC program for metals analysis for Cruise SA-5 are presented in Table 62. For reporting purposes, the replicate blank analyses assumed a sample with a dry weight of 5 g. Three different standard reference materials were used in the analysis of Cruise SA-5 samples: NBS Bovine Liver (SRM-1577), NBS Oyster Tissue (SRM-1566), and EPA SRM-1183 (Metals in Fish Tissue). Recoveries of Fe were low; recoveries of Cu differed by a factor of 3 from reported values for bovine liver and within 102 to 109 percent for oyster and fish tissue. Zinc values ranged from 99 percent to 108 percent recovery; whereas mercury values were inconsistent and results are not reliable. This Hg recovery pattern may have resulted from a change of methodology from Cruise SA-4 to SA-5 for Hg analyses. Nickel results were variable ranging from 114 percent (fish tissue) to 652 percent recovery and are not reliable.

TABLE 61. CONCENTRATIONS (μg/g) OF TRACE METALS, METHOD BLANKS, AND REFERENCE MATERIAL FOR SAMPLES COLLECTED ON CRUISE SA-4.

Sample		Al*	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	V	Zn
NBS (Oyster Tissue)	1) Rep 1	460	--	3.5	.64	63	173	.06	17	.66	.54		817
	2) Rep 2	406	--	3.7	.64	63	142	.06	20	.99	.61		796
	3) Certified Value	--	--	3.5	.69	.63	195	.06	18	1.0	.48		852
Blank	1) Rep 1	1.6	--	.03	.04	2.0	<20	<.01	1.0	<.1	.09		2.0
	2) Rep 2	1.0	--	<.01	.05	1.8	<20	<.01	.90	.14	.06		1.8
MDL		0.05	1.5	.01	.1	.12	20	.01	2	.02	.02	25	2.0

*Assuming a starting material equal to 5 gram sample.
NBS (Oyster Tissue) = Standard Reference Material No. 1566.
MDL = Minimum Detection Limit.

TABLE 62. CONCENTRATIONS (μg/g) OF TRACE METALS, METHODS BLANKS, AND REFERENCE MATERIAL FOR SAMPLES COLLECTED ON CRUISE SA-5.

Sample	Al	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	V	Zn
NBS 1577a (Bovine liver)	3.28	--	0.345	--	377	111	0.068	10.1	--	0.175	--	131
NBS 1577a Dupl. (Bovine liver)	2.15	--	0.348	--	477	94.0	0.060	9.70	--	0.144	--	133
Certified Value	2	--	0.44	--	158	194	0.004	9.9	--	0.135	--	123
EPA 1183 (Fish tissue)	--	--	0.690	0.565	2.02	126	0.451	0.760	0.618	0.380	--	43.2
Certified Value	--	--	0.16	0.58	2.21	--	2.52	--	0.54	0.26	--	45.6
NBS 1566 (Oyster tissue	--	--	2.24	0.480	61.7	141	0.428	15.6	6.72	0.493	--	910
Certified Value	--	--	3.5	0.69	63.0	195	0.057	17.5	1.03	0.48	--	852
Blank	1.25	--	0.0006	0.033	0.054	1.61	0.009	<20	0.301	0.017	--	<2
Blank Dupl.	1.79	--	0.0008	0.150	0.139	3.86	0.010	<20	0.149	0.091	--	<2

NBS-National Bureau of Standards, Standard Reference Material.
--Data Not Collected.

DISCUSSION

Sediment Analyses

The sediment hydrocarbon composition and areal trends found in the South Atlantic Slope and Rise study yield the same range of values to be found on the U.S. North Atlantic Slope and Rise (Maciolek et al., 1986b) and the U.S. Mid-Atlantic Slope and Rise (Maciolek et al., 1986a; 1987). Values for the North Atlantic were reported as saturated hydrocarbons, 1-8 µg/g and total PAH as 60-360 ng/g. Results for the Mid-Atlantic were reported as saturated hydrocarbons, 2-30 µg/g and total PAH as 160-870 ng/g. Values for the South Atlantic were determined to be 1-25 µg/g and PAH were 40-580 µg/g. In general, the saturated hydrocarbon ranges in the South Atlantic samples were similar to the Mid-Atlantic Slope and Rise, but the PAH range showed to be most similar to the North Atlantic Slope and Rise results.

Results from the South Atlantic study showed no indications of petroleum contamination in the sediment analyses. The GC/FID patterns were indicative of naturally occurring biogenic hydrocarbons with a predominance of odd-carbon-number n-alkanes in the n-C_{15} to n-C_{30} range. Pristane could be identified in some samples, but amounts were usually low. Phytane, an indicator of petroleum influence, was usually not found. None of the sediment samples analyzed showed the homologous series of n-alkanes from n-C_{12} to n-C_{34} and beyond indicative of crude oil. Most of the odd-even preference indices were 1.5-3, indicating a biogenic source of high molecular weight alkanes. Even when this index was at or below 1.0, the chromatograms showed a strong influence of one n-alkane or indications of minor blank contamination problems rather than the petroleum-like alkane distribution.

The unresolved saturated organics, as identified by GC/FID, normally averaged around 50 percent or less of the total hydrocarbon levels. This is consistent with results from the Mid-Atlantic Slope and Rise Study. The "unresolved complex mixture," a characteristic of petroleum-derived hydrocarbons in GC/FID analysis, was not presented in all sediment analyses. There were some samples that exhibited something of a UCM contribution, but not of the type found for petroleum-derived hydrocarbons.

Results of the UV/fluorescence analyses substantiate the GC/FID results. Most of the data cluster around a value of 20-40 μg/g total ALCO equivalents material. However, the concentrations were different for different wavelengths of emission, showing that the aromatic (i.e., fluorescent) character of the sediment samples is unlike that of the ALCO oil standard. This result was expected and illustrates why the UV/F results are useful for comparative purposes, but not to determine absolute concentrations of hydrocarbons in samples.

Results of the GC/MS analysis of sediments were for the most part consistent throughout the three cruises. The distribution of the specific PAHs found in the study was indicative of combustion inputs from continental deposition in the slope and rise marine sediments. High temperature combustion processes have been shown to produce non-alkylated aromatic species on 2- to 6- member aromatic rings. Petroleum sources of PAH are found to contain a greater proportion of alkyl substituted polynuclear aromatics. The unsubstituted polynuclear aromatic therefore is associated with anthropogenic combustion sources. A determination of possible sources of PAH can be verified by comparison of this observed behavior with other PAH's including fluoranthene, pyrene, phenanthrene and isomers of chrysene and benzopyrene. The FFPI index, defined by Boehm and Farrington, (1984), should be near 0 for sediment with PAH of a pyrogenic or combustion origin, and near 100 for sediment with PAH of a petrogenic origin. Values for FFPI in this study were most consistently around the 20-35 range. Only six values of FFPI were near or above 50, and even at these stations there was no consistency between cruises SA-4, SA-5, and SA-6. Higher levels of total sediment PAH did not mean that the FFPI would also be high. There appeared to be no correlation between total PAH concentration and FFPI values in this study indicating that PAH concentrations vary according to depositional rates and not according to petroleum inputs.

Regardless of analytical technique (UV/F, GC/FID and GC/MS), hydrocarbon concentrations consistently were highest in each data set at Stations 9 and 10. These areas showed the most consistent picture of high hydrocarbon levels among all cruises. Hydrocarbon levels did not correlate with the sediment grain size or percent carbon in the sediment as has been shown in other studies (Boehm et al., 1982; Boehm and Farrington, 1984).

Table 63 presents the results of total PAH values in the sediments vs. grain size (silt/clay percent) and percent carbon for Cruise SA-4. Instead of finding high values of

TABLE 63. TOTAL PAH CONCENTRATIONS, PERCENT SILT/CLAY, AND PERCENT CARBON IN SEDIMENT FOR CRUISE SA-4.

Station	PAH (ng/g)	Silt/Clay (%)	Carbon (%)
4	62	78.7	1.65
9	471	48.0	1.27
10	449	44.8	1.14
11	95	59.0	1.95
12	318	94.5	2.90
13	285	86.0	1.06
14	218	61.6	3.33
15	830	41.3	1.86
16	393	94.3	1.20

PAH with high percent silt/clay, there is apparently little relationship between the fineness of the sediment and its hydrocarbon geochemistry. These results are not expected for a depositional area where PAH totals are often found to be higher than other areas. A similar phenomenon was observed in data from Cruise SA-5 and SA-6. Inspection of the high PAH values of Stations 9 and 10 show a distribution more indicative of anthropogenic combustion sources than of petroleum-derived sources.

Taken together, the sediment hydrocarbon data present a consistent picture of relatively low levels throughout in the study area, dominated by terrestrial and combustion-sourced hydrocarbons. Little petroleum-derived pollution was found. There is strong evidence for an unusual non-depositional area at Stations 9 and 10; these stations show higher hydrocarbon concentrations than other stations in the study area. These higher levels were not correlated with percent silt/clay or percent carbon in the sediments. The hydrocarbon levels also could not be correlated with depth or other physical parameters. The concentrations of saturated and aromatic hydrocarbons are similar to other slope and rise areas on the East Coast (Boehm and Requejo, 1986). For this study, areas of deposition and erosion were identified through the relationship between grain size and PAH distribution.

Tissues

Hydrocarbons

A small set of benthic samples were collected for hydrocarbon and trace metal analyses on Cruises SA-4 and SA-5. For hydrocarbons, there was little evidence of petroleum contamination. The GC/FID chromatograms showed the presence of biogenic hydrocarbons with a large "unresolved complex mixture" similar to weathered petroleum beginning in the n-C_{18} area of the chromatograms. However, the alkane distribution showed marked preference to odd numbered alkanes, which is not indicative of petroleum origin of the UCM. Biogenic alkanes clustered around the n-C_{20} area and were indicative of several isoprenoid-type hydrocarbons. This was especially typical for the brittle stars Ophiomusium lymani and Bathypectinura heros. By contrast, no UCM was observed in the

analysis of galatheid shrimp tissue. This shrimp tissue showed 1.23 µg total levels of pristane and other isoprenoid hydrocarbons which accounted for almost 50 percent of the resolved hydrocarbons found in the analysis. For Cruise SA-4, brittle stars showed the characteristic UCM with levels of pristane at 0.3 µg/g and other biogenic hydrocarbons accounting for almost 50 percent of the total resolved hydrocarbon values. Unresolved hydrocarbons contributed over 70 percent of the total analyzed hydrocarbon concentrations, although this distribution was not observed in all brittle stars. Shrimp tissue collected from Station 9 showed little evidence of an UCM with one sample containing 4.1 µg/g resolved saturated hydrocarbons and a replicate sample containing 52 µg/g resolved and 36 µg/g unresolved saturated hydrocarbons. Aromatic hydrocarbons were determined in shrimp tissues collected at Station 14, values of 314 and 412 ng/g (wet weight). Identified aromatic hydrocarbons included fluoranthene through perylene in both samples. PAH distributions did not correlate well with saturated hydrocarbon distributions found in GC analyses.

The limited number of tissue samples collected under this program limits also the interpretability of the results. The tissue PAH data were highly variable with data on shrimp tissue ranging from very low values at Station 9 to the higher values found at Station 14 on Cruise SA-4. It is risky to reach firm conclusions on data showing this wide range of variability on very few samples. However, since the data set is internally valid (i.e., good blanks, acceptable recoveries, done in the same batch, etc.) the same data set and the identified differences are valid resources of the PAH distributions as found in the study. No data were collected on particulate or detrital matter which could have been used to better interpret data on PAH values on tissues of filter feeders. There was, however, no correlation between sediment and benthic tissue hydrocarbon levels or any correspondence of hydrocarbon compositional patterns between the two types of samples. The small number of tissue samples collected did not provide a representative sampling of the highly variable population.

Therefore, although previous studies on the relationship between hydrocarbon body burdens between different species have indicated that a combination of feeding type (i.e. food source) and hydrocarbon metabolic activity of an individual species largely determine the resultant concentration and composition of hydrocarbons (NAS, 1985), definitive conclusions are difficult to draw from this data set. However, the data do appear to

indicate that the animals analyzed do not contain appreciable quantities of petroleum hydrocarbons. The levels of the saturated and unsaturated hydrocarbons are related to the individual species examined and individual concentrations probably were a function of feeding mode, rather than having any relationship to station collected.

Trace Metals

For both brittle stars and sea urchins, tissue values of metals represent whole body burdens. Results showed the high variability inherent in any such analysis. For Cruise SA-4, the metals Al, Ba, Cd, Cr, Fe, Mn, Ni, Pb, and Zn had low blanks and levels at least 10 times the minimum quantification level; thus there is reasonable assurance that the values were accurate enough for data interpretation.

Some species specific variability in the tissue concentrations were observed (Tables 64 and 65). The shrimp samples tended to have higher Al, Cd, Cu, Fe, Hg, Mn and Zn relative to the brittle stars collected in SA-4. Crab samples also showed higher Al, Cr, Cn, Fe, Mn, and Ni but lower Cd and possibly Pb than found in the brittle stars. Shrimp samples from SA-5 also tended to show higher Al, Cu, Mn, Ba, Pb and V concentration relative to the brittle star. However, Cd showed the opposite trend with significantly less Cd detected in the shrimp than in the brittle stars. The sea urchin and crab samples had either higher or lower elevated concentrations than found in the brittle star depending upon the element. Generally, there was insufficient similarity of species between the stations to clearly establish station trends. Only the brittle star was sampled at more than one station in either cruise.

TABLE 64. TRACE METAL DATA NORMALIZED TO ALUMINUM FOR TISSUE SAMPLES COLLECTED ON CRUISE SA-4.

Species	Station-Replicate	Ba/Al	Cd/Al	Cr/Al	Fe/Al	Mn/Al	Ni/Al	Pb/Al	Zn/Al	Cu/Al
Brittle Star *Ophiomusium lymani*	4	--	0.161	0.002	0.537	0.067	0.028	0.006	1.322	0.021
Brittle Star *Bathypectinura heros*	15-1	0.043	0.024	0.002	0.655	0.053	0.008	0.003	0.165	0.016
Brittle Star *B. heros*	15-2	--	0.017	0.002	0.571	0.045	0.007	0.002	0.133	0.012
Brittle Star *B. heros*	15-1	0.031	0.024	0.003	0.743	0.056	0.008	0.001	0.140	0.010
Brittle Star *B. heros*	15-2	--	0.016	0.002	0.598	0.045	0.005	0.001	0.116	0.008
Brittle Star *B. heros*	15-1	0.058	0.016	0.003	0.676	0.067	0.010	0.002	0.213	0.012
Brittle Star *B. heros*	15-2	--	0.012	0.003	0.502	0.049	0.007	0.002	0.172	0.008
Galatheid Crab *Munida valida*	11	0.038	0.002	0.001	0.654	0.037	0.005	0.001	0.072	0.042
Galatheid Crab *M. valida*	11	0.023	0.003	0.002	0.378	0.052	0.005	0.0003	0.086	0.113
Galatheid Crab *M. valida*	11	0.034	0.004	0.002	0.371	0.050	0.007	0.0004	0.088	0.119
Shrimp *Stereomastis sp.*	14	--	0.148	0.002	0.678	0.032	0.004	0.001	0.149	0.247
Shrimp *Stereomastis sp.*	14	--	0.084	0.001	0.459	0.028	0.003	0.001	0.123	0.160

-- No data.

TABLE 65. TRACE METAL DATA NORMALIZED TO ALUMINUM FOR TISSUE SAMPLES COLLECTED ON CRUISE SA-5.

Sample	Station-Replicate	Cd/Al	Cr/Al	Fe/Al	Mn/Al	Ni/Al	Pb/Al	Zn/Al	Cu/Al
Crab *Munida valida*	11-1	0.002	0.001	0.464	0.016	0.002	0.001	0.037	0.044
Crab *M. valida*	11-2	0.002	0.001	0.600	0.020	0.001	0.001	0.045	0.061
Sea Urchin *Echinus affinis*	4-1	0.002	0.003	0.759	0.037	0.003	0.001	0.058	0.002
Sea Urchin *E. affinis*	4-2	0.004	0.003	0.716	0.046	0.003	0.001	0.064	0.001
Brittle Star *B. heros*	4-1	0.009	0.002	1.057	0.013	0.004	0.001	0.056	0.004
Brittle Star *B. heros*	4-2	0.009	0.003	0.841	0.011	0.003	0.001	0.061	0.004

CHAPTER 7. SEDIMENT CHARACTERISTICS: GRAIN SIZE AND CHN

INTRODUCTION

Sediment grain size can be correlated with the occurrence of certain infaunal species or animal assemblages. Variability in patterns of species distributions or concentrations of one species or another can be linked to differences in grain-size composition. This relationship was clearly demonstrated for dominant species on Georges Bank (Maciolek-Blake et al., 1984; Maciolek-Blake et al., 1985) and from the U.S. Mid-Atlantic Slope and Rise Study (Maciolek et al., 1987).

The concentrations of organic carbon, hydrogen, and nitrogen in the sediments may reflect the food supply available to benthic animals that either directly ingest sediments or filter particles from the water. Organic matter in sediments originates from both terrestrial and marine sources, and may precipitate directly out of the water column as detritus or as dissolved matter adsorbed to suspended mineral particles. Documentation of sediment parameters and their variability on a temporal and spatial basis provides insight into the importance of sedimentary processes to benthic fauna. In other environments, changes in this sediment over time can be correlated to changes in fauna over the same periods (Gray, 1974). Numbers of individuals and biomass decline with increasing depth in the deep sea (Grassle et al., 1987) and functional groups change (Jumars & Fauchald, 1977).

Most of the sediment-bound trace metals derived from the overlying water column tend to be associated with the clay-sized fraction of the sediment because of the large surface area and high sorptive capacity of that sediment fraction (Bothner et al., 1987). In addition, organic contaminants such as petroleum hydrocarbons tend to be bound selectively to the organic fraction of the sediment. Sediment with high silt-clay content and greater amounts of organic carbon are likely to have increased amounts of metal and organic contaminants. Therefore, information about sediment grain size and organic carbon is essential for interpreting data on concentrations and distributions of chemical components in sediment.

The second year (Phase 2) of the deep-sea slope and rise study continued sampling at the 2000 m depth station off Cape Lookout (Station 4), added stations off

Cape Hatteras (Block 510), and extended the sampling further south to transects off Cape Fear and Charleston. The entire combined study consists of transects across depth contours at Cape Hatteras, extending out to 3000 m on the Blake Ridge.

In the present report, data are presented for the Phase 2 results. In addition we have incorporated the results of Phase 1 in order to develop a broader synthesis of the complex sedimentary environment on the slope and rise off North and South Carolina.

METHODS

Sediment Grain-Size Analysis

Approximately 20 cm^3 (30-40 g wet weight, 10-20 g dry weight) of the top 2 cm of sediments from each replicate box core was removed and frozen until analysis at the Woods Hole Oceanographic Institution (WHOI). Pretreatment of sediments included an overnight soak and 30-min ultrasonification (at 80 watts) in 80 ml of 0.5 percent Calgon and 2 ml of 30 percent H_2O_2. The Calgon solution was prefiltered to remove submicrometer and larger particles. Silt and clay fractions were analyzed by standard pipette procedures at whole phi (Ø) intervals (Folk, 1974). Calgon blanks were dried, weighed, and analyzed using pipette technique in order to calculate correction factors for the sediment dry weights. Sand fractions of samples with greater than 10 percent sand were sieved at whole phi intervals for 15 min on a Ro-Tap shaker. Size-class composition is reported as percent sediment dry weight. Water content of sediments was computed as weight loss between wet and dry samples and is reported as percent sediment wet weight uncorrected for salt content.

Percent weight for major size classes (gravel, sand, silt, clay), silt/clay ratio, silt-mode height, and moment statistics (mean phi, sorting, and skewness) were computed for each replicate. Most of the variability in sediment characteristics is easily shown in sand, silt, and clay size classes. The silt/clay ratio is a useful summary measure of those two size classes. Silt-mode height proved a meaningful measure of regional size gradients in sediment studies of the Nova Scotia Rise (Driscoll et al., 1985) and could be a sensitive measure of refractory, silt-sized inputs (such as drilling muds). Moment statistics are conventional measures of sediment grain-size distributions. Mean phi value, MØ, is a

convenient transformation of grain diameter in particular: $M\emptyset = -\log_2$ (average grain size in mm). Thus, an increasing phi value reflects a smaller grain size. It was not uncommon for samples analyzed in this study to have particles smaller than 1 μm (10 ∅) composing over 30 percent of the dry weight of sediment. Moment statistics include this size class with a class midpoint arbitrarily set at 12 ∅ (Folk, 1974). The result, however, is that moment statistics may be relatively insensitive to changes in silt and sand size classes.

CHN Analysis

Approximately 10 cm^3 of the top 2 cm of sediment from each replicate box core was removed and frozen until analysis. Just prior to analysis, frozen samples were thawed at room temperature and homogenized. For analysis, a 2.5 to 5.0-g subsample was removed from each replicate; the remaining portion was refrozen and archived at Battelle. Large animals were removed during subsampling. Each subsample was placed in a prelabeled glass vial and dried at 70°C for 24 h. Dried material was ground by a mortar and pestle to a fine homogenous powder. All glassware was previously fired at 550°C for 24 h to remove traces of organic carbon.

Carbonates were eliminated with the addition of 6 percent sulfurous acid (Gibbs, 1977). Several samples required successive acid treatments for complete removal of carbonates. Treatments were applied until carbon/nitrogen ratios stabilized over successive treatments. Following acid treatment, each sample was placed in a Millipore apparatus fitted with a glass-fiber filter and washed to eliminate acid salts. Organic-carbon-free water used in the washing process was prepared by filtering hot tap water through a particle filter, seven in-line deionizing and water-softening filters, and a Milli-Q reagent-grade water system. This system, consisting of a Super-C carbon filter, two ion exchange cartridges, and an Organex-Q filter, produced water with a resistivity of 18 megohm/cm. Washed samples were subsequently redried at 70°C for 24 h.

All samples were sent to WHOI for analysis. A Perkin-Elmer Model 240 Elemental Analyzer was used to determine the carbon, hydrogen, and nigrogen content of organic compounds by analyzing their combustion products; i.e., CO_2, H_2O, and N_2, respectively. Combustion occurred in pure oxygen under static conditions at 1000°C. Helium was used as the carrier gas. The combustion products were then analyzed automatically in a self-

integrating, steady-state, thermal conductivity analyzer. An on-line computer converted the digital display into weight percentages of carbon, hydrogen, and nitrogen present in the sample.

Statistical Analysis

Differences in carbon, nitrogen and selected grain-size measures among stations and cruises were each tested by use of t-tests, one-way or two-way analysis of variance (ANOVA) according to the number of stations included in the hypotheses tested. For significant ANOVAs ($p>.05$), a Student-Newman-Keuls (SNK) test was used to identify significantly different stations or cruises. If the station and cruise interaction was significant in the two-way ANOVA, SNK tests were performed on each cruise individually. Transformations were used if the maximum to minimum variance ratio was reduced when the data were transformed. Transformations used were log=log (x+1), log log=log (log(x+1)+1) and arc=arc sin proportion.

The coefficient of variation was calculated for selected parameters. This value is calculated as

$$CV = \frac{\text{Standard Deviation} \times 100}{\text{Mean}}$$

Quality Control

Measures of percent sand, silt, clay, silt-mode height, silt/clay ratio, and moment mean phi of six samples (three replicates each) of mud analyzed at different times by two operators were not significantly different (one-way ANOVA, alpha = 0.05). However, moment phi sorting and phi skewness were not significantly uniform among control sample analyses. Standard errors for any size class were less than 3.0 percent dry weight.

Test blanks and replicates of labeled total organic carbon samples were analyzed daily at WHOI and test standards were run routinely to ensure that the CHN analyses were quantitatively accurate.

RESULTS

The continental slope and rise sediments from off North and South Carolina are more variable than the Mid- and North Atlantic slope from Cape Hatteras to Cape Cod. Upper slope stations may be quite sandy and even the deeper stations may have relatively coarse sediments owing to the effect of the Western Boundary Undercurrent (WBUC). The sand fraction is generally made up of planktonic foraminiferan tests (except for Stations 9 and 10 off Cape Hatteras) and the muds are generally an olive gray color. All of the sediments are very poorly sorted. Results from the Phase 1 sampling off Cape Lookout and at the 2000-m depth in Hatteras Canyon were reported in Blake et al. (1985: Table 7.1). Phase 2 results from transects off Cape Hatteras, Cape Fear, Charleston with continuation of the Phase 1 Station 4 (2000-m) station off Cape Lookout are presented in Appendix I and Appendix J. CHN results of Phase 1 were presented in Blake et al. (1985: Table 6.1). Phase 2 CHN results are presented in Appendix K. Replicate samples during Phase 2 are within 0.5 km of one another at all stations except Stations 4, 13, and 15. The average percentage by weight of sand, silt, and clay at each station is shown in Figure 120. The mean and standard deviation of sediment variables at each station within each cruise are shown in Figures 121 through 126.

Percent Sand

Figure 127 shows the mean percent sand at each station from both Phases 1 and 2. On the Cape Lookout transect, the coarsest sediments are at 600 m, where the sand content ranges from 19 to 43 percent. At 1000 m the sand content ranges from 9 to 14 percent in individual samples. The 1500-m depth is similar, with a somewhat more patchy sediment distribution and a range of 7 to 16 percent sand. The 2000-m depth has been studied over a two-year period, and the sand content there ranges from 14 to 24 percent. Sediments are a little finer at 2000 m in the Hatteras Canyon (Station 6), with 6 to 14 percent sand. At the 3000-m station on the Cape Lookout transect, the sediments are a reddish brown, compacted muddy clay with only 3 to 6 percent sand.

At Cape Hatteras, the sediments are sandy at both 600 m and at 2000 m. The percent sand at 600 m (Station 9) ranges from 37 to 56 percent in nine samples and at

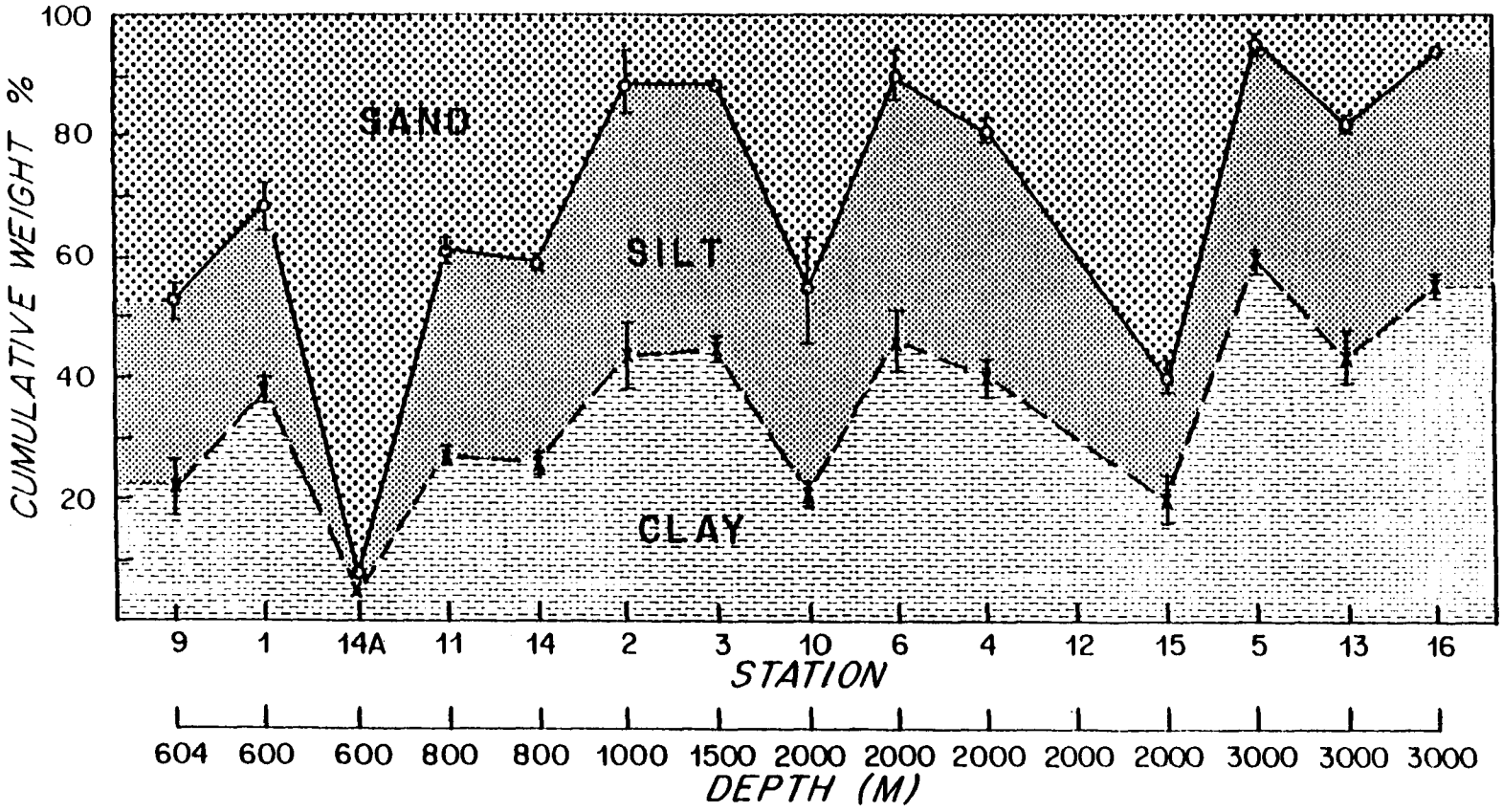


Figure 120. Average Percentage of Weight of Sand, Silt and Clay at Each Station (± 1 S.D.).

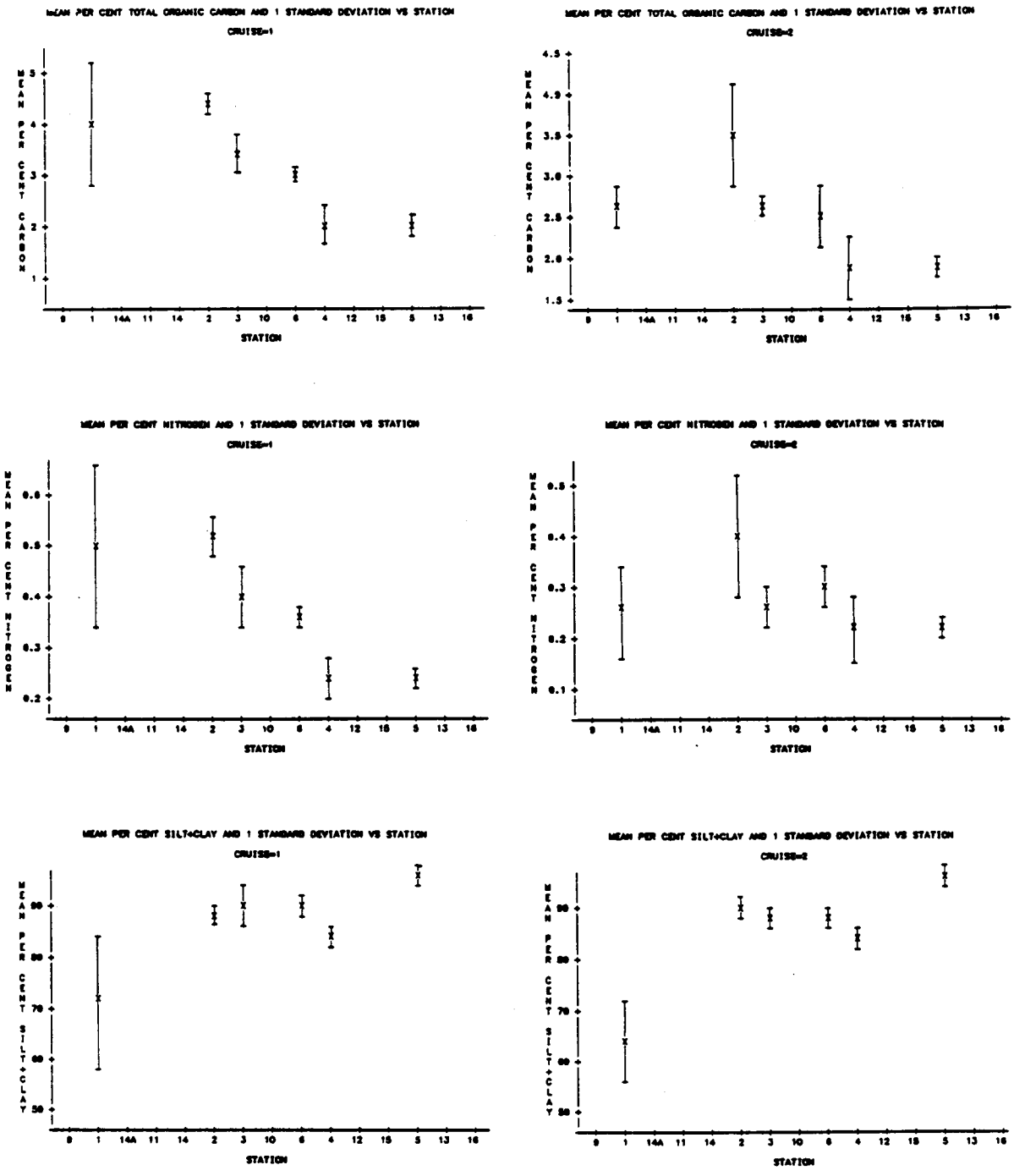


Figure 121. Average Percentage of Carbon, Nitrogen, and Silt + Clay (± 1 S.D.) for All Stations Sampled During Cruises 1 and 2.

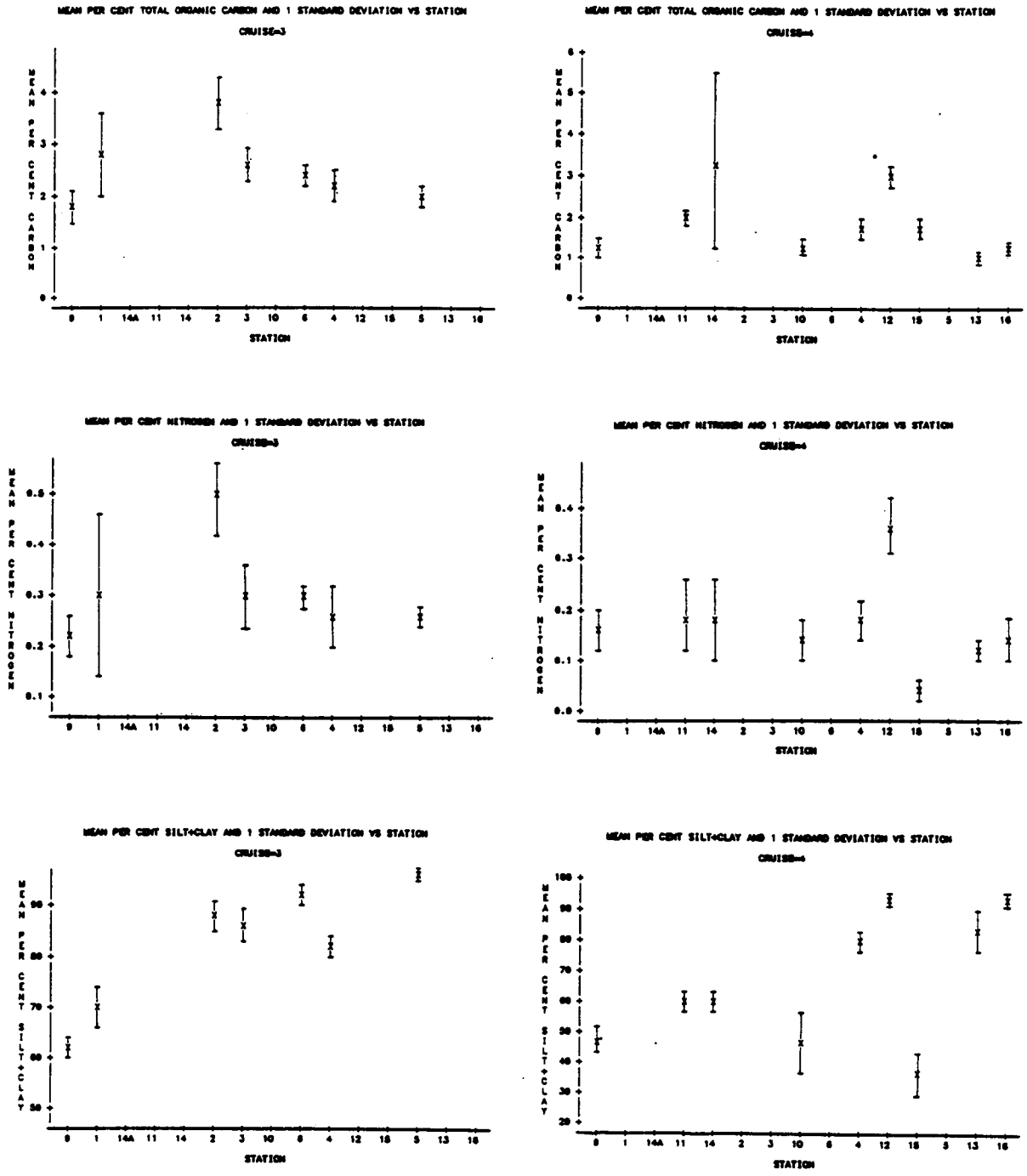


Figure 122. Average Percentage of Carbon, Nitrogen, and Silt + Clay (± 1.S.D.) for All Stations Sampled During Cruises 3 and 4.

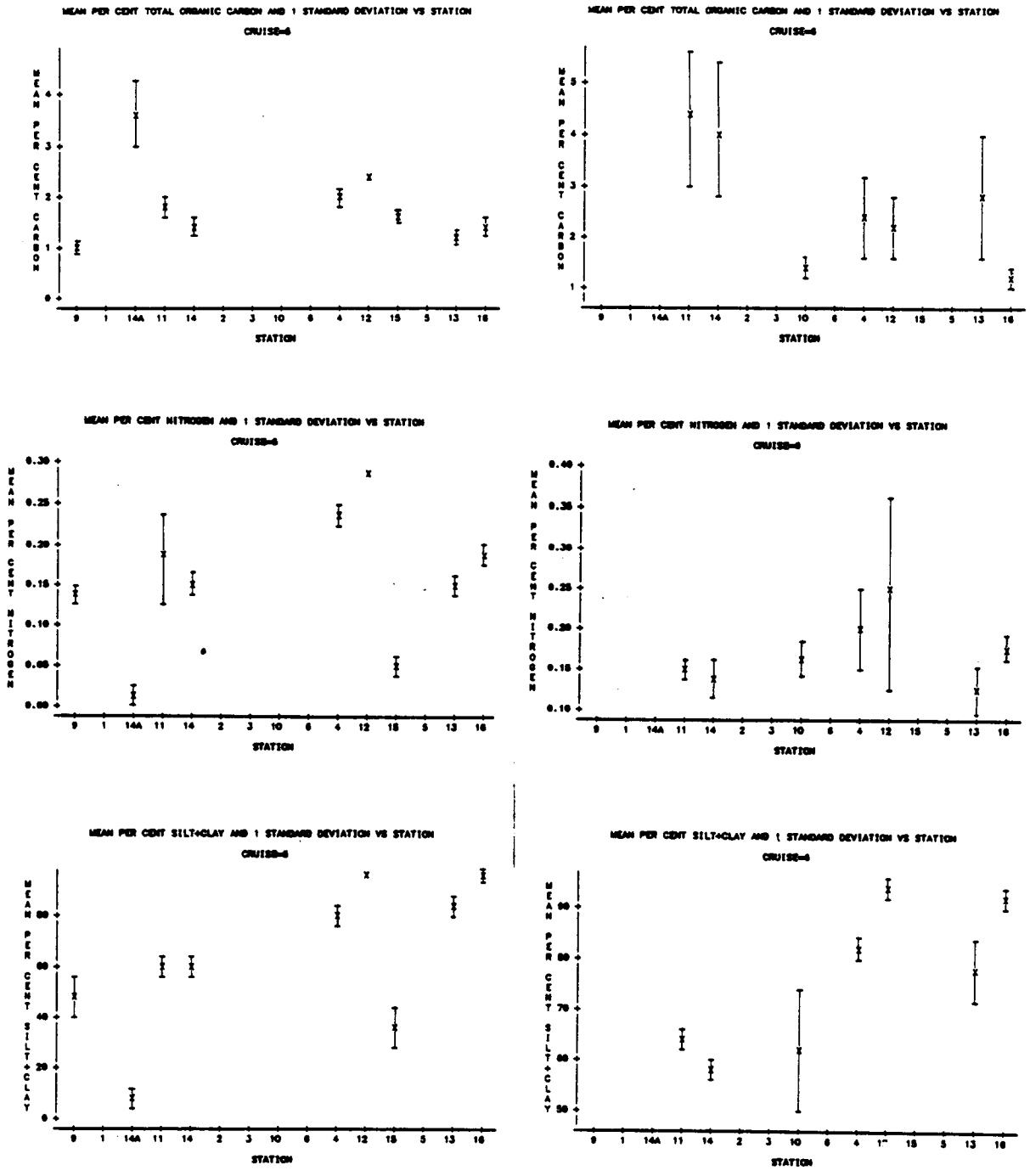


Figure 123. Average Percentage of Carbon, Nitrogen, and Silt + Clay (± 1 S.D.) for All Stations Sampled During Cruises 5 and 6.

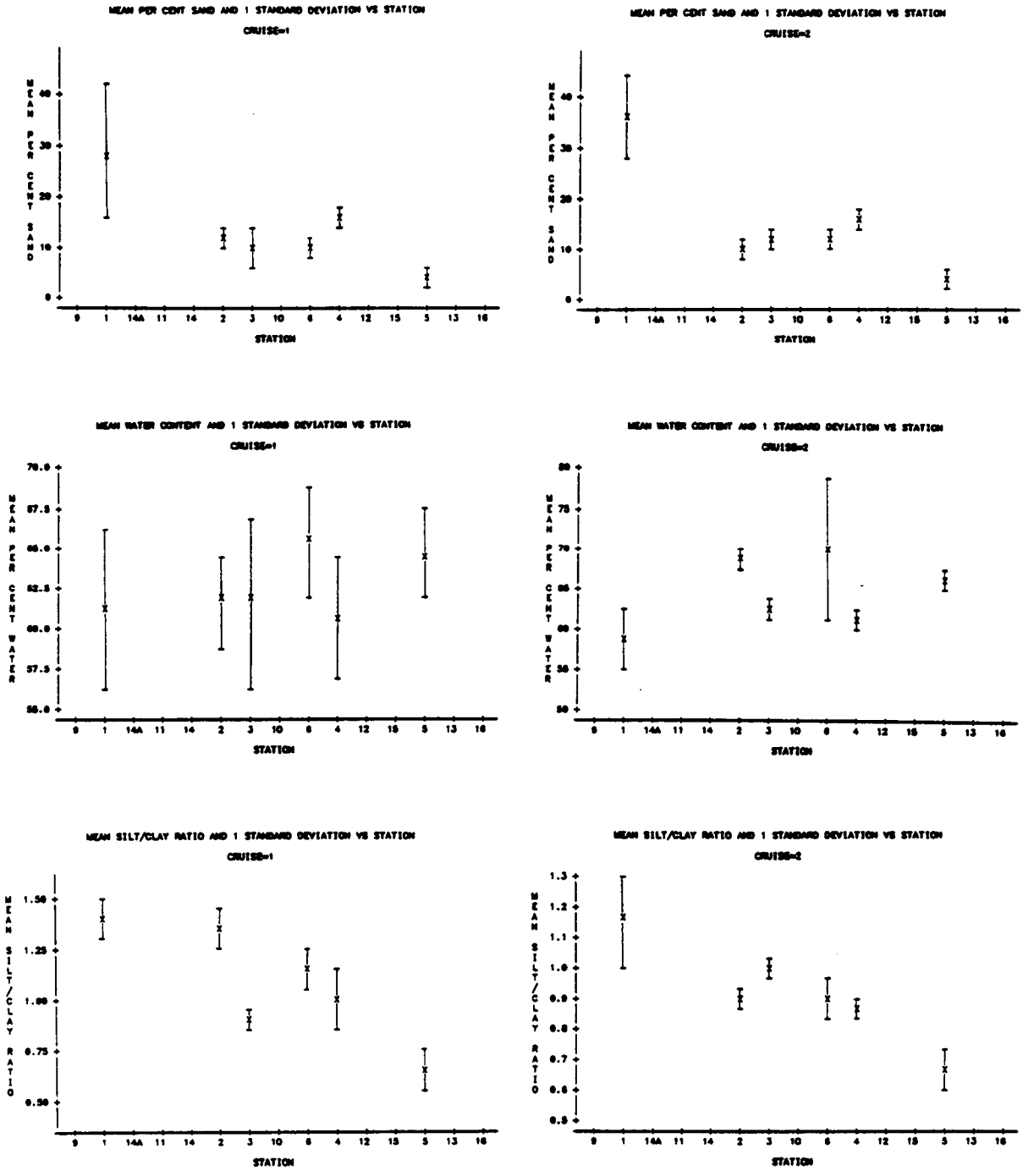


Figure 124. Average Percentage of Sand, Water, and the Silt/Clay Ratio(± 1 S.D.) for All Stations Sampled During Cruises 1 and 2.

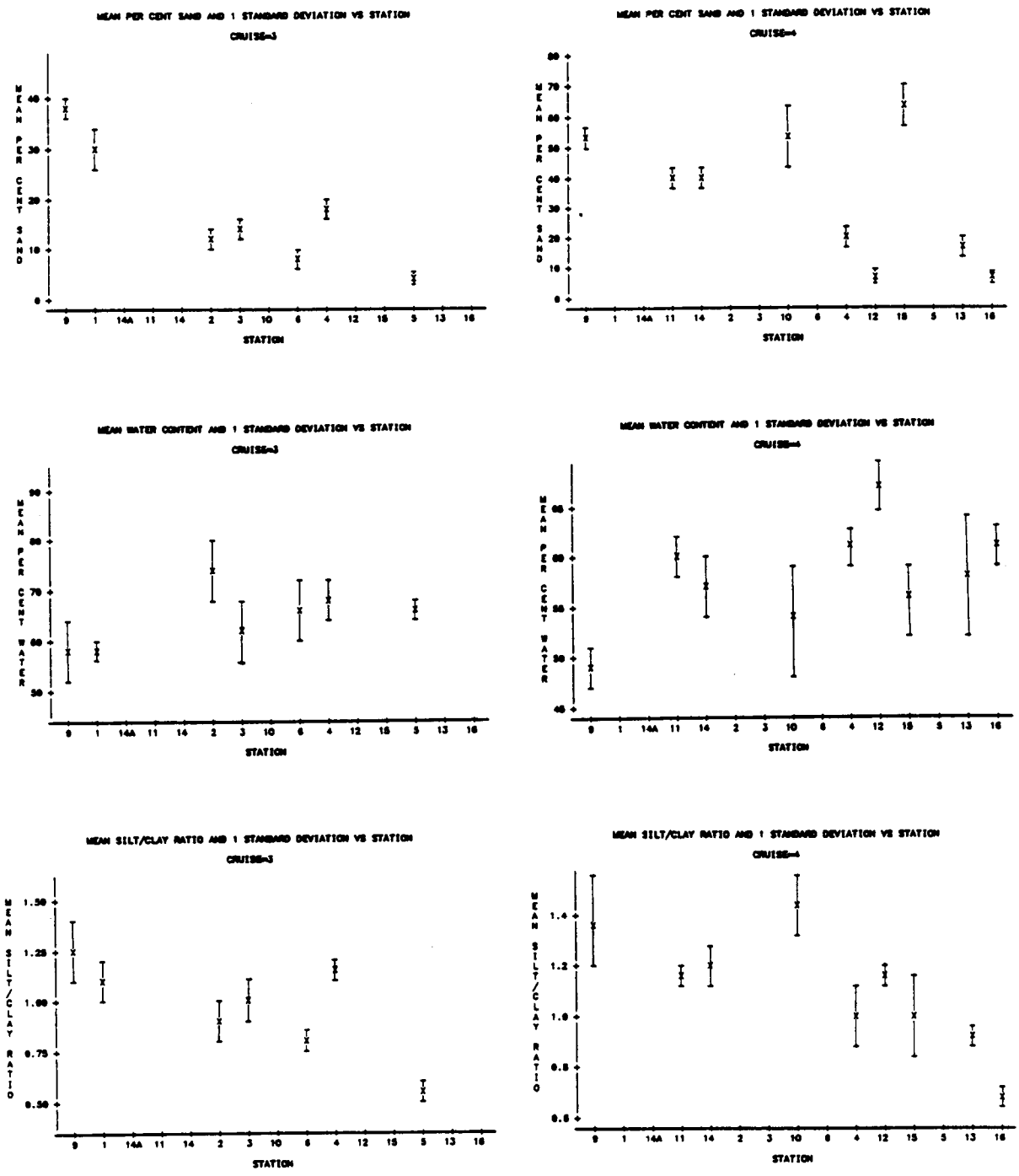


Figure 125. Average Percentage of Sand, Water, and the Silt/Clay Ratio (± 1 S.D.) for All Stations Sampled During Cruises 3 and 4.

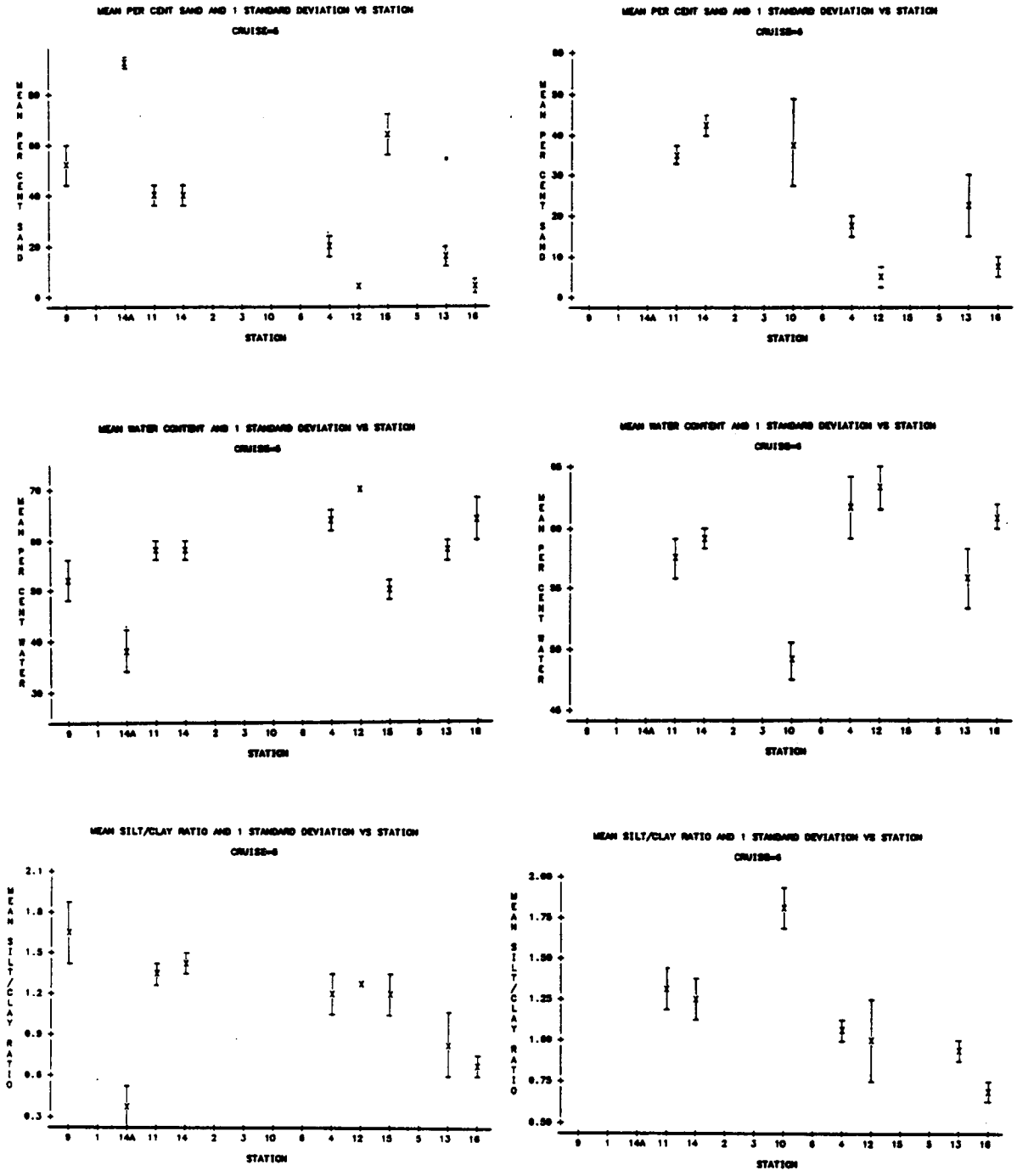


Figure 126. Average Percentage of Sand, Water, and the Silt/Clay Ratio (± 1 S.D.) Sampled During Cruises 5 and 6.

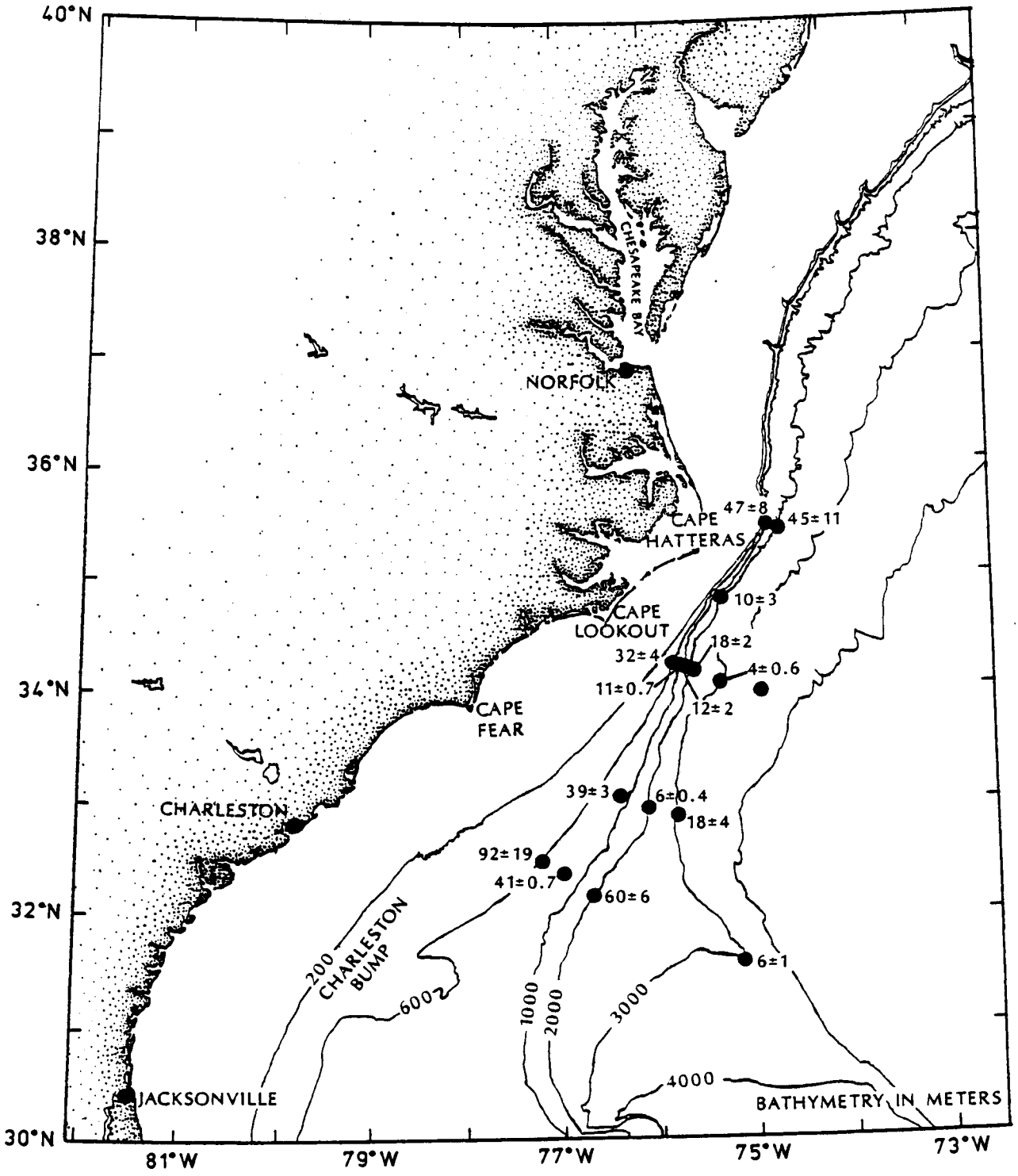


Figure 127. Mean Percent Sand by Weight at Each Station (± 1 S.D.).

2000 m (Station 10) the sediments are more patchy, with 25 to 61 percent sand in six samples. These sands are a mixture of planktonic foraminiferan tests and quartz sand.

Off Cape Fear, the sediments at 800 m are from 35 to 44 percent sand. This transect has the most gentle slope of all the transects, and the 2000-m station (Station 12) has relatively uniform muddy sediments with 4 to 7 percent sand. At 3000 m the sediments are coarser again, with 12 to 30 percent sand.

The sandiest sediments encountered were at 600 m off Charleston, under the eastern part of the Charleston gyre. Here the sand content ranged from 91 to 94 percent in three samples from a single date. At 800 m the sediments are less sandy and have sand contents of 38 to 44 percent. Sand content increases again at 2000 m (Station 15) to 53 to 72 percent and at 3000 m on the Blake Ridge (Station 16), sand content declines to a very low 4 to 9 percent.

In Figure 128, the coefficients of variation of sand content are plotted against percent sand.

Correlation of Sediment Characteristics

Because gravel is an insignificant fraction of these sediments, sand and silt plus clay are simply the inverse of one another as shown in Figure 129. The coefficients of variation with silt plus clay vs. percent silt plus clay and the coefficients of variation of the silt-clay ratio vs. silt-clay ratio are shown in Figures 130 and 131. The relationship between silt/clay ratio and percent sand is shown in Figure 132. Except for Stations 14A at 600 m and Station 15 at 2000 m on the Charleston transect, there is a trend toward a increase in silt/clay ratio increase as percent sand increases. Figure 133 shows a positive relationship between percent water content and percent silt plus clay. Tests of significance of relationships (Pearson correlation) between sediment variables were done for each cruise separately to avoid problems associated with potential time dependence. Positive correlation between silt/clay ratio and sand, and negative correlation with silt plus clay was significant on all cruises except for Cruises SA-4 and Cruise SA-5. However, these were the only two cruises in which water content and sand or silt plus clay were significantly correlated.

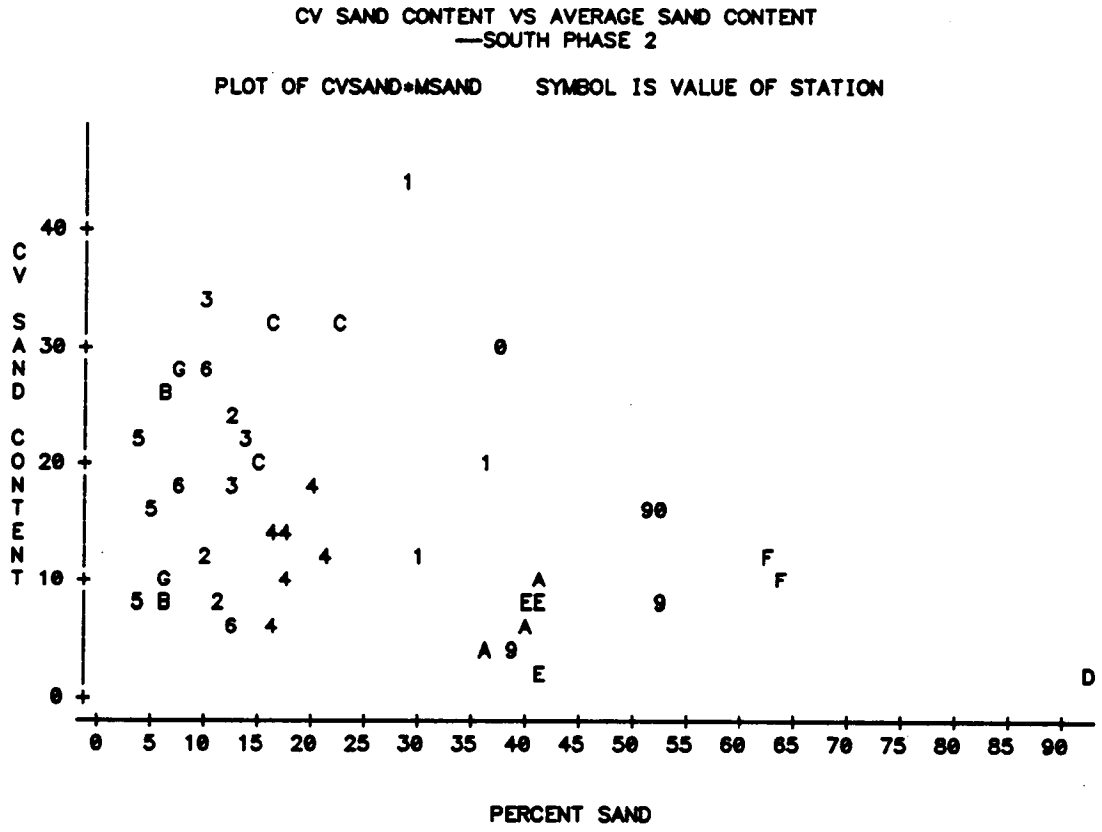


Figure 128. Plot of Coefficient of Variation (CV) of Sand Content Against Percent Sand. Stations 1-9 Plotted with Their Numbers; Stations 10-16 Plotted with the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14A, E = 14, F = 15, G = 16. Note: 2 Observations had Missing Values and 1 Observation was Hidden.

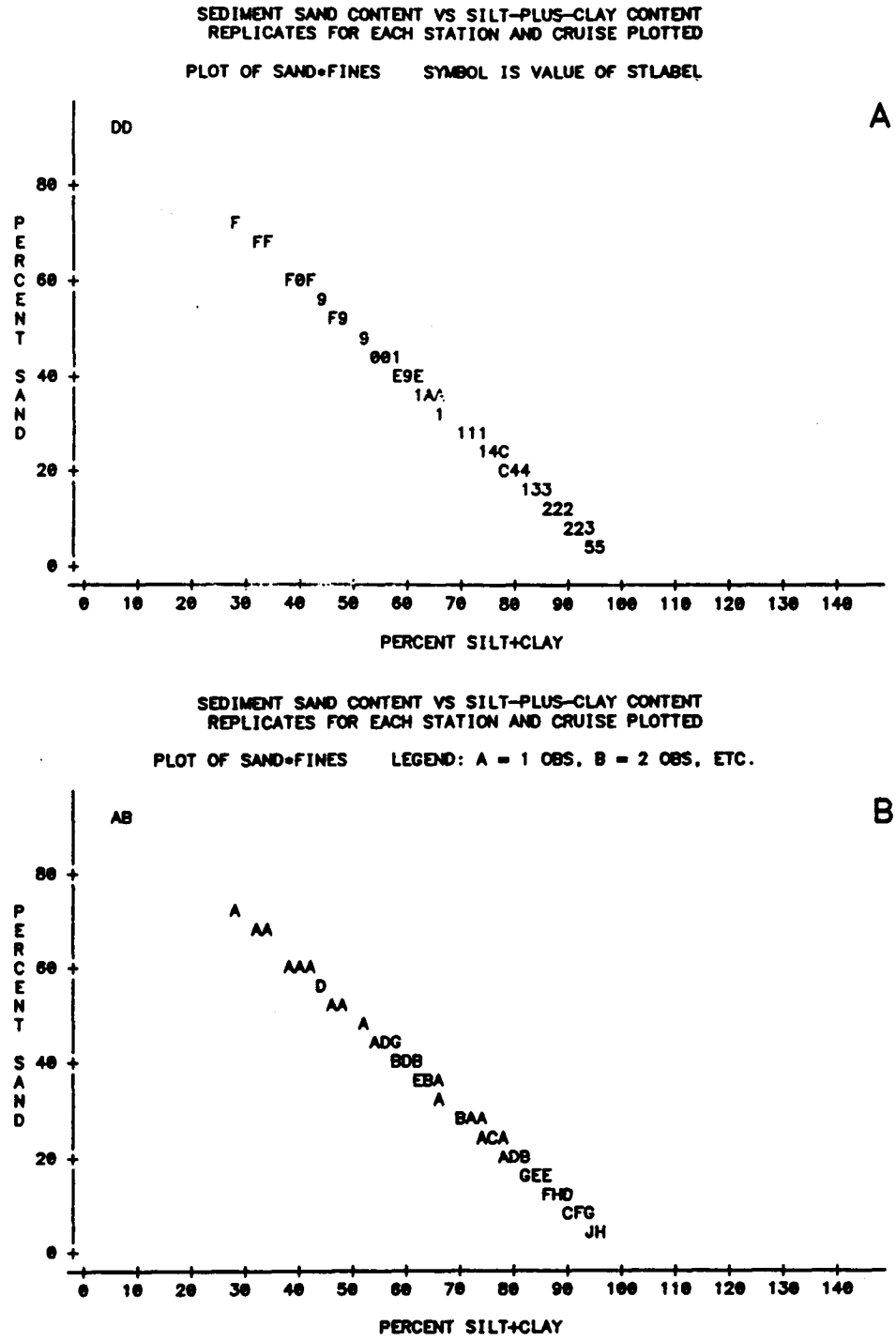


Figure 129. A. Plot of Percent Sand Against Percent Silt + Clay. Stations 1-9 Plotted with Their Numbers: Stations 10-16 Plotted With the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14A, E = 14, F = 15, G = 16. Note: 88 Observations Were Hidden. B. Same as A, with Hidden Observations Depicted as: A = 1, B = 2, C = 3, D = 4, E = 5, F = 6, G = 7, H = 8, I = 9, J = 10 Observations.

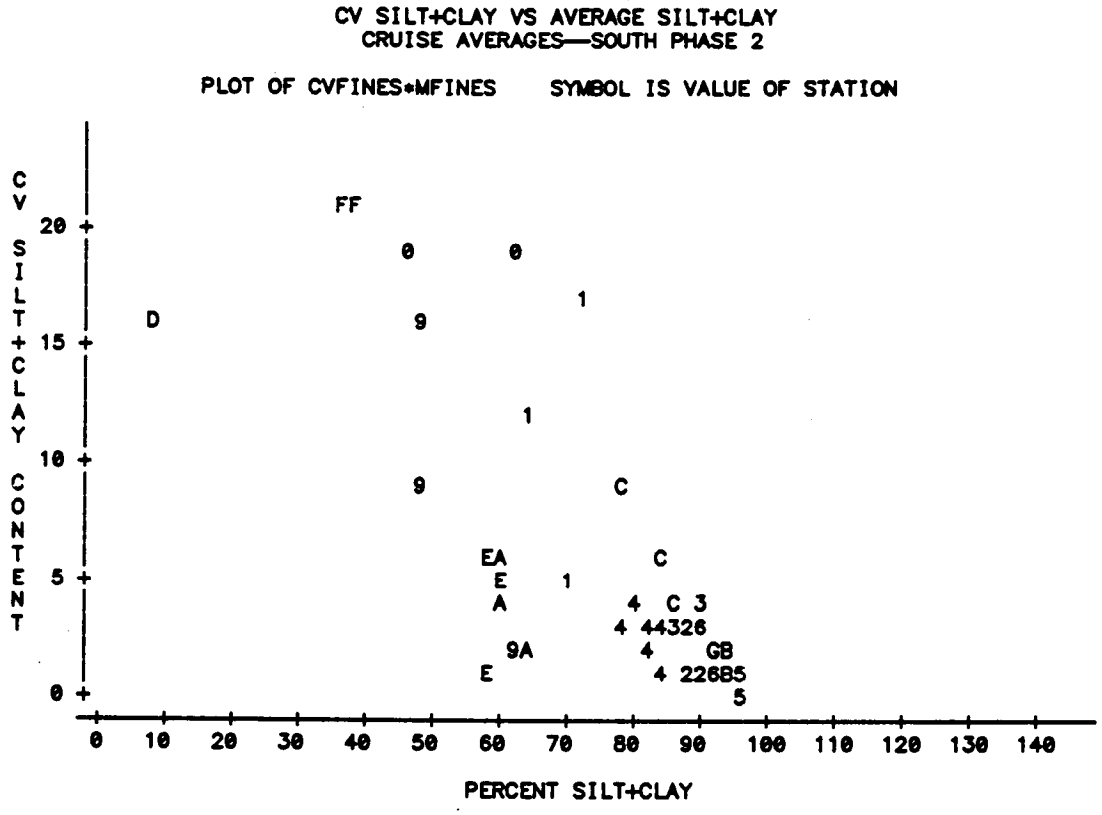


Figure 130. Plot of Coefficient of Variation (CV) of Silt + Clay Against Average Silt + Clay. Stations 10-16 Plotted with the Following Letters: _0 = 10, A = Sta. 11, B = Sta. 12, C = 13, D = 14A, E = 14, F = 15, F = 16. Note: 2 Observations had Missing Values and 5 Observations were Hidden.

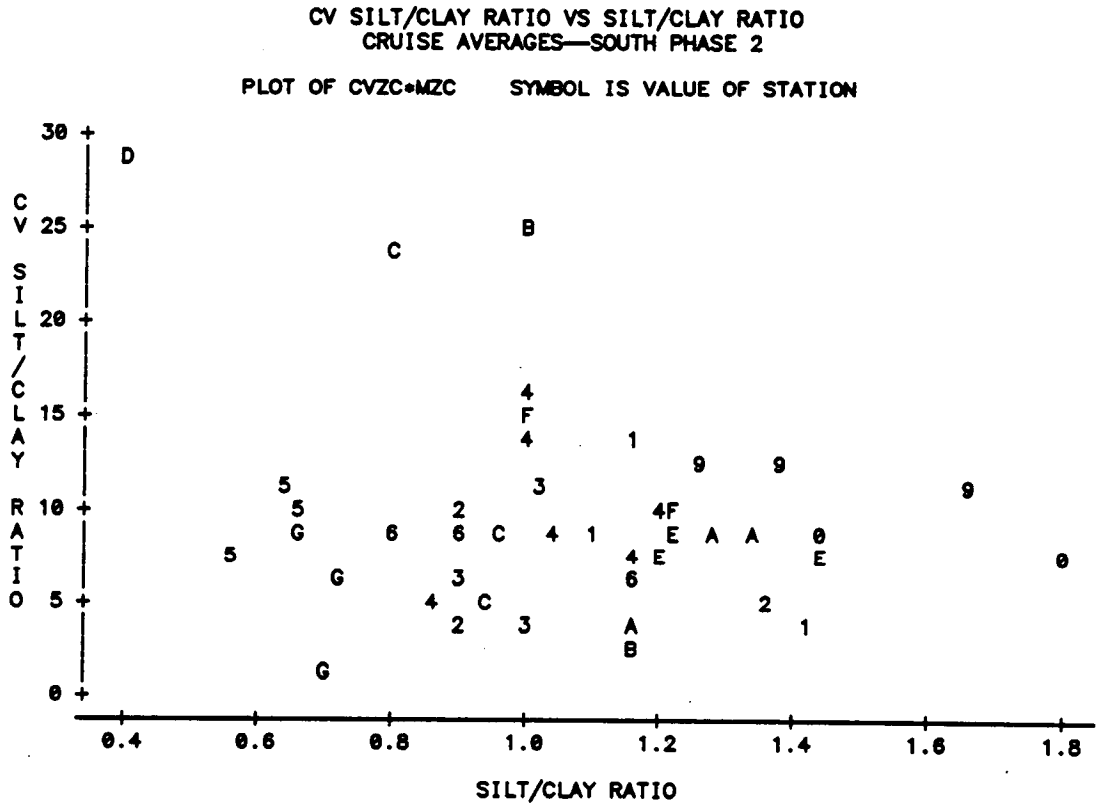


Figure 131. Plot of Coefficient of Variation (CV) of Silt/Clay Ratio Against Silt/Clay Ratio. Stations 10-16 Plotted with the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14A, E = 14, F = 15, G = 16. Note: 2 Observations had Missing Values.

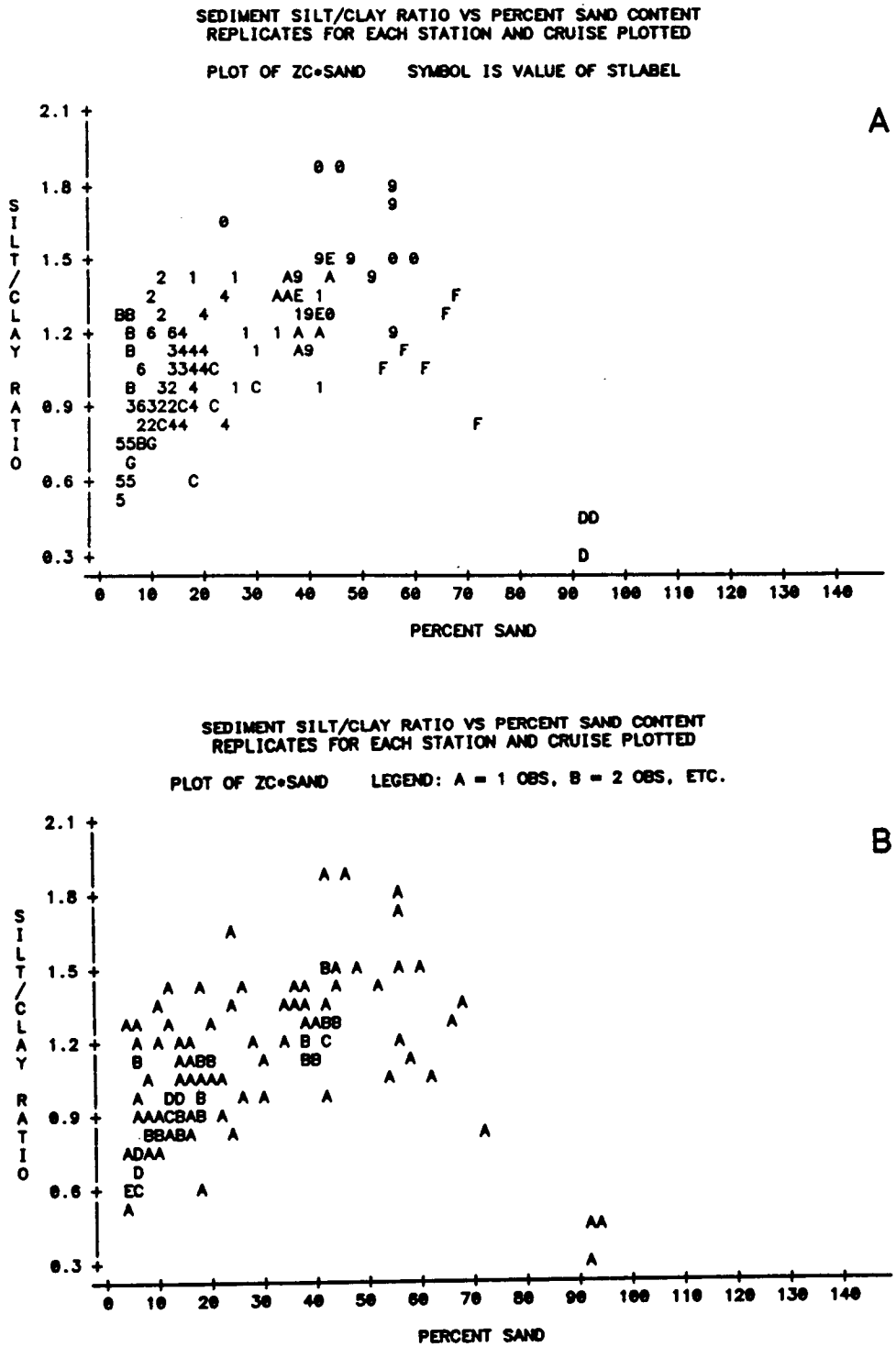
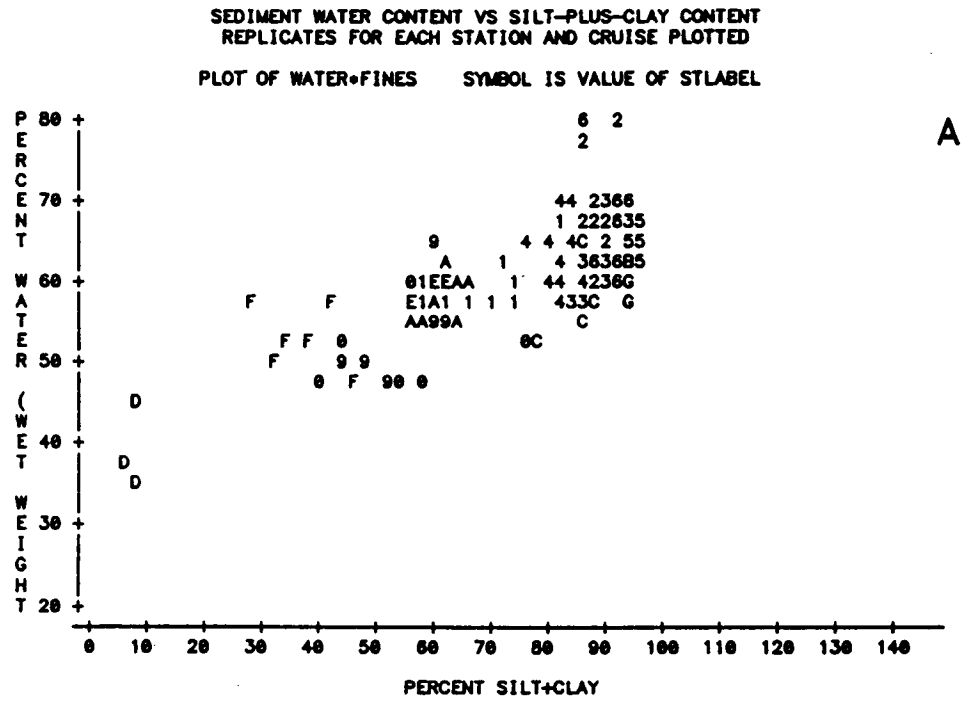


Figure 132. A. Plot of Silt/Clay Ratio Against Percent Sand. Stations 1-9 Plotted with Their Numbers; Stations 10-16 Plotted with the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14A, E = 14, F = 15, G = 16. Note: 37 Observations had Hidden Values. B. Same as A, with Hidden Observations Depicted as: A = 1, B = 2, C = 3, D = 4, E = 5 Observations.



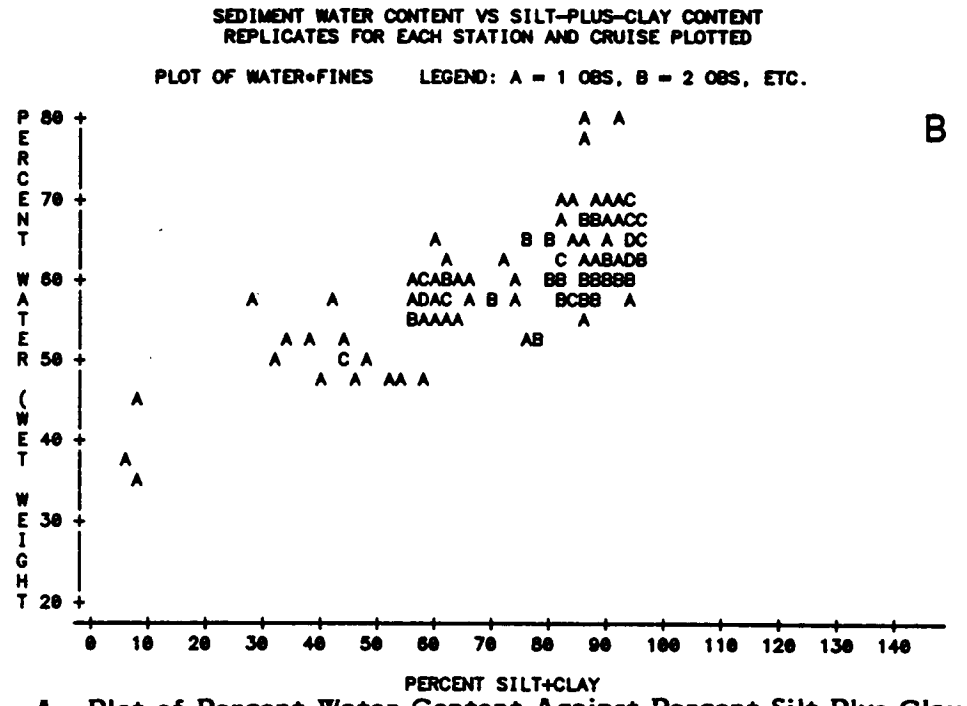


Figure 133. A. Plot of Percent Water Content Against Percent Silt Plus Clay. Stations 1-9 Plotted with Their Numbers; Stations 10-16 Plotted with the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14A, E = 14, F = 15, G = 16. Note: 47 Observations had Hidden Values. B. Same as A, with Hidden Observations Depicted as: A = 1, B = 2, C = 3, D = 4 Observations.

For the majority of samples, carbon and nitrogen are linearly related (Figure 134), but no relationship between these two variables is apparent at Stations 11, 13, 14A, 14, and 15. Tables K.1. and K.2. show the carbon, hydrogen, and nitrogen percent composition for each replicate. Carbon and nitrogen were significantly positively related to one another on Cruises SA-1 through SA-3, and water content was positively related to nitrogen content on Cruise SA-5. The only other significant correlation was a negative relationship between silt/clay ratio and water content on Cruise SA-6.

Percent carbon is not correlated with sediment texture (Figure 135), but percent nitrogen appears to be positively related to the amount of silt plus clay (Figure 136); however, this relationship is not significant (Uchupi and Emery, 1972). The average percent nitrogen at each station is shown in Figure 137. The entire Cape Lookout transect and the 2000-m stations at Hatteras Canyon (Station 6) and off Cape Fear (Station 12) have the highest amounts of nitrogen in the sediments. Nitrogen concentrations peak at upper slope depths. The greatest biomass and density of animals might be expected in these areas. Figures 138 and 139 show the coefficient of variation of carbon and nitrogen content plotted against percent carbon and nitrogen.

Analysis of Variance of Differences Between Sampling Dates

Using analysis of variance, with transformations where appropriate, differences in sediment texture (percent sand or silt plus clay) were tested among the sampling periods May, September, and November of 1985, at Stations 10, 11, 12, 13, 14, 15, and 16 and found to be not significantly different over time. Stations 1 through 5 were similarly tested for differences among the first three sampling dates (November 1983, March-May 1984, July 1984) and found not to vary significantly over this period. Station 6, at a depth of about 2000 m depth in Hatteras Canyon, did vary over this period ($p > 0.03$) (Appendix L, Figures L.21-L.24). A SNK test showed that the percent silt plus clay did not differ between the first two sampling periods but significantly increased during the third cruise in July 1984. The only other station to vary in sediment texture over time was Station 9 at 600 m just north of Cape Hatteras (log sand, $p > 0.02$; silt plus clay, $p > 0.03$) (Appendix L, Figures L.25-L.28). This station was sampled first on the third cruise in July 1984 and subsequently in May and September of 1985. The SNK test indicated that

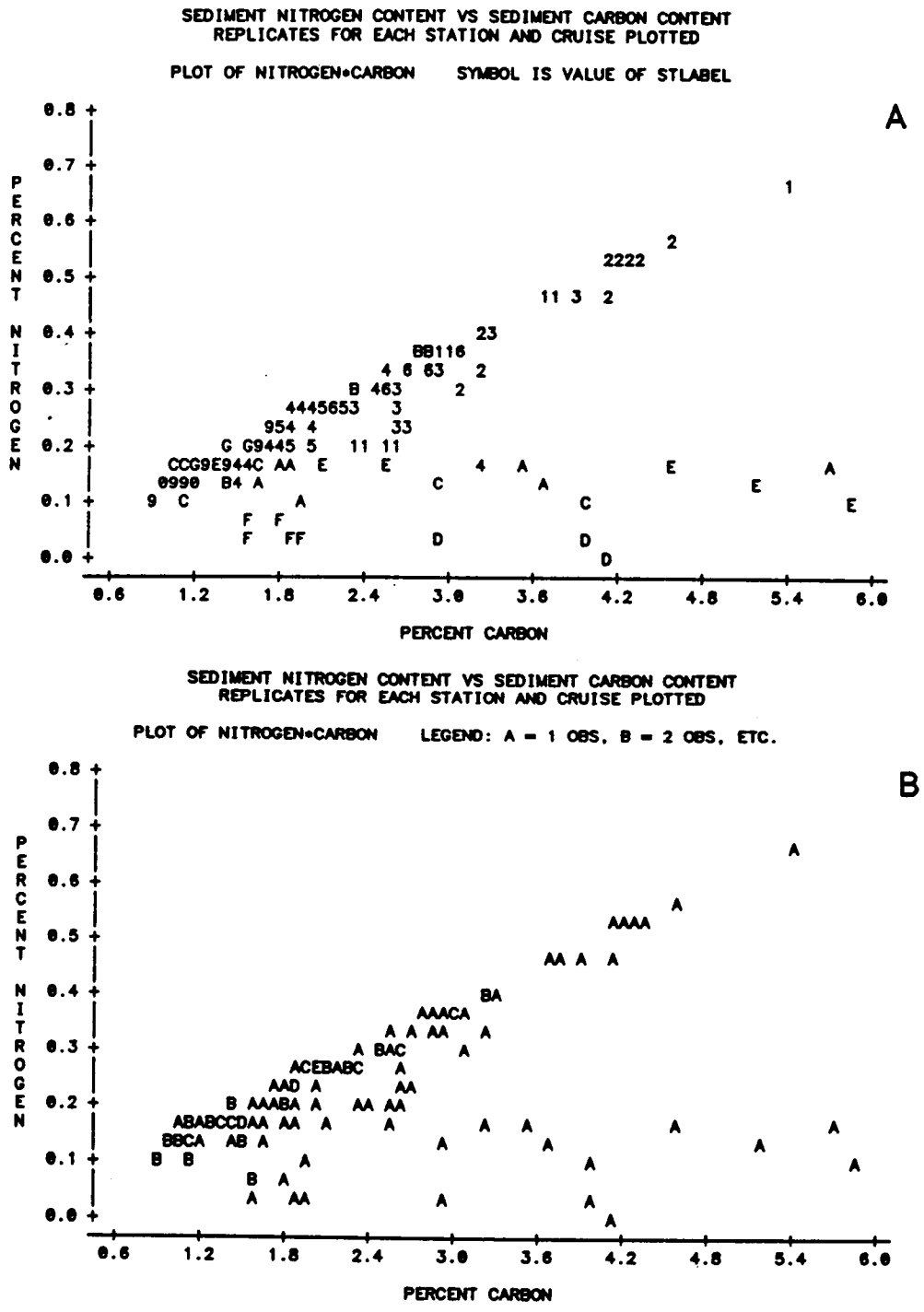


Figure 134. A. Plot of Percent Nitrogen Content Against Percent Carbon. Stations 1-9 Plotted with Their Numbers; Stations 10-16 Plotted with the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14A, E = 14, F = 15, G = 16. Note: 38 Observations had Hidden Values. B. Same as A, With Hidden Observations Depicted as: A = 1, B = 2, C = 3, D = 4, E = 5, Observations.

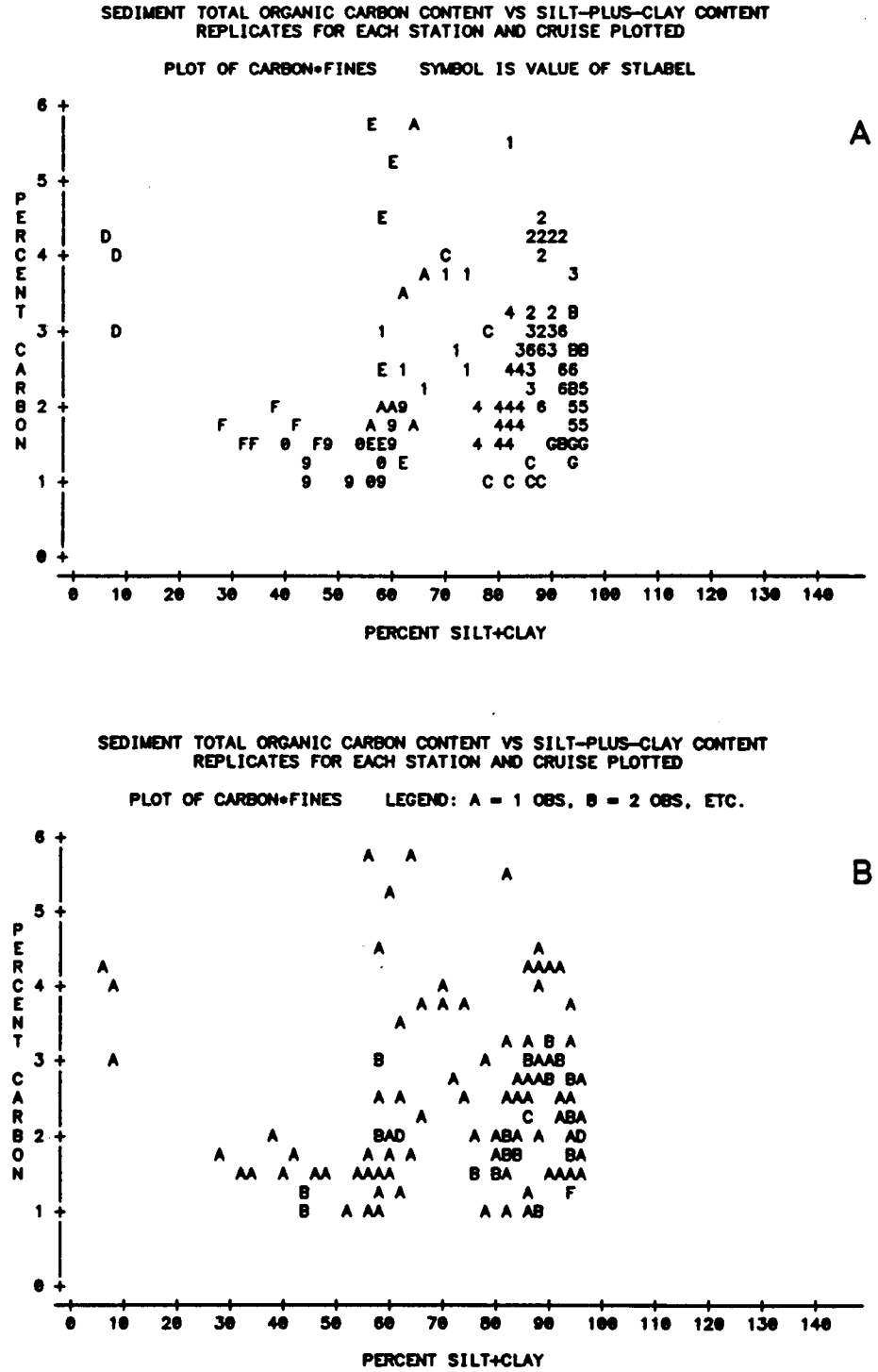


Figure 135. A. Plot of Percent Carbon Against Percent Silt Plus Clay. Stations 1-9 Plotted with Their Numbers; Stations 10-16 Plotted with the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14, E = 15, F = 16. Note: 30 Observations had Hidden Values. B. Same as A, with Hidden Observations Depicted as: A = 1, B = 2, C = 3, D = 4.

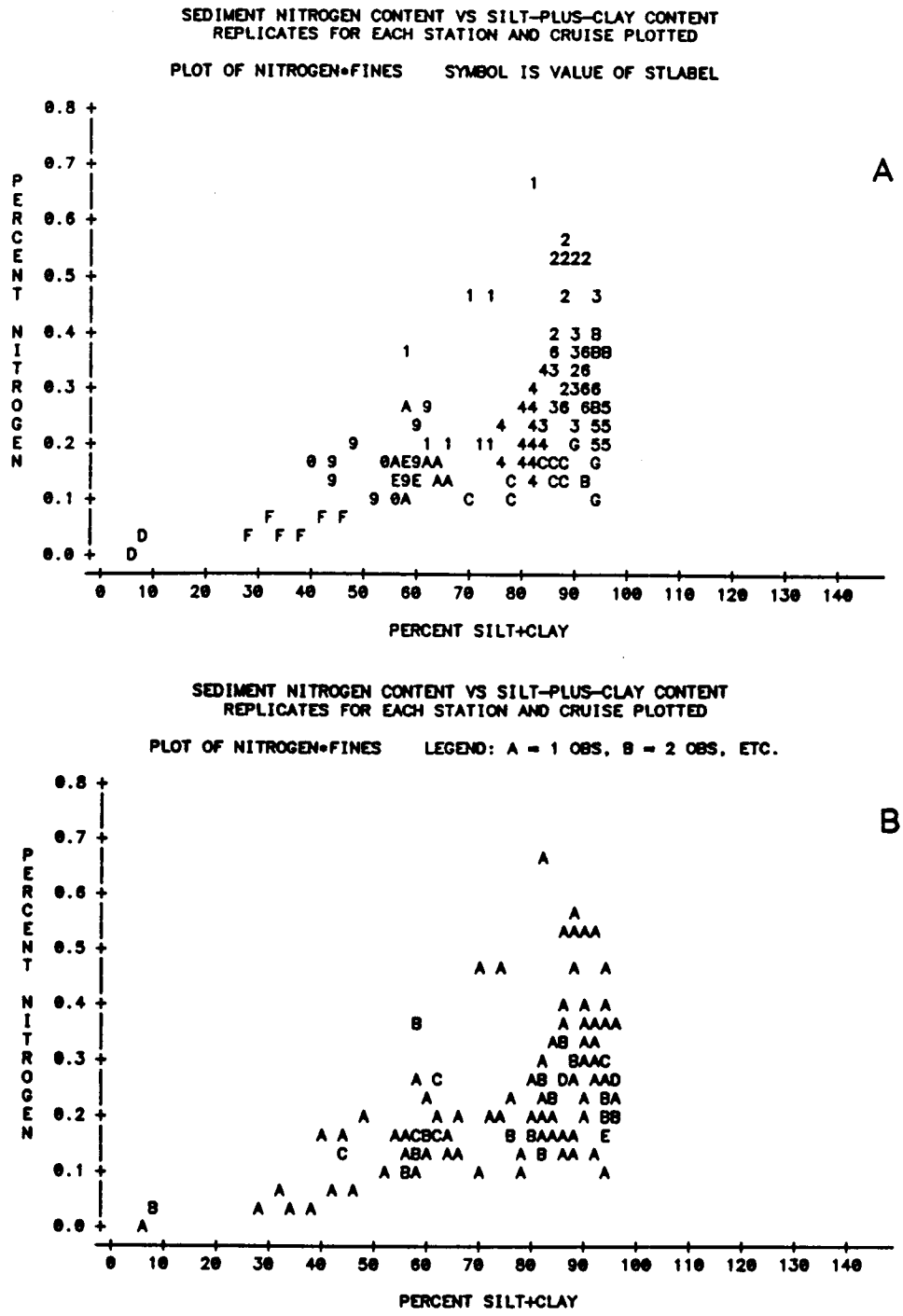


Figure 136. A. Plot of Percent Nitrogen Against Percent Silt Plus Clay. Stations 1-9 Plotted with Their Numbers; Stations 10-16 Plotted with the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14, E = 15, F = 16. Note: 35 Observations had Hidden Values. B. Same as A, with Hidden Observations Depicted as: A = 1, B = 2, C = 3, D = 4, E = 5.

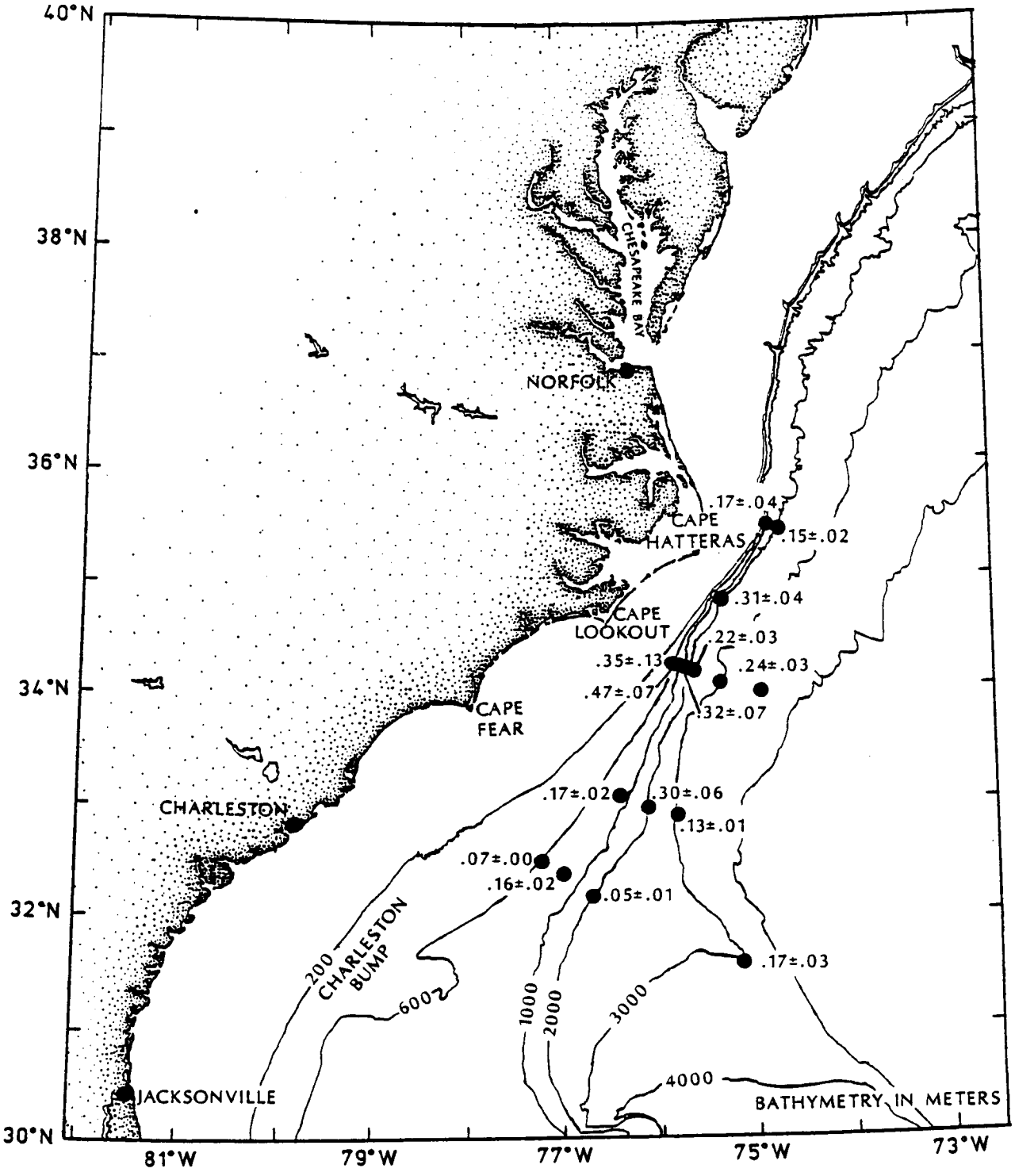


Figure 137. Map of the U.S. South Atlantic Station Design Depicting Percent Nitrogen at Each Station (± 1 S.D.).

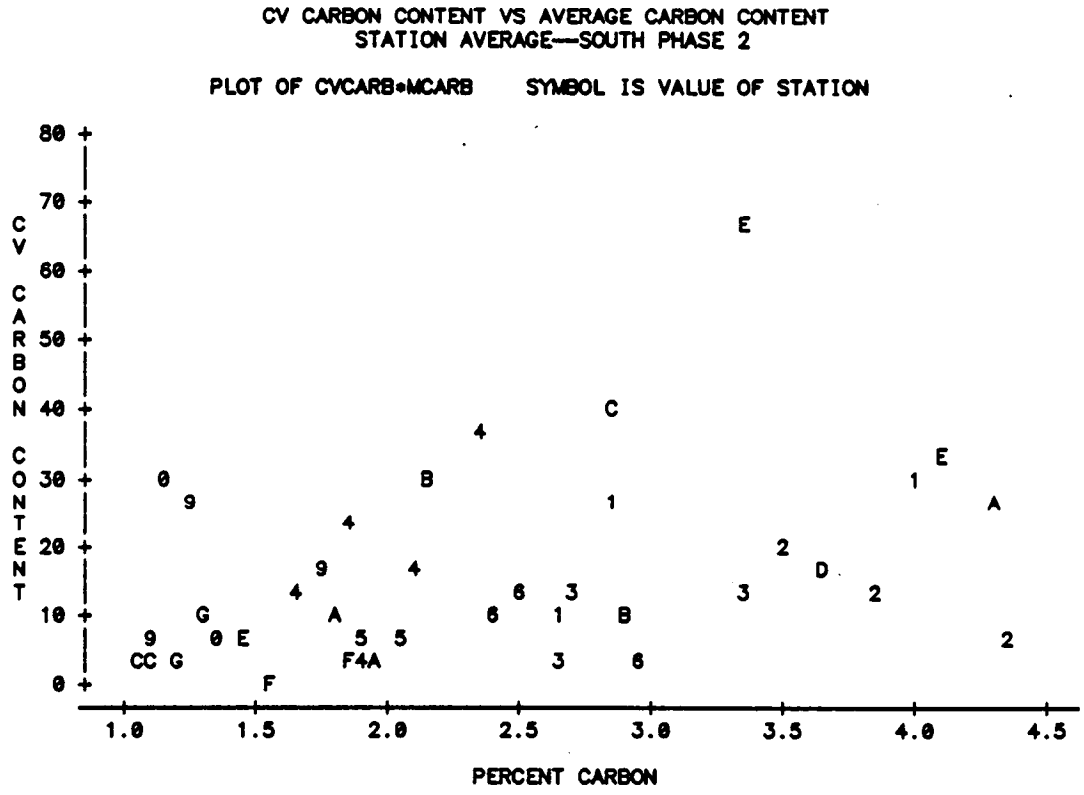


Figure 138. Plot of Coefficient of Variation (CV) of Percent Carbon Against Percent Carbon. Stations 1-9 Plotted with Their Numbers: Stations 10=16 Plotted with the Following Letters: 0 = 10, A = 11, B = 12, C = 13, D = 14, E = 15, F = 16. Note: Two Observations had Missing Values; Three Observations had Hidden Values.

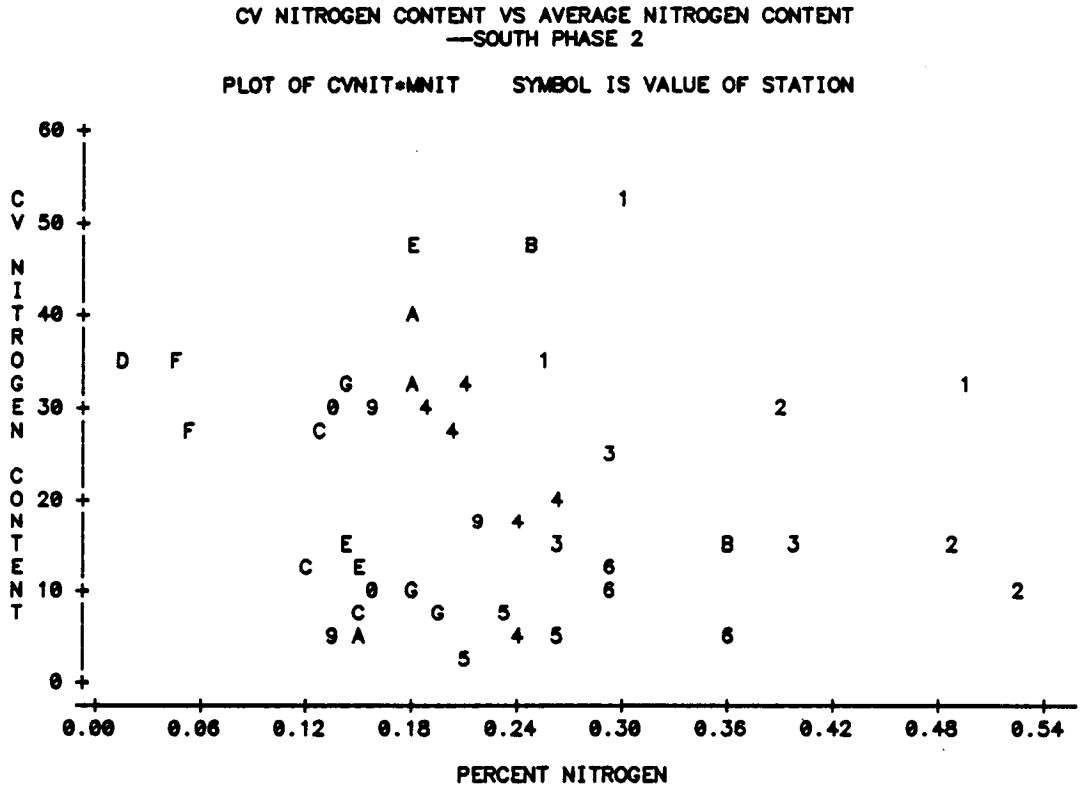


Figure 139. Plot of Coefficient of Variation (CV) of Percent Nitrogen Against Percent Nitrogen. Stations 1-9 Plotted with Their Numbers: Stations 10-16 Plotted with the Following Letters 0 = 10, A = 11, B = 12, C = 13, D = 14, E = 15, F = 16. Note: Two Observations had Missing Values.

the fourth and fifth cruises were not different, but silt plus clay was significantly greater (and percent sand significantly less) in July, Cruise SA-3. The longest time series was at Station 4 (Cape Lookout transect, 2000 m); the sediment parameters for each of the six cruises are shown in Appendix L, Figures L.29-L.34.

Similar tests were performed on the results for percent carbon and percent nitrogen. The only station to show significant nitrogen differences over time was Station 5, at 3000 m off Cape Lookout (log nitrogen, $p > 0.008$). Carbon varied significantly over time at Station 11 (800 m) and Station 13 (3000 m) on the Cape Fear transect (log log carbon, $p > 0.001$ and $p > 0.008$, respectively). At these two stations an SNK test indicated that Cruise SA-6 had significantly more carbon than either Cruises SA-4 or SA-5. At Station 15, percent carbon is significantly greater on Cruise SA-5 than Cruise SA-4 (log log carbon, $p > 0.002$).

Analysis of Variance of Differences Between Stations

The differences among three depths were analyzed on the Cape Fear and Charleston transects (Tables 66 and 67). For sand and silt plus clay, SNK tests indicated that each station was significantly different from each of the other two stations in both transects. Percent nitrogen varied significantly with depth in the same way at each of the two transects. The intermediate depth station at 2000 m was significantly different from either the 800 m station or the 3000 m station, and these opposite extremes of the transects were not significantly different from each other. For carbon there was a significant interaction between station and cruise so that the result was less clear. On the Cape Fear transect, the results from Cruise SA-4 showed the same pattern as for nitrogen but Cruise SA-5 shows each station to be distinct and Cruise SA-6 shows no differences. On the Charleston transect, carbon varied more continuously with depth. Carbon was higher at 800 m that at 2000 m or 3000 m, but the 2000 m station (15) was not significantly different from either 800 m or 3000 m on Cruise SA-4. On Cruise SA-5, carbon levels were not significantly different among stations.

At 600 m the Cape Hatteras station sand and silt plus clay differed from both the Cape Lookout and Charleston stations (Tables 68). Carbon and nitrogen differed only

TABLE 66. STATISTICAL COMPARISON OF THE CAPE FEAR TRANSECT (CRUISES 4-6; STATIONS 11, 12, 13) (2-WAY ANOVA).

Variable	Transformation	Probability			SNK Test[1]
		Main Effects		Interaction	
		Station	Cruise	Station by Cruise	
Carbon	Log	.0009***	.0006***	.0022***	See carbon by cruise
Nitrogen	Raw	.0002***	.2274	.4454	12, 11, 13
Sand	Raw	.0001***	.8823	.0994	11, 13, 12
Silt and clay	Log	.0001***	.9703	.0754	12, 13, 11

Carbon by Cruise:

Cruise	Probability	SNK test[1]
4	.0001***	12, 11, 13
5	.001***	12, 11, 13
6	.118 n.s.	11, 13, 12

[1]Lines connect stations not significantly different.
* = 0.05 >p> 0.01.
** = 0.01 >p> 0.001.
*** = p< 0.001.

TABLE 67. STATISTICAL COMPARISON OF THE CHARLESTON TRANSECT STATIONS (CRUISES 4, 5, AND 6; STATIONS 14, 15, 16).

Part I.

Cruises 4 and 5, 2-way ANOVA

Variable	Transformation	Probability: Main Effects: Station	Probability: Main Effects: Cruise	Probability: Interaction: Station by Cruise	SNK Test[1]
Carbon	Log log	.028*	.064	.026*	See carbon by cruise
Nitrogen	Raw	.0004***	.543	.341	16, 14, 15
Sand	Log	.0001***	.433	.538	15, 14, 16
Silt and clay	Arc	.0001***	.703	.857	16, 14, 15

Carbon by Cruise:

Cruise	Probability	SNK test[1]
4	.051	14, 15, 16
5	.298	

Part II.

Cruise 6, t-test

Variable	Transformation	Probability: Main Effects: Station	Probability: Main Effects: Cruise	Probability: Interaction: Station by Cruise	SNK Test[1]
Carbon	Log log	.007**	14>16		
Nitrogen	Raw	.079			
Sand	Raw	.0001***	14>16		
Silt and clay	Log	.0001***	16>14		

[1]Lines connect stations not significantly different.
* = 0.05 >p> 0.01.
** = 0.01 >p> 0.001.
*** = p< 0.001.

TABLE 68. STATISTICAL COMPARISONS OF SEDIMENT CHARACTERISTICS FOR 600M ISOBATH STATIONS IN THE U.S. SOUTH ATLANTIC REGION.

Part I.

600 m Comparison of Cruise 3, Cape Lookout (Station 1) vs. Cape Hatteras (Station 9) (t-Test)

Variable	Transformation	Probability	
Carbon	Log	.059	
Nitrogen	Log	.462	
Sand	Raw	.017*	9>1
Silt and clay	Log	.014*	1>9

Part II.

600 m Comparison of Cruise 5, Cape Hatteras (Station 9) vs. Charleston (Station 14A) (t-Test)

Variable	Transformation	Probability	
Carbon	Log log	.0005***	14A>9
Nitrogen	Raw	.0001***	9>14A
Sand	Log	.0001***	9>14A
Silt and clay	Raw	.0111*	14A>9

* = 0.05 >p> 0.01.
** = 0.01 >p> 0.001.
*** = p< 0.001.

between the Cape Hatteras station and the very sandy Charleston station. Carbon was greater at the sandy Station 14A and nitrogen was greater at the less sandy Station 9.

At 800 m the Cape Fear Station 11 did not differ from the Charleston Station 14 for any variable, but carbon values did vary over time at the two stations (Table 69). At the 2000-m stations only 15 and 10 were similar for sand, silt plus clay, and carbon (Tables 70-71). For nitrogen, Stations 4 and 10 were similar. All other comparisons showed significant differences among stations. At 3000 m nitrogen and silt plus clay were significantly greater at the Charleston station than at the Cape Fear station (Table 72). Carbon was relatively homogenous, but varied significantly among cruises at Station 13.

DISCUSSION

Cape Hatteras Stations 9 and 10

Just north of Cape Hatteras, Stations 9 and 10 at depths of 600 m and 2003 m are on a steep slope (16°--Popenoe et al., 1982) in an area of intense southwestward current flows associated with WBUC (Richardson, 1977). A current meter at 2575 m just south of our Station 10 at 34° 59' indicated mean flows of 10.9 cm/sec and maximum flows of 47 cm/sec. Labrador Basin Water extends along the bottom in this region from about 500 m to below 2000 m for at least part of the time. This steep slope coincides with a band of white tubes observed in bottom photographs from depths of less than 600 m to nearly 1900 m (Chapter 5). The reason for the distribution of the white tubes will remain obscure until the animal is collected. If it is a filter feeder, the more intense flow may carry more particles per unit time to be filtered from the water. Despite the great difference in depth between the two stations, the sediments are quite similar, with perhaps slightly more variation between samples in the amount of silt plus clay at Station 10 (Figure 130). Our results for Station 10 are the same as those of Bothner et al. (1987) for the top 10 cm of a core in which the sand content was greater than 40 percent and the sand fraction was mostly quartz. Below the top 10 cm the sand content dropped to 25 percent and remained at about that value to the bottom of the core at 34 cm. The high lead inventories of 31.7 and 68.9 $\mu g/cm^2$ observed by Bothner et al. (1987) at Stations 9 and 10, respectively, indicate increased scavenging of lead from the water column at these locations.

TABLE 69. STATISTICAL COMPARISON OF TWO 800 M STATIONS ON CRUISES 4-6, CAPE FEAR (STATION 11) VS. CHARLESTON (STATION 14) (2-WAY ANOVA).

		Probability			
		Main Effects		Interaction	
Variable	Transformation	Station	Cruise	Station by Cruise	SNK Test[1]
Carbon[1]	Log log	.819		.0008***	.216
Nitrogen	Log	.608		.644	.919
Sand	Arc	.159		.382	.203
Silt and clay	Log	.163		.376	.208

[1]SNK test: cruises 6> 4> 5.
* = 0.05 >p> 0.01.
** = 0.01 >p> 0.001.
*** = p< 0.001.

TABLE 70. STATISTICAL COMPARISON OF TWO 2000-M STATIONS ON CRUISES 1-3, CAPE LOOKOUT (STATION 4) VS. HATTERAS CANYON (STATION 6) (2-WAY ANOVA).

Variable	Transformation	Probability			SNK Test[1]
		Main Effects		Interaction	
		Station	Cruise	Station by Cruise	
Carbon	Raw	.002**	.178	.285	6>4
Nitrogen	Raw	.005**	.223	.281	6>4
Sand	Raw	.0001***	.136	.020*	See Sand by Cruise
Silt and clay	Raw	.0001***	.133	.021*	See Silt and Clay by Cruise

Sand by Cruise (t-test):

Cruise	Probability	SNK test
1	.024*	4>6
2	.049*	4>6
3	.001**	4>6

Silt and clay by cruise:

Cruise	Probability	SNK test
1	.022*	6>4
2	.049*	6>4
3	.001*	6>4

* = 0.05 >p> 0.01.
** = 0.01 >p> 0.001.
*** = p< 0.001.

TABLE 71. STATISTICAL COMPARISONS OF FOUR 2000 M STATIONS IN THE U.S. SOUTH ATLANTIC REGION.

Part I.

2000 m Comparison of Cruise 4, All Transects Compared, (Stations 4, 10, 12, 15) (1-way ANOVA)

Variable	Transformation	Probability	SNK test[1]
Carbon	Raw	.0002***	15, 10, 4, 12
Nitrogen	Log	.0001***	12, 4, 10, 15
Sand	Log	.0001***	15, 10, 4, 12
Silt and clay	Arc	.0001***	12, 4, 10, 15

Part II.

2000 m Comparison of Cruise 5, Cape Lookout (Station 4) vs. Charleston (Station 15) (t-Test)

Variable	Transformation	Probability	Station
Carbon	Log	.0003***	4 >15
Nitrogen	Raw	.0001***	4 >15
Sand	Log	.0007***	15 >4
Silt and clay	Arc	.0010***	4 >15

TABLE 71. (CONTINUED)

Part III.

2000 m Comparison of Cruise 6, Cape Lookout (Station 4)
vs. Cape Hatteras (Station 10),
vs. Cape Fear (Station 12).
(1-way ANOVA)

Variable	Transformation	Probability	SNK Test
Carbon	Log log	.140	
Nitrogen	Log	.497	
Sand	Log	.0005***	10, 4, 12
Silt and clay	Raw	.004**	12, 4, 10

[1]Lines connect cruises not significantly different.
* = 0.05 >p> 0.01.
** = 0.01 >p> 0.001.
*** = p< 0.001.

TABLE 72. STATISTICAL COMPARISON OF TWO 3000 M STATIONS ON CRUISES 4-6, CAPE FEAR (STATION 13), VS. CHARLESTON (STATION 16) (2-WAY ANOVA).

Variable	Transformation	Probability			SNK Test[1]
		Main Effects		Interaction	
		Station	Cruise	Station by Cruise	
Carbon	Log log	.229	.002**	.002**	See carbon by cruise[1]
Nitrogen	Raw	.012*	.086	.614	16>13
Sand	Log	.0001***	.058	.913	13>16
Silt and clay	Arc	.0001***	.086	.619	16>13

Carbon by Station:

Station	Probability	SNK test[1]
13	.008**	6, 5, 4
16	.063	5, 6, 4'

[1]Lines connect stations not significantly different.
* = 0.05 >p> 0.01.
** = 0.01 >p> 0.001.
*** = p< 0.001.

According to Bothner (1987), these values are higher than predicted from the atmospheric flux by a factor of 5-10 respectively. There may be more rapid transport of materials to slope depths in this area but the reasons are unclear. Another possibility is greater activity of filter feeders.

A slump scarp extending from depths of about 500 m to 1500 m has been observed north of Station 9 and 10 at about 36° 20', leaving an anomalously smooth section of slope. The slumping probably took place in the late Pleistocene or Holocene epochs (Popenoe et al., 1982). Stations 9 and 10 are in an area dissected by many submarine canyons cut into Pleistocene-age sediments. The relative importance of downslope sediment slumping and current resuspension and resedimentation in determining the similarity of sediments over such a broad depth interval is not yet clear. Sedimentary processes in the region are reviewed by Knebel (1984).

Cape Lookout and Cape Fear Transects

On the Cape Lookout transect the currents are not well known, but they may be less intense than in the other transects. The lower boundary of the Gulf Stream is close to 600 m (Pratt, 1966) and the upper boundary of the WBUC is about 1000 m (Rowe and Menzies, 1968). A mooring close to Station 11 at 800 m off Cape Fear indicates variable currents with maxima seldom greater than 10 cm/sec (Casagrande, 1984: Figure 4-18). Current velocities have not been measured on the Cape Lookout transect. The shallowest station on this transect is more of a depositional environment than the other 600-m stations (Figure 120). The increased nitrogen content of sediments throughout the transect suggests that there is greater deposition of organic material on this transect than on the others. This is probably the result of upwelling in the region and less intense bottom currents (Atkinson & Targett, 1983). Carbon and nitrogen were positively correlated with one another on Cruises SA-1 through SA-3 but, with addition of the more southerly transects on Cruises SA-4 through SA-6, this relationship is no longer held.

Further south on the Cape Fear transect, a current meter at a depth of approximately 1800 m on a mooring on the 2000-m contour indicates a southerly current with velocities from 20 to 40 cm/sec (Casagrande, 1984). Despite this finding, the sediment data indicates a depositional environment at 2000 m, with more intense currents

shallower and deeper (Figure 127). Field observations support the suggestion of a depositional site. The bottom was too soft to allow normal operation of the box core and "snowshoes" were required to prevent the deep penetrations that were overfilling the boxes. Station 12 (2000 m) is close to a site where subsidence accompanying leaching of salt from two large salt diapirs causes gradual slumping of sediments upslope. This leaves a dimpled bottom over rotational slump faults extending across the 2000-m depth contour (Popenoe et al., 1982). We do not know if this very slow slumping has any effect on the patterns of sediment distribution.

Charleston Transect

The southern-most transect starts at Station 14A (600 m depth) on the eastern side of the Charleston Gyre, a cyclonic eddy that results from deflection of the Gulf Stream by the Charleston Bump (Singer et al., 1983; McClain and Atkinson, 1985). Current meter records in the first half of 1983 indicate the central area of the gyre may move far enough east to be close to Station 14A (Casagrande, 1984). Our sediment data (92 percent sand) indicate that this station is swept by the Gulf Stream. This is confirmed by the bottom photographs from the transect in the same area (Chapter 5). Station 14A is characterized by rippled sediments in sand waves 2-m high with a period of up to 16 m.

The 800-m site (Station 14) appears depositional with a clearly visible biogenic microtopography (Chapter 5). A mooring located to the southwest indicates that the 800-m contour is east of the Gulf Stream (Casagrande, 1984), and the sediment data indicate a higher silt plus clay content than at the 2000-m station. The station at 2000 m (Station 15) appears in the photographs to be swept by currents. A mooring on the transect to the southwest indicates a generally southerly current from February to July, 1983, except for short northward events in late February and mid-April (Casagrande, 1984). The average sand content of 60 percent (Figure 127) is in agreement with these observations. The slope here has an inclination of 3.5° in comparison to an average of 8 to 10° between Cape Fear and Cape Hatteras (Popenoe et al., 1982). Over the long traverse between depths of 2000 m and 3000 m, the environment becomes much more depositional.

CHAPTER 8. HYDROGRAPHY

INTRODUCTION

A limited set of near-bottom hydrographic data were collected at each station during Phase 2 of the U.S. South Atlantic study. The purpose of these data collections was to characterize near-bottom conditions to assist in the interpretation of biological results. The parameters measured included temperature, salinity, and dissolved oxygen concentration. These parameters are important because they may influence the distribution and abundance of benthic infaunal organisms. Field sampling and data collection were discussed in Chapter 2 of this report. The analytical methods and results are discussed in this chapter.

METHODS

Hydrographic samples were collected using a Niskin bottle equipped with reversing thermometers, two protected and one unprotected. The temperatures recorded on the individual reversing thermometers were first corrected by using the method established by the U.S. Naval Oceanographic Office (1975). The actual depth (z) of the hydrocast was calculated by the following equation:

$$z = \frac{(Tu-Tw)}{(rho)(Q)}$$

where Tu is the corrected temperature of the unprotected thermometer, Tw is the corrected temperature of the protected temperature, rho is the mean density of the water column above the estimated depth, and Q is the pressure-response coefficient for the unprotected thermometer.

Dissolved oxygen concentrations were determined on board ship by the Winkler titration method (HS 607). Salinity samples were analyzed at WHOI using an Autosal conductivity probe. On Cruise SA-5, a Neal Brown Mark III CTD was used to record temperature and salinity at intervals of one meter, providing a vertical profile at each station.

RESULTS

The mean of the temperature recorded by the two protected thermometers at each station on each cruise of Phase 2 is presented in Table 73. Values presented for depth represent the depth at which the actual temperature readings were made. The salinity and dissolved oxygen concentration data, including station means and standard deviation, are presented in Tables 74 and 75, respectively. Mean values for each parameter represent averages of the replicate measurements of a single sample; within-station variability is not represented in these data. The CTD plots of temperature and salinity versus depth for each station are presented in Appendix M.

The salinity data varied little between stations and cruises. Mean salinity values ranged from 34.76 °/oo at Station 16 (3000 m) to 36.33 °/oo at Station 11 (800 m). The dissolved oxygen concentration showed little variation between cruises but a wide variation between stations. The mean dissolved oxygen concentrations ranged from 5.25 mg/l (Station 10, 2000 m) to 9.08 mg/l (Station 13, 3000 m). Temperature decreased consistently with depth. Stations 13 and 16 (3000 m) had the lowest mean temperature on all sampling occasions.

The CTD salinity measurements were consistent with the Niskin measurements for all stations except 14A, where the hydrocast tripped near the surface (Table 76). The temperatures recorded on the reversing thermometers were consistently lower than the CTD temperature values (Table 76). The salinity concentration initially increased followed by a gradual decrease in the top 100 m of water. The temperature decreased gradually with depth in the top 1000 m of water. The decrease in both temperature and salinity was much more gradual than observed for the U.S. Mid-Atlantic slope stations (Maciolek et al., 1987). Above 500 m, the temperature and salinity CTD plots for the U.S. South Atlantic stations have a slight plateau that is probably the effect of the Gulf Stream (Appendix M). The dissolved oxygen concentrations in the U.S. South Atlantic were slightly lower than those recorded in the Mid-Atlantic, although still high for western North Atlantic deep water. The lowest dissolved oxygen values were recorded at Station 9 on Cruises SA-4 and SA-5 and Station 10 on SA-4.

The CTD near-bottom temperature and salinity data was uniform at stations of similar depth with the exception of the 600-m stations. At Station 9, the temperature

TABLE 73. DEPTH(m) AND TEMPERATURE (°C) OF NEAR-BOTTOM WATER AT U.S. SOUTH ATLANTIC STATIONS, PHASE 2.

Station	SA-4		SA-5		SA-6	
	Temp	Depth	Temp	Depth	Temp	Depth
4	3.50	1983	4.56	915*	3.62	2087
9	6.35	434	*	*	**	**
10	3.79	1566	**	**	3.40	1869
11	4.84	766.3	4.88	764	9.61	652
12	3.63	1924	*	*	3.55	1876
13	2.55	2899	2.38	2903	2.32	***
14	4.63	765	4.89	760	4.84	740
14A	**	**	11.98	125*	**	**
15	3.47	1918	3.57	1697	**	**
16	3.25	2789	2.26	2923	2.43	2914

* Bottle tripped near surface.
** Sample not taken.
*** Equipment failure.

TABLE 74. SALINITY (°/oo) OF NEAR-BOTTOM WATER AT U.S. SOUTH ATLANTIC STATIONS, PHASE 2.

Station	Cruise SA-4					Cruise SA-5					Cruise SA-6				
	Rep. 1	Rep. 2	Rep. 3	$\bar{x}$	SD	Rep. 1	Rep. 2	Rep. 3	$\bar{x}$	SD	Rep. 1	Rep. 2	Rep. 3	$\bar{x}$	SD
4	34.979	34.330	35.000	34.770	0.381	35.022	35.008	35.031	35.020	0.012	34.995	34.992	34.986	34.991	0.005
9	36.160	36.071	36.105	36.112	0.045	*36.267	36.267	36.265	36.266	0.001	**	**	**		
10	35.614	35.589	36.160	35.788	0.323	**	**	**			34.996	34.980	34.977	34.984	0.010
11	35.001	35.013	35.015	35.010	0.008	35.020	35.026	35.020	35.022	0.004	36.302	36.330	36.360	36.331	0.029
12	34.848	34.841	34.841	34.843	0.004	*36.635	36.632	36.630	36.632	0.002	34.984	34.983	34.989	34.985	0.003
13	34.854	34.840	34.839	34.844	0.008	**	**	**			34.918	34.918	34.941	34.926	0.013
14	35.011	35.010	35.013	35.011	0.002	35.031	35.029	35.041	35.034	0.006	35.027	35.027	35.027	35.027	0.000
14A	**	**	**			35.130	35.130	35.128	35.129	0.001	**	**	**		
15	35.584	34.978	34.971	35.178	0.352	34.978	34.979	34.978	34.978	0.001	**	**	**		
16	34.684	34.782	34.804	34.757	0.064	34.921	34.921	34.922	34.921	0.001	34.953	34.940	34.947	34.947	0.006

* Bottle tripped near surface.
** No data.

TABLE 75. DISSOLVED OXYGEN CONCENTRATION (MG/L) OF NEAR-BOTTOM WATER AT U.S. SOUTH ATLANTIC STATIONS, PHASE 2.

Station	Cruise SA-4					Cruise SA-5					Cruise SA-6				
	Rep. 1	Rep. 2	Rep. 3	$\bar{x}$	SD	Rep. 1	Rep. 2	Rep. 3	$\bar{x}$	SD	Rep. 1	Rep. 2	Rep. 3	$\bar{x}$	SD
4	8.48	8.46	8.48	8.47	0.01	8.19	8.24	8.21	8.21	0.02	7.30	7.38	7.36	7.35	0.04
9	6.01	5.95	5.97	5.98	0.03	*5.61	5.57	5.83	5.67	0.14	**	**	**		
10	5.09	5.25	5.41	5.25	0.16	**	**	**			7.60	7.51	8.36	7.82	0.47
11	7.66	7.72	7.51	7.63	0.11	7.59	7.60	7.50	7.56	0.06	5.71	5.75	5.85	5.77	0.07
12	8.27	8.50	8.35	8.37	0.12	*6.23	6.02	6.21	6.15	0.12	8.94	8.85	8.73	8.84	0.10
13	8.66	8.69	8.65	8.67	0.02	8.49	8.89	9.86	9.08	0.70	8.63	8.47	8.54	8.55	0.08
14	7.68	7.63	7.96	7.76	0.18	8.84	7.75	7.64	8.08	0.66	7.97	7.60	7.65	7.74	0.20
14A	**	**	**			5.71	5.74	5.90	5.78	0.10	**	**	**		
15	8.18	8.49	8.41	8.36	0.16	8.26	8.48	8.68	8.47	0.21	**	**	**		
16	7.55	7.61	7.56	7.57	0.03	8.73	8.89	8.74	8.79	0.09	8.62	8.31	8.67	8.53	0.20

* Bottle tripped near surface.
** No data.

TABLE 76. BOTTOM TEMPERATURE AND SALINITY MEASUREMENTS TAKEN AT SOUTH ATLANTIC STATIONS DURING CRUISE SA-5.

Station	Hydrocast/CTD Depth (m)	Hydrocast Temp (°C)	CTD Temp (°C)	Hydrocast Salinity (o/oo)	CTD Salinity (o/oo)
4	915.5*	4.56	4.65	35.020	35.016
11	764.9	4.88	5.51	35.022	35.043
13	2903.1	2.38	2.72	**	34.931
14	760.8	4.89	4.90	35.034	35.026
14A	606.5	11.98*	7.66	35.129	35.117
15	1697.4	3.57	3.80	34.978	34.980
16	2923.8	2.26	2.47	34.921	34.920

* Bottle tripped near surface.
** No data.

decreased more rapidly than at Station 14A, resulting in a lower near-bottom temperature and salinity. Each of the other depth pairs (800 m, 2000 m, and 3000 m) exhibited similar rates of decline for temperature and salinity. The 3000-m stations (13 and 16) had slower rates of decline than the 600-m stations (9, 14A) and the 800-m stations (11, 14).

A plot of temperature versus salinity is presented in Figure 140. Average temperature-salinity curves for the Western North Atlantic Water (WNAW), North Atlantic Deep Water (NADW), Norwegian Sea Overflow Water (NSOW), and Antarctic Bottom Water (AABW) (Emery and Uchupi, 1972) are shown for comparison.

A temperature profile of the southern-most transect is presented in Figure 141. The presence of higher temperatures at greater depths for Station 14 is possibly due to the Gulf Stream. A similar temperature profile of the Cape Fear transect is presented in Figure 142.

DISCUSSION

The U.S. South Atlantic Bight is a very difficult area to characterize hydrographically because of the currents, the water masses that feed the currents, and the unique topography. To further complicate the issue, inclement weather, physical damage to the sampling equipment, and other obstacles encountered in field sampling resulted in failure to obtain samples at certain stations on some cruises.

The Gulf Stream is the main surface current in the South Atlantic Bight. Approximately 1100 m below the Gulf Stream flows a countercurrent, the Western Boundary Undercurrent (WBUC). The northern-most part of the WBUC is comprised mostly of Norwegian Sea Overflow Water. There is a mixing of bottom waters just northeast of Cape Hatteras which changes the character of the WBUC. The deep water off Cape Hatteras is mainly Western North Atlantic Water, while further south, the North Atlantic Deep Water and the Antarctic Bottom Water are the major contributors to the Western Boundary Undercurrent.

The hydrographic data presented in this chapter is in agreement with similar data recorded for this area (Schmitz et al., 1987). The dissolved oxygen concentrations were uniformly higher than those typically observed in deep Western Atlantic water masses. This is possibly due to the influence of the Norwegian Sea Overflow Water (Emery and

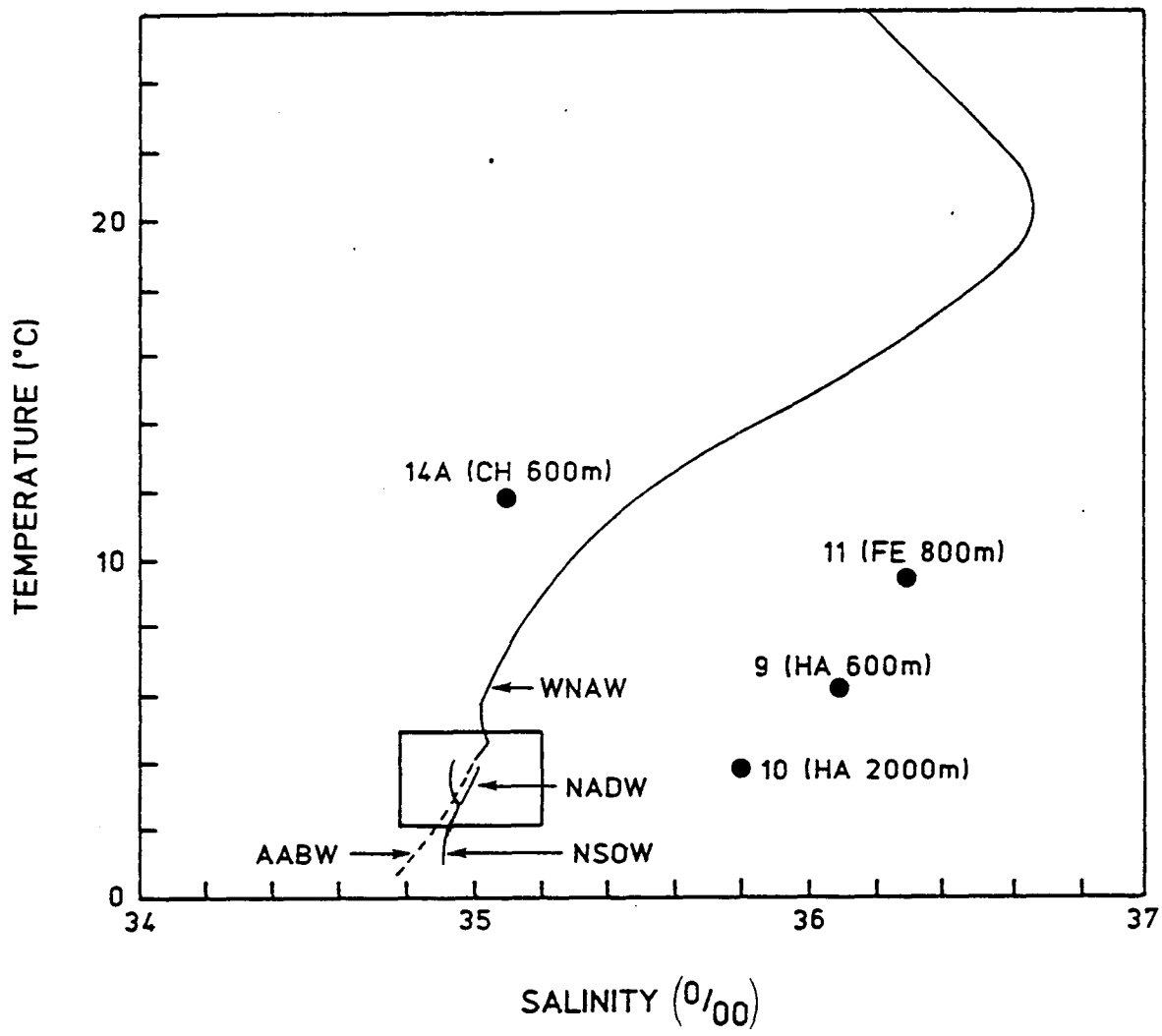


Figure 140. Temperature vs. Salinity of Near Bottom Water of the U.S. South Atlantic Stations. Boxed Area Shows Ranges of 17 T-S Measurements. Others are Designated by Station (Location and Depth), e.g., 9 (HA 600m) Station 9 Cape Hatteras 600 m. Average T-S Curves for the Western North Atlantic Water (WNAW), North Atlantic Deep Water (NADW), Norwegian Sea Overflow Water (NSOW), and Antarctic Bottom Water (AABW) Redrawn from Emery and Uchupi (1972, Figure 241, p. 288) for Comparison.

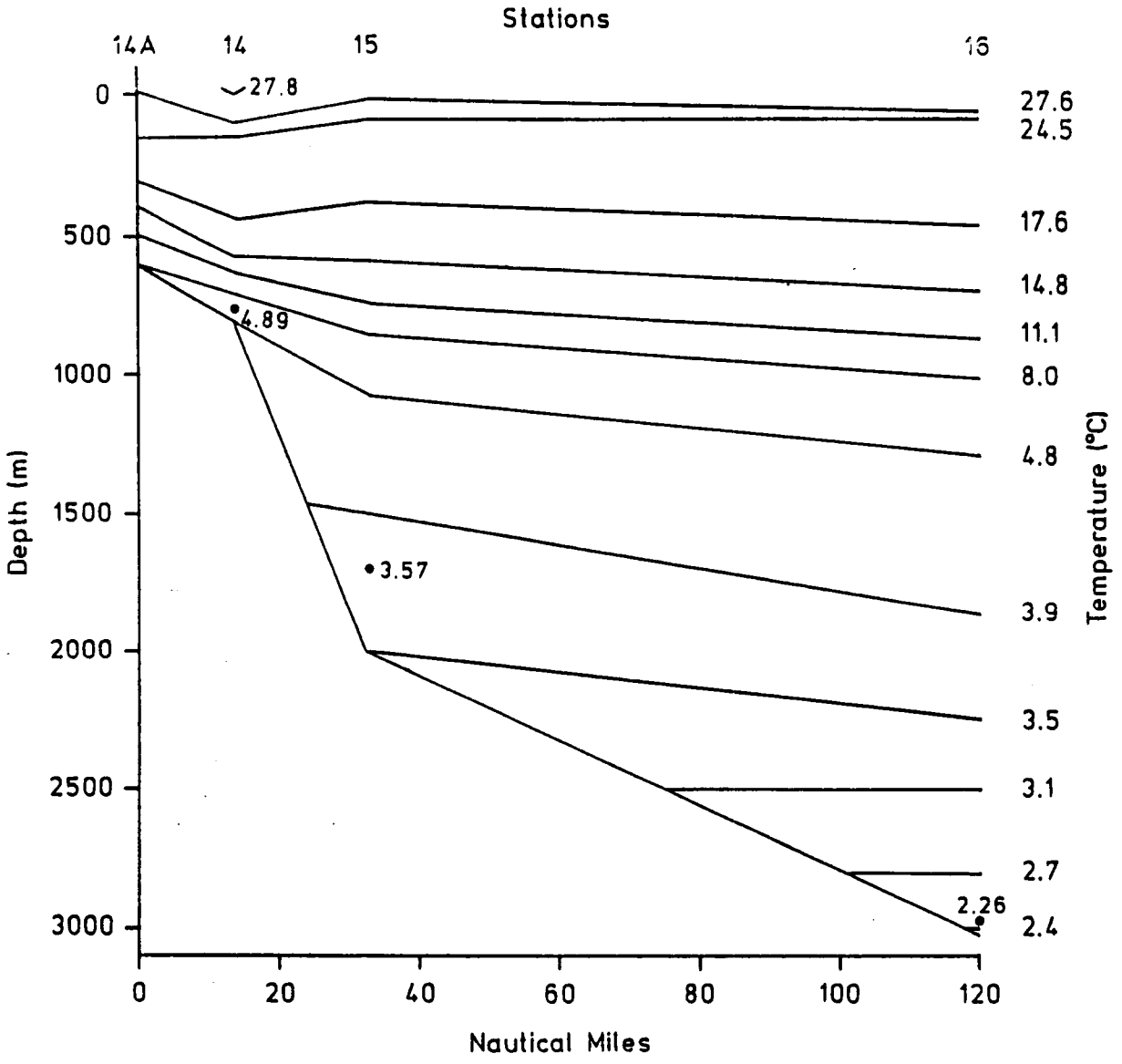


Figure 141. Profile of Water Column Along Charleston Transect Using CTD and Some Reversing Thermometer Data During Cruise SA-5. Data Point Represent Reversing Thermometer Data in Degree Celcius (°C).

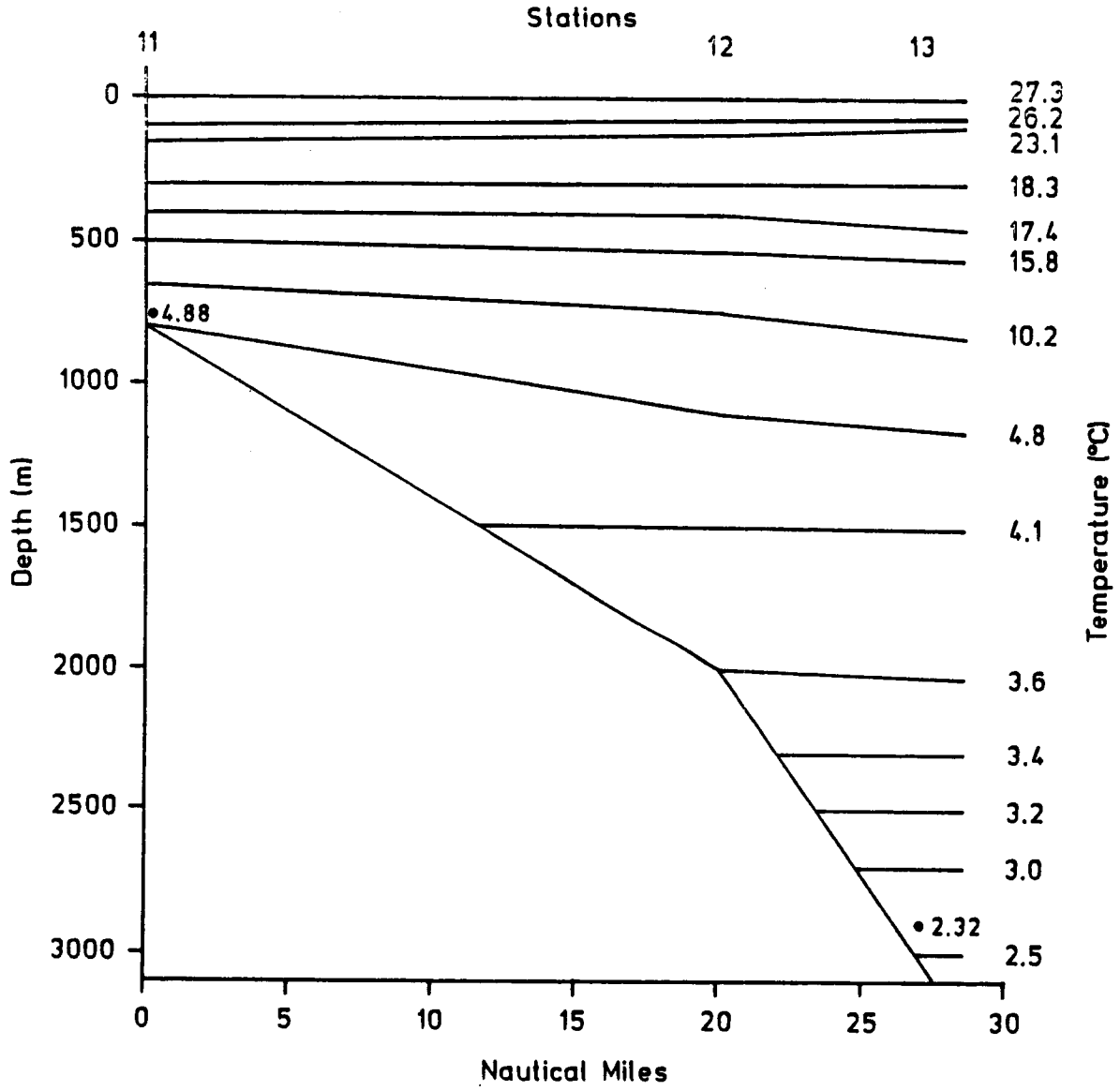


Figure 142. Profile of Water Column Along Cape Fear Transect Using CTD and Some Reversing Thermometer Data During Cruise SA-5. Data Points Represent Reversing Thermometer Data in Degree Celcius (°C).

Uchupi, 1972). Most of the outlier values observed on the temperature-salinity plot (Figure 140) are from the shallow stations and suggest contamination with highly variable slope water. The suspect value at Station 10 at 2000 m, is possibly due to the narrow belt of slope water directly off Cape Hatteras which is more like the Western North Atlantic Water than the other stations. Unfortunately, this sparse hydrographic data does not provide adequate understanding of the complex oceanographic processes which occur off North and South Carolina. An important review of the water masses in this area has been compiled by Schmitz et al. (1987). An overview of the dynamics of the Gulf Stream in the U.S. South ACSAR may be found in Han et al. (1986).

CHAPTER 9. DISCUSSION OF BIOLOGICAL PROCESSES

The biological processes on the continental slope and rise off the Carolinas were characterized in areas of potential oil and gas development by evaluating the biological, geological, and chemical environments. The program was divided into two distinct phases. Phase 1 included three seasonal sampling periods during 1983-1984 at sites off Cape Lookout in depths of 600 to 3000 m and at one site off the Hatteras Canyon in 2000 m. This portion of the program included characterization of infauna, epifauna, and sediments, but did not include chemical analyses. Phase 2 included three seasonal sampling cruises in 1985 at sites off Cape Hatteras in the vicinity of Block 510 in depths of 600 and 2000 m, one station at 2000 m off Cape Lookout retained from Phase 1, a transect off Cape Fear in depths of 800-3000, and a transect off Charleston in depths of 600-3000 m. During Phase 2 all of the above parameters were assessed in addition to trace metal and organic geochemistry. The epifauna were characterized from film footage taken from phototransects with a towed camera sled to document the distribution and abundance of the benthic epifauna at all of the above sites and on the Charleston Bump.

The locations of the different transects were selected on the basis of proximity to areas of oil industry interest, usually in blocks leased during one of the Lease Offerings.

In this chapter, the results presented in the previous sections are discussed and compared with previous works from the region and other areas on the Atlantic coast. Those results having implications for understanding global deep-sea processes are considered as well, with reference to pertinent literature where appropriate.

GEOLOGICAL AND PHYSICAL SETTING

The geology of the continental slope off the southeastern United States was reviewed by Popenoe et al. (1982). Results of the sedimentary distribution patterns support these previous findings with local exceptions.

In general, the slope sediments off North Carolina are composed mostly of silts and clays except for sandy areas in upper slope localities swept by the Gulf Stream. Some of the areas appear, however, to be dominated by erosion and mass wasting with minor

amounts of deposition. One depositional site off Cape Fear (Station 12) at 2000 m was identified in the present study. Sediments swept off the continental shelf are picked up by the Gulf Stream. These particles are either carried to local depositional sites, moved downslope and picked up by the Western Boundary Undercurrent (WBUC) to be swept southward, or carried downslope onto the rise and the Hatteras Abyssal Plain. Mineralogical data from selected stations in the present study reveals a change in the quartz content of sediments from Cape Hatteras south to Charleston along the 2000 m isobath. The quartz content of sands off Cape Hatteras is 95 percent, off Cape Lookout is 55 percent, off Cape Fear is 19 percent, and off Charleston is 6 percent. Since the 600 m station on the Cape is 96 percent quartz, it is evident that the sediments are of terrigenous origin. The canyons and gullies of this area are probable conduits for sediments as they are swept downslope. These data are in agreement with the results of Milliman et al. (1972) who determined that Cape Hatteras serves as a natural boundary in sediment types. South of Cape Hatteras, the shelf and slope are dominated by carbonate bearing sediments. While to the north, the sediments are characterized by decreasing amounts of carbonate and increasing amounts of quartz (Milliman et al., 1972; Tucholke, 1987).

The slope and the Blake Plateau join at about 32°30'N, where the angle of declination is approximately 3.5°. From here, the slope narrows and steepens to a maximum 16° declination off Cape Hatteras. The average declination between Cape Fear and Cape Lookout is 8° and 10° and about 7° north of Hatteras (Popenoe, 1980).

Beginning just south of Cape Hatteras, the slope is cut with a complex system of canyons, dominated by the Hatteras canyon. To the north of this feature are a complex system of gullies and smaller canyons which have probably arisen from slumping and mass wasting recorded from the region near Block 510. The canyons appear to be maintained by erosion of the sides and head. These canyon features are believed to play an important role in the sediment transport from the slope to the continental rise or Hatteras Abyssal Plain.

The most important physical oceanographic features of the region are the Gulf Stream and WBUC. The depth of influence and pattern of flow of these two currents in the slope areas off North and South Carolina were documented by Richardson (1977). The Gulf Stream leaves the Blake Plateau and turns northeasterly following the contour of the

continental margin to off Cape Hatteras where it generally turns into the North Atlantic. The stream extends no deeper than 1000 m in this area and does not mix with the WBUC which crosses its axis at depths greater than 2000 m. Thus the Gulf Stream tends to influence the bottom in upper slope areas off the Carolinas, while the WBUC tends to influence the lower slope and rise. The middle slope would appear to have the least direct influence from either of these currents. The pattern of these two currents is critical in explaining the unusual patterns of faunal distribution seen in the slope off the Carolinas.

All of the biological, sedimentary, and chemical results tend to indicate conditions which are different from any other location encountered on the U.S. Atlantic Continental Slope and Rise (ACSAR).

BENTHIC COMMUNITY CHARACTERISTICS

Infauna

Analysis of deep-sea benthic infaunal communities off North and South Carolina has revealed one of the richest and most diverse faunas on the U.S. ACSAR. A total of 1202 infaunal species were identified in the present study, of which over 40 percent are new to science. The discovery of this previously unknown fauna is of considerable interest to biologists concerned about the extinction of life on this planet. The very high diversity at certain sites, such as Station 14 at 800 m off Charleston, South Carolina, begins to rival the diversity of tropical rain forests, which are thought to contain the highest diversities of life on earth. For example, as part of a study of insects in forest canopies at one location in Brazil, Erwin (1983) collected 1080 species of Coleoptera (beetles) and from this data went on to estimate that there were up to 30 million species of beetles world-wide. The collection of 1202 species of infaunal invertebrates in the U.S. South ACSAR and 436 at a single site (Station 14) could be similarly extrapolated for deep-sea environments to enhance previous statements about high diversity in the deep sea (Sanders, 1968; Sanders and Hessler, 1969).

The fauna is dominated by polychaetes, with 542 species or 45.1 percent. Of these, 288 species representing 53 percent are new to science. Among the polychaetes, the families Spionidae (63 species), Paraonidae (35 species), Ampharetidae (33 species),

Cirratulidae (31 species), Phyllodocidae (26 species), Maldanidae (26 species), Dorvilleidae (24 species), and Capitellidae (20 species) are the most diverse. With the exception of the Phyllodocidae, these same families tend to be similarly important in the U.S. Mid- and North ACSAR (Maciolek et al, 1986b; 1987). The U.S. South Atlantic region is the only one of the three ACSAR regions where the Phyllodocidae have such a high number of species. Twenty-two percent of the fauna was comprised of arthropods, with one hundred and forty-five species or 53 percent being new to science. The Tanaidacea (100 species), Amphipoda (74 species), Isopoda (59 species), and Cumacea (29 species) are the most diverse arthropod groups. Molluscs represented 15 percent of the fauna, with the bivalves having the most species (38). Gastropods (46 species) and aplacophorans (36 species) are the next most numerous mollusc classes. The phyla Cnidaria, Echinodermata, Nemertea, Sipuncula, and Pogonophora accounted for the most of the remaining species.

Species diversity of the U.S. South Atlantic stations, evaluated by both the Shannon-Weiner Index and Hurlbert rarefaction, include higher values than those recorded for the U.S. Mid- and North ACSAR stations. At least one station, Station 14 off Charleston, S.C. in 800 m, is one of the most diverse marine infaunal stations yet encountered. At that station, the Shannon index is 6.93 and the expected number of species per 1000 individuals is 223.1. Since so few deep-sea stations have ever been analyzed for the entire fauna as was done in the ACSAR program, there is little global data with which to compare the present results. One general trend is apparent, however, in that stations with the highest diversities in the ACSAR tend to be in the middle slope depths of 800-1500 m. The only exceptions to this trend are in the U.S. South Atlantic region, where high diversity values are also found at selected upper slope (600 m), lower slope (2000 m), and rise (3000 m) locations. At the same time, some of the lowest diversities yet recorded from the ACSAR are from stations in the southern study area. This heterogeneity across depth contours is probably the result of a diverse sedimentary regime and the influence of the Gulf Stream and WBUC. Prior to the ACSAR program, it was generally believed that the highest species diversity in a shelf to rise transect would be found at the 2000 m depth (Rex, 1982). The results of the present program has demonstrated that such concepts must be revised. The earlier misconceptions were undoubtedly due to the lack of full analyses of the fauna at individual stations, the reliance on data from selected taxa, and the qualitative rather than quantitative nature of the samples used in the evaluation.

The patterns revealed by the cluster analysis and diversity data indicate distinct differences in patterns by depth and surprisingly along depth contours. Instead of the predictable similarities present in the U.S. Mid-Atlantic data along the 2000-2100 m depth contours, patterns have been revealed which demonstrate differences along these same depth contours from Cape Hatteras to Charleston. Corresponding evidence of appearance and disappearance of individual species off Cape Lookout and Cape Fear lends support for a partial zoogeographic barrier discussed later in this chapter.

Each of the 600-m upper-slope stations clusters separately from one another, with the stations off Cape Hatteras and Charleston differing the most from all other stations sampled in this program. At 800 to 1000 m depth, stations off Cape Lookout, Cape Fear, and Charleston are more similar to each other than to all other stations. Stations at depths of 1500-2000 m are heterogeneous. The Cape Hatteras and Charleston stations show less similarity to each other and to the Cape Lookout and Cape Fear stations. The Cape Lookout station clusters separately from the Cape Fear and Charleston (Blake Spur) stations.

Several dramatic changes in dominant species patterns are apparent along isobaths. Two aplacophorans, Prochaetoderma yongei and Spathoderma clenchi, are dominant ACSAR species in the North and Mid-Atlantic regions in middle and upper slope depths. These species retain that role as far south as Cape Lookout, but virtually disappear further south. At the same time, the sipunculan Aspidosiphon zinni follows a similar pattern, dropping to a lower rank among dominant species. The most spectacular faunal change is with two polychaetes, Aurospio dibranchiata and Microrbinia linea. The former species is the top dominant species at most of the 2000- to 2100-m stations in the North and Mid-Atlantic ACSAR stations, but is never ranked number one in the south. It is replaced at Cape Lookout and further south by M. linea. The latter species, while originally described from the Gay-Head Bermuda Transect by Hartman (1965), has only rarely been found in the Mid- and North Atlantic ACSAR stations. The unusual feature of the dominance of M. linea in the southern region is that it is the top dominant at all depths from 800-3000 m. No other invertebrate species is dominant over such a wide depth range in the entire ACSAR program.

Density data developed for the U.S. ACSAR program are considerably higher than previous results published for the Western North Atlantic by Sanders et al. (1965), for

depths in the 550 to 2500-m range. Densities from the 3000 to 3500-m depths are similar to the earlier database. The densities recorded from the U.S. South Atlantic stations are the most variable on the ACSAR. For example, three 600-m stations had values ranging from 2351 individuals per m^2 off Charleston to 46,255 per m^2 off Cape Hatteras. Wide ranges in density were also recorded from the 2000-m stations. Such wide variations were not seen in the North and Mid-Atlantic ACSAR data (Maciolek et al., 1986b; 1987).

All of these data for diversity, community patterns, dominance, and density clearly indicate a heterogeneous infaunal assemblage on the ACSAR between Cape Hatteras and Charleston.

The development of a limited life history database on five species of dominant polychaetes has provided the first evidence of seasonality in infaunal invertebrates from the ACSAR. One species exhibiting some evidence of seasonality is the spionid, Aurospio dibranchiata. Since this species is the dominant at 2000 to 2100 m in the Mid- and North Atlantic regions, and essentially replaced in the south by M. linea, further studies on this species from the more northern localities would be instructive to determine if seasonal patterns suggested in the southern data analysis are also present at the northern localities. A relationship between organic input and seasonal reproduction has been suggested, but as yet evidence for this relationship is scanty (see p. 186).

Biomass studies have focused on wet weight analysis of infauna along the Cape Lookout transect (600-3500 m) in Phase 1, and wet weight and ash-free dry weight (AFDW) measurements at two selected 2000 m stations (Station 4, Cape Lookout; Station 10, Cape Hatteras) in Phase 2. The results of the Cape Lookout transect study support the view that infaunal biomass decreases with increasing depth (Rowe, 1983). A comparison of wet weight and AFDW measurements between the 2000 m stations at Cape Lookout and Cape Hatteras indicates that the Cape Hatteras station is higher. This result correlates well with the high infaunal densities recorded at Cape Hatteras. When the Phase 1 and Phase 2 results are compared, there is some evidence of seasonality at Station 4 off Cape Lookout because the Phase 2 values are considerably higher. In general, the values at the two South ACSAR stations are similar to data developed in the Mid- and North ACSAR for 2000 m (Maciolek et al., 1987; in preparation). Biomass values for the Western North Atlantic are generally higher than have been recorded for the eastern North Atlantic by Dinet et al. (1985), but the techniques are not exactly comparable.

Epifauna

Like the infauna, the epifauna on the U.S. South ACSAR is heterogeneous, with a wide variety of habitats, which change over relatively short horizontal distances. Unlike the U.S. Mid- and North ACSAR, where the epifauna are controlled by depth and canyon versus slope gradients, the epifauna in the southern area appears to be controlled by a more complex oceanographic system dominated by a current regime which includes the Gulf Stream and WBUC and by a greater diversity of substrate types. Canyon processes are only important in the Cape Hatteras area, but even these show marked differences from sites further north. For purposes of presentation in this report, the slope environments from Cape Hatteras to Charleston have been presented separately from the Charleston Bump environment. This is because the epifauna encountered in the two habitats are so totally different that there is no basis for mutual treatment. The Charleston Bump epifauna represents the northern Blake Plateau, rather than the unusual continental slope environment studied throughout the rest of the ACSAR program.

Distinct faunal breaks by depth were revealed in the classification analysis in the present study and in the Phase 1 results from off Cape Lookout and the Hatteras Canyon. Distinct faunal breaks occurred at 500, 1200, and 1500 m off Cape Hatteras; at 600, 1400, and 1550 m in the Hatteras Canyon area; at 600, 900, 1600, and 2750 off Cape Lookout; at 1590 m in a limited coverage of Cape Fear, and at 640, 790, 950, and 1370 m off Charleston (Blake et al., 1985; This study).

The zonation of the fauna revealed in the classification analysis and the faunal breaks represent changes in trophic strategies along a resource gradient. As a general pattern, the upper slope (500-700 m) is dominated by a mixture of carnivores and filter feeders, the middle slope (700-1600 m) by carnivores, the lower slope (1600-2500 m) by deposit feeders, and the upper rise (2800-3100 m) by filter feeders. This general pattern holds for most areas in the ACSAR and everywhere in the U.S. South Atlantic region except off Charleston, where the middle slope surprisingly is dominated by filter feeders, separated by narrow bands of mixed filter feeders and carnivores. The dominance of filter feeders in this middle slope habitat has only previously been observed in submarine canyons, where hard substrates or enhanced current regimes afford suitable habitat for corals and sponges.

An examination of total megafaunal densities reveals that the highest densities are normally recorded from the lower slope, where large populations of the brittlestar Ophiomusium lymani are present. This single species, with densities of up to 12.9 individuals per m^2 is the major contributor to high megafaunal densities in the lower slope. Normally, densities are consistently low on the middle slope, however, off Charleston, densities alternated between intermediate and low. Several species typically found in the middle slope further north were either absent or occurred in very low numbers. A hard coral, Bathypsammia tintinnabulum, is very abundant in the middle slope on this transect, where it attaches to the compacted sediment and ridges characteristic of the area. The species has not been found in any other U.S. South Atlantic transect. Densities on the lower slope off Charleston were intermediate rather than high due to reduced numbers of O. lymani.

ZOOGEOGRAPHY

The ASCAR study area extends from the Canadian boundary to off Charleston, N.C. Within this area two biogeographic regions are recognized by biological oceanographers: the North Atlantic Temperate Region ("Slope Water"), and the North Atlantic Subtropical Region ("Northern Sargasso Sea"). The division between the two regions is marked by the Gulf Stream, with the northern edge of the current forming the boundary as it turns east off Cape Hatteras. This boundary, formed by the Gulf Stream results in a sharp barrier in the distribution of pelagic and nektonic organisms. The northern edge of the Gulf Stream typically is the southern limit to the range of many cold-water species. The barrier is not as strong or clear for southern species, however.

The influence of the Gulf Stream and the different overlying water masses on the benthic fauna is not as strong as on the pelagic and nektonic organisms. Water depth is normally more important than the nature or source of the overlying water mass. Changes are more likely due to the differences in the amount of organic material reaching the bottom. Hence, the identification of a zoogeographic barrier off North Carolina is more difficult to interpret in the benthos than it is in the overlying water column.

Some evidence that the upper slope off Cape Lookout represents a partial zoogeographic barrier was first offered by Cutler (1975) based on data for sipunculans and

pogonophorans. The present program provides the first comprehensive database on which a test of this hypothesis can be developed.

For the megafaunal organisms, the photographic transects and supporting trawl samples provide some evidence that a partial zoogeographic barrier is present. Trawl data indicate that the most pronounced faunal break occurs between Cape Lookout and Cape Fear. For example, trawls at 800 m depth off Cape Fear were dominated by Munida valida and Parapagurus sp.. These species were joined off Charleston by two additional crustaceans, Stereomastus sp. and Glyphocrangon sp. At 2000 m, Ophiomusium lymani dominated off Cape Lookout, while another brittlestar, Bathypectinura heros, dominated off Charleston. Photographic evidence, however, suggests a more gradual transition between a northern and southern faunal component. It is also clear that the distributional limits of many individual species differ from one another, and that there is no clear dividing line.

Similar evidence of a faunal break between Cape Lookout and Cape Fear is apparaent in the infaunal data. Some species, such as the aplapcophorans, Prochaetoderma yongei and Spathoderma clenchi, which are dominant species in the North and Mid-ACSAR and important as far south as Cape Lookout, are virtually absent from the Cape Fear samples. The sipunculan Aspidosiphon zinni follows a similar pattern, but is not as drastically reduced as the aplacophorans. The most interesting polychaete species is the small orbiniid, Microrbinia linea. This species appears to be more southern in its distribution, being the top dominant species at most of the Charleston and Cape Fear stations from 800 to 3000 m and at the 2000-m station off Cape Lookout. At other Cape Lookout stations and at all stations further north in the South Atlantic region and in the Mid- and North ACSAR regions, the species is rare or entirely missing.

The most impressive data showing faunal differences between regions is with the cumaceans (see Chapter 3 for details). Only seven species are shared between the North and South ACSAR, out of a total of 55 species. Southern species occurring at the Hatteras Canyon and Cape Lookout stations are almost entirely different from those further south off Cape Fear and Charleston, thus supporting the view that the most significant faunal changes take place between Cape Lookout and Cape Fear. Similar analysis of the other taxa will undoubtedly yield similar patterns.

REGIONAL TRANSECTS

Cape Hatteras Transect (Block 510)

The area of most recent interest is Block 510 located off Cape Hatteras, N.C. This site is on a steep slope with depths dropping from 100 to 1000 m diagonally across the block. The bottom morphology of Block 510 is rugged, with numerous gullies and valleys. Changes in relief are often abrupt and slopes in the interior portions of some valleys may exceed 15 to 20 degrees (Palmer, 1982). These features continue from the edge of the shelf to a depth of 2000 m. In observations taken from the DSRV Alvin, Milliman et al. (1967) described steplike ledges up to 5 to 10 m in the area. Palmer (1982) concluded that the area is characterized by deposition of sediment swept from the adjacent shelf.

Two benthic stations were established. Station 9 was in Block 510 at a depth of 600 m, while Station 10 was downslope in 2000 m. Collections were made at Station 9 in July 1984, May 1985, and September 1985. Station 10 was sampled in May 1985 and November 1985. Camera transects were attempted on all three 1985 cruises with tows being conducted in an upslope direction from about the 2000 m depth to 500 m.

All biological, sedimentary, and chemical results indicate that benthic environment at Block 510 appears to be different from any other location encountered on the ACSAR.

The sediment results indicate that Station 9 is sandy, with 37 to 56 percent sand of which 96 percent of the grains are quartz. Station 10 was more variable with 25 to 61 percent sand and 95 percent quartz. Since the sand at these stations is mostly comprised of quartz grains, terrestrial input is certain. The chemical data, indicates that lead and aromatic inventories are elevated (Bothner et al., 1987; Chapter 6, this volume), suggesting a depositional environment. Bothner et al. (1987) indicates that more lead is being deposited at Stations 9 and 10 than is being added to an equivalent area of the sea surface. This suggests that the concentration of lead may be related to processes which enhance the scavenging of lead from the water column. These processes could include bioturbation, sediment resuspension and deposition, and chemical precipitation. The anomalously high concentration of hydrocarbons at these same stations support the suggestion that scavenging processes are enhanced in this area. High infaunal density, high biomass, and photographic documentation of concentrations of worm tubes clearly

support a suggestion that bioturbation is important in the dynamics of sedimentology in the area.

Epifaunal photographic coverage of the Cape Hatteras Transect clearly indicated the complexity of the seafloor. An unusual feature was the presence of high densities of large white tubes projecting from the sediment on the steep seaward facing slopes in three areas between 600 m and 1950 m. Some of these tubes were taken from the infaunal box cores and subsequently examined, but no intact animals were found. It is possible that since the largest populations were found between the 600- and 2000-m box core stations, only a death assemblage of this animal was present at Station 9. In an environment with high sand content, it is plausible that the tubes help stabilize the sediment and prevent erosion. The box cores from Station 9 were observed to have large maldanid tubes projecting from the sediment surface along with the white tubes. The stabilization of sediments by tubes of infaunal invertebrates is known from many shallow water environments (Fager, 1964). It is reasonable to assume that such processes are operative in a continental slope environment.

In addition to large tubes in the sediment, the epifaunal patterns along this transect are anomalous when compared to other areas of ACSAR. The most striking faunal difference is in the abundance of eel pouts, which dominate on the upper and middle slope. These fish normally have minor roles in other regions of the slope. Their importance in this area is probably due to the very high infaunal densities on which they feed.

The infauna at Stations 9 and 10 are also unique. The densities at Station 9 are the highest yet recorded on the ACSAR. Diversities, however, are low, possibly due to nutrient enrichment and resulting dominance of several opportunistic species. The fauna that dominates these sites, especially at 600 m, is more characteristic of continental shelf depositional locations, than of the upper continental slope. The exceptionally high densities of infauna at Station 9 may be attributable to the flux of transported material off the shelf which would result in a higher nutrient input. In the field, the cores, when extruded, were noted to be streaked with black, suggesting reducing conditions. The dissolved oxygen levels of the near-bottom water at Stations 9 and 10 were the lowest of any of the sites sampled during the program. No data is available for in-situ dissolved oxygen.

Cape Lookout Transect

Five stations at depths of 600 m, 1000 m, 1500 m, 2000 m, and 3000 m were sampled on the Cape Lookout Transect during Phase 1 (Blake et al., 1985). This phase was strictly a biological study and included infaunal and epifaunal characterization. Chemistry data were not collected, although sediment texture was characterized. The sediments were coarsest at 600 m, with sand content ranging between 19 and 43 percent. Sand content decreased between 1000 and 1500 m, then increaed at 2000 m with values of 14 to 24 percent. Sediments at the 3000-m station were a muddy clay with only 3 to 6 percent sand. The infauna along this transect was found to be rich and highly diverse with over 800 species present. The faunal density was highest at 600 m on the upper slope and lowest at 3000 m on the continental rise. Species diversity along this transect was high, with the highest values recorded from the deepest station. The fauna separated into distinct clusters on the upper slope, lower slope and rise. The epifauna was distinctly zoned. High densities occurred on the upper slope, dropped on the middle slope, increased again on the lower slope, and dropped with depth on the rise.

During Phase 2, Station 4 at 2000 m was retained in order to obtain a longer seasonal database. No seasonal trends were evident in faunal densities or sediment data.

Cape Fear Transect

Three stations at depths of 800 m, 2000 m, and 3000 m were sampled during Phase 2. The infauna along this transect was variable, with elements of similarity to the more southern Charleston transect and also to the northern Cape Lookout transect. The 800-m station (Station 11) was most similar to the 800-m site (Station 14) off Charleston, while the 2000-m station (Station 12) was more similar to the 2000-m station off Cape Lookout. The 3000-m station (Station 13) was more similar to Station 16 off Charleston than to Station 5 off Cape Lookout. The highest infaunal densities occurred at 800 m and decreased with depth. Faunal diversities were highest at the 2000-m site. Station 12 is a depositional area with very soft sediments. The station had low faunal densities and high diversities. Transects for characterization of epifauna were limited to the lower slope. Zonation and density patterns were similar to those off Cape Lookout, but different from those off Charleston.

The Charleston Transect

Four stations at depths of 600 m, 800 m, 2000 m, and 3000 m were sampled off Charleston, S.C. during Phase 2. Each station was uniquely different from one another in faunal composition. The highest densities occurred at Station 14 (800 m) and the lowest at Station 16 (3000 m). The infauna of Station 14A at 600 m differed from that of all other stations sampled in the U.S. South Atlantic region in terms of species composition and species shared with other stations. In some cluster analyses Station 14A had only a .04 to .08 level of similarity (Bray-Curtis) with other stations. There was no similarity at all when only bivalves were considered. For an upper slope station, Station 14A had relatively low densities and low species diversity. The unusual nature of this station is due to the very sandy sediments, with 91 to 94 percent sand (100 percent formaniferans). The 800-m station (Station 14) is less sandy with 38 to 44 percent sand. The reason for these four stations being so different is probably the result of varying erosional and depositional processes. The low infaunal density at the 600 m site is probably a reflection of the shifting sand waves observed in the photographic survey. This environment in addition to being abrasive, is probably low in nutrients. Lower infaunal densities may also explain the lower epifaunal densities as well.

Station 14 has the most species and, correspondingly, the highest species diversity measures of any station sampled along the entire U.S. ACSAR, from the Canadian border to the Charlston transect. The occurrence of 436 species in nine box cores taken at this one station is the highest ever recorded. The high species diversity at the 800 m site may be related to the proximity of the Charleston gyre and the transport of sediments to the slope at 800-1200 m. Seaweeds observed in the bottom are a source of carbon. Station 15 at 2000 m has 53 to 72 percent sand. This site has low faunal densities and relatively high species diversity. The station does not have a high degree of similarity with the other 2000-m stations in the U.S. South Atlantic region. Station 16 at 3000 m has a very low sand content, with only 4 to 9 percent sand. The infauna at this station is most similar to that that found at Station 13, the 3000-m station off Cape Fear.

Epifaunal densities on the slope off Charleston differed from the northern transects in the exceptionally low densities of the common galatheid crab Munida valida and absence of the characteristic anemone, Bolocera tudiae. One species of hard coral,

Bathypsammia tintinnabulum occurred in high abundance on the middle slope off Charleston, but has not been found in any of the other areas studies. Ophiomusium lymani, the widespread and characterisic ophiuroid of the lower slope, dominated the lower slope off Charleston, but occurred in greatly reduced numbers.

Charleston Bump

In contrast to the slope areas to the north, the Blake Plateau offers an entirely different environment. Instead of the soft sediments characteristic of the continental slope, the seafloor on the northern Blake Plateau consists of a hard pavement of cemented sediments and manganese-encrusted outcrops, occasionally draped with a thin layer of coarse grained material. The Charleston Bump is a seaward projecting ridge on the northern Blake Plateau, that causes a seaward deflection of the Gulf Stream north of the bump. The topography and surficial geology in this region varied considerably, ranging from rippled sand to manganese-encrusted rock ledges. Our camera transects on the Charleston Bump revealed a very rich and dense bottom fauna, dominated by filter-feeding corals and sponges.

The fauna inhabiting the upstream and downstream sides of the bump differed considerably. While most taxa were found throughout the region, they showed marked depth and location preferences that are probably related to current intensity and surficial geological differences between the areas. Stylasterin corals dominated the fauna on the downstream side of the bump, while gorgonians dominated the remaining areas. Structural differences between these two groups may explain this distribution. Stylasterids are more massive and rigid than gorgonians, and thus would require stabler attachment sites and possibly lower current intensities. Individual species similarly displayed marked habitat and depth preferences.

The fauna inhabiting the top of the Charleston Bump was relatively homogeneous, and gradually changed with increasing depth on either side of the bump. The most pronounced faunal change on the upstream side occurred at 500 m, where the seafloor steepened and was incised by valleys. The most pronounced faunal changes on the downstream side coincided with steep slopes that separate the three ledges characteristic of this side of the bump. No pronounced faunal breaks were discerned, indicating a

pattern of gradual faunal change between the different regions of the Charleston Bump. In addition to changes in topography and surficial geology between various regions of the bump, differences in the bottom currents between these areas probably account for some of the observed faunal changes.

The geological heterogeneity and strong current regime of the Charleston Bump area provides suitable habitats for exceptionally dense populations of filter-feeding taxa, making this area very reminiscent of shallow-water reef habitats. How extensively this type of community is distributed in other regions of the Blake Plateau is presently not known. However, based on geological and current regime considerations we predict that these organisms would be widely distributed throughout this region.

REGIONAL HETEROGENEITY

The biological communities of the U.S. South ACSAR differ substantially from those recorded from the U.S. North and Mid-Atlantic programs. Communities appear to be more heterogeneous both in terms of faunal composition and their associated sediment characteristics. More infaunal species have been found in the South (1202) compared with the North (880) and Mid-Atlantic (866) regions. In the South, the most diverse stations are scattered over several depth ranges, with the most diverse stations at 800 m followed by 3000 m stations. In the Mid- and North Atlantic ACSAR the highest diversities are usually at the deeper stations. Three of the southern stations have the highest densities recorded in the entire program. Station 9 densities of over 46,000 per m^2 are by far the highest recorded from the ACSAR.

Epifaunal communities are unusual on the Cape Hatteras transect and on the Charleston transect. The Cape Lookout and Cape Fear transects are more typical of ACSAR epifaunal communities.

The reasons for this heterogeneity are undoubtedly due to the distribution of currents and different types of substrata in the region. Seasonal influences of the Gulf Stream may impinge to 700-1000 m. This undoubtedly influences infaunal and megafaunal communities in the upper and middle slope, where very high infaunal species diversity has been observed. The influence of the semipermanent cyclonic gyre formed as the Gulf Stream passes over the Charleston Bump is not understood. At the 600 m station off

Charleston, low species density and diversity in an area of sand ridges are directly influenced by this structure. At 800 m, however, the highest species diversity yet encountered in the ACSAR may be yet another result. Photographic data from the Charleston transect indicate the remains of seaweed on the seabed. This seaweed may provide a ready source of carbon to maintain a highly diverse benthic infauna. The presence of fine silts and less sand at the 800 m station off Charleston suggest more of a depositional environment which might account for the seaweed litering the floor in the 800-1200 m depth range. The route of transport of this material is not fully understood, but it could be part of a local system derived from the Charleston gyre.

The conditions off Cape Hatteras, offer a striking contrast to the more gentle slope off Charleston. Here the area is dissected by numerous smaller canyons and gullies. The sides of these gullies are steep, with gradients up to 30^{o} on the walls recorded by McGregor (1984). Photographic coverage of the epifauna and boxcore data at the two stations reveal an anomalous area for the ACSAR. Sediment and chemical results with elevated lead and aromatic inventories suggest a complex depositional environment. Quartz grain data clearly indicates that sediments are of a terrestrial origin. Sediment transport patterns may be important in the observed sediment heterogeneity at 2000 m. Heterogeneity in upper slope depths is probably influenced more by the Gulf Stream.

Epifaunal data are summarized above, but the presence of the dense beds of large white tubes from 600-1950 m and the dominance of eel pouts are unlike other slope sites in the ACSAR. The white tubes have previously only been observed on the steep wall of some submarine canyons further north (Hecker et al., 1980; 1983).

The infauna of the Cape Hatteras transect is highly unusual in the low species diversity and high density of a few species. In many respects the species which dominate the 600 m station are more typical of continental shelf habitats. The sediment data with its high quartz grain content, along with the chemistry data indicate a terrestrial origin rather than oceanic. The canyons and gullies are probable transport conduits for materials to be swept down the slope and carried to depositional sites.

The deeper portions of the Cape Hatteras transect are undoubtedly influenced by the WBUC. Richardson (1977) noted mean flows of 10.9 cm per second at a 2575 m site to the south of our Station 10. The Gulf Stream has already been noted to impinge to 1000 m in this area and this coupled with the strong WBUC in an area of dissected bottoms most

certainly cause unusual bottom conditions. The presence of numerous tubes in the bottom sediments undoubtedly serve to stabilize the sandy sediments in an environment with strong erosional potential.

The South Atlantic OCS region is clearly the most heterogeneous and variable of the ACSAR environments. Because of these findings, it is essential that the efforts of this program be synthesized with those of the recently completed Physical Oceanographic projects to understand more fully the distribution of the biological communities and sediment types found in the U.S. South ACSAR. Since the bottom conditions have been found to change so rapidly over relatively short distances it is not possible to predict with any degree of confidence what biological communities and sediment types will be present at locations we have not sampled. Consequently, we strongly recommend that a biological reconnaissance be conducted at any proposed drilling site on the U.S. South ACSAR. Such studies should be conducted prior to exploratory activities and at a minimum should include a design which will permit assessment of variability along and across isobaths. Data should be developed to determine infaunal densities, species diversity, and dominance hierarchy. It will also be essential that sediment texture and CHN measurements be taken, since faunal communities are largely dependent upon the sediment characteristics.

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APPENDIX A

APPENDIX A

CRUISE RESULTS

A summary of sampling positions, dates, and depths for the three cruises of Phase 2 is presented in Table A.1. Replicate positions of box cores and hydrocasts are plotted in Figures B.1 through B.10 for the three cruises.

Cruise 4 (SA-4)

Cruise SA-4 departed Beaufort, NC on May 13, 1985 aboard the R/V Cape Hatteras, operated by Duke University. All replicate box cores were successfully collected at each of nine stations (4, 9, 10, 11, 12, 13, 14, 15, 16). It was necessary, however to relocate Stations 11 and 14 to depths of 800 m because of the sandy sediments encountered at the 600 m depth which proved difficult to sample with the box core. An otter trawl planned for the 2000 m station off Cape Fear (Station 12) was relocated to Station 4 off Cape Lookout to avoid the very deep, soft mud encountered at the former station which would preclude a successful trawl.

All hydrocasts were successfully completed during SA-4. Past experience gained from working in the Gulf Stream indicated that additional weight on the hydrowire could overcome the drag effect which had interfered with hydrocasts on several occasions during Phase 1.

Two full camera transects were completed on both the north and south sides of the Charleston Bump during SA-4. The southernmost transect was completed without incident, while several severe hangups of the camera sled during the northern transect caused sufficient damage to the primary sled (BERNEI) to necessitate use of the backup sled (BABS) at Block 510.

Cruise 5 (SA-5)

Cruise SA-5 departed Norfolk, VA on September 12, 1985 aboard the R/V Gyre, operated by Texas A&M University. The original cruise track was planned to include

sampling first at Block 510. High winds and rough seas off Cape Hatteras precluded sampling and the ship continued south to the Charleston transect and Station 16. All three stations on the transect were successfully sampled and three successful camera runs were completed. During a trawl attempt at Station 15 the otter trawl was torn in half and subsequent plans for otter trawl collections were therefore cancelled. A new station (Station 14A) was established at 600 m at a site where an unsuccessful attempt at box coring had occurred during SA-4. A modified spade using indoor-outdoor carpet instead of rubber proved effective in retaining the sandy sediments found at Station 14A.

The weather continued to be unsettled and work was slow on the Cape Fear transect. All three box cores were taken at Stations 11 and 13. At Station 12, a site of very soft muds, despite several modifications to the box core only a single sample could be collected after six attempts. A successful otter trawl was conducted at Station 11, followed by a successful trawl at Station 4 off Cape Lookout. All three replicate box cores were taken at Station 4.

The ship proceeded to Block 510 and began work at Station 9 with hurricane warnings being posted along the entire southeastern U.S. coast. Following three successful box cores and a CTD cast the ship returned to Norfolk, VA to seek sanctuary from the impending storm, arriving early on the morning of September 26. After the storm passed, the ship returned to Cape Hatteras and completed a camera run before transiting to Woods Hole, MA. There was insufficient time to collect samples at Station 10. In summary, a total of 25 out of 30 box cores were successfully collected.

Cruise 6 (SA-6)

Cruise SA-6 departed Beaufort, NC on November 15, 1986 aboard the R/V Cape Hatteras, operated by Duke University. The cruise encountered fair weather from the start and except for losing 37 hours due to heavy seas when Tropical Storm Kate passed over, all operations went very smoothly. The cruise track included an initial transit to the Charleston Bump to conduct two camera transects and five Day dredge tows. The first camera transect was a full tow across the top of the Charleston Bump using the camera sled BERNEI. BERNEI sustained sufficient damage during this transect that use of the alternate sled (BABS) was required to complete the camera work during the cruise.

Following epifaunal work, the ship transited to the Charleston transect. Attempts to collect box core samples at Station 14A (600 m) were unsuccessful due to problems with the spade modifications needed to sample in sand. The station was abandoned after several attempts. All replicate box core samples were successfully collected at Station 14 (800 m). The single otter trawl of the cruise at Station 14 was poor, and a second attempt was not conducted. Box core sampling at Station 15 was quite difficult, with the site being characterized by thick clays overlayed with fine silt which made it difficult for the box core to penetrate deep enough to collect a sample. After four complete washouts the station was abandoned. Three replicates were collected at Station 16 (3000 m) and the ship then transited to Station 13 (3000 m) on the Cape Fear transect. Sampling then followed at Stations 12 and 11. One successful camera run was completed in the vicinity of Station 12. During the transit to Station 4 off Cape Lookout, the weather deteriorated and the seas became too rough to sample. The decision was made to leave the Gulf Stream and to move inshore to ride out the passage of Tropical Storm Kate, with a subsequent loss of 37 hours to weather.

TABLE A-1. SUMMARY OF SAMPLE POSITIONS FOR SOUTH ATLANTIC PHASE 2.

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 4 (R/V CAPE HATTERAS)					
4	Box Core 1	1110	23 May 85	34°11.20'	75°38.44	26890.4	39741.6	2093
4	Box Core 2	1252	23 May 85	34°11.22'	75°38.44'	26890.9	39740.9	2051
4	Box Core 3	1421	23 May 85	34°11.29'	75°38.67'	26891.2	39741.1	2015
4	Hydrocast	1540	23 May 85	34°11.24'	75°38.03'	26889.2	39743.7	2204
9	Box Core 1	0948	24 May 85	35°28.41'	74°47.44'	26779.9	40560.1	640
9	Box Core 2	1026	24 May 85	35°28.41'	74°47.56'	26780.4	40559.7	603
9	Box Core 3	1207	24 May 85	35°28.28'	74°47.52'	26780.1	40558.7	623
9	Hydrocast	0910	24 May 85	35°28.68'	74°47.35'	26779.8	40562.8	754
10	Box Core 1	0017	24 May 85	35°26.27'	74°41.43'	26756.1	40561.9	2003
10	Box Core 2	0423	24 May 85	35°26.34'	74°41.57'	26756.7	40562.0	1988
10	Box Core 3	0603	24 May 85	35°26.44'	74°41.30'	26755.8	40563.8	1985
10	Hydrocast	0746	24 May 85	35°27.54'	74°40.51'	26753.7	40576.2	1948
11	Box Core 1	1424	22 May 85	33°04.86'	76°25.13'	44869.6	59265.0	800
11	Box Core 2	1518	22 May 85	33°04.92'	76°24.97'	44869.4	59264.5	802
11	Box Core 3	1652	22 May 85	33°04.87'	76°25.14'	44869.6	59264.9	799
11	Hydrocast	1605	22 May 85	33°05.19'	76°24.80'	44870.0	59262.9	802

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 4 (R/V CAPE HATTERAS)					
12	Box Core 1	0530	22 May 85	33°00.31'	76°07.39'	44807.6	59271.5	1996
12	Box Core 2	0710	22 May 85	33°00.23'	76°07.26'	44807.0	59271.8	2010
12	Box Core 3	0825	22 May 85	33°00.20'	76°07.25'	44807.0	59272.2	2000
12	Hydrocast	2126	21 May 85	33°00.32'	76°07.34'	44807.6	59271.4	1999
13	Box Core 1	0918	21 May 85	32°55.19'	75°49.78'	44746.3	59281.2	3015
13	Box Core 2	1354	21 May 85	32°55.78'	75°49.80'	44748.9	59278.5	3013
13	Box Core 3	1632	21 May 85	32°55.02'	75°49.47'	44745.1	59281.7	3023
13	Hydrocast	1836	21 May 85	32°54.58'	75°49.59'	44743.6	59283.9	3019
14	Box Core 1	0042	20 May 85	32°23.64'	77°01.13'	44790.7	59588.2	805
14	Box Core 2	0155	20 May 85	32°23.64'	77°01.19'	44790.7	59587.7	802
14	Box Core 3	0330	20 May 85	32°23.67'	77°01.12'	44790.8	59588.1	803
14	Hydrocast	0431	20 May 85	32°23.67'	77°00.46'	44789.0	59586.1	805
15	Box Core 1	1009	16 May 85	32°12.02'	76°42.18'	44688.4	59608.2	1993
15	Box Core 2	1240	16 May 85	32°12.05'	76°42.18'	44688.5	59608.0	1991
15	Box Core 3	1845	16 May 85	32°10.74'	76°42.93'	44684.5	59618.1	2003
15	Hydrocast	0356	17 May 85	32°12.46'	76°41.74'	44689.2	59604.2	1995

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 4 (R/V CAPE HATTERAS)					
14 Sediment Type Survey	Van Veen 7	1636	18 May 85	32°30.32'	77°22.31'	44881.3	59613.3	585
14 Sediment Type Survey	Van Veen 8	2305	19 May 85	32°22.65'	77°01.20'	44788.9	59597.8	806
4	Trawl Deployed	0240	23 May 85	34°12.68'	75°39.29'	45005.9	59029.4	1600
4	Trawl Recovered	0750	23 May 85	34°20.11'	75°22.25'	26845.2	39873.0	2900
11	Trawl Deployed	1805	22 May 85	33°05.73'	76°24.66'	44871.8	59259.9	796
11	Trawl Recovered	2035	22 May 85	33°13.98'	76°18.55'	44888.9	59214.1	796
14	Trawl Deployed	0643	20 May 85	32°23.62'	77°00.54'	44789.0	59586.1	803
14	Trawl Recovered	0915	20 May 85	32°32.73'	76°55.17'	44815.8	59509.9	760
15	Trawl Deployed	2045	16 May 85	32°09.72'	76°42.95'	44680.2	59624.6	2100
15	Trawl Recovered	0215	17 May 85	32°15.66'	76°39.89'	44699.2	59579.5	2100
S.A. Tow 11	Sled on Bottom	2209	17 May 85	31°29.78'	78°52.04'	44887.9	60524.4	473
	Sled off Bottom	1111	18 May 85	31°16.66'	79°00.99'	44848.9	60666.8	610
S.A. Tow 12	Sled on Bottom	2250	18 May 85	31°49.83'	78°18.26'	44868.6	60175.5	628
	Sled off Bottom	1020	19 May 85	31°42.33'	78°23.68'	44848.7	60258.7	643
S.A. Tow 13	Sled on Bottom	1827	24 May 85	35°28.97'	74°38.20'	26746.1	40595.8	2013
	Sled off	0150	25 May 85	35°28.18'	74°48.25'	26782.6	40665.5	548

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
				SOUTH ATLANTIC CRUISE 5 (R/V GYRE)				
4	Box Core 1	1317	24 Sep 85	34°11.27'	75°38.63'	26891.1	39741.1	2032
4	Box Core 2	1540	24 Sep 85	34°11.35'	75°38.74'	26891.5	39741.2	2000
4	Box Core 3	1732	24 Sep 85	34°11.22'	75°38.56'	26890.8	39741.1	2051
4	CTD/Hydrocast	2110	24 Sep 85	34°11.68'	75°38.75'	26891.8	39743.2	1984
9	Box Core 1	0627	25 Sep 85	35°28.41'	74°47.46'	26780.8	40560.0	629
9	Box Core 2	0938	25 Sep 85	35°28.41'	74°47.47'	26780.0	40560.0	629
9	Box Core 3	1051	25 Sep 85	35°28.27'	74°47.61'	26780.4	40558.2	609
9	CTD/Hydrocast	1213	25 Sep 85	35°28.50'	74°47.36'	26779.7	40561.2	651
11	Box Core 1	0924	23 Sep 85	33°04.83'	76°25.19'	44869.6	59265.2	796
11	Box Core 2	1032	23 Sep 85	33°04.83'	76°25.17'	44869.5	59265.2	896
11	Box Core 3	1304	23 Sep 85	33°04.86'	76°25.12'	44869.5	59264.9	797
11	CTD/Hydrocast	1155	23 Sep 85	33°05.01'	76°24.60'	44868.8	59263.7	802
12	Box Core 1	0634	22 Sep 85	33°00.36'	76°07.27'	44807.6	59271.2	2004
12	CTD/Hydrocast	1426	22 Sep 85	33°00'34'	76°07.04'	44806.9	59271.0	2028

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 5 (R/V GYRE)					
13	Box Core 1	1449	21 Sep 85	32°55.25'	75°50.00'	44747.2	59281.1	3006
13	Box Core 2	1753	21 Sep 85	32°55.12'	75°49.87'	44746.4	59281.5	3009
13	Box Core 3	2112	21 Sep 85	32°55.22'	75°49.77'	44746.5	59281.1	3014
13	CTD/Hydrocast	1151	21 Sep 85	32°55.74'	32°49.50'	44748.0	59278.4	3024
14	Box Core 1	1940	19 Sep 85	32°23.67'	77°01.18'	44790.9	59588.2	796
14	Box Core 2	2356	19 Sep 85	32°23.72'	77°01.24'	44791.0	59588.6	799
14	Box Core 3	0133	20 Sep 85	32°23.63'	77°01.11'	44790.6	59588.3	799
14	CTD/Hydrocast	2213	19 Sep 85	32°24.15'	77°00.83'	44792.2	59584.0	797
14A	Box Core 1	0744	20 Sep 85	32°32.25'	77°15.24'	44869.1	59574.9	600
14A	Box Core 2	1037	20 Sep 85	32°32.26'	77°15.29'	44869.3	59574.9	605
14A	Box Core 3	1337	20 Sep 85	32°32.22'	77°15.31'	44869.2	59575.3	605
14A	CTD/Hydrocast	1216	20 Sep 85	32°32.56'	77°14.83'	44869.3	59571.4	605
15	Box Core 1	0419	18 Sep 85	32°12.00'	76°42.23'	44688.4	59608.5	1988
15	Box Core 2	0735	18 Sep 85	32°11.99'	76°42.23'	44688.4	59608.5	1991
15	Box Core 3	1028	18 Sep 85	32°11.97'	76°42.24'	44688.3	59608.4	1991
15	CTD/Hydrocast	0210	18 Sep 85	32°11.99'	76°42.19'	44688.3	59608.4	1994

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 5 (R/V GYRE)					
16	Box Core 1	1945	14 Sep 85	31°35.19'	75°10.39'	44340.3	59610.7	8009
16	Box Core 2	0906	16 Sep 85	31°35.14'	75°10.28'	44339.9	59610.8	3011
16	Box Core 3	1328	16 Sep 85	31°35.00'	75°10.46'	44339.6	59611.7	2999
16	CTD/Hydrocast	1549	14 Sep 85	31°35.69'	75°10.04'	44341.9	59607.7	3014
4	Otter Trawl Deployed	0540	24 Sep 85	34°16.62'	75°37.39'	26891.7	39782.2	
4	Otter Trawl on Bottom	0706	24 Sep 85	34°15.88'	75°37.55'	26891.6	39772.9	2044
4	Otter Trawl Off Bottom	0830	24 Sep 85	34°13.27'	75°38.16'	26891.3	39756.4	2057
4	Otter Trawl On Deck	1000	24 Sep 85	34°12.41'	75°37.69'	26889.1	39749.8	
11	Otter Trawl Deployed	1708	23 Sep 85	33°06.08'	76°24.40'	44872.6	59257.8	
11	Otter Trawl On Bottom	1748	23 Sep 85	33°07.01'	76°23.71'	44874.5	59252.4	795
11	Otter Trawl Off Bottom	1914	23 Sep 85	33°09.28'	76°21.99'	44879.1	59239.3	790
11	Otter Trawl on Deck	1950	23 Sep 85	33°11.20'	76°20.79'	44883.5	59228.8	
15	Otter Trawl Deployed	1635	18 Sep 85	32°09.90'	76°43.08'	44681.0	59623.9	
15	Otter Trawl on Bottom	1806	18 Sep 85	32°10.24'	76°42.83'	44681.9	59620.9	2020
15	Otter Trawl Off Bottom	2023	18 Sep 85	32°13.39'	76°41.06'	44691.7	59596.6	1990
15	Otter Trawl on Deck	2300	18 Sep 85	32°13.94'	76°35.10'	44679.4	59577.8	

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
				SOUTH ATLANTIC CRUISE 5 (R/V GYRE)				
S.A Tow 14	Sled on Bottom	0817	7 Sep 85	32°11.03'	76°41.67'	44682.6	59612.9	2052
	Sled off Bottom	2117	17 Sep 85	32°21.18'	76°56.38'	44766.8	59590.3	863
S.A. Tow 15	Sled on Bottom	0302	19 Sep 85	32°20.98'	76°55.53'	44763.6	59589.1	877
	Sled off Bottom	1601	19 Sep 85	32°28.66'	77°08.55'	44833.8	59577.7	692
S.A Tow 16	Sled on Bottom	1640	20 Sep 85	32°28.32'	77°07.03'	44828.1	59575.2	705
	Sled off Bottom	0041	21 Sep 85	32°35.02'	77°15.51'	44882.2	59556.4	560
S.A. Tow 16	Sled on Bottom	1040	28 Sep 85	35°28.17'	74°39.60'	26750.9	40584.9	1895
	Sled off Bottom	1835	28 Sep 85	35°28.30'	74°49.47'	26787.4	40552.1	300

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 6 (R/V CAPE HATTERAS)					
4	Box Core 1	0415	24 Nov 85	34°11.17'	75°38.64'	26891.1	39740.4	2054
4	Box Core 2	0600	24 Nov 85	34°11.21'	75°38.61'	26891.0	39740.7	2049
4	Box Core 3	0759	24 Nov 85	34°11.23'	75°38.53'	26890.7	39741.3	2057
4	Hydrocast	1000	24 Nov 85	34°10.52'	75°37.59'	26887.1	39741.0	2350
4	Box Core Biomass 1	1120	24 Nov 85	34°11.07'	75°38.58'	26890.7	39740.0	2066
4	Box Core Biomass 2	1302	24 Nov 85	34°11.06'	75°38.72'	26891.2	39739.3	2042
4	Box Core Biomass 3	1432	24 Nov 85	34°11.11'	75°38.55'	26890.7	39740.4	2074
10	Box Core 1	0016	25 Nov 85	35°26.30'	74°41.44'	26756.2	40562.1	2004
10	Box Core 2	0143	25 Nov 85	35°26.35'	74°41.46'	26756.3	40562.5	2004
10	Box Core 3	0319	25 Nov 85	35°26.22'	74°41.45'	26756.2	40561.4	1994
10	Hydrocast	0900	25 Nov 85	35°26'41'	74°41.30'	26755.8	40563.5	2113
10	Box Core Biomass 1	0443	25 Nov 85	35°26.27'	74°41.41'	26756.1	40561.9	2004
10	Box Core Biomass 2	0604	25 Nov 85	35°26.30'	74°41.41'	26756.1	40562.6	2005
10	Box Core Biomass 3	0735	25 Nov 85	35°26.33'	74°41.43'	26756.2	40562.3	2004
11	Box Core 1	0308	22 Nov 85	33°04.95'	76°25.15'	44869.9	59264.6	804
11	Box Core 2	0417	22 Nov 85	33°04.94'	76°25.17'	44869.9	59264.5	804
11	Box Core 3	0630	22 Nov 85	33°04.84'	76°25.06'	44869.3	59265.0	807
11	Hydrocast	0525	22 Nov 85	33°06.29'	76°24.07'	44872.6	59256.5	804

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 6 (R/V CAPE HATTERAS)					
12	Box Core 1	0835	21 Nov 85	33°00.55'	76°07.45'	44808.7	59270.4	1992
12	Box Core 2	1041	21 Nov 85	33°00.44'	76°07.29'	44807.9	59270.8	2002
12	Box Core 3	1305	21 Nov 85	33°00.38'	76°07.46'	44808.1	59271.2	1994
12	Hydrocast	1503	21 Nov 85	33°00.73'	76°07.41'	44809.4	59269.5	1967
13	Box Core 1	2109	20 Nov 85	32°55.16'	75°50.25'	44747.4	59281.7	2999
13	Box Core 2	2337	20 Nov 85	32°55.22'	75°50.20'	44747.6	59281.4	3002
13	Box Core 3	0204	21 Nov 85	32°55.25'	75°50.08'	44747.4	59281.4	3006
13	Hydrocast	0438	21 Nov 85	32°55.29'	75°49.42'	44746.0	59280.4	2986
14	Box Core 1	1458	18 Nov 85	32°23.73'	77°01.10'	44791.0	59587.6	799
14	Box Core 2	1627	18 Nov 85	32°23.67'	77°01.09'	44790.7	59587.9	799
14	Box Core 3	1812	18 Nov 85	32°23.70'	77°01.06'	44790.7	59587.6	799
14	Hydrocast	2000	18 Nov 85	32°25.31'	76°59.90'	44794.8	59573.5	794
15	Box Core 1	0707	19 Nov 85	32°11.98'	76°42.16'	44688.2	59608.4	1944
16	Box Core 1	0206	20 Nov 85	31°35.12'	75°10.34'	44339.9	59611.0	3029
16	Box Core 2	0522	20 Nov 85	31°35.10	75°10.34'	44339.9	59611.0	3009
16	Box Core 3	0831	20 Nov 85	31°35.16'	75°10.22'	44340.0	59610.6	3012
16	Hydrocast	1056	20 Nov 85	31°35.14'	75°10.58'	44340.4	59611.3	3000

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 6 (R/V CAPE HATTERAS)					
*	Day Dredge on Bottom	0239	17 Nov 85	31°17.30'	79°00.65'	44851.2	60660.4	572
*	Day Dredge off Bottom	0247	17 Nov 85	31°17.19'	79°00.72'	44850.8	60661.6	575
*	Day Dredge on Bottom	0455	17 Nov 85	31°18.05'	79°00.20'	44853.8	60652.8	545
*	Day Dredge off Bottom	0502	17 Nov 85	31°18.02'	79°00.21'	44853.6	60653.0	549
*	Day Dredge on Bottom	0812	17 Nov 85	31°23.62'	78°56.65'	44871.3	60594.2	498
*	Day Dredge off Bottom	0820	17 Nov 85	31°23.58'	78°56.77'	44871.6	60595.2	512
*	Day Dredge on Bottom	1139	17 Nov 85	31°37.10'	78°40.68'	44883.6	60401.1	440
*	Day Dredge off Bottom	1155	17 Nov 85	31°37.04'	78°40.31'	44881.9	60399.0	450
*	Day Dredge on Bottom	0014	18 Nov 85	31°49.81'	78°19.21'	44871.5	60181.0	625
*	Day Dredge off Bottom	0033	18 Nov 85	31°49.61'	78°19.33'	44870.9	60183.1	625
14	Otter Trawl Deployed	2240	18 Nov 85	32°24.04'	77°00.44'	44790.7	59583.6	
14	Otter Trawl on Bottom	2316	18 Nov 85	32°25.87'	76°59.98'	44791.5	59570.1	810
14	Otter Trawl off Bottom	2345	18 Nov 85	32°29.10'	76°59.00'	44809.2	59545.9	800
14	Otter Trawl on Deck	0045	19 Nov 85	32°22.50'	76°58.10'	44825.7	59513.5	

TABLE A-1. (Continued).

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 6 (R/V CAPE HATTERAS)					
S.A. Tow 18	Sled on Bottom	0701	16 Nov 85	31°42.94'	78°22.11'	44851.3	60238.1	665
	Sled off Bottom	2012	16 Nov 85	31°37.12'	78°34.42'	44859.7	60356.8	461
S.A. Tow 19	Sled on Bottom	1410	17 Nov 85	31°37.38'	78°42.17'	44891.2	60409.7	433
	Sled off Bottom	2012	17 Nov 85	31°34.77'	78°46.88'	44894.9	60458.5	449
S.A. Tow 20	Sled on Bottom	1729	21 Nov 85	33°00.15'	76°05.87'	44803.4	59271.0	2132
	Sled off Bottom	0002	22 Nov 85	33°01.44'	74°13.77'	44827.6	59271.7	1580
S.A. Tow 21	Sled on Bottom	1440	25 Nov 85	35°30.39'	74°43.67'	26767.5	40590.6	1375
	Sled off Bottom	2001	25 Nov 85	35°27.43'	74°49.74'	26787.6	40543.4	311

*Charleston Bump, off South Carolina. Taken in conjunction with epifaunal camera runs.

TABLE A-2. SUMMARY OF SAMPLE POSITIONS FOR STATIONS 4 AND 9 FOR SOUTH ATLANTIC PHASE 1.

Station	Sample	Time (EST)	Date	Latitude (N)	Longitude (W)	Loran Time Delays		Depth (m)
			SOUTH ATLANTIC CRUISE 1 (R/V COLUMBUS ISELIN)					
4	Box Core 1	1654	16 Nov 83	34°11.68'	75°39.54'	26893.5	39738.3	1860
4	Box Core 2	0619	17 Nov 83	34°12.54'	75°39.03'	26894.6	39740.1	1940
4	Box Core 3	0833	17 Nov 83	34°11.77'	75°38.97'	26893.0	39738.0	1937
4	Hydrocast	1245	17 Nov 83	34°12.24'	75°38.55'	26894.0	39739.4	2025
			SOUTH ATLANTIC CRUISE 2 (R/V GYRE)					
4	Box Core 1	0750	20 May 84	34°11.7'	75°38.6'	26890.7	39743.3	2064
4	Box Core 2	1314	20 May 84	34°11.9'	75°38.7'	26891.1	39744.4	2029
4	Box Core 3	1754	20 May 84	34°11.5'	75°39.0'	26891.9	39740.5	1969
4	Hydrocast	1142	23 May 84	34°11.6'	75°38.5'	26890.5	39743.2	2079
			SOUTH ATLANTIC CRUISE 3 (R/V GYRE)					
4	Box Core 1	2017	13 July 84	34°12.1'	75°38.6'	26890.9	39746.5	2066
4	Box Core 2	0739	14 July 84	34°10.41'	75°39.1'	26891.0	39732.9	2005
4	Box Core 3	0925	14 July 84	34°11.17'	75°38.98'	26891.3	39738.3	2006
4	CTD/Hydrocast	1908	18 July 84	34°12.79'	75°37.91'	26889.4	39753.8	2168
9	Box Core 1	0959	22 July 84	35°28.3'	74°47.7'	26780.7	40558.4	579
9	Box Core 2	1110	22 July 84	35°28.4'	74°47.5'	26780.2	40559.6	614
9	Box Core 3	1429	22 July 84	35°28.3'	74°47.6'	26780.3	40538.5	598
9	CTD/Hydrocast	0905	22 July 84	35°28.6'	74°47.4'	26780.0	40562.1	680

APPENDIX B

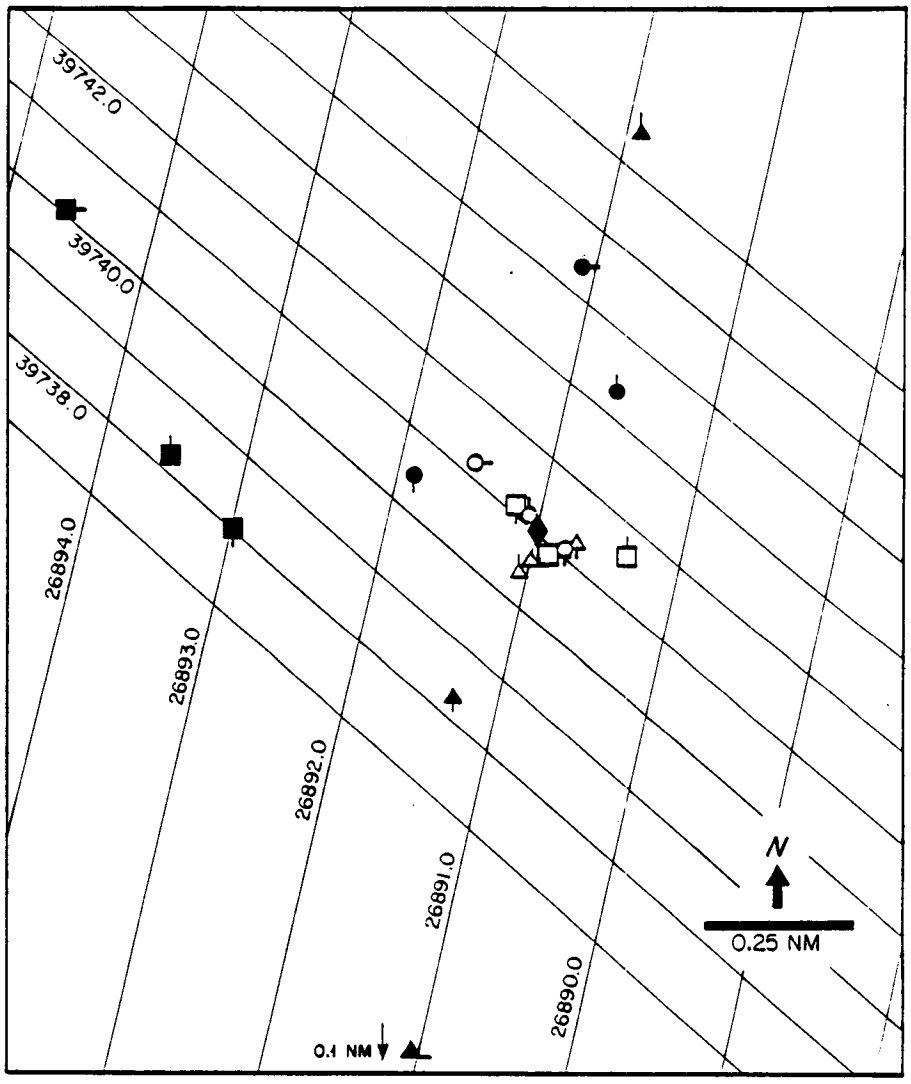
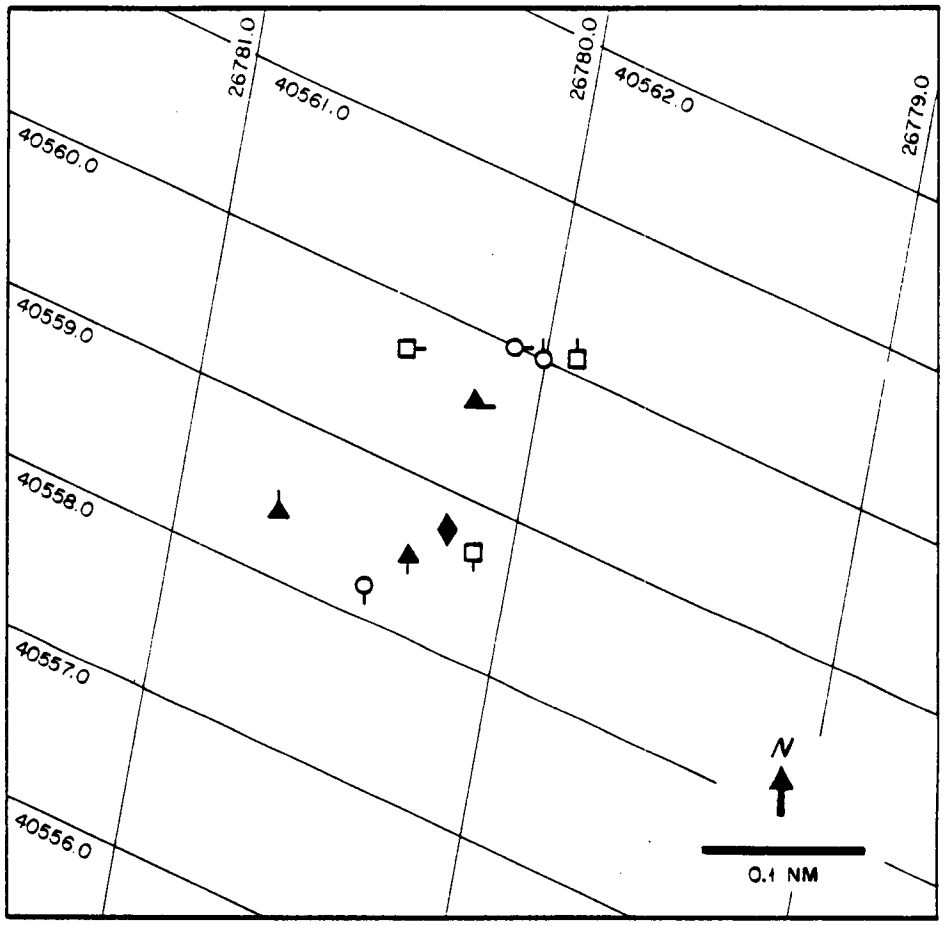


Figure B.1. Positions of replicate box cores taken at U.S. South Atlantic Station 4.



Rep 1 Rep 2 Rep 3

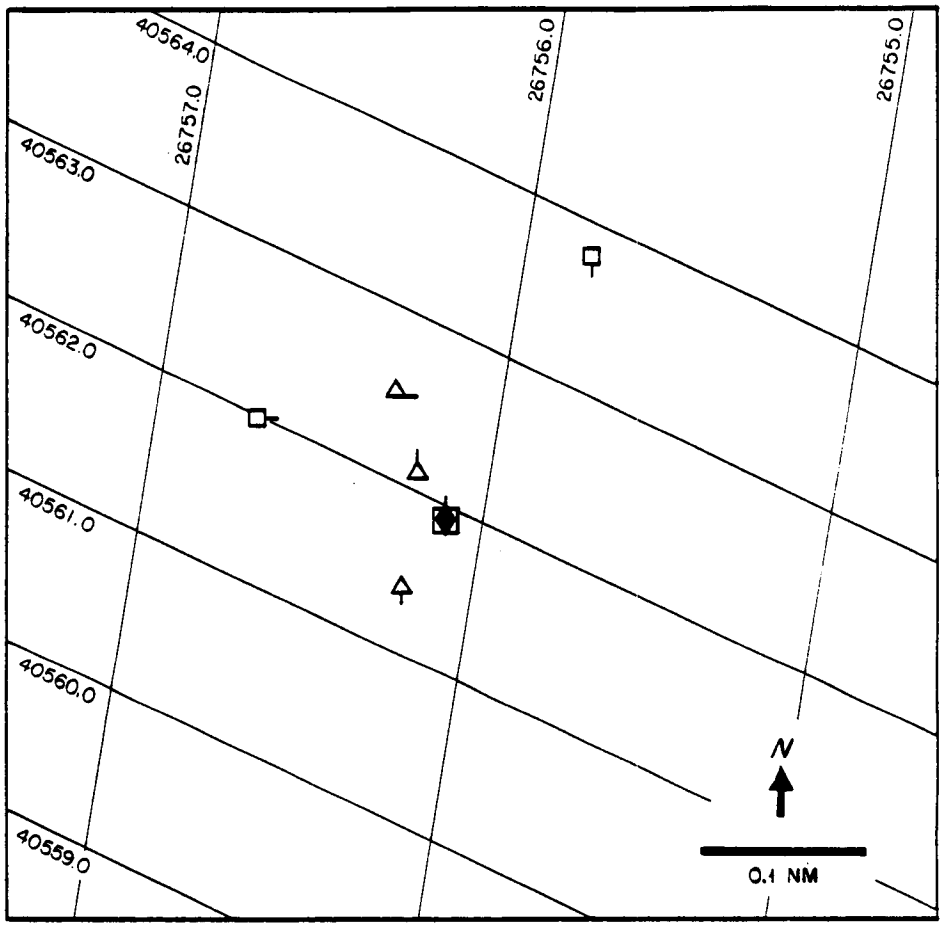
SOUTH - 3 R/V Gyre

SOUTH - 4 R/V Cape Hatteras

SOUTH - 5 R/V Gyre

REFERENCE COORDINATES
26780.2 40558.8

Figure B.2. Positions of replicate box cores taken at U.S. South Atlantic Station 9.



Rep 1 Rep 2 Rep 3

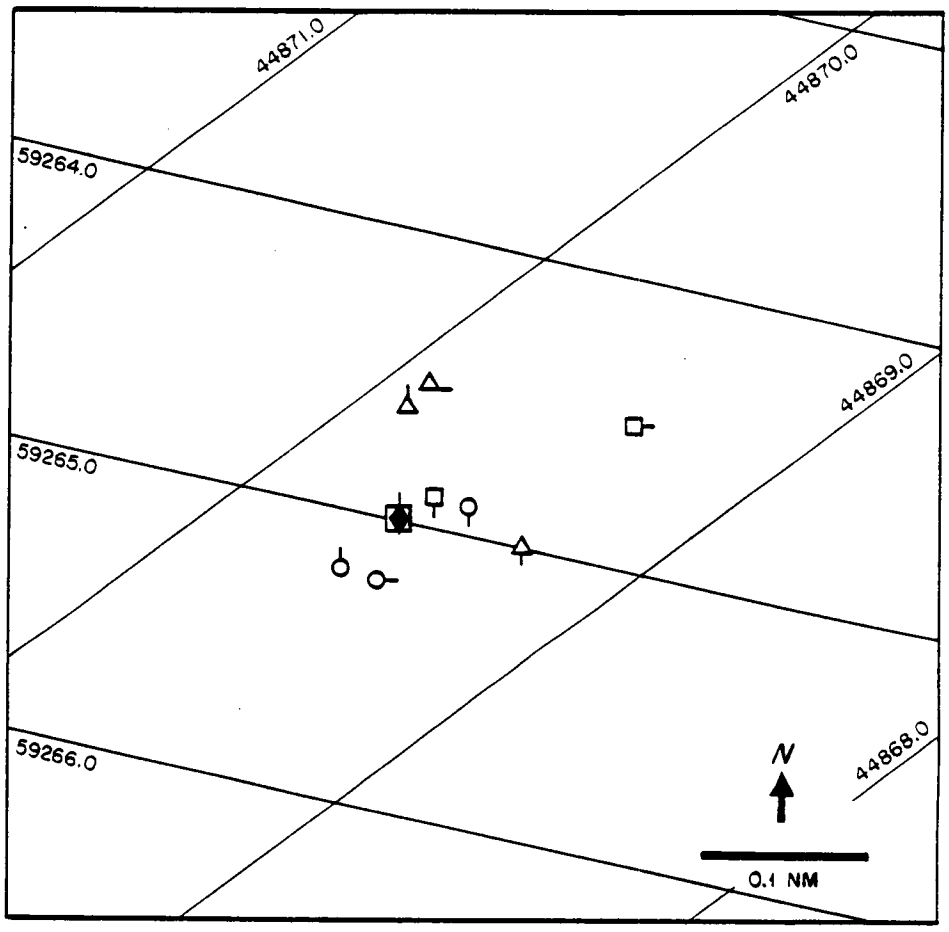
SOUTH - 4 R/V Cape Hatteras

SOUTH - 5 R/V Gyre

SOUTH - 6 R/V Cape Hatteras

REFERENCE COORDINATES
26756.1 40561.9

Figure B.3. Positions of replicate box cores taken at U.S. South Atlantic Station 10.



Rep 1 Rep 2 Rep 3

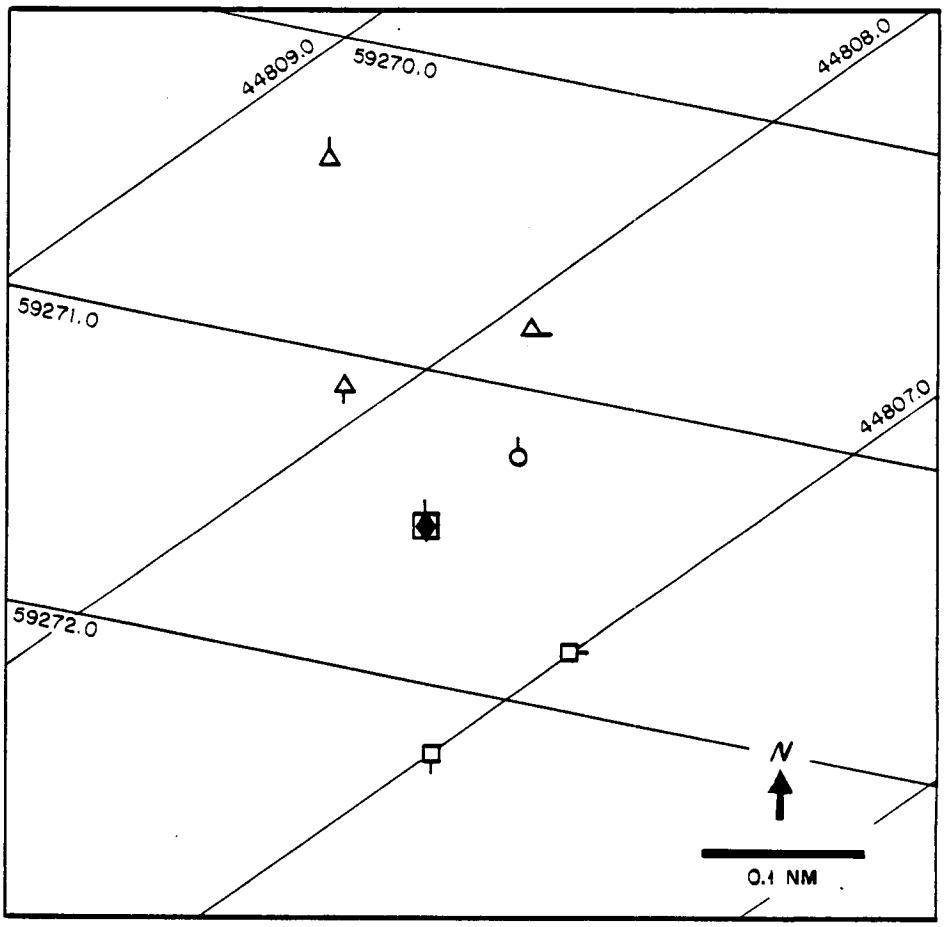
SOUTH - 4 R/V Cape Hatteras

SOUTH - 5 R/V Gyre

SOUTH - 6 R/V Cape Hatteras

REFERENCE COORDINATES
44869.6 59265.0

Figure B.4. Positions of replicate box cores taken at U.S. South Atlantic Station 11.



Rep 1 Rep 2 Rep 3

SOUTH - 4 R/V Cape Hatteras

SOUTH - 5 R/V Gyre

SOUTH - 6 R/V Cape Hatteras

REFERENCE COORDINATES
44807.6 59271.5

Figure B.5. Positions of replicate box cores taken at U.S. South Atlantic Station 12.

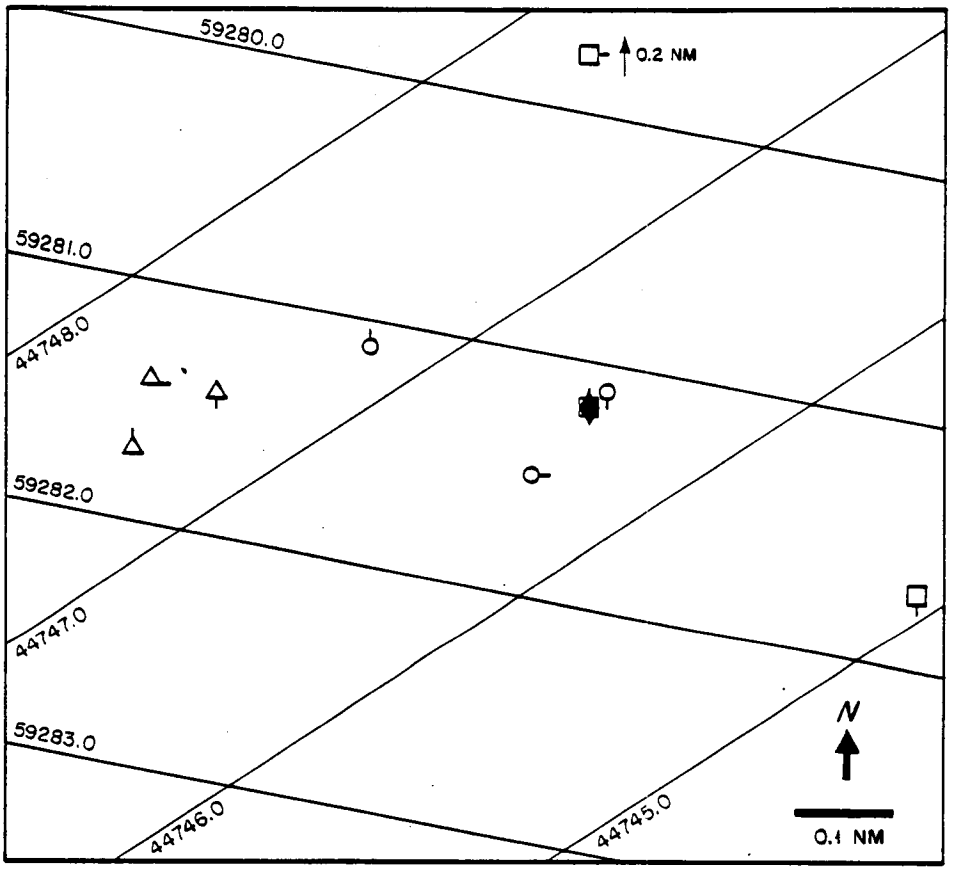
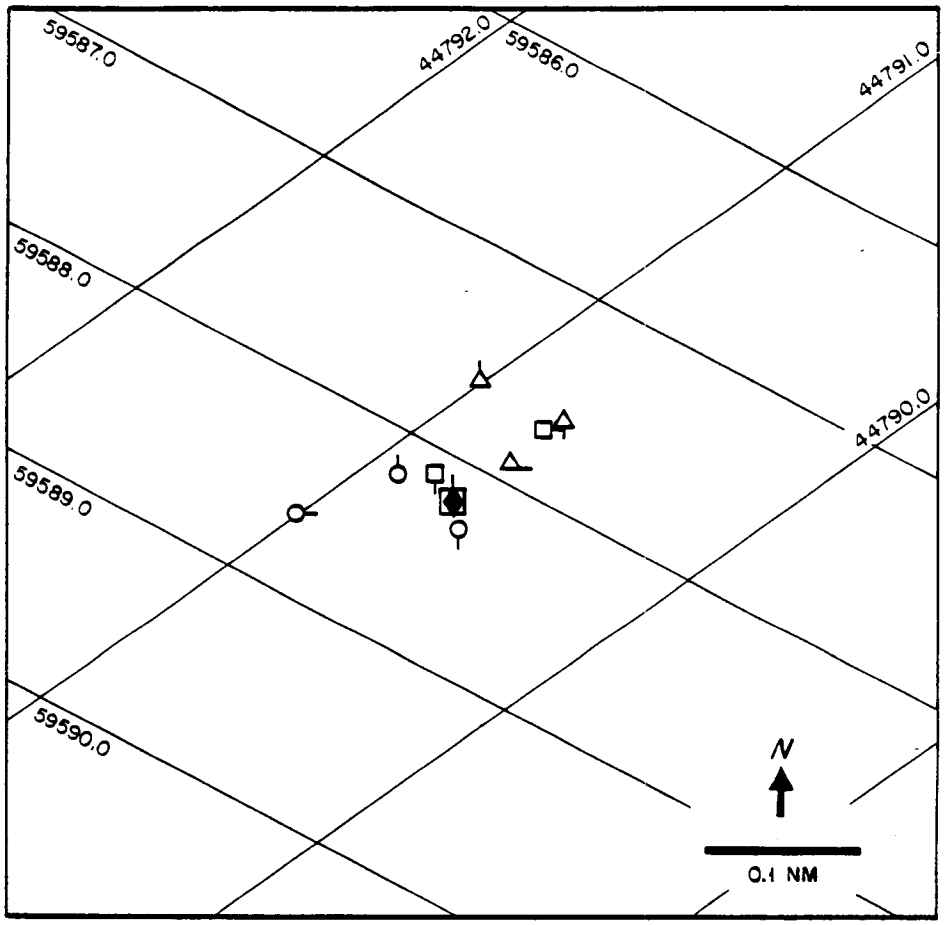


Figure B.6. Positions of replicate box cores taken at U.S. South Atlantic Station 13.



Rep 1 Rep 2 Rep 3

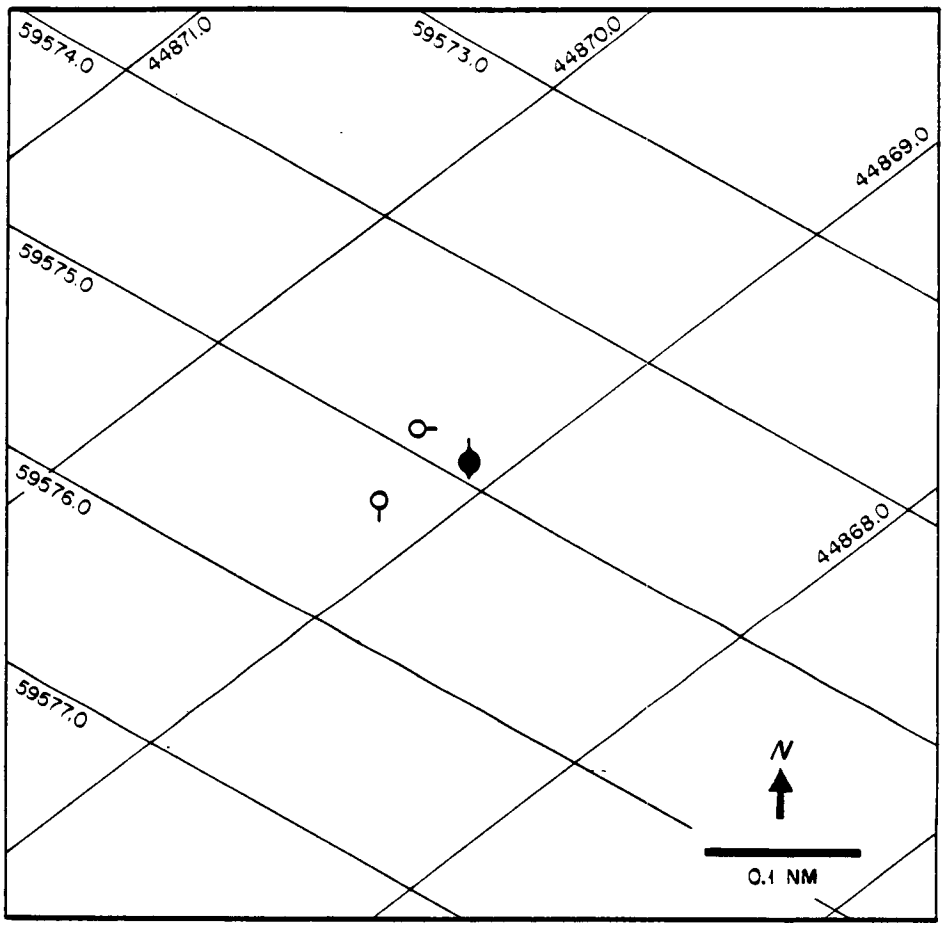
SOUTH - 4 R/V Cape Hatteras

SOUTH - 5 R/V Gyre

SOUTH - 6 R/V Cape Hatteras

REFERENCE COORDINATES
44790.7 59288.2

Figure B.7. Positions of replicate box cores taken at U.S. South Atlantic Station 14.

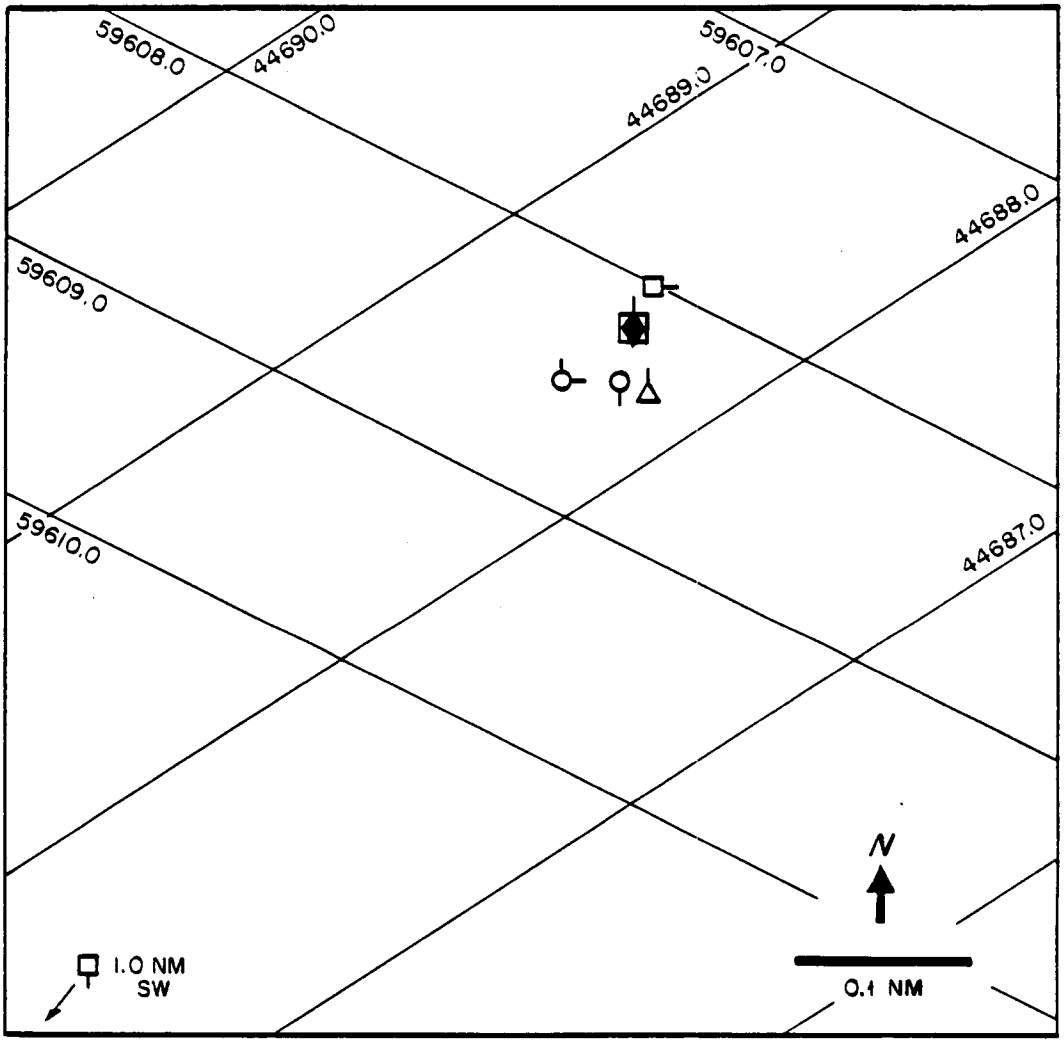


Rep 1 Rep 2 Rep 3

SOUTH - 5 R/V Gyre

REFERENCE COORDINATES
44869.1 59574.9

Figure B.8. Positions of replicate box cores taken at U.S. South Atlantic Station 14A.



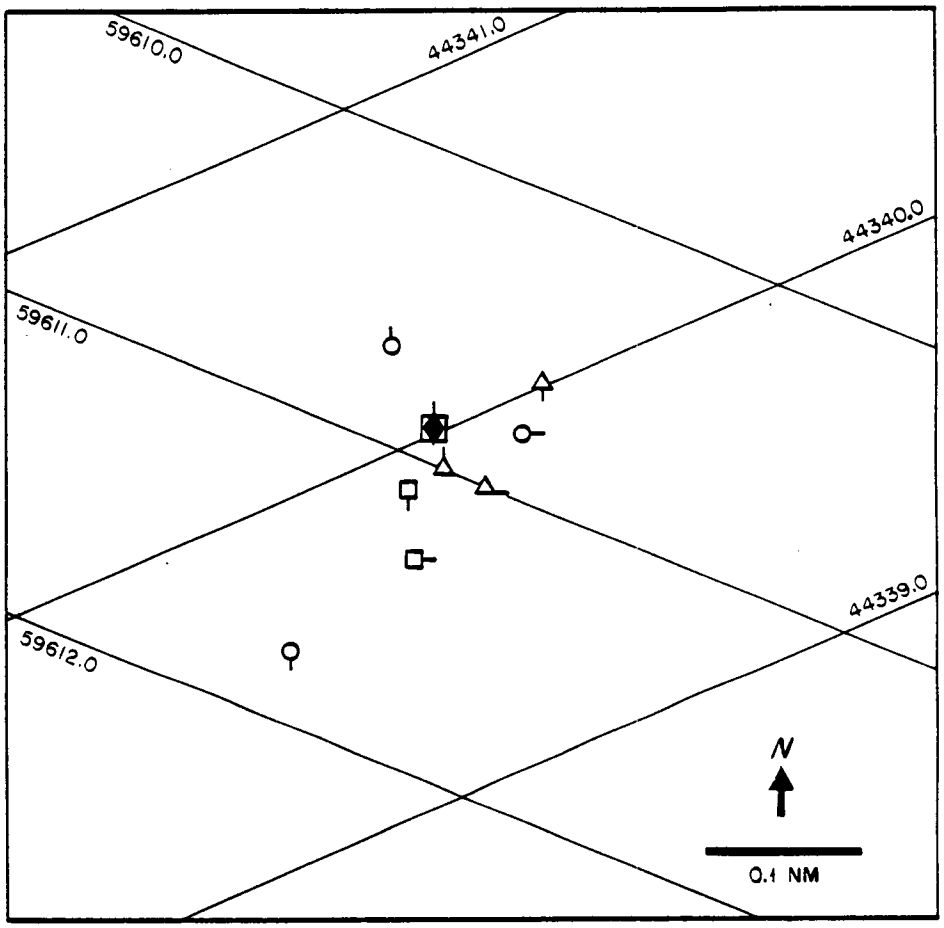
Rep 1 Rep 2 Rep 3

SOUTH - 4 R/V Cape Hatteras

SOUTH - 5 R/V Gyre

REFERENCE COORDINATES
44688.4 59608.2

Figure B.9. Positions of replicate box cores taken at U.S. South Atlantic Station 15.



Rep 1 Rep 2 Rep 3

SOUTH - 4 R/V Cape Hatteras

SOUTH - 5 R/V Gyre

SOUTH - 6 R/V Cape Hatteras

REFERENCE COORDINATES
44340.0 59610.9

Figure B.10. Positions of replicate box cores taken at U.S. South Atlantic Station 16.

APPENDIX C

APPENDIX C

SPECIES RECORDED FROM U.S. SOUTH ATLANTIC SLOPE AND RISE INFAUNAL SAMPLES
Species marked with an * were not included in statistical analyses

PORIFERA
*Leucosolenia sp. 1
*Calcarea sp. 2, sp. 3, sp. A
*Porifera sp. 1, sp. 2
*Porifera olynthus sp. 1, sp. 2, sp. 3, sp. 4, sp. 5

CNIDARIA
Hydrozoa
*Bimeria spp. indeterminate
*Clytia longicyatha (Allman, 1877)
*Cuspidella grandis Hincks, 1868
Dahlgrenella farcta Miles, 1937
*Egmundella superba Stechow, 1921
*Eucuspidella sp. 1
*Eudendrium spp. indeterminate
*Grammaria cf. elegans Fraser, 1943
*Monobrachium parasitum Mereschkowsky, 1877
*Plumularia profunda Nutting, 1900
*Sertularella cf. tenella (Alder, 1856)
*Sertularia cf. westwindica (Stechow, 1919)
*Stegopoma plicatile (Alder, 1860)
Athecata sp. A
*Atractylidae spp. indeterminate
*Campanularidae sp. 1
Hypolitidae sp. 2
*Lafoeidae sp. 1
*Plumularidae sp. 1
Hydrozoa sp. 1, sp. 2*, sp. 3, sp. 4, sp. 5*, sp. 8*, sp. 9*, sp. 11, sp. 12
Tubularidae sp. 2

Anthozoa
Fungiacyanthus sp. 1
Halcampa duodecimcirrata (Sars, 1851)
Kophobelemnon stelliferum (Muller, 1776)
Octocorallia sp. A
Paraedwardsia arenaria (Carlgren, 1905)
*Plumarella pourtalesii (Verrill, 1883)
Protoptilum carpenteri Kolliker, 1872
Scleroptilum grandiflorum Kolliker, 1880
Cerianthidae sp. 1
Anthozoa sp. 1*, sp. 2, sp. 4, sp. 5, sp. 7, sp. 8, sp. 0*
Gorgonacea spp. indeterminate

Scyphozoa
*Coronatae polyp

PLATYHELMINTHES
*Turbellaria

NEMERTEA
Cerebratulus sp. 1
Lineus sp. 1
Micrura sp. 1, sp. 2
Nemertea sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 7, sp. 9, sp. 10, sp. 11, sp. 13, sp. 16, sp. A, sp. D, sp. E, sp. Q, sp. R

PRIAPULIDA
Priapulopsis bicaudatus (Danielssen, 1868)
Priapulus caudatus Lamarck, 1816
Priapulida sp. 1

ANNELIDA
Polychaeta
Acrocirridae
Flabelligella cirrata Hartman & Fauchald, 1971
Flabelligella macrochaeta (Fauchald, 1972)
Flabelligella sp. 2, sp. 3

Ampharetidae
Ampharete arctica Malmgren, 1866
Amphicteis gunneri (Sars, 1835)
Amphicteis vestis Hartman, 1965
Anobothurs gracilis (Malmgren, 1866)
Anobothrus sp. 1
Auchenoplax crinita Ehlers, 1887
Eclysippe vanelli (Fauvel, 1936)
Eclysippe sp. 1, sp. 2, sp. 4
Glyphanostomum sp. 1, sp. 2
Lysippe sp. 1
Lysippides sp. 1
Melinna cristata (Sars, 1851)
Melinna elisabethae McIntosh, 1914
Melinna sp. 1
Melinnata sp. 1
Mugga wahrbergi Eliason, 1955
Muggoides nr. cinctus Hartman, 1965
Muggoides sp. 1
Sabellides cf. octocirrata (Sars, 1835)
Sosanides sp. 1
Ampharetidae sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 9, sp. 10, sp. 11, sp. 16

Amphinomidae
Paramphinome jeffreysii (McIntosh, 1868)
Paramphinome sp. 1

Aphroditidae
Aphrodita spp. (juvenile)

Apistobranchidae
Apistobranchus tullbergi (Theel, 1879)

Arabellidae
Drilonereis longa Webster, 1879
Drilonereis sp. 1

Bogueidae
Boguella sp. 1

Capitellidae
Barantolla sp. 1, sp. 3, sp. 4
Capitella spp. (complex)
Heteromastus sp. 1, sp. 2, sp. 3
Mediomastus sp. 1, sp. 2
nr. Neoheteromastus sp. 1
Neomediomastus sp. 1
Notomastus americanus Day, 1973
Notomastus latericeus Sars, 1851
Notomastus cf. tenuis Moore, 1909
Notomastus teres Hartman, 1965
Notomastus sp. 2, sp. 3
Capitellidae sp. 1, sp. 3, sp. 4, sp. 6

Chaetopteridae
Phyllochaetopterus sp. 1

Chrysopetalidae
Dysponetus cf. gracilis Hartman, 1965
Dysponetus sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp 7, sp. 8, sp. 9

Cirratulidae
Caulleriella sp. 1, sp. 2, sp. 3, sp. 8
Chaetozone gayheadia Hartman, 1965
Chaetozone setosa Malmgren, 1867
Chaetozone sp. 1, sp. 2, sp. 4, sp. 6, sp. 7, sp. 8, sp. 9, sp. 10, sp. 11, sp. 15
Tharyx acutus Webster & Benedict, 1887
Tharyx dorsobranchialis (Kirkegaard, 1959)
Tharyx cf. marioni (Saint-Joseph, 1894)
Tharyx nr. monilaris Hartman, 1960
Tharyx sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 7, sp. 8, sp. 9, sp. 10, sp. 13

Cossuridae
Cossura longocirrata Webster & Benedict, 1887
Cossura sp. 1, sp. 2
Cossurella sp. 1

Dorvilleidae
Dorvillea sp. 1, sp. 2, sp. 3
Exallopus cropion Jumars, 1974
Exallopus sp. 1, sp. 2, sp. 3, sp. 4
Meiodorvillea minuta (Hartman, 1965)
Meiodorvillea sp. 1, sp. 2
Ophryotrocha sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 8, sp. 9, sp. 10
Parophryotrocha sp. 1
Pettiboneia sp. 1
Protodorvillea nr. kefersteini (McIntosh, 1869)
Schistomeringos anoculata (Hartman, 1965)
Schistomeringos caeca (Webster & Benedict, 1884)
Schistomeringos sp. 3
Dorvilleidae sp. 1, sp. 2

Euphrosinidae
Palmyreuphrosyne sp. 1

Fauveliopsidae
Fauveliopsis brevis (Hartman, 1965)
Fauveliopsis glabra (Hartman, 1960)
Fauveliopsis olgae Hartmann-Schroder, 1983
Fauveliopsis scabra Hartman & Fauchald, 1971

Flabelligeridae
Brada sp. 1
Diplocirrus hirsutus (Hansen, 1879)
Flabelligera sp. 1, sp. 2
Therochaeta collarifera (Ehlers, 1887)
Flabelligeridae sp. 1, sp. 3, sp. 4, sp. 5, sp. 10, sp. 11, sp. 12, sp. 13, sp. 15, sp. 17

Glyceridae
- Glycera capitata Oersted, 1843
- Glycera nr. oxycephala Ehlers, 1887

Goniadidae
- Glycinde profunda Hartman & Fauchald, 1971
- Goniada annulata Moore, 1905
- Goniada brunnea Treadwell, 1906
- Goniada norvegica Oersted, 1845
- Goniadella gracilis (Verrill, 1873)
- Progoniada regularis Hartman, 1965

Hesionidae
- Hesiocaeca nr. bermudensis Hartman, 1965
- Hesiospina sp. 1
- Microphthalmus listenis Westheide, 1966
- Microphthalmus sp. 1, sp. 2
- Nereimyra punctata (Muller, 1788)
- Nereimyra sp. 2, sp. 3
- Hesionidae sp. 3, sp. 4, sp. 6, sp. 7

Heterospionidae
- Heterospio nr. longissima Ehlers, 1874

Lacydoniidae
- Lacydonia cirrata (Hartman & Fauchald, 1971)

Lumbrineridae
- Augeneria bidens (Ehlers, 1887)
- Lumbrinerides nr. carpinei (Ramos, 1976)
- Lumbrineris nr. coccinea (Renier, 1804)
- Lumbrineris fragilis (Muller, 1776)
- Lumbrineris impatiens (Claparede, 1868)
- Lumbrineris latreilli Audouin & Milne Edwards, 1834
- Lumbrineris sp. 1, sp. 2, sp. 6, sp. 9
- Ninoe nr. brevipes (McIntosh, 1903)
- Ninoe nigripes Verrill, 1873

Maldanidae
- Asychis cf. biceps (Sars, 1861)
- Clymenella torquata (Leidy, 1855)
- Clymenopsis sp. 1
- Clymenura lankesteri (McIntosh, 1885)
- Clymenura polaris (Theel, 1879)
- Lumbriclymene sp. 1
- Maldane glebifex Grube, 1860
- Maldane sarsi Malmgren, 1865
- Maldanella sp. 1
- Notoproctus nr. abyssus Hartman & Fauchald, 1971
- Notoproctus nr. oculatus Arwidsson, 1907
- Praxillella gracilis (Sars, 1861)
- Praxillella praetermissa (Malmgren, 1866)
- Praxillella sp. 1
- Praxillura cf. longissima Arwidsson, 1907
- Rhodine gracilior Tauber, 1879
- Rhodine sp. 1
- Maldanidae sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 7, sp. 8, sp. 9

Nephtyidae
- Aglaophamus groenlandiae Hartman, 1967
- Aglaophamus sp. 1, sp. 2, sp. 3
- Nephtys nr. hystricis McIntosh, 1900
- Nephtys incisa Malmgren, 1865
- Nephtys paradoxa Malm, 1874

Nereididae
- Ceratocephale loveni (Malmgren, 1867)
- Nereis caecoides Hartman, 1965
- Nereis sp. 1
- Nicon sp. 1

Onuphidae
- Hyalinoecia artifex Verrill, 1880
- Hyalinoecia sp. 1, sp. 2, sp. 3
- Kinbergonuphis sp. 1
- Nothria textor Hartman & Fauchald, 1971
- Nothria sp. 1, sp. 2
- Onuphis geophiliformis(Moore, 1903)
- Onuphis opalina (Verrill, 1873)
- Onuphis rullieriana (Amoureux, 1977)
- Onuphis sp. 1, sp. 2, sp. 3, sp. 4
- Paradiopatra glutinatrix (Ehlers, 1887)
- Paronuphis sombreriana (McIntosh, 1885)
- Sarsonuphis nr. fragosa (Ehlers, 1887)
- Sarsonuphis hartmanae (Kirkegaard, 1980)
- Sarsonuphis paucibranchis (Ehlers, 1908)

Opheliidae
- Ammotrypanella arctica McIntosh, 1879
- Kesun gravieri (McIntosh, 1908)
- Ophelia profunda Hartman, 1965
- Ophelia sp. 2
- Ophelina abranchiata Støp-Bowitz, 1948

Ophelina acuminata Oersted, 1843
Ophelina aulogastrella (Hartman & Fauchald, 1971)
Ophelina cylindricaudata (Hansen, 1878)
Ophelina sp. 3
Tachytrypane cf. jeffreysii McIntosh, 1879
Opheliidae sp. 1, sp. 2, sp. 3

Orbiniidae
Califia schmitti (Pettibone, 1957)
Leitoscoloplos acutus (Verrill, 1873)
Leitoscoloplos nr. kerguelensis (McIntosh, 1885)
Leitoscoloplos sp. 1
Microrbinia linea Hartman, 1965
Orbinia sp. 1
Orbiniella sp. 1, sp. 2, sp. 3, sp. 4
Phylo norvegicus (Sars, 1872)
Scoloplos sp. 1, sp. 2, sp. 3, sp. 4, sp. 5

Oweniidae
Galathowenia sp. 1
Myriochele cf. heeri Malmgren, 1867
Myriochele sp. 1, sp. 2, sp. 3, sp. 3B, sp. 4, sp. 5, sp. 6, sp. 7, sp. 8, sp. 9, sp. 13
Myrioglobula sp. 1
Myriowenia sp. 1
Oweniidae sp. 1

Paralacydoniidae
Paralacydonia paradoxa Fauvel, 1913

Paraonidae
Aricidea abranchiata Hartman, 1965
Aricidea catherinae Laubier, 1967
Aricidea cerruti Laubier, 1966
Aricidea nr. claudiae Laubier, 1967
Aricidea nr. facilis Strelzov, 1973
Aricidea nr. fragilis Webster, 1879
Aricidea quadrilobata Webster & Benedict, 1887
Aricidea tetrabranchia Hartman & Fauchald, 1971
Aricidea sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 10, sp. 12
Cirrophorus branchiatus Ehlers, 1908
Cirrophorus furcatus (Hartman, 1957)
Levinsenia flava (Strelzov, 1973)
Levinsenia uncinata (Hartman, 1965)
Levinsenia sp. 1, sp. 2, sp. 3, sp. 5, sp. 6, sp. 7, sp. 8, sp. 9
Paradoneis abranchiata Hartman, 1965
Paradoneis brevicirratus (Strelzov, 1973)
Paradoneis lyra (Southern, 1914)
Paradoneis sp. 2
Paraonella sp. 1
Paraonis sp. 1
Sabidius cornatus (Hartman, 1965)
Paraonidae sp. 3

Pholoidae
Pholoe anoculata Hartman, 1965
Pholoe minuta (Fabricius, 1780)
Pholoididae sp. 1

Phyllodocidae
Eulalia sp. 1, sp. 2
Eumida sp. 1, sp. 2, sp. 3
Genetyllis sp. 1
Mystides caeca Langerhans, 1879
Mystides davi Hartmann-Schroder, 1983
Mystides nr. limbata Saint-Joseph, 1888
Mystides punctata (Hartman, 1965)
Mystides rarica (Uschakov, 1958)
Mystides nr. schroederae Uschakov, 1972
Paranaitis nr. caecum Ushchakov, 1972
Paranaitis wahlbergi (Malmgren, 1865)
Phyllodoce sp. 1
Protomystides anoculata (Hartman & Fauchald, 1971)
Protomystides occidentalis (Ditlevsen, 1917)
Protomystides punctata (Hartman, 1965)
Protomystides sp. 1, sp. 2, sp. 3, sp. 5
Pterocirrus sp. 1
Steggoa sp. 1
Phyllodocidae sp. 1, sp. 2, sp. 3, sp. 4, sp. 5

Pilargidae
Ancistrosyllis nr. groenlandica McIntosh, 1879
Ancistrosyllis jonesi Pettibone, 1966
Sigambra tentaculata (Treadwell, 1941)
Sigambra sp. 1, sp. 2
Synelmis sp. 1, sp. 2

Poecilochaetidae
Poecilochaetus bermudensis Hartman, 1965
Poecilochaetus fulgoris Claparede, 1875

Polynoidae
- Alentiana aurantiaca (Hartman, 1942)
- Hermadion acanelle (Verrill, 1881)
- Macellicephala atlantica Støp-Bowitz, 1948
- Paradyte sp. 1
- Subadyte pellucida (Ehlers, 1864)

Questidae
- Novaquesta trifurcata Hobson, 1970

Sabellariidae
- Lygdamis sp. 1
- Monorchos sp. 1

Sabellidae
- Chone sp. 3, sp. 4, sp. 5
- Euchone hancocki Banse, 1970
- Euchone incolor Hartman, 1965
- Euchone papillosa (Sars, 1851)
- Euchone scotiarum Hartman, 1978
- Euchone sp. 1, sp. 2, sp. 3, sp. 8, sp. 9
- Fabricia sp. 1
- Jasmineira bermudensis Hartman, 1965
- Jasmineira filiformis Hartman, 1965
- Jasmineira cf. pacifica Annenkova, 1937
- Potamethus malmgreni (Hansen, 1882)
- Sabellidae sp. 5

Scalibregmatidae
- Asclerocheilus beringianus Uschakov, 1955
- Asclerocheilus sp. 1
- Oligobregma aciculatum (Hartman, 1965)
- Oligobregma sp. 1
- Pseudoscalibregma parvum (Hansen, 1878)
- Scalibregma inflatum Rathke, 1843
- Sclerobregma branchiata Hartman, 1965
- Sclerobregma nr. stenocerum Bertelsen & Weston, 1980
- Sclerocheilus sp. 2

Serpulidae
- *Serpulidae sp. 1, sp. 2, sp. 3

Sigalionidae
- Leanira minor Hartman, 1965
- Leanira sp. 1, sp. 2, sp. 3
- Neoleanira tetragona (Oersted, 1845)
- Pareupholoe sp. 1

Sphaerodoridae
- Clavidorum sp. 1
- Commensodorum sp. 1
- Ephesiella macrocirrus Hartman & Fauchald, 1971
- Ephesiopsis guayanae Hartman & Fauchald, 1971
- Sphaerephesia sp. 1, sp. 2
- Sphaerodoridium sp. 1
- Sphaerodoropsis sp. 1, sp. 2, sp. 3

Spionidae
- Aonidella sp. 1
- Aonides paucibranchiata Southern, 1914
- Aonides sp. 1
- Aurospio dibranchiata Maciolek, 1981
- Laonice cirrata (Sars, 1851)
- Laonice sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 8, sp. 10, sp. 11, sp. 13, sp. 14, sp. 15, sp. 16, sp. 17, sp. M
- Microspio sp. 1, sp. 2, sp. 3,
- Prionospio cirrifera Wiren, 1883
- Prionospio delta Hartman, 1965
- Prionospio ehlersi Fauvel, 1928
- Prionospio fauchaldi Maciolek, 1985
- Prionospio steenstrupi Malmgren, 1867
- Prionospio sp. 1, sp. 2, sp. 3, sp. 6, sp. 7, sp. 8, sp. 9, sp. 11, sp. 13, sp. 14, sp. 16, sp. 17, sp. 18, sp. 20, sp. 21, sp. 24, sp. 25
- Scolecolepides carunculatus Maciolek, 1984
- Scolelepis sp. 1
- Spiophanes kroeyeri Grube, 1860
- Spiophanes sp. 1, sp. 3, sp. 5, sp. 6, sp. 10
- Spionidae n. gen., n. sp. 1; n. gen., n. sp. 2; n. gen., n. sp. 3; n. gen., n. sp. 4; n. gen., n. sp. 7; n. gen., n. sp. 8; n. gen., n. sp. 9; n. gen., n. sp. 11; n. gen., n. sp. 12

Sternaspidae
- Sternaspis scutata (Renier, 1807)

Syllidae
- Autolytus sp. 2
- Braniella nr. palpata Hartman, 1967
- Eusyllis lamelligera Marion & Bobretzky, 1875

Eusyllis sp. 1
Exogone verugera profunda Hartman, 1965
Exogone sp. 1, sp. 2, sp. 3
Parapionosyllis sp. 1
Sphaerosyllis sp. 1, sp. 2
Streptosyllis sp. 1
Syllides longocirrata Oersted; 1845
Syllis sp. 1
Syllides sp. 1
Syllidae sp. 1, sp. 2

Terebellidae
Amphitrite cirrata Muller, 1771
Artacama globosa
Hartman & Fauchald, 1971
Lysilla sp. 1
Nicolea sp. 1
Pista cristata (Muller, 1776)
Polycirrus sp. 3, sp. 4, sp. 6
Streblosoma sp. 1, sp. 2, sp. A
Amphitritinae sp. 1
Terebellidae sp. 1, sp. 3, sp. 6, sp. 7, sp. 10

Trichobranchidae
Terebellides sp. 1, sp. 2, sp. 4, sp. 5, sp. 6
Trichobranchus cf. roseus (Malm, 1874)
Trichobranchus sp. 1
Trichobranchidae sp. 3, sp. 5, sp. 6

Trochochaetidae
Trochochaeta watsoni
(Fauvel, 1916)

Uncispionidae
Uncispionidae n. gen., n. sp. 1

Unassigned
Aberranta enigmatica Hartman, 1965
Aberranta sp. 1
Polychaeta sp. 2, sp. 3, sp. 4, sp. 6, sp. 7

Oligochaeta
Tubificidae
Adelodrilus fimbriatus Erseus, 1983
Bathydrilus asymmetricus Cook, 1970
Limnodriloides medioporus Cook, 1969
Limnodriloides monothecus Cook, 1974
Limnodriloides rubicundus Erseus, 1982
Phallodrilus biparis Erseus, 1983
Phallodrilus grasslei Erseus, 1984
Phallodrilus sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6
Tubificoides aculeatus Cook, 1970
Tubificoides apectinatus Brinkhurst, 1965
Tubificoides intermedius (Cook, 1969)
Tubificoides maureri (complex)
Brinkhurst & Baker, 1979
Tubificoides sp. 3, sp. 4
Tubificidae sp. 2, sp. 3

Enchytraeidae
Grania atlantica Coates & Erseus, 1985

ECHIURA
Echiura sp. 1, sp. 2, sp. 3, sp. 4, sp. 6

SIPUNCULA
Aspidosiphon zinni Cutler, 1969
Apionsoma murinae Cutler, 1969
Golfingia elongata (Keferstein, 1862)
Golfingia improvisa (Theel, 1905)
Golfingia margaritacea (Sars, 1851)
Golfingia sp. 6
Nephasoma abyssorum (Herubel, 1925)
Nephasoma bulbosum (Southern, 1912)
Nephasoma cf. capilleforme (Murina, 1973)
Nephasoma diaphanes (Gerould, 1913)
Nephasoma eremita (Sars, 1851)
Nephasoma flagriferum (Selenka, 1885)
Onchnesoma squamatum
(Koren & Danielssen, 1875)
Phascolion lutense Selinka, 1885
Phascolion strombi (Montagu, 1804)
Sipunculus norvegicus
Koren & Danielssen, 1875
Sipunculus sp. 2
Sipuncula sp. 3, sp. 8

POGONOPHORA
Diplobrachia similis
Southward & Brattegard, 1968
Lamellisabella coronata Southward, 1969
Nereilinum sp. 1
Oligobrachia floridana Nielsen, 1965
Polybrachia lepida
Southward & Brattegard, 1968
Siboglinum angstum
Southward & Brattegard, 1968
Siboglinum bayeri Southward, 1971

Siboglinum ekmani Jagersten, 1956
Siboglinum fulgens
Southward & Brattegard, 1968
Siboglinum longicollum
Southward & Brattegard, 1968
Siboglinum pholidotum
Southward & Brattegard, 1968
Siboglinum sp. 2, sp. 11, sp. 15

MOLLUSCA

Gastropoda

Archaeogastropoda

Cocculina spp. indeterminate
Cyclostrema ponsonbyi
Dautzenberg & Fisher, 1897
Lissospira diaphana (Verrill, 1884)
Lissospira sp. 1, sp. 4
Propilidium pertenue Jeffreys, 1882
Solariella tubula Dall, 1927
Solariella sp. 1
Solariellinae sp. 3
Cyclostrematidae sp. 2

Cephalaspida

Acteocina sp. 1
Acteon delicatus Dall, 1889
Acteon hebes (Verrill, 1885)
Crenilabrum exilis (Jeffreys, 1870)
Cylichna alba (Brown, 1827)
Cylichna eburnea Verrill, 1885
Cylichna gouldi (Couthouy, 1839)
Cylichna vortex (Dall, 1881)
Philine sagra d'Orbigny, 1841
Philine sp. 1
Retusa obtusa (Montagu, 1807)
Retusa ovata (Jeffreys, 1870)
Retusa pertenuis (Mighels, 1843)

Entomotaeniata

Odostomia sp. 1
Turbonilla bushiana Verrill, 1882
Turbonilla bushiana var. abyssicola
Bartsch, 1909
Turbonilla emertoni Verrill,1882

Mesogastropoda

Aclis cf. tenuis Verrill, 1882
Aclis walleri (Jeffreys, 1884)
Alvania acuticostata (Dall, 1889)
Atlanta spp. indeterminate
Balcis sp. 1
Benthonella gaza Dall, 1889
Caecum sp. 1
Haliella stenostoma (Jeffreys, 1858)
Omalogyra densicostata (Jeffreys, 1884)
Omalogyra sp. 1
Truncatella sp. 1

Neogastropoda

Benthobia tyronii Dall, 1883
Benthomangelia macra (Watson, 1881)
Colus caelatus (Verrill & Smith, 1880)
Colus pygmaeus (Gould, 1841)
Corinnaeturris leucomata (Dall, 1881)
Eubela sofia var. hyperlissa (Dall, 1889)
Gymnobela agassizii (Verrill & Bush, 1880)
Gymnobela aquilarium (Watson, 1881)
Mitrella pura Verrill, 1882

Aplacophora

Chaetoderma sp. 3, sp. 10, sp. 11, sp. 12
Falcidens caudatus (Heath, 1918)
Falcidens sp. 2, sp. 4
Prochaetoderma yongei Scheltema, 1985
Pruvotina sp. 1
Psilodens sp. 5
Spathoderma clenchi Scheltema, 1985
Uncimenia sp. 1
Lepidomeniidae sp. 1, sp. 2, sp. 3, sp. 4,
sp. 5, sp. 6, sp. 7, sp. 8, sp. 9, sp. 11,
sp. 12, sp. 13
Neomeniidae sp. 1, sp. 2, sp. 3, sp. 4, sp. 5,
sp. 6, sp. 7
Neomeniomorpha sp. 2
Prochaetodermatidae sp. 1, sp. 2, sp. 3
*Wireniidae spp.

Bivalvia

Arcoida

Bathyarca sp. 1, sp. 2, sp. 3
Limopsis tenella Jeffreys, 1876
Limopsis nr. surinamensis
Oliver & Allen, 1980
Nucinella sp. 1
Arcidae spp. (juvenile)

Myoida

Xyloredo sp. 1

Mytiloida
- Dacrydium sp. 1

Nuculoida
- Brevinucula verrilli (Dall, 1886)
- Lametila abyssorum Allen & Sanders, 1973
- Malletia abyssorum (Verrill & Bush, 1898)
- Malletia nr. cuneata (Jeffreys, 1876)
- Malletia johnsoni Clarke, 1961
- Malletia sp. 1, sp. 2
- Neilonella subovata (Verrill & Bush, 1897)
- Nucula cancellata Jeffreys, 1881
- Nucula granulosa Verrill, 1884
- Nucula subovata Verrill & Bush, 1898
- Nucula sp. 2, sp. 3, nr. sp. D
- Nuculana (Jupiteria) sp. 1
- Pristogloma alba (Sanders & Allen, 1973)
- Pristogloma nitens (Jeffreys, 1876)
- Spinula sp. 1
- Tindaria acinula (Dall, 1890)
- Tindaria sp. 3, sp. A
- Tindariopsis sp. 1
- Yoldia thraciaeformis Storer, 1838
- Yoldiella curta Verrill & Bush, 1898
- Yoldiella dissimilis (Verrill & Bush, 1898)
- Yoldiella frigida (Torell, 1859)
- Yoldiella inconspicua (Verrill & Bush, 1898)
- Yoldiella lucida (Loven, 1846)

Pholadomyoida
- Cardiomya perrostrata (Dall, 1881)
- Cuspidaria atlantica Allen & Morgan, 1981
- Cuspidaria nr. fraterna Verrill & Bush, 1893
- Cuspidaria obesa (Loven, 1846)
- Cuspidaria parva Verrill & Bush, 1898
- Lyonsiella abyssicola (Sars, 1872)
- nr. Halonympha sp. 1
- Myonera paucistriata Dall, 1886
- Periploma sp. 1, sp. 2
- Policordia sp. 1
- Protocuspidaria sp. 1
- Verticordia nr. triangularis Locard, 1898
- Cuspidaridae sp. 4, sp. 5
- Poromyidae sp. 1
- Verticordiidae sp. 1

Pteroida
- Catillopecten eucymatus (Dall, 1898)
- Limatula setifera Dall, 1886
- Limatula sp. 1

Solemyoida
- Solemya sp. 1

Veneroida
- Abra longicallis americana Verrill & Bush, 1898
- Astarte sp. 1
- Cerastoderma pinnulatum (Conrad, 1831)
- Kelliella sp. 1, sp. 2
- Lucinoma filosa (Stimpson, 1851)
- Semele sp. 1
- Tellina sp. 1
- Thyasira brevis (Verrill & Bush, 1898)
- Thyasira croulinensis (Jeffreys, 1874)
- Thyasira equalis (Verrill & Bush, 1898)
- Thyasira ferruginea (Locard, 1886)
- Thyasira (Leptaxinus) minutus (Verrill & Bush, 1898)
- Thyasira obsoleta (Verrill & Bush, 1898)
- Thyasira pygmaea (Verrill & Bush, 1898)
- Thyasira rotunda Jeffreys, 1881
- Thyasira subovata (Jeffreys, 1881)
- Thyasira tortuosa (Jeffreys, 1881)
- Thyasira trisinuata (d'Orbigny, 1846)
- Thyasira sp. 6, sp. 13, sp. 14

Unassigned
- Bivalvia sp. 7, sp. 8, sp. 10

Scaphopoda

Dentaliidae
- Antalis entale Linnaeus, 1758
- Antalis sp. A
- Bathoxiphus ensiculus (Jeffreys, 1877)
- Compressidens sp. 1
- Fissendentalium nr. meridionale (Pilsbry & Sharp, 1897)
- Dentaliidae sp. 2

Siphonodentaliidae
- Cadulus atlanticus Henderson, 1920
- Cadulus nr. minisculus Dall, 1889
- Cadulus pandionis Verrill & Smith, 1880
- Cadulus nr. transitorius Henderson, 1920
- Entalina platamodes (Watson, 1879)
- Pulsellum affine (Sars, 1864)
- Pulsellum verrilli (Henderson, 1920)
- Siphonodentalium grandis (Verrill, 1884)
- Striopulsellum sp. 1

ARTHROPODA
CHELICERATA
Pycnogonida
*Nymphon spp. indeterminate

Arachnida
*Acarina

CRUSTACEA
Cephalocarida
Hutchinsoniella macracantha (Sanders, 1965)

Ostracoda
*Myodocopa

Cumacea
Bodotriidae
Cyclaspis spectabilis Zimmer, 1908

Diastylidae
Leptostylis sp. 1
Makrokylindrus sp. 4
Vemakylindrus hastata (Hansen, 1920)
Diastylidae sp. 1

Lampropidae
Bathylamprops motasi Bacescu & Muradian, 1976
Hemilamprops cristatus Sars, 1870
Hemilamprops sp. 1
Paralamprops sp. 1, sp. 2

Leuconidae
Eudorella cf. pusilla G.O. Sars, 1871
Eudorella sp. 2
Leucon serratus Norman, 1876
Leucon sp. 1, sp. 10, sp. 11
Leuconidae sp. 1, sp. 2 (juvenile)

Nannastracidae
Atlantocuma n. sp. 1
Campylaspis vitrea (Calman, 1906)
Campylaspis sp. 3, sp. 4
Cumella antipai (Bacescu & Muradian, 1974)
Cumella sp. 3, sp. 4, sp. 5, sp. 6, sp. 7
Cumellopsis sp. 1

Decapoda
Penaeidea
Lucifer sp. 1
Sergestidae sp. 1

Anomura: Axiidae
Calocaris templemani (Squires, 1965)
Paguridae spp. (juvenile)

Isopoda
Arcturidae
Astacilla sp. 1

Cirolanidae
Cirolana borealis (Liljeborg, 1851)
Eurydice sp. 1

Dendrotioniidae
Dendrotion sp. 1

Desmosomatidae
Chelator insignis (Hansen, 1916)
Chelator verecundus Hessler, 1970
Chelator vulgaris Hessler, 1970
Chelator sp. 3
Desmosoma lineare G.O. Sars, 1864
Eugerda fulcimandibulata Hessler, 1970
Eugerda latipes (Hansen, 1916)
Eugerda tetarta Hessler, 1970
Eugerdella pugilator Hessler, 1970
Mirabilicoxa gracilipes (Hansen, 1916)
Mirabilicoxa similis (Hansen, 1916)
Momedossa sp. 1
Oecidiobranchus plebejum (Hansen, 1916)
Prochelator lateralis (G.O. Sars, 1899)
Prochelator uncatus Hessler, 1970
Pseudomesus sp. 1
Torwolia creper Hessler, 1970
Torwolia subchelatus Hessler, 1970
Whoia angusta (G.O. Sars, 1899)

Eurycopidae
Betamorpha fusiformis (Barnard, 1920)
Disconectes sp. 1
Eurycope grasslei Wilson, 1982
Munnopsurus sp. 1
Eurycopidae n. gen. Y sp. 1

Gnathiidae
Gnathia sp. 1, sp. 2

Haploniscidae
Haploniscus sp. 1, sp. 2, sp. 3
Hydroniscus sp. 1

Ilyarachnidae
Ilyarachna hirticeps G.O. Sars, 1870
Ilyarachna longicornis (G.O. Sars, 1864)

Ischnomesidae
Haplomesus sp. 1, sp. 2, sp. 7
Heteromesus sp. 5
Ischnomesus sp. 2, sp. 4, sp. 5

Janiridae
Ioella nr. spinosa (Harger, 1879)
Janirella sp. 1, sp. 2

Macrostylidae
Macrostylis sp. 1, sp. 2, sp. 4, sp. 5

Munnidae
Munna cf. acanthifera Hansen, 1916
Pleurogonium pulchrum Hansen, 1916
Pleurogonium rubicundrum Sars, 1863
Pleurogonium nr. spinosissimum (Sars, 1865)

Nannoniscidae
Exiliniscus clipeatus
Siebenaller & Hessler, 1981
Nannoniscus minutus Hansen, 1916
Nannoniscus sp. 3
Thaumostoma platycarpus Hessler, 1970

Thambematidae
Thambema sp. 1

Tanaidacea
Agathotanaidae
Agathotanais cf. hanseni Lang, 1970
Paragathotanais cf. typicus Lang, 1970
Paragathotanais sp. 1

Anarthruridae
Anarthrura cf. simplex G.O. Sars, 1882
Paranarthrura cf. insignis Hansen, 1913
Paranarthrura sp. 1
Siphonolabrum sp. 1, sp. 2
Anarthruridae sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 7

Apseudidae
Sphyrapus sp. 1

Leptocheliidae
Pseudoleptochelia filum (Stimpson, 1853)
Leptocheliidae sp. 1, sp. 2

Leptognathiidae
Araphura sp. 1
Collettea cf. cylindrata (G.O. Sars, 1882)
Collettea sp. 2
Filitanais sp. 1
Leptognathia cf. armata Hansen, 1913
Leptognathia breviremus (Lilljeborg, 1864)
Leptognathia gracilis (Kroyer, 1842)
Leptognathia multiserrata Hansen, 1913
Leptognathia ochracea (Hansen, 1913)
Leptognathia uncinata Hansen, 1913
Leptognathia unguicillata
(Norman & Stebbing, 1886)
Leptognathia voringii (Sars, 1877)
Leptognathia sp. 3, sp. 4, sp. 5, sp. 7, sp. 8, sp. 9, sp. 10, sp. 11, sp. 12, sp. 13, sp. 17, sp. 18, sp. 19, sp. 20, sp. 22, sp. 23, sp. 24, sp. 25, sp. 26, sp. 27, sp. 34, sp. 35, sp. 36, sp. 37, sp. 38, sp. 39, sp. 41, sp. 42, sp. 43, sp. 44, sp. 45
Leptognathiella abyssi (Hansen, 1913)
Leptognathiella spinicauda
Bird & Holdich, 1985
Leptognathiella sp. 2, sp. 3
Macrinella sp. 2
Stenotanais crassiseta Holdich & Bird, 1984
Stenotanais sp. 1, sp. 2, sp. 3, sp. 4
Typhlotanais nr. spinicauda Hansen, 1913
Typhlotanais trispinosus Hansen, 1913
Typhlotanais sp. 1, sp. 2, sp. 3, sp. 11, sp. 12, sp. 13, sp. 16, sp. 19, sp. 20, sp. 21, sp. 22
Leptognathiidae sp. 1

Neotanaidae
Neotanais affinis Wolff, 1956
Neotanais americanus Beddard, 1886
Neotanais micromorpher Gardiner, 1975
Neotanais sandersi Gardiner, 1975

Nototanaidae
Tanaissus sp. 1

Pseudotanaidae
Cryptocope cf. abbreviata (Sars, 1868)
Pseudotanais sp. 1, sp. 2, sp. 3, sp. 4, sp. 5

Whitelegiidae
Leviapseudes gracillimus (Hansen, 1913)
Leviapseudes zenkevitchioides Bacescu, 1981
Leviapseudes sp. 1

Amphipoda
Ampeliscidae
Ampelisca agassizi (Judd, 1896)
Ampelisca pugetica Barnard, 1954
Byblis brachycephala Mills, 1971
Haploops setosa Boeck, 1871
Haploops sp. 1, sp. 2

Amphilochidae
Amphilochus sp. 2

Aoridae
Unciola sp. 1, sp. 2, sp. 3

Caprellidae
*Caprellidae n. gen., n. sp. 1

Corophiidae
Corophium bonelli (Milne Edwards, 1830)
Corophium sp. 1 (juvenile)
Erichthonius sp. 3, sp. 4
Gammaropsis sp. 1
Corophiidae n. gen., n. sp. 1; sp. 2

Dexaminidae
Lepechinella raja Barnard, 1973

Eusiridae
*Eusirus sp. 1
Eusiridae sp. 2*, sp. 3*, sp. 4

Haustoriidae
Carangolia sp. 1

Liljeborgiidae
Liljeborgia sp. 2
Listriella sp. 1

Lysianassidae
Lepidepecreum sp. 1
Lysianassidae sp. 1, sp. 3, sp. 4, sp. 5, sp. 7, sp. 8, sp. 9, sp. 11, sp. 17, sp. 19

Melphidippidae
Melphidippidae sp. 1

Oedicerotidae
Aceroides sp. 1
Arrhis sp. 1
Bathymedon sp. 1, sp. 2
Monoculodes sp. 10
Synchelidium sp. 1
Oedicerotidae sp. 5, sp. 6, sp. 7, sp. 10, sp. 16

Pardaliscidae
Caleidoscopis sp. 1
*Nicippe sp. 1
Pardaliscella symmetrica Barnard, 1959
Rhynohalicella sp. 1

Phoxocephalidae
Eobrolgus sp. 1
Harpinia clivicola Watling, 1981
Harpinia crenulata G.O. Sars, 1891
Harpinia propinqua G.O. Sars, 1891
Harpinia truncata Sars, 1891
Harpinia sp. 2, sp. 8, sp. 10
Leptophoxus sp. 1
Pseudharpinia sp. 1
Phoxocephalidae sp. 1

Podoceridae
Podoceridae sp. 1

Stenothoidae
Stenothoidae sp. 1, sp. 2, sp. 3, sp. 6

Synopiidae
*Syrrhoites sp. 1
*Synopiidae sp. 1, sp. 2

Unassigned
Amphipoda sp. 2*, sp. 8

BRYOZOA
Aethozoon pellucida Hayward, 1978
*Anasca sp. 1, sp. 2
*Bugula sp. 1

*Crisia eburnea (Linnaeus, 1758)
*Euginoma cavalieri Lagaaij, 1963
*Euginoma sp. 2, sp. 3
*Formosocellaria abyssicola d'Hondt, 1981
*Membranipora tuberculata (Bosc, 1802)
*Notoplites sp. 1
*Pseudocellaria sp. 1
*Sphaerulobryozoan pendunculatum d'Hondt, 1981
*Ctenostomata sp. 1, sp. 2, sp. 3

BRACHIOPODA
*Cryptopora gnomon Jeffreys, 1869
*Pelagodiscus atlanticus (King, 1868)
*Brachiopoda sp. 1

ECHINODERMATA
Crinoidea
Crinoidea sp. 1 (juvenile)

Echinoidea
Brisaster sp. 1 (juvenile)
Brissopsis sp. 1
Pourtalesia sp. 1
Echinoidea sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 7 (all juveniles)
Spantagoidea sp. 1

Ophiuroidea
Amphilepsis sp. 1 (juvenile), sp. 2
Amphipolis squamata (delle Chiaje, 1828)
Amphiura griegi Mortenson, 1920
Amphiura palmeri Lyman, 1882
Homalophiura falcifera Lyman, 1869
Ophiacantha abyssicola Sars, 1871
Ophiomusium lymani Wyv. Thomson, 1874
Ophiura sp. 1 (juvenile), sp. 2, sp. 3 (juvenile)
Amphiuridae sp. 3 (juvenile)
Ophiolepidae sp. 1
Ophiuroidea sp. 2, sp. 7, sp. 8 sp. 9 (all juveniles)

Asteroidea
Hemiaster expergitus Loven, 1875
Porcellanaster caeruleus Thompson, 1877

Holothuroidea
Acanthotrochus mirabilis Danielssen & Koren, 1879
Echinocucumis hispida (Barrett, 1856)
Elpidia sp. 1 (juvenile)
Hedingia albicans (Theel, 1886)
Labidoplax buskii (McIntosh, 1866)
Molpadia blakei (Theel, 1886)
Molpadia musculus (Risso, 1826)
Molpadia sp. 2 (juvenile)
Myriotrochinae sp. 1 (juvenile)
Holothuroidea sp. 2, sp. 3 (juveniles)

HEMICHORDATA
Enteropneusta sp. 1, sp. 2, sp. 3, sp. 4

CHORDATA
Dicarpa simplex Millar, 1955
*Corellidae sp. 1
*Polyclinidae sp. 1

APPENDIX D

TABLE D.1. DOMINANT SPECIES AT EACH U.S. SOUTH ATLANTIC STATION FOR EACH SAMPLING PERIOD.

Station 1

Nov 1983	May 1984	July 1984
Fabricia sp. 1	Fabricia sp. 1	Fabricia sp. 1
Meiodorvillea minuta	Meiodorvillea minuta	Meiodorvillea minuta
Galathowenia sp. 1	Galathowenia sp. 1	Thyasira (Leptaxinus) minutus
Thyasira (Leptaxinus) minutus	Auchenoplax crinita	Galathowenia sp. 1
Barantolla sp. 1	Limnodriloides monothecus	Barantolla sp. 1
Paradoneis lyra	Thyasira (Leptaxinus) minutus	Tharyx sp. 1
Ophelina abranchiata	Barantolla sp. 1	Tharyx sp. 2
Tharyx sp. 2	Tharyx sp. 1	Paradoneis lyra
Auchenoplax crinita	Ophelina abranchiata	Auchenoplax crinita
Tharyx sp. 1	Cossura longocirrata	Ninoe nigripes
Ninoe nigripes	Euchone hancocki	Ophelina abranchiata
Cossura longocirrata	Levinsenia sp. 1	Euchone hancocki
Ceratocephale loveni	Paradoneis lyra	Cossura longocirrata
Flabelligella cirrata	Paradoneis brevicirratus	Thyasira croulinensis
Myriochele sp. 1	Dysponetus sp. 1	Tubificoides apectinatus
Euchone hancocki	Ninoe nigripes	Paradoneis brevicirratus
Levinsenia sp. 1	Tharyx sp. 2	Limnodriloides monothecus
Limnodriloides monothecus	Phascolion strombus	Limnodriloides rubicundus
Ophelina cylindricaudata	Flabelligella cirrata	Levinsenia sp. 1
Lepidomeniidae sp. 1	Aurospio dibranchiata	Ceratocephale loveni

Station 2

Nov 1983	May 1984	July 1984
Cossura longocirrata	Meiodorvillea minuta	Meiodorvillea minuta
Tubificoides sp. 3	Cossura longocirrata	Tubificoides sp. 3
Meiodorvillea minuta	Tubificoides sp. 3	Cossura longocirrata
Paradoneis lyra	Paradoneis lyra	Paradoneis lyra
Nemertea sp. A	Dysponetus sp. 1	Levinsenia flava
Levinsenia flava	Nemertea sp. A	Braniella nr. palpata
Cossura sp. 1	Levinsenia flava	Kelliella sp. 1
Dysponetus sp. 1	Grania atlantica	Nemertea sp. 5
Thyasira (Leptaxinus) minutus	Flabelligella cirrata	Cossura sp. 1
Tharyx sp. 1	Thyasira subovata	Dysponetus sp. 1
Kelliella sp. 1	Braniella nr. palpata	Thyasira (Leptaxinus) minutus
Flabelligella cirrata	Kelliella sp. 1	Thyasira croulinensis
Labidoplax buskii	Cossura sp. 1	Flabelligella cirrata
Grania atlantica	Pholoe anoculata	Labidoplax buskii
Braniella nr. palpata	Prionospio sp. 1	Myriotrochinae sp. 1 juv.
Tubificoides apectinatus	Tharyx sp. 1	Nemertea sp. 3
Lepidomeniidae sp. 1	Thyasira tortuosa	Thyasira subovata
Nemertea sp. 3	Labidoplax buskii	Prochaetodermatidae sp. 1
Thyasira croulinensis	Thyasira (Leptaxinus) minutus	Tharyx sp. 1
Prochaetodermatidae sp. 1	Prochaetodermatidae sp. 1	Nemertea sp. 2

TABLE D.1. (Continued).

Station 3 Nov 1983	May 1984	July 1984
Pholoe anoculata	Pholoe anoculata	Pholoe anoculata
Aspidosiphon zinni	Aurospio dibranchiata	Auropsio dibranchiata
Aurospio dibranchiata	Bathydrilus asymmetricus	Aspidosiphon zinni
Bathydrilus asymmetricus	Labidoplax buskii	Labidoplax buskii
Labidoplax buskii	Aspidosiphon zinni	Bathydrilus asymmetricus
Haploops setosa	Tubificoides aculeatus	Prionospio sp. 11
Tubificoides sp. 3	Prochaetoderma yongei	Siboglinum pholidotum
Prochaetodermatidae sp. 1	Prochaetodermatidae sp. 1	Haploops setosa
Prionospio sp. 2	Haploops setosa	Prochaetoderma yongei
Dysponetus sp. 1	Nemertea sp. A	Nemertea sp. 2
Prochaetoderma yongei	Nephasoma diaphanes	Myriotrochinae sp. 1 juv.
Nemertea sp. A	Myriotrochinae sp. 1 juv.	Prochaetodermatidae sp. 1
Falcidens sp. 2	Levinsenia sp. 2	Byblis brachycephala
Prionospio sp. 11	Nemertea sp. 2	Nephasoma diaphanes
Levinsenia sp. 1	Tharyx sp. 1	Tubificoides aculeatus
Myriochele cf. heeri	Prionospio sp. 2	Prionospio sp. 2
Nephasoma abyssorum	Echinoidea sp. 3 juv.	Nephasoma abyssorum
Myriotrochinae sp. 1 juv.	Prionospio sp. 11	Levinsenia sp. 1
Tharyx sp. 1	Dysponetus sp. 1	Cossura sp. 2
Peoecilochaetus fulgoris	Siboglinum pholidotum	Striopulsellum atlantisae

TABLE D.1. (Continued).

Station 4

Nov 1983	May 1984	July 1984
Microrbinia linea	Microrbinia linea	Microrbinia linea
Prionospio sp. 2	Aspidosiphon zinni	Prionospio sp. 2
Aspidosiphon zinni	Pholoe anoculata	Pholoe anoculata
Aurospio dibranchiata	Aurospio dibranchiata	Siboglinum pholidotum
Pholoe anoculata	Prionospio sp. 2	Aurospio dibranchiata
Siboglinum pholidotum	Anarthruridae sp. 1	Aspidosiphon zinni
Streblosoma sp. 2	Sabidius cornatus	Sabidius cornatus
Sabidius cornatus	Spathoderma clenchi	Prochaetoderma yongei
Prochaetoderma yongei	Dysponetus sp. 4	Anarthruridae sp. 1
Anarthruridae sp. 1	Siboglinum pholidotum	Notomastus latericeus
Haploops setosa	Prionospio sp. 11	Thyasira ferruginea
Myriochele sp. 1	Tharyx sp. 1	Spathoderma clenchi
Grania atlantica	Grania atlantica	Dysponetus sp. 4
Kesun gravieri	Nemertea sp. 2	Nemertea sp. 5
Tubificoides aculeatus	Glycera capitata	Glycera capitata
Paradoneis abranchiata	Kesun gravieri	Myriotrochinae sp. 1 juv.
Spathoderma clenchi	Trochochaeta watsoni	Haploops setosa
Aglaophamus sp. 1	Myriotrochinae sp. 1 juv.	Nemertea sp. 2
Glycera capitata	Thyasira croulinensis	Siboglinum fulgens
Dysponetus sp. 4	Prochaetoderma yongei	Myriochele sp. 1

May 1985	Sept 1985	Nov 1985
Microrbinia linea	Microrbinia linea	Microrbinia linea
Anarthruridae sp. 1	Pholoe anoculata	Pholoe anoculata
Aspidosiphon zinni	Aurospio dibranchiata	Aspidosiphon zinni
Pholoe anoculata	Prionospio sp. 2	Aurospio dibranchiata
Prionospio sp. 2	Aspidosiphon zinni	Siboglinum pholidotum
Aurospio dibranchiata	Anarthruridae sp. 1	Prionospio sp. 2
Siboglinum pholidotum	Siboglinum pholidotum	Sabidius cornatus
Sabidius cornatus	Sabidius cornatus	Nemertea sp. 2
Spathoderma clenchi	Aglaophamus sp. 1	Glycera capitata
Levinsenia sp. 1	Glycera capitata	Tubificoides aculeatus
Notomastus latericeus	Haplomeus sp. 2	Gnathia sp. 2
Nephasoma diaphanes	Notomastus latericeus	Aglaophamus sp. 1
Aglaophamus sp. 1	Nemertea sp. A	Dysponetus sp. 3
Kesun gravieri	Dysponetus sp. 4	Spathoderma clenchi
Nemertea sp. 5	Spathoderma clenchi	Anarthruridae sp. 1
Glycera capitata	Myriotrochinae sp. 1 juv.	Nephasoma diaphanes
Dysponetus sp. 4	Sclerobregma branchiata	Dysponetus sp. 4
Spiophanes kroeyeri	Tharyx sp. 7	Notomastus latericeus
Prionospio sp. 11	Prionospio sp. 11	Tharyx sp. 1
Sclerobregma branchiata	Tubificoides aculeatus	Prochaetoderma yongei

TABLE D.1. (Continued).

Station 5

Nov 1983	May 1984	July 1984
Prionospio fauchaldi	Siphonolabrum sp. 1	Aspidosiphon zinni
Macrostylis sp. 1	Siboglinum angstum	Macrostylis sp. 1
Brevinucula verrilli	Macrostylis sp. 1	Brevinucula verrilli
Prionospio sp. 2	Prionospio sp. 2	Prionospio sp. 2
Heteromastus sp. 1	Thambema sp. 1	Macrostylis sp. 4
Exogone sp. 1	Brevinucula verrilli	Siboglinum angstum
Laonice sp. 2	Dacrydium sp. 1	Leptognathia sp. 9
Kesun gravieri	Nemertea sp. A	Nemertea sp. 2
Stenotanais sp. 1	Laonice sp. M	Sabidius cornatus
Thambema sp. 1	Harpinia sp. 2	Ophelina abranchiata
Nemertea sp. A	Aspidosiphon zinni	Harpinia sp. 2
Siboglinum angstum	Prionospio ehlersi	Prionospio sp. 3
Phallodrilus biparis	Prionospio faunchaldi	Dacrydium sp. 1
Laonice sp. M	Leptophoxus sp. 1	Nemertea sp. 5
Lineus sp. 1	Glycera capitata	Leptognathia sp. 4
Thyasira brevis	Echinoidea sp. 5 juv.	Exogone sp. 1
Ophelina cylindricaudata	Macrostylis sp. 4	Aricidea sp. 5
Leptognathia sp. 4	Enteropneusta sp. 1	Kelliella sp. 1
Bivalve sp. 7	Cardiomya perrostrata	Spathoderma clenchi
Ophelina abranchiata	Chaetoderma sp. 3	Labidoplax buskii

Station 6

Nov 1983	May 1984	July 1984
Tubificoides aculeatus	Pholoe anoculata	Pholoe anoculata
Pholoe anoculata	Tubificoides sp. 4	Tubificoides aculeatus
Aurospio dibranchiata	Tubificoides aculeatus	Spathoderma clenchi
Spathoderma clenchi	Aurospio dibranchiata	Aurospio dibranchiata
Siphonolabrum sp. 2	Barantolla sp. 3	Nemertea sp. 5
Tharyx sp. 1	Leptognathia sp. 10	Sabidius cornatus
Lumbrineris latreilli	Prochaetoderma yongei	Lumbrineris latreilli
Prochaetoderma yongei	Tharyx sp. 1	Aglaophamus sp. 1
Nemertea sp. A	Lumbrineris latreilli	Aspidosiphon zinni
Anarthruridae sp. 1	Siphonolabrum sp. 2	Prochaetodermatidae sp. 1
Ninoe nr. brevipes	Spathoderma clenchi	Barantolla sp. 3
Barantolla sp. 3	Tharyx sp. 6	Falcidens sp. 4
Myriochele sp. 1	Falcidens sp. 4	Glycera capitata
Aglaophamus sp. 1	Glycera capitata	Prochaetoderma yongei
Falcidens sp. 4	Thyasira tortuosa	Ninoe nr. brevipes
Oecidiobranchus plebejum	Tubificoides maureri (complex)	Siphonolabrum sp. 2
Siboglinum pholidotum	Aglaophamus sp. 1	Tharyx sp. 1
Galathowenia sp. 1	Anarthruridae sp. 1	Dysponetus sp. 4
Glycera capitata	Califia schmitti	Notomastus latericeus
Sabidius cornatus	Kesun gravieri	Siboglinum pholidotum

TABLE D.1. (Continued).

Nov 1983	May 1984	July 1984
Station 7		
No samples taken	Siboglinum angstum Prionospio fauchaldi Leptognathia sp. 23 Dentaliidae sp. 2 Myriochele sp. 8 Glycinde profunda Siboglinum sp. 2 Sigambra sp. 2 Paragathotanais sp. 1 Hesionidae sp. 6 Aglaophamus sp. 1 Siboglinum sp. 15 Siboglinum fulgens Nemertea sp. 5 Thyasira subovata Aspidosiphon zinni Leptognathia sp. 9 Progoniada regularis Leptognathia uncinata Nemertea sp. 3	No samples taken

July 1984	May 1985	Sept 1985
Station 9		
Cossura longocirrata Limnodriloides medioporus Scalibregma inflatum Tubificoides intermedius Aricidea quadrilobata Pseudotanais sp. 5 Schistomeringos caeca Leitoscolopos acutus Terebellides sp. 4 Chaetozone sp. 11 Dorvilleidae sp. 2 Pleurogonium nr. spinosissimum Melinna cristata Thyasira rotunda Athecata sp. A Ceratocephale loveni Nemertea sp. A Levinsenia sp. 1 Lumbrineris fragilis Ninoe nr. brevipes	Scalibregma inflatum Cossura longocirrata Limnodriloides medioporus Tubificoides intermedius Aricidea quadrilobata Pseudotanais sp. 5 Schistomeringos caeca Terebellides sp. 4 Chaetozone sp. 11 Dorvilleidae sp. 2 Leitoscoloplos acutus Pleurogonium nr. spinosissimum Nicolea sp. 1 Ceratocephale loveni Lumbrineris fragilis Nemertea sp. A Praxillella sp. 1 Thyasira rotunda Levinsenia sp. 1 Erichthonius sp. 3	Cossura longocirrata Scalibregma inflatum Limnodriloides medioporus Tubificoides intermedius Aricidea quadrilobata Leitoscoloplos acutus Pseudotanais sp. 5 Schistomeringos caeca Terebellides sp. 4 Pleurogonium nr. spinosissimum Erichthonius sp. 3 Chaetozone sp. 11 Pseudoleptochelia filum Nicolea sp. 1 Dorvilleidae sp. 2 Ceratocephale loveni Lumbrineris fragilis Thyasira rotunda Tindaria sp. 3 Melinna cristata

TABLE D.1. (Continued).

Station 10

May 1985	Sept 1985	Nov 1985
Cossura longocirrata		Cossura longocirrata
Harpinia clivicola		Tharyx sp. 1
Tharyx sp. 1		Harpinia clivicola
Thyasira equalis		Paradoneis lyra
Barantolla sp. 3		Barantolla sp. 3
Myriochele sp. 4		Aricidea sp. 6
Thyasira (Leptaxinus) minutus		Thyasira equalis
Aricidea sp. 6		Ophryotrocha sp. 1
Thyasira croulinensis		Scalibregma inflatum
Paradoneis lyra		Thyasira tortuosa
Thyasira tortuosa		Levinsenia sp. 1
Athecata sp. A	No samples taken	Ophelina cylindricaudata
Myriochele sp. 6		Microphthalmus sp. 2
Galathowenia sp. 1		Falcidens sp. 2
Aricidea sp. 4		Aricidea catherinae
Levinsenia sp. 1		Thyasira (Leptaxinus) minutus
Falcidens sp. 2		Tubificoides maureri (complex)
Yoldiella curta		Neilonella subovata
Aricidea catherinae		Yoldiella lucida
Scalibregma inflatum		Maldanidae sp. 3

Station 11

May 1985	Sept 1985	Nov 1985
Microrbinia linea	Microrbinia linea	Microrbinia linea
Leptocheliidae sp. 1	Leptocheliidae sp. 1	Leptocheliidae sp. 1
Aspidosiphon zinni	Tubificoides sp. 3	Aspidosiphon zinni
Bathydrilus asymmetricus	Bathydrilus asymmetricus	Bathydrilus asymmetricus
Chone sp. 5	Kelliella sp. 1	Chone sp. 5
Kelliella sp. 1	Aspidosiphon zinni	Spionidae n. gen. n. sp. 11
Nephasoma diaphanes	Tharyx sp. 1	Kelliella sp. 1
Jasmineira filiformis	Jasmineira filiformis	Myriotrochinae sp. 1 juv.
Bathyarca sp. 1	Myriorochinae sp. 1 juv.	Jasmineira filiformis
Tubificoides sp. 3	Limnodriloides monothecus	Bathyarca sp. 1
Myriotrochinae sp. 1 juv.	Cossura sp. 2	Tubificoides sp. 3
Lumbrineris latreilli	Chone sp. 5	Tharyx sp. 1
Spionidae n. gen. n. sp. 11	Spionidae n. gen. n. sp. 11	Nephasoma abyssorum
Meiodorvillea minuta	Thyasira croulinensis	Cossura sp. 2
Cossura sp. 2	Leptognathiella sp. 3	Lumbrineris latreilli
Nephasoma abyssorum	Bathyarca sp. 1	Phallodrilus sp. 2
Myriochele sp. 4	Myriochele sp. 4	Meiodorvillea minuta
Nemertea sp. 2	Levinsenia sp. 1	Leptognathiella sp. 3
Limnodriloides monothecus	Thyasira (Leptaxinus) minutus	Thyasira croulinensis
Pholoe anoculata	Nemertea sp. 13	Nemertea sp. 2

TABLE D.1. (Continued).

Station 12

May 1985	Sept 1985	Nov 1985
Prionospio sp. 2	Prionospio sp. 2	Gnathia sp. 2
Pholoe anoculata	Flabelligeridae sp. 12	Aurospio dibranchiata
Paradoneis abranchiata	Paradoneis abranchiata	Prionospio sp. 2
Aurospio dibranchiata	Aspidosiphon zinni	Pholoe anoculata
Rhodine sp. 1	Pseudotanais sp. 2	Paradoneis abranchiata
Sabidius cornatus	Prionospio sp. 21	Microrbinia linea
Glycera capitata	Leptognathia sp. 10	Prionospio sp. 21
Phallodrilus grasslei	Grania atlantica	Rhodine sp. 1
Prionospio sp. 11	Pholoe anoculata	Thyasira croulinensis
Aspidosiphon zinni	Aurospio dibranchiata	Chelator insignis
Myriotrochinae sp. 1 juv.	Labidoplax buskii	Labidoplax buskii
Grania atlantica	Thyasira (Leptaxinus) minutus	Streblosoma sp. 2
Streblosoma sp. 2	Sabidius cornatus	Grania atlantica
Nemertea sp. 2	Myriochele sp. 1	Glycera capitata
Pseudotanais sp. 2	Aglaophamus sp. 1	Flabelligeridae sp. 12
Exogone sp. 1	Chelator insignis	Sclerobregma branchiata
Prionospio sp. 21	Lepidomeniidae sp. 11	Flabelligeridae sp. 13
Aglaophamus sp. 1	Synelmis sp. 1	Nemertea sp. 2
Leptognathiella spinicauda	Nereis caecoides	Myriochele sp. 4
Dysponetus sp. 3	Ophiancantha abyssicola	Phallodrilus grasslei

Station 13

May 1985	Sept 1985	Nov 1985
Microrbinia linea	Microrbinia linea	Microrbinia linea
Spiophanes sp. 1	Prionospio sp. 2	Myriochele sp. 1
Pholoe anoculata	Siboglinum sp. 2	Prionospio sp. 2
Prionospio sp. 2	Exogone sp. 1	Dacrydium sp. 1
Myriochele sp. 13	Dacrydium sp. 1	Pholoe anoculata
Exogone sp. 1	Siboglinum ekmani	Myriochele sp. 4
Hesionidae sp. 3	Pholoe anoculata	Spiophanes sp. 1
Capitella spp. complex	Siboglinum sp. 11	Nephasoma diaphanes
Pristogloma alba	Spiophanes sp. 1	Siphonolabrum sp. 2
Nemertea sp. 5	Capitella spp. complex	Exogone sp. 1
Siboglinum fulgens	Pristogloma alba	Prionospio sp. 20
Dacrydium sp. 1	Hesionidae sp. 4	Capitella spp. complex
Aspidosiphon zinni	Prionospio sp. 20	Siboglinum fulgens
Nephasoma diaphanes	Sabidius cornatus	Aspidosiphon zinni
Ophiura sp. 1 juv.	Tubificidae sp. 2	Nephasoma cf. capilleforme
Nephasoma cf. capilleforme	Trochochaeta watsoni	Laonice sp. 17
Kesun gravieri	Apionsoma murinae	Leptognathia sp. 10
Prionospio sp. 20	Paragathotanais sp. 1	Tubificidae sp. 3
Anarthruridae sp. 2	Anarthruridae sp. 2	Eugerda latipes
Siboglinum sp. 11	Pseudotanais sp. 4	Nemertea sp. 2

TABLE D.1. (Continued).

Station 14

May 1985	Sept 1985	Nov 1985
Microrbinia linea	Microrbinia linea	Microrbinia linea
Bathydrilus asymmetricus	Bathydrilus asymmetricus	Bathydrilus asymmetricus
Tubificoides sp. 3	Pholoe anoculata	Kelliella sp. 1
Pholoe anoculata	Cossura sp. 2	Tubificoides sp. 3
Tharyx sp. 1	Tubificoides sp. 3	Pholoe anoculata
Phallodrilus sp. 4	Myriotrochinae sp. 1 juv.	Spionidae n. gen. n. sp. 11
Kelliella sp. 1	Tharyx sp. 1	Cossura longocirrata
Myriotrochinae sp. 1 juv.	Phallodrilus grasslei	Nemertea sp. 13
Spionidae n. gen. n. sp. 11	Spionidae n. gen. n. sp. 11	Tharyx sp. 1
Phallodrilus grasslei	Braniella nr. palpata	Phallodrilus sp. 4
Myriochele sp. 4	Kelliella sp. 1	Aurospio dibranchiata
Aricidea sp. 3	Nemertea sp. 2	Myriotrochinae sp. 1 juv.
Cossura sp. 2	Notomastus latericeus	Nephasoma abyssorum
Ophelina abranchiata	Leptognathiella sp. 3	Cossura sp. 2
Trichobranchidae sp. 6	Jasmineira filiformis	Notoproctus nr. abyssus
Dysponetus sp. 1	Phallodrilus sp. 4	Limnodriloides monothecus
Boguella sp. 1	Flabelligeridae sp. 1	Dysponetus sp. 1
Levinsenia sp. 1	Limnodriloides monothecus	Aricidea sp. 3
Aurospio dibranchiata	Dysponetus sp. 1	Striopulsellum atlantisae
Galathowenia sp. 1	Boguella sp. 1	Jasmineira filiformis

Station 14A

May 1985	Sept 1985	Nov 1985
	Caulleriella sp. 3	
	Protodorvillea nr. kefersteini	
	Prionospio sp. 24	
	Aricidea catherinae	
	Novaquesta trifurcata	
	Ceratocephale loveni	
	Glycera capitata	
	Leptognathia cf. armata	
	Nereimyra sp. 2	
No samples taken	Ophelia sp. 2	No samples taken
	Notomastus cf. tenuis	
	Phallodrilus sp. 5	
	Tanaissus sp. 1	
	Scoloplos (Leodamas) sp. 3	
	Aonides paucibranchiata	
	Exogone verugera profunda	
	Polycirrus sp. 3	
	Thambema sp. 1	
	Phoxocephalidae sp. 1	
	Enteropneusta sp. 2	

TABLE D.1. (Continued).

Station 15

May 1985	Sept 1985	Nov 1985
Microrbinia linea	Microrbinia linea	
Euchone scotiarum	Grania atlantica	
Aonides sp. 1	Glycera capitata	
Grania atlantica	Aonides sp. 1	
Paradoneis abranchiata	Caulleriella sp. 3	
Caulleriella sp. 3	Aspidosiphon zinni	
Glycera capitata	Phallodrilus grasslei	
Anarthruridae sp. 7	Prionospio sp. 2	
Prionospio sp. 2	Paradoneis abranchiata	
Aurospio dibranchiata	Ophelia profunda	
Aspidosiphon zinni	Aurospio dibranchiata	No samples taken
Phallodrilus grasslei	Euchone scotiarum	
Exogone sp. 2	Nereimyra sp. 2	
Exogone sp. 1	Nephasoma cf. capilleforme	
Nemertea sp. 5	Spiophanes sp. 1	
Bathydrilus asymmetricus	Tharyx sp. 7	
Sabellidae sp. 5	Lepidomeniidae sp. 3	
Tharyx sp. 1	Exogone sp. 1	
Prionospio sp. 21	Leptognathia sp. 23	
Nemertea sp. 2	Myriochele sp. 4	

Station 16

May 1985	Sept 1985	Nov 1985
Microrbinia linea	Microrbinia linea	Microrbinia linea
Prionospio sp. 2	Prionospio sp. 2	Prionospio sp. 2
Siboglinum sp. 2	Macrostylis sp. 1	Grania atlantica
Nemertea sp. 2	Leptognathiella abyssi	Nemertea sp. 5
Laonice sp. 8	Hesionidae sp. 3	Macrostylis sp. 1
Leptognathiella abyssi	Ammotrypanella arctica	Neotanais americanus
Hesionidae sp. 3	Tubificidae sp. 2	Siboglinum sp. 2
Fauveliopsis brevis	Heterospio nr. longissima	Leptognathiella abyssi
Brevinucula verrilli	Exogone sp. 1	Paragathotanais cf. typicus
Chelator vulgaris	Capitella spp. complex	Ophelina abranchiata
Pseudotanais sp. 4	Leptognathia sp. 5	Anarthruridae sp. 5
Microspio sp. 2	Spiophanes sp. 1	Spiophanes sp. 1
Apionsoma murinae	Nemertea sp. 5	Phallodrilus sp. 6
Dysponetus cf. gracilis	Thyasira (Leptaxinus) minutus	Orbiniella sp. 2
Capitella spp. complex	Pristogloma alba	Prionospio sp. 21
Leptognathia voringii	Spiophanes sp. 6	Pristogloma alba
Ammotrypanella arctica	Paragathotanais cf. typicus	Exogone sp. 1
Haploniscus sp. 2	Siboglinum sp. 2	Capitella spp. complex
Flabelligella cirrata	Paranarthrura cf. insignis	Brevinucula verrilli
Prionospio sp. 20	Limopsis tenella	Kesun gravieri

APPENDIX E

TABLE E.1. BENTHIC COMMUNITY PARAMETERS FOR SOUTH ATLANTIC STATIONS CALCULATED FOR EACH CRUISE, REPLICATES SEPARATE.

Station	Cruise	Rep.	Density Per 0.09 m^2	Total Species	Species Per 50 Indiv.	Species Per 100 Indiv.	Species Per 500 Indiv.	Species Per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
1	1	1	808	125	30.4	46.8	106.8	*	5.78	0.830
		2	2,063	165	26.9	42.5	96.7	128.6	5.38	0.730
		3	1,046	151	31.5	49.9	117.5	*	5.97	0.825
	2	1	1,503	168	31.9	50.0	116.5	154.0	6.05	0.819
		2	1,183	141	29.8	46.1	103.4	136.8	5.76	0.801
		3	2,213	148	24.4	38.7	88.6	115.2	4.91	0.682
	3	1	1,438	138	27.6	42.9	97.2	126.7	5.44	0.766
		2	1,260	146	31.6	49.1	108.1	139.0	5.95	0.828
		3	1,719	159	31.0	48.5	107.6	138.6	5.92	0.809
2	1	1	679	122	30.6	47.7	109.8	*	5.76	0.831
		2	449	99	30.0	46.7	*	*	5.58	0.842
		3	1,274	134	28.8	43.8	93.9	123.9	5.61	0.794
	2	1	930	138	31.1	47.6	108.7	*	5.87	0.826
		2	693	120	29.5	45.6	106.7	*	5.65	0.818
		3	956	126	29.3	45.6	101.1	*	5.66	0.812
	3	1	890	134	32.9	50.7	108.7	*	6.03	0.854
		2	695	116	30.8	47.0	102.7	*	5.79	0.844
		3	830	124	31.5	47.9	102.4	*	5.87	0.844

TABLE E-1. (Continued).

Station	Cruise	Rep.	Density Per 0.09 m^2	Total Species	Species Per 50 Indiv.	Species Per 100 Indiv.	Species Per 500 Indiv.	Species Per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
3	1	1	507	127	32.1	52.2	*	*	5.87	0.839
		2	359	93	29.2	45.9	*	*	5.45	0.834
		3	623	140	33.3	53.4	130.1	*	6.08	0.853
	2	1	364	102	31.6	50.5	*	*	5.70	0.855
		2	500	102	29.2	46.3	*	*	5.47	0.820
		3	493	131	34.2	55.4	*	*	6.14	0.873
	3	1	359	109	34.6	55.8	*	*	6.05	0.894
		2	408	119	35.3	57.2	*	*	6.17	0.895
		3	451	122	34.7	56.1	*	*	6.14	0.887
4	1	1	532	108	26.0	42.2	130.1	*	5.08	0.752
		2	241	71	30.1	46.3	*	*	5.39	0.877
		3	558	125	28.7	46.6	120.7	*	5.52	0.793
	2	1	493	99	28.5	44.5	*	*	5.42	0.817
		2	669	127	28.2	45.2	113.2	*	5.51	0.788
		3	626	115	27.4	43.4	105.1	*	5.36	0.784
	3	1	453	99	27.5	43.6	*	*	5.18	0.782
		2	466	108	28.7	46.0	*	*	5.49	0.813
		3	523	116	31.3	49.4	115.5	*	5.79	0.844

TABLE E.1. (Continued).

Station	Cruise	Rep.	Density Per 0.09 m^2	Total Species	Species Per 50 Indiv.	Species Per 100 Indiv.	Species Per 500 Indiv.	Species Per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
4	4	1	385	80	26.8	40.9	*	*	5.19	0.822
		2	474	105	28.8	45.4	*	*	5.52	0.822
		3	576	103	26.4	41.9	98.9	*	5.21	0.780
	5	1	391	93	28.3	45.2	*	*	5.25	0.803
		2	489	105	29.1	46.6	*	*	5.56	0.828
		3	379	109	30.6	50.6	*	*	5.63	0.832
	6	1	396	101	30.2	48.1	*	*	5.63	0.845
		2	337	95	32.0	50.2	*	*	5.75	0.875
		3	440	111	31.0	50.1	*	*	5.75	0.846
5	1	1	92	51	33.7	*	*	*	5.21	0.919
		2	95	53	35.2	*	*	*	5.34	0.933
		3	87	43	31.3	*	*	*	4.85	0.893
	2	1	83	49	36.6	*	*	*	5.41	0.964
		2	51	31	*	*	*	*	4.72	0.952
		3	66	35	31.0	*	*	*	4.71	0.918
	3	1	100	52	33.3	*	*	*	5.28	0.927
		2	63	40	38.8	*	*	*	5.19	0.974
		3	68	39	35.7	*	*	*	5.13	0.970

TABLE E.1. (Continued).

Station	Cruise	Rep.	Density Per 0.09 m^2	Total Species	Species Per 50 Indiv.	Species Per 100 Indiv.	Species Per 500 Indiv.	Species Per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
6	1	2	568	113	29.9	45.8	108.7	*	5.69	0.835
		3	563	107	29.9	46.8	104.9	*	5.62	0.833
		4	585	98	29.8	44.5	94.5	*	5.63	0.850
	2	1	546	100	30.5	46.1	99.6	*	5.66	0.852
		2	581	113	31.0	48.5	110.5	*	5.79	0.850
		3	676	110	30.8	47.8	102.1	*	5.76	0.849
	3	1	441	103	32.3	50.5	*	*	5.83	0.872
		2	581	115	31.7	49.8	111.8	*	5.85	0.855
		3	489	97	26.6	41.7	*	*	5.22	0.791
7	2	1	71	38	33.5	*	*	*	5.07	0.967
		2	109	51	31.5	51.0	*	*	5.10	0.900
9	3	1	4,630	54	10.8	14.5	28.8	36.9	2.93	0.508
		2	5,474	55	9.4	12.8	26.0	34.1	2.72	0.470
		3	4,302	56	9.8	13.5	29.1	38.4	2.80	0.482
	4	1	5,523	53	9.0	12.6	26.5	34.6	2.56	0.447
		2	4,726	58	8.8	12.2	26.4	35.7	2.66	0.454
		3	3,996	59	9.8	14.4	30.8	40.1	2.73	0.464

TABLE E.1. (Continued).

Station	Cruise	Rep.	Density Per 0.09 m^2	Total Species	Species Per 50 Indiv.	Species Per 100 Indiv.	Species Per 500 Indiv.	Species Per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
9	5	1	3,378	65	11.9	16.8	33.7	44.4	2.97	0.493
		2	3,393	54	11.0	15.8	31.4	40.3	2.93	0.509
		3	2,046	31	7.2	9.6	18.7	24.8	2.05	0.413
10	4	1	832	62	15.9	22.6	50.6	*	3.92	0.658
		2	1,183	68	18.9	26.2	51.3	67.1	4.37	0.718
		3	538	49	17.7	24.9	48.7	*	4.08	0.727
	6	1	812	58	16.0	23.1	48.5	*	3.91	0.633
		2	701	59	15.8	22.9	51.8	*	3.84	0.652
		3	767	48	16.3	22.1	42.4	*	3.95	0.707
11	4	1	1,043	132	31.1	48.2	105.8	*	5.84	0.166
		2	1,049	156	31.6	50.3	120.4	*	5.97	0.819
		3	927	149	34.7	55.2	123.6	*	6.26	0.867
	5	1	830	147	33.2	53.1	125.8	*	6.12	0.850
		2	814	135	33.2	52.4	116.8	*	6.06	0.857
		3	924	155	33.1	53.2	126.4	*	6.13	0.842
	6	1	911	137	31.2	48.8	111.8	*	5.88	0.828
		2	950	146	32.0	51.2	119.2	*	5.97	0.831
		3	805	140	33.5	53.1	121.0	*	6.11	0.858

TABLE E.1. (Continued).

Station	Cruise	Rep.	Density Per 0.09 m^2	Total Species	Species Per 50 Indiv.	Species Per 100 Indiv.	Species Per 500 Indiv.	Species Per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
12	4	1	263	88	33.0	52.8	*	*	5.76	0.892
		2	263	90	35.3	56.6	*	*	5.95	0.916
		3	196	71	34.4	53.4	*	*	5.73	0.932
	5	1	168	80	37.2	60.9	*	*	5.94	0.940
	6	1	229	83	32.9	52.4	*	*	5.71	0.896
		2	198	60	25.2	41.1	*	*	4.45	0.754
		3	236	81	31.4	49.6	*	*	5.58	0.881
13	4	1	84	38	29.9	*	*	*	4.76	0.907
		2	73	39	31.2	*	*	*	4.78	0.905
		3	91	38	28.1	*	*	*	4.66	0.889
	5	1	104	44	28.2	*	*	*	4.79	0.878
		2	90	35	25.5	*	*	*	4.30	0.839
		3	77	40	31.4	*	*	*	4.96	0.933
	6	1	220	62	24.4	39.8	*	*	4.56	0.765
		2	141	54	30.4	47.3	*	*	5.17	0.898
		3	181	61	28.0	44.6	*	*	5.10	0.860
14	4	1	943	174	35.6	58.1	142.4	*	6.41	0.861
		2	973	162	34.4	56.5	136.9	*	6.26	0.853
		3	753	151	34.6	57.0	141.3	*	6.22	0.859

TABLE E.1. (Continued).

Station	Cruise	Rep.	Density Per 0.09 m^2	Total Species	Species Per 50 Indiv.	Species Per 100 Indiv.	Species Per 500 Indiv.	Species Per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
14	5	1	495	139	38.4	64.4	*	*	6.53	0.918
		2	925	170	36.7	60.6	145.4	*	6.54	0.882
		3	748	152	35.0	58.0	140.6	*	6.27	0.865
	6	1	913	177	36.2	60.7	148.1	*	6.50	0.870
		2	844	167	36.8	60.4	144.7	*	6.52	0.883
		3	723	160	35.0	58.0	143.2	*	6.30	0.860
14A	5	1	263	37	18.9	26.2	*	*	4.14	0.794
		2	201	45	22.0	32.7	*	*	4.39	0.800
		3	171	26	16.5	22.6	*	*	3.63	0.772
15	4	1	131	48	28.3	44.2	*	*	4.83	0.865
		2	132	35	22.9	33.0	*	*	4.12	0.802
		3	181	50	25.0	38.5	*	*	4.51	0.800
	5	1	75	27	23.0	*	*	*	4.03	0.848
		2	77	29	24.6	*	*	*	4.28	0.881
		3	112	40	26.6	*	*	*	4.52	0.848
16	4	1	70	33.0	27.0	*	*	*	4.26	0.844
		2	85	34.0	25.8	*	*	*	4.16	0.817
		3	88	41.0	29.6	*	*	*	4.51	0.841

TABLE E.1. (Continued).

Station	Cruise	Rep.	Density Per 0.09 m^2	Total Species	Species Per 50 Indiv.	Species Per 100 Indiv.	Species Per 500 Indiv.	Species Per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
16	5	1	45	24	*	*	*	*	4.05	0.884
		2	63	31	29.0	*	*	*	4.55	0.919
		3	53	25	*	*	*	*	4.23	0.911
	6	1	82	39	28.8	*	*	*	4.27	0.808
		2	44	26	*	*	*	*	4.13	0.878
		3	65	29	26.1	*	*	*	4.29	0.884

*Sample size too small to allow calculation of this parameter.

APPENDIX F

TABLE F-1. BENTHIC COMMUNITY PARAMETERS FOR U.S. SOUTH ATLANTIC STATIONS, CALCULATED SEPARATELY FOR EACH CRUISE.

Station	Cruise	Total Reps.	Density per m^2	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 500 Indiv.	Species per 1000 Indiv.	Species per 2000 Indiv.	Species per 3000 Indiv.	Shannon-Wiener Diversity (H^1)	Evenness (E)
1	1	3	14,507	237	29.9	47.8	113.9	152.9	198.1	225.7	5.91	0.749
	2	3	18,144	235	29.1	106.3	141.7	183.2	209.6	5.77	0.733	
	3	3	16,359	228	30.9	48.6	110.4	145.8	186.2	210.7	5.99	0.765
2	1	3	8,896	192	30.4	47.2	106.2	141.7	183.6	*	5.90	0.778
	2	3	9,551	215	30.6	47.7	113.0	153.9	200.9	*	5.98	0.772
	3	3	8,944	208	32.5	50.2	111.0	149.2	196.8	*	6.15	0.798
3	1	3	5,574	227	34.7	56.7	141.4	194.4	*	*	6.46	0.825
	2	3	5,026	203	32.8	53.4	133.1	183.2	*	*	6.19	0.808
	3	3	4,511	204	36.0	59.0	143.2	192.4	*	*	6.56	0.855
4	1	3	4,930	179	29.2	47.3	121.1	163.7	*	*	5.72	0.764
	2	3	6,622	185	28.5	45.5	111.5	150.7	*	*	5.68	0.754
	3	3	5,340	181	30.1	48.3	116.9	158.2	*	*	5.83	0.778
	4	3	5,314	162	27.5	43.4	105.7	142.9	*	*	5.55	0.756
	5	3	4,663	175	29.9	48.6	123.0	163.9	*	*	5.84	0.783
	6	3	4,344	174	31.9	51.5	126.6	167.2	*	*	6.08	0.817
5	1	3	1,015	105	35.8	59.5	*	*	*	*	6.04	0.899
	2	3	740	80	36.2	57.9	*	*	*	*	5.92	0.937
	3	3	855	595	37.2	61.5	*	*	*	*	6.11	0.930
6	1	3	6,355	175	31.2	48.3	109.8	146.7	*	*	5.98	0.802
	2	3	6,677	173	31.8	49.4	111.2	145.2	*	*	6.04	0.812
	3	3	5,596	177	31.7	50.8	120.5	157.5	*	*	6.05	0.810
7	2	2	1,000	74	34.7	56.4	*	*	*	*	5.71	0.919

TABLE F-1. (Continued).

Station	Cruise	Total Reps.	Density per m^2	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 500 Indiv.	Species per 1000 Indiv.	Species per 2000 Indiv.	Species per 3000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
9	3	3	53,355	84	10.3	14.1	29.1	38.4	49.0	55.9	2.88	0.451
	4	3	52,755	82	9.6	13.8	29.7	39.1	50.0	57.1	2.73	0.429
	5	3	32,655	88	11.1	16.0	34.0	44.8	58.4	67.7	2.88	0.446
10	4	3	9,455	102	18.4	26.1	55.1	73.7	96.6	*	4.36	0.653
	6	3	8,444	97	16.7	24.1	54.4	73.7	95.3	*	4.06	0.615
11	4	3	11,181	242	33.0	52.8	125.5	169.3	220.5	*	6.28	0.793
	5	3	9,511	236	33.6	53.8	128.9	175.1	227.6	*	6.34	0.805
	6	3	9,874	228	32.7	52.3	124.1	166.8	214.8	*	6.23	0.795
12	4	3	2,674	154	36.2	59.0	138.4	*	*	*	6.43	0.885
	5	1	1,867	80	37.2	60.9	*	*	*	*	5.94	0.940
	6	3	2,455	143	32.8	53.3	129.6	*	*	*	6.06	0.847
13	4	3	918	84	31.6	51.7	*	*	*	*	5.52	0.864
	5	3	1,003	79	29.9	47.6	*	*	*	*	5.37	0.851
	6	3	2,007	116	28.5	46.5	*	*	*	*	5.46	0.796
14	4	3	9,885	267	35.5	58.7	146.9	200.4	261.4	*	6.60	0.818
	5	3	8,030	258	37.2	62.4	158.3	212.1	*	*	6.81	0.850
	6	3	9,185	285	37.0	62.2	158.1	213.8	279.6	*	6.81	0.836
14A	5	3	2,351	64	20.9	30.6	61.0	*	*	*	4.46	0.743
15	4	3	1,644	85	26.5	41.5	*	*	*	*	4.96	0.775
	5	3	977	67	26.1	41.1	*	*	*	*	4.85	0.799
16	4	3	900	85	29.1	49.9	*	*	*	*	5.07	0.791
	5	3	596	65	31.2	51.6	*	*	*	*	5.21	0.865
	6	3	707	69	29.1	48.3	*	*	*	*	4.93	0.807

*Sample size was too small to allow calculation of this parameter.

APPENDIX G

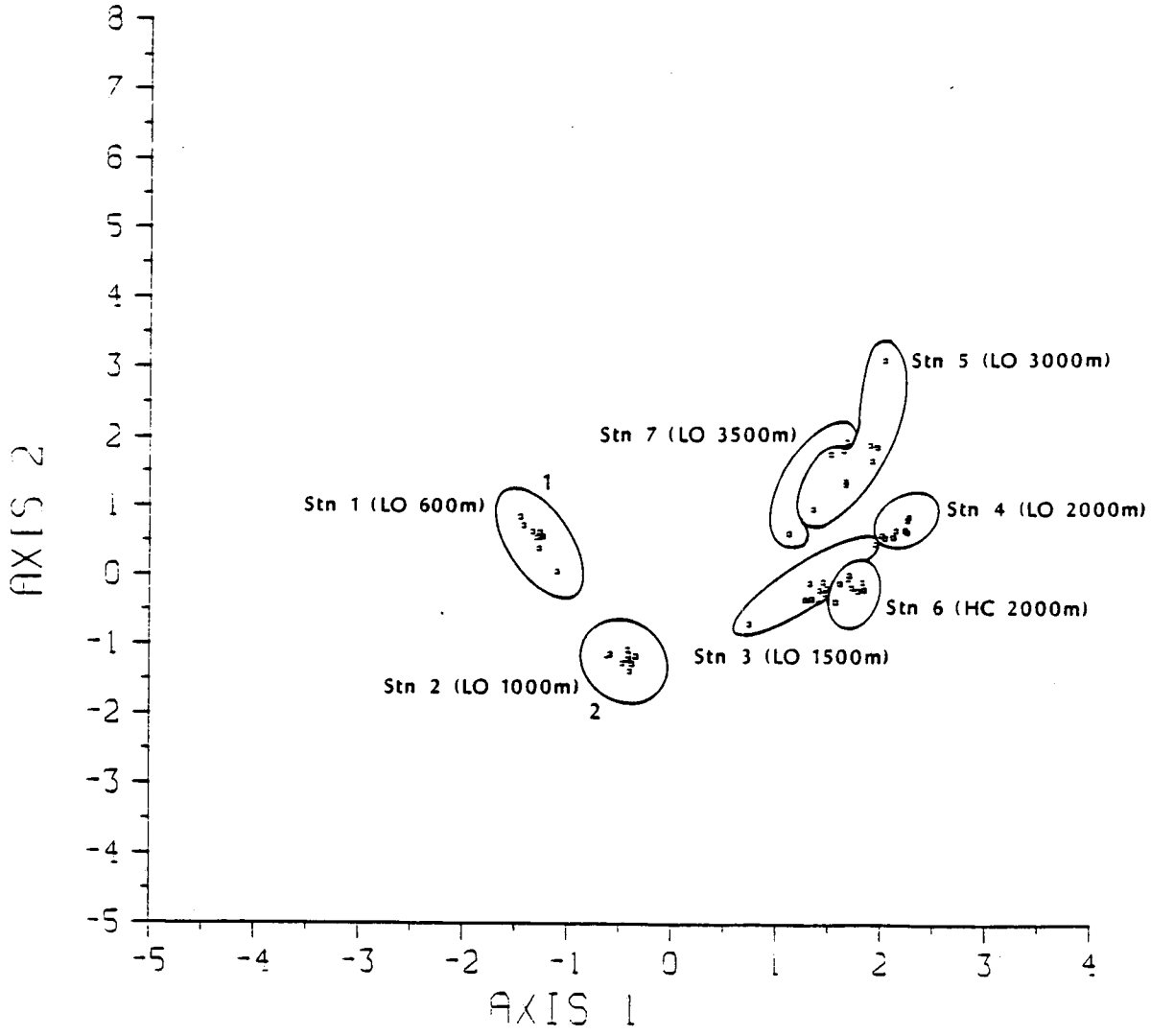


Figure G.1. Reciprocal averaging ordination of Phase 1 South Atlantic samples. Stations 1, 2, 5 and 7 separate along axes 1 and 2.

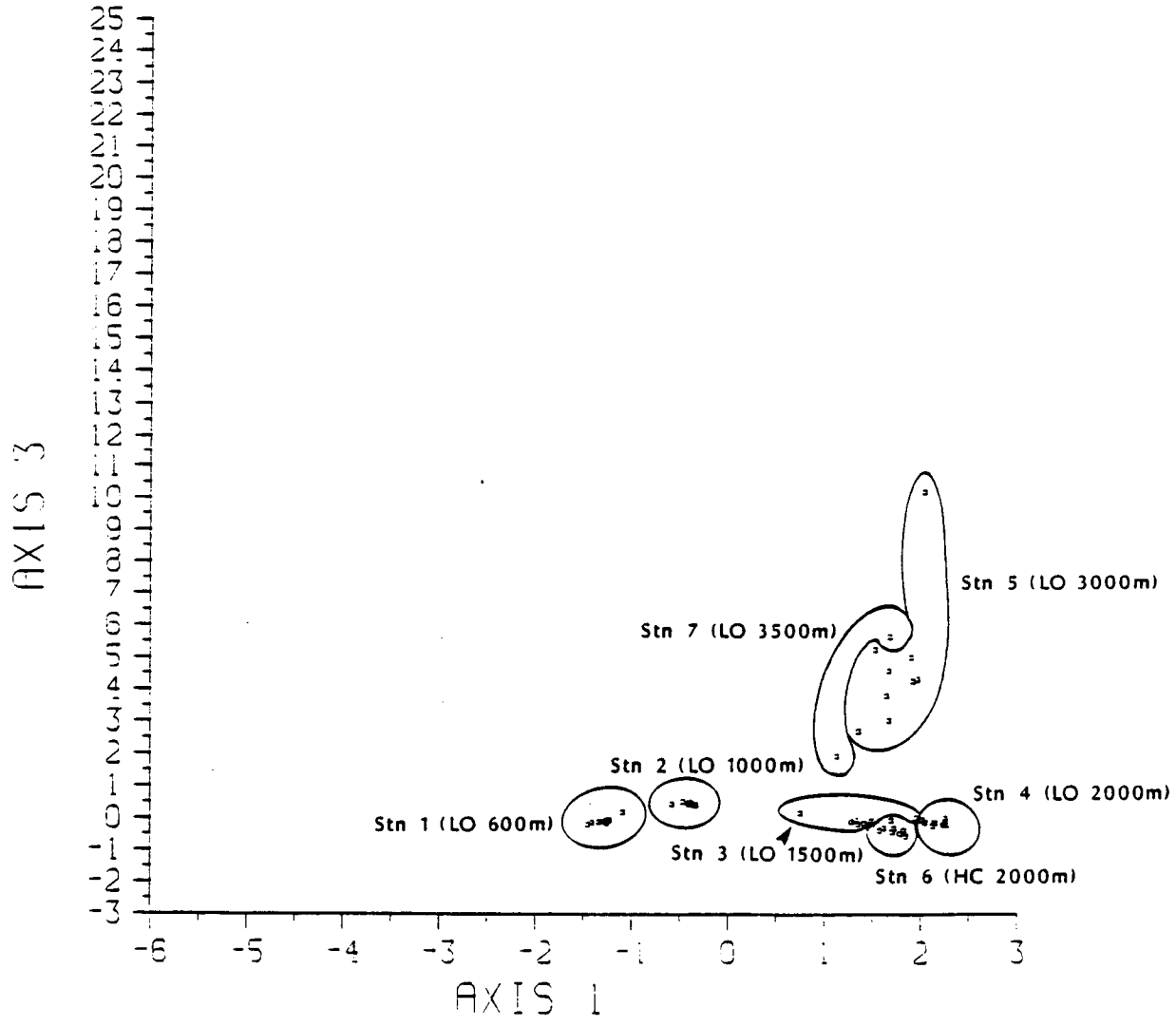


Figure G.2. Reciprocal averaging ordination of Phase 1 South Atlantic samples. Stations 1, 2, 5, 7 separate along axes 1 and 3.

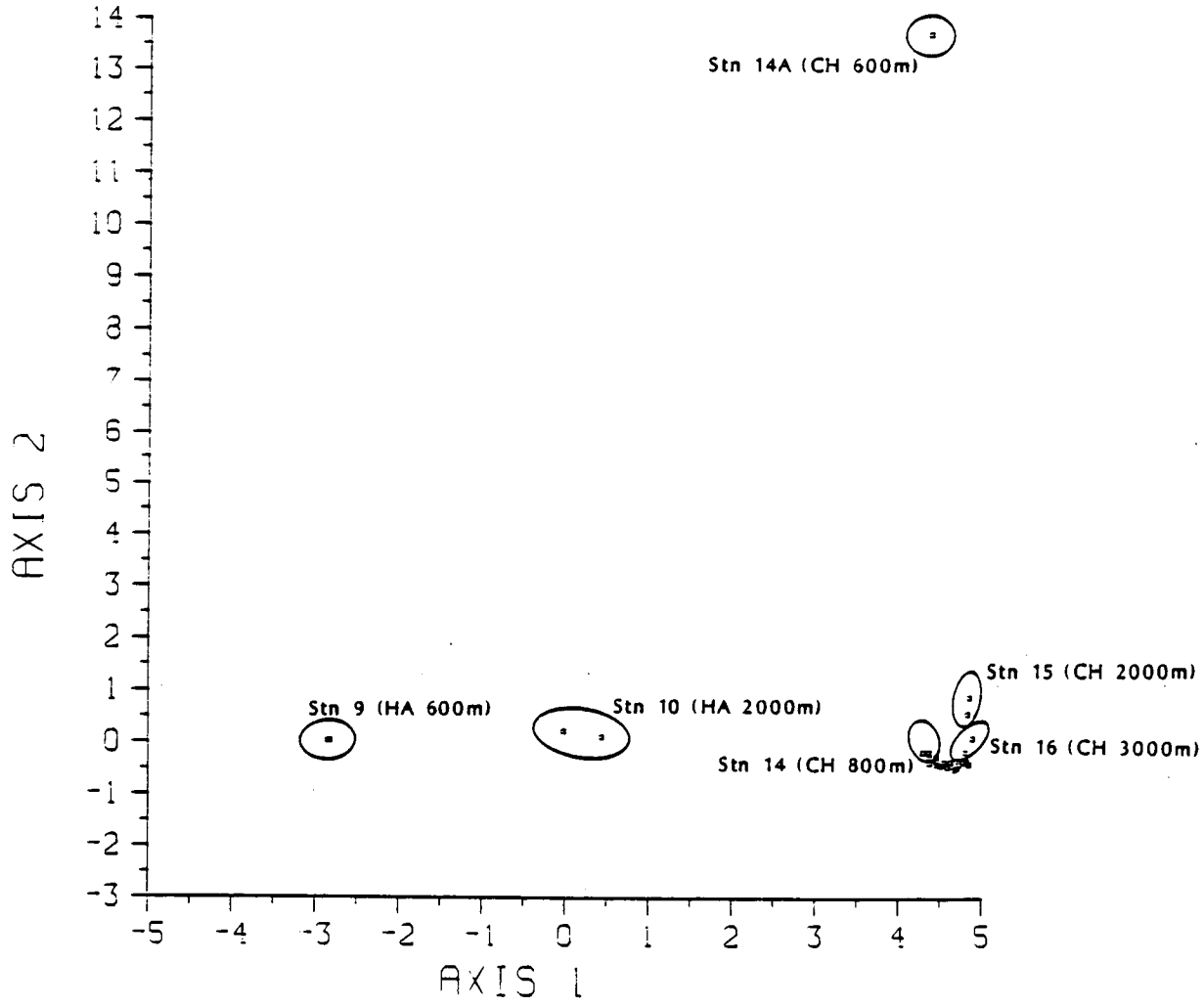


Figure G.3. Reciprocal averaging ordination of Phase 2 South Atlantic samples. Stations 9, 10, and 14A separate along axes 1 and 2.

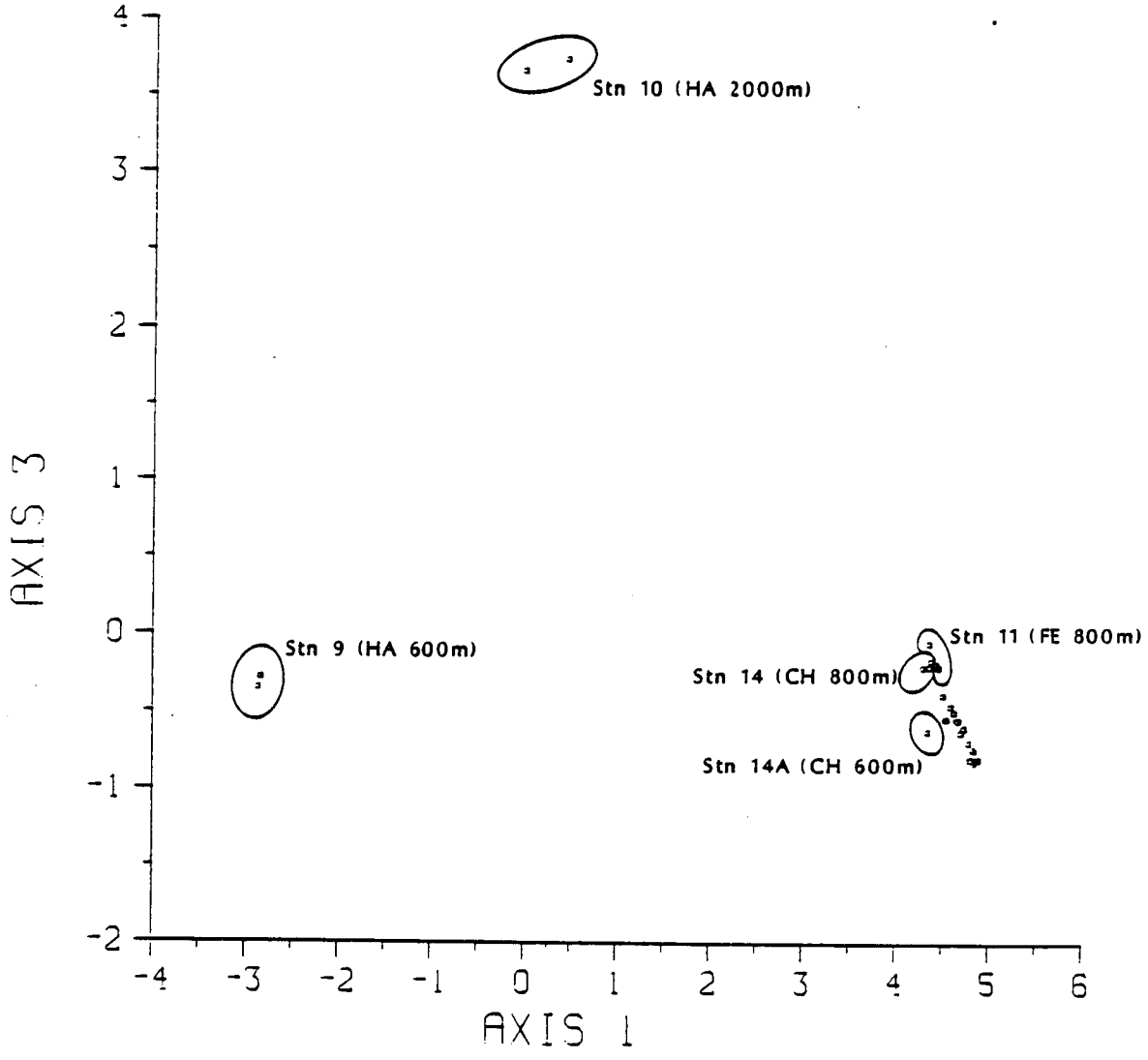


Figure G.4. Reciprocal averaging ordination of Phase 2 South Atlantic samples. Stations 9 and 10 separate along axes 1 and 3.

APPENDIX H

TABLE H.1. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE SA-3.

	Station								
	4	9	10	11	12	13	14	15	16
	Concentration (µg/g dry weight)								
Total Hydrocarbons[a]		80.89							
Saturated		39.95							
Aromatic		40.94							
	Saturated Hydrocarbon Parameters[b]								
Resolved Saturated (%)		54.5							
Unresolved Saturated (%)		45.5							
OEPI[c]		0.44							
Pristane/Phytane		2.17							
Pristane/n-C_{17}		0.428							
Phytane/n-C_{18}		0.485							

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index= $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2\,(n\text{-}C_{28}) + n\text{-}C_{30}}$

TABLE H.2. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE SA-4.

	Station								
	4	9	10	11	12	13	14	15	16
	Concentration (µg/g dry weight)								
Total Hydrocarbons[a]	5.73	26.51	17.26	11.08	14.83	1.74	8.21	0.87	3.82
Saturated	3.07	11.16	8.56	4.53	8.65	1.12	5.52	0.59	3.06
Aromatic	2.66	15.35	8.70	6.55	6.18	0.62	2.69	0.28	0.76
	Saturated Hydrocarbon Parameters[b]								
Resolved Saturated (%)	34.8	19.8	43.4	52.0	52.7	49.6	48.2	26.4	25.4
Unresolved Saturated (%)	65.2	80.2	56.6	48.0	47.3	50.4	51.8	73.6	74.6
OEPI[c]	1.18	4.03	1.42	1.58	1.22	2.72	1.01	1.89	2.66
Pristane/Phytane	U[d]	U[d]	U[d]	5.19	1.82	2.67	2.43	0	2.19
Pristane/n-C_{17}	0	0.731	0.407	0.577	0.994	0.647	0.405	0	0.670
Phytane/n-C_{18}	0	0	0	0.273	0.645	0.309	0.343	0.891	0.377

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index= $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2\,(n\text{-}C_{28}) + n\text{-}C_{30}}$

[d]U=Undefined.

TABLE H.3. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE SA-5.

	Station								
	4	9	10	11	12	13	14	15	16
	Concentration (µg/g dry weight)								
Total Hydrocarbons[a]	59.3	52.75	NC[d]	22.78	117.68	8.12	26.91	14.06	18.38
Saturated	28.18	25.76	NC	11.11	27.88	6.63	15.24	5.83	10.53
Aromatic	31.12	26.99	NC	11.67	89.8	1.49	11.67	8.23	7.85
	Saturated Hydrocarbon Parameters[b]								
Resolved Saturated (%)	43.0	41.8	NC[d]	52.3	50.9	100	57.8	65.4	67.6
Unresolved Saturated (%)	57.0	58.2	NC	47.7	49.1	0	42.2	34.5	32.4
OEPI[c]	3.33	2.70	NC	2.03	2.36	2.78	1.97	1.63	1.98
Pristane/Phytane	2.73	2.39	NC	U[e]	2.97	1.64	3.18	2.42	10.84
Pristane/n-C_{17}	0.211	0.232	NC	0.195	0.209	0.200	0.591	0.728	2.32
Phytane/n-C_{18}	0.204	0.319	NC	0	0.187	0.308	0.296	0.357	0.222

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index= $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2\,(n\text{-}C_{28}) + n\text{-}C_{30}}$
[d]Sample not collected at this station.
[e]U=Undefined.

TABLE H.4. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE SA-6.

	Station								
	4	9	10	11	12	13	14	15	16
	Concentration (µg/g dry weight)								
Total Hydrocarbons[a]	44.6	NC[d]	50.1	23.6	40.8	13.2	31.0	7.18	15.4
Saturated	25.2	NC	24.8	12.4	24.1	6.92	19.0	5.05	8.99
Aromatic	19.4	NC	25.3	11.2	16.7	6.26	12.0	2.13	6.46
	Saturated Hydrocarbon Parameters[b]								
Resolved Saturated (%)	27.3	NC[d]	38.0	46.5	41.5	22.6	28.0	7.7	24.4
Unresolved Saturated (%)	72.7	NC	62.0	53.5	58.5	77.4	72.0	93	75.9
OEPI[c]	7.71	NC	5.39	3.08	3.35	2.12	1.64	2.39	3.12
Pristane/Phytane	7.95	NC	3.07	2.17	1.67	2.11	0	Undef[e]	3.06
Pristane/n-C_{17}	0.942	NC	0.408	0.220	0.210	0.139	0	0	0.291
Phytane/n-C_{18}	0.188	NC	0.511	0.226	0.196	0.138	0.041	0	0.162

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index= $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2\,(n\text{-}C_{28}) + n\text{-}C_{30}}$
[d]Sample not collected at this station.
[e]Ratio undefined.

TABLE H.5. CONCENTRATIONS (ng/g DRY WEIGHT) OF POLYNUCLEAR AROMATIC HYDROCARBONS FOUND IN SA-3, STATION 9 SEDIMENT SAMPLES.

Compound	
Naphthalene	6.0
C_1-Naphthalenes	8.0
C_2-Naphthalenes	15.0
C_3-Naphthalenes	19.0
C_4-Naphthalenes	3.0
Biphenyl	2.0
Fluorene	3.0
C_1-Fluorenes	5.0
C_2-Fluorenes	11.0
C_3-Fluorenes	13.0
Phenanthene	19.0
C_1-Phenanthrenes[a]	23.0
C_2-Phenanthrenes[a]	23.0
C_3-Phenanthrenes[a]	22.0
C_4-Phenanthrenes[a]	3.0
Dibenzothiophene	2.0
C_1-Dibenzothiophenes	2.0
C_2-Dibenzothiophenes	5.0
C_3-Dibenzothiophenes	2.0
Fluoranthene	29.0
Pyrene	23.0
Benz(a)anthracene	14.0
Chrysene	17.0
Benzofluoranthene	38.0
Benzo(e)pyrene	16.0
Benzo(a)pyrene	12.0
Perylene	77.0
Total PAH (Sum of above compounds)	412.0
FFPI[b]	32

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalenes } (C_0 - C_4) + \text{dibenzothiophenes } (C_0 - C_3) + 1/2 \text{ phenanthrenes } (C_0 - C_1) + \text{phenanthrenes } (C_2 - C_4)}{\text{PAH}}$$

TABLE H.6 SEDIMENT POLYNUCLEAR HYDROCARBON CONCENTRATIONS (ng/g DRY WEIGHT) FOR SAMPLES COLLECTED ON CRUISE SA-4.

Station	4	9	9	9	9	9	9	10	10
Sample Number	32-04-1001	32-09-1001	32-09-1001	32-09-1001	32-09-1002	32-09-1003	32-09-1001	32-10-1001	32-10-1002
Rep or Pooled	Pooled	A	B	C			Pooled		
Napthalene	1	2	5	4	6	5	4	6	5
C_1-Naphthalenes	ND	3	3	4	6	6	4	5	7
C_2-Naphthalenes	ND	2	7	6	12	11	10	9	12
C_3-Naphthalenes	ND	ND	5	7	13	11	11	4	12
C_4-Naphthalenes	ND	ND	1	ND	5	1	4	ND	2
Biphenyl	ND	2	1	1	2	2	2	2	2
Fluorene	ND	3	1	1	3	2	3	2	4
C_1-Fluorenes	ND	ND	2	1	4	1	5	1	3
C_2-Fluorenes	ND	ND	2	13	13	9	6	8	8
C_3-Fluorenes	ND	ND	3	1	10	ND	9	ND	2
Phenanthrene	4	13	9	9	23	16	16	15	16
C_1-Phenanthrenes[a]	12	11	8	9	32	13	12	15	12
C_2-Phenanthrenes[a]	8	3	40	31	48	27	36	26	26
C_3-Phenanthrenes[a]	ND	10	19	10	34	14	27	13	20
C_4-Phenanthrenes[a]	ND	ND	ND	ND	44	3	5	1	5
Dibenzothiophene	ND	6	1	1	2	1	2	1	2
C_1-Dibenzothiophenes	ND	ND	2	3	5	2	6	ND	2
C_2-Dibenzothiophenes	ND	ND	5	3	15	1	11	ND	4
C_3-Dibenzothiophenes	ND	ND	3	1	7	1	29	ND	4
Fluoranthene	5	21	20	19	31	24	21	26	19
Pyrene	4	17	14	14	22	18	22	19	13
Benz(a)anthracene	2	23	12	12	18	14	16	15	6
Chrysene	3	21	9	16	20	13	47	15	11
Benzofluoranthene	11	33	38	49	51	35	21	40	19
Benzo(e)pyrene	4	12	16	21	22	15	19	18	9
Benzo(a)pyrene	2	38	12	21	22	11	119	17	9
Perylene	6	98	87	127	115	65	4	191	91
Total PAH	62	318	325	384	585	321	471	449	325
FFPI[b]	31	12	30	21	31	29	34	18	34

TABLE H.6 (Continued).

Station Sample Number Rep or Pooled	10 32-10-1001 Pooled	10 32-10-1003	11 32-11-1001 Pooled	12 32-12-1001 Pooled	13 32-13-1001 Pooled	14 32-14-1001 Pooled	15 32-15-1001 Pooled	16 32-16-300 F2
Naphthalene	4	6	1	2	11	2	135	3.7
C_1-Naphthalenes	6	6	1	24	14	37	57	2.0
C_2-Naphthalenes	12	13	2	19	27	7	25	ND
C_3-Naphthalenes	11	14	3	33	31	24	29	ND
C_4-Naphthalenes	3	3	1	28	12	15	63	ND
Biphenyl	2	2	ND	3	4	ND	ND	ND
Fluorene	4	3	ND	1	4	ND	ND	ND
C_1-Fluorenes	3	4	ND	5	4	ND	ND	ND
C_2-Fluorenes	6	6	ND	ND	6	ND	ND	ND
C_3-Fluorenes	2	3	ND	ND	ND	ND	ND	ND
Phenanthrene	13	12	8	18	20	16	33	1.8
C_1-Phenanthrenes	14	12	5	16	27	2	ND	ND
C_2-Phenanthrenes	14	11	6	9	15	ND	ND	ND
C_3-Phenanthrenes	7	17	3	8	12	ND	ND	ND
C_4-Phenanthrenes	ND	ND	5	ND	ND	ND	ND	ND
Dibenzothiophene	2	2	1	1	5	ND	ND	ND
C_1-Dibenzothiophene	1	3	ND	4	4	ND	ND	ND
C_2-Dibenzothiophene	2	4	1	ND	4	ND	ND	ND
C_3-Dibenzothiophene	1	1	ND	ND	1	ND	ND	ND
Fluoranthene	19	17	12	21	13	17	32	ND
Pyrene	14	12	9	17	19	20	26	1.8
Benz(a)anthracene	13	7	4	21	10	5	107	ND
Chrysene	12	14	6	35	10	19	68	5
Benzofluoranthene	30	23	14	35	1	24	749	6
Benzo(e)pyrene	3	10	5	1	1	6	11	ND
Benzo(a)pyrene	9	8	4	4	14	9	41	3
Perylene	123	107	4	13	16	15	129	16
Total PAH	330	310	95	318	285	218	830	39.3
FFPI	23	26	26	46	56	43	39	0.2

[a]May include some anthracene alkyl homologues.
[b]Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).
FFPI=naphthalenes (C_0-C_4) + dibenzothiophenes (C_0-C_3) + 1/2 phenanthrenes (C_0-C_1) + phenanthrenes (C_2-C_4).

TABLE H.7. CONCENTRATIONS (ng/g DRY WEIGHT) OF POLYNUCLEAR AROMATIC HYDROCARBONS FOUND IN CRUISE SA-5 SEDIMENT SAMPLES.

Compound	Station No. 4	9	11	12	13	14	15A	15B	15C	15	16
Naphthalene	3.0	5.0	2.0	7.0	1.0	3.0	1.0	2.0	2.0	1.0	2.0
C_1-Naphthalenes	5.0	6.0	3.0	8.0	2.0	2.0	1.0	4.0	2.0	2.0	3.0
C_2-Naphthalenes	9.0	12.0	3.0	11.0	3.0	3.0	2.0	5.0	3.0	2.0	5.0
C_3-Naphthalenes	11.0	13.0	3.0	11.0	4.0	4.0	2.0	7.0	3.0	3.0	6.0
C_4-Naphthalenes	ND	2.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
Biphenyl	1.0	2.0	1.0	2.0	1.0	1.0	ND	1.0	ND	ND	1.0
Fluorene	2.0	4.0	18.0	2.0	1.0	1.0	ND	ND	ND	ND	1.0
C_1-Fluorenes	4.0	5.0	1.0	2.0	2.0	1.0	ND	1.0	ND	ND	2.0
C_2-Fluorenes	8.0	9.0	1.0	4.0	3.0	2.0	ND	ND	ND	1.0	3.0
C_3-Fluorenes	8.0	14.0	ND	ND	3.0	1.0	ND	ND	ND	ND	4.0
Phenanthrene	18.0	18.0	40.0	24.0	4.0	8.0	4.0	6.0	5.0	3.0	10.0
C_1-Phenanthrenes[a]	14.0	14.0	7.0	17.0	5.0	5.0	4.0	9.0	5.0	3.0	14.0
C_2-Phenanthrenes[a]	13.0	15.0	5.0	16.0	5.0	5.0	3.0	10.0	5.0	3.0	19.0
C_3-Phenanthrenes[a]	10.0	12.0	3.0	7.0	4.0	4.0	1.0	3.0	1.0	2.0	13.0
C_4-Phenanthrenes[a]	6.0	2.0	4.0	5.0	2.0	5.0	1.0	ND	1.0	1.0	3.0
Dibenzothiopene	2.0	2.0	2.0	2.0	ND	1.0	ND	1.0	ND	ND	1.0
C_1-Dibenzothiopenes	3.0	3.0	1.0	1.0	ND	1.0	ND	1.0	ND	1.0	2.0
C_2-Dibenzothiopenes	4.0	7.0	1.0	2.0	1.0	2.0	ND	ND	ND	1.0	6.0
C_3-Dibenzothiopenes	1.0	1.0	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Fluoranthene	22	18.0	10.0	32.0	5.0	11.0	4.0	4.0	3.0	3.0	11.0
Pyrene	17.0	14.0	8.0	25.0	4.0	9.0	3.0	5.0	4.0	3.0	9.0
Benz(a)anthracene	7.0	7.0	3.0	14.0	1.0	4.0	2.0	1.0	2.0	1.0	4.0
Chrysene	14.0	14.0	9.0	27.0	4.0	6.0	4.0	3.0	3.0	3.0	11.0
Benzofluoranthene	27.0	22.0	10.0	41.0	6.0	12.0	5.0	3.0	5.0	4.0	14.0
Benzo(e)pyrene	11.0	9.0	4.0	16.0	2.0	5.0	2.0	2.0	2.0	2.0	6.0
Benzo(a)pyrene	6.0	12.0	3.0	20.0	1.0	3.0	2.0	1.0	1.0	1.0	5.0
Perylene	22.0	88.0	2.0	31.0	5.0	2.0	3.0	2.0	1.0	1.0	12.0
Total PAH (Sum of above compounds)	248.0	330.0	144.0	327.0	69.0	101.0	44.0	71.0	48.0	41.0	168.0
FFPI[b]	34	29	35	28	38	36	34	56	46	46	45

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalenes } (C_0\text{-}C_4) + \text{dibenzothiophenes } (C_0\text{-}C_3) + 1/2 \text{ phenanthrenes } (C_0\text{-}C_1) + \text{phenanthrenes } (C_2\text{-}C_4)}{\text{PAH}}$$

ND = Not detected

TABLE H.8. CONCENTRATIONS (ng/g DRY WEIGHT) OF POLYNUCLEAR AROMATIC HYDROCARBONS FOUND IN CRUISE SA-6 SEDIMENT SAMPLES.

Compound	Station No. 4	9	10	11	12	13	14	15	16
Napthalene	6.0	NC[c]	5.0	2.0	4.0	2.0	2.0	1.0	2.0
C_1-Naphthalenes	7.0	NC[c]	6.0	2.0	5.0	2.0	2.0	1.0	3.0
C_2-Naphthalenes	10.0	NC[c]	11.0	2.0	5.0	3.0	1.0	1.0	2.0
C_3-Naphthalenes	13.0	NC[c]	10.0	1.0	5.0	3.0	1.0	1.0	2.0
C_4-Naphthalenes	3.0	NC[c]	1.0	ND	1.0	ND	ND	ND	ND
Biphenyl	2.0	NC[c]	1.0	ND	1.0	ND	1.0	ND	1.0
Fluorene	2.0	NC[c]	2.0	ND	2.0	1.0	ND	ND	1.0
C_1-Fluorenes	4.0	NC[c]	3.0	ND	2.0	1.0	ND	ND	1.0
C_2-Fluorenes	8.0	NC[c]	7.0	1.0	2.0	2.0	ND	ND	1.0
C_3-Fluorenes	9.0	NC[c]	8.0	ND	1.0	2.0	ND	ND	1.0
Phenanthrene	17.0	NC[c]	12.0	5.0	16.0	6.0	6.0	2.0	8.0
C_1-Phenanthrenes[a]	17.0	NC[c]	15.0	3.0	9.0	5.0	4.0	2.0	6.0
C_2-Phenanthrenes[a]	20.0	NC[c]	16.0	3.0	7.0	5.0	3.0	2.0	5.0
C_3-Phenanthrenes[a]	14.0	NC[c]	14.0	1.0	4.0	3.0	1.0	ND	2.0
C_4-Phenanthrenes[a]	6.0	NC[c]	2.0	ND	1.0	1.0	ND	1.0	ND
Dibenzothiophene	2.0	NC[c]	1.0	ND	1.0	ND	ND	ND	1.0
C_1-Dibenzothiophenes	3.0	NC[c]	3.0	ND	1.0	1.0	ND	ND	1.0
C_2-Dibenzothiophenes	3.0	NC[c]	3.0	ND	1.0	ND	ND	ND	ND
C_3-Dibenzothiophenes	1.0	NC[c]	1.0	ND	ND	ND	ND	ND	ND
Fluoranthene	23.0	NC[c]	21.0	7.0	21.0	8.0	8.0	3.0	10.0
Pyrene	17.0	NC[c]	17.0	5.0	17.0	6.0	7.0	2.0	8.0
Benz(a)anthracene	10.0	NC[c]	8.0	3.0	11.0	3.0	4.0	2.0	4.0
Chrysene	14.0	NC[c]	12.0	4.0	12.0	6.0	4.0	3.0	7.0
Benzofluoranthene	32.0	NC[c]	28.0	9.0	33.0	16.0	13.0	6.0	19.0
Benzo(e)pyrene	12.0	NC[c]	13.0	4.0	13.0	6.0	6.0	2.0	6.0
Benzo(a)pyrene	9.0	NC[c]	8.0	2.0	8.0	3.0	4.0	1.0	4.0
Perylene	28.0	NC[c]	131.0	2.0	17.0	10.0	3.0	2.0	12.0
Total PAH (Sum of above compounds)	292.0	NC[c]	359.0	56.0	200.0	95.0	70.0	32.0	107.0
FFPI[b]	36	NC[c]	24	27	23	26	21	28	23

[a]May include some anthracene alkyl homologues.
[b]Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).
FFPI = naphthalenes (C_0-C_4) + dibenzothiophenes (C_0-C_3) + 1/2 phenanthrenes (C_0-C_1) + phenanthrenes (C_2-C_4).

PAH

[c]Sample not collected.

TABLE H.9. TISSUE HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARMETERS FOR SAMPLES COLLECTED ON CRUISE SA-4.

Station	4	4	4	4	14	14
Organism	O. lymani (Brittle Star)	O. lymani (Brittle Star)	O. lymani (Brittle Star)	O. lymani (Brittle Star)	Stereomastis (Shrimp)	Stereomastis (Shrimp)
	Concentration (µg/g dry weight)					
Total Hydrocarbons[a]	5.24	0	0	0	0	0
Saturated	5.24	0	0	0	0	0
Aromatic	0	0	0	0	0	0
	Saturated Hydrocarbon Parameters[b]					
Resolved Saturated (%)	100	70	24	23	59	100
Unresolved Saturated (%)	0	30	76	77	41	0
OEPI[c]	1.1	1.1	1.0	1.3	1.1	1.1
Pristane/Phytane	U[d]	U[d]	U[d]	U[d]	11.8	U[d]
Pristane/n-C_{17}	7	0	11	85.9	0	0
Phytane/n-C_{18}	0	0	0	0	0	0

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index = $\frac{2(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2(n\text{-}C_{28}) + n\text{-}C_{30}}$

[d]U=Undefined.

TABLE H.10. TISSUE HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE SA-5.

Station	11	4	4	4
Organism	M. valida (Crab)	O. lymani (Brittle Star)	E. affinis (Sea Urchin)	B. heros (Brittle Star)
	Concentration (µg/g wet weight)			
Total Hydrocarbons[a]	84.20	184.5	46.14	322.37
Saturated	4.48	46.06	26.3	54.2
Aromatic	79.72	138.44	19.84	268.2
	Saturated Hydrocarbon Parameters[b]			
Resolved Saturates (%)	100	63	65	55
Unresolved Saturates (%)	0	37	35	45
OEPI[c]	2.6	0.98	1.68	1.56
Prestane/Phytane	U[d]	U[d]	15.4	U[d]
Prestane/n-C_{17}	0	0	1.03	0.002
Phytane/n-C_{18}	0	0	2.61	0

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index = $\frac{2(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2(n\text{-}C_{28}) + n\text{-}C_{30}}$
[d]U=Undefined.

TABLE H.11. CONCENTRATIONS (ng/g WET WEIGHT) OF POLYNUCLEAR AROMATIC HYDROCARBONS FOUND IN TISSUE SAMPLES COLLECTED ON CRUISE SA-4.

Station	4	11	14(A)[a]	14(B)	14(C)	15(A)[a]	15(B)	15(C)
Organism	O. lymani (Brittle Star)	M. valida (Crab)	Stereomastis (Shrimp)	Stereomastis (Shrimp)	Stereomastis (Shrimp)	B. heros (Brittle Star)	B. heros (Brittle Star)	B. heros (Brittle Star)
Compound								
Napthalene	5.0	5.0	29.0	35.0	19.0	3.0	8.0	2.0
C_1-Napthalenes	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
C_2-Napthalenes	ND	ND	ND	ND	ND	ND	1.0	ND
C_3-Napthalenes	ND	ND	ND	ND	ND	ND	ND	ND
C_4-Napthalenes	ND	ND	ND	ND	ND	ND	ND	3.0
Biphenyl	1.0	ND	2.0	1.0	ND	1.0	1.0	ND
Fluorene	ND	ND	ND	ND	ND	ND	ND	ND
C_1-Fluorenes	ND	ND	ND	ND	ND	ND	ND	ND
C_2-Fluorenes	ND	ND	ND	ND	ND	ND	ND	3.0
C_3-Fluorenes	ND	ND	ND	ND	ND	ND	ND	39.0
Phenanthrene	1.0	1.0	6.0	ND	ND	1.0	1.0	2.0
C_1-Phenanthrenes[b]	ND	ND	1.0	ND	ND	ND	ND	4.0
C_2-Phenanthrenes[b]	7.0	ND	ND	ND	ND	5.0	5.0	55.0
C_3-Phenanthrenes[b]	ND	ND	ND	ND	ND	5.0	4.0	113.0
C_4-Phenanthrenes[b]	ND	ND	ND	ND	ND	ND	ND	6.0
Dibenzothiopene	ND	ND	ND	ND	ND	ND	ND	ND
C_1-Dibenzothiopenes	ND	ND	ND	ND	ND	ND	ND	ND
C_2-Dibenzothiopenes	ND	ND	ND	ND	ND	2.0	ND	14.0
C_3-Dibenzothiopenes	ND	ND	ND	ND	ND	1.0	ND	103.0
Fluoranthene	ND	ND	11.0	ND	ND	1.0	1.0	9.0
Pyrene	ND	ND	23.0	ND	ND	2.0	ND	7.0
Benz(a)anthracene	2.0	ND	33.0	4.0	2.0	3.0	2.0	14.0
Chrysene	1.0	2.0	26.0	7.0	1.0	6.0	6.0	25.0
Benzofluoranthene	ND	ND	42.0	ND	ND	ND	ND	6.0
Benzo(e)pyrene	ND	ND	49.0	ND	ND	ND	1.0	5.0
Benzo(a)pyrene	ND	ND	42.0	7.0	ND	3.0	ND	1.0
Perylene	ND	2.0	49.0	ND	ND	2.0	ND	ND
Total PAH (Sum of above compounds)	18.0	11.0	314.0	55.0	23.0	36.0	32.0	412.0

[a]Replicate samples of species collected at Stations 14 and 15.
[b]May include some anthracene alkyl homologues.
ND=Not detected.

TABLE H.12. CONCENTRATIONS (ng/g WET WEIGHT) OF POLYNUCLEAR AROMATIC HYDROCARBONS FOUND IN TISSUE SAMPLES COLLECTED ON CRUISE SA-5.

Station	11	4	4	4
Organism	M. valida (Crab)	O. lymani (Brittle Star)	B. heros (Brittle Star)	E. affinis (Sea Urchin)
Compound				
Napthalene	3.0	3.0	10	4.0
C_1-Napthalenes	1.0	1.0	10	1.0
C_2-Napthalenes	ND	ND	ND	ND
C_3-Napthalenes	ND	ND	ND	ND
C_4-Napthalenes	ND	ND	ND	ND
Biphenyl	1.0	ND	2.0	ND
Fluorene	ND	ND	ND	ND
C_1-Fluorenes	ND	ND	ND	ND
C_2-Fluorenes	ND	1.0	3.0	ND
C_3-Fluorenes	ND	ND	ND	ND
Phenanthrene	3.0	2.0	2.0	ND
C_1-Phenanthrenes	ND	ND	ND	ND
C_2-Phenanthrenes	ND	ND	ND	ND
C_3-Phenanthrenes	ND	ND	ND	ND
C_4-Phenanthrenes	ND	ND	ND	ND
Dibenzothiophene	ND	ND	ND	ND
C_1-Dibenzothiophenes	ND	ND	ND	ND
C_2-Dibenzothiophenes	ND	ND	ND	ND
C_3-Dibenzothiophenes	ND	ND	ND	ND
Fluoranthene	ND	ND	3.0	ND
Pyrene	ND	ND	3.0	ND
Benz(a)anthracene	ND	ND	4.0	1.0
Chrysene	ND	ND	5.0	2.0
Benzofluoranthene	ND	1.0	ND	1.0
Benzo(e)pyrene	ND	ND	ND	ND
Benzo(a)pyrene	2.0	ND	11	1.0
Perylene	2.0	ND	13	2.0
Total PAH	12	13	70	12

ND=Not detected.

TABLE H.13. TRACE METAL CONCENTRATIONS (µg/g DRY WEIGHT) IN BENTHIC FAUNA COLLECTED DURING CRUISE SA-4.

Species	Station	Al	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	V	Zn
O. lymani	4	22	8.5	0.41	0.05	2.0	<20	0.02	1.8	0.35	0.39	0.32	32
(Brittle Star)		97		16	0.21	2.0	52	0.11	6.5	2.8	0.63		129
M. valida	11	764	29.0	1.2	1.1	32	500	0.24	28	3.5	0.75	<0.2	55
(Crab)		555	13.0	1.5	0.97	63	210	0.32	29	2.9	0.17	0.28	48
		550	19.0	2.1	1.1	65	204	0.24	28	4.0	0.24	<0.2	48
B. heros	15	235	10.0	5.7	0.55	3.7	154	0.32	12	1.9	0.61	1.7	39
(Brittle Star)		296		5.1	0.58	3.6	169	0.30	13	2.2	0.53		40
B. heros	15	225	9.7	5.4	0.60	2.4	168	0.26	13	1.8	0.24	<0.2	32
(Brittle Star)		229		3.6	0.41	1.8	137	0.18	10	1.2	0.33		26
B. heros	15	173	10.0	2.8	0.52	2.1	117	0.22	12	1.6	0.35	<0.2	37
(Brittle Star)		215		2.6	0.60	1.8	108	0.17	10	1.6	0.40		37
Stereomastis sp.	14	494	<2.0	73	0.80	122	335	0.59	16	2.1	0.56	<0.2	74
(Shrimp)		575		48	0.82	92	264	0.82	16	1.9	0.51		71

TABLE H.14. TRACE METAL CONCENTRATIONS (µg/g DRY WEIGHT) IN BENTHIC FAUNA COLLECTED DURING CRUISE SA-5.

Species	Station	Al	Ba	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	V	Zn
E. affinis (Sea Urchin)	4	810	2.88	1.90	2.45	1.45	615	0.214	30.0	2.41	1.03	38.9	46.6
E. affinis	4	677	2.64	2.40	2.08	0.979	485	0.178	31.1	2.12	0.987	39.0	43.5
B. heros	4	1050	1.52	9.20	2.40	3.98	1110	0.360	13.2	3.88	0.760	9.86	58.6
B. heros	4	1120	1.63	10.22	2.92	5.03	942	0.495	12.0	3.87	0.891	11.32	67.8
Munida valida (Crab)	11	1920	2.53	3.71	2.85	83.6	890	0.289	30.9	3.63	2.08	15.47	71.5
Munida valida	11	1630	2.31	3.58	0.877	99.9	978	0.425	31.8	2.38	1.80	17.95	72.9

APPENDIX I

TABLE I-1. SEDIMENT GRAIN-SIZE DATA FOR U.S. SOUTH ATLANTIC STATIONS, PHASE 2.

Cruise	Station/ Replicate	Percent Water	Percent Sand					Percent Silt				Percent Clay		
			-1ϕ-0ϕ	0ϕ-1ϕ	1ϕ-2ϕ	2ϕ-3ϕ	3ϕ-4ϕ	4ϕ-5ϕ	5ϕ-6ϕ	6ϕ-7ϕ	7ϕ-8ϕ	8ϕ-9ϕ	9ϕ-10ϕ	>10ϕ
4	4-1	59.8	0.1	1.2	3.0	4.1	11.4	6.9	15.0	9.5	9.9	8.0	9.5	21.2
	4-2	64.2	0.0	1.6	4.1	5.9	12.5	5.1	10.9	8.6	10.2	7.8	7.8	25.4
	4-3	59.6	0.0	0.5	2.7	2.7	13.7	13.4	12.1	8.4	8.0	7.0	7.4	24.1
5	4-1	63.7	0.0	1.1	2.9	2.5	11.9	11.1	13.2	9.0	10.1	9.7	7.6	20.8
	4-2	65.0	0.0	1.6	3.8	3.8	16.9	11.1	11.5	9.9	11.1	7.9	7.9	16.6
	4-3	61.2	0.0	0.8	2.1	2.6	12.2	9.1	3.6	20.2	10.8	8.8	9.5	20.2
6	4-1	62.4	0.0	0.9	2.1	2.0	12.6	13.8	11.3	7.3	8.4	5.5	7.6	28.4
	4-2	63.8	0.0	0.7	2.2	2.3	14.3	14.4	12.0	7.4	9.1	6.2	7.0	24.3
	4-3	58.9	0.0	1.0	1.9	1.5	10.2	13.9	11.4	9.2	7.6	7.3	7.9	28.1
3	9-1	64.3	0.2	0.2	0.3	2.5	36.7	11.3	8.3	5.7	6.0	3.0	4.5	21.2
	9-2	54.7	0.1	0.2	0.3	2.3	36.2	20.2	5.6	1.5	6.6	5.1	2.0	19.7
	9-3	55.7	0.1	0.2	0.3	2.4	34.2	13.5	8.5	7.3	7.3	5.3	4.4	16.4
4	9-1	49.4	0.0	0.0	0.2	8.9	42.7	10.4	8.4	5.1	4.6	3.9	3.9	12.0
	9-2	51.0	0.0	0.0	0.2	12.9	43.0	7.4	7.7	4.5	4.0	3.7	4.0	12.5
	9-3	47.4	0.0	0.0	0.1	5.4	42.5	13.1	7.7	5.7	4.7	4.7	6.7	9.4
5	9-1	49.3	0.1	0.1	0.2	11.0	44.1	10.2	7.9	5.1	4.6	3.7	4.2	8.5
	9-2	50.5	0.1	0.1	0.3	10.6	45.2	10.8	7.5	5.2	4.7	3.1	3.8	8.5
	9-3	56.9	0.1	0.1	0.3	9.9	32.1	9.3	10.7	7.5	6.6	5.4	4.8	13.1
4	10-1	58.8	0.0	0.0	0.2	4.3	38.9	9.4	11.0	6.3	5.3	4.1	6.0	14.6
	10-2	48.0	0.0	0.0	0.1	3.1	57.4	9.9	6.9	3.4	3.4	3.0	7.9	4.8
	10-3	53.7	0.0	0.0	0.2	9.6	45.4	11.1	7.0	4.7	4.1	3.4	2.6	11.9
6	10-1	51.6	0.1	0.1	0.1	1.1	23.2	17.4	12.3	10.5	6.7	6.0	6.0	16.5
	10-2	48.5	0.1	0.1	0.2	3.9	41.6	16.8	7.8	5.8	4.9	3.8	3.1	11.7
	10-3	48.3	0.0	0.7	0.5	2.7	38.9	17.7	8.4	6.4	4.6	4.6	3.5	11.9

TABLE I.1. (Continued).

Cruise	Station/ Replicate	Percent Water	Percent Sand					Percent Silt				Percent Clay		
			-1ϕ-0ϕ	0ϕ-1ϕ	1ϕ-2ϕ	2ϕ-3ϕ	3ϕ-4ϕ	4ϕ-5ϕ	5ϕ-6ϕ	6ϕ-7ϕ	7ϕ-8ϕ	8ϕ-9ϕ	9ϕ-10ϕ	>10ϕ
4	11-1	59.4	0.2	3.6	11.0	13.9	13.5	7.2	11.0	6.8	6.2	5.1	3.8	17.8
	11-2	61.8	0.2	3.2	9.0	11.8	13.2	9.7	10.9	6.9	5.4	4.9	5.4	19.2
	11-3	57.9	0.3	3.8	10.1	13.8	13.0	10.6	9.9	6.8	4.7	4.0	4.7	18.3
5	11-1	59.1	0.3	3.5	8.2	11.5	12.9	11.8	10.9	8.4	6.2	5.6	8.7	11.8
	11-2	55.9	0.4	5.4	10.9	13.9	13.1	11.0	10.1	5.7	6.0	4.7	5.3	13.5
	11-3	56.0	0.4	4.5	10.7	12.5	14.3	9.9	11.6	5.0	5.2	3.9	5.8	16.3
6	11-1	57.2	0.2	3.4	8.8	12.4	13.0	12.6	10.0	5.7	5.2	3.7	4.3	20.7
	11-2	55.9	0.1	2.7	7.2	15.0	10.5	12.0	10.9	8.4	5.9	5.0	5.0	17.2
	11-3	58.9	0.2	3.2	8.1	11.6	11.7	14.5	10.7	6.5	5.5	5.5	3.2	19.4
4	12-1	66.3					5.6	10.7	17.0	13.2	10.7	7.6	5.7	29.6
	12-2	69.0					6.5	8.1	16.8	14.8	10.1	8.7	6.7	28.2
	12-3	64.3					5.6	10.6	14.8	14.2	11.2	8.3	7.7	27.7
5	12-1	69.3					5.9	8.4	16.8	12.8	14.2	9.9	8.4	23.7
	12-2*	*	*	*	*	*	*	*	*	*	*	*	*	*
	12-3*	*	*	*	*	*	*	*	*	*	*	*	*	*
6	12-1	65.3					4.2	9.5	16.6	14.3	13.1	11.5	7.9	23.0
	12-2	61.0					7.1	9.0	10.7	10.3	9.9	7.4	8.2	37.4
	12-3	62.6					6.6	8.4	15.0	11.3	11.7	8.4	8.1	30.4
4	13-1	52.5	0.1	3.7	8.8	4.8	4.8	5.3	15.6	8.8	7.7	7.2	6.3	26.9
	13-2	56.3	0.0	1.8	3.2	2.7	5.0	10.5	13.0	9.3	10.5	9.3	6.8	28.0
	13-3	64.1	0.0	1.9	4.1	3.4	4.6	10.7	11.5	9.6	8.8	7.4	5.7	32.3
5	13-1	57.7	0.0	2.1	3.3	2.2	4.2	8.9	12.7	8.9	10.3	6.4	8.9	32.2
	13-2	54.3	0.0	2.1	3.8	2.9	5.1	8.6	13.1	10.3	10.3	9.2	7.5	27.0
	13-3	59.8	0.1	3.6	5.4	3.2	5.5	10.2	11.7	8.3	0.6	14.8	8.6	28.0
6	13-1	56.3	0.1	6.7	13.0	5.6	4.3	9.6	9.3	7.7	7.7	6.1	5.8	24.0
	13-2	57.4	0.2	3.6	5.2	2.5	3.9	9.1	12.1	8.5	10.0	8.5	8.8	27.6
	13-3	53.0	0.1	2.3	8.3	5.4	5.4	12.7	11.3	8.1	8.3	7.1	6.9	24.0

TABLE I.1. (Continued).

Cruise	Station/ Replicate	Percent Water	Percent Sand					Percent Silt				Percent Clay		
			-1ϕ-0ϕ	0ϕ-1ϕ	1ϕ-2ϕ	2ϕ-3ϕ	3ϕ-4ϕ	4ϕ-5ϕ	5ϕ-6ϕ	6ϕ-7ϕ	7ϕ-8ϕ	8ϕ-9ϕ	9ϕ-10ϕ	>10ϕ
4	14-1	57.5	0.4	4.4	10.0	13.5	10.2	13.0	10.2	5.7	4.2	2.6	3.6	22.1
	14-2	54.1	0.3	4.4	12,3	16.5	10.3	12.6	10.2	5.0	4.0	3.8	4.8	15.8
	14-3	59.6	0.2	4.8	9.6	14.2	9.6	12.3	10.4	6.4	3.7	4.0	3.7	21.1
5	14-1	56.5	0.3	4.8	11.8	16.8	10.7	12.1	9.5	5.9	5.6	4.7	4.7	13.0
	14-2	57.1	0.2	3.8	10.5	15.5	11.6	12.3	10.1	6.5	6.5	5.4	5.4	12.3
	14-3	59.9	0.1	3.8	9.2	13.5	11.0	13.3	10.6	6.3	5.5	5.5	5.1	16.1
6	14-1	60.9	0.2	3.8	10.0	15.4	11.7	11.8	9.3	6.9	4.9	4.7	4.4	16.9
	14-2	58.9	0.2	4.1	10.4	15.4	10.8	9.6	10.1	6.6	4.6	4.6	4.6	18.9
	14-3	58.4	0.4	3.8	10.0	15.2	13.0	15.0	7.3	5.4	4.8	4.1	3.5	17.5
5	14A-1	34.5	3.4	26.9	54.2	6.0	1.8	0.6	0.8	0.3	0.5	1.8	1.7	1.8
	14A-2	44.2	7.5	26.1	47.5	8.6	1.5	0.5	0.4	0.4	0.4	2.1	2.1	2.1
	14A-3	36.5	6.2	36.9	44.4	4.9	1.2	0.8	0.4	0.1	0.6	1.3	1.3	1.3
4	15-1	57.1	0.8	18.1	37.6	10.9	4.4	5.5	4.2	1.6	1.0	0.6	0.6	13.8
	15-2	51.8	0.4	13.9	33.2	10.3	3.9	6.6	6.4	4.4	2.2	2.6	2.6	13.6
	15-3	58.3	0.8	13.5	24.3	12.3	7.8	8.9	6.0	4.5	2.4	1.8	3.2	14.5
5	15-1	52.4	0.3	16.1	35.4	9.9	4.4	6.7	5.8	3.2	3.2	2.8	3.5	8.6
	15-2	48.1	0.2	10.1	27.6	9.8	5.6	6.3	8.8	4.4	4.7	3.4	13.1	5.9
	15-3	51.2	0.3	17.6	35.8	9.7	4.2	6.4	5.0	3.6	3.4	1.8	3.4	8.7
4	16-1	58.1					5.0	4.7	10.8	11.8	11.8	9.8	10.1	35.8
	16-2	63.2					6.1	4.6	10.6	11.6	12.0	11.1	11.1	32.9
	16-3	61.0					6.0	4.5	9.1	13.3	11.5	9.8	11.2	34.6
5	16-1	66.0					5.8	5.1	9.9	10.3	11.5	9.5	9.5	39.1
	16-2	64.6					4.2	1.9	10.6	10.6	13.0	11.6	9.6	38.5
	16-3	59.8					5.2	4.6	9.8	11.3	13.7	10.9	11.3	32.7
6	16-1	62.0					5.4	4.8	10.4	11.4	12.8	11.0	11.7	32.5
	16-2	59.9					9.4	4.5	12.4	10.3	11.7	11.4	10.0	30.3
	16-3	61.4					6.8	3.2	10.4	12.1	11.8	11.1	12.9	31.8

*No samples collected.

APPENDIX J

TABLE J-1. SUMMARY MEASURES (INCLUDING MEAN AND STANDARD DEVIATION) OF WATER CONTENT AND SEDIMENT GRAIN SIZE OF U.S. SOUTH ATLANTIC STATIONS, PHASE 2.

Station	Cruise	Rep.	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/ Clay Ratio	% Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
4	4	1	59.8	0.2	19.9	41.3	38.7	1.07	18.8	7.17	3.28	0.06
		2	64.2	0.1	24.1	34.8	41.0	0.85	14.4	7.26	3.50	0.00
		3	59.6	0.0	19.6	41.9	38.5	1.09	16.7	7.19	3.32	0.23
		$\bar{x}$	61.2	0.1	21.2	39.3	39.4	1.00	16.6	7.21	3.37	0.10
		S.D.	2.6	0.1	2.5	3.9	1.4	0.13	2.2	0.05	0.12	0.12
	5	1	63.7	0.0	18.4	43.4	38.1	1.14	16.2	7.14	3.20	0.18
		2	65.0	0.0	24.1	43.6	32.4	1.35	15.1	6.70	3.19	0.27
		3	61.2	0.0	17.7	43.7	38.5	1.14	24.6	7.33	3.07	0.09
		$\bar{x}$	63.3	0.0	20.1	43.6	36.3	1.21	18.6	7.06	3.15	0.18
		S.D.	1.9	0.0	3.5	0.2	3.4	0.12	5.2	0.32	0.07	0.09
	6	1	62.4	0.0	17.6	40.8	41.5	0.98	16.8	7.47	3.40	0.12
		2	63.8	0.0	19.5	42.9	37.5	1.14	17.9	7.17	3.32	0.26
		3	58.9	0.0	14.6	42.1	43.3	0.97	16.3	7.59	3.32	0.07
		$\bar{x}$	61.7	0.0	17.2	41.9	40.8	1.03	17.0	7.41	3.35	0.15
		S.D.	2.5	0.0	2.5	1.1	3.0	0.10	0.8	0.22	0.05	0.10
9	3	1	64.3	0.1	39.9	31.3	28.7	1.09	18.8	6.36	3.39	0.69
		2	54.7	0.1	39.1	33.9	26.8	1.26	33.3	6.13	3.32	0.87
		3	55.7	0.0	37.2	36.6	26.1	1.40	21.5	6.20	3.14	0.81
		$\bar{x}$	58.2	0.1	38.7	33.9	27.2	1.25	24.5	6.23	3.28	0.79
		S.D.	5.3	0.1	1.4	2.6	1.3	0.16	7.7	0.12	0.13	0.09
	4	1	49.4	0.0	51.8	28.5	19.6	1.45	21.6	5.45	2.98	1.21
		2	51.0	0.0	56.1	23.6	20.2	1.17	17.6	5.37	3.07	1.20
		3	47.4	0.0	48.0	31.2	20.8	1.50	25.2	5.52	2.84	1.15
		$\bar{x}$	49.3	0.0	52.0	27.8	20.2	1.37	21.5	5.45	2.96	1.19
		S.D.	1.8	0.0	4.1	3.8	0.6	0.18	3.8	0.08	0.12	0.03
	5	1	49.3	0.3	55.5	27.8	16.4	1.70	23.1	5.12	2.79	1.30
		2	50.5	0.1	56.3	28.2	15.4	1.83	24.8	5.08	2.75	1.40
		3	56.9	0.1	42.5	34.1	23.3	1.46	18.6	5.85	3.07	0.86
		$\bar{x}$	52.2	0.2	51.4	30.0	18.4	1.66	22.2	5.35	2.87	1.19
		S.D.	4.1	0.1	7.7	3.5	4.3	0.19	3.2	0.43	0.17	0.29

TABLE J-1. (Continued).

Station	Cruise	Rep.	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/ Clay Ratio	% Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
10	4	1	58.8	0.0	43.4	32.0	24.7	1.30	19.4	5.98	3.10	0.91
		2	48.0	0.0	60.6	23.6	15.7	1.50	25.2	4.97	2.48	1.55
		3	53.7	0.0	55.2	26.9	17.9	1.50	24.8	5.29	2.96	1.34
		$\bar{x}$	53.5	0.0	53.1	27.5	19.4	1.43	23.1	5.41	2.85	1.27
		S.D.	5.4	0.0	8.8	4.2	4.7	0.12	3.2	0.52	0.32	0.33
	6	1	51.6	0.0	24.6	46.9	28.5	1.65	23.1	6.55	3.00	0.71
		2	48.5	0.1	45.9	35.3	18.6	1.90	31.2	5.51	2.89	1.24
		3	48.3	0.0	42.8	37.1	20.0	1.85	31.0	5.61	2.91	1.16
		$\bar{x}$	49.5	0.0	37.8	39.8	22.4	1.80	28.4	5.89	2.93	1.04
		S.D.	1.8	0.1	11.5	6.2	5.4	0.13	4.6	0.57	0.06	0.28
11	4	1	59.4	0.0	42.2	31.2	26.7	1.17	19.0	5.77	3.66	0.52
		2	61.8	0.1	37.4	32.9	29.5	1.12	17.5	6.03	3.67	0.44
		3	57.9	0.0	41.0	32.0	27.0	1.19	18.0	5.77	3.68	0.54
		$\bar{x}$	59.7	0.0	40.2	32.0	27.7	1.16	18.2	5.86	3.67	0.50
		S.D.	2.0	0.1	2.5	0.8	1.5	0.04	0.8	0.15	0.01	0.05
	5	1	59.1	0.1	36.4	37.3	26.1	1.43	18.6	5.74	3.34	0.46
		2	55.9	0.1	43.7	32.8	23.5	1.40	19.5	5.39	3.53	0.61
		3	56.0	0.0	42.4	31.7	26.0	1.22	20.1	5.63	3.63	0.56
		$\bar{x}$	57.0	0.1	40.8	33.9	25.2	1.35	19.4	5.59	3.50	0.54
		S.D.	1.8	0.1	3.9	3.0	1.5	0.11	0.8	0.18	0.15	0.08
	6	1	57.2	0.0	37.8	33.5	28.7	1.17	20.3	6.00	3.73	0.49
		2	55.9	0.0	35.5	37.2	27.2	1.37	18.6	5.96	3.52	0.51
		3	58.9	0.0	34.8	37.2	28.1	1.32	22.2	6.01	3.61	0.49
		$\bar{x}$	57.3	0.0	36.0	36.0	28.0	1.29	20.4	5.99	3.62	0.50
		S.D.	1.5	0.0	1.6	2.1	0.8	0.10	1.8	0.03	0.11	0.01
12	4	1	66.3	0.0	5.6	51.6	42.9	1.20	18.0	8.01	2.95	0.23
		2	69.0	0.0	6.5	49.8	43.6	1.14	18.0	8.00	2.90	0.24
		3	64.3	0.0	5.6	50.8	43.7	1.16	15.7	8.01	2.89	0.22
		$\bar{x}$	66.5	0.0	5.9	50.7	43.4	1.17	17.2	8.01	2.91	0.23
		S.D.	2.4	0.0	0.5	0.9	0.4	0.03	1.3	0.01	0.03	0.01
	5	1	69.3	0.0	5.9	52.2	42.0	1.24	17.8	7.89	2.75	0.28

TABLE 3.1. (Continued).

Station	Cruise	Rep.	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/ Clay Ratio	% Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
	6	1	65.3	0.0	4.2	53.5	42.4	1.26	17.3	7.89	2.70	0.33
		2	61.0	0.0	7.1	39.9	53.0	0.75	11.5	8.55	3.06	-0.13
		3	62.6	0.0	6.6	46.4	46.9	0.99	16.1	8.18	2.94	0.11
		$\bar{x}$	63.0	0.0	6.0	46.6	47.4	1.00	15.0	8.21	2.90	0.10
		S.D.	2.2	0.0	1.6	6.8	5.3	0.26	3.1	0.33	0.18	0.23
13	4	1	52.5	0.0	22.2	37.4	40.4	0.93	20.1	7.12	3.72	-0.06
		2	56.3	0.0	12.7	43.3	44.1	0.98	14.9	7.68	3.33	-0.09
		3	64.1	0.0	14.0	40.6	45.4	0.89	13.4	7.76	3.51	-0.14
		$\bar{x}$	57.6	0.0	16.3	40.4	43.3	0.93	16.1	7.52	3.52	-0.10
		S.D.	5.9	0.0	5.2	3.0	2.6	0.04	3.5	0.35	0.20	0.04
	5	1	57.7	0.0	11.8	40.8	47.5	0.86	14.4	7.97	3.40	-0.24
		2	54.3	0.0	13.9	42.3	43.7	0.97	15.2	7.60	3.34	-0.10
		3	59.8	0.0	17.8	30.8	51.4	0.60	14.2	7.49	3.62	-0.19
		$\bar{x}$	57.3	0.0	14.5	38.0	47.5	0.81	14.6	7.69	3.45	-0.18
		S.D.	2.8	0.0	3.0	6.2	3.8	0.19	0.5	0.25	0.15	0.07
	6	1	56.3	0.0	29.7	34.3	35.9	0.96	13.7	6.49	3.95	0.10
		2	57.4	0.0	15.4	39.7	44.9	0.88	14.3	7.54	3.52	-0.21
		3	53.0	0.0	21.5	40.4	38.0	1.06	16.2	6.94	3.60	0.07
		$\bar{x}$	55.6	0.0	22.2	38.1	39.6	0.97	14.7	6.99	3.69	-0.01
		S.D.	2.3	0.0	7.2	3.3	4.7	0.09	1.3	0.53	0.23	0.17
14	4	1	57.5	0.1	38.5	33.1	28.3	1.17	21.2	5.91	3.85	0.49
		2	54.1	0.1	43.8	31.8	24.4	1.30	22.4	5.40	3.64	0.66
		3	59.6	0.0	38.4	32.8	28.8	1.14	20.0	5.90	3.81	0.49
		$\bar{x}$	57.1	0.1	40.2	32.6	27.2	1.20	21.2	5.74	3.77	0.55
		S.D.	2.8	0.1	3.1	0.7	2.4	0.08	1.2	0.29	0.11	0.10
	5	1	56.5	0.0	44.4	33.1	22.4	1.48	21.8	5.27	3.49	0.69
		2	57.1	0.0	41.6	35.4	23.1	1.53	21.0	5.44	3.40	0.62
		3	59.9	0.0	37.6	35.7	26.7	1.34	21.3	5.77	3.55	0.54
		$\bar{x}$	57.8	0.0	41.2	34.7	24.1	1.45	21.4	5.49	3.48	0.62
		S.D.	1.8	0.0	3.4	1.4	2.3	0.10	0.4	0.25	0.08	0.08
	6	1	60.9	0.1	41.1	32.9	26.0	1.27	20.0	5.67	3.63	0.57
		2	58.9	0.0	40.9	30.9	28.1	1.10	17.1	5.80	3.74	0.51
		3	58.4	0.0	42.4	32.5	25.1	1.29	26.0	5.57	3.65	0.65
		$\bar{x}$	59.4	0.0	41.5	32.1	26.4	1.22	21.0	5.68	3.67	0.58
		S.D.	1.3	0.1	0.8	1.1	1.5	0.10	4.5	0.12	0.06	0.07

TABLE J-1. (Continued).

Station	Cruise	Rep.	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/ Clay Ratio	% Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
14A	5	1	34.5	0.3	92.3	2.2	5.3	0.42	10.7	1.80	2.21	3.08
		2	44.2	0.8	91.2	1.7	6.3	0.27	6.3	1.79	2.39	2.77
		3	36.5	0.6	93.6	1.9	3.9	0.49	13.8	1.47	2.01	3.38
		$\bar{x}$	38.4	0.6	92.4	1.9	5.2	0.39	10.3	1.69	2.20	3.08
		S.D.	5.1	0.2	1.2	0.2	1.2	0.11	3.8	0.19	0.19	0.31
15	4	1	57.1	0.8	71.8	12.3	15.0	0.82	20.1	3.49	3.80	1.45
		2	51.8	0.0	61.7	19.6	18.8	1.04	17.2	4.16	3.85	1.04
		3	58.3	0.1	58.7	21.8	19.5	1.12	21.5	4.41	3.85	0.95
		$\bar{x}$	55.7	0.3	64.1	17.9	17.8	0.99	19.6	4.02	3.83	1.15
		S.D.	3.4	0.4	6.9	5.0	2.4	0.16	2.2	0.48	0.03	0.27
	5	1	52.4	0.1	66.1	18.9	14.9	1.27	19.8	3.68	3.50	1.23
		2	48.1	0.0	53.3	24.2	22.4	1.08	18.9	4.55	3.52	0.64
		3	51.2	0.0	67.6	18.4	13.9	1.32	19.8	3.59	3.50	1.30
		$\bar{x}$	50.6	0.0	62.3	20.5	17.1	1.22	19.5	3.94	3.51	1.06
		S.D.	2.2	0.1	7.8	3.2	4.6	0.13	0.5	0.53	0.01	0.36
16	4	1	58.1	0.0	5.0	39.1	55.7	0.70	12.4	8.72	2.83	-0.14
		2	63.2	0.0	6.1	38.8	55.1	0.70	12.8	8.60	2.82	-0.12
		3	61.0	0.0	6.0	38.4	55.6	0.69	14.1	8.69	2.83	-0.16
		$\bar{x}$	60.8	0.0	5.7	38.8	55.5	0.70	13.1	8.67	2.83	-0.14
		S.D.	2.6	0.0	0.6	0.4	0.3	0.01	0.9	0.06	0.01	0.02
	5	1	66.0	0.0	5.1	36.8	58.1	0.63	12.1	8.82	3.01	-0.45
		2	64.6	0.0	4.2	36.1	59.7	0.60	13.6	8.95	2.84	-0.44
		3	59.8	0.0	5.7	39.4	54.9	0.72	14.5	8.55	2.95	-0.39
		$\bar{x}$	63.5	0.0	5.0	37.4	57.6	0.65	13.4	8.77	2.93	-0.43
		S.D.	3.2	0.0	0.8	1.8	2.4	0.06	1.2	0.20	0.09	0.03
	6	1	62.0	0.0	5.4	39.4	55.2	0.71	13.5	8.62	2.78	-0.12
		2	59.9	0.0	9.4	38.9	51.7	0.75	13.7	8.32	2.91	-0.05
		3	61.4	0.0	6.8	37.5	55.8	0.67	13.0	8.61	2.79	-0.15
		$\bar{x}$	61.1	0.0	7.2	38.6	54.2	0.71	13.4	8.52	2.83	-0.12
		S.D.	1.1	0.0	2.0	1.0	2.2	0.04	0.4	0.17	0.07	0.05

APPENDIX K

TABLE K.1. RESULTS OF TOTAL ORGANIC CARBON, HYDROGEN, AND NITROGEN ANALYSES FROM ALL CRUISES OF U.S. SOUTH ATLANTIC STUDY, PHASE 2.

Sta.	Rep.	SA-4				SA-5				SA-6			
		%C	%H	%N	C/N	%C	%H	%N	C/N	%C	%H	%N	C/N
4	1	1.49	0.87	0.16	9.31	1.87	0.62	0.23	8.13	3.20	0.60	0.16	20.00
	2	1.54	0.98	0.15	10.27	1.88	0.80	0.23	8.17	1.52	0.52	0.18	8.44
	3	1.91	0.84	0.25	7.64	1.97	0.76	0.25	7.88	2.32	0.82	0.26	8.92
	$\bar{X}$	1.65	0.90	0.19	9.07	1.91	0.73	0.24	8.06	2.35	0.65	0.20	12.46
	S.D.	0.23	0.07	0.06	1.33	0.06	0.09	0.01	0.16	0.84	0.16	0.05	6.54
9	1	1.62	0.50	0.20	8.10	1.12	0.30	0.14	8.00			*	
	2	1.30	0.50	0.16	8.12	1.14	0.34	0.14	8.14			*	
	3	0.90	0.36	0.11	8.18	1.03	0.31	0.13	7.92			*	
	$\bar{X}$	1.27	0.45	0.16	8.14	1.10	0.32	0.14	8.02				
	S.D.	0.36	0.08	0.04	0.04	0.06	0.02	0.01	0.11				
10	1	0.88	0.30	0.10	8.80			*		1.40	0.47	0.17	8.24
	2	1.53	0.48	0.18	8.50			*		1.39	0.39	0.16	8.69
	3	1.00	0.31	0.12	8.33			*		1.23	0.35	0.14	8.78
	$\bar{X}$	1.14	0.36	0.13	8.54					1.34	0.40	0.16	8.57
	S.D.	0.34	0.10	0.04	0.24					0.10	0.06	0.02	0.29
11	1	1.97	1.13	0.11	17.91	1.67	0.94	0.14	11.93	3.51	0.94	0.15	23.40
	2	1.99	2.06	0.25	7.96	1.80	1.10	0.16	11.25	5.69	0.65	0.15	37.93
	3	1.90	1.72	0.18	10.56	1.99	1.07	0.25	7.96	3.71	0.67	0.14	26.50
	$\bar{X}$	1.95	1.64	0.18	12.14	1.82	1.04	0.18	10.38	4.30	0.75	0.15	29.28
	S.D.	0.05	0.47	0.07	5.16	0.16	0.08	0.06	2.12	1.20	0.16	0.01	7.65
12	1	2.83	1.25	0.37	7.65	2.35	0.96	0.29	8.10	2.79	1.05	0.35	7.97
	2	3.20	1.26	0.41	7.80		*			1.46	0.60	0.12	12.17
	3	2.66	1.51	0.31	8.58		*			2.26	1.10	0.27	8.37
	$\bar{X}$	2.90	1.34	0.36	8.01	2.35	0.96	0.29	8.10	2.17	0.92	0.25	9.50
	S.D.	0.28	0.15	0.05	0.50	0.00	0.00	0.00	0.00	0.67	0.28	0.12	2.32

TABLE K.1. (Continued)

Sta.	Rep.	SA-4 %C	SA-4 %H	SA-4 %N	SA-4 C/N	SA-5 %C	SA-5 %H	SA-5 %N	SA-5 C/N	SA-6 %C	SA-6 %H	SA-6 %N	SA-6 C/N
13	1	1.10	1.09	0.11	10.00	1.08	0.56	0.15	7.20	3.96	0.64	0.10	39.60
	2	1.00	0.93	0.14	7.14	1.14	0.76	0.16	7.12	1.64	0.70	0.17	9.65
	3	1.08	0.84	0.12	9.00	1.10	0.70	0.14	7.86	2.94	0.69	0.12	24.50
	$\bar{X}$	1.06	0.95	0.12	8.71	1.11	0.67	0.15	7.39	2.85	0.68	0.13	24.58
	S.D.	0.05	0.13	0.02	1.45	0.03	0.10	0.01	0.40	1.16	0.03	0.04	14.98
14	1	2.05	2.06	0.27	7.59	1.47	1.58	0.13	11.31	4.57	0.81	0.16	28.56
	2	5.83	0.70	0.11	53.00	1.52	1.78	0.17	8.94	5.16	0.73	0.12	43.00
	3	2.11	1.16	0.15	14.07	1.34	0.48	0.16	8.38	2.55	1.01	0.15	17.00
	$\bar{X}$	3.33	1.31	0.18	24.89	1.44	1.28	0.15	9.54	4.09	0.85	0.14	29.52
	S.D.	2.16	0.69	0.08	24.56	0.09	0.70	0.02	1.56	1.37	0.14	0.02	13.03
14A	1		*			3.98	0.85	0.02	199.00		*		
	2		*			2.90	1.02	0.02	145.00		*		
	3		*			4.13	0.80	0.01	413.00		*		
	$\bar{X}$					3.67	0.89	0.02	252.33				
	S.D.					0.67	0.12	0.01	141.74				
15	1	1.87	1.04	0.03	62.33	1.54	0.82	0.04	38.50		*		
	2	1.93	1.06	0.04	48.25	1.55	0.58	0.07	22.14		*		
	3	1.77	0.98	0.06	29.50	1.56	1.28	0.05	31.20		*		
	$\bar{X}$	1.86	1.03	0.04	46.69	1.55	0.89	0.05	30.61				
	S.D.	0.08	0.04	0.02	16.47	0.01	0.36	0.02	8.19				
16	1	1.27	1.12	0.18	7.06	1.45	0.89	0.19	7.63	1.32	0.84	0.17	7.76
	2	1.18	1.16	0.16	7.38	1.56	0.71	0.21	7.43	1.40	0.82	0.20	7.00
	3	1.16	1.06	0.09	12.89	1.34	0.82	0.18	7.44	1.16	0.86	0.17	6.82
	$\bar{X}$	1.20	1.11	0.14	9.11	1.45	0.81	0.19	7.50	1.29	0.84	0.18	7.20
	S.D.	0.06	0.05	0.05	3.28	0.11	0.09	0.02	0.11	0.12	0.02	0.02	0.50

*No sample collected.

TABLE K.2. RESULTS OF CHN ANALYSIS FROM CRUISE SA-3 STATION 9.

Sta.	Rep.	%C	%H	%N	C/N
9	1	1.42	0.40	0.18	7.89
	2	1.73	0.48	0.22	7.86
	3	2.04	0.59	0.26	7.85
	$\bar{x}$	1.73	0.49	0.22	7.87
	S.D.	0.31	0.10	0.04	0.02

APPENDIX L

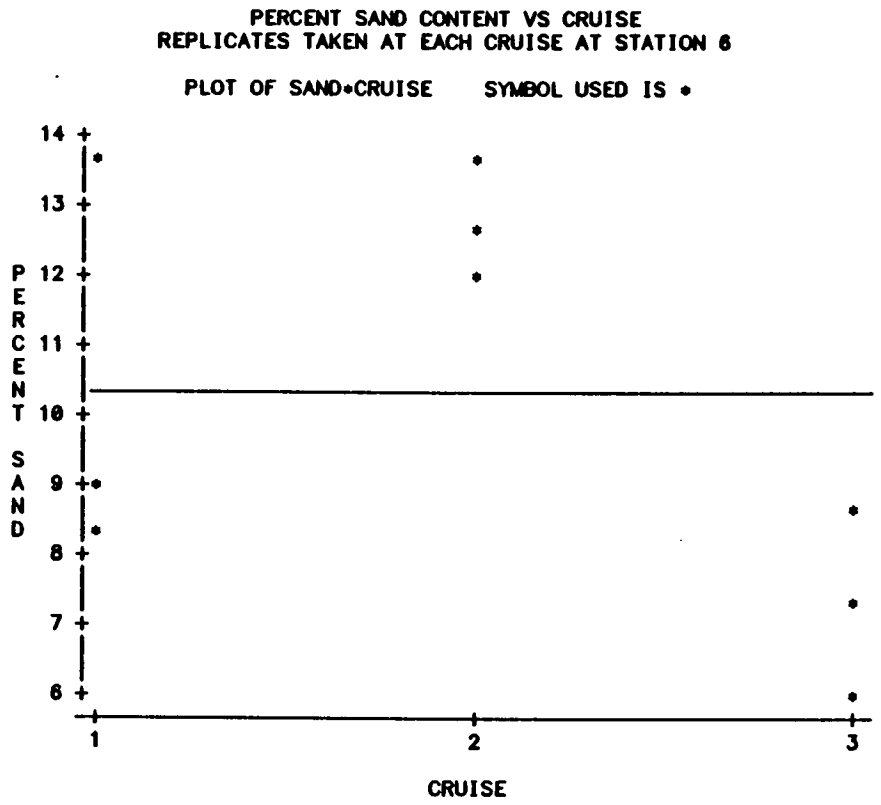


Figure L.1. Analysis of variance of difference between sampling dates for station 6, tested for percent sand content against cruise.

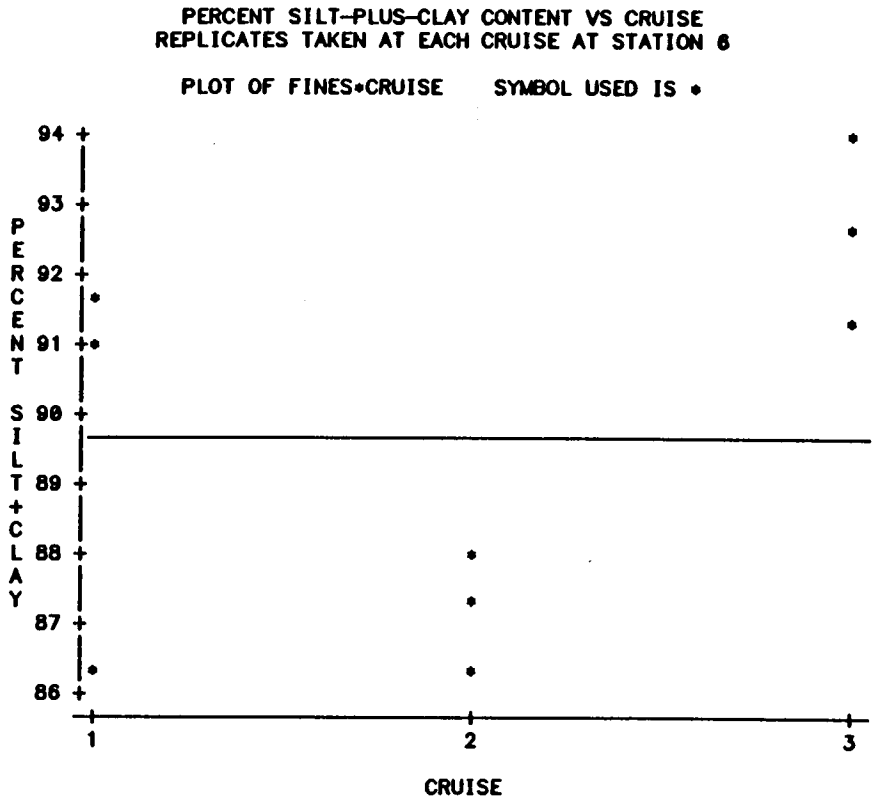


Figure L.2. Analysis of variance of difference between sampling dates for station 6, tested for silt/clay ratio against cruise.

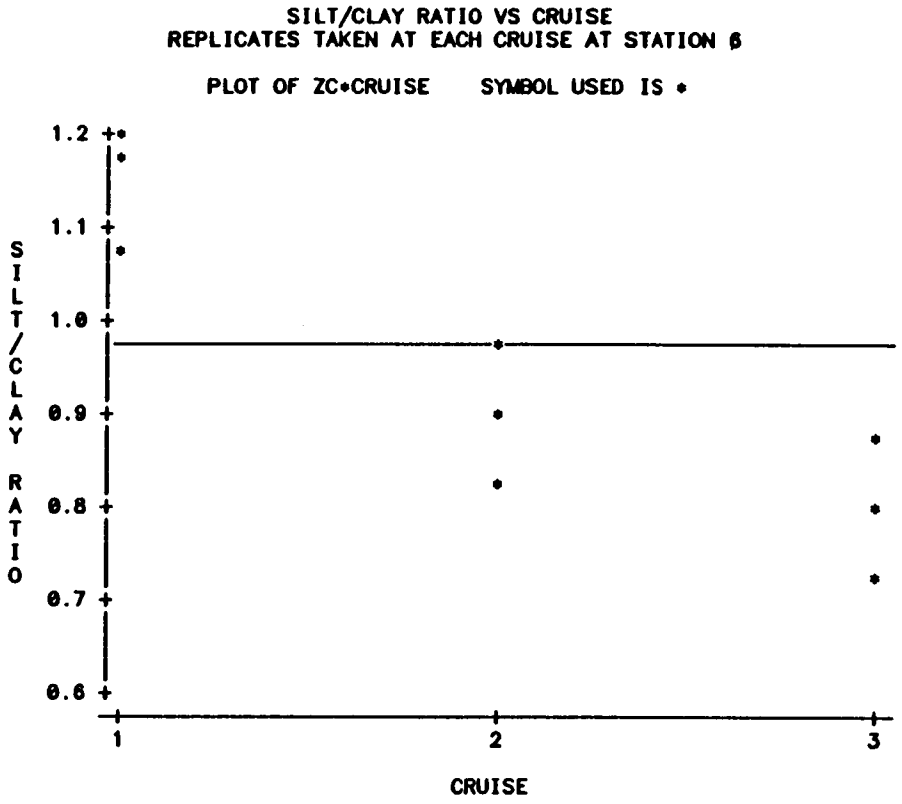


Figure L.3. Analysis of variance of difference between sampling dates for station 6, tested for silt/clay ratio against cruise.

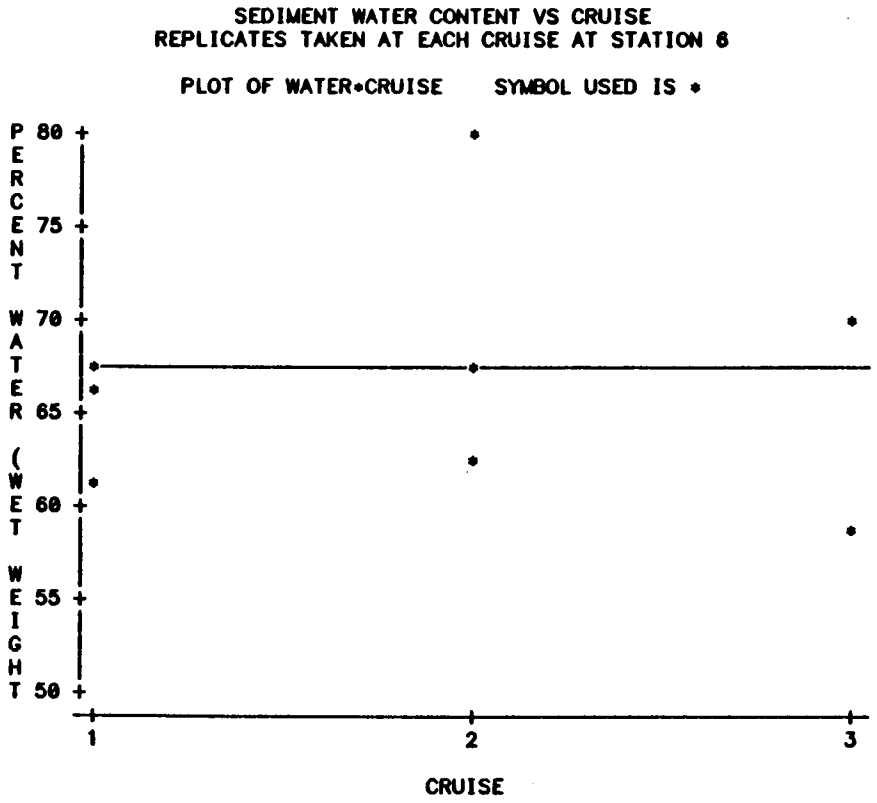


Figure L.4. Analysis of variance of difference between sampling dates for station 6, tested for sediment water content against cruise.

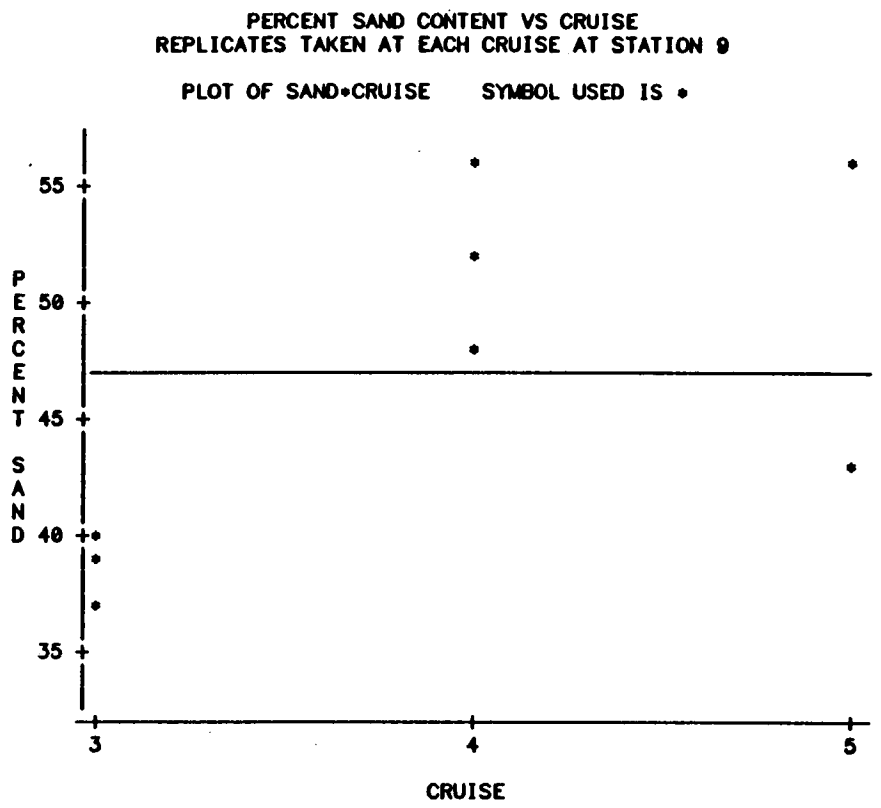


Figure L.5. Analysis of variance of difference between sampling dates for station 9, tested for percent sand content against cruise.

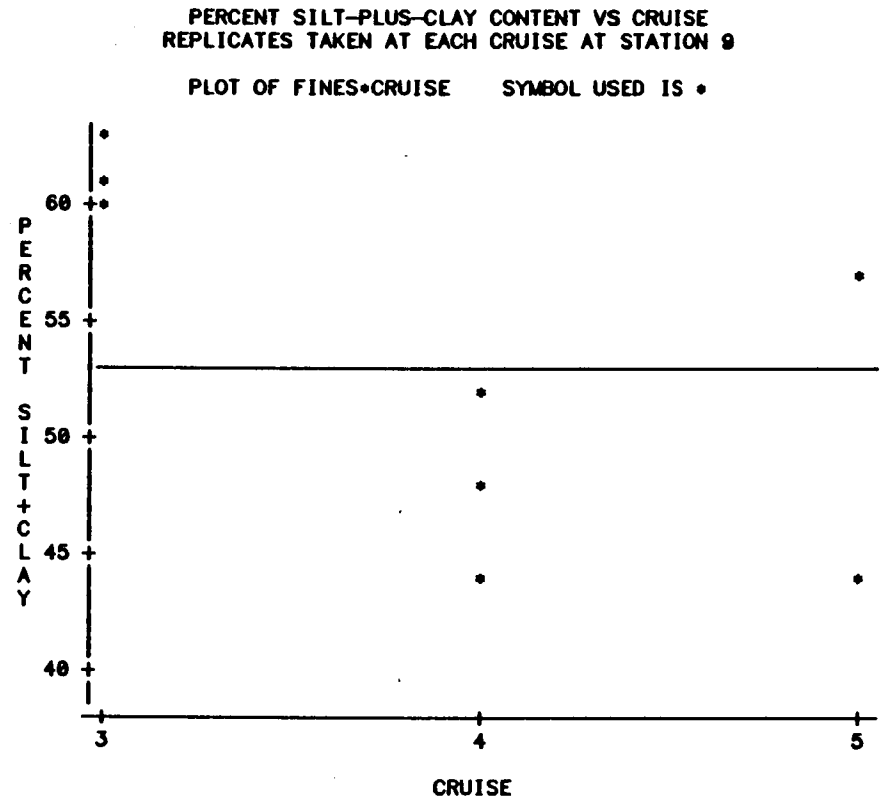


Figure L.6. Analysis of variance of difference between sampling dates for station 9, tested for percent silt-plus-clay content against cruise.

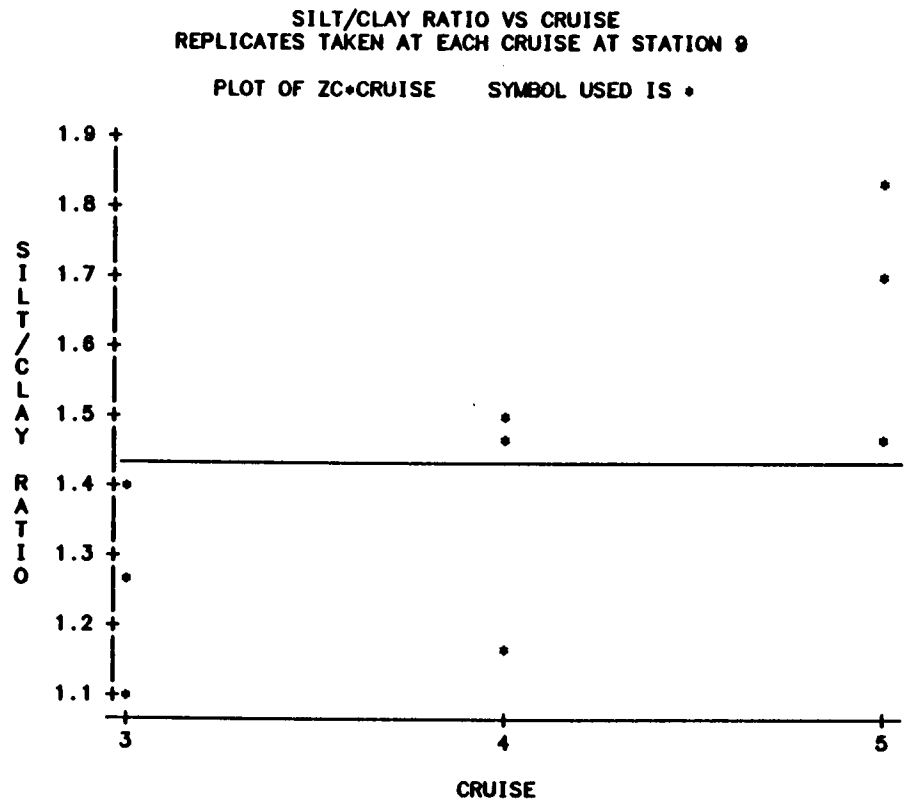


Figure L.7. Analysis of variance of difference between sampling dates for station 9, tested for silt/clay ratio against cruise.

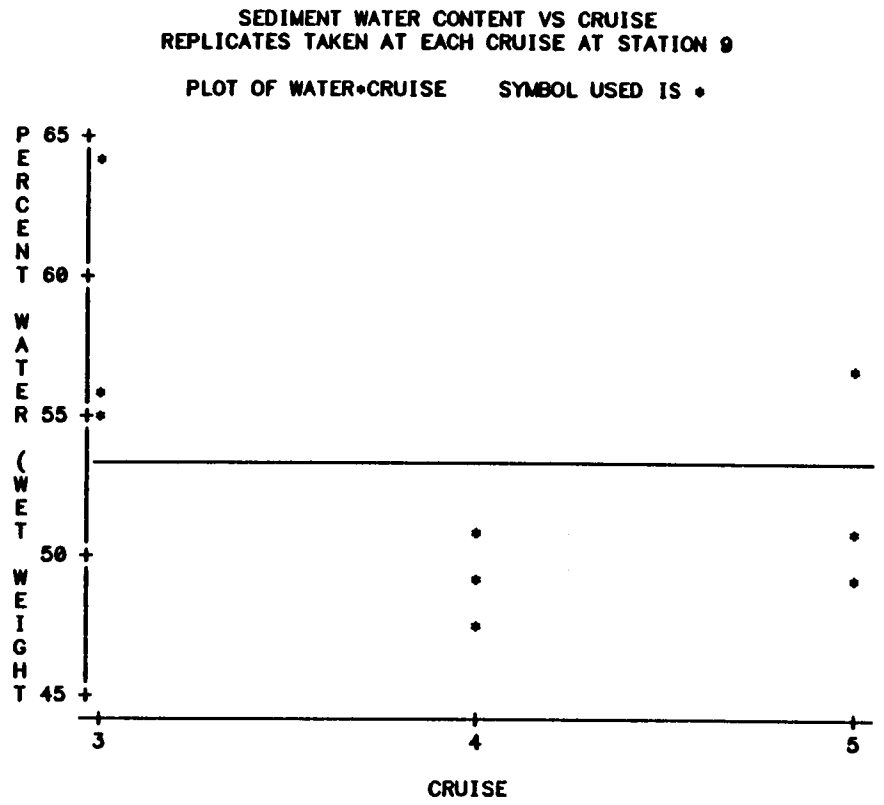


Figure L.8. Analysis of variance of difference between sampling dates for station 9, tested for sediment water content against cruise.

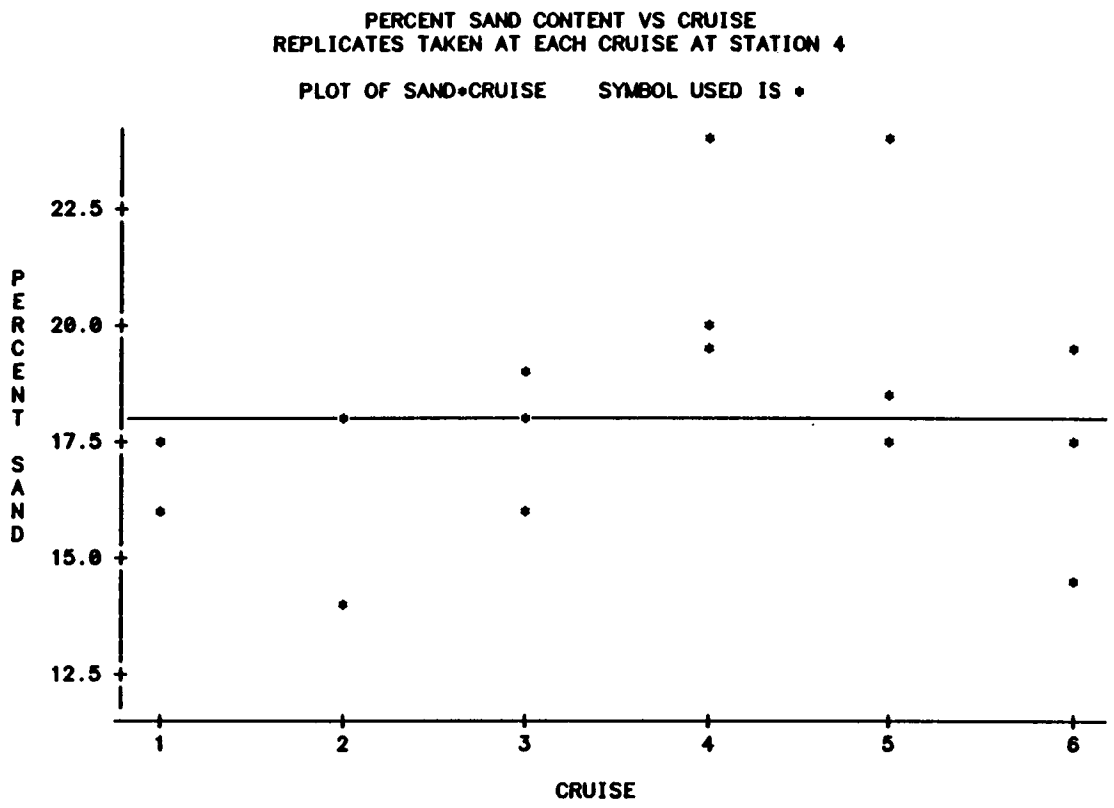


Figure L.9. Analysis of variance of difference between sampling dates for station 4, tested for percent sand content against cruise.

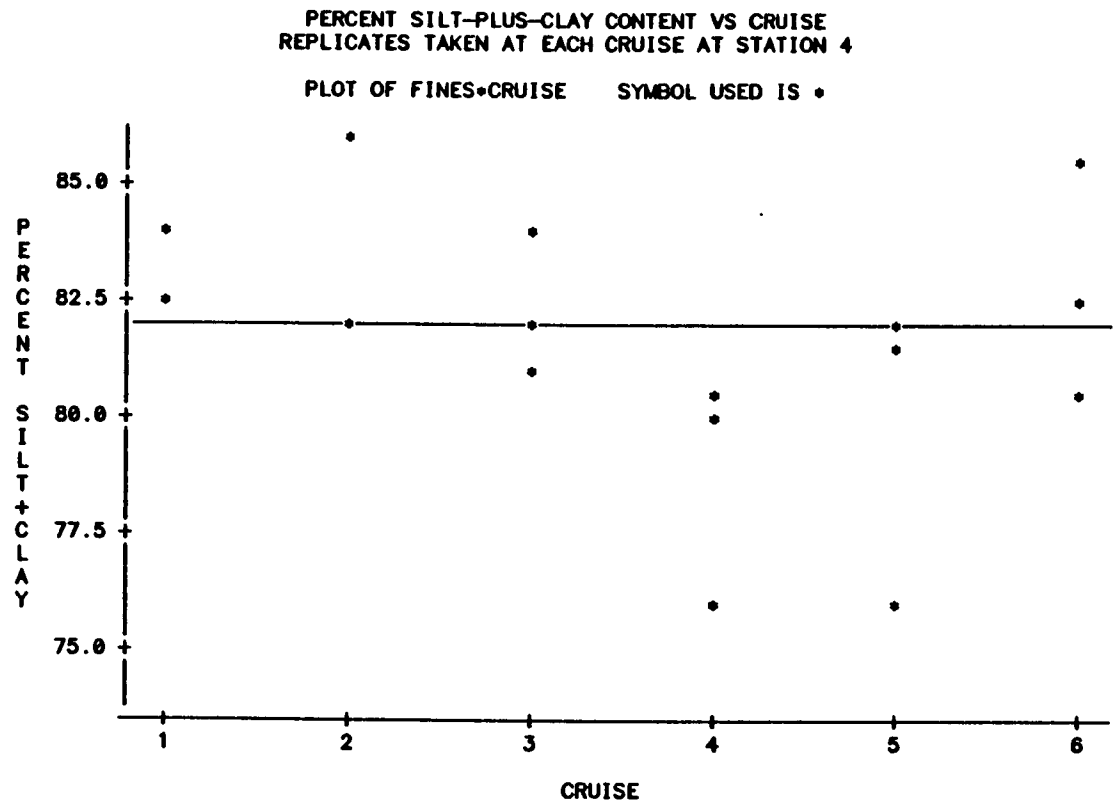


Figure L.10. Analysis of variance of difference between sampling dates for station 4, tested for percent silt-plus-clay content against cruise.

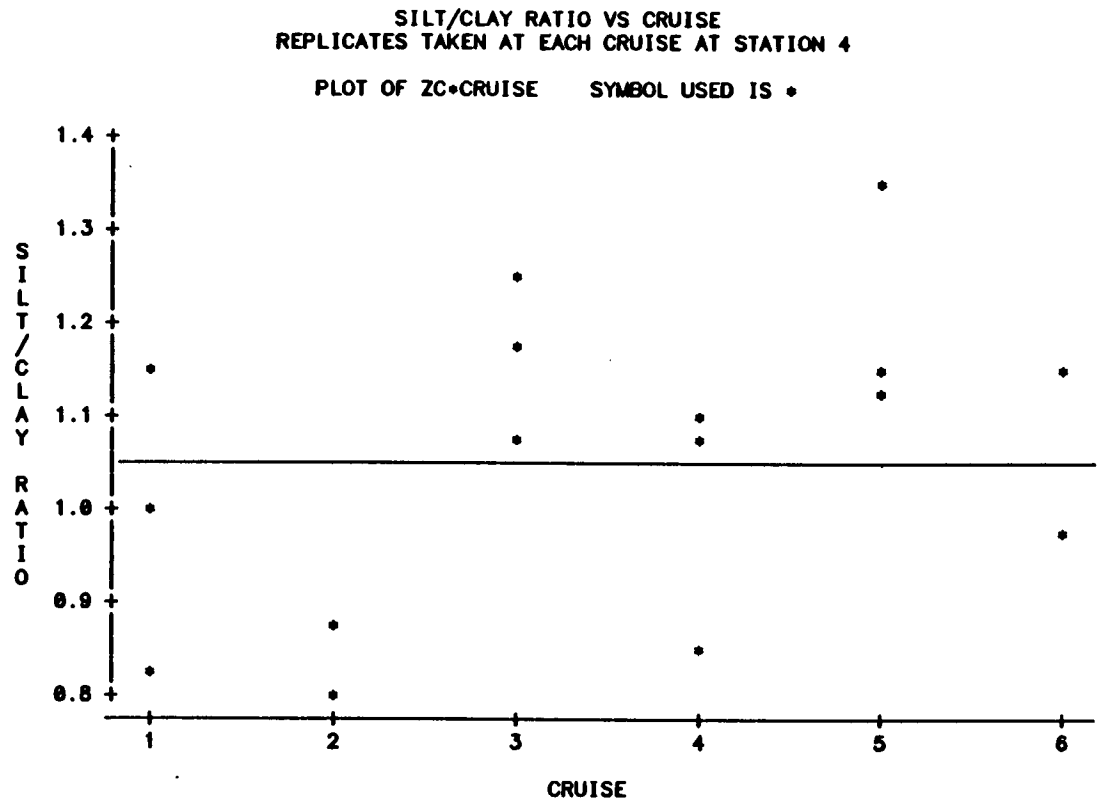


Figure L.11. Analysis of variance of difference between sampling dates for station 4, tested for silt/clay ratio against cruise.

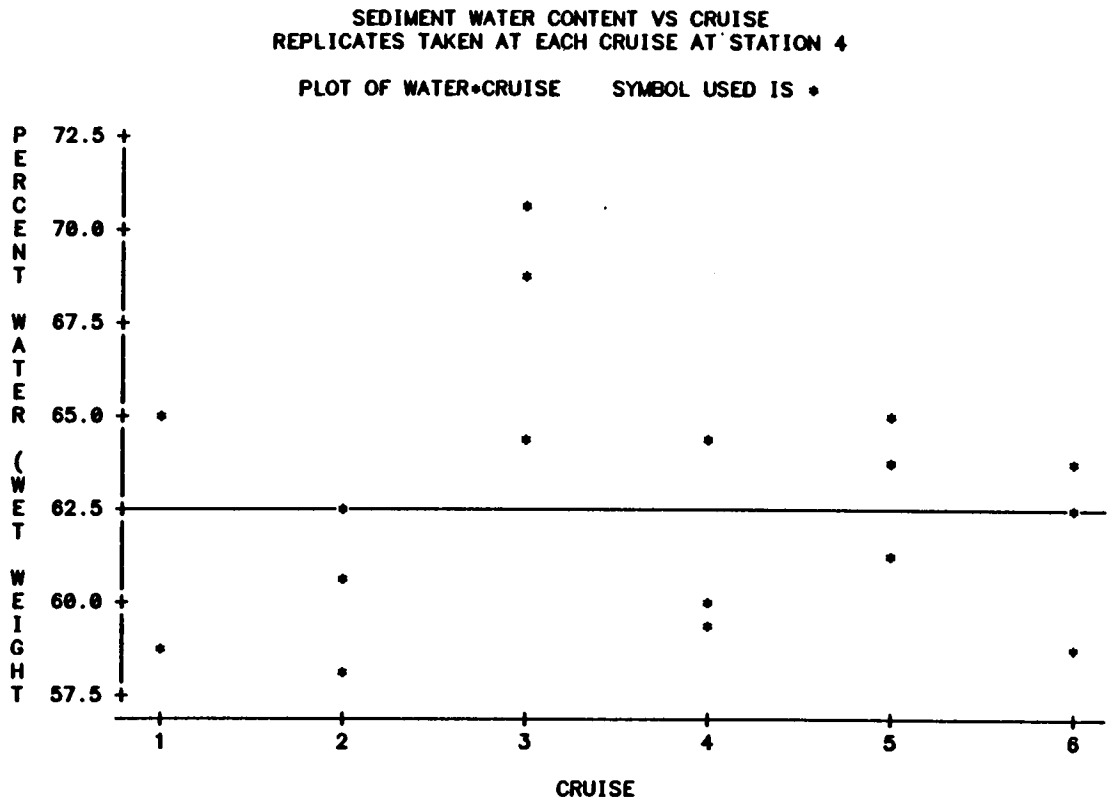


Figure L.12. Analysis of variance of difference between sampling dates for station 4, tested for sediment water content against cruise.

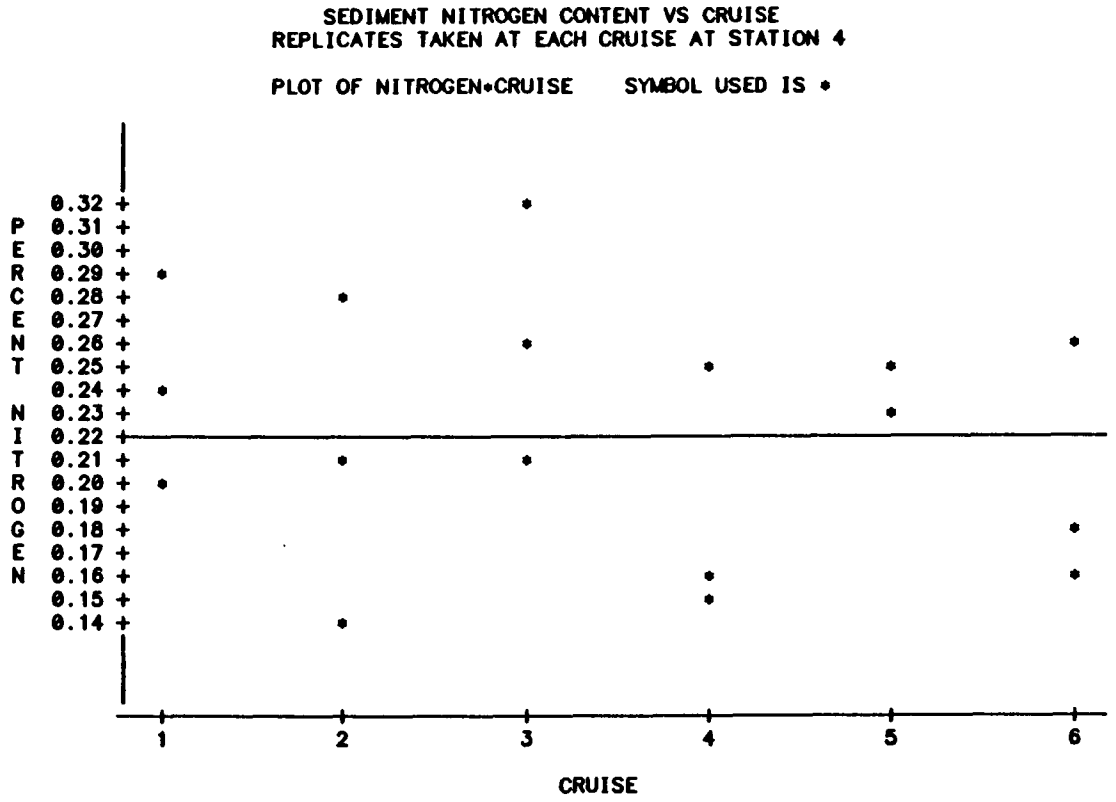


Figure L.13. Analysis of variance of difference between sampling dates for station 4, tested for sediment nitrogen content against cruise.

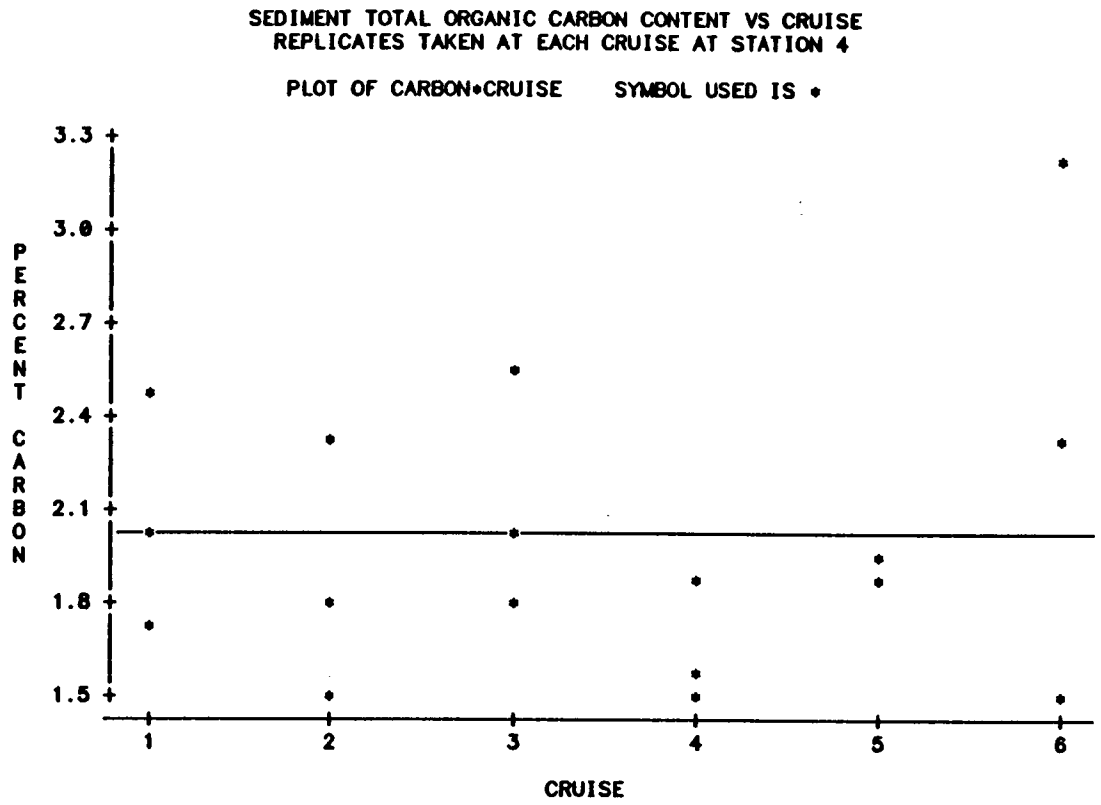


Figure L.14. Analysis of variance of difference between sampling dates for station 4, tested for sediment total organic carbon content against cruise.

APPENDIX M

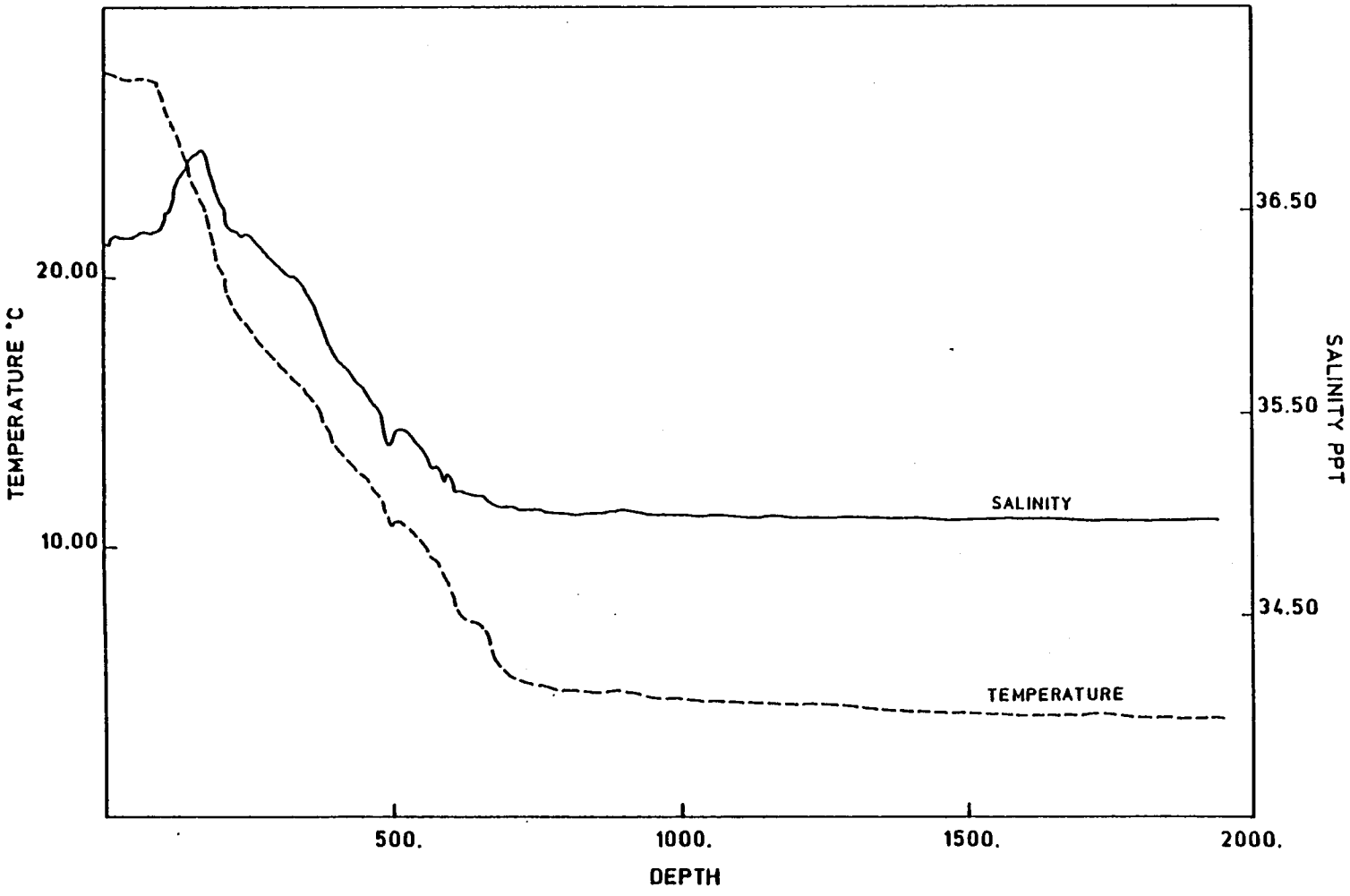


Figure M.1. Profile of temperature and salinity with depth at station 4 on Cruise SA-5.

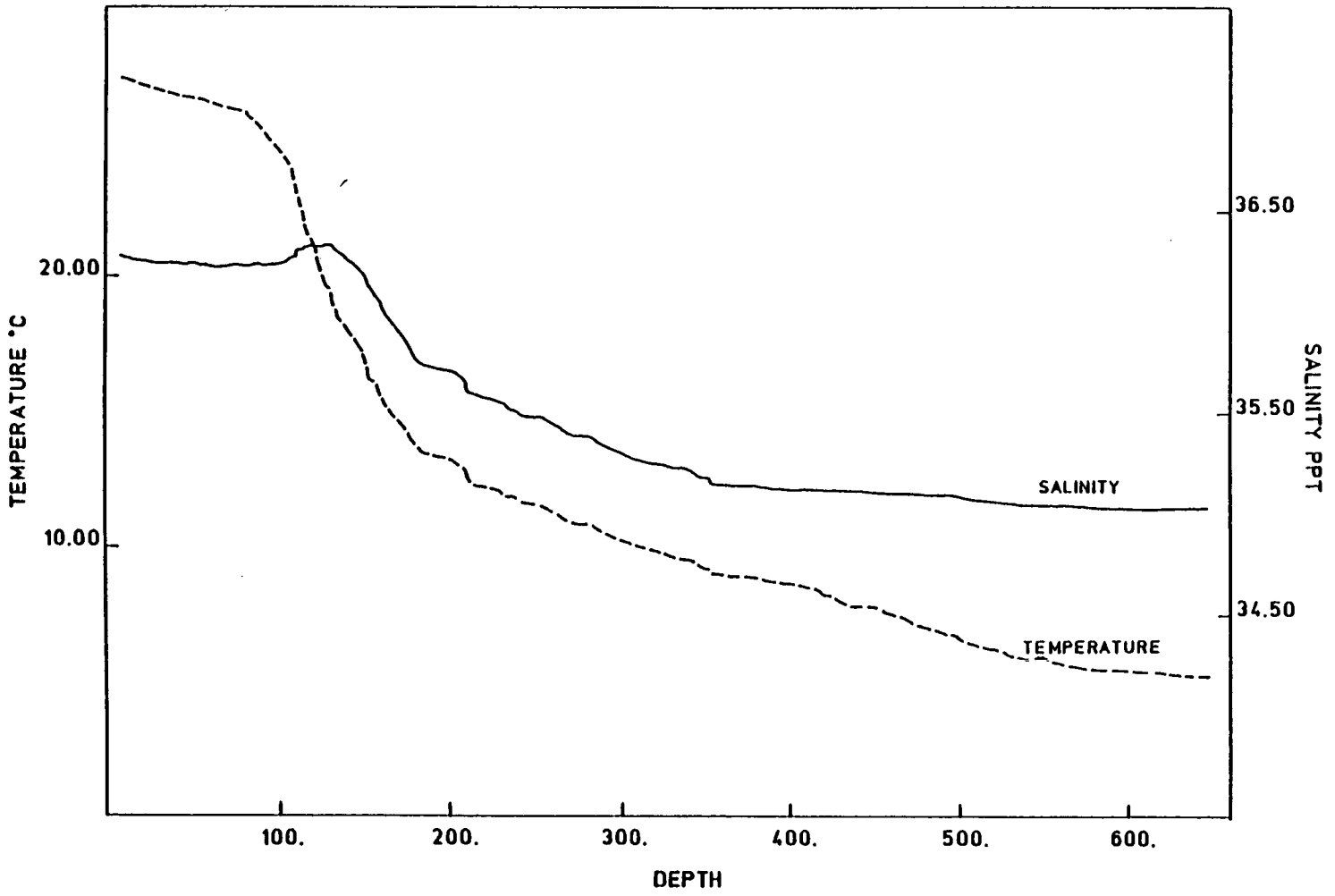


Figure M.2. Profile of temperature and salinity with depth at station 9 on Cruise SA-5.

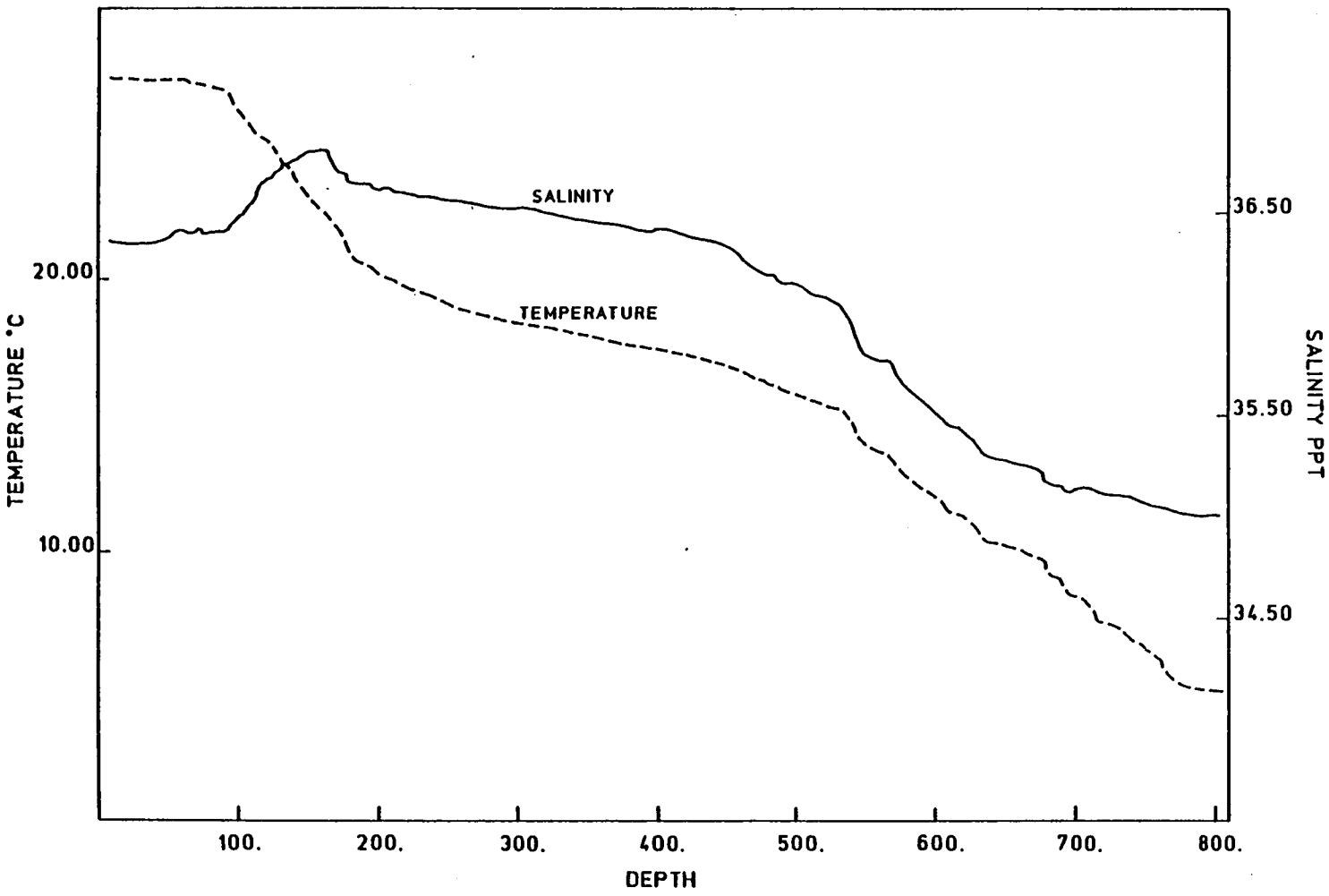


Figure M.3. Profile of temperature and salinity with depth at station 11 on Cruise SA-5.

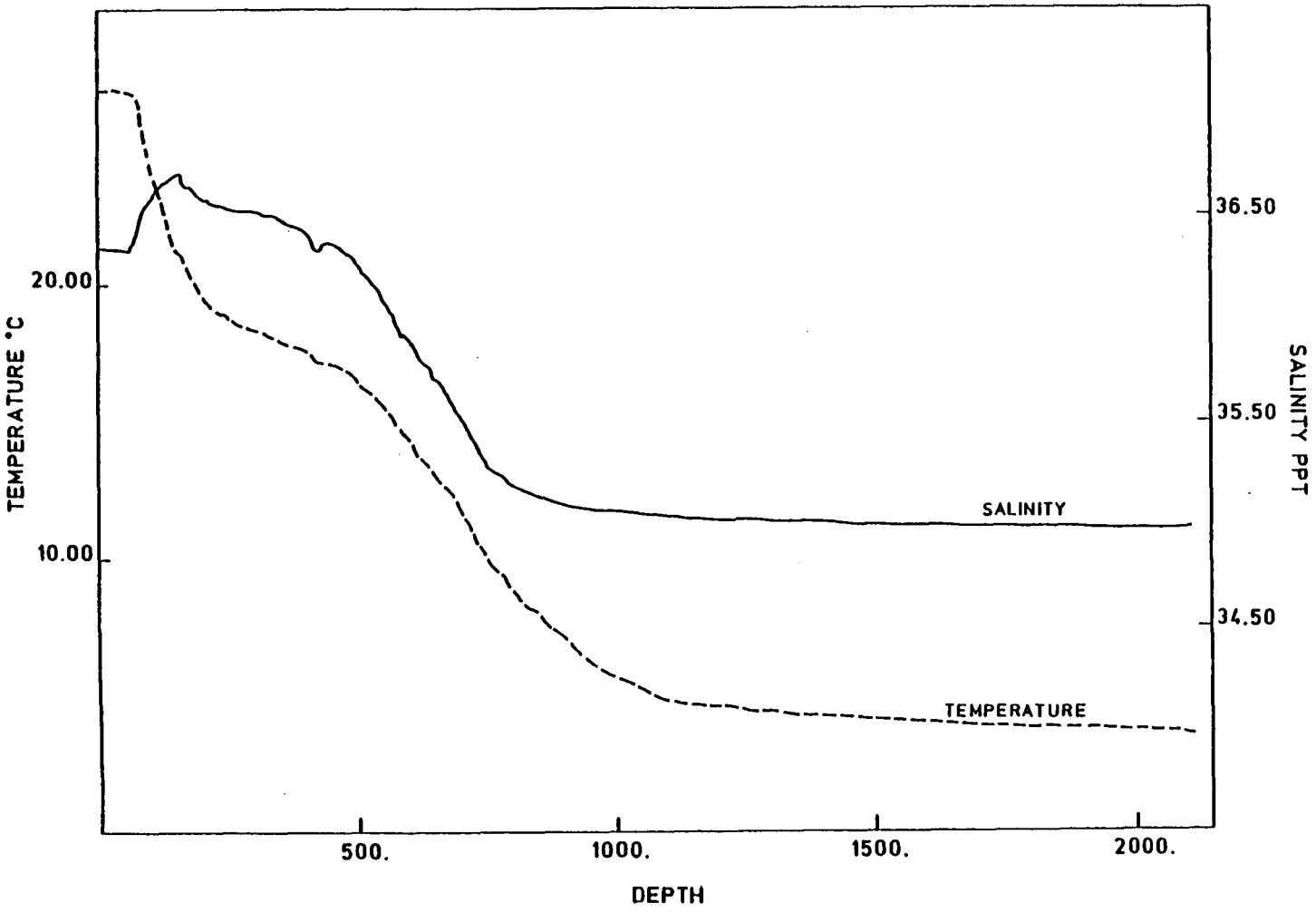


Figure M.4. Profile of temperature and salinity with depth at station 12 on Cruise SA-5.

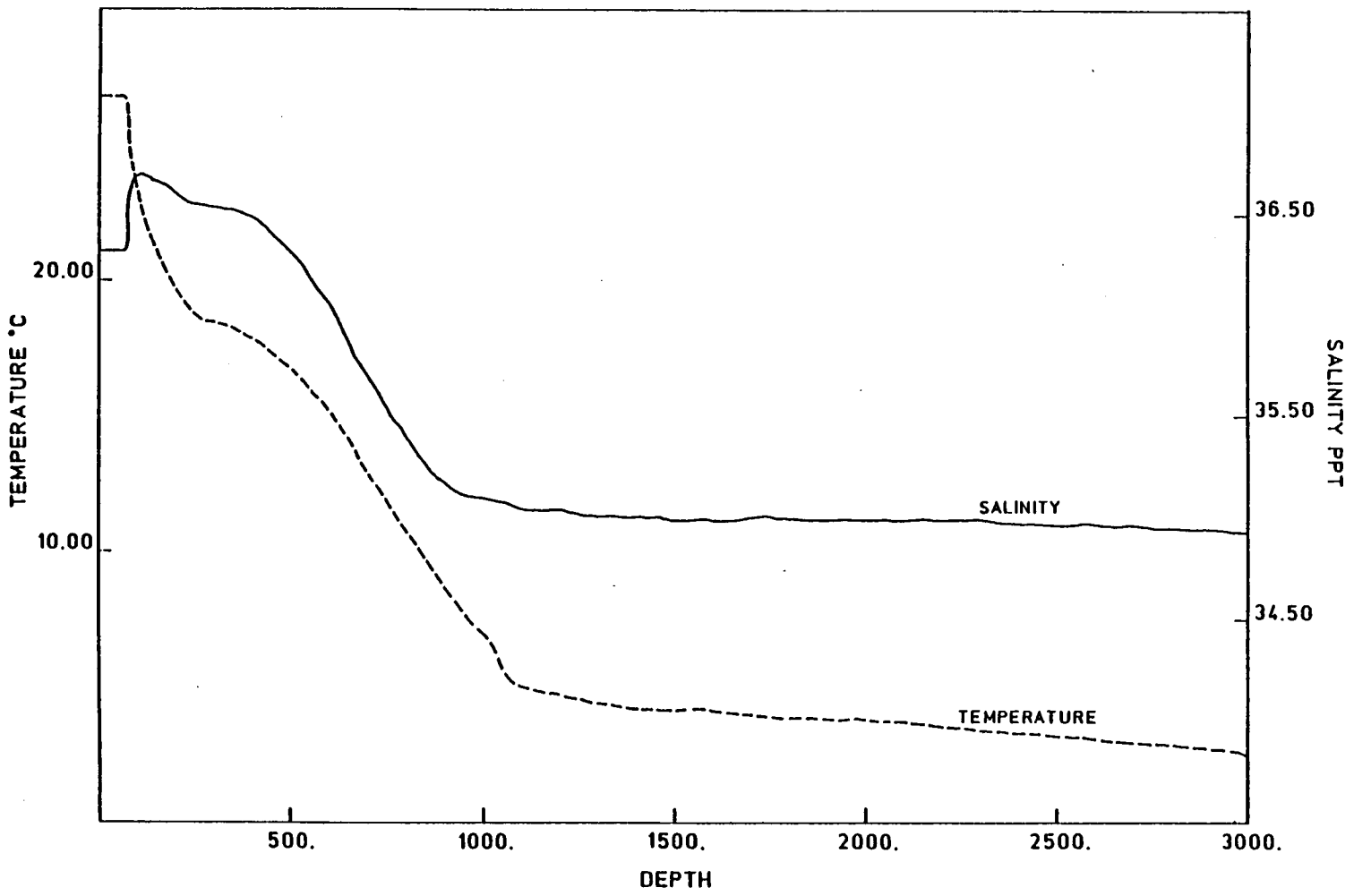


Figure M.5. Profile of temperature and salinity with depth at station 13 on Cruise SA-5.

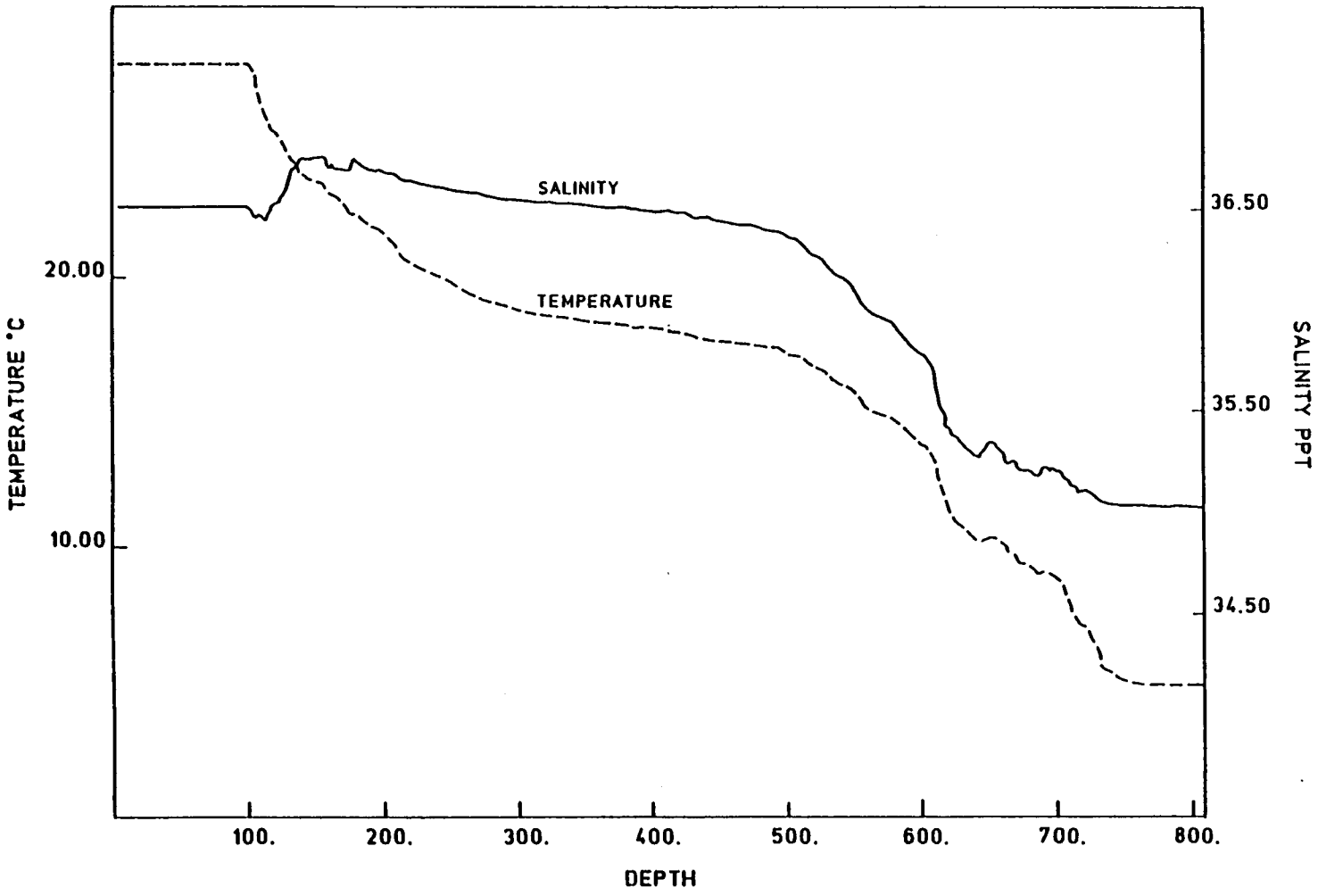


Figure M.6. Profile of temperature and salinity with depth at station 14 on Cruise SA-5.

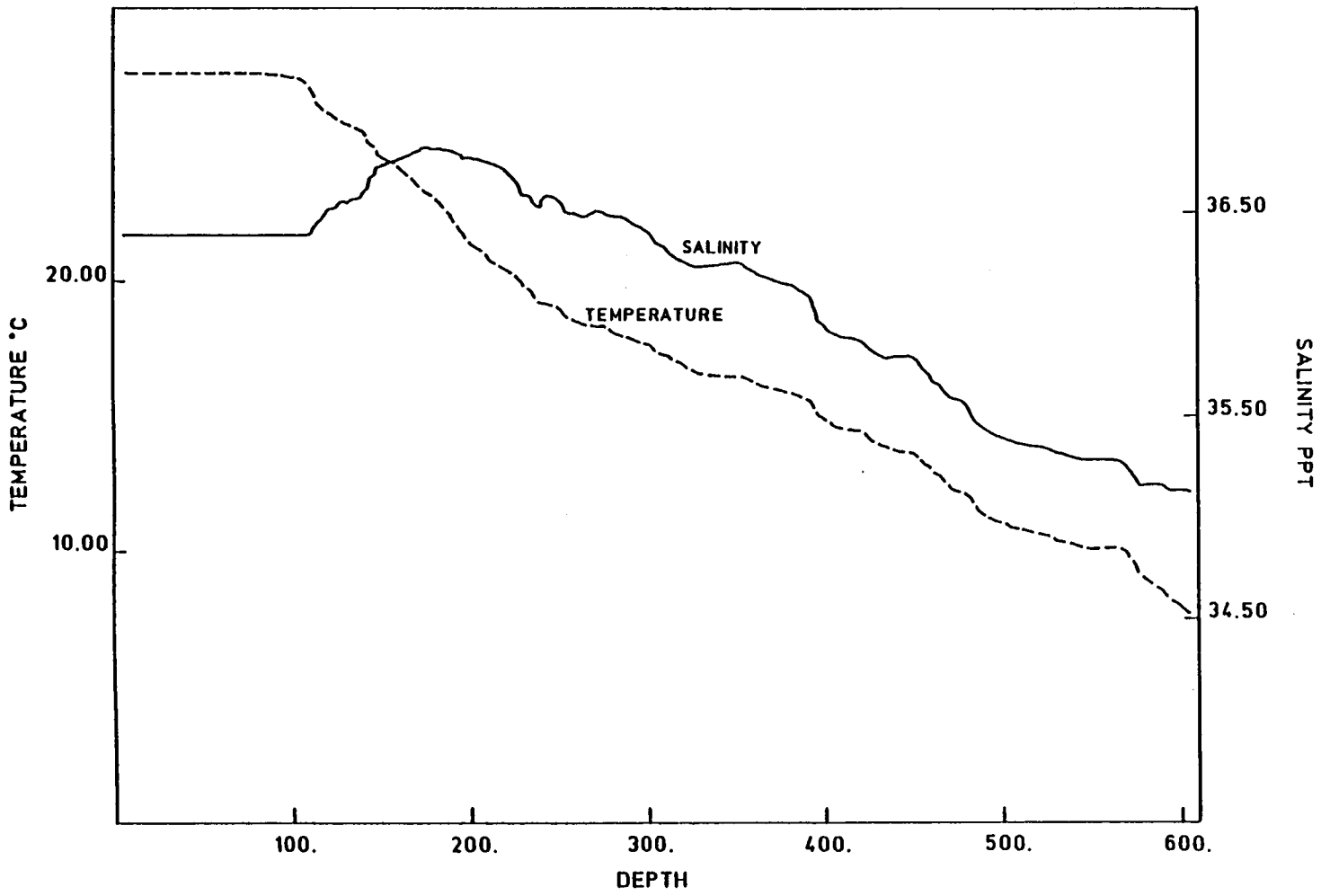


Figure M.7. Profile of temperature and salinity with depth at station 14A on Cruise SA-5.

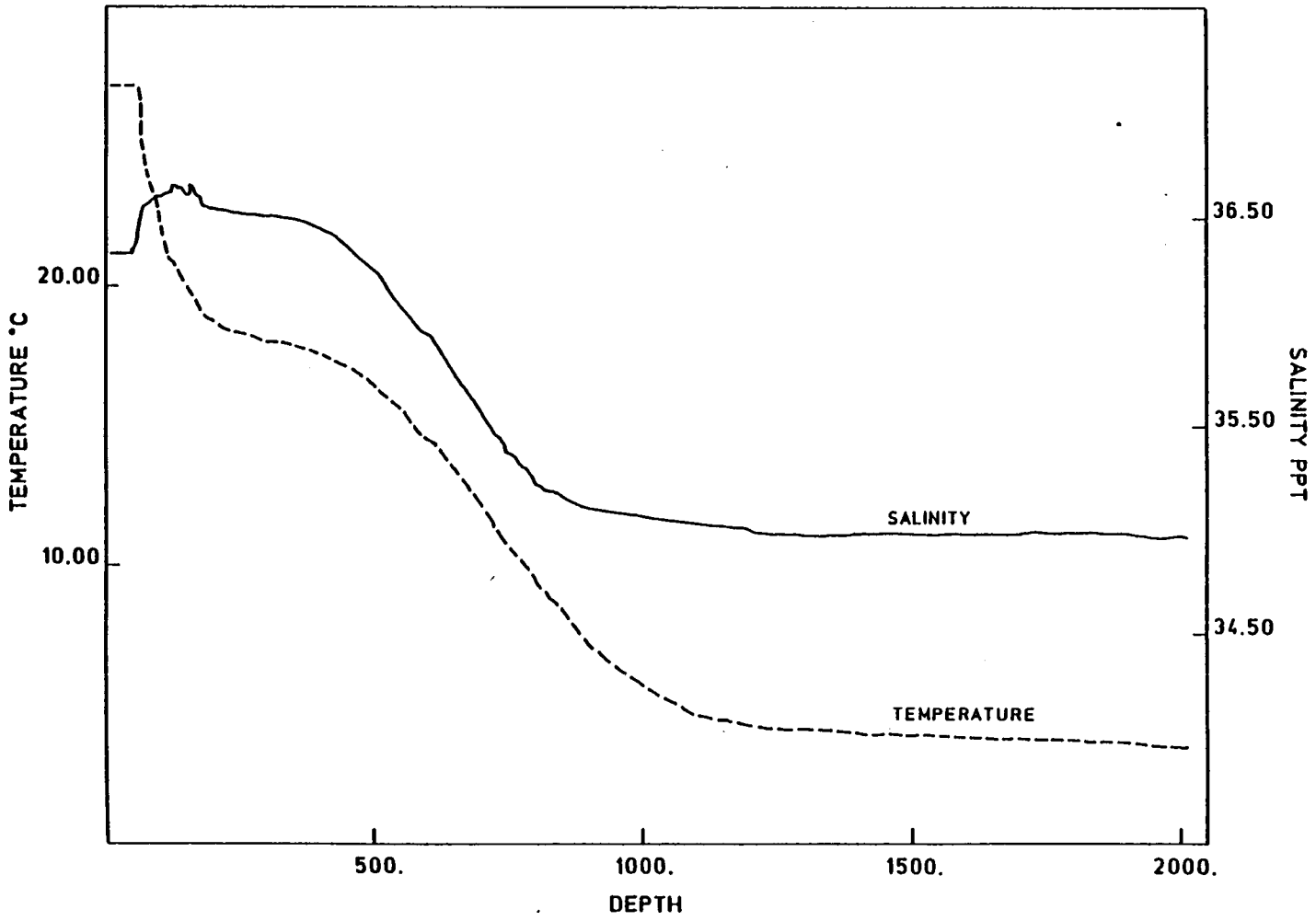


Figure M.8. Profile of temperature and salinity with depth at station 15 on Cruise SA-5.

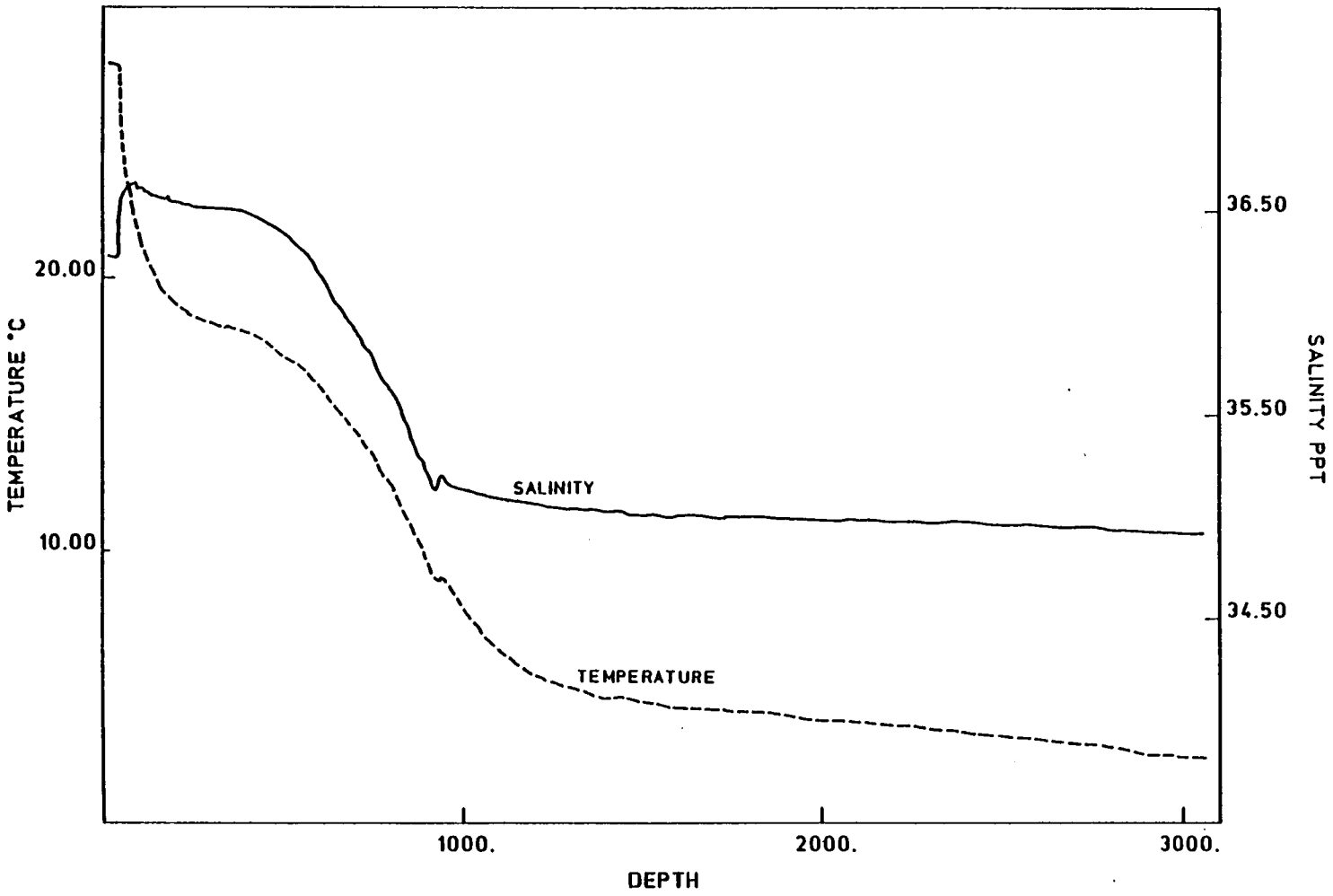


Figure M.9. Profile of temperature and salinity with depth at station 16 on Cruise SA-5.