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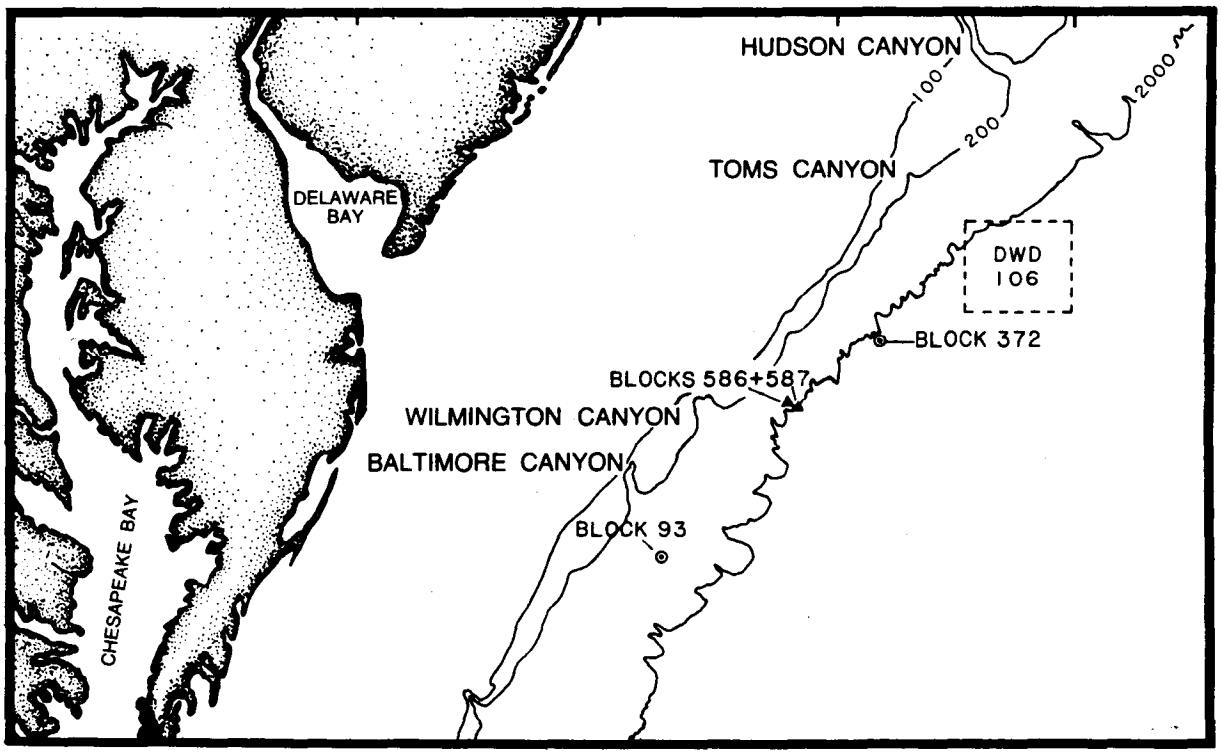

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STUDY OF BIOLOGICAL PROCESSES ON THE U.S. MID-ATLANTIC SLOPE AND RISE

by

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16. Abstract (Limit: 200 words)

Box core samples were collected at 14 stations as part of a monitoring program to evaluate potential effects of exploratory drilling in water depths of 1500 and 2100 m. The box core samples were analyzed for benthic infauna, hydrocarbons, sediment grain size, and total organic carbon, hydrogen, and nitrogen. Benthic infaunal diversity was high at all stations on all sampling dates. As a group, the shallower (1515-1613 m) stations were more diverse than the deeper stations. Species composition and abundance was homogeneous at depths of 2020 to 2195 m along a 176-km transect. Changes in diversity or similarity among stations over time could be explained by changes in the densities of a few dominant species, and were often related to differences in sediment texture, rather than drilling activities. Transect and classification analysis of epifaunal data collected from photographs taken on camera-sled tows indicated trends in trophic structure and species composition that were related to a combination of depth and topography. In one area down-slope of the drill site, a change in the density of a species of sea pen may have been due to drilling activities; however, sedimentary changes not related to drilling may have caused the observed decrease in the abundance of this species. There was no evidence that hydrocarbons in the sediments, or hydrocarbons and metals in brittle stars and sea urchins, originated from sources associated with drilling activities.

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CHAPTER 1. INTRODUCTION

OBJECTIVES

This is the final report on the "Study of Biological Processes on the U.S. Mid-Atlantic Slope and Rise" performed by Battelle Ocean Sciences, 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 multidisciplinary study is a monitoring program with the following specific objectives:

1. To characterize pre-drilling biological, geological, and chemical properties of benthic environments at stations in the vicinity of two exploratory drilling rigs.

2. To monitor potential changes in these properties with time, and determine whether the changes are caused by drilling-related activities or are the result of other phenomena including natural temporal or spatial variation.

3. To determine the distribution and fate of discharged drilling-related materials that may have accumulated above background levels.

4. To estimate recovery rates of deep-sea benthic communities potentially impacted by drilling-related activities.

The parameters measured as part of this study were infaunal benthic community structure, including determination of ash-free dry weight of infauna at selected stations; rates of colonization of azoic sediments; megafaunal (epifaunal) population densities; hydrocarbon levels in sediments and faunal tissues; trace metal levels in faunal tissues; chemical analyses of discharged drilling muds; sediment grain-size composition; and levels of total organic carbon, hydrogen, and nitrogen (CHN) in sediments. In addition, the U. S. Geological Survey (USGS) analyzed trace metals in sediments (Bothner et al., 1985a, b, 1987).

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

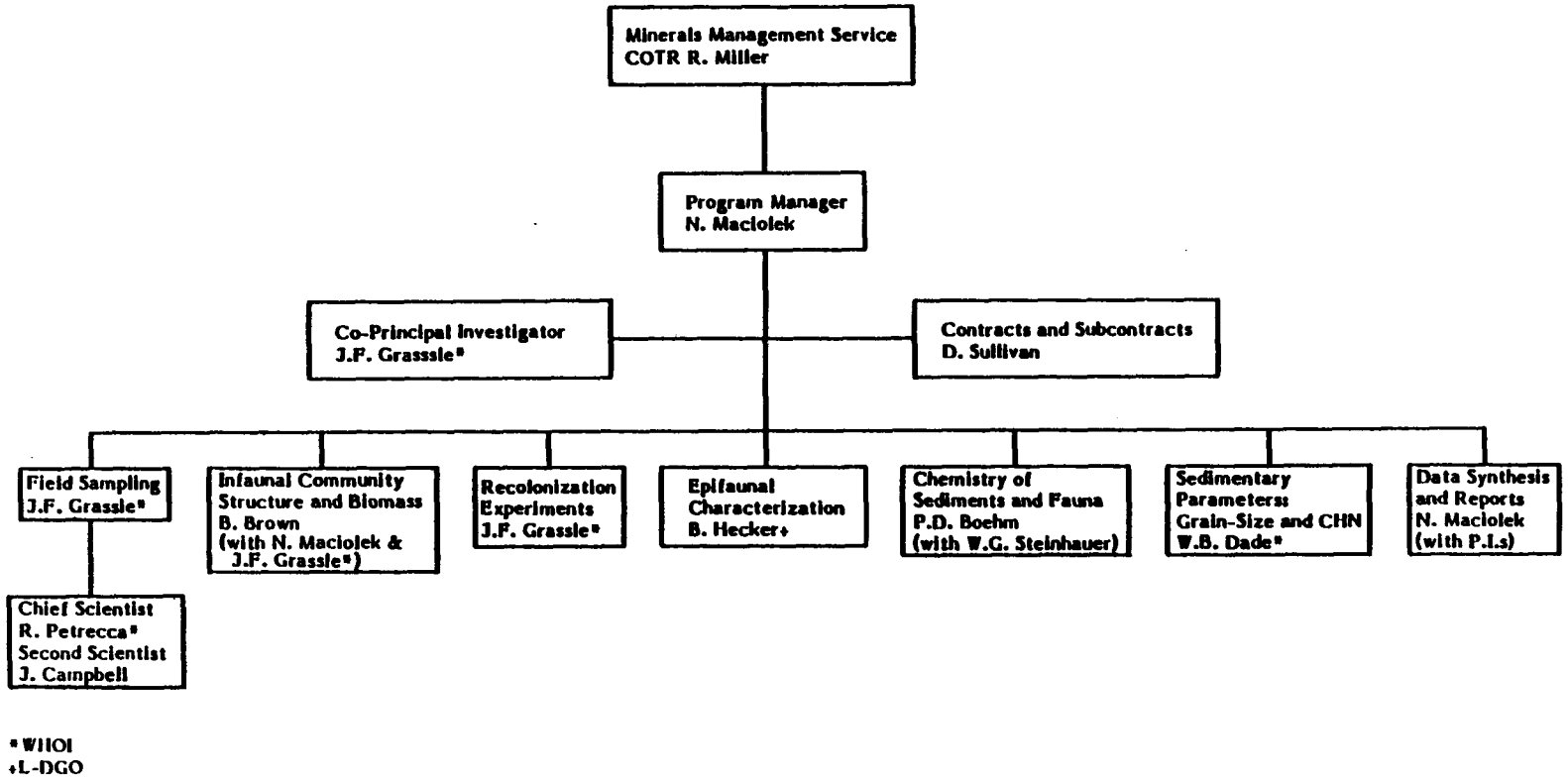

Figure 1. Program Organization Chart.

BACKGROUND OF STUDY DESIGN

A series of six cruises over a two-year period was planned to address the objectives stated above. An array of 12 sampling stations was planned to be centered around a deep-water drilling site. The study began in late March 1984. At that time, Shell Offshore, Inc. had completed drilling one well in the U.S. Mid-Atlantic in Block 587 and was nearing completion of a well in Block 586. The choice of the site of Shell's third well had been narrowed to either Block 93 or Block 372, but could not be pinpointed further, although it was likely that this third well would be spudded as early as mid-April 1984. A great deal of consideration was given by MMS, USGS, and the Battelle/WHOI/L-DGO team to the suitability of either the Block 93 or Block 372 site for a monitoring study. The primary issue was whether the previous drilling activities in Blocks 586 and 587 would bias the results of the pre-drilling samples, especially with reference to Block 93, which was approximately 34 km downcurrent from the earlier drilling sites. At a meeting held in Woods Hole on March 21, 1984, it was decided that there would be no definite advantage to monitoring one block over the other in terms of removing all risks of previous exposure to drilling discharges or non-drilling-related pollution sources such as the U.S. Environmental Protection Agency (EPA) Dumpsite 106. The rationale for this decision is presented below.

The limited knowledge of current dynamics and sediment transport processes in the area indicated that muds and cuttings discharged from exploratory wells drilled on the slope might be spread over a large area. This distribution would result from the length of time required for particles to settle to the seafloor and because of the combined effects of several types of current flows moving in various directions. Current flows in the area include a westward mean flow of about 5 cm/sec parallel to isobaths; subtidal fluctuating currents with a period of 10 to 20 days and approximate amplitudes of 10 cm/sec for flows parallel to isobaths and 2 cm/sec for flows across isobaths; tidal currents with an amplitude of 1-5 cm/sec, which flow primarily across isobaths; and occasional very strong eastward flows exceeding 50 cm/sec, which are associated with the clockwise currents around Gulf Stream warm-core rings. It was estimated that, at a water depth of about 2000 m, barite-sized particles could be distributed as far as 80 km downcurrent from the point of discharge and 'smeared' in a cross-isobath direction for a distance of up to 4 km

(Butman, USGS, unpublished calculations). Block 93, which is approximately 34 km downcurrent (i.e., to the southwest) of Blocks 586 and 587 could, therefore, have received particles discharged from the latter two blocks. Although Block 372 is approximately 60 km upcurrent from Blocks 586 and 587 and, therefore, relatively free from exposure to discharges at these sites, it is approximately 60 km downcurrent from the center of EPA's Dumpsite 106.

The decision was made that either Block 93 or Block 372 could be monitored as long as the assumption that "no previous pollutant impacts have occurred in the area prior to collection of pre-drilling samples" was not made. Comparisons of pre-drilling and post-drilling samples would allow detection of potential drilling-related environmental changes even if the analysis of pre-drilling samples indicated contamination from unrelated activities.

Once the decision was made to initiate the monitoring program at the next well spudded by Shell, irrespective of which of the two blocks was chosen, it was necessary to ensure that critical pre-drilling samples be collected before the well was spudded. Except for an ongoing sampling cruise being conducted by Battelle for MMS as part of the U.S. South Atlantic study, no cruise dates were available prior to the spudding of Shell's third well. In order to obtain pre-drilling samples, the South Atlantic cruise (SA-2) was diverted from its sampling mission off North Carolina and redirected to collect box core samples and occupy camera sled transects in the vicinity of Blocks 93 and 372. After Shell chose to spud their third well in Block 372, samples were collected from the remaining 12-station array specifically designed for that site.

Shell spudded a well in Block 372 on May 26, 1984, but plugged and abandoned the site on July 9, 1984, after drilling to a depth of 4,679 ft below the mud line and discharging 4,144 barrels of drilling muds and 541 barrels of cuttings.

Shell subsequently spudded a well in Block 93 on July 12, 1984. The initiation of the Block 93 well was just prior to the second cruise of this program, and MMS chose to add a station near the drilling site in Block 93. This station, which had previously been sampled on the first cruise in late March 1984, now became Station 13 in the program. After drilling to a depth of 12,727 ft below the mud line and discharging 40,387 barrels of drilling muds and 2,506 barrels of cuttings, Shell plugged and abandoned the Block 93 well on November 4, 1984, just prior to the third sampling cruise.

A Scientific Review Board meeting was held in March 1985. Participants included representatives of the Minerals Management Service, Mr. Jeffrey Petrino, Ms. Rosalind E. Cohen, and Ms. Alyce Fritz; three consultants external to the program, Dr. Eugene Gallagher, University of Massachusetts, Dr. Jim Henry, University of Georgia, and Dr. Thomas Lee, University of Miami; and the Principal Investigators, Drs. Maciolek, Boehm, Hecker, Grassle, Blake, Brown, and Butman. The results of the first year of the program were reviewed and discussed, and two changes in the sampling design were agreed upon.

The first change was the result of evaluating the hypothesis that nearfield differences in depth would not account for more variability than could be detected between stations at the same depths but several kilometers apart. Stations 7 and 8, which differed in depth by 50 m, were a topographic high/low pair established to test this null hypothesis. Results of the first two sample sets clearly demonstrated that the two stations were not significantly different. It was therefore decided to discontinue sampling at Station 8, the "low" or deeper station.

The second change was the result of reviewing information concerning the amount of drilling-related material discharged at the two drilling sites. The station located at the Block 93 drill site, Station 14, had been sampled only on the first of the three cruises that had been conducted by the time of the Scientific Review Board meeting. Based on the information that Block 93 had received an order of magnitude more material than Block 372, it was decided that Station 14 should be reoccupied for the remaining cruises in the program, and that the archived samples collected on the first cruise should be analyzed.

The final station design is shown in Figure 2. In the six-cruise series, therefore, one pre-drilling and five post-drilling sample sets were collected at Block 372. One pre-drilling, one during-drilling, and four post-drilling sample sets were collected at Station 13 in Block 93; one pre-drilling and three post-drilling sample sets were collected at Station 14.

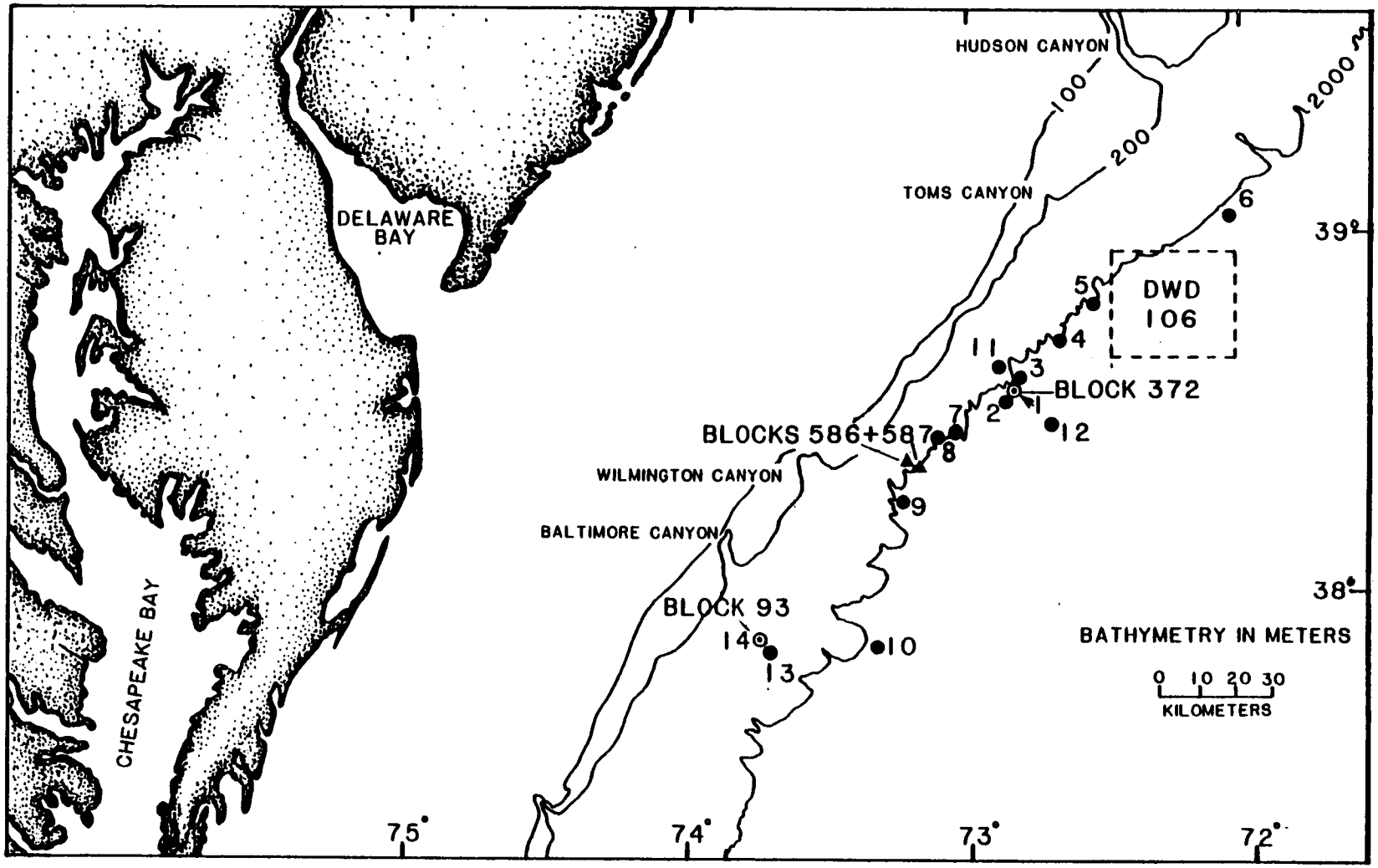

Figure 2. Station Locations on the Continental Slope and Rise for the U.S. Mid-Atlantic Monitoring Program.

CHAPTER 2. FIELD PROGRAM

INTRODUCTION

The field portion of the Mid-Atlantic study was carried out by personnel from the three participating laboratories, with Ms. Rose Petrecca of Woods Hole Oceanographic Institution (WHOI) serving as Chief Scientist, and either Dr. James Blake, Mr. James Campbell, Dr. Betsy Brown or Ms. Ellen Baptiste of Battelle serving as Second Scientist. Dr. Barbara Hecker and Mr. Ivars Bitte of Lamont-Doherty Geological Observatory were responsible for the operation of the camera sled used to collect film footage for the analysis of epifaunal organisms.

METHODS

General

A series of six sampling cruises over a two-year period were conducted for this program. All cruises except the first leg of Cruise Mid-1 were staged from Woods Hole, Massachusetts. The cruise schedule is given in Table 1 and the types of samples collected are summarized in Table 2. The program for analysis of hydrocarbons in sediments was designed to sample all stations on the first two sampling cruises, but only five of the stations on the last four cruises. Similarly, collection of epifaunal organisms for chemical analysis of tissues and exposure of film footage for characterization of epifaunal populations was made on the first, second, and fifth cruises in the series. Observers from Manomet Bird Observatory participated in Cruises Mid-2 and Mid-6 to document cetacean sightings in the study area. Results of the Cruise Mid-2 observer program are included as Appendix B in the report submitted for the cruise (Battelle et al., 1984).

Dr. Joseph Germano, then of Marine Surveys, Inc., participated in Cruise Mid-2 as a visiting investigator. Time available after the completion of all contracted work allowed Dr. Germano to test a new REMOTS (Remote Ecological Monitoring of the Seafloor) camera system in deep water. Details of the REMOTS test were included as Appendix A in the report for Cruise Mid-2 (Battelle et al., 1984).

TABLE 1. SAMPLING SCHEDULE FOR U.S. MID-ATLANTIC MONITORING PROGRAM.

Cruise	Date	Vessel
Mid-1		
Leg 1	Mar/Apr 1984	R/V Cape Hatteras
Leg 2	May 1984	R/V Oceanus
Leg 3	May 1984	R/V Gyre
Mid-2	Aug 1984	R/V Gyre
Mid-3	Nov/Dec 1984	R/V Oceanus
Mid-4	May 1985	R/V Oceanus
Mid-5	Aug 1985	R/V Oceanus
Mid-6	Nov 1985	R/V Gyre

TABLE 2. SUMMARY OF SAMPLES COLLECTED AND ANALYZED FOR THE U.S. MID-ATLANTIC MONITORING PROGRAM.

Sample Type	Number of Stations or Transects	Number of Replicates Per Station	Number of Cruises	Total Collected	Total Analyzed
Infaunal Box Cores[a,b]	13-14[a]	3	6	237	233
Meiofauna[c]	13-14	6	6	474	0
Sediment Grain Size	13-14	3	6	237	237
Sediment CHN	13-14	3	6	237	237
Sediment Hydrocarbons[d]	5-14	3	6	237	144 UV/F 40 GC/GCMS
Sediment Trace Metals[e]	13-14	6	6	474	[e]
Tissue Hydrocarbons[f]	3	1	3	9	9
Tissue Trace Metals[f]	3	1	3	9	9
Camera Sled Transects[f]	2.5	1	3	7.5	7.5
Colonization Trays	2	3	3	12	11
Biomass Box Cores	2	3	1	6	6
Hydrography[g]					
Dissolved Oxygen	13-14	3	6	237	225
Salinity	13-14	3	6	237	225
Temperature	13-14	3	6	237	225

[a]Fourteen stations were sampled on the first cruise, 13 stations were sampled on Cruises 2-6.
[b]Four replicates were not processed, see Chapter 3.
[c]Meiofauna samples are archived at Battelle.
[d]See Chapter 7, Volume 2, for chemistry analytical program.
[e]Sediment trace metal samples were analyzed at USGS, Woods Hole. See Bothner et al. (1987).
[f]Tissue samples and camera transects were taken on Cruises 1, 2, and 5.
[g]Some hydrographic data were not collected on certain cruises, or were unusable.

Station Locations

The reference coordinates, including latitude, longitude, and Loran time delays, and depths of the 14 stations sampled in this study are given in Table 3. A diagram of the station design is shown in Figure 3. The majority of stations were located along the 2100 m isobath, with actual station depths ranging from 2005 to 2209 m. One station was established as close as possible (1 km) to the actual drilling site in Block 372, and stations were then positioned at distances of 2, 22.5, 45, and 90 km on either side of the drilling site station. Stations 7 and 8 were approximately 22.5 km downcurrent of the drill site in a topographic high/low relationship; that is, the two stations were located as close as possible to each other, but at depths that differed by 50 m. As discussed in Chapter 1, sampling at Station 8 was discontinued after the first three cruises.

Personnel from Lamont-Doherty Geological Observatory were responsible for the operation of the camera sled used to collect film footage for the analysis of epifaunal organisms.

Navigation

Loran-C was the major navigational aid for station positioning. Loran time delays established from the bathymetric surveys performed at each station on Cruises Mid-1, Legs 1 and 2, were used to reoccupy these stations on subsequent cruises. The time delays were in the 9960 Group Repetition Interval (GRI) and were based on the X (Nantucket) and Y (Carolina Beach) secondary stations. The X and Y stations corresponded to the 26-k and 42-k lines, respectively.

On the first two sampling cruises, a Northstar 6000 Loran-C receiver was integrated with a Texas Instrument Silent 700 series microcomputer to record time, date, latitude, longitude, and time delays. On the remaining four cruises, a Northstar 7000 Loran-C receiver was used for navigation. Software developed by Eliason Data Services integrated an Apple IIe microcomputer and an Epson printer with the Loran. An EPSCO plotter was used on all cruises to provide a graphic plot of the ship's actual position during sampling.

TABLE 3. STATION REFERENCE COORDINATES FOR THE U.S. MID-ATLANTIC SLOPE AND RISE STUDY. LATITUDES AND LONGITUDES ARE BASED ON NORTHSTAR 6000.

Station	Latitude/ Longitude	Loran Time Delays	Reference Depth (m)	Actual Depths Sampled (m)
1	38°35.98'N 72°52.97'W	26365.6 42588.7	2195	2165-2209
2	38°35.78'N 72°53.65'W	26369.5 42586.2	2020	2005-2024
3	38°36.84'N 72°51.35'W	26357.0 42598.0	2055	2045-2064
4	38°44.47'N 72°33.01'W	26297.1 42675.1	2100	2091-2124
5	38°50.49'N 72°33.01'W	26249.4 42734.3	2065	2055-2090
6	39°05.54'N 72°02.97'W	26063.1 42878.2	2090	2045-2091
7	38°27.36'N 73°03.44'W	26423.0 42499.2	2100	2085-2110
8	38°27.31'N 73°04.87'W	26431.0 42497.8	2150	2148-2159
9	38°17.28'N 73°14.51'W	26480.6 42392.3	2105	2100-2114
10	37°51.80'N 73°19.84'W	26496.2 42137.0	2095	2093-2114
11	38°40.17'N 72°56.37'W	26386.8 42627.1	1515	1502-1540
12	38°29.30'N 72°42.15'W	26301.9 42532.0	2505	2495-2509
13	37°53.33'N 73°45.09'W	26628.4 42121.0	1613	1605-1619
14	37°53.91'N 73°44.62'W	26626.3 42126.8	1500	1409-1515

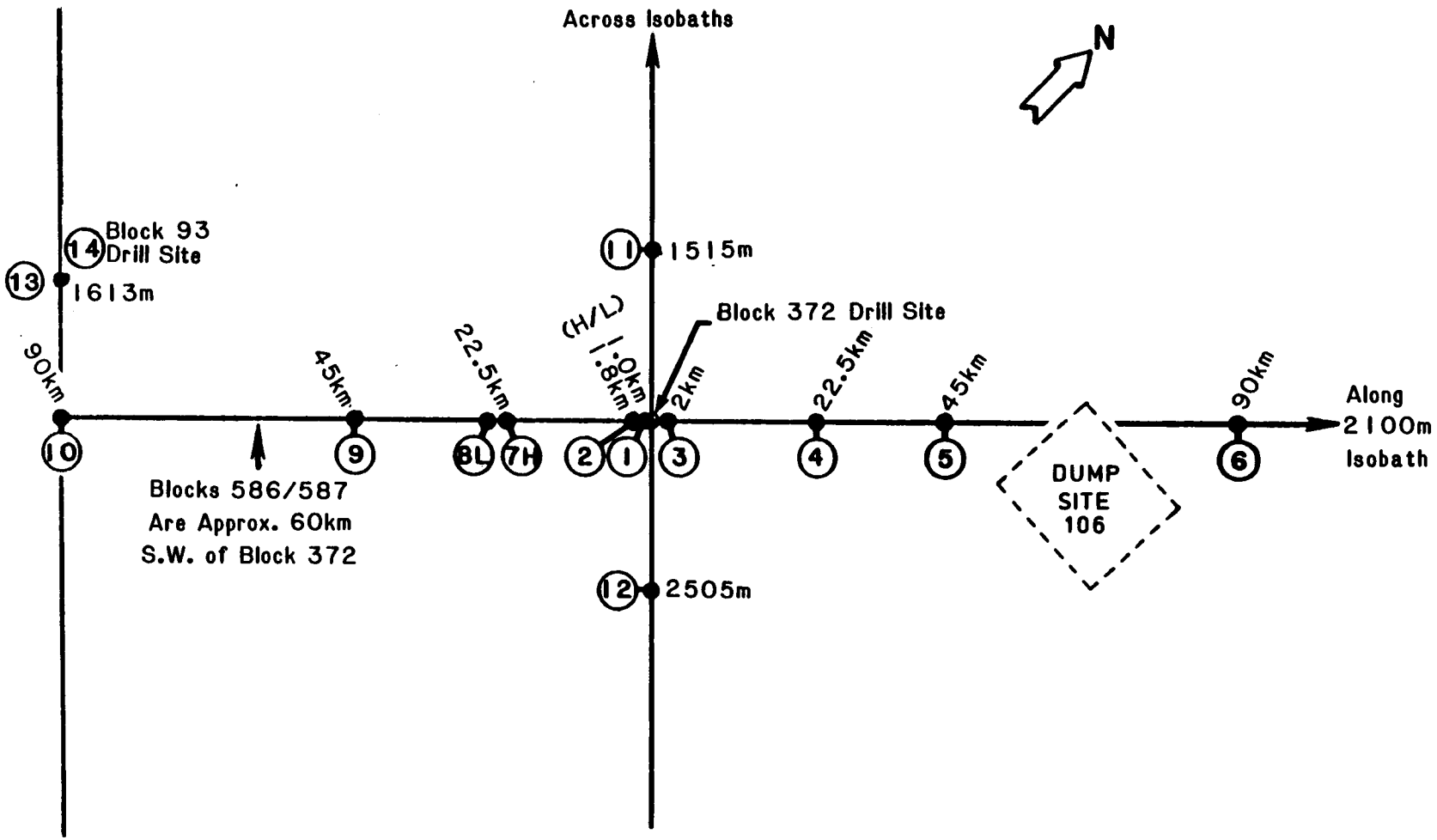

Figure 3. **Diagrammatic Representation of U.S. Mid-Atantic Station Locations.**

Box Core Sampling

At all stations on each cruise, a Mark III 0.25-m^2 box corer was used to collect three replicate box cores. The core box was partitioned into 25 subcores, each with a surface area of 0.01 m^2. All subcores for trace metal samples were precoated with Teflon. Each subcore was fitted with a removable 0.3-mm mesh screen that allowed overlying water to escape as the box corer entered the bottom sediment, but trapped animals present in the overlying water. A block of nine contiguous subcores was designated for infaunal analysis, with additional subcores designated for CHN, sediment grain size, trace metal chemistry, hydrocarbon chemistry, and meiofauna. On Cruises Mid-1 and Mid-2, the block of nine biology subcores was taken with one row of three subcores being lateral, or against the side of the box (Appendix A, Figure A-1). On the third cruise, the innermost nine cores were designated for biology (Appendix A, Figure A-2), because laboratory analysis of the first samples indicated lower faunal densitites in the side row of the subcores due to an edge-effect. However, this arrangement was also unacceptable because a lateral core was then designated for hydrocarbon analysis. Therefore, on Cruises Mid-4, Mid-5, and Mid-6, one of the inner nine subcores was designated for hydrocarbon analysis at the five stations at which these samples were collected (Appendix A, Figures A-3 and A-4). The block of nine inner subcores was used for infaunal analysis at those stations not designated for hydrocarbon analysis.

Three additional box cores were taken on Cruise Mid-5 at Stations 6 and 10 for determination of infaunal biomass. The inner nine subcores were preserved in the same manner used for the other infaunal samples.

Infauna

Subcores for infaunal analysis were removed individually from the core box and placed on top of a wooden extruding post that fit exactly within the dimensions of the subcore. 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 sieve and the sediment was extruded from the aluminum sleeve by pushing the sleeve down around the wooden post. On the first two cruises, the top 10 cm of each subcore were removed in three sections (0-2, 2-5, and 5-10 cm) by slicing the sediment with a stainless steel blade. Each section was washed with filtered seawater onto a 0.3-mm mesh screen and transferred to prelabeled

glass jars. On the remaining cruises, a slightly different procedure was used. For those samples, the top 0 to 3- or 0 to 4-cm section was transferred without sieving into a 16-oz jar. The remainder of the 10-cm core was sieved before transfer to a second glass jar. All sections were preserved in 10 percent buffered formalin.

Sediment Trace Metals

Two (sometimes three) subcores from each box core were designated for trace metal analysis. These subcores had been coated with Teflon to preclude metal contamination. 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 the plastic tube was then capped at both ends and frozen. At the completion of each cruise, these samples were transferred to the U.S. Geological Survey (USGS) in Woods Hole.

Sediment Hydrocarbons

On Cruises Mid-1 and Mid-2, one subcore from each replicate box core was designated for hydrocarbon analysis. On Cruises Mid-3, Mid-4, Mid-5, and Mid-6, analysis of hydrocarbon samples was planned only for replicates collected at Stations 1, 2, 3, 10, and 13 (see Chapter 6); however, replicate samples were taken at each station and archived. The top 2 cm of the subcore were extruded and sectioned into a prelabeled 250-ml Teflon jar. Frozen samples were stored at Battelle until analysis.

Meiofauna

Two small cores were removed from one subcore of each replicate box core. These samples were not sieved, but were preserved in 5 percent buffered formalin. The meiofauna samples have been archived at Battelle.

CHN

A plastic core was used to remove a 15-cm^3 plug of sediment from each replicate box core. Each sample was placed in a prelabeled Whirlpak and frozen until analysis at Battelle.

Sediment Grain Size

The top 2 cm of the subcore designated for grain-size analysis were removed and placed in a prelabeled Whirlpak. All samples were frozen until analysis at WHOI.

Camera Transects

The camera sled BERNEI (Benthic Equipment for Reptant and Natant Epifaunal Imaging) equipped with a Benthos survey camera was used to photograph epifauna. The camera sled was designed and built as part of an MMS-sponsored project performed by Lamont-Doherty Geological Observatory (L-DGO) of Columbia University (Hecker et al., 1983).

One full camera transect consisted of 13 nmi. Two and a half transects were surveyed on each of the first two cruises in the program and repeated on the fifth cruise. Two transects extended for 13 nmi and one circular transect around the drill site extended for 7 nmi. 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. This resulted in maximal coverage of 52 percent of an approximately 2.5-m wide swath along the track of the tow.

An additional 6-hr camera tow was made in the vicinity of Station 7 on Cruise Mid-5 to test the operating limits of Lamont-Doherty's second sled, a modified design of BERNEI.

Bottom Trawls

A 40-ft Gulf of Mexico trawl with steel "V" doors was used on Cruises Mid-1, Mid-2, and Mid-5 to collect the brittle star Ophiomusium lymani and the sea urchin Echinus affinis for tissue analysis of trace metals and hydrocarbons. Voucher specimens were also collected for correlation with the bottom photographs. Specimens for chemical analysis were placed in prelabeled Teflon jars and frozen until analysis. Specimens to be retained as biological vouchers were preserved in 10 percent buffered formalin.

Hydrographic Measurements

At each station, hydrocasts were made using a Niskin bottle equipped with three reversing thermometers. Samples of near-bottom water were collected for measurements of temperature, salinity, and dissolved oxygen. Dissolved oxygen was determined by the Winkler titration method. Samples were analyzed in triplicate on board ship. Triplicate salinity samples were drawn and stored for transfer to WHOI where salinity was determined using an Autosal conductivity probe. A Neil Brown Mark III CTD unit integrated with the shipboard Hewlett Packard computer system was used on Cruise Mid-2 to provide a continuous profile of temperature and salinity with depth.

Recolonization Trays

The schedule for deployment and retrieval of the free vehicles that hold the recolonization trays is shown in Table 4. Of the 12 arrays deployed, all except the last two were of the original rectangular design. Each vehicle held six trays, three of which were filled to the brim with sediment that was collected from the 2100-m stations on earlier cruises, frozen to kill the organisms present, then thawed and homogenized. Sometimes the other three trays were left empty to see how much sediment would be trapped; at other times these trays were also filled with sediment for additional analyses, if needed. A hydrodynamic study of the rectangular array was conducted as part of this program, and resulted in a major redesign of the array. Details of the flume study were presented in the interim report for the U.S. North Atlantic component of the program (Chapter 4 in Maciolek et al., 1986) and will not be repeated here. The redesigned array consisted of a large circular tray into which six smaller circular trays were placed. The entire array was filled with pretreated mud as described for the original design.

Vehicles were deployed by using the ship's crane to lift and swing the assembly over the side of the vessel and lower it to just below the surface of the water. The deployment line was released and the transponder was enabled by sending a 12-kHz acoustic signal from the ship. The transponder answered this signal for 2.5 hr, allowing shipboard personnel to track the descent of the vehicle to the bottom. The final bottom position was logged for later recovery of the vehicle. Recovery was initiated by sending a 12-kHz acoustic signal from the ship to enable the transponder, which responded with a

TABLE 4. DEPLOYMENT AND RETRIEVAL SCHEDULE OF FREE-VEHICLE ARRAYS AND TRAYS PROCESSED IN THE U.S. MID-ATLANTIC STUDY AREA.

Deployment Cruise/Date	Station	Free Vehicle Number	Retrieval Cruise/Date	Trays Processed
Six-Month Trays				
Mid-1, Leg 2 May 1984	2	2209	Mid-3 Nov 1984	2, 3, 5
Mid-1, Leg 2 May 1984	2	2206	Mid-3 Nov 1984	-----
Mid-1, Leg 2 May 1984	4	2207	Mid-3 Nov 1984	1 and 5
Mid-1, Leg 2 May 1984	4	2210	Mid-3 Nov 1984	3
Mid-4 May 1985	2	2206	Mid-6 Nov 1985	1, 3, 5
Mid-4 May 1985	2	2207	Mid-6 Nov 1985	1, 3, 5
Mid-4 May 1985	2	2312*	Not Recovered	Not Applicable
Mid-4 May 1985	2	2314*	Mid-6 Nov 1985	Not processed due to loss of surface sediment.
One-Year Trays				
Mid-1, Leg 3 May 1984	2	2211	Mid-4 May 1985	1 and 3
Mid-1, Leg 3 May 1984	2	2213	Mid-4 May 1985	5
Mid-1, Leg 3 May 1984	4	2204	Mid-4 May 1985	1 and 3
Mid-1, Leg 3 May 1984	4	2205	Mid-4 May 1985	5

* New, circular design.

verification signal. A specific release command was then sent to the transponder. Within about 10 min, this command resulted in the release of weights from the free vehicle, which then ascended through the water column. The vehicle was acoustically tracked to the surface. The vehicles were retrieved in daylight during the calmest sea conditions possible. As a precaution, each vehicle was equipped with a back-up radio beacon and strobe light. Vehicles in the second set deployed also carried international orange signal flags to make them more visible.

Once the vehicles were secured on deck, the sediments in the rectangular trays were subdivided into 12 equal sections. Nine of these 10 x 10-cm sections were processed as described above for infaunal analysis and the remaining three subcores were frozen for trace metal, hydrocarbon, sediment grain size, or total organic carbon (CHN) analyses (Figure A-5). This procedure was followed for trays recovered on Cruises Mid-3 and Mid-4. On Cruise Mid-6, all 12 sections were processed for infaunal analysis; no samples were saved for other types of analyses.

Day Dredge

A 5-ft Day dredge (rock dredge) was used in the vicinity of Station 7 on the fourth and fifth cruises to collect specimens of the large clam shells observed in film footage. Large numbers of clam shells that appeared similar to those found near hydrothermal vents had been noted in film taken on an earlier cruise. Collection was attempted so that further identification of the clams could be made and the shells dated through radiocarbon isotope technique.

RESULTS

Box Core Sampling

Box core sampling progressed smoothly in the U.S. Mid-Atlantic study area, resulting in the successful collection of 237 box cores on six cruises. Two pingers were lost during the second leg of the first cruise, leading to the installation of an improved mount to protect the pinger. Box core replicates were positioned in a tight array at each station. Relative positions of the box cores collected on all six cruises are plotted in the figures in Appendix B. The position of each replicate is listed in Appendix C.

Camera Transects

Camera transects were successfully completed on Cruises Mid-1, Mid-2, and Mid-5. On the first leg of Cruise Mid-1, camera tows were made at Blocks 93 and 372 near Stations 14 and 1, respectively. Although conditions at Block 93 resulted in poor bottom coverage, conditions at Block 372 were excellent and resulted in good quality film footage. The transect at Block 93 was not reoccupied on subsequent cruises because this site was not selected as the drilling site to be monitored. Two additional camera transects, including a circular transect around the Block 372 drill site, were completed on leg 3 of Cruise Mid-1. A third camera tow, located southwest of the drill site at Station 1, was a continuation of the original camera transect occupied on the first leg of this cruise. All camera transects were successfully photographed during each of the second and fifth sampling cruises.

Bottom Trawls

Bottom trawls were made during Cruises Mid-1, Mid-2, and Mid-5. On the first cruise, successful trawls were made at Stations 1 and 4 and between Stations 7 and 8. On Cruise Mid-2, a successful trawl was made only at Station 4. At Station 1, the net was hung up during retrieval and the entire rig was lost. Four successful trawls were made on Cruise Mid-5, although the trawl fished too deeply at Station 7 and was filled with mud. The net was undamaged, however, and was brought on board by using the ship's crane to haul the cod end.

Hydrographic Measurements

Measurement of hydrographic parameters was successful for the majority of this program. No problems were encountered on Cruises Mid-1, Mid-2, and Mid-5. On Cruise Mid-3, poor weather conditions precluded hydrographic sampling at Stations 4, 5, and 10. Temperature measurements were not taken at Station 6 on Cruise Mid-4. On Cruise Mid-6, one of the two protected deep-sea reversing thermometers malfunctioned at Stations 9 and 10. Sampling was successfully completed at stations other than those listed above for Cruises Mid-3, Mid-4, and Mid-6.

Recolonization Trays

A total of 12 free vehicles, including 10 of the original design and two of the new design, were deployed during this program. Of these, 11 were retrieved as scheduled. One free vehicle, a circular array deployed at Station 2 on Cruise Mid-4, was not recovered because of a failure of the transponder release system. The second circular array, also deployed at Station 2 on Cruise Mid-4, was retrieved on Cruise Mid-6. However, the cover was not secure enough to prevent washing of the sediments during retrieval operations, and this array was not processed. The overall success of the deployment and retrieval operations was facilitated by calm weather conditions and expert handling by experienced scientific and ship's crew.

Day Dredge

Attempts to sample the large clam shells visible on film footage taken at Station 7 were made on Cruises Mid-4 and Mid-5. On Cruise Mid-4, the dredge failed to collect any shells, but two extremely successful hauls were made on Cruise Mid-5. Further information on these shells is given in Chapter 6 of this report.

CHAPTER 3. BENTHIC INFAUNAL COMMUNITY STRUCTURE

INTRODUCTION

One of the major components of this study was the analysis of the infaunal macrobenthos from box core samples. Benthic environments are potential sinks for discharged materials, and because of their relative immobility, benthic organisms are susceptible to exposure to these materials. It was hypothesized that any impacts due to drilling would be reflected in changes in the diversity and species composition of the communities and/or in the densities of individual infaunal species.

The deep-sea benthos and the processes that affect it are very poorly known. Based on qualitative trawl samples from off New England and other areas, the deep sea is thought to sustain a very high diversity of organisms associated with soft sediments (Hessler and Sanders, 1967; Sanders, 1968). Numerous taxonomic studies of the material collected on the fine-mesh screens used by Hessler and Sanders have confirmed the initial reports of high diversity for a portion of the fauna (e.g., Hartman, 1965, polychaetes; Rex, 1973, gastropods; Hessler, 1970, isopods). However, prior to the present study, complete analyses of macrofaunal species have been made for less than 100 quantitative samples, and, of these, most are from depths below 5000 m in the low-density Mid-Pacific gyre. It has therefore not been possible for ecologists to appreciate fully the high diversity of the deep sea nor to understand the processes that shape the structure of individual populations or the whole community. In spite of this unsophisticated level of understanding, the deep sea has been proposed for activities that might severely affect these complex highly diverse communities. In addition to drilling operations that have already taken place at water depths of 2100 m, various federal agencies propose to discharge municipal sludges and industrial wastes at locations off the continental shelf (e.g., EPA's 106-Mile Dumpsite at 2500 m), and even deeper areas have been proposed as the site of deep-sea mining operations. In-situ experiments have suggested that large disturbances to deep-sea communities would have long-lasting effects that would require recovery times several orders-of-magnitude greater than those observed for shallow-water environments (Grassle, 1977; Chapter 5, this report).

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 80 percent alcohol. 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 4 hr 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 fresh water and transferring it to clean 80 percent alcohol.

Samples were examined under a dissecting microscope and each organism or fragment 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 recorded separately for each subcore for the first set of samples collected. This procedure proved to be very time-consuming

(i.e., expensive), and beginning with the second set of samples, the specimens from the nine separate subcores were pooled, resulting in only one set of counts for each replicate 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.

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 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 John Allen, Dove Marine Laboratory, Scotland (thyasirid bivalves), Edward Cutler, Union College (sipunculans), Michael Rex, University of Massachusetts (gastropods), Amalie Scheltema, WHOI (aplacophorans), Kenneth Sebens, Northeastern University (anthozoans), Les Watling, University of Maine (amphipods), and George Wilson, Scripps Institution of Oceanography (isopods).

Data Reduction and Analysis

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 key punching 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 D.

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) was set at 50 and 200. The clustering strategy used was group average (Boesch, 1977). NESS similarity, followed by group average clustering, was also used with the polychaete data alone, with m set at 20 individuals. The Bray-Curtis coefficient (Boesch, 1977), with group average 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.

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 30 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:

$$H'(s) = -\Sigma\, p_j \log p_j$$

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:

$$E[S_m|N] = \sum_{i=1}^{k} 1 - \frac{(n - n_i, m)}{(n, m)}$$

where n_i is the finite population of species i, n is the total number of individuals in the finite population:

$$n = \Sigma_i\, n_i$$

and S_m is the random variable denoting the number of species in a sample of size m (Smith and Grassle, 1977). For the rarefaction analyses, the number of individuals was set at 32 points ranging between 50 and 40,000. Increments between points were as follows: 50 individuals between 50 and 200; 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 40,000.

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 methods 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 and also for replicates pooled for three combinations of stations. The number of stations that could be pooled was limited by the number of replicates (130) that could be processed by the computer. Therefore, species accumulation curves were drawn for pooled replicates from Stations 11, 13, and 14 (1515 to 1613 m) and for two combinations of the 2100-m stations: Stations 1-9 (except Stations 6 and 8), and Stations 1-10 (except Stations 4 and 6).

The densities of the 18 most abundant species were tested to determine whether mean density of any species differed between stations or sampling times. For each species, a two-way Analysis of Variance (ANOVA) was performed with density as the dependent variable and sampling time and stations as the two main effects. Stations 8 and 14 were excluded from these ANOVAS because these stations were not sampled on all sampling dates. To test for differences at those stations, separate one-way ANOVAS were performed for the times sampled.

Nine contrasts were used to test specific a priori hypotheses about the mean densities between sites. Each hypothesis was tested for each sampling time to control for time-station interaction. The a priori hypotheses tested were:

Hypothesis 1: Does the mean density of a species at the 2100-m Stations 1-7, 9, and 10 differ from the mean density at the 2500-m Station 12?

Hypothesis 2: Does the mean density of a species at the 2100-m Stations 1-7, 9, and 10 differ from the mean density at the 1500-m Stations 11 and 13?

Hypothesis 3: Does the mean density of a species at the "central" 2100-m Stations 1-5, 7, and 9 differ from the mean density at Station 6, at the northeast end of the transect?

Hypothesis 4: Does the mean density of a species at the "central" 2100-m Stations 1-5, 7, and 9 differ from the mean density at Station 10, at the southwest end of the transect?

Hypothesis 5: Does the mean density of a species at the "central" 2100-m Stations 1-5, 7, and 9 differ from the mean density at the 2500-m Station 12?

Hypothesis 6: Does the mean density of a species at the "central" 2100-m Stations 1-5, 7, and 9 differ from the mean density at the 1500-m Stations 11 and 13?

Hypothesis 7: Does the mean density of a species differ between the 1500-m Stations 11 and 13?

The following planned contrasts were tested for densities recorded in samples collected on Cruises Mid-1, -4, -5 and -6 only:

Hypothesis 8: Does the mean density of a species differ between the 1500-m Stations 11 and 14?

Hypothesis 9: Does the mean density of a species differ between the 1500-m Stations 13 and 14?

In addition to testing a priori hypotheses involving differences in densities between stations, a Student-Newman-Keuls multiple comparison test was performed to determine which sampling dates at each station had significantly different densities.

The F ratio (F ratio = maximum variance/minimum variance) test (Sokal and Rohlf, 1983) was used to determine whether the densities should be transformed to reduce heterogeneity of variances between different sample times and stations. A significant F ratio indicated that variances were not homogeneous. A log (x+1) transformation of

densities was used in the analyses when the F ratio was lower for transformed densities than untransformed densities.

RESULTS

Taxonomy

A total of 237 box cores were collected on the six sampling cruises. Eighteen box cores were collected from most stations. Nine box cores were collected from Station 8 and 12 box cores were collected from Station 14. The data from all but four box cores were used in the analyses presented below. The four samples that were deleted were Station 6, replicate 3, Cruise Mid-6; Station 7, replicate 3, Cruise Mid-4; Station 8, replicate 1, Cruise Mid-3; and Station 11, replicate 2, Cruise Mid-6. These samples were deleted owing to the loss of portions of the samples during processing.

A total of 862 species representing 16 phyla as summarized in Table 5 has been identified. A complete list of all species identified is provided in Appendix D. The results of the examination of voucher specimens by the consultants have been incorporated into the data set reported earlier (Maciolek-Blake et al., 1985; Maciolek et al., 1986a) and are reflected in the species list. Additional species have also been recorded, resulting in a net increase of 93 species over the total reported for the first four sampling cruises.

Of the 862 species recorded in this study, 56.7 percent, or 489 species, are new to science. The largest percentage of new species recorded in major phyla were found in the Arthropoda: 139 species, or 68 percent, are undescribed. Sixty-four percent, or 236 species, of polychaetes are undescribed. Within several polychaete families that have a high number of species, such as the Dorvilleidae, Cirratulidae, Spionidae, Flabelligeridae, and Terebellidae, the percentage of new species ranged from 75 to 93 percent. Five new species of oligochaetes were also found out of 18 recorded. Forty-two species, or 36.5 percent, of the molluscs are new to science. Additional undescribed species were found in the phyla Porifera (4), Cnidaria (22), Nemertinea (23), Echiurida (4), Bryozoa (3), Brachiopoda (2), Echinodermata (5), and Hemichordata (4). In many cases, these new species represent 100 percent of the species recorded in the particular phylum (Table 5).

TABLE 5. TAXONOMIC COMPOSITION OF SPECIES IDENTIFIED FROM U.S. MID-ATLANTIC INFAUNAL SAMPLES.

Taxon	Number of Species	Percent of Total Species
Porifera	5	0.6
Cnidaria	42	4.9
Hydrozoa	25	
Anthrozoa	14	
Scyphoroa	3	
Platyhelminthes	1	0.1
Nemertinea	23	2.7
Priapulida	2	0.2
Annelida		44.7
Polychaeta	367	42.6
Acrocirridae	2	
Ampharetidae	28	
Amphinomidae	1	
Aphroditidae	2	
Apistobranchidae	1	
Arabellidae	1	
Capitellidae	20	
Chaetopteridae	1	
Chrysopetalidae	5	
Cirratulidae	26	
Cossuridae	2	
Dorvilleidae	24	
Fauveliopsidae	3	
Flabelligeridae	7	
Glyceridae	2	
Goniadidae	3	
Hesionidae	6	
Heterospionidae	1	
Lacydoniidae	1	
Lumbrineridae	10	
Maldanidae	21	
Nephtyidae	3	
Nereididae	4	
Onuphidae	10	
Opheliidae	6	
Orbiniidae	7	
Oweniidae	16	
Paralacydoniidae	1	
Paraonidae	24	
Pholoidiidae	1	
Phyllodocidae	18	
Pilargidae	4	
Poecilochaetidae	1	
Polynoidae	3	
Protodrilidae	1	
Sabellariidae	1	
Sabellidae	16	
Scalibregmatidae	4	
Sigalionidae	4	
Sphaerodoridae	8	
Spionidae	33	
Syllidae	8	
Terebellidae	14	
Trichobranchidae	8	
Trochochaetidae	1	
Uncispionidae	1	
Unassigned	3	
Oligochaeta	18	2.1
Echiurida	4	0.5
Sipuncula	15	1.7
Pogonophora	13	1.5
Mollusca	115	13.3
Bivalvia	45	
Gastropoda	36	
Scaphopoda	9	
Aplacophora	25	
Arthropoda	202	23.4
Mysidacea	4	
Decapoda	3	
Cumacea	26	
Tanaidacea	45	
Isopoda	59	
Amphipoda	64	
Pycnogonida	1	
Bryozoa	4	0.5
Brachiopoda	2	0.2
Echinodermata	39	4.5
Echinoidea	9	
Ophiuroidea	16	
Asteroidea	3	
Holothuroidea	11	
Hemichordata	4	0.5
Chordata		
Ascidiacea	5	0.6
TOTAL:	862	100.0

The representation of each phylum was similar to that reported earlier. Annelids accounted for 44.7 percent of all species and were represented by 367 species of polychaetes in 46 families and 18 species of oligochaetes. The Spionidae, Ampharetidae, Paraonidae, Cirratulidae, and Dorvilleidae continued to be the best represented polychaete families, with 33, 27, 24, 24, and 23 species, respectively.

The phylum Arthropoda was an important component of the fauna and accounted for 23.4 percent of all species recorded. The orders Isopoda (59 species), Amphipoda (64 species), Tanadaicea (45 species), and Cumacea (26 species) were the dominant arthropod groups.

Approximately 13.3 percent of the species were molluscs, including bivalves (45 species), gastropods (36 species), aplacophorans (25 species), and scaphopods (9 species). The remaining phyla were relatively less common, and included groups such as sipunculans (15 species), echinoderms (39 species), and pogonophorans (13 species), that are typical of deep-sea environments. Twenty-three species of nemerteans and 12 species of sediment-dwelling anemones were recorded.

Diversity

Differences in Diversity Among Stations

Community parameters are presented in Table 6 for all replicates combined for each station. Community parameters calculated separately for each replicate and sampling date are given in Appendix G, and the same parameters calculated for replicates combined at each station on each sampling date are presented in Appendix H.

The calculated expected number of species in successively smaller samples is the best way to illustrate deep-sea diversity (Sanders, 1968; Smith 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. Both the species-individuals plot based on rarefaction of the combined samples and the species accumulation plot of species vs. number of samples are shown on the same graph (Figure 4) for the entire fauna from Stations 1-5, 7, and 9 at 2100 m. Average densities were used to make the axis for the number of replicate

TABLE 6. BENTHIC COMMUNITY PARAMETERS FOR EACH U.S. MID-ATLANTIC STATION, ALL REPLICATES FOR CRUISES MID-1 THROUGH MID-6 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 750 Indiv.	Species per 1000 Indiv.	Species per 2500 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
1	18	2195	4694	301	33.2	52.1	118.4	140.1	156.8	217.2	6.33	0.768
2	18	2020	5361	329	34.5	54.7	123.3	145.7	163.1	226.6	6.48	0.774
3	18	2055	4335	325	34.8	55.3	126.8	151.2	170.4	240.6	6.52	0.782
4	18	2100	5061	281	32.7	50.6	109.6	128.9	143.7	198.0	6.21	0.763
5	18	2065	4727	308	32.1	50.3	117.9	140.8	158.5	223.1	6.23	0.754
6*	17	2090	3642	267	32.7	51.0	116.0	137.8	154.6	215.0	6.25	0.776
7*	17	2100	4181	304	35.9	57.6	130.4	153.4	171.1	234.7	6.63	0.804
8*	8	2150	3708	225	35.4	56.4	126.5	148.3	164.8	223.4	6.50	0.832
9	18	2105	3883	278	35.0	55.2	122.3	143.6	159.7	216.8	6.49	0.799
10	18	2095	4972	351	33.9	53.8	124.6	149.1	168.5	240.2	6.43	0.761
11*	17	1515	5163	363	33.6	54.1	135.4	163.2	184.3	259.8	6.50	0.764
12	18	2505	3567	311	31.1	49.5	123.0	149.6	170.3	244.1	6.14	0.742
13	18	1613	5359	356	32.9	52.6	128.5	155.0	175.6	249.6	6.38	0.753
14*	12	1500	5709	324	34.0	55.6	135.6	161.2	180.5	249.4	6.47	0.776

* Stations with fewer than 18 replicates. The total number of species at these stations cannot be compared directly with the number of species at other stations.

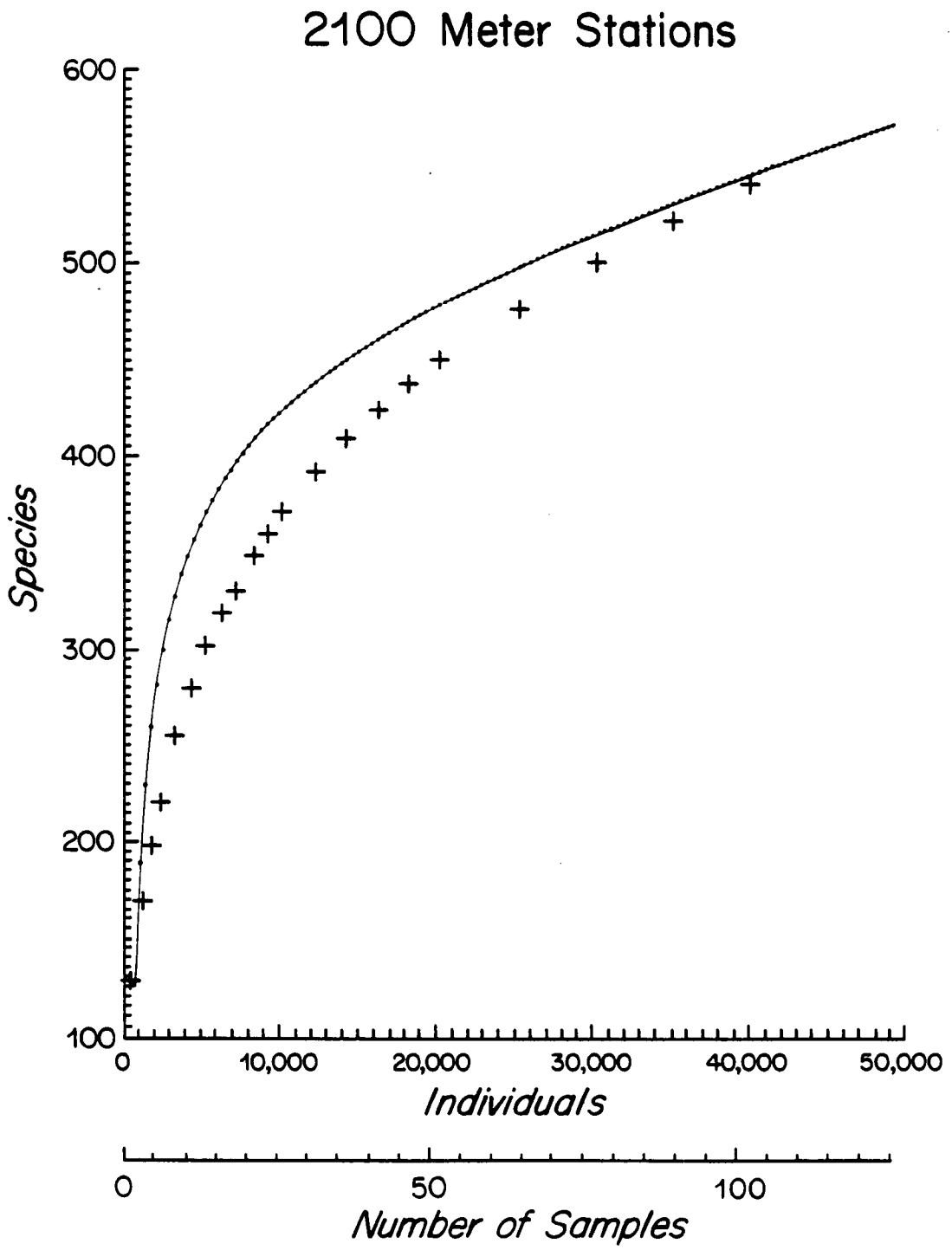

Figure 4. The Upper Curve is a Computer-Generated Species-Area Plot of the Mean Number of Species for Each Combination of Samples from the 2100-m Stations 1-5, 7, and 9 Regardless of Sampling Date. Plus (+) Symbols Mark the Species/Individuals Relationship Calculated by Rarefaction From a Single Summation of the 125 Separate Samples.

samples coincide with the axis for number of individuals. The curves are somewhat different mainly because of patchiness in density of the fauna; however, the overall impression of an extremely diverse fauna with many more species to be found is inescapable. The curve does not reach an asymptote but continues to climb, adding on the order of 30 species for every 10,000 additional individuals sampled.

Figure 5 shows the number of species in each box core (species per 0.09 m^2) plotted against number of individuals. This figure illustrates the diversity of each sample and shows that most of the variance in the number of species per sample is related to variation in the density of total fauna. The number of species ranged from about 55 to 135 per 0.09 m^2. The rarefaction line indicated in the figure was calculated from a single sample consisting of a summation of all 168 individual samples. It is a small portion of the rarefaction plot in Figure 4. The most diverse samples are closest to the expected number of species on the rarefaction plot. If all individuals in the community were distributed randomly, then all the points would be on the rarefaction line.

To examine the relationship between the calculated expected number of species in combined samples separated by time and distance and the actual number of species in the samples, the number of species per 100 individuals were compared as means of individual replicates, means of replicates combined and cruises kept separate, and the value calculated from all replicates combined (Table 7). The estimates based on individual samples are not very different from estimates based on combined samples. Since the average of estimates based on individual samples are less affected by temporal or spatial patchiness, these should be used to compare stations. Of the 2100-m stations, Station 7 is the most diverse and Station 4 is the least diverse. The 1500-m stations have as great a diversity as the most diverse 2100-m stations, but Station 12 at 2500 m has a somewhat lower diversity at 100 individuals.

Figures 6 and 7 show rarefaction diversity curves for the total fauna and three major faunal groups considered separately at each station. When the curve for total fauna is considered, Station 10 is the most diverse of the 2100-m stations and Station 4 the least diverse. This is, in part, because of a number of rare species present in the samples from Station 10 that are presumed to be more common to the south of this station. Again considering the curves for total fauna, the 1500-m stations are more diverse than the 2100-m stations. The curves sometimes cross, but the higher the number of individuals, the greater the separation between curves.

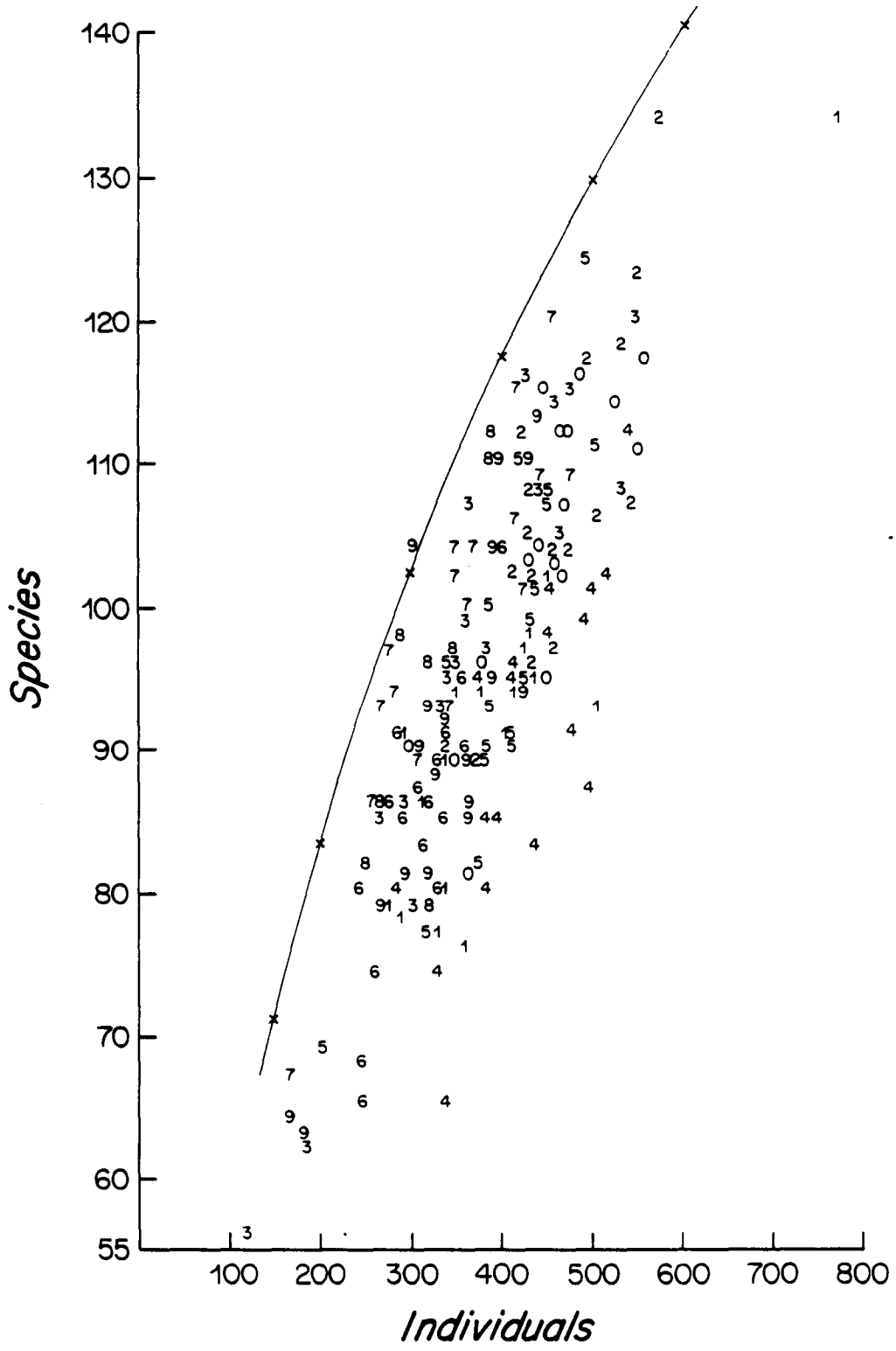

Figure 5. Each Number Represents the Number of Species and Number of Individuals in a Single 900-cm^2 Sample from Stations 1 Through 10. The Number Indicates the Station (Sta. 1=1, Sta. 2=2, ... Sta. 10=0). The Line Connecting the Xs is a Portion of the Rarefaction Curve Calculated From a Summation of All 168 Individual Samples.

TABLE 7. RAREFACTION CALCULATED FOR SPECIES PER 100 INDIVIDUALS.

Station	Replicates[1] and Cruises[2] Separate $\bar{X}$	Replicates[1] Summed, Cruises[2] Separate $\bar{X}$	Replicates and Cruises Summed
1	48.04	50.21	52.07
2	51.21	53.12	54.69
3	51.50	53.36	55.32
4	47.15	49.13	50.57
5	47.95	49.00	50.28
6	48.64*	49.96	50.99
7	54.23*	56.09	57.59
8	53.19*	55.14**	56.37
9	51.03	53.02	55.20
10	50.80	52.44	53.79
11	49.58*	51.82	54.11
12	44.88	47.18	49.51
13	49.37	50.91	52.55
14	52.12*	54.07**	55.62
Mean Sta. 1-10:	50.37	52.15	53.69
95% Confidence Limits	±1.69	±1.77	±1.84

[1]n=18 except where noted: *Stations 6, 7, and 11, n=17; Stations 8, n=8, Station 14, n=12
[2]n=6 except where noted: **Station 8, n=3; Station 14, n=4.

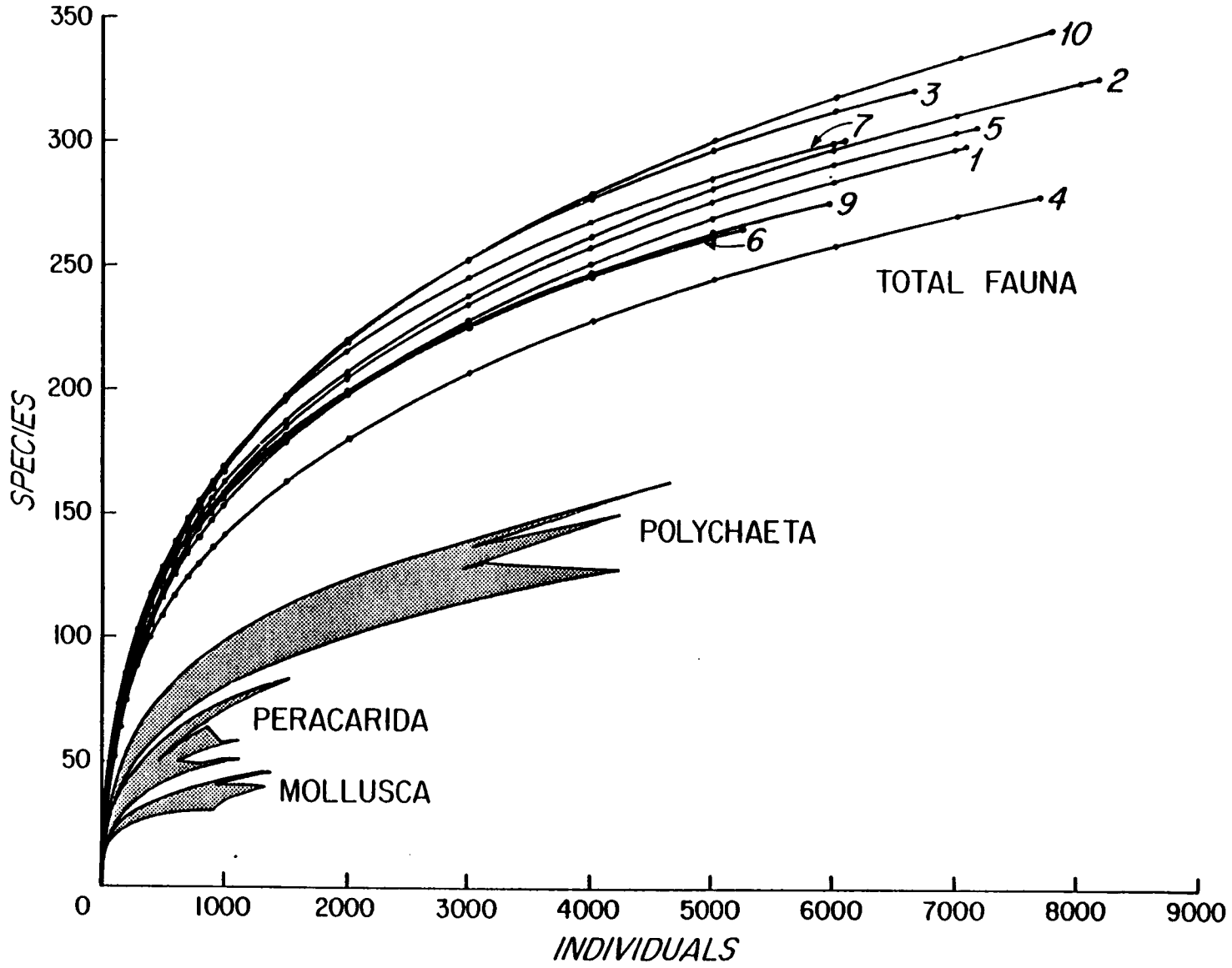

Figure 6. **Rarefaction Curves for Total Fauna, Polychaeta, Peracarida, and Mollusca at U.S. Mid-Atlantic Stations 1-7, 9, and 10. The Jagged Right Edges of the Lower Curves Indicate the Actual Endpoints of the Nine Stations Included in Each of the Three Shaded Areas.**

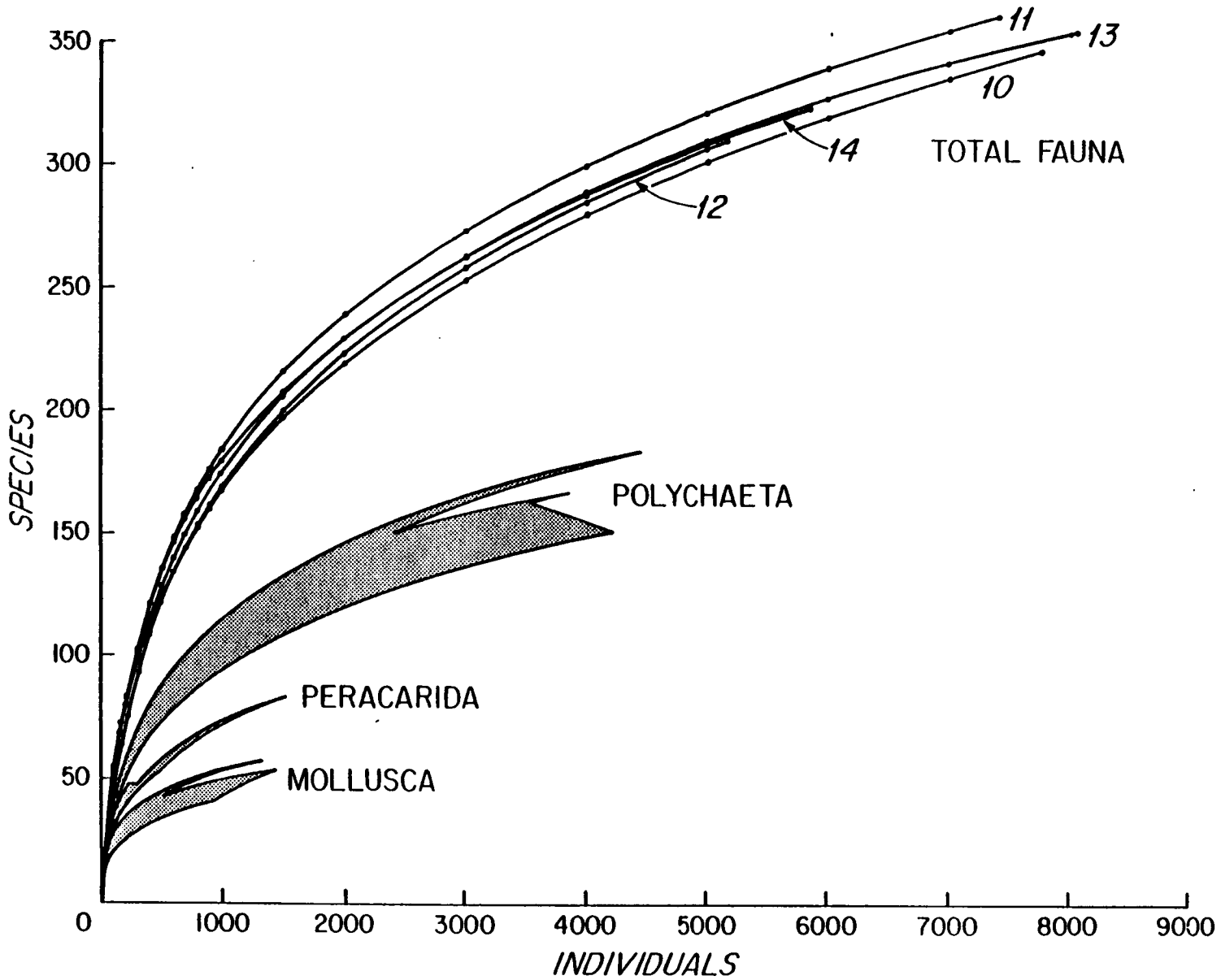

Figure 7. **Rarefaction Curves for Total Fauna, Polychaeta, Peracarida, and Mollusca at U.S. Mid-Atlantic Stations 10 through 14. The Jagged Right Edges of the Lower Curves Indicate the Actual Endpoints of the Five Stations Included in Each of the Three Shaded Areas.**

Polychaetes were always the most diverse taxon, followed by peracarid crustacea and molluscs. The peracarid diversity curve at 2500 m depth (Station 12) is particularly steep and close to the diversity of polychaetes at 2100-m stations (Figure 7).

Species accumulation curves for each station (Figures 8 and 9) do not show the high diversity at Station 12 because these curves are sensitive to the density of the fauna. By this method, Station 10 is the most diverse of the 2100-m stations and Stations 6, 9, and 4 are the least diverse stations. In the accumulation curves calculated for combined stations, Stations 11, 13, and 14 are more diverse than the 2100-m stations (Figure 10 vs Figure 4). This is also clear from the plots of the stations considered separately.

Figures 11 and 12 are rarefaction curves for major phylogenetic components of the fauna. The calculations were based on samples from Stations 1-10 combined for all cruises. The faunal groups represented in Figure 11, in order of diversity, are the polychaetes, peracarid crustacea, and molluscs. In Figure 12, two crustacean groups, the isopods and the tanaids, are seen to be more diverse than the bivalve molluscs. The diversity curve for the tanaids is steeper for collections of less than 1000 individuals than for samples with higher numbers of individuals. The line parallels that for the isopods but is steeper, up to 1000 individuals, then bends rather sharply. This result may be because the tanaids are represented by fewer genera than are the isopods.

Shannon-Wiener diversity at individual stations ranged from means of 5.35 at the 2500-m Station 12 to 6.00 at the 2100-m Station 7 (Appendix G). This method of diversity gives results close to the expected species at 10 individuals (Smith, Grassle, and Kravitz, 1979). The higher diversity at the 1500-m stations is not evident in this measure of diversity. The diversity at the 2500-m station is influenced by the low density of individuals (see below).

Changes in Diversity Over Time

The Shannon diversity measure calculated for Station 1 ranged from a pre-drilling value of 6.16 to a low of 5.94 for Cruises Mid-3 (November 1984) and Mid-5 (July 1985) (Appendix H). The highest value obtained was 6.24 for the November 1985 sampling date (Cruise Mid-6). Stations 2 and 3, within 2 km of the drilling site, fluctuated in Shannon diversity over the six sampling periods, but the differences among values are not

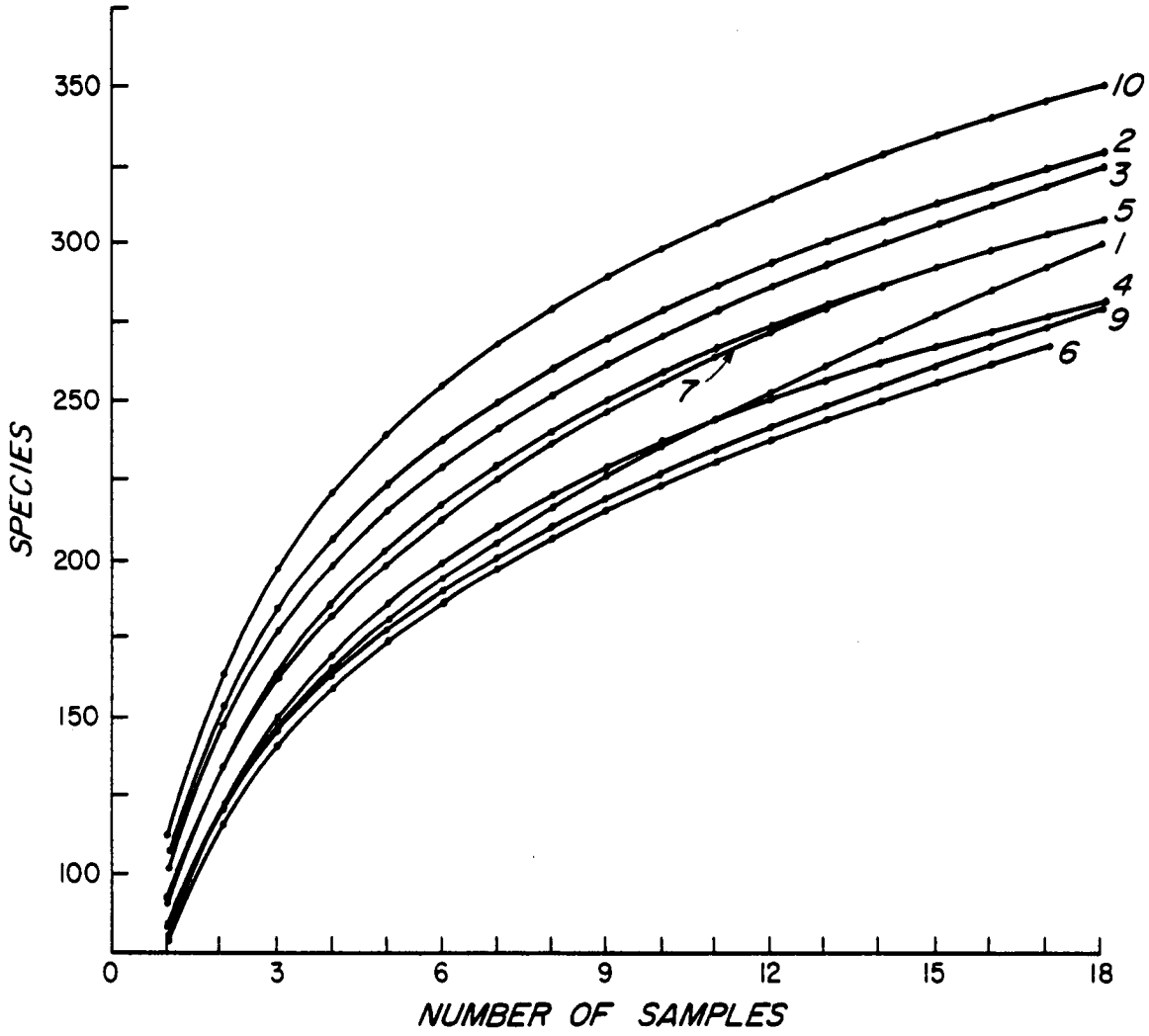

Figure 8. Species Accumulation Curves for U.S. Mid-Atlantic Stations 1-7, 9, and 10.

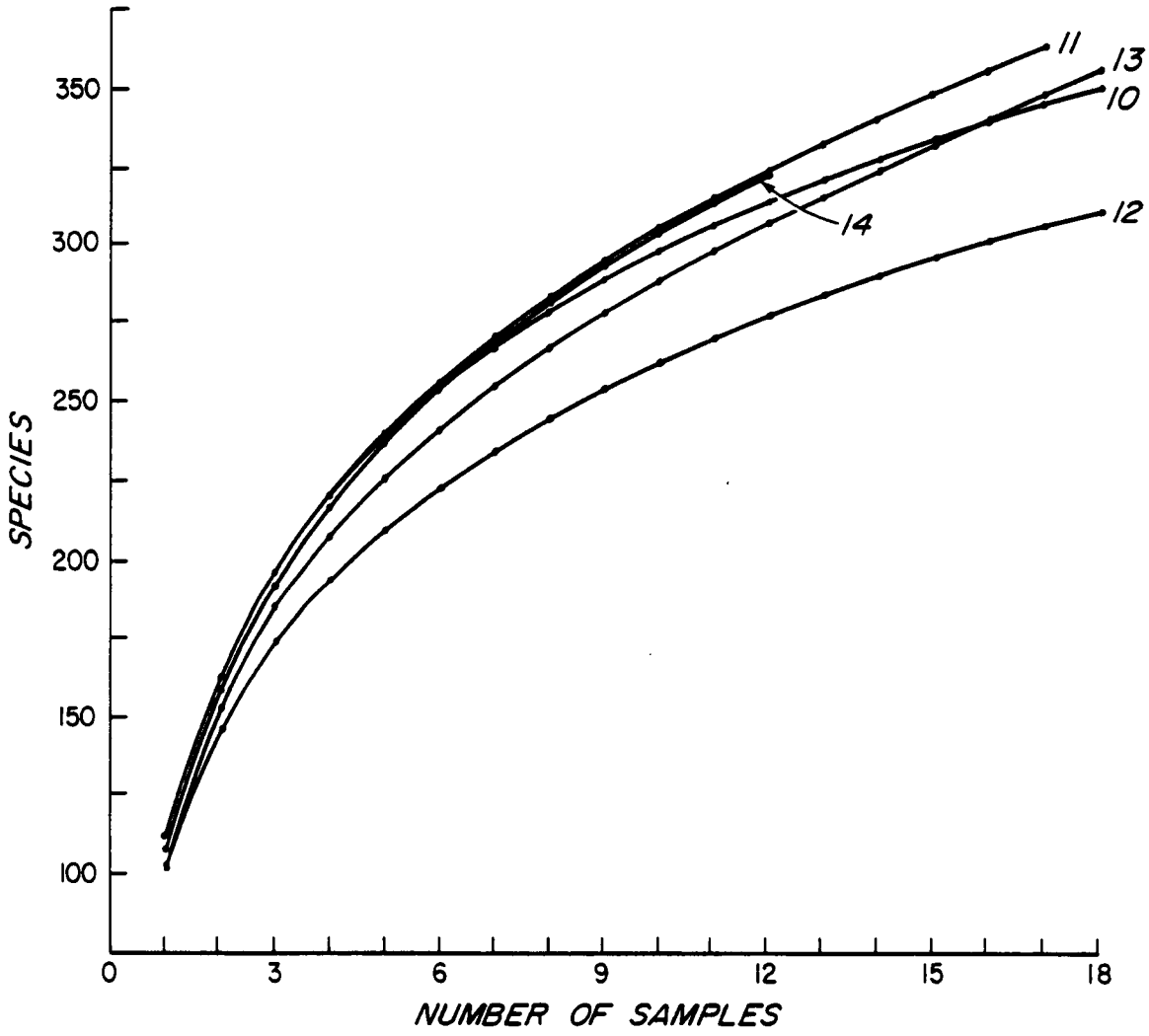

Figure 9. Species Accumulation Curves for U.S. Mid-Atlantic Stations 10 through 14.

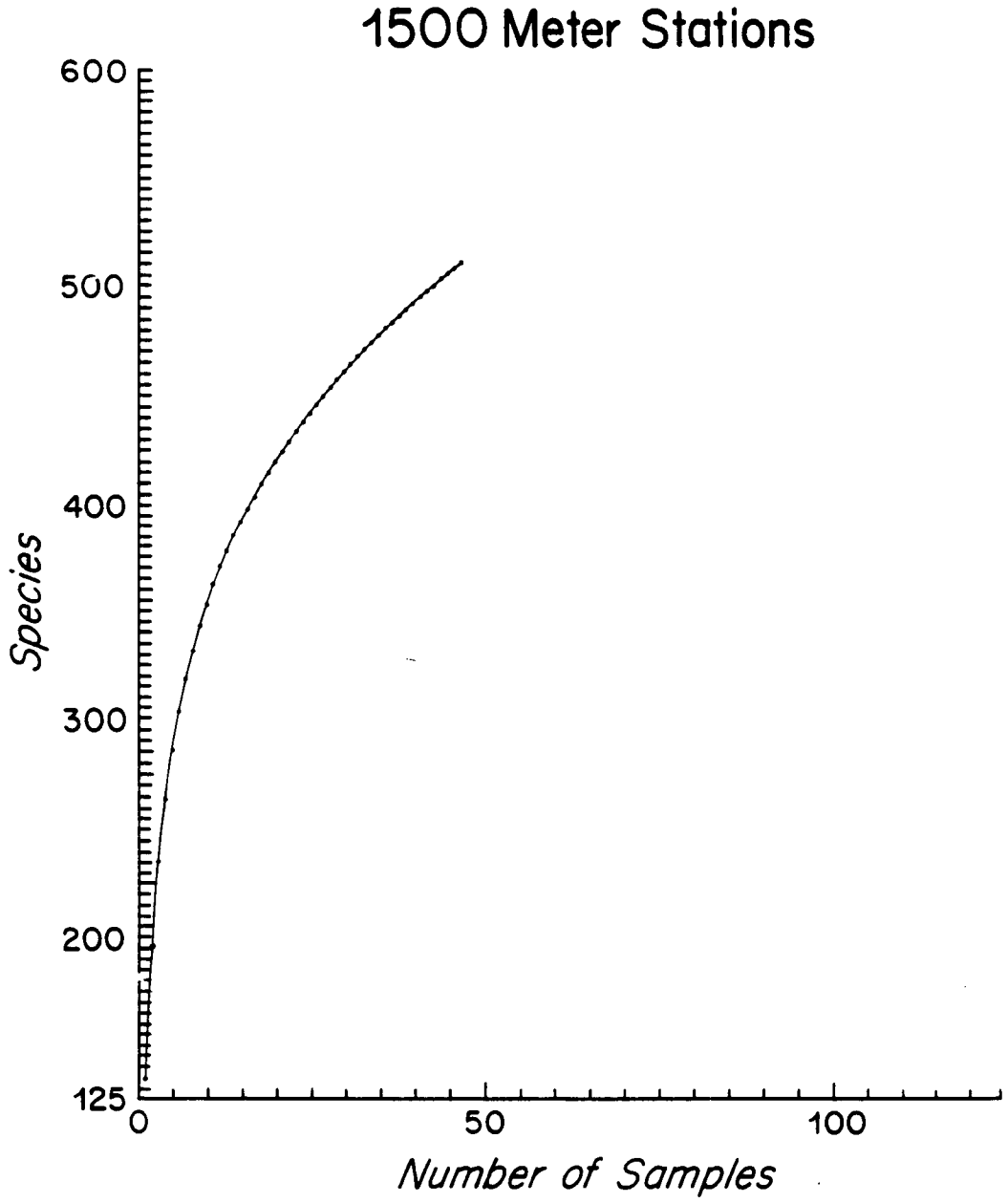

Figure 10. **Species Accumulation Curve for a Summation of Samples from Stations 11, 13, and 14.**

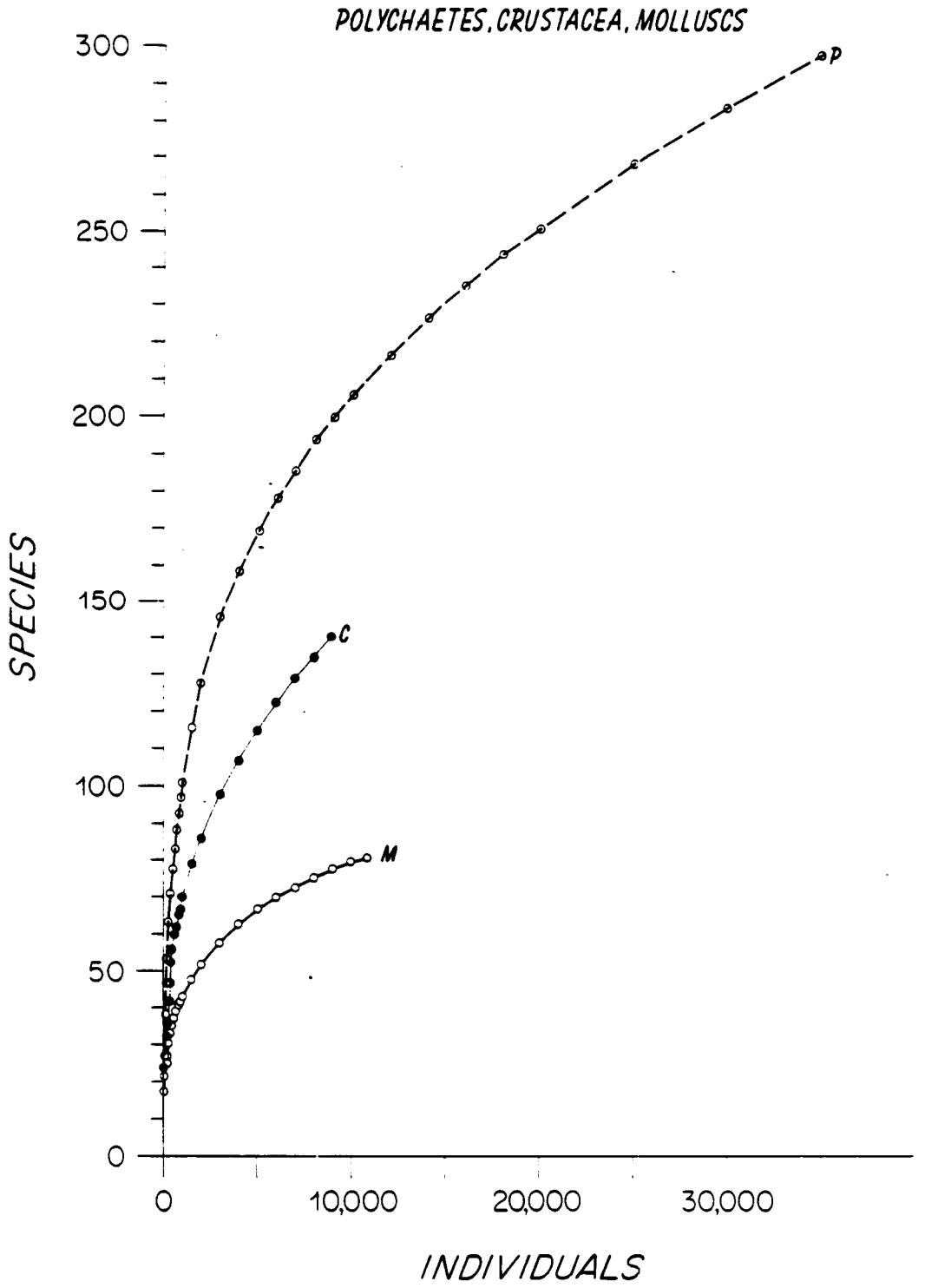

Figure 11. **Hurlbert Rarefaction Curves for Polychaetes, Peracarid Crustacea, and Molluscs for Combined Replicates from Station 1-10.**

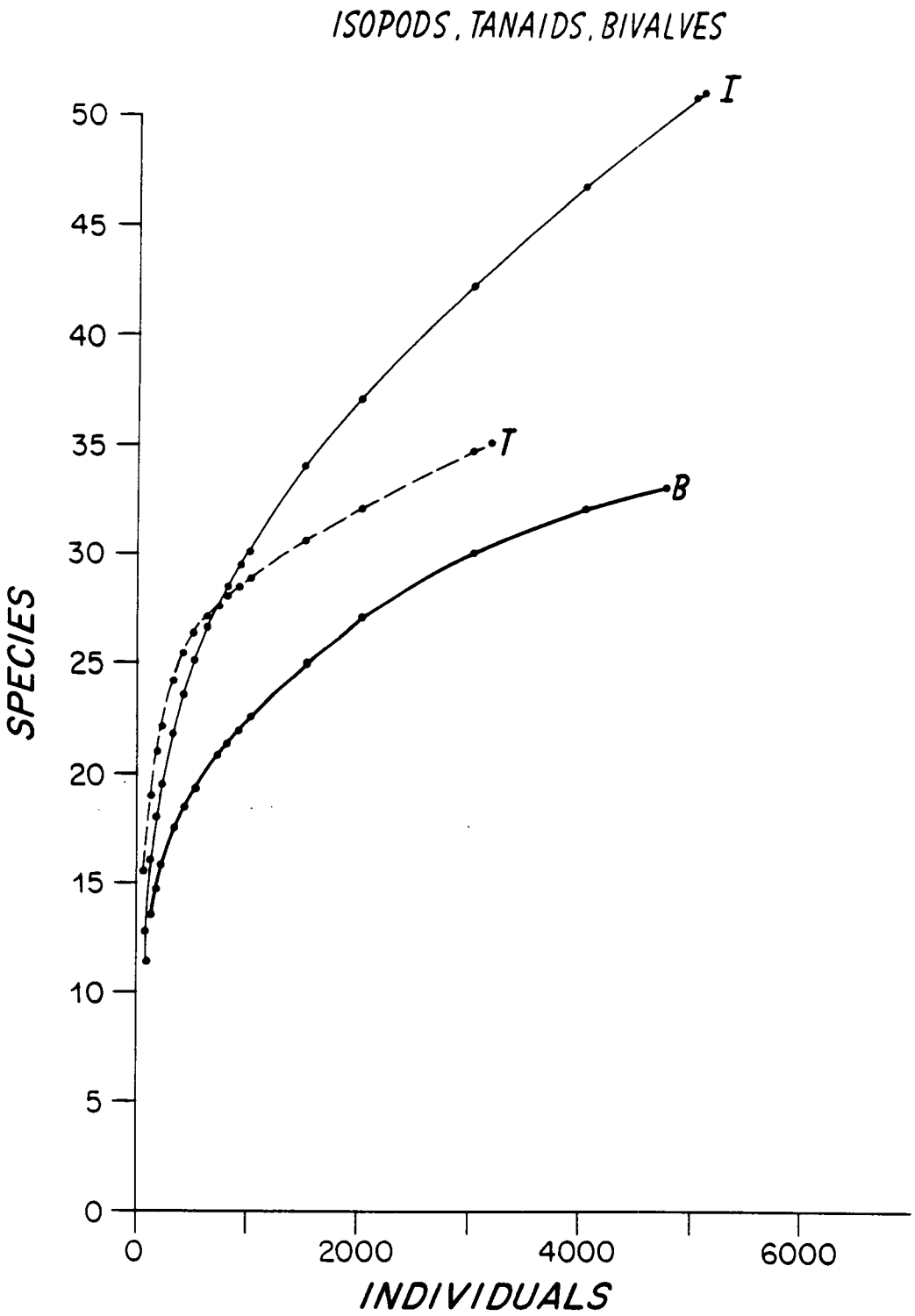

Figure 12. **Hurlbert Rarefaction Curves for Isopods, Tanaids, and Bivalves for Combined Replicates from Stations 1-10.**

considered to be significant. At Station 14, the drilling site in Block 93, diversities were similar on the pre-drilling Cruise Mid-1 in March 1984 and a year later on the post-drilling Cruise Mid-4. Subsequently, diversity dropped from 6.48 on Cruise Mid-4 to 6.08 and 6.01 on Cruises Mid-5 and Mid-6, respectively. Diversity at Station 13, also in Block 93, ranged between a low of 6.07 on the first cruise to a high of 6.12 on the last cruise.

Shannon diversity values for Stations 1, 2, 13, and 14 are compared with Hurlbert rarefaction values in Table 8. From this comparison it can be seen that changes in the Shannon diversity value H' are not consistently reflected by the Hurlbert values. The calculated species per 1000 individuals appears to be the most conservative measure in that these values fluctuate less over time than do the values of H'. Thus, at Station 2, an H' value of 6.09 on Cruise Mid-1 corresponds to a species per 1000 Hurlbert value of 152.6; whereas an H' value of 6.36 on Cruise Mid-6 corresponds to a rarefaction value of 153.4. Although the difference in H' might be considered to be large, the differences in the rarefaction values are very small. Based on the calculations presented in Table 8, Station 1 appears to have a higher diversity on the last sampling date than on the pre-drilling Cruise Mid-1 if species per 100 individuals or Shannon diversities are considered, but a lower diversity if species per 1000 individuals is considered. Station 2, approximately 2 km to the southwest of Station 1, is slightly more diverse at the end of the sampling period no matter which calculation is considered. Diversity at the drilling site Station 14 increased slightly over time when species per 1000 individuals is considered, but decreased if species per 100 individuals or Shannon diversity is evaluated. The opposite pattern was seen at Station 13, located 2 km to the southwest of Station 14. At Station 13, diversity decreased slightly according to calculated values for species per 100, but increased slightly for species per 1000 and Shannon diversity.

Cluster Analysis

Cluster analysis was used to elucidate patterns of station similarity. If impacts due to drilling occurred, samples from post-drilling cruises might be expected to show a very low level of similarity with samples collected on pre-drilling cruises. Both the NESS and Bray-Curtis clustering techniques gave similar results, although the patterns are clearer

TABLE 8. CHANGES OVER TIME IN HURLBERT RAREFACTION VALUES FOR SPECIES PER 100 AND 1000 INDIVIDUALS AND IN SHANNON-WIENER DIVERSITY (H') AT THE DRILL-SITE STATIONS 1 AND 14 AND STATIONS LOCATED 2 KM TO THE SOUTHWEST.

	Drill-Site Station 1			Station 2		
	spp/100	spp/1000	H'	spp/100	spp/1000	H'
Cruise Mid-1	51.9	153.8	6.16	50.9	152.6	6.09
Cruise Mid-2	49.3	135.9	5.99	53.6	146.1	6.25
Cruise Mid-3	48.7	138.9	5.94	54.1	153.4	6.30
Cruise Mid-4	48.5	128.0	5.95	52.1	142.8	6.18
Cruise Mid-5	49.0	134.4	5.94	52.2	154.2	6.19
Cruise Mid-6	53.8	149.6	6.24	55.8	153.4	6.36
	Drill-Site Station 14			Station 13		
	spp/100	spp/1000	H'	spp/100	spp/1000	H'
Cruise Mid-1	55.1	166.5	6.34	50.2	163.3	6.07
Cruise Mid-2	NS	NS	NS	50.8	152.3	6.08
Cruise Mid-3	NS	NS	NS	50.3	164.7	6.11
Cruise Mid-4	57.3	177.2	6.48	51.7	157.2	6.10
Cruise Mid-5	52.1	161.0	6.08	51.2	157.1	6.09
Cruise Mid-6	51.8	167.2	6.01	51.1	156.4	6.12

NS = Not sampled.

and the levels of similarity are higher with NESS. Figures 13 and 14 are the dendrograms based on NESS at 50 and 200 individuals, respectively. In both diagrams, three major station groups are clear. The three groups correspond to the three depth intervals sampled. Station 12, at 2500 m the deepest station sampled, forms a distinct unit to the right of each diagram. The 1515- to 1615-m stations, Stations 11, 13, and 14, form a second large cluster. At both values of m (50 and 200), Stations 13 and 14 cluster with each other before joining with Station 11. This difference may be related to geographic position, since Station 11 is approximately 90 km to the northeast of Stations 13 and 14, which were approximately only 2 km distant from each other. In both figures, the Cruise Mid-6 value for Station 11 was highly dissimilar not only to the other sampling times for Station 11, but also to the rest of the cluster composed of the three shallower stations. This result can be explained by the fact that of the two Cruise Mid-6 replicates analyzed for this station, one replicate had a highly unusual faunal composition. Several species present in high numbers in that one replicate were either rare or were not found at all in any other sample analyzed during this study. Such species included two species of tanaid, Leptognathia sp. 12 and L. sp. 40, and a species of polychaete, Lysilla sp. 1. Other species that were common in other replicates of Station 11, such as the aplacophorans Spathoderma clenchi and Prochaetoderma yongei, were rare in this particular replicate.

The third major cluster shown in Figures 13 and 14 is composed of the 2100-m stations. Within this large cluster, there are several subunits. For NESS with m set at 50 (Figure 13), all samples from Station 10 form a distinct cluster that is similar at the 0.84 level to the large cluster composed of the other 2100-m stations. The majority of the remaining samples also form distinct station clusters before joining with samples from other stations. There are, however, some exceptions to this pattern. Samples from Stations 7 and 8, which were a pair of stations located in close proximity to each other, are all highly similar, and samples from the two stations do not form discrete clusters. Similarly, samples from Stations 2 and 3 do not form discrete station clusters, but do form a subunit composed of samples from both stations. Samples from Station 1, Cruise Mid-6, and Station 9, Cruises Mid-1 and Mid-6, also do not cluster tightly with the other samples from those stations. However, the remaining samples from Stations 1, 4, 5, 6, and 9 all form distinct station clusters at the very high similarity value of 0.90 to 0.95.

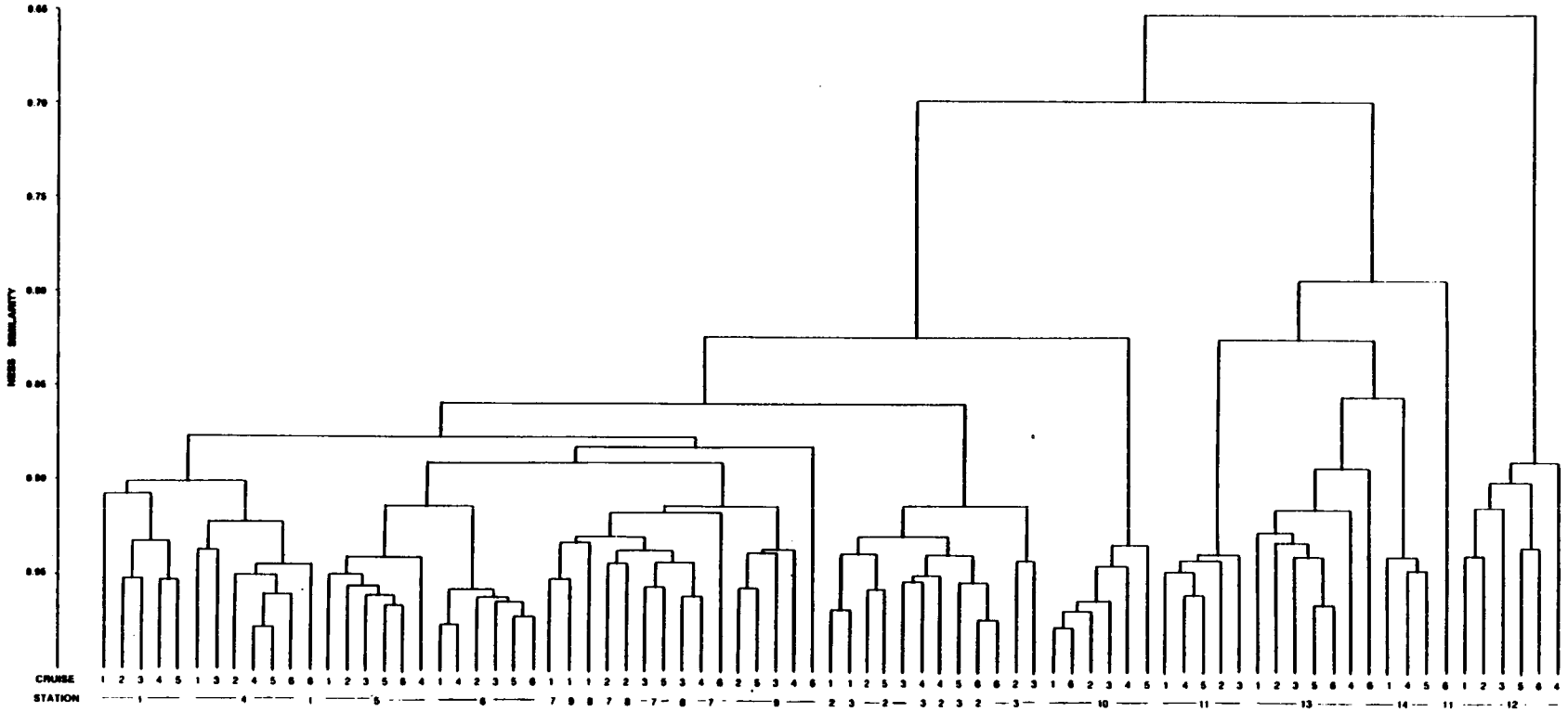

Figure 13. Summed Replicates Collected at Each Station Between April 1984 and November 1985 (Cruises Mid-1 Through Mid-6) Clustered by NESS at 50 Individuals and Group Average Sorting.

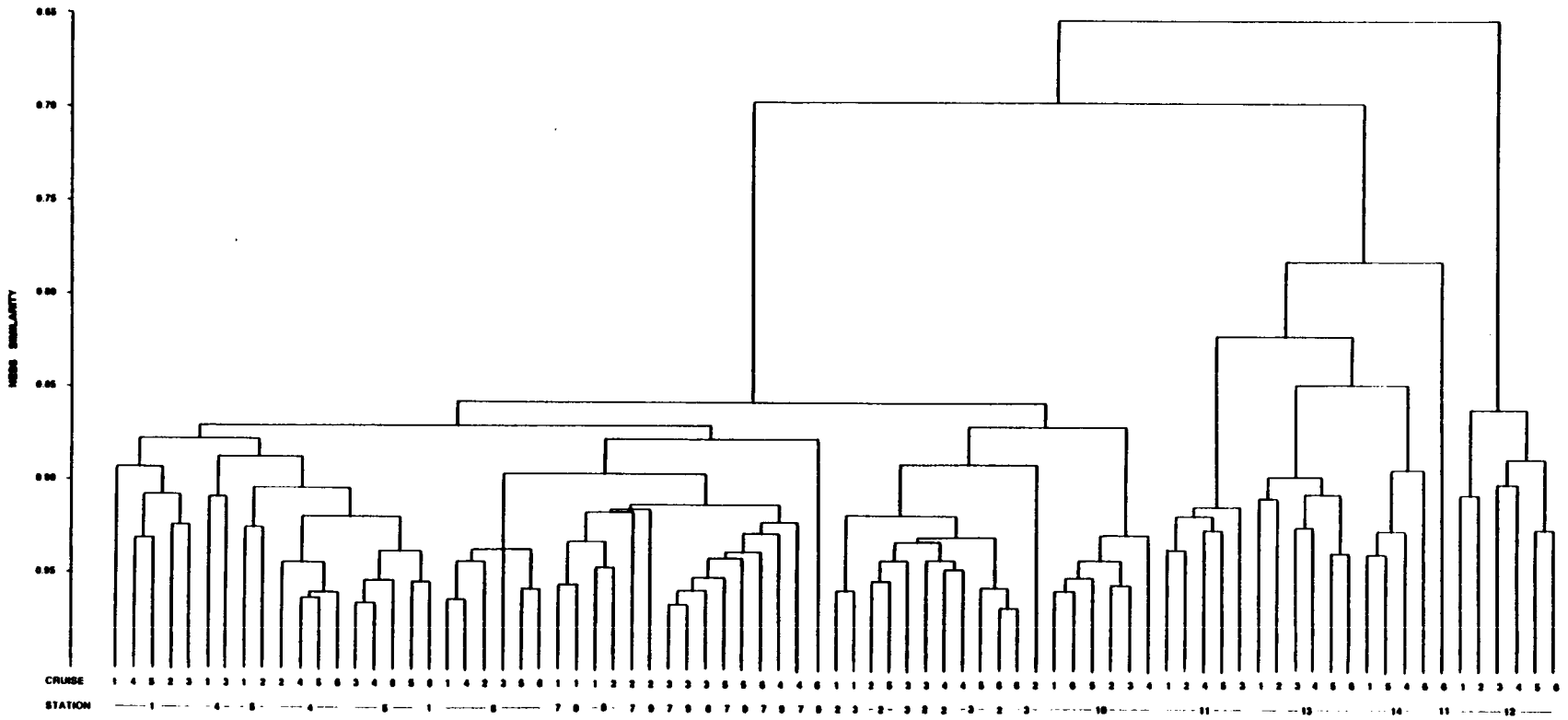

Figure 14. Summed Replicates Collected at Each Station Between April 1984 and November 1985 (Cruises Mid-1 Through Mid-6) Clustered by NESS at 200 Individuals and Group Average Sorting.

For NESS with m set at 200 individuals (Figure 14), the pattern of station distinctiveness is not as clear. Samples from Station 10 form a distinct station cluster, but this group joins with a cluster composed of samples from Stations 2 and 3 before joining with samples from the remaining 2100-m stations. Station 6 is the only other station for which all samples cluster together before joining with samples from remaining stations. Samples from Stations 7, 8, and 9 form a large cluster that, with the exception of Station 9, Cruise Mid-6, joins with Station 6 at the 0.90 level. Samples from Stations 4 and 5 cluster together before joining with samples from Station 1.

The dendrogram presented in Figure 15 is based on the polychaete fraction alone. The patterns of similarity discerned in this figure are similar to those seen in the figure for the total fauna based on NESS at 50 individuals (Figure 13). The two figures are not identical, but the basic patterns are the same. The same clustering of major station groups according to depth intervals is seen, although there are differences in the way samples from the 2100-m stations cluster together. In particular, samples from Station 1 are more similar to samples from Station 4 when only the polychaetes are considered.

Figures 16 and 17 present the dendrograms based on the Bray-Curtis similarity index for untransformed and square-root-transformed data, respectively. The patterns of station similarities are very consistent with those discerned using NESS, but the levels at which samples and stations are similar is much lower with Bray-Curtis than with NESS. In both figures, samples from Station 12 form a discrete unit. In the dendogram based on untransformed data, this unit clusters first with the 2100-m stations before joining with the cluster composed of Stations 11, 13, and 14 (Figure 16). Using the transformed data set, the pattern is more similar to that seen with NESS, in which samples from Stations 11, 13, and 14 cluster with samples from the 2100-m stations before joining with Station 12 (Figure 17). In both figures, as with NESS, samples from Station 11 form a separate unit before joining with Stations 13 and 14. The dendrogram based on untransformed data is the only one of the five dendrograms presented in which all samples from Station 1 cluster together before joining with samples from other stations. In all cases, the samples from Cruise Mid-1 are the most distinct (i.e., dissimilar) of the six sample collections. Using untransformed data, Station 1 is next most similar to samples from Station 4 (Figure 16); however, using transformed data, Station 1 next joins with a large cluster composed of Stations 2, 3, 4, and 5 (Figure 17). In both figures, samples from Station 6

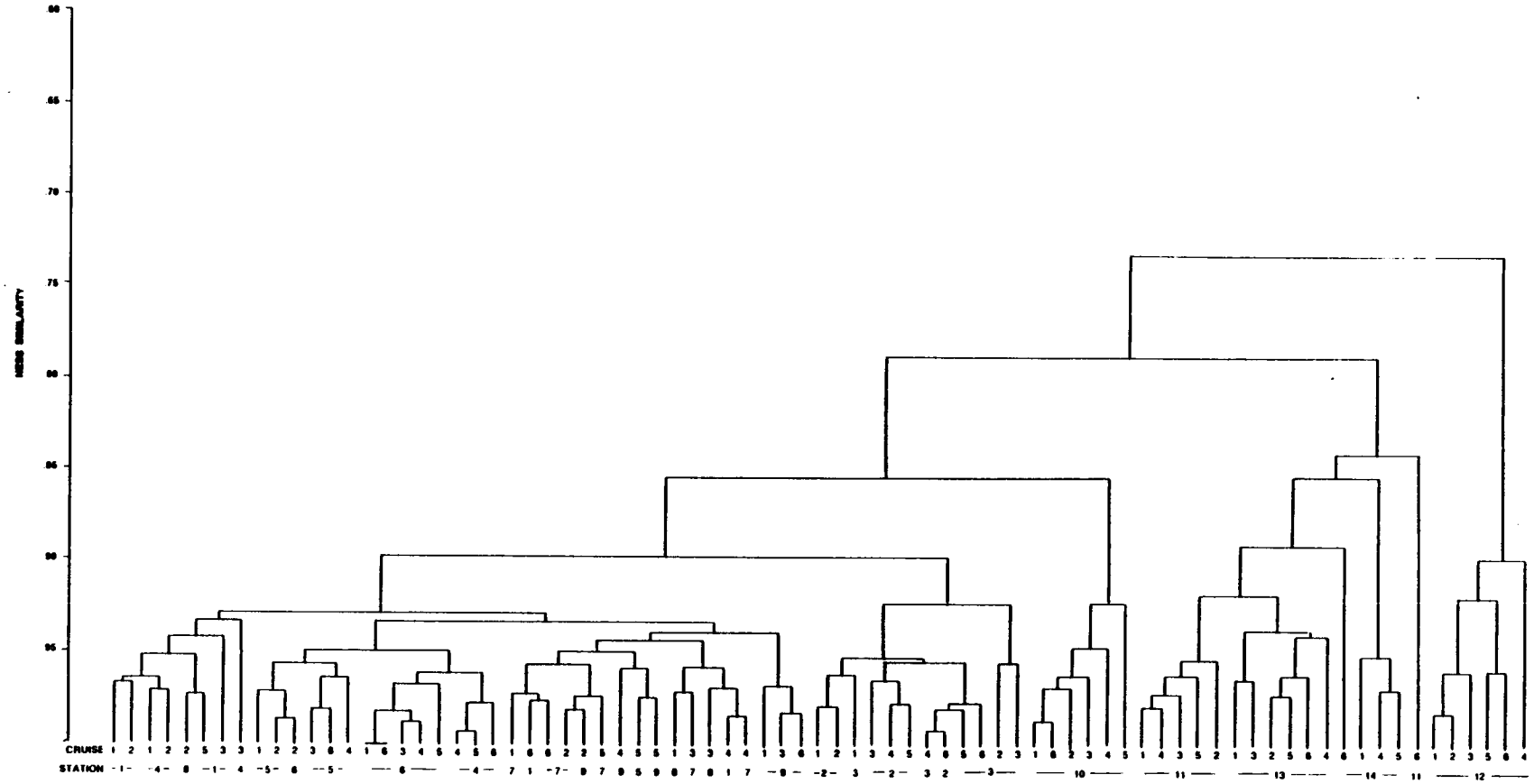

Figure 15. Summed Replicates of Polychaete Fauna Only Collected at Each Station Between April 1984 and November 1985 (Cruises Mid-1 Through Mid-6) Clustered by NESS at 20 Individuals and Group Average Sorting.

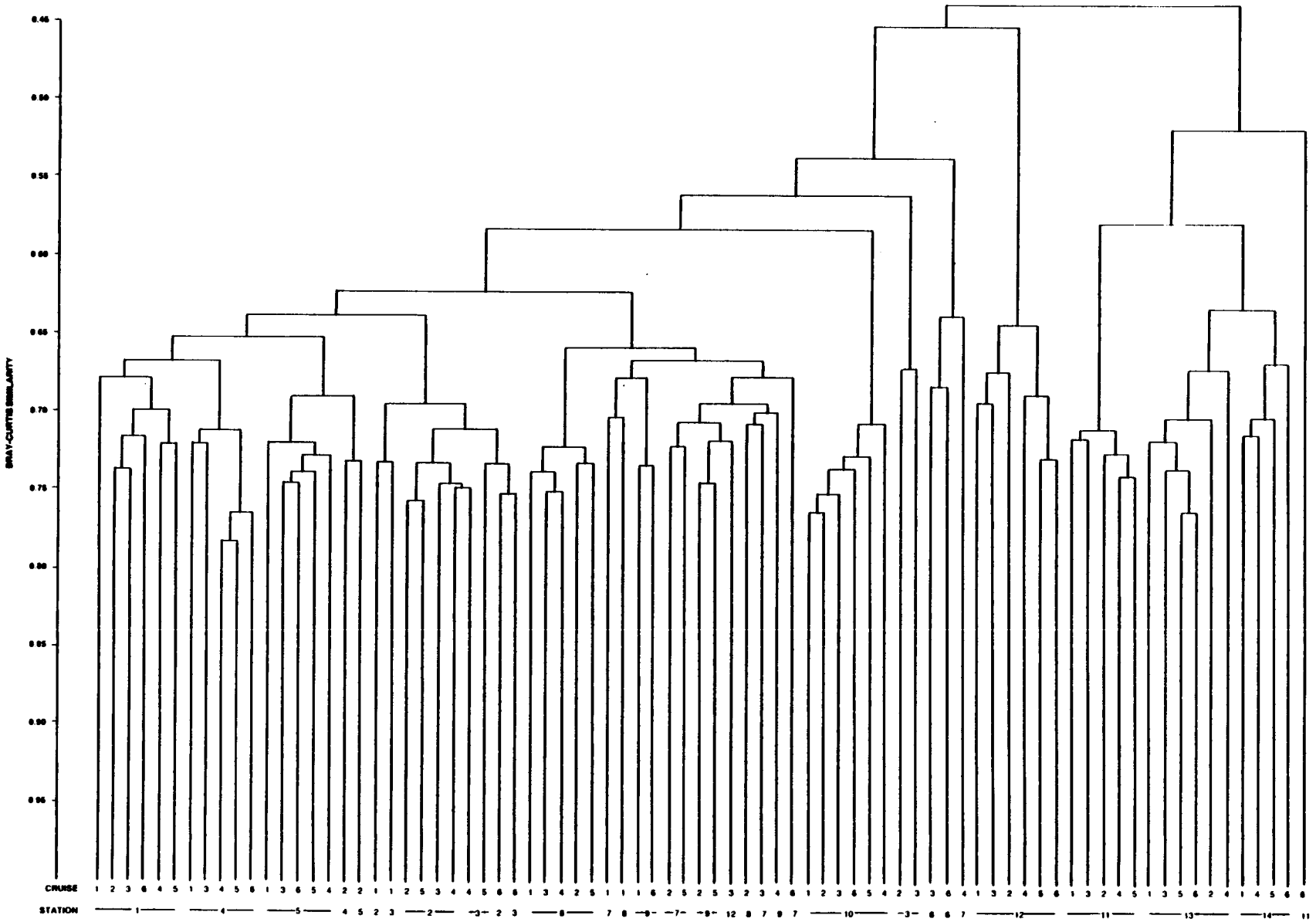

Figure 16. Summed Replicates Collected at Each Station Between April 1984 and November 1985 (Cruises Mid-1 Through Mid-6) Clustered by Bray-Curtis and Group Average Sorting.

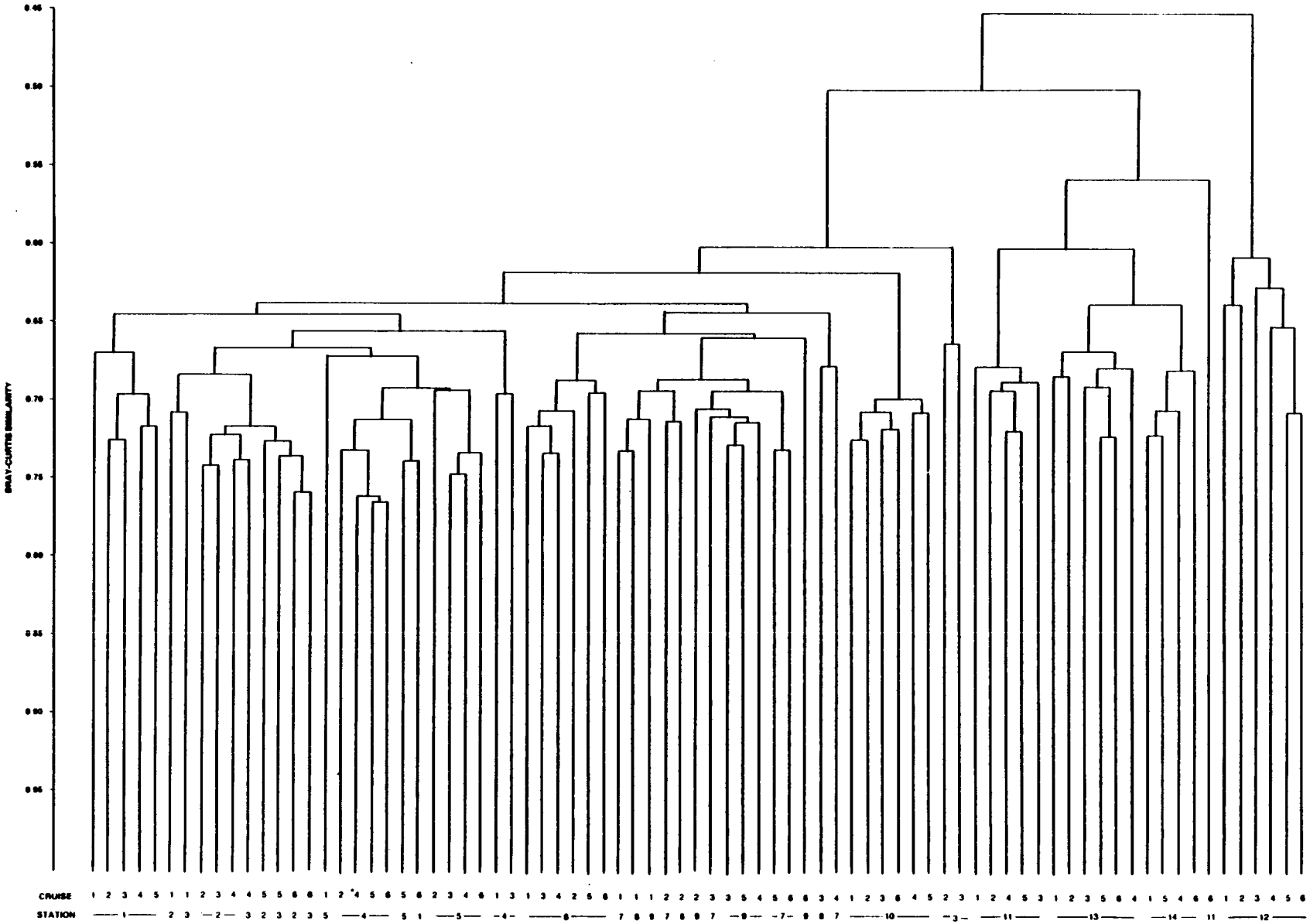

Figure 17. Summed Replicates of Samples Collected April 1984 Through November 1985 (Cruises Mid-1 Through Mid-6) Clustered by Bray-Curtis After Square-Root Transformation of the Data and Using Group Average Sorting.

cluster as a unit, then join with a cluster composed of samples from Stations 7, 8, and 9. These two large groups join at about the 0.63 or 0.64 level of similarity, then join with the unit composed of samples from Station 10. Using untransformed data, there are five exceptions to this pattern: Station 3, Cruises Mid-2 and Mid-3, and Station 6, Cruise Mid-6; Station 7, Cruise Mid-4, and Station 8, Cruise Mid-3 join the other 2100 m samples at a lower level of similarity (Figure 16).

Correspondence Analysis

The results of the ordination of separate replicates using the reciprocal averaging or correspondence analysis technique are shown in Figures 18 and 19. The shallower Stations 11, 13, and 14 clearly separate from the remaining stations along Axis 1. The three stations can be distinguished from one another, although there is a high degree of overlap in the ordinational space, implying a gradient rather than a clean separation. This may be a faunal gradient reflecting latitudinal differences rather than differences in sediment composition alone. Station 12 is distinct from all other stations along Axis 2; differences in sediment composition are reflected in this separation. With the exception of Station 10, no other stations separate out along Axis 2. The uncircled swarm of points in Figure 18 represents replicates from Stations 1 through 9. Figure 19 illustrates the separation of replicates along Axes 1 and 3. The most noticeable feature of this figure is that Replicate 3 from Station 11, Cruise Mid-6, is distinctly separated from all other replicates, including the remaining replicates from Station 11. This result is clearly not related to depth, sediment type, or latitude, but is due to an unexplained difference in the faunal composition of that replicate. As mentioned earlier, several species occurring in high numbers in that replicate were not found in any other sample analyzed in this study; whereas additional species that were common in other replicates were very rare in this sample. Figures 20 and 21 are similar presentations of the results of ordination based on replicates combined at each station. The same relationships among stations are seen in Figure 20, in which Axes 1 and 2 are represented. In Figure 21 a latitudinal component is apparent, with the southernmost Stations 10, 13, and 14 most clearly separated along Axis 3.

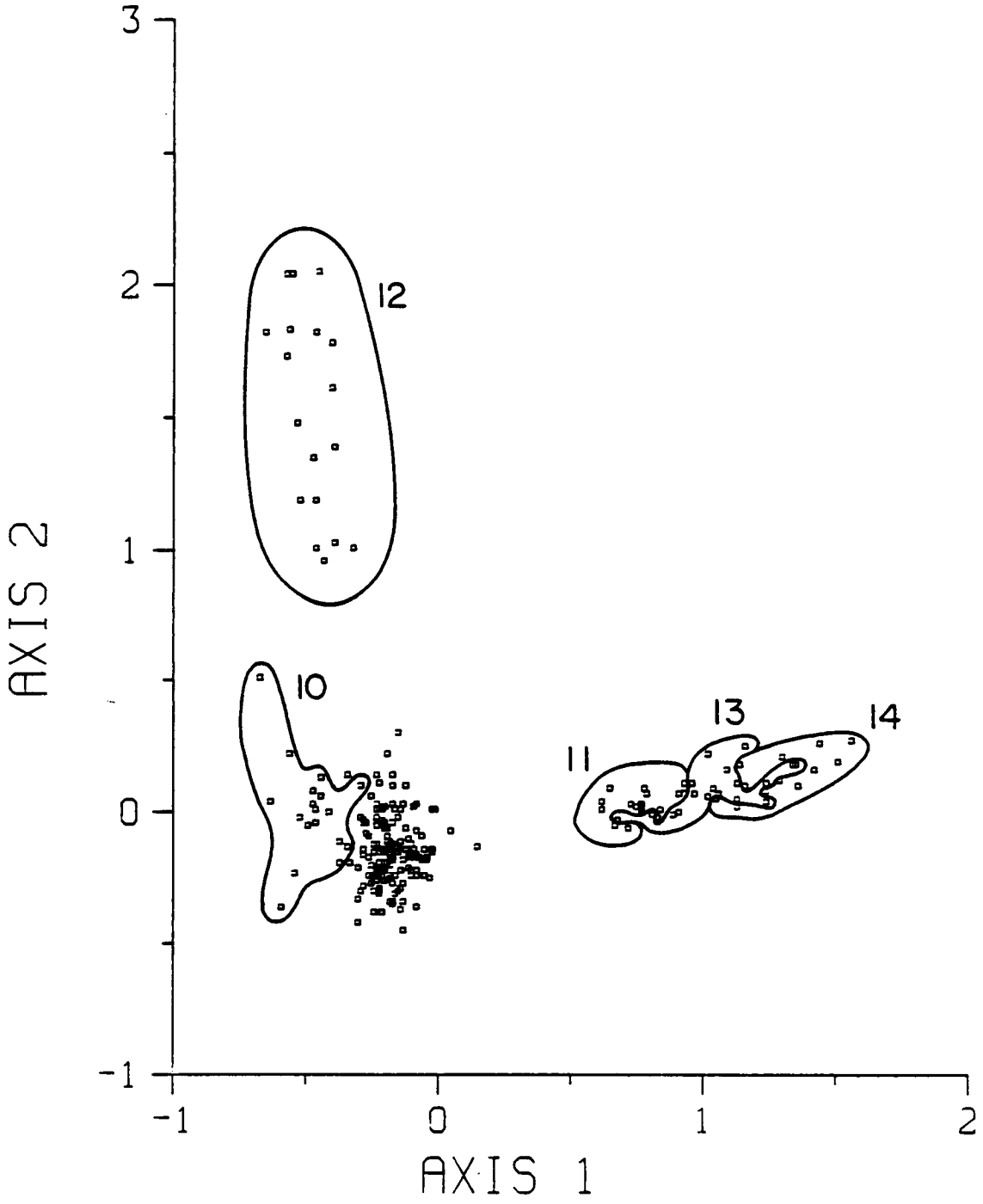

Figure 18. **Reciprocal Averaging Ordination of Replicates Analyzed From All U.S. Mid-Atlantic Stations. Stations 10, 11, 13, and 14 Separate Along Axes 1 and 2 and Station 12 Separates Along Axis 2.**

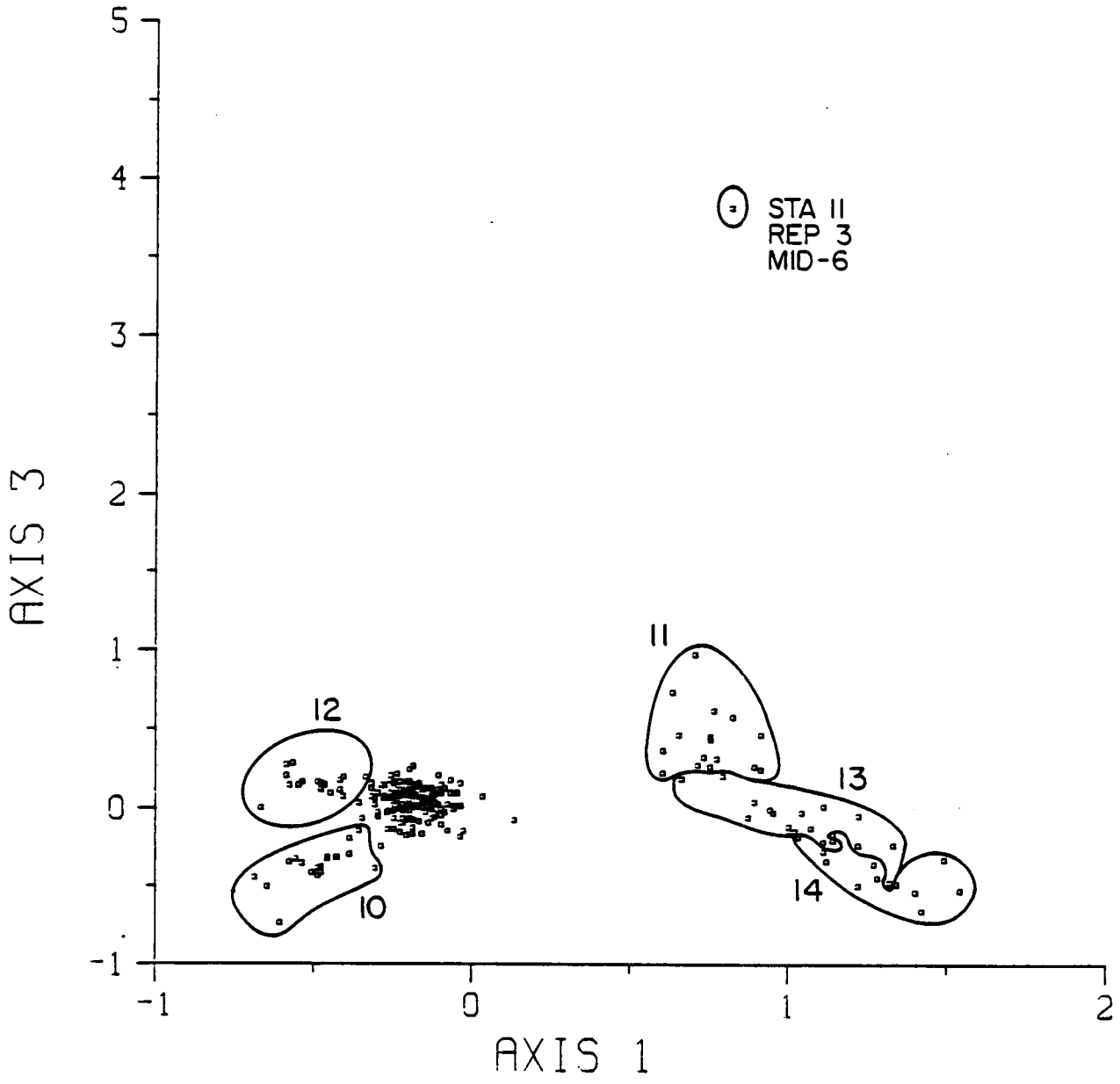

Figure 19. **Reciprocal Averaging Ordination of Separate Replicates From U.S. Mid-Atlantic Stations. Replicate 3 From Station 11, Cruise Mid-6 is the Most Distinct Along Axis 3.**

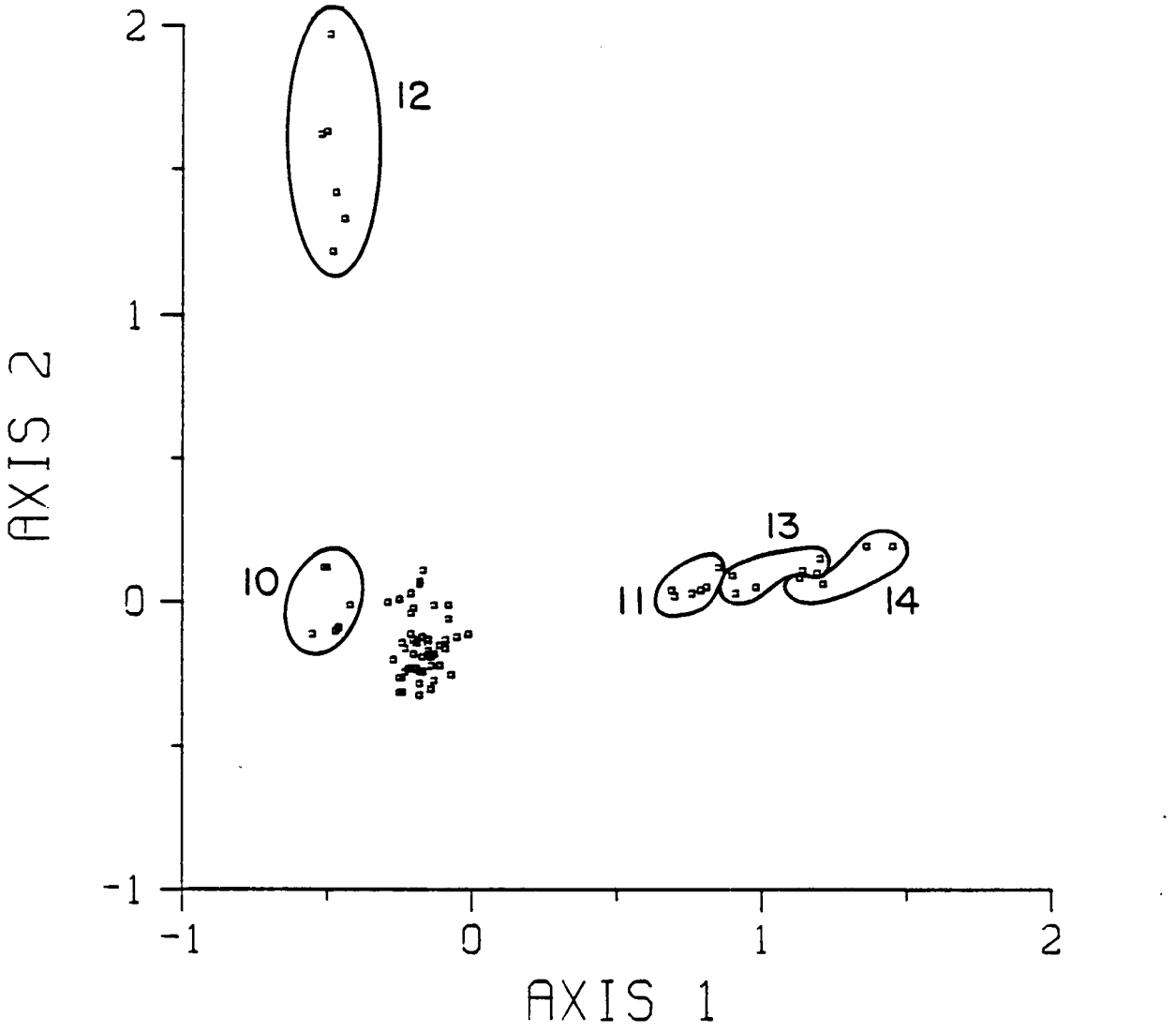

Figure 20. **Reciprocal Averaging Ordination of Summed Replicates From All U.S. Mid-Atlantic Stations. Stations 10, 11, 13, and 14 Separate Along Axis 1 and Station 12 Separates Along Axis 2.**

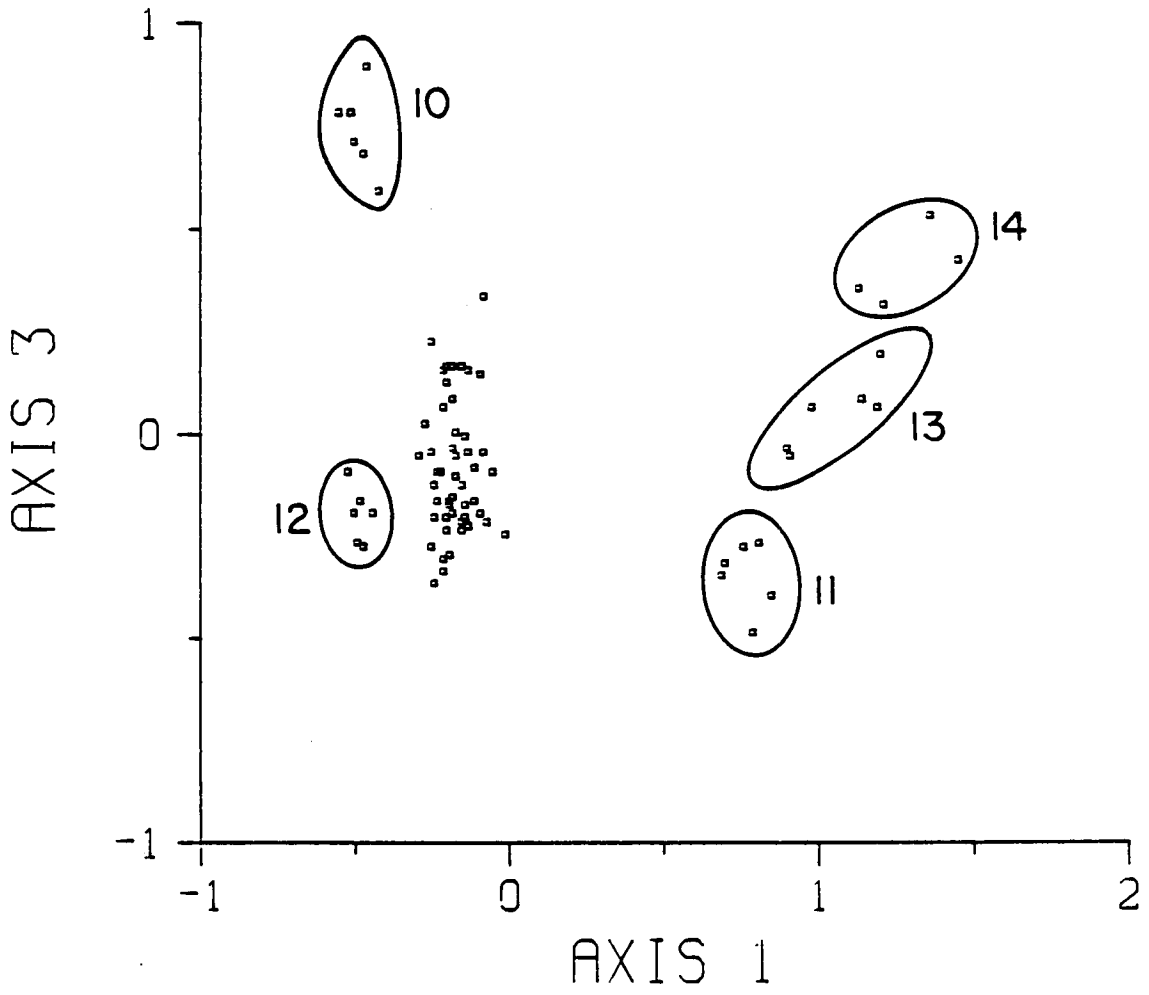

Figure 21. Reciprocal Averaging Ordination of Summed Replicates From All U.S. Mid-Atlantic Stations. The Southernmost Stations 10, 13, and 14 Separate Along Axis 3.

Dominant Species

Dominant Species at Each Depth Interval

Table 9 is a rank order summation of the top 20 species occurring at the stations monitored in this study. Samples have been summed for stations within each of three depth intervals. The polychaete Aurospio dibranchiata was the overall top dominant species; it ranked first at all stations except the 1500- to 1600-m Stations 11, 13, and 14 (and Station 5, where it ranked second, see Appendix E). The shallower stations were dominated by the sipunculan Aspidosiphon zinni and the aplacophoran Prochaetoderma yongei, with A. dibranchiata ranking third. A. zinni was not among the top 20 dominant species at the 2100-m stations, but ranked tenth at Station 12 at 2500 m. Similarly, P. yongei ranked seventh at the 2100-m stations, but was not among the top 20 at the 2500-m station.

The majority of dominant species at any depth interval were polychaetes, which comprised a total of 11 to 13 of the top 20 species. In addition to A. dibranchiata, the polychaete species Pholoe anoculata, Tharyx sp. 1, Prionospio sp. 2, Aricidea tetrabranchia, and Glycera capitata ranked among the top nine species at the 2100-m stations. These species were also dominants at the 1500- and 2500-m stations, but held different, usually lower, ranks at those stations. Two species of polychaetes, Fauveliopsis brevis, which ranked twelfth at the 2100-m stations, and Notomastus latericeus, which ranked sixteenth, held similar ranks at the 2500-m station, ranking twelfth and seventeenth respectively. However, those two species were not among the top 20 species at the 1500-m stations. Another two species, Kesun gravieri and Prionospio sp. 11, which ranked fourteenth and nineteenth, respectively, at the 2100-m stations, ranked seventh and eleventh, respectively, at the 1500-m stations, but were not among the top 20 species at the 2500-m station. Finally, Sabidius cornatus, Aricidea abranchiata, and Levinsenia sp. 1, which ranked eleventh, thirteenth, and seventeeth, respectively, at the 2100-m stations, were not dominants at stations at either of the other two depth intervals.

TABLE 9. DOMINANT SPECIES RECORDED AT U.S. MID-ATLANTIC STATIONS, PRESENTED FOR STATIONS SUMMED ACCORDING TO DEPTH INTERVALS.

Stations 11, 13 and 14 (1515-1615 m)	Stations 1-10 (2020-2195 m)	Station 12 (2500 m)
1. Aspidosiphon zinni (S)	1. Auropsio dibranchiata (P)	1. Aurospio dibranchiata (P)
2. Prochaetoderma yongei (A)	2. Pholoe anoculata (P)	2. Tharyx sp. 1 (P)
3. Aurospio dibranchiata (P)	3. Spathoderma clenchi (A)	3. Prionospio sp. 2 (P)
4. Aricidea tetrabranchia (P)	4. Tharyx sp. 1 (P)	4. Myriochele sp. 1 (P)
5. Glycera capitata (P)	5. Prionospio sp. 2 (P)	5. Paradoneis abranchiata (P)
6. Pholoe anoculata (P)	6. Tubificoides aculeatus (O)	6. Phallodrilus grasslei (O)
7. Kesun gravieri (P)	7. Prochaetoderma yongei (A)	7. Glycera capitata (P)
8. Tharyx sp. 1 (P)	8. Aricidea tetrabranchia (P)	8. Pholoe anoculata (P)
9. Lumbrineris latreilli (P)	9. Glycera capitata (P)	9. Nemertea sp. 5 (N)
10. Leptognathiella spinicauda (T)	10. Nemertea sp. 5 (N)	10. Aspidosiphon zinni (S)
11. Prionospio sp. 11 (P)	11. Sabidius cornatus (P)	11. Spathoderma clenchi (A)
12. Tubificoides aculeatus (O)	12. Fauveliopsis brevis (P)	12. Fauveliopsis brevis (P)
13. Nemertea sp. 5 (N)	13. Aricidea abranchiata (P)	13. Tubificoides aculeatus (0)
14. Prionospio sp. 2 (P)	14. Kesun gravieri (P)	14. Chaetozone sp. 1 (P)
15. Paranarthrura cf. insignis (T)	15. Grania atlantica (O)	15. Dacrydium sp. 1 (B)
16. Nucula granulosa (B)	16. Notomastus latericeus (P)	16. Sabellidae sp. 5 (P)
17. Dysponetus sp. 4 (P)	17. Levinsenia sp. 1 (P)	17. Notomastus latericeus (P)
18. Chaetozone sp. 1 (P)	18. Haplomesus sp. 2 (I)	18. Aricidea tetrabranchia (P)
19. Nemertea sp. 2 (N)	19. Prionospio sp. 11 (P)	19. Euchone sp. 3 (P)
20. Euchone sp. 3 (P)	20. Oecidiobranchus plebejum (I)	20. Nucula cancellata (B)

A = Aplacophora; B = Bivalvia; I = Isopoda; N = Nemertea; O = Oligochaeta; P = Polychaeta; S = Sipuncula; T = Tanaidacea

Dominant Species at Each Station

Dominant species and their contribution to the total fauna at each of the 14 stations sampled are presented in the tables included in Appendix E. Stations 1 through 10, located along a 176-km transect and at actual sampling depths ranging from 2020 to 2195 m, had remarkably consistent faunal composition (Tables E-1 through E-10). The high diversity of these stations is evident in the fact that no one species contributed more than 6 to 8 percent of the total fauna, and 20 or more species were required to make up 50 percent of the total number of individuals. With the exception of Station 5, the polychaete Aurospio dibranchiata was the top dominant, contributing from 5.8 to 7.6 percent of the total number of individuals. At Station 5, A. dibranchiata ranked second, but contributed 5.7 percent of the total number of individuals. The polychaete Tharyx sp. 1 ranked second at Station 1, with 5.2 percent of the total individuals. This contribution is slightly higher than was found at nearby Stations 2 and 3. At those stations, T. sp. 1 ranked sixth and fourth, respectively, and contributed 3.0 and 2.9 percent to the total number of individuals. At Station 6 at the northeast end of the transect, T. sp. 1 contributed 4.1 percent and ranked fourth, while at Station 10 at the southwestern end of the transect, it ranked sixth with a 2.6 percent contribution. In addition to polychaetes, other taxonomic groups showed a consistent pattern along the transect. The aplacophoran Spathoderma clenchi ranked fourth at Station 10 and third at both Stations 1 and 6. S. clenchi contributed 3.2, 5.1, and 4.3 percent of the total number of individuals at Stations 10, 1, and 6, respectively. There were, of course, differences among the dominants at these stations. For example, the isopod Oecidiobranchus plebejum ranked sixth at Station 1, where it made up 3.5 percent of the fauna. This species ranked ninth at Station 4, thirteenth at Station 6, and fifteenth at Station 9, contributing 2.2, 1.8, and 1.7 percent of the individuals, respectively. O. plejebum was not among the top 20 species at Stations 2, 3, 5, 7, 8, or 10. Such differences cannot be attributed to latitudinal gradients, but are correlated with the sediment grain size composition of the stations.

The deeper 2500-m station, Station 12, was basically similar to the 2100-m stations in the composition of the top 20 dominants although some differences in percentage composition and shifts in rank occurred. The top dominant, Auropsio dibranchiata, contributed 10.1 percent of the individuals at this station (Table E-12). The second-

ranked species, Tharyx sp. 1, contributed 7.0 percent. Thus, these two species contributed higher percentages of individuals at Station 12 than at the shallower stations, for example, Station 1 (see above). Other dominants, for example Spathoderma clenchi, occurred in much lower numbers and had correspondingly lower ranks.

Stations 11, 13, and 14 as a unit exhibited greater differences from the 2100-m stations than did Station 12. Also, Station 11 differed somewhat from the two stations farther to the southwest, Stations 13 and 14. Station 11 was dominated by the aplacophoran Prochaetoderma yongei which made up 6.7 percent of the individuals (Table E-11). However, the second-ranked species at Station 11 was Aurospio dibranchiata, which contributed 6.6 percent of the individuals. The contribution of A. dibranchiata to the total fauna was therefore similar to that at the 2100-m stations, but the contribution of P. yongei was greater. The polychaete Pholoe anoculata ranked fifth at both Stations 1 and 11, and contributed similar percentages of individuals, i.e., 3.5 at Station 1 and 3.9 at Station 11. Other species that were dominant at Station 11, such as the polychaete Lumbrineris latreilli, which ranked third and contributed 4.0 percent of the individuals, did not occur among the top dominants at the deeper stations. Other species dominant at Station 11 but not at the deeper Station 1 included the oligochaete Bathydrilus asymetricus, the bivalve Nucula granulosa, and the tanaid Leptognathia spinicauda.

Stations 13 and 14, about 90 km to the southwest of Station 11, were dominated by the sipunculan Aspidosiphon zinni, which contributed 8.6 and 11.5 percent of the total individuals, respectively, at those stations. A. zinni ranked seventeenth at Station 11, where it contributed only 1.2 percent of the total individuals. The aplacophoran Prochaetoderma yongei ranked second at both Stations 13 and 14, and contributed 6.2 and 6.1 percent of the total individuals, respectively.

Dominant Species Over Time

The top species found at each station on each of the six sampling dates are presented in the tables included in Appendix F. Inspection of these tables shows that the dominant species may have fluctuated in actual rank over the three sampling dates each year, and over the two-year period of this study, but usually stayed within two to four places of the original rank held when sampling began. For example, at Station 1, the

overall top dominant species, Aurospio dibranchiata, actually ranked anywhere from first to fourth over the six sampling dates. Also at Station 1, Tharyx sp. 1 ranked either first or second throughout 1984 and then dropped to fifth and sixth place on the fourth and fifth sampling dates, returning to third place by November 1985. The significance of the fluctuations in density of these species, which determined their rank within the community, was examined more closely using Analysis of Variance (ANOVAs). The results are presented in the next section.

Density

The mean number of individuals per 0.09 m^2 (i.e., one replicate box core) for each station on each sampling date is shown in Figure 22. Mean densities were higher at Station 1 on Cruise Mid-1 than on any of the remaining cruises; however, this was not a statistically significant difference. Densities at Station 14 in Block 93 were consistently high, both before and after drilling. No consistent pattern of seasonal variation is evident from the results.

The results of the 2-way ANOVA of mean densities of selected species are presented in Table 10. All of the species tested, except Nemertea sp. 5, showed highly significant differences in total densities among stations. Five species also showed significant differences among sampling times (cruises).

Figure 23 shows the mean density of Aurospio dibranchiata at each station. The ANOVA of densities at each station over time indicate that there were no signficant differences at 10 of the 14 stations. At Stations 3, 7, and 11, densities recorded on Cruise Mid-5 were higher than those recorded on other cruises and differed significantly from densities at those stations at other times (Table 11). For the most part, however, densities recorded on the pre-drilling cruises did not differ from densities recorded on post-drilling cruises. The results of the contrasts among stations are shown in Table 12. These results indicate that although there are significant differences on certain cruises in the density of A. dibranchiata between the 2100-m stations and the 2500-m station (Contrasts 1 and 5), between the 2100-m stations and the shallower Stations 11 and 13 (Contrasts 2 and 6), and between the central 2100-m Stations and Station 10 (Contrast 4), the greatest differences were between Station 11 and either Station 13 or Station 14 (Contrasts 7 and 8). Densities of this species were higher at Station 11 than at either Station 13 or 14.

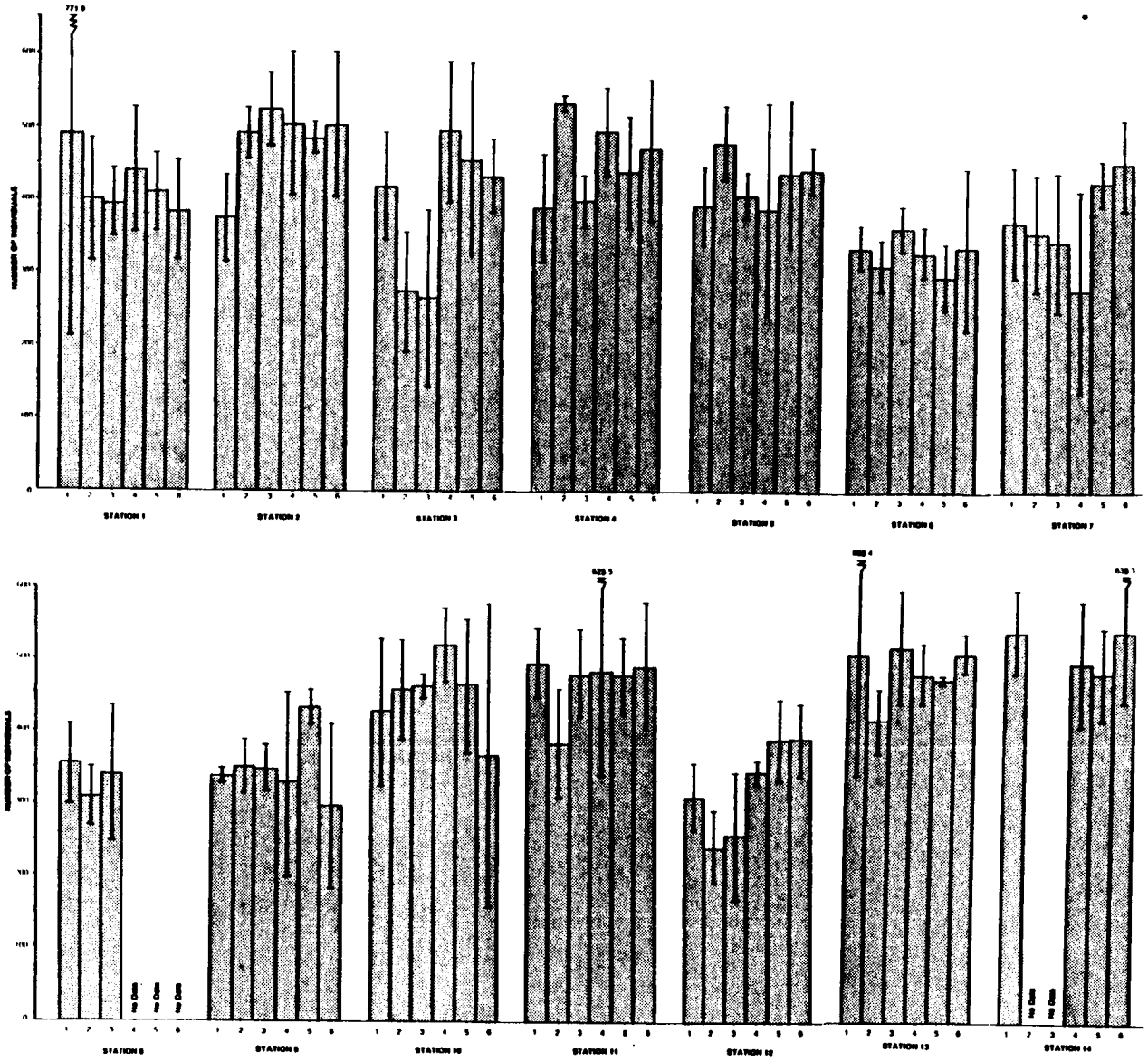

Figure 22. Mean Number of Individuals per 0.09 M^2 ± One Standard Deviation at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 10. RESULTS OF TWO-WAY ANOVA OF MEAN DENSITIES OF THE TOP EIGHTEEN DOMINANT SPECIES AMONG STATIONS 1-7, 9-13, AND ALL SIX SAMPLING DATES.[a]

	Probability		
	Main Effects		Interaction
Species	Station	Cruise	Station By Cruise
Malletia johnsoni	***	NS	NS
Paranarthrura cf. insignis	***	NS	NS
Haplomesus sp. 2	***	NS	NS
Spathoderma clenchi	***	NS	NS
Prochaetoderma yongei	***	NS	NS
Glycera capitata	***	NS	NS
Aspidosiphon zinni	***	NS	NS
Tubificoides aculeatus	***	NS	*
Aurospio dibranchiata	***	**	*
Tharyx sp. 1	***	***	***
Fauveliopsis brevis	***	NS	NS
Kesun gravieri	***	NS	NS
Aricidea tetrabranchia	***	NS	NS
Sabidius cornatus	***	**	NS
Pholoe anoculata	***	NS	NS
Prionospio sp. 11	***	***	NS
Nemertea sp. 5	NS	***	NS
Prionospio sp. 2	***	NS	**

[a]NS=Not significant; *=0.05 > p > 0.01; **=0.01 > p > 0.001; ***= p < 0.001.

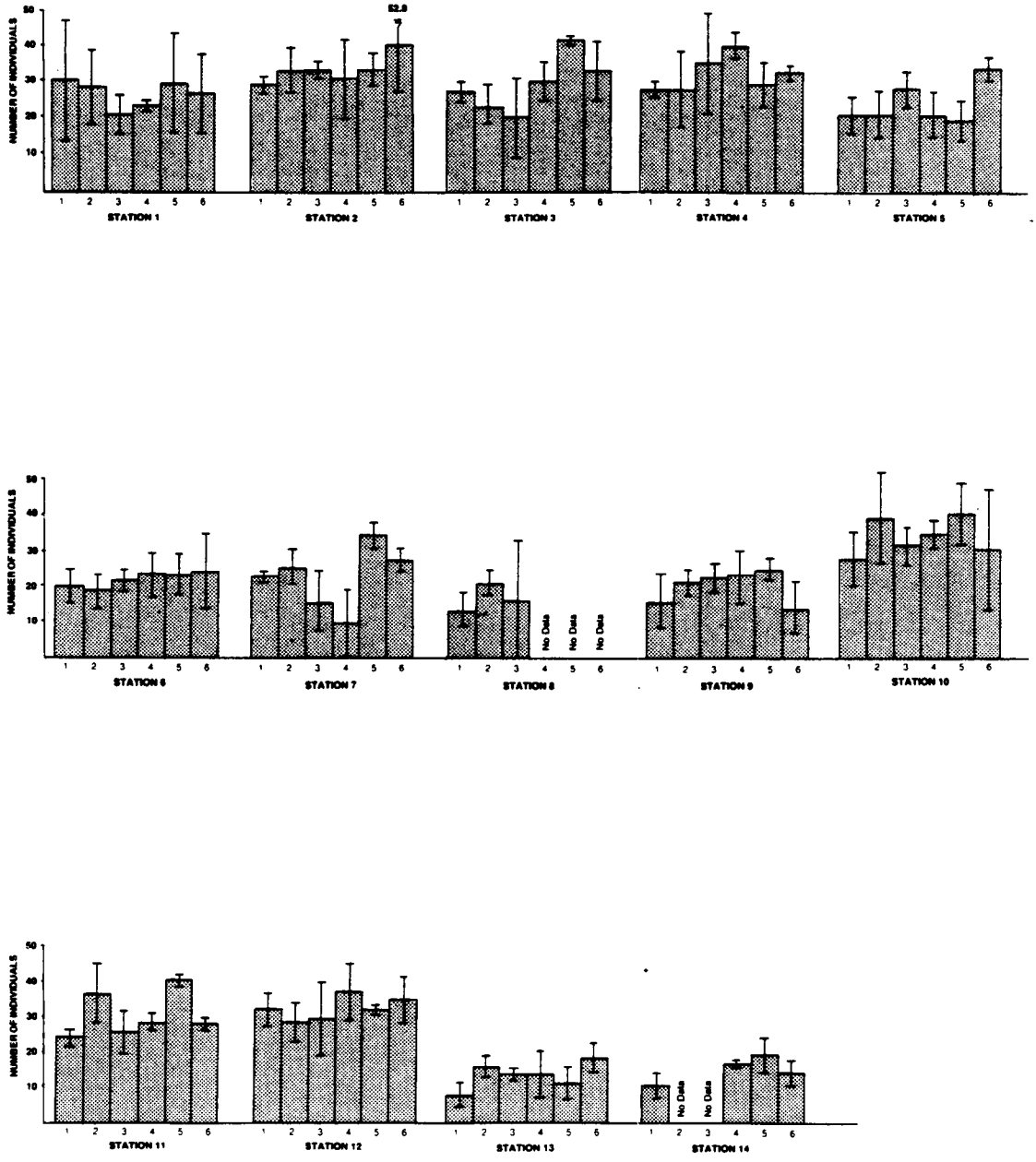

Figure 23. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Aurospio dibranchiata at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 11. RESULTS OF ANOVA AND STUDENT-NEWMAN-KEULS LEAST SIGNIFICANT RANGE TEST FOR DIFFERENCES IN UNTRANSFORMED MEAN DENSITIES OF AUROSPIO DIBRANCHIATA AMONG SAMPLING TIMES AT EACH STATION. UNDERLINED CRUISES ARE NOT SIGNIFICANTLY DIFFERENT.

Station	Cruise Mid-
1	Not Significant
2	Not Signficant
3	3 2 1 4 6 5
4	Not Significant
5	Not Significant
6	Not Significant
7	4 3 1 2 6 5
8	Not Signficant
9	Not Signficant
10	Not Signficant
11	1 3 4 6 2 5
12	Not Signficant
13	Not Signficant
14	Not Signficant

TABLE 12. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF AUROSPIO DIBRANCHIATA AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)				*		
2 (1-7, 9, 10 vs. 11 and 13)	**					
3 (1-5, 7, 9 vs. 6)						
4 (1-5, 7, 9 vs. 10)		**		*	*	
5 (1-5, 7, 9 vs. 12)				**		
6 (1-5, 7, 9 vs. 11 and 13)	**					
7 (11 vs. 13)	**	**		*	***	
8 (11 vs. 14)	**	NT	NT	**	***	*
9 (13 vs. 14)		NT	NT			

[a]NT= Not tested; * = 0.05 > p > 0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

Mean densities of Tharyx sp. 1 are graphed in Figure 24, and the results of the ANOVA tests are given in Tables 13 and 14. The most notable result is that, at Stations 1 and 3, densities of this species were significantly higher on Cruise Mid-1 than on the majority of remaining sampling times (Table 13). At both stations, densities were comparable between Cruise Mid-1 and at least one other post-drilling cruise, i.e., Cruises Mid-1 and Mid-3 at Station 1; Cruises Mid-1 and Mid-4 at Station 3). There does not appear to be a long-term trend of decline in abundance at Station 1, because densities on Cruise Mid-6 were intermediate between the highest (Mid-1) and lowest (Mid-5) densities recorded. Densities at the remaining stations, including the other drill site, Station 14, did not vary significantly over time.

When differences among stations were tested within each sampling date, the most notable differences were between the 2100-m stations and Station 12 at 2500-m (Table 14, Contrasts 1 and 5). Densities at Station 12 tended to be slightly higher, especially those recorded on Cruise Mid-4. Densities of Tharyx sp. 1 at Station 14 were lower than densities at the other 1500-m stations; these differences were significant only for Cruise Mid-6 (Table 14, Contrasts 8 and 9).

Abundances of Pholoe anoculata are graphed in Figure 25. The large standard deviations around the mean evident in several instances indicate a great deal of variability among replicates (e.g., Station 2, Cruise Mid-5; Station 11, Cruise Mid-6). Significant differences among sampling dates were evident at Station 4, where densities of this species on Cruises Mid-1 and Mid-3 were lower than densities recorded on Cruise Mid-2 or Mid-5 (Figure 25). The results of contrasts among stations are presented in Table 15. Differences between the 2100-m stations and Station 12 were highly significant for the first three sampling dates, but not for the last three cruises (Table 15). Densities at Station 12 were lower on Cruises Mid-1, Mid-2, and Mid-3 than on the last three cruises (Figure 25).

The mean densities of two aplacophoran molluscs, Prochaetoderma yongei and Spathoderma clenchi, are presented in Figures 26 and 27, respectively. P. yongei was essentially absent from Station 12, and occurred in highest densities at Stations 11, 13, and 14. This distribution is reflected in the results of the ANOVA contrasts given in Table 16. Additionally, the density of P. yongei at the southwestern Station 10 was lower and differed at a low level of significance from the mean density of this species at the central 2100-m stations on most cruises (Contrast 4). Spathoderma clenchi differed in distribution from P. yongei, being more abundant at the 2100-m stations than at either the

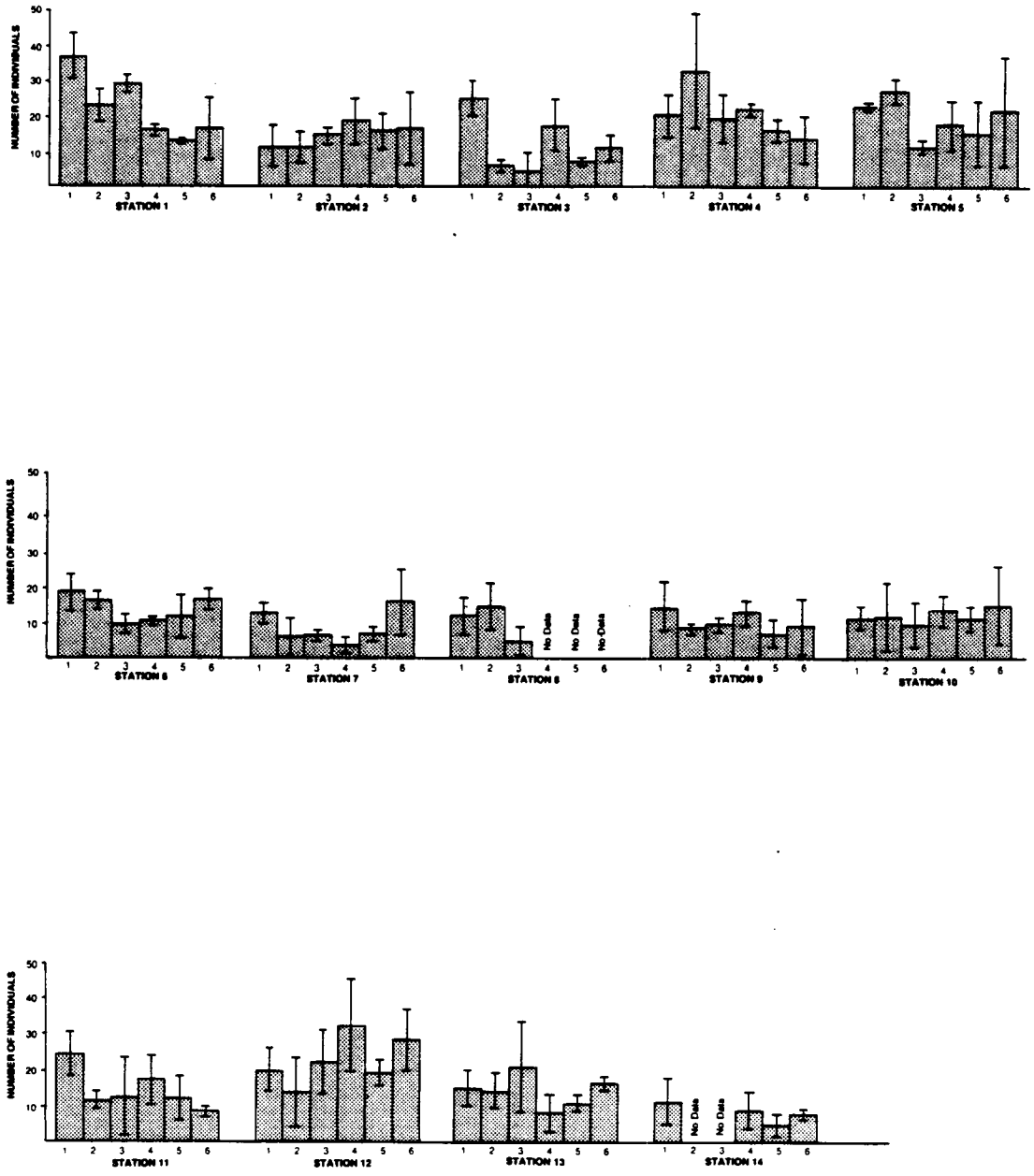

Figure 24. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Tharyx sp. 1 at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 13. RESULTS OF ANOVA AND STUDENT-NEWMAN-KEULS LEAST SIGNFICANT RANGE TEST FOR DIFFERENCES IN UNTRANSFORMED MEAN DENSITIES OF THARYX SP. 1 AMONG SAMPLING TIMES AT EACH STATION. UNDERLINED CRUISES ARE NOT SIGNIFICANTLY DIFFERENT.

Station	Cruise Mid-
1	5 4 6 2 3 1
2	Not Significant
3	3 2 5 6 4 1
4	Not Significant
5	Not Significant
6	Not Significant
7	Not Significant
8	Not Significant
9	Not Significant
10	Not Significant
11	Not Significant
12	Not Significant
13	Not Significant
14	Not Significant

TABLE 14. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF THARYX SP. 1 AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)			*	***	**	*
2 (1-7, 9, 10 vs. 11 and 13)						
3 (1-5, 7, 9 vs. 6)						
4 (1-5, 7, 9 vs. 10)	**					
5 (1-5, 7, 9 vs. 12)			*	***	**	*
6 (1-5, 7, 9 vs. 11 and 13)						
7 (11 vs. 13)	*					
8 (11 vs. 14)		NT	NT			**
9 (13 vs. 14)		NT	NT			***

[a]NT = Not tested; * = 0.05 > p > 0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

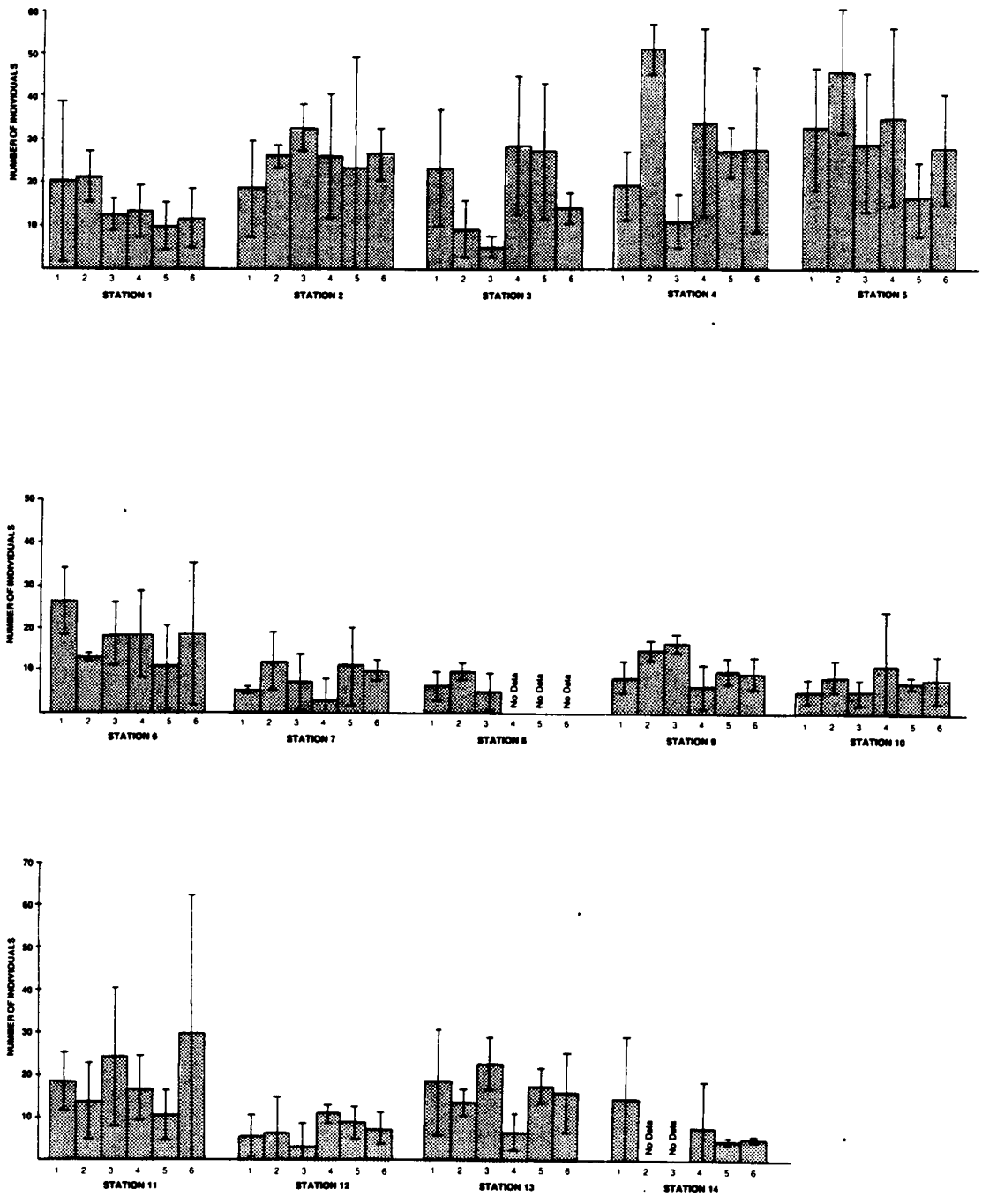

Figure 25. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Polychaete Pholoe anoculata at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 15. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF PHOLOE ANOCULATA AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)	*	***	***			
2 (1-7, 9, 10, vs. 11 and 13)			*			
3 (1-5, 7, 9 vs. 6)						
4 (1-5, 7, 9 vs. 10)	*	*	*			
5 (1-5, 7, 9 vs. 12)	*	***	***			
6 (1-5, 7, 9 vs. 11 and 13)						
7 (11 vs. 13)						
8 (11 vs. 14)		NT	NT			
9 (13 vs. 14)		NT	NT		*	

[a]NT = Not tested; * = 0.05 > p >0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

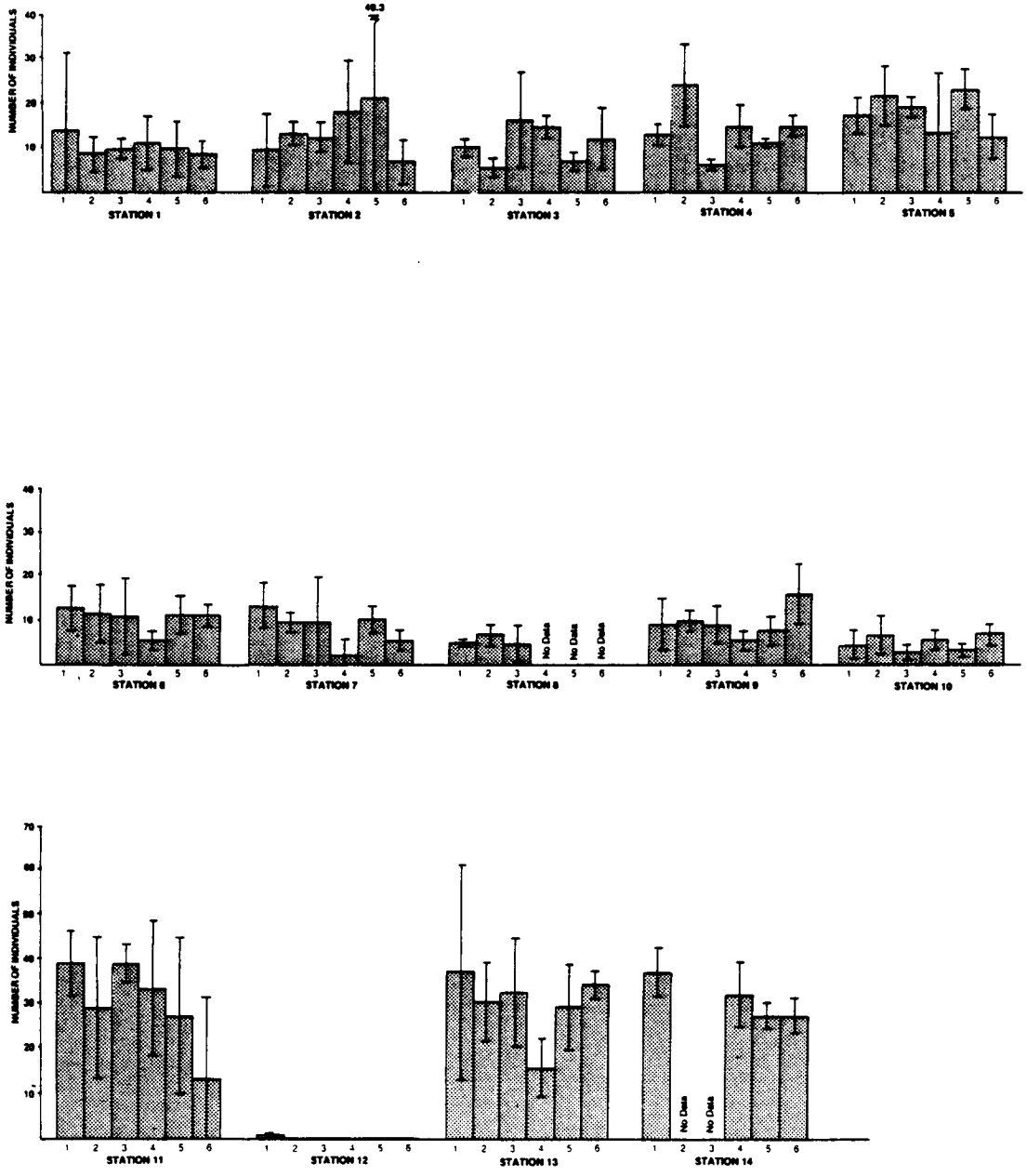

Figure 26. Mean Population Density per (No./0.09 m^2 ± 1 SD) of the Aplacophoran Prochaetoderma yongei at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

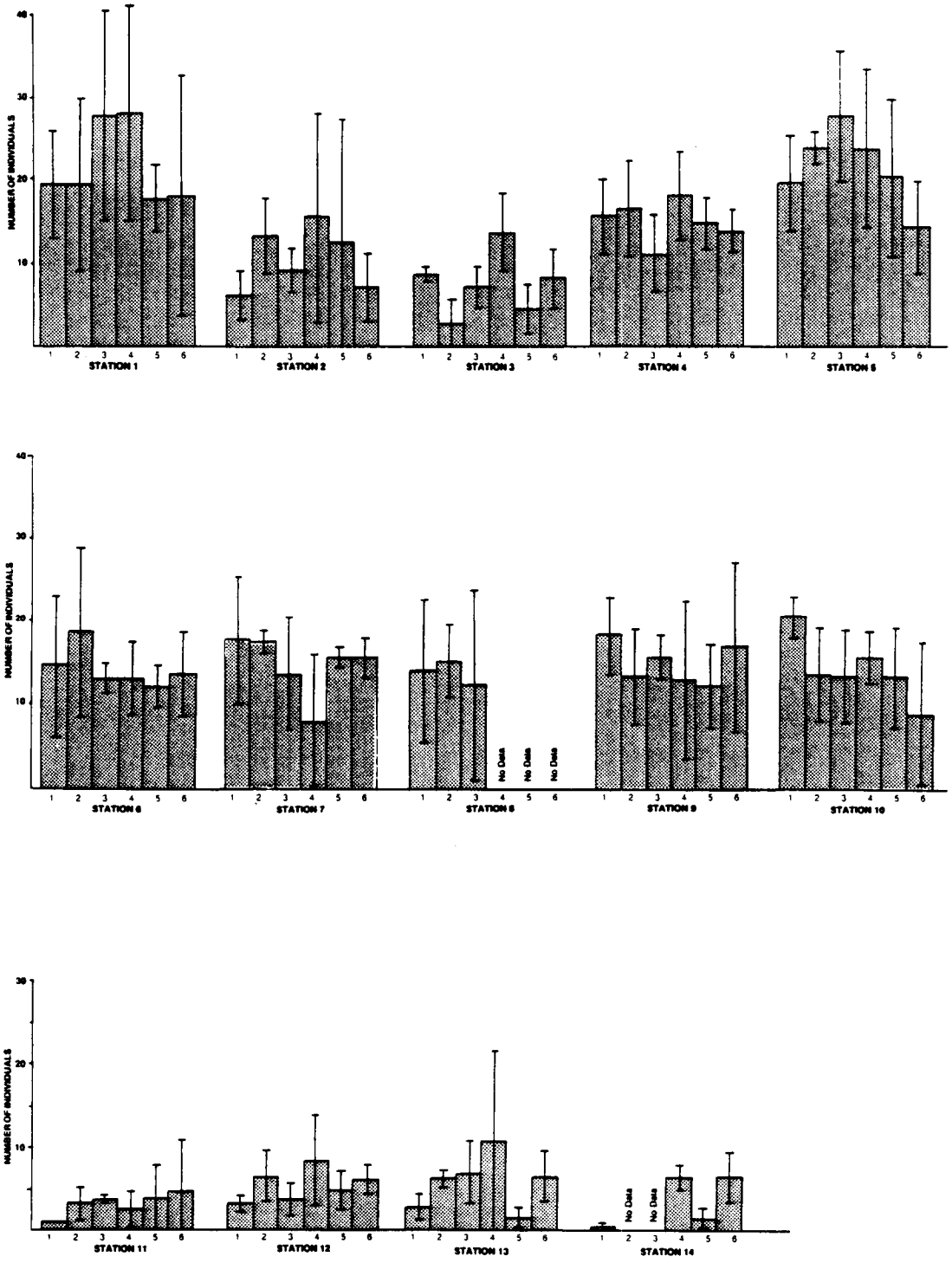

Figure 27. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Aplacophoran Spathoderma clenchi at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 16. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF PROCHAETODERMA YONGEI AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)	***	***	***	***	***	***
2 (1-7, 9, 10, vs. 11 and 13)	***	***	***	**	**	
3 (1-5, 7, 9 vs. 6)						
4 (1-5, 7, 9 vs. 10)	*	*	**		**	
5 (1-5, 7, 9 vs. 12)	***	***	***	***	***	***
6 (1-5, 7, 9 vs. 11 and 13)	***	***	***	**	*	
7 (11 vs. 13)						**
8 (11 vs. 14)		NT	NT			
9 (13 vs. 14)		NT	NT	*		

[a]NT = Not tested; * = 0.05 > p >0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

shallower Stations 11, 13, and 14 or the deeper Station 12 (Figure 27). Table 17 shows the results of the contrasts tested for S. clenchi. Significant differences were obtained for Contrasts 2 and 6 for all six sampling cruises, while Contrasts 1 and 5, which tested the 2100-m stations against Station 12, were significant only for the first three cruises.

The mean densities of Aspidosiphon zinni are plotted in Figure 28. This species was the top dominant at Stations 13 and 14, where it occurred in clearly higher densities than at any other station. The results of the ANOVA contrasts are given in Table 18. These results confirm the observation based on Figure 28: there were significant differences between the mean densities of A. zinni at the 2100-m stations and mean densities at Stations 11 and 13, on every sampling date (Contrasts 2 and 6). Further comparisons of mean densities at Station 11 vs. Station 13 (Contrast 7) also revealed significant differences between those two stations on four of the six sampling cruises.

Figures 29 and 30 represent the mean densities of two common crustacean species, the tanaid Paranarthrura cf. insignis and the isopod Haplomesus sp. 2, respectively. P. cf. insignis was virtually absent from Station 12, resulting in signficant differences when mean densities were contrasted (Table 19, Contrasts 1 and 5). Densities of this species were highest at Station 14, where they differed from densities at Stations 11 and 13 on almost all sampling dates (Contrasts 8 and 9). Results for Haplomesus sp. 2 are more complex. The species was virtually absent from both the shallower Stations 11, 13, and 14 and the deeper Station 12 (Figure 30). Densities of this species were also low at Stations 5 and 6 to the northeast of Station 1, and also at Station 9, to the southwest. When ANOVA contrasts were used to test for significant differences, the results not only reflect this distribution pattern, but also indicate that almost all contrasts were significant for Cruises Mid-2, Mid-4, and Mid-5 (Table 20). In many instances, contrasts could not be evaluated for the shallower stations, because densities were zero at some stations on certain cruises (Figure 30). Results presented in Table 20 also indicate that densities of H. sp. 2 were significantly different (higher) at Station 10 than at other 2100-m stations (Contrast 4).

Figure 31 shows the mean abundance of the bivalve Malletia johnsoni at each station. This species occurred in fairly low densities at each station, with no significant differences within stations over time. Results of the contrasts used to compare stations are given in Table 21. These results indicate some significant differences between

TABLE 17. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF SPATHODERMA CLENCHI AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)	***	*	***			
2 (1-7, 9, 10, vs. 11 and 13)	***	***	***	**	***	***
3 (1-5, 7, 9 vs. 6)						
4 (1-5, 7, 9 vs. 10)						
5 (1-5, 7, 9 vs. 12)	***	*	***			
6 (1-5, 7, 9 vs. 11 and 13)	***	***	***	**	***	***
7 (11 vs. 13)						
8 (11 vs. 14)		NT	NT			
9 (13 vs. 14)	*	NT	NT			

[a]NT = Not tested; * = 0.05 > p >0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

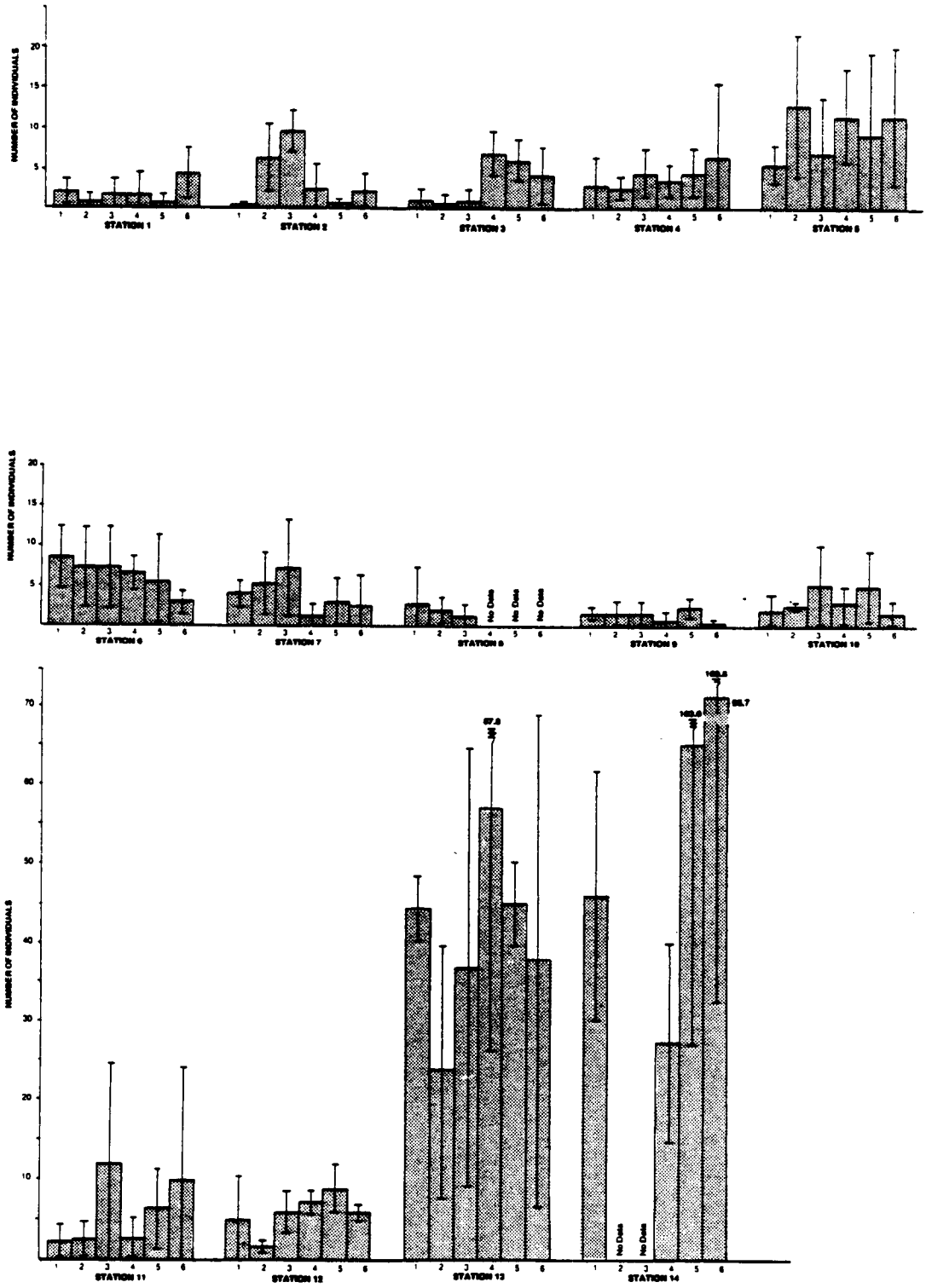

Figure 28. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Sipunculan Aspidosiphon zinni at Each U.S. Mid-Atlantic Stations for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 18. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF ASPIDOSIPHON ZINNI AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)					*	
2 (1-7, 9, 10, vs. 11 and 13)	***	*	**	**	***	*
3 (1-5, 7, 9 vs. 6)	**					
4 (1-5, 7, 9 vs. 10)						
5 (1-5, 7, 9 vs. 12)				*	*	
6 (1-5, 7, 9 vs. 11 and 13)	***	**	**	**	***	*
7 (11 vs. 13)	***	**		***	**	
8 (11 vs. 14)	**	NT	NT	**	**	
9 (13 vs. 14)						

[a]NT = Not tested; * = 0.05 > p >0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

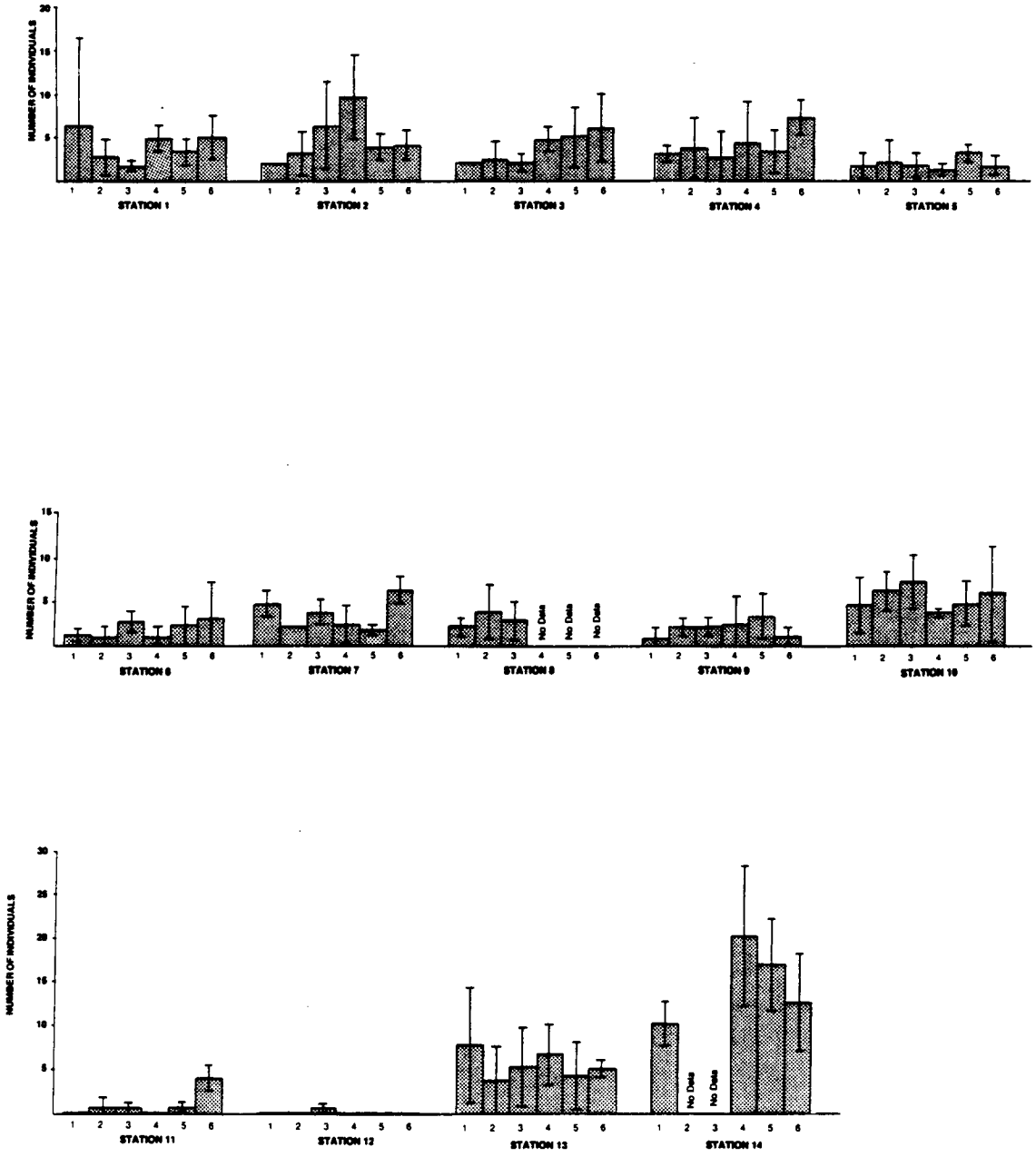

Figure 29. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Tanaid Paranarthrura cf. insignis at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

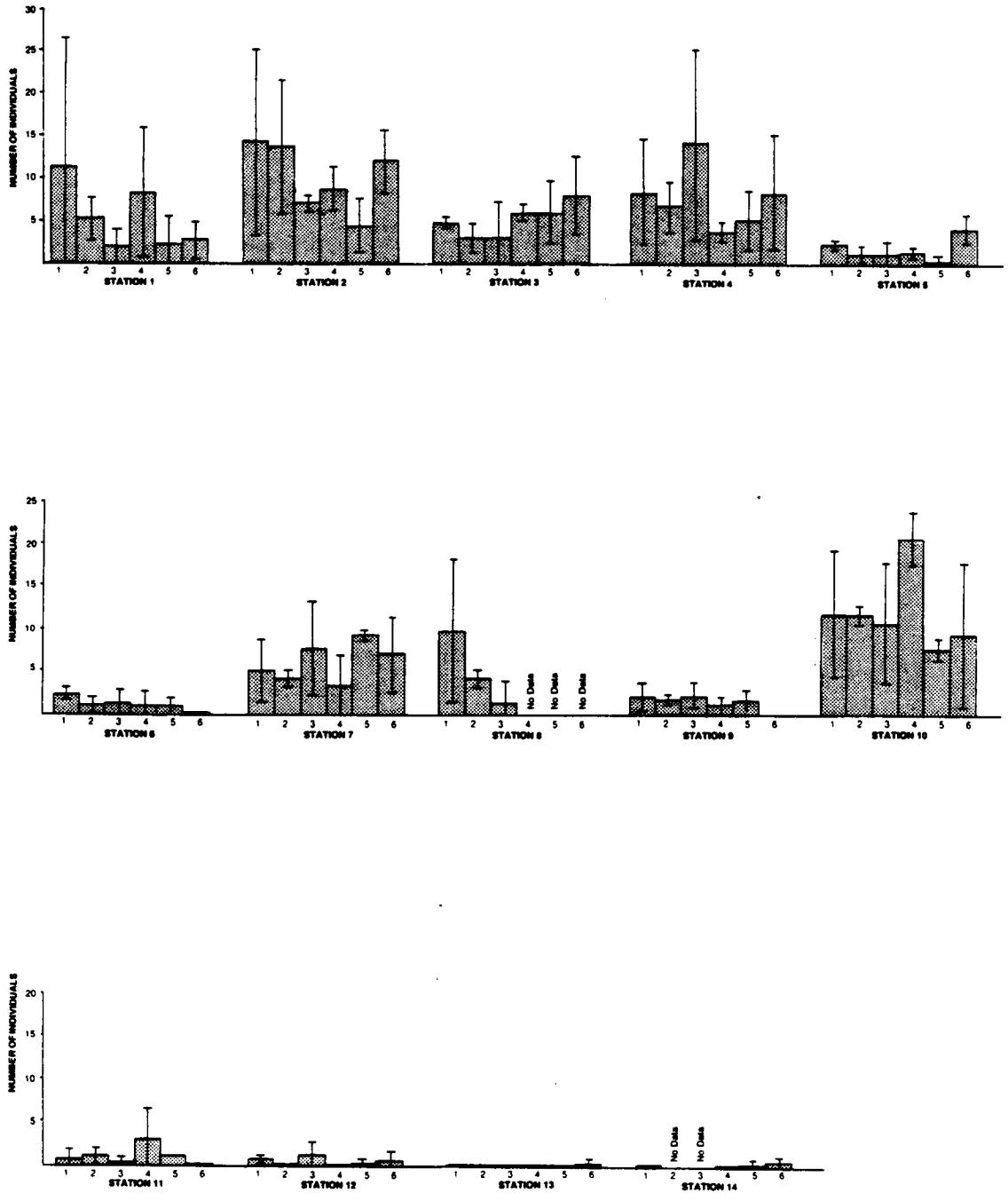

Figure 30. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Isopod Haplomesus sp. 2 at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 19. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF PARANARTHRURA CF. INSIGNIS AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)	**	**	*	**	***	***
2 (1-7, 9, 10, vs. 11 and 13)						
3 (1-5, 7, 9 vs. 6)				*		
4 (1-5, 7, 9 vs. 10)		*	*			
5 (1-5, 7, 9 vs. 12)	**	*	*	***	**	***
6 (1-5, 7, 9 vs. 11 and 13)						
7 (11 vs. 13)	**		*	***		
8 (11 vs. 14)	**	NT	NT	**		
9 (13 vs. 14)		NT	NT	*	*	*

[a]NT = Not tested; * = 0.05 > p >0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

TABLE 20. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF HAPLOMESUS SP. 2 AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)		**		**	**	
2 (1-7, 9, 10 vs. 11 and 13)	*	**	*	**	**	*
3 (1-5, 7, 9 vs. 6)		*			*	
4 (1-5, 7, 9 vs. 10)		**		***	*	
5 (1-5, 7, 9 vs. 12)		**		*	**	*
6 (1-5, 7, 9 vs. 11 and 13)	*	**	*	*	**	**
7 (11 vs. 13)					CBE	
8 (11 vs. 14)						
9 (13 vs. 14)	CBE	NT	NT	CBE		

CBE = Cannot be evaluated.
[a]NT = Not tested; * = 0.05 > p >0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

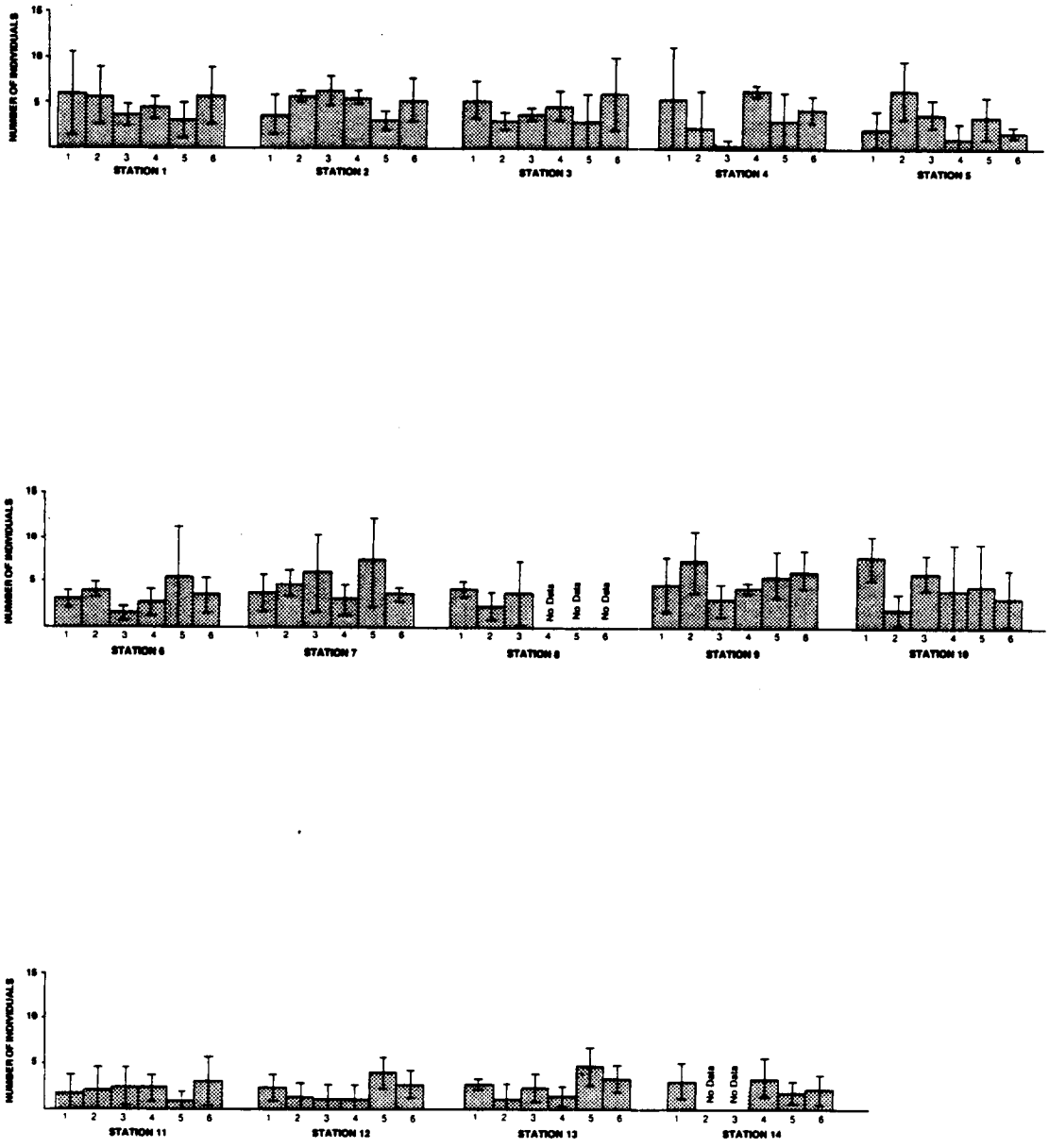

Figure 31. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Bivalve Malletia johnsoni at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 21. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF MALLETIA JOHNSONI AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)		*	*	*		
2 (1-7, 9, 10 vs. 11 and 13)		**		*		
3 (1-5, 7, 9 vs. 6)						
4 (1-5, 7, 9 vs. 10)		*				
5 (1-5, 7, 9 vs. 12)		*	*	*		
6 (1-5, 7, 9 vs. 11 and 13)		**		*		
7 (11 vs. 13)						
8 (11 vs. 14)		NT	NT		*	
9 (13 vs. 14)		NT	NT		*	

[a]NT = Not tested; * = 0.05 > p >0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

densities at the 2100-m stations and Station 12 (Contrasts 1 and 5) and the shallower Stations 11, 13, and 14 (Contrasts 2 and 6). These differences were most evident on Cruise Mid-2 and a lesser extent on Cruises Mid-3 and Mid-4. No differences were detected for Cruises Mid-1 or Mid-6.

Abundances of the dominant oligochaete Tubificoides aculeatus are graphed in Figure 32. At Station 1, there was a significant difference in the density of this species only between Cruises Mid-4 and Mid-5. Mean densities at other stations were stable over time. Results of the contrasts among stations are shown in Table 22. These results indicate that densities at Station 12 differed significantly from those recorded at the 2100-m stations on Cruises Mid-3, Mid-4, and Mid-5 (Contrasts 1 and 5). Contrasts 2 and 6, which tested differences between densities at the 2100-m stations and Stations 11 and 13, were significant only on Cruise Mid-2.

DISCUSSION

The present study has been unique for several reasons. The number (233) of quantitative box cores that have been fully analyzed has more than doubled the number previously available for the deep sea. Analysis of all faunal groups has allowed better documentation of the fauna, the diversity, and the general pattern of community structure both spatially (from 1515 to 2500 m and along a transect 176 km long) and temporally (six collections over two years). In addition, a man-made perturbation has been monitored.

A total of 862 species has been recorded from the samples analyzed in this study. Of these 862 species, 56.7 percent, or 489 species, are new to science. These undescribed species inlcude 236 species of polychaetes, 139 species of arthropods, and 42 species of molluscs. The remainder are from eight other phyla. As is typical for benthic marine environments, the fauna is dominated by annelids, which accounted for over 44 percent of all species recorded. The majority of stations were dominated by species of polychaetes, but the shallower Stations 11, 13, and 14 were dominated by sipunculans and aplacophoran molluscs. Although such taxa are known to be more common in the deep sea than in shallower water, the dominance of the infaunal community by these taxa is unusual. Aplacophorans and sipunculans are also dominant at several of the mid-slope (1220-1350 m) stations sampled as part of the U.S. North Atlantic study (Maciolek et al., 1986b).

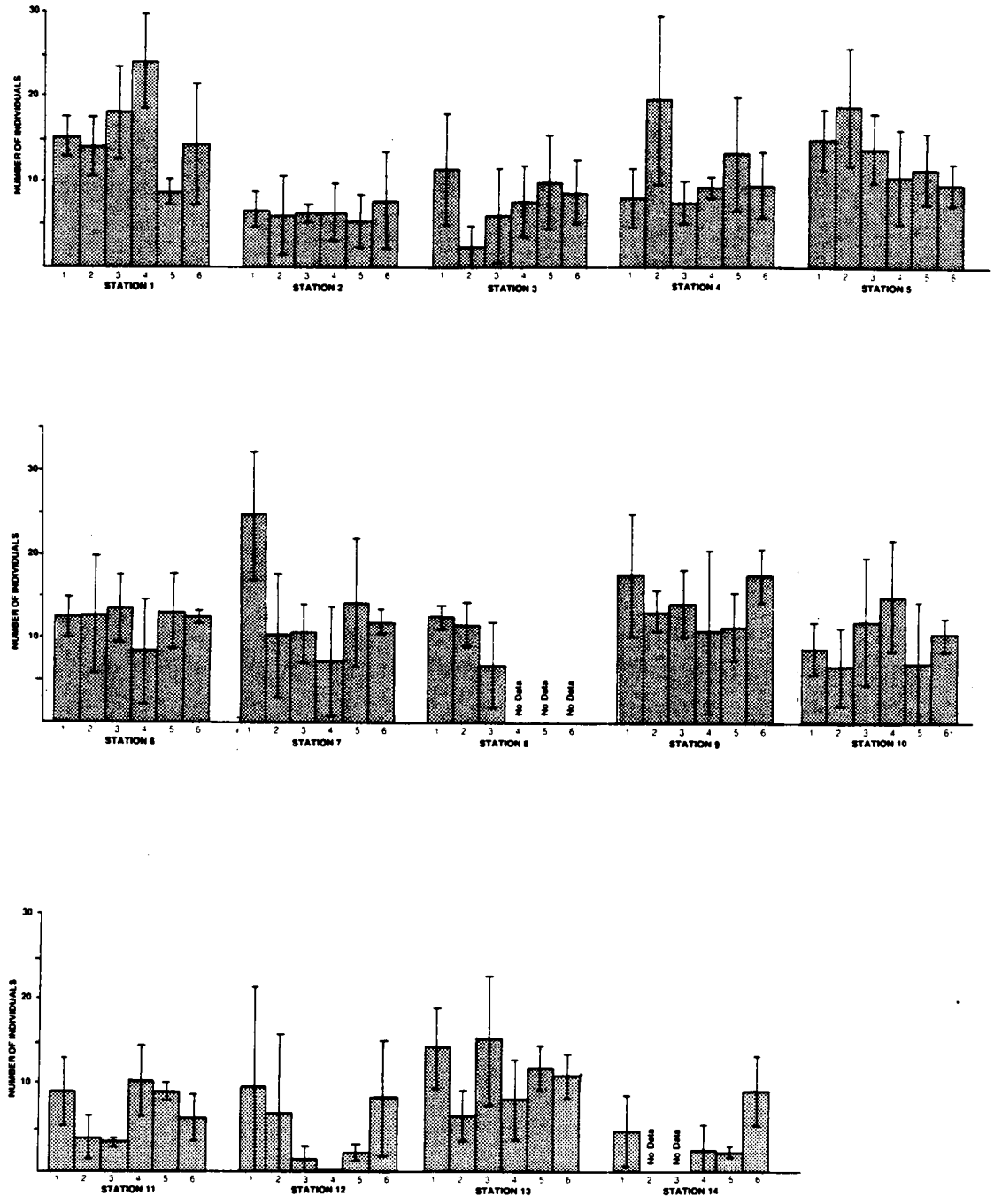

Figure 32. Mean Population Density (No./0.09 m^2 ± 1 SD) of the Oligochaete Tubificoides aculeatus at Each U.S. Mid-Atlantic Station for Each of Six Sampling Seasons (See Table 1 for Corresponding Dates).

TABLE 22. RESULTS OF CONTRASTS TESTED TO COMPARE MEAN DENSITIES OF TUBIFICOIDES ACULEATUS AT U.S. MID-ATLANTIC STATIONS.[a]

Contrast (Stations)	Cruise					
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6
1 (1-7, 9, 10 vs. 12)			**	**	**	
2 (1-7, 9, 10 vs. 11 and 13)		*				
3 (1-5, 7, 9 vs. 6)						
4 (1-5, 7, 9 vs. 10)						
5 (1-5, 7, 9 vs. 12)			**	**	**	
6 (1-5, 7, 9 vs. 11 and 13)		*				
7 (11 vs. 13)			**			
8 (11 vs. 14)		NT	NT			
9 (13 vs. 14)	*	NT	NT		***	

[a]NT = Not tested; * = 0.05 > p >0.01; ** = 0.01 > p > 0.001; *** = p < 0.001.

Several measures of diversity have been evaluated, including Hurlbert rarefaction, species accumulation over increasing area, and Shannon-Wiener diversity. The Hurlbert rarefaction method is considered to be the method of choice for evaluating diversity. Species diversity at all stations has been shown to be uniformly high over all sampling seasons. It has been hypothesized that any sudden, unnatural disturbance such as burial by discharged drilling mud would result in a sharp drop in diversity; such a decrease was not seen at any station. The changes in diversity that were seen, e.g., at Station 1, are not considered to be significant.

At Station 1, the Shannon diversity values indicated an increase from 6.16 on the pre-drilling Cruise Mid-1 to 6.25 on Cruise Mid-6. The results of the Hurlbert rarefaction indicated a decrease from 154 to 150 species per 1000 individuals over the same time period. At Station 14, the Shannon diversity dropped from 6.34 on Cruise Mid-1 to 6.01 on Cruise Mid-6, but the Hurlbert rarefaction values did not change over the same time period.

When diversity of the total fauna at the 2100-m stations is considered, Station 4 is the least diverse station and Station 10 at the southeastern end of the 176-km transect is the most diverse station. That is, at least in part, because samples from Station 10 contained a number of rare species that are presumed to be more common in areas to the south of this station. As a group, the shallower Stations 11, 13, and 14 are more diverse than the deeper stations. A similar result was obtained in the U.S. North Atlantic study area (Maciolek et al., 1986b) where the mid-slope stations at 1220 to 1350 m exhibited higher diversities than either shallower (250 to 500 m) or deeper (2100 m) stations. These results do not agree with the conclusions reached by Rex (1983), who reviewed patterns of diversity for several major faunal groups. In Rex's review, he reported that diversities increased with depth to a maximum at about 2000 to 3000 m. However, most of the data that Rex used were based on qualitative epibenthic sled samples; whereas the present results are based on detailed quantitative data.

The diversity measurements from the U.S. Atlantic Slope and Rise studies provide the most complete description of deep-sea diversity ever made. The initial finding of high diversity in the deep sea was based on nonquantitative samples (Hessler and Sanders 1967, Sanders 1968). A few studies using methods similar to ours have enumerated the number of species in an order of magnitude fewer box cores. Jumars (1976) obtained 69 spp. /0.25

m^2 from the Santa Catalina Basin and 144 spp. / 0.25 m^2 from the San Diego Trough from 1130 m and 1230 m depth off California. Gage obtained 110 spp. / 0.25 m^2 from 2875 m depth in the Rockall Trough off the west coast of Scotland and Hessler and Jumars obtained 21 spp. / 0.25 m^2 at 5500-5800 m depth in the mid-Pacific Ocean Gyre. The data presented here from 233 box cores show a diversity of 95 spp. in 36 percent of the area of the full box core or 900 cm^2. The important new finding is that the number of species continues to increase as quantitative samples are added together even though the depth remains the same (Figure 4). If samples from different depths were added the rate of accumulation of species would be much greater. The recent estimates of 30 million species of beetles in the world are based on samples with an aggregate number of species of 1080 (Erwin 1983) in comparison to 862 species in the present study and 1202 species in the recently completed U.S. South Atlantic Slope and Rise Study (Blake et al., 1987).

The causes of the changes in diversity with depth are not well understood and in fact are the subject of much debate. Several factors may be important, including environmental heterogeneity on both a temporal and spatial scale. These factors may influence not only diversity, but also species distributions, that are reflected in the patterns discussed below.

The several statistical analyses performed on the data set all support similar conclusions concerning faunal patterns. The major clusters delineated by classification and ordination correspond to the three major depth intervals sampled: 1500, 2100, and 2500 m. Within each of these depth intervals, samples from each station were generally more similar to each other than to samples from any other station. This pattern was clearer for Stations 11, 12, 13, and 14, but even for the large group of stations along the 176-km transect that centered around 2100 m depth (Stations 1-10), there was a high level of similarity among samples from discrete stations. Samples from most stations clustered with other samples from the same station before joining with the next station. Subgroupings of stations along the 2100-m transect were also evident. Station 10 was most similar to a unit made up of samples from Stations 2 and 3, but Station 1 was most similar to Stations 4 and 5. This pattern can be explained, at least in part, by similarities in sediment grain-size composition among stations. In general, Stations 2, 3, 4, and 10 were relatively sandier and had lower levels of total organic carbon; Stations 1 and 5 through 9 had fine-grained sediments and were relatively rich in total organic carbon.

The data presented in this chapter confirm the patterns reported earlier for fewer samples (Maciolek-Blake et al., 1985; Maciolek et al., 1986a). When the total fauna was evaluated using similarity analysis, the pre-drilling samples collected at Station 1, the drill site in Block 372, were shown to differ from samples collected on the remaining five cruises. However, all of the six sample sets were similar at the very high 0.90 level (using the similarity measure NESS), implying that the differences between the pre-drilling samples and the remaining samples were very small. Bothner et al. (1986b) reported evidence suggesting that a small amount of drilling mud settled at Station 1; however, no measurable amount of drill cuttings could be detected in an analysis of sediment texture. One sediment sample from Station 1 analyzed as part of this study was earlier reported to contain material that could possibly be drill cuttings (Maciolek-Blake et al., 1985; Maciolek et al., 1986a); however, this material has now been shown to be present in additional samples from other stations, but is not related to drilling discharges (Chapter 8, this report). The changes in the fauna noted at Station 1 can be related to changes in the total density of certain dominant species, e.g., the polychaete Tharyx sp. 1. The density of this species was much higher in the pre-drilling (Cruise Mid-1) sample set than it was in subsequent samples; however, the lower densities are more comparable with the density of this species at nearby stations. Such changes are most likely related to differences in sediment texture. The sediment grain-size composition increased from 6.57 to 14.40 percent sand at Station 1 between pre-drilling and post-drilling cruises (see Chapter 8, this report). Although this change was not statistically significant, it was possibly great enough to account for some of the fluctuations seen in the densities of some species.

Pre-drilling samples collected at Station 14, the drill site in Block 93, were highly similar to samples collected a year later. Samples collected on Cruise Mid-6, however, were highly dissimilar to other replicates collected at this station; this dissimilarity was apparent when only the polychaete fauna was evaluated as well as when the total fauna was evaluated. No statistically significant changes in sediment grain-size composition were detected at Station 14; therefore, it is difficult to account for dissimilarity of this one sample set.

CHAPTER 4. BIOMASS ANALYSIS OF INFAUNAL BENTHOS

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. The data are then subjected to numerous statistical tests for interpretation. These fundamental analyses, based on numbers of organisms per unit area, can be complimented by other studies, e.g., estimation of recolonization rates or measurement of benthic productivity. Productivity measurements are costly and time-consuming to conduct even in shallow-water environments. Biomass measurements which determine standing stock of benthic infauna by obtaining a measure of the weight of the animals present are frequently made instead of productivity estimates. The study of the biological processes on the U.S. Mid-Atlantic slope and rise provided the opportunity to make standing stock (i.e., wet weight and ash-free dry weight) measurements of preserved specimens.

The measurements of ash-free dry weight (AFDW) made in this study are the first of their kind ever made for the deep sea. Measurements of wet weight and AFDW were obtained for six box cores taken expressly for biomass estimates. The samples were collected during Cruise Mid-5 in August 1985 at two stations at a depth of 2100 m. 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. coast and throughout the world. As part of a preliminary study, measurements of wet weight were made on samples collected during Cruise Mid-1 (March/April 1984); these results are also described in this chapter.

METHODS AND MATERIALS

Cruise Mid-1: March/April 1984

Wet weights were determined for approximately 15 percent of the samples from Cruise Mid-1. This procedure was discontinued before completion because the effort was

time consuming and proved to be more expensive than the budget for this study would allow. Of these samples, only three of the groups that correspond to the taxonomic categories described below for the determination of AFDW were completely analyzed for the entire cruise. These categories were the Bivalvia, Ophiuroidea, and Other Echinodermata. Arthropoda completely analyzed at all stations included the Tanaidacea, Decapoda, and Cumacea; but not the Amphipoda and Isopoda.

Methods for handling, preserving, and sorting the subcores were identical to those used for infaunal samples. After organisms were identified to species, wet weights were determined. Forceps were used to remove soft-bodied animals from their vials and place them on a screen-covered blotting pad for drying. Hard-bodied animals (i.e., molluscs and echinoderms) were rinsed from their vials onto a screen, blotted dry, and handled with soft forceps to avoid crushing the specimens. Drying time depended upon the size of the animal because it was important to avoid dehydration. Specimens were usually blotted for 15 to 30 sec until all visible alcohol was removed. The specimens were then placed in a petri dish containing a small piece of screening to facilitate later removal of the animals. The dish was covered to reduce fluctuations due to evaporation of alcohol during weighing.

All specimens were weighed to the nearest 0.1 mg on a Mettler balance (with an accuracy of 0.01 mg). The Mettler balance was calibrated according to a routine maintenance schedule and zeroed prior to use. Weights of 1 mg or more (without rounding) were recorded to the nearest mg, while weights of 0.9 mg or less were recorded as <0.001 g.

Cruise Mid-5: August 1985

During Cruise Mid-5, a Mark III 0.25-m^2 box corer was used to collect six box cores specifically for biomass measurements. Three samples were collected at Station 6 and three at Station 10 (see Appendix C for positions). All three replicates from Station 6 were collected in a water depth of 2080 m. Replicates 1 and 3 from Station 10 were collected at a water depth of 2095 m, while replicate 2 was collected at a water depth of 2090 m. Methods for handling, preserving, and sorting the subcores were identical to those used for infaunal samples with the exception that resieving was carried out using

both 2.0-mm and 0.3-mm sieves when samples were transferred to alcohol. Organisms removed from the 2.0-mm and 0.3-mm fractions were sorted into nine taxonomic categories as follows: Annelida, Bivalvia, Other Mollusca, Arthropoda, Sipuncula, Pogonophora, Ophiuroidea, Other Echinodermata, and All Other Taxa. Both fractions were kept separate throughout the analyses.

Wet weights were obtained prior to obtaining ash-free dry weights (AFDW) by removing organisms from vials with forceps and blotting them dry on a screen-covered blotting pad. Specimens were usually blotted for 15-30 sec until all visible alcohol was removed. The specimens were then placed in a preweighed, organic-free, aluminum container. The type of weighing container used depended on the sample size; aluminum pans (57-mm diameter) and microbalance weighing boats (1 ml) were used. All aluminum containers had been placed in a muffle furnace for 2 hr at 500°C to remove any organic material. All pans were weighed on the Mettler analytical balance (described above) and all boats were weighed on a Cahn 28 automatic electrobalance (with an accuracy of 1.0 µg). The Cahn balance was zeroed daily before use and calibrated with standard weights. Calibration and use of the Mettler balance was the same as described above. Weights and forceps used for handling weights and boats were always cleaned with an organic solvent (i.e., hexane or CH_3Cl) prior to use. After every five samples weighed on either balance, the balance was re-zeroed. When weighing on either balance, a reading was taken 30 sec after placing the sample on the balance. After weighing, all containers were placed in a dessicator until used.

Dry weights were obtained by placing containers into a drying oven at 60°C for 24 hr to remove water, after which samples were placed in a dessicator for at least 12 hr. The containers were weighed by taking a reading 30 sec after being placed on the balance. Samples were then ashed in a muffle furnace at 450°C for 4 hr. After ashing, containers were placed in a dessicator for at least 12 hr, after which the ash was weighed as it was for dry weight. After subtraction of the container weight from the wet, dry, and ash weights, AFDW was calculated as follows for each sample:

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

DATA REDUCTION AND ANALYSES

Cruise Mid-1: March/April 1984

The data for wet weight included all fragments and indeterminate taxa of any taxonomic group, but excluded epibenthic or pelagic species. The four categories into which data were grouped and that were included in the analyses were as follows: Bivalvia, Ophiuroidea, Other Echinodermata, and Arthropoda. The Arthropoda in this case included the Decapoda, Cumacea, and Tanaidacea, but not the Isopoda or Amphipoda. Simple statistics were computed for the data including totals, means, and standard deviations. Data expressed as grams per 0.09 m^2 were multiplied by a factor of 11.11 to convert them to grams per m^2.

Cruise Mid-5: August 1985

Prior to statistical analyses, epibenthic or pelagic species were excluded from the database. Biomass estimates for AFDW included all fragments and indeterminate taxa of each taxonomic group. Once the data were computerized, totals, means, and standard deviations were determined where appropriate. The coefficient of variation (CV) was determined for wet, dry, and ash-free dry weights for the two size fractions separately and combined for each station, as follows:

$$CV = \frac{SD}{\bar{X}} (100)$$

where $\bar{X}$ is the mean of the particular weight and SD is the standard deviation. When data were converted from grams per 0.09 m^2 to grams per m^2, a multiplier of 11.11 was used.

RESULTS

Cruise Mid-1: March/April 1984

Wet weight biomass of the four taxa measured varied considerably among stations during Cruise Mid-1 (Table 23, Figure 33). Stations can be ranked from highest to lowest

TABLE 23. AVERAGE WET WEIGHT (g/m^2) FOR DIFFERENT STATIONS AND TAXONOMIC GROUPS FOR CRUISE MID-1.

Taxonomic Category	Station 1	2	3	4	5	6	7	8	9	10	11	12	13
Arthropoda	0.0367	0.0411	0.0078	0.0078	0.0256	0.0367	0.0189	0.0189	0.5000	0.3033	0.1478	0.1300	0.3189
Bivalvia	0.3522	0.1778	0.6299	0.9110	0.2744	1.6332	0.3333	1.3632	1.5554	0.3744	2.2409	0.0700	0.0000
Ophiuroidea	6.1105	5.6439	0.4922	0.0000	0.0256	0.0411	0.0030	0.3000	0.0444	2.0853	1.0699	2.4853	0.7255
Other Echinodermata	0.0478	0.0078	4.8773	0.0633	0.0589	0.7144	1.5554	1.1554	28.7227	15.1463	0.4333	0.0667	1.9409
TOTAL	6.5472	5.8706	6.0072	0.9821	0.3845	2.4254	1.9106	2.8375	30.8225	17.9093	3.8919	2.7520	2.9853

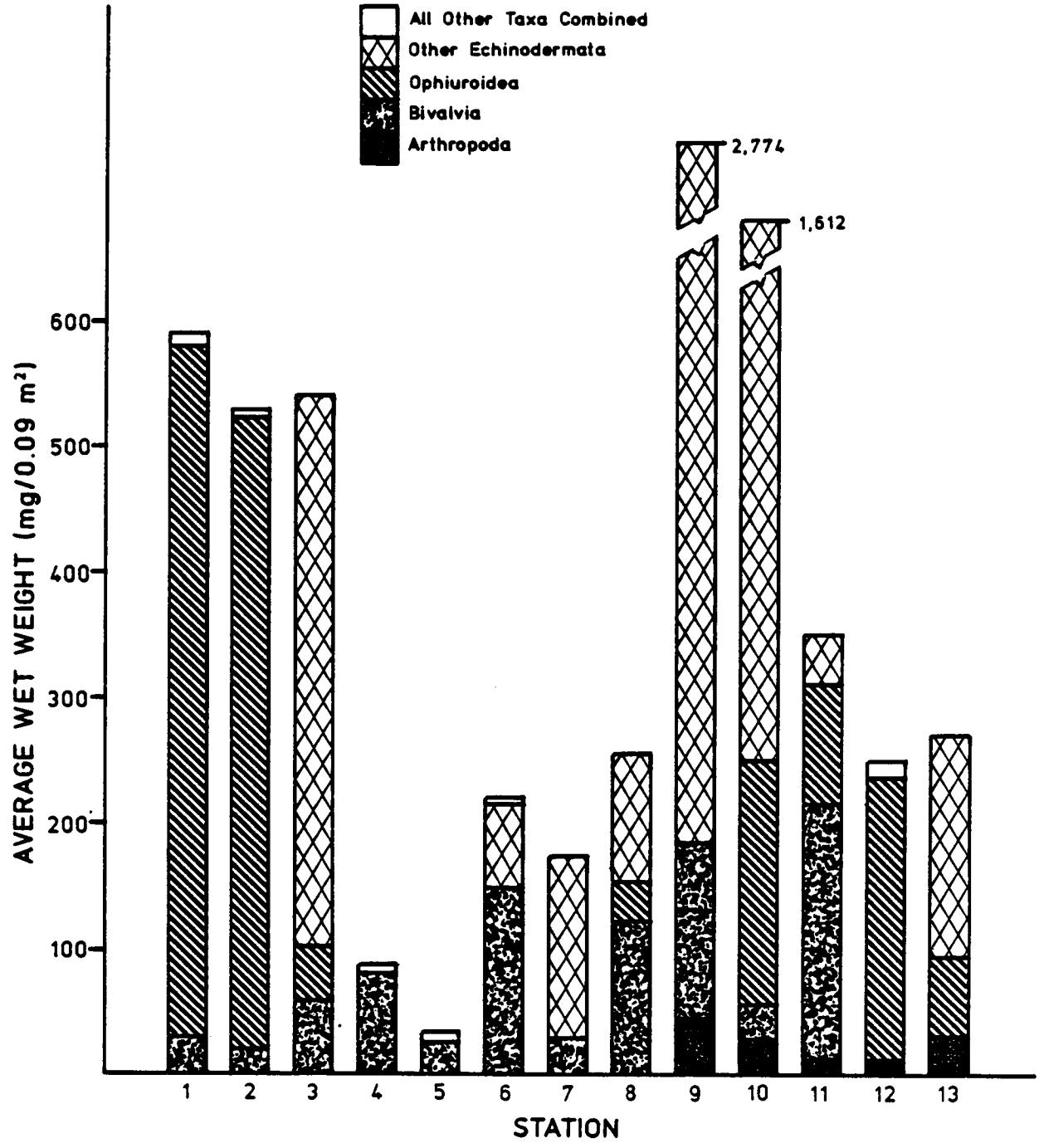

Figure 33. Average Wet Weight Biomass (mg/0.09 m^2) for the Four Taxonomic Categories Analyzed in Samples Taken During Cruise Mid-1. The Category "All Other Taxa Combined" Was Created to Include Weights of Any of the Other Four that Were too Small to Show Separately.

total wet weight biomass as follows: 9, 10, 1, 3, 2, 11, 13, 8, 12, 6, 7, 4, and 5. Station 5, with the lowest average wet weight biomass, contained 0.385 g/m^2 and Station 9, with the highest average wet weight biomass, contained 30.823 g/m^2. Stations 1, 2, and 12 were composed primarily of Ophiuroidea, with 6.111, 5.644, and 2.485 g/m^2, respectively. Stations 3, 7, 9, 10, and 13 were composed primarily of Other Echinodermata, with 4.877, 1.555, 28.723, and 15.146 g/m^2, respectively. Station 8 was dominated by Bivalvia and Other Echinodermata, with 1.363 and 1.155 g/m^2, respectively. Average total wet weight biomass at Stations 6 and 10 during Cruise Mid-1 (2.425 and 17.909 g/m^2, respectively) comprised only four taxa, but these values were higher than those determined for the same stations during Cruise Mid-5 (see below), which included all taxa.

To some extent, the different stations did follow a geographic pattern in taxonomic composition. For instance, Stations 4, 5, and 6 were all dominated by Bivalvia and contained low levels of total biomass. Stations 1, 2, and 12 were composed primarily of ophiuroids, although biomass at Stations 1 and 2 was almost twice that of Station 12. Station 9 contained more biomass of bivalves while Station 10 contained more of ophiuroids.

Cruise Mid-5: August 1985

Total wet weight, dry weight, and AFDW at Station 10 were approximately five, six, and two times higher, respectively, than wet weight, dry weight, and AFDW at Station 6 (Tables 24 and 25, Figure 34). At Station 6, total wet weight ranged between 1.0232 and 1.4609 g/m^2, total dry weight ranged between 0.4022 and 0.5311 g/m^2, and total AFDW ranged between 0.1333 and 0.1878 g/m^2. At Station 10, total wet weight ranged between 1.1987 and 15.2140 g/m^2, total dry weight ranged between 0.3877 and 8.7191 g/m^2, and total AFDW ranged between 0.1677 and 0.7788 g/m^2. The coefficient of variation for Station 10 was much higher than that for Station 6 owing to the higher biomass weight in replicate 3, Station 10. The taxonomic groups in replicate 3 with weights higher than the other two replicates at Station 10 were the Ophiuoroidea, Bivalvia, and All Other Taxa.

The wet weight, dry weight, and AFDW were not different between the 0.3-mm and 2.0-mm size fractions at Station 6 (Tables 24 and 25, Figure 34). Total wet weight of the

TABLE 24. WET, DRY, AND ASH-FREE DRY WEIGHT (g/m^2) FOR SIZE FRACTIONS INDIVIDUALLY AND SUMMED BY STATION AND REPLICATE.

Station	Rep.	Wet Weight			Dry Weight			Ash-Free Dry Weight		
		0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total
6	1	0.4344	0.5888	1.0232	0.2422	0.2889	0.5311	0.1267	0.0500	0.1767
	2	0.5866	0.4777	1.0643	0.1900	0.2122	0.4022	0.0689	0.0644	0.1333
	3	0.6755	0.7855	1.4610	0.2300	0.2933	0.5233	0.0889	0.0989	0.1878
10	1	0.7077	1.0843	1.7920	0.2189	0.3066	0.5255	0.0767	0.1178	0.1945
	2	0.8932	0.3055	1.1987	0.2955	0.0922	0.3877	0.1144	0.0533	0.1677
	3	1.6887	13.5253	15.2140	0.5477	8.1714	8.7191	0.2544	0.5244	0.7788

TABLE 25. MEAN (g/m^2), STANDARD DEVIATION (SD) AND COEFFICIENT OF VARIATION (CV) FOR THREE REPLICATES OF WET, DRY, AND ASH-FREE DRY WEIGHTS FOR STATIONS 6 AND 10. WEIGHT DATA PRESENTED WITH SIZE FRACTIONS SEPARATE AND COMBINED.

	Wet Weight			Dry Weight			Ash-Free Dry Weight		
	0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total	0.3 mm	2.0 mm	Total
Station 6									
Mean	0.5655	0.6177	1.1832	0.2211	0.2644	0.4855	0.0944	0.0711	0.1665
SD	0.1222	0.1555	0.2422	0.0278	0.0456	0.0722	0.0289	0.0256	0.0289
CV	21.61	25.17	20.47	12.57	17.25	14.87	30.61	36.01	17.46
Station 10									
Mean	1.0966	4.9717	6.0683	0.3544	2.8564	3.2108	0.1489	0.2322	0.3811
SD	0.5211	7.4181	7.9259	0.1722	4.6040	4.7706	0.0933	0.2555	0.3455
CV	47.52	149.21	130.61	48.59	161.18	148.58	62.66	110.03	90.92

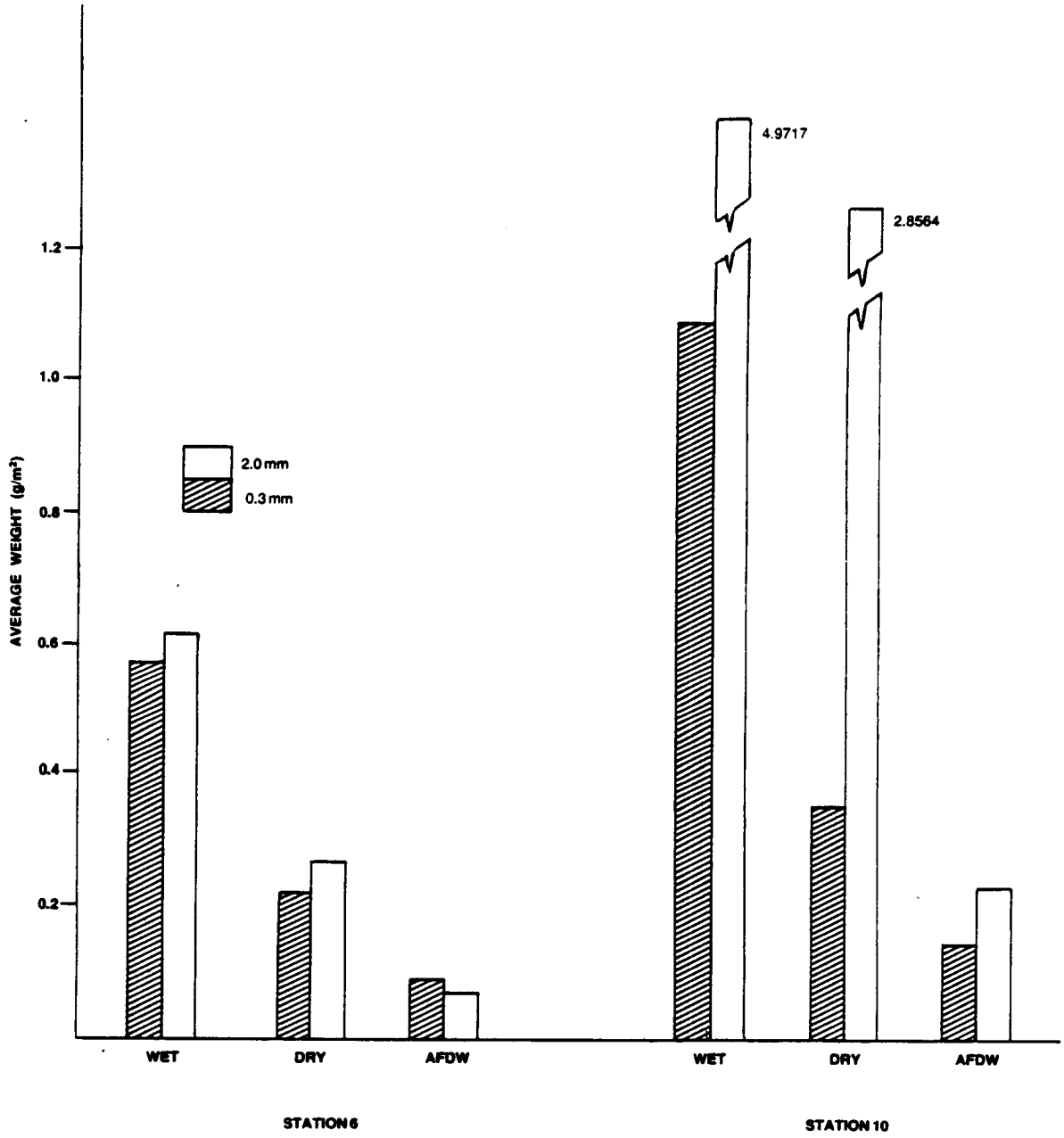

Figure 34. Average Wet, Dry, and Ash-Free Dry Weights (AFDW) (g/m^2) For Each Size Fraction at Stations 6 and 10 From Cruise Mid-5.

2.0-mm size fraction of Station 10 was 4.5 times that of the 0.3-mm fraction; whereas total AFDW of the 2.0-mm size fraction was 1.6 times that of the 0.3-mm fraction. The 0.3- and 2.0-mm size fractions accounted for 57.1 and 42.9 percent, respectively, of the fauna at Station 6. At Station 10, the 0.3-mm and 2.0-mm size fractions made up 39.0 and 61.0 percent, respectively.

At Station 6, annelids and bivalves constituted 82.6 percent of the mean total AFDW, accounting for 0.1070 and 0.0301 g/m^2, respectively (Table 26, Figure 35). At Station 6, higher AFDW of Annelida, All Other Taxa, Arthropoda, Other Mollusca, and Ophiuroidea occurred in the 0.3-mm size fraction than in the 2.0-mm fraction. The converse was true for the Bivalvia, Pogonophora, Sipuncula, and Other Echinodermata. At Station 10, higher AFDW of Annelida, Arthropoda, Bivalvia, Sipuncula, and Other Echinodermata occurred in the 0.3-mm size fraction than in the 2.0-mm fraction. At Station 10, the taxonomic groupings of Annelida, All Other Taxa, and Ophiuroidea constituted 82.4 percent of the mean total AFDW, contributing 0.1241, 0.1237, and 0.0658 g/m^2, respectively.

DISCUSSION

Biomass values varied between stations for both Cruises Mid-1 and Mid-5. AFDW values during Cruise Mid-5 (August 1985) at Station 10 were twice as high as those at Station 6. This was similar to the situation in Cruise Mid-1 (March/April 1984). Unfortunately, not all taxa in Cruise Mid-1 samples were measured, making comparisons between cruises impossible. The remaining discussion applies to Cruise Mid-5 only.

Ash-free dry weight data are considered a good measure 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). In this study, organic material was burned off at 450°C for two hours, a time period less than that recommended by Crisp (1984), to avoid volatilization of inorganic matter. Therefore, the main source of possible error is a slight overestimate of AFDW. Financial resources were not available to test thoroughly the methods that were used; therefore, the methods were based on tests made previously (Blake et al., 1985). These data are the first available AFDW measurements for deep-sea communities and will provide a basis for

TABLE 26. PERCENT COMPOSITION OF MEAN TOTAL ASH-FREE DRY WEIGHT (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	Size Fractions Combined	Percent of Combined Size Fractions
Station 6						
Taxon						
Annelida	0.0598	55.9	0.0472	44.1	0.1070	64.5
All Other Taxa	0.0061	69.6	0.0027	30.4	0.0088	5.3
Arthropoda	0.0064	100.0	0.0000	0.0	0.0064	3.9
Bivalvia	0.0139	46.1	0.0162	53.9	0.0301	18.1
Other Mollusca	0.0057	96.2	0.0002	3.3	0.0059	3.5
Pogonophora	0.0017	39.5	0.0026	60.5	0.0043	2.6
Sipuncula	0.0006	45.5	0.0007	54.5	0.0013	0.8
Ophiuroidea	0.0001	100.0	0.0000	0.0	0.0001	0.1
Other Echinodermata	0.0003	16.3	0.0017	83.3	0.0020	1.2
Total	0.0946	57.1	0.0713	42.9	0.1659	100.0
Station 10						
Taxon						
Annelida	0.0760	61.2	0.0481	38.8	0.1241	32.6
All Other Taxa	0.0307	24.8	0.0929	75.2	0.1237	32.5
Arthropoda	0.0176	66.1	0.0090	33.9	0.0266	7.0
Bivalvia	0.0123	68.1	0.0058	31.9	0.0181	4.8
Other Mollusca	0.0076	42.5	0.0102	57.5	0.0178	4.7
Pogonophora	0.0009	32.0	0.0019	68.0	0.0028	0.7
Sipuncula	0.0011	90.9	0.0001	9.1	0.0012	0.3
Ophiuroidea	0.0020	3.0	0.0638	97.0	0.0658	17.3
Other Echinodermata	0.0003	60.0	0.0002	40.0	0.0005	0.1
Total	0.1486	39.0	0.2320	61.0	0.3806	100.0

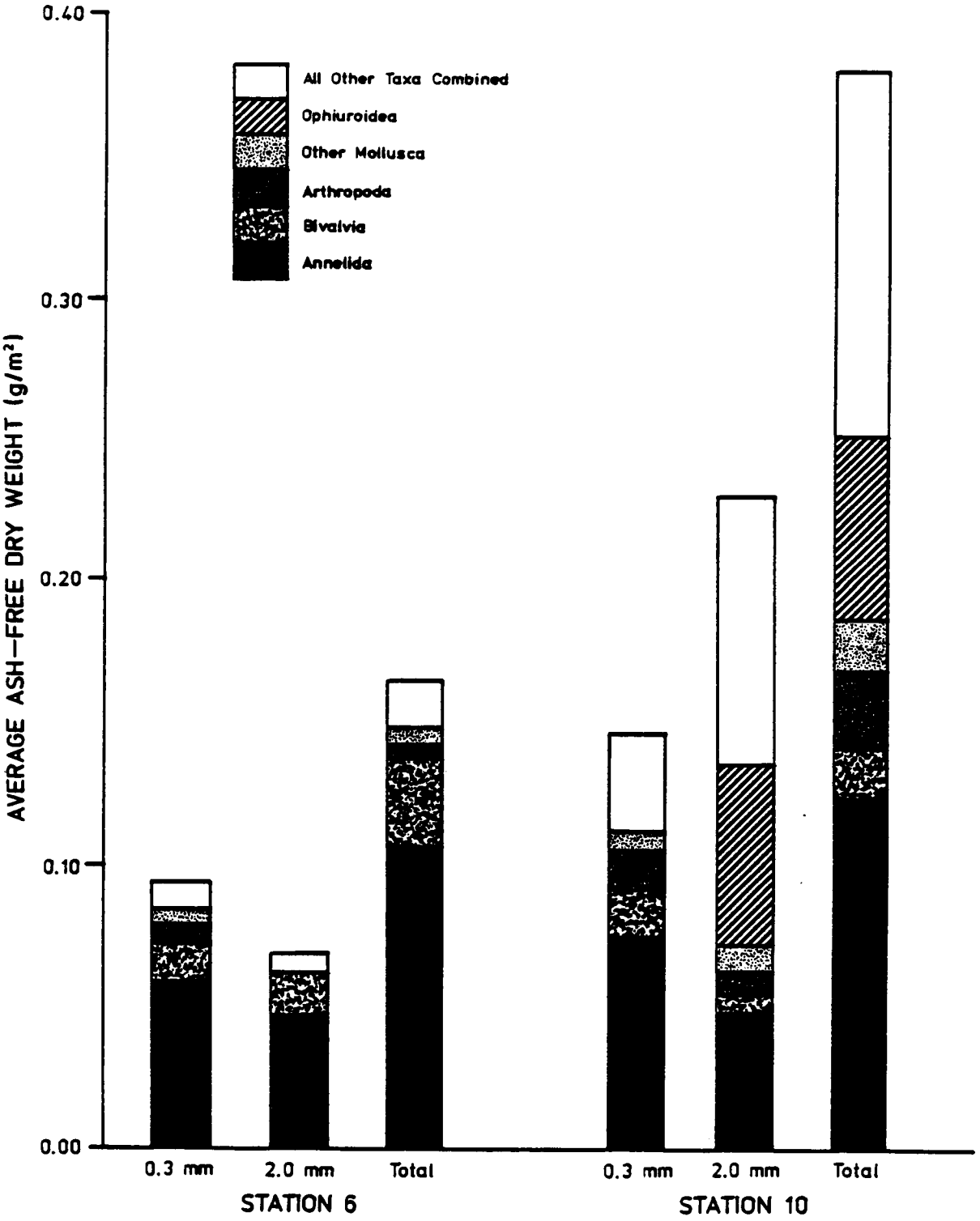

Figure 35. Average Ash-Free Dry Weight (AFDW) (mg/m^2) for Taxonomic Categories in Each Size Fraction at Stations 6 and 10. Size Fractions Presented Separately and Combined.

future comparisons with the results of studies in other geographic areas. Because the AFDW data are the first produced for the deep sea, only wet and dry weight standing stock can be compared with data reported by other investigators.

Wet and dry weight measurements reported here are comparable to those reported by other investigators, although values were higher in the present study. Using a 0.250-mm mesh screen, Khripounoff et al. (1980) measured 0.157 g/m^2 dry weight for macrofauna only at a station of similar depth (2100 m) and 0.161 g/m^2 for all fauna (i.e., including meiofauna) retained on the screen. Using a 0.250-mm mesh screen, Dinet et al. (1985) measured dry weights of 0.29 and 0.18 g/m^2 at depths of 2100 and 4100 m, respectively. In this study, dry weight measurements were higher than those of both of the above studies and ranged between 0.402 and 0.531 g/m^2 at Station 6 and 0.388 and 8.719 g/m^2 at Station 10. Similarly, using a 0.297-mm mesh screen, Rowe (1983) measured wet weight values that ranged between 0.1 and 1.0 g/m^2 for depths between 2000 and 5000 m; whereas the present values ranged between 1.0 and 1.5 g/m^2 wet weight at Station 6 and between 1.2 and 15.2 g/m^2 at Station 10.

As might be predicted (Jumars and Gallagher, 1982), annelids were dominant components of the biomass, comprising over half the biomass at Station 6 and one-third the biomass at Station 10. The taxonomic groupings Ophiuroidea and All Other Taxa appear as dominant groups in the 2.0-mm fraction of the average AFDW biomass of Station 10 (Figure 35); but, in fact, this average represents a disproportionate amount of biomass in replicate 3 of Station 10 for both taxonomic groups. The large variability, indicated by the coefficient of variation for the station (Table 25), is not unusual (Brown, 1985a; Blake et al., 1985) and underscores the need for sufficient samples to develop an accurate picture of standing stocks or productivity in the deep sea.

At Station 6, the 0.3-mm fraction contained more biomass than did the 2.0-mm fraction in two of three replicates; at Station 10, more biomass was contained in the 2.0-mm fraction (Table 24). These observations indicate that the biomass in the 2.0-mm fractions resulted from a few relatively heavy individuals, with the converse being true for the 0.3-mm fraction. The data demonstrate the high degree of patchiness in the samples.

Because relatively few species are numerically dominant in deep-sea communities (Sanders and Hessler, 1969; Chapter 3, this report), the approach taken gives the most

insight into the distribution of standing stocks among taxa. It should be noted that these data provide information only on standing stocks and not on productivity. A valuable addition to this type of research would be an analysis of biochemical constituents of the standing stocks such as the work conducted by Khripounoff et al. (1980) and Khripounoff and Rowe (1985).

CHAPTER 5. BENTHIC RECOLONIZATION EXPERIMENTS

INTRODUCTION

One objective of the U.S. Mid-Atlantic program was to estimate the recovery rates of deep-sea benthic communities that may be affected by drilling-related activities (Chapter 1). Responses of the infauna may occur at any stage in their life history and interpretation of data is hindered if information on the initial settlement stages is unavailable. For example, a decrease in population numbers detected in box core samples over time may be due either to high mortality of the established population or to lack of natural larval settlement. In the first case, drilling muds would be suspected of directly affecting the growth and survival of the organisms by clogging tubes or feeding apparatuses, or by diluting food resources. In the second case, however, a drilling-mud veneer could be inhibiting larval settlement at the site (i.e., if the animals settle in response to specific cues from the seabed), even though established organisms were able to survive. In addition, infaunal samples represent an integration of benthic processes over long periods of time; thus, although settling larvae may respond quickly to drilling effects, these responses may be masked by other signals in the infaunal community and not detected from analysis of bottom cores alone. To overcome this limitation it was necessary to estimate settling and recruitment of organisms on the seabed. Sediment trays were therefore used to provide data for comparison with collections by bottom cores.

METHODS

Design of Free-Vehicle Sediment Trays

The free vehicle (Figures 36 and 37) consists of a fiberglass frame that holds six sediment trays, a fiberglass lid to cover the trays, and an aluminum support structure to which the flotation, the transponder-release, the radio beacon, the strobe-light and signal flag, and the pelican-hook release are attached (Figure 36). To make the structure negatively buoyant, seven steel plates are attached to a ring underneath the center of the frame. The ring attaches to the pelican-hook release and, upon an acoustic command

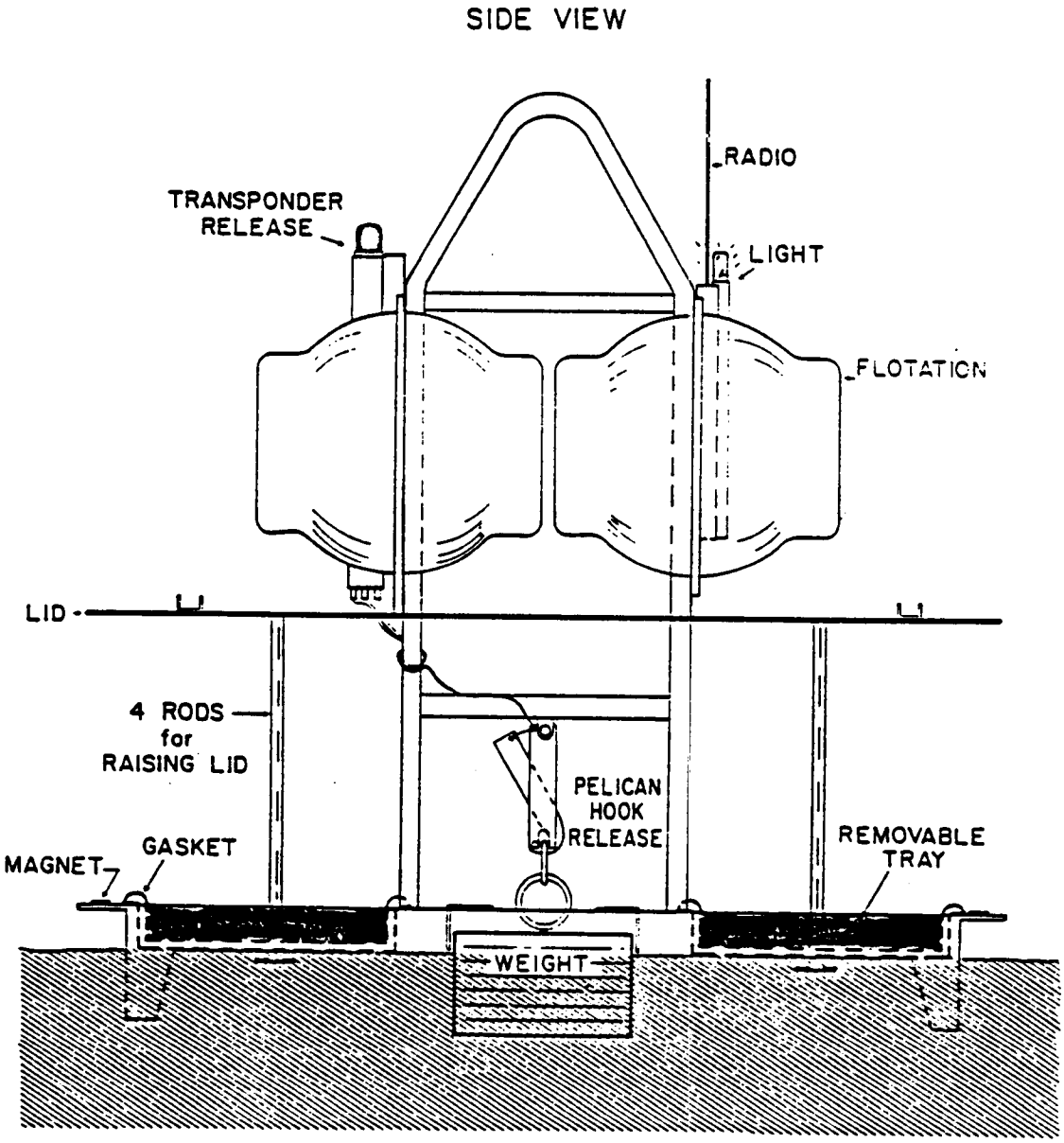

Figure 36. Side View of Free-Vehicle Sediment Tray Array.

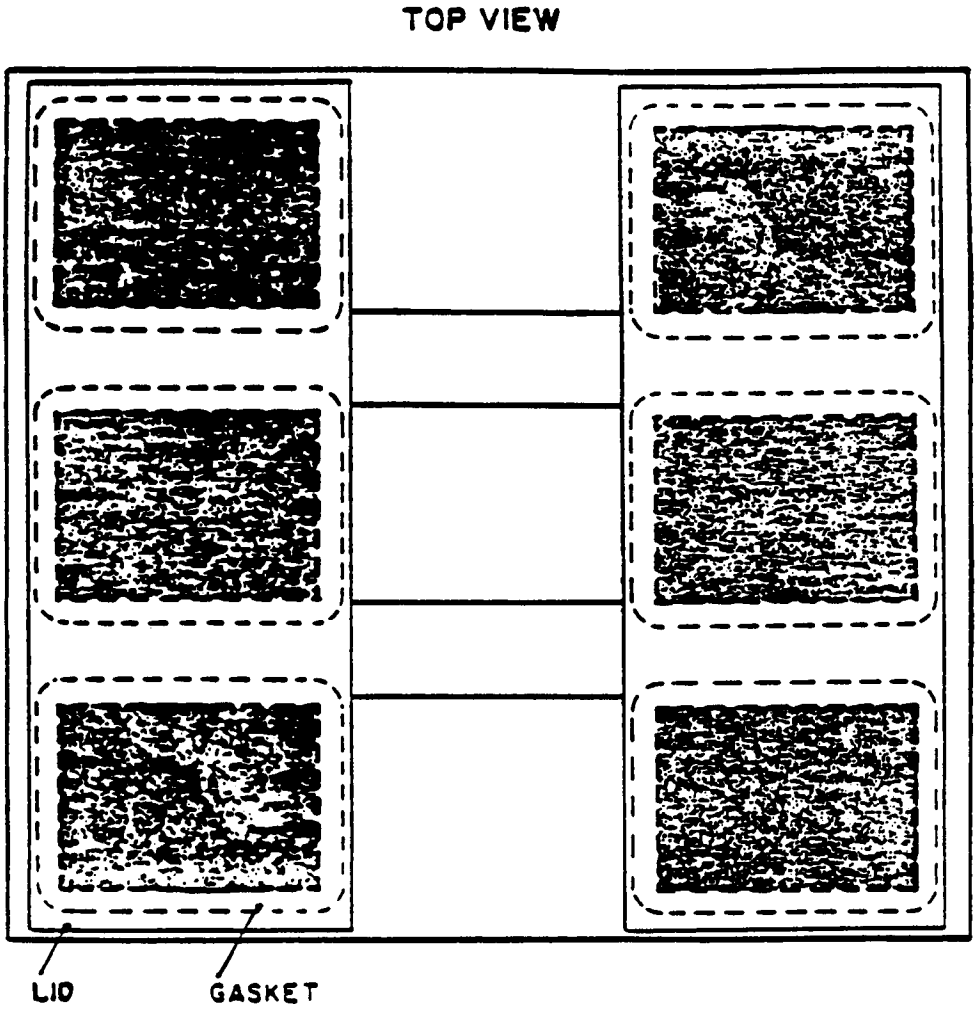

Figure 37. Top View of Free-Vehicle Sediment Tray Array.

from the surface vessel, a burn-wire holding the pelican hook vertical is electrically corroded. The hook falls down horizontally and the ring slides out. The weights are then released from the frame, the structure rises up to meet the lid. The lid seals tightly by means of silicone rubber gaskets around each tray and magnets all around the perimeter of the lid and the whole vehicle floats to the surface. The aluminum frame is about 1 m tall from the trays to the horizontal cross-bar (Figure 36) and has a loop on top to allow deployment and retrieval using the ship's crane.

A rectangular fiberglass frame (1.52 m by 1.42 m) holds six removeable polyethylene trays (30 cm by 40 cm by 7.5-cm deep) that can be filled with sediment (Figure 37). Each tray is surrounded by a silicone rubber gasket (1 cm by 1 cm) to ensure a tight seal with the lid. The frame is raised on feet that would hold the tray sediments 10 cm above the bottom on flat, hard ground, but sink into soft sediments in the field (Figure 36). The lid rests on stainless steel rods that slide through holes in the fiberglass frame. When the free vehicle rests on the bed, the feet raise the lid about 43 cm above the tray sediments, but when the vehicle lifts off the bottom, the trays rise up to meet the lid. All materials used in the construction of the trays and free vehicles were selected for their chemical inertness in seawater.

Mud to be used in the free vehicles was collected from all U.S. Mid-Atlantic stations. This mud consisted of the 0 to 10-cm fraction of the undesignated subcores from each box core (see Chapter 2). The sediment was stored in 20-gal polyethylene trash cans and frozen until use, at which time it was thawed and homogenized. Each of three trays was filled to the brim with sediment. Sometimes the other three trays were left empty to see how much sediment was trapped; at other times, additional trays were filled with sediment for additional analyses if needed.

Study Design

The schedule for deployment and retrieval of the recolonization trays was discussed in Chapter 2 (Table 4). Four free vehicles were deployed and retrieved at each of two stations, Stations 2 and 4. These free vehicles were deployed in May 1984; half were recovered after six months on the bottom, and half were retrieved after one year. A final group of four free vehicles was deployed at Station 2 in May 1985 on Cruise Mid-4 and retrieved on Cruise Mid-6 in November 1985 after a six-month deployment.

Nine of the subcores from each tray were processed for infaunal analysis; the remaining three subcores were frozen and archived for sediment grain size, CHN, trace metal, or hydrocarbon analyses. Only biology samples were collected from the six trays analyzed from the last group of free vehicles. The archived samples were to be analyzed only if results of the infaunal analyses indicated a need for additional information.

Laboratory Processing

The samples from the sediment trays were processed in the same way as the box core samples (see Chapter 3).

RESULTS

Tables 27 to 30 show the results of four colonization experiments left at Stations 2 and 4 from May 1984 before drilling started until November 1984 or until May 1985. Results from each experiment consist of data from three replicate samples. With the exception of the November 1984 trays retrieved from Station 2, one of the three replicates was from a separate free vehicle.

The six-month trays retrieved in November 1984 were quite similar between replicates and stations. The total number of individuals in each tray ranged from 12 to 24 and the number of species ranged from 9 to 18. Aurospio dibranchiata was the most common species at both stations, with a total of five individuals in each set of three trays. Although it is unclear whether Capitella was represented by one or more species, this genus was also represented by five individuals at each site after six months.

At Station 2, the deployment closest to the drilling rig, the numbers of A. dibranchiata and Capitella spp. declined after approximately one year. At Station 4, the numbers of A. dibranchiata increased sharply while Capitella remained the same. Ophelina cylindricaudata increased sharply at Station 4, but not at Station 2. The aplacophoran mollusc Spathoderma clenchi increased at both stations and juvenile ampharetid polychaetes increased at Station 2. The total number of individuals in the one-year trays at Station 4 was also significantly greater than in the one-year trays deployed at Station 2.

TABLE 27. SPECIES RECORDED IN RECOLONIZATION TRAYS DEPLOYED AT U.S. MID-ATLANTIC STATION 2 FOR SIX MONTHS (5/84 TO 11/84).

	Tray 2*	Tray 3*	Tray 5*	Total
POLYCHAETA				
Ampharetidae spp. juv.	1			1
Ampharetidae sp. 12	1			1
Aricidea catherinae	1			1
Aricidea tetrabranchia			1	1
Aurospio dibranchiata	2	3		5
Capitellidae sp. 3		1		1
Capitella spp. complex		4	1	5
Chaetopteridae sp. juv.		1		1
Dorvilleidae sp. 2	2			2
Glycera capitata		1		1
Kesun gravieri	1			1
Laonice sp. 1	1			1
Leitoscoloplos spp. juv.		1		1
Paramphinome jeffreysii		1	2	3
Pholoe anoculata	2			2
Poecilochaetus fulgoris	1			1
Prionospio sp. 2	2			2
Prionospio sp. 11	3			3
Pseudoscalibregma parvum		1		1
Sclerobregma branchiata			1	1
Spiophanes sp. 1	1			1
Terebellidae spp. juv.	1			1
Trochochaeta watsoni			1	1
ARTHROPODA				
Amphipoda				
Liljeborgia sp. 1	1			1
Isopoda				
Nannoniscus minutus	1			1
Tanaidacea				
Agathotanais cf. hanseni			2	2
Paranarthrura cf. insignis			2	2
Pseudotanais sp. 3		1		1
MOLLUSCA				
Aplacophora				
Chaetoderma sp. 3		1		1
Chaetoderma sp. 4		1		1
Bivalvia				
Neilonella subovata		1		1
Nucula cancellata	1			1
Thyasira subovata	1			1
Gastropoda				
Eulima sp. 1			1	1
MISCELLANEOUS				
Anthozoa sp. 2		1		1
Nemertea sp. 5		2		2
Siboglinum pholidotum		1		1
Tubulariidae sp. 1	1			1
TOTAL				
Individuals	24	21	11	56
Species	18	15	8	38

* All trays are from Free Vehicle 2209.

TABLE 28. SPECIES RECORDED IN RECOLONIZATION TRAYS DEPLOYED AT U.S. MID-ATLANTIC STATION 4 FOR SIX MONTHS (5/84 TO 11/84).

	Tray 1*	Tray 3*	Tray 5*	Total
POLYCHAETA				
Aricidea abranchiata		1		1
Aricidea tetrabranchia		1		1
Aurospio dibranchiata	2		3	5
Capitella spp. complex	3	1	2	6
Glycera capitata		1		1
Laonice sp. 1		1		1
Mystides rarica		1		1
Notomastus latericeus		1		1
Ophelina cylindricaudata			1	1
Orbiniella sp. 1	1			1
Paramphinome jeffreysii	1	2	1	4
Prionospio sp. 2	2		1	3
Prionospio sp. 11	2		2	4
Spiophanes sp. 1			1	1
Tharyx sp. 9			1	1
Trochochaeta watsoni	1	1		2
ARTHROPODA				
Amphipoda				
Amphipoda sp. 8	2			2
Lysianassidae sp. 10	1	1		2
Isopoda				
Eugerda tetarta		1		1
Tanaidacea				
Paranarthrura cf. insignis		1		1
MOLLUSCA				
Bivalvia				
Thyasira subovata		2		2
Gastropoda				
Cocculina sp. indet.		1		1
Scaphopoda spp. indet.		1		1
MISCELLANEOUS				
Anthozoa sp. 2	1			1
Nemertea sp. 5			1	1
Nemertea sp. 9		1	1	2
Tubulariidae sp. 1	1			1
Priapulus caudatus			1	1
TOTAL				
Individuals	17	18	15	50
Species	11	16	11	28

* Trays 1 and 5 are from Free Vehicle 2207; Tray 3 is from Free Vehicle 2210.

TABLE 29. SPECIES RECORDED IN RECOLONIZATION TRAYS DEPLOYED AT U.S. MID-ATLANTIC STATION 2 FOR ONE YEAR (5/84 TO 4/85).

	Tray 1*	Tray 3*	Tray 5*	Total
POLYCHAETA				
Ampharetidae spp. juv.	3	3	2	8
Aricidea tetrabranchia			1	1
Aurospio dibranchiata		1	1	2
Capitella spp.	1			1
Lacydoniidae spp.			1	1
Laonice sp. M			1	1
Maldanidae spp.			2	2
Ophelina cylindricaudata		1		1
Paramphinome jeffreysii			1	1
Paraonidae spp. juv.	1			1
Pholoe annoculata	1			1
Prionospio sp. 2			1	1
Prionospio spp.	1			1
Spiophanes sp. 1	1			1
Terebellidae spp. juv.	3	1	1	5
Trochochaeta watsoni			1	1
ARTHROPODA				
Amphipoda				
Amphipoda sp. 7		2		2
Liljeborgia sp. 1		1		1
Isopoda				
Chelator insignis		1		1
Gnathia sp. 2	3	1		4
Mirabilicoxa similis			1	1
Nannoniscus sp. 1		1		1
Tanaidacea				
Agathotanais cf. hanseni		1		1
Anarthrurid sp.			1	1
Paranarthrura cf. insignis			1	1
Typhlotanais sp. 3	1			1
MOLLUSCA				
Aplacophora				
Lepidomeniidae sp. 2		1		1
Spathoderma clenchi			1	1
Bivalvia				
Neilonella subovata		1		1
Nucula cancellata		1		1
Yoldiella curta		1		1
Scaphopoda				
Dentallidae sp. 5		1		1
MISCELLANEOUS				
Dicarpa simplex	1	2		3
Echiura sp. 1	1	1		2
Echiura sp. 5		1		1
Molpadia albiens	1			1
TOTAL				
Individuals	18	22	16	56
Species	12	18	14	36

* Trays 1 and 3 are from Free Vehicle 2211; Tray 5 is from Free Vehicle 2213.

TABLE 30. SPECIES RECORDED IN RECOLONIZATION TRAYS DEPLOYED AT U.S. MID-ATLANTIC STATION 4 FOR ONE YEAR (4/84 TO 4/85).

	Tray 1*	Tray 3*	Tray 5*	Total
POLYCHAETA				
Aricidea catherinae			1	1
Aricidea tetrabranchia			1	1
Augeneria bidens			1	1
Aurospio dibranchiata	2	5	10	17
Capitellidae spp.	1	3	1	5
Cirratulidae spp. juv.		1	1	2
Dorvilleidae sp. 2	1			1
Flabelligella cirrata	1			1
Laonice sp. M		1	1	2
Lumbrineridae spp. juv.	1			1
Nereimyra punctata	1			1
Ophelina cylindricaudata	5	2		7
Phyllochaetopterus sp. 1		1		1
Poecilochaetus bermudensis			1	1
Prionospio sp. 2	1	1		2
Spionid spp. indet.	1		4	5
Terebellidae spp. juv.	2			2
Tharyx sp. 1	1			1
Trochochaeta watsoni		1	1	2
ARTHROPODA				
Amphipoda				
Oradarea sp. 1		2		2
Cumacea				
Hemilamprops cristatus	1		1	2
Leptostylus sp. 1		2		2
MOLLUSCA				
Aplacophora				
Falcidens sp. 4		1		1
Bivalvia				
Yoldiella lucida		1		1
Thyasira subovata			1	1
Scaphopoda				
Dentalliidae sp. 5		1		1
MISCELLANEOUS				
Dicarpa simplex		1	1	2
Echinoidea sp. 3 juv.	1			1
Echiura sp. 1		2		2
Echiura sp. 5	2			2
Echiura spp. indet.		1		1
Holothuroidea spp. juv.	1			1
Myriotrochinae sp. 1 juv.	1		2	3
Nemertea sp. A	1			1
Nemertea sp. 2			4	4
Ophiuroidea sp. 1 juv.			1	1
Priapulus caudatus		1		1
TOTAL				
Individuals	24	27	32	83
Species	17	17	16	37

* Trays 1 and 3 are from Free Vehicle 2204; Tray 5 is from Free Vehicle 2205.

The grain-size composition of the sediments in the trays was analyzed in order to evaluate the possibility that the differences in the fauna were due to differences in sediment grain size. Percent sand in the trays deployed at Station 2 ranged from 7.3 to 18.0 percent in the six-month trays and from 22.7 to 44.5 percent in the one-year trays. Percent sand in the trays deployed at Station 4 ranged from 6.0 to 8.6 percent in the six-month trays and from 5.0 to 5.2 percent in the one-year trays.

The six-month trays deployed at Station 2 from May to November 1985 sampled a different fauna than was recorded over the same time period in 1984 (Table 31). The sediment-dwelling tunicate Dicarpa simplex and the ectoparasitic isopod Gnathia sp. 2 were absent in 1984 but common in 1985. Two similar species were among the most abundant colonists of a two-year experiment conducted further north at 1760-m depth in 1972-74 (Grassle, unpublished data). Gnathia is an ectoparasite on fish and probably depends on visits to the trays by these animals. Sediment-dwelling tunicates are among the most rapidly growing deep-sea species, and their reproduction may be episodic and independent of seasonal cues from spring blooms of phytoplankton. The polychaete Paramphinome jeffeysii was common in 1984 and absent in 1985. This species is much less abundant at 2100 m than at 1500 m, implying that successful recruitment may depend on transport of larvae down-slope by currents.

Spionid polychaetes and Capitella-like species were both much more common in 1984 than in 1985. Since these groups are favored by organic-rich sediments, the differences in abundance might be explained by small differences in the sediments used in the trays in subsequent years.

DISCUSSION

Instrumentation to accurately document larval settlement and subsequent recruitment in soft sediments in the field is still in the developmental stages. In shallow subtidal habitats (i.e., < 30 m), the relatively high and variable flows over structures raised above the seabed generally trap artifacts (e.g., Hannan, 1981; 1984), making it difficult to interpret data. In intertidal habitats, directly removing patches of the seafloor and replacing these areas with defaunated sediments made flush with the adjacent bed has probably been the most successful method for determining processes that control larval

TABLE 31. SPECIES RECORDED IN RECOLONIZATION TRAYS DEPLOYED AT U.S. MID-ATLANTIC STATION 2 FOR SIX MONTHS (5/85 TO 11/85)

	Free Vehicle E			Free Vehicle F			
	Tray 1	Tray 3	Tray 5	Tray 1	Tray 3	Tray 5	Total
POLYCHAETA							
Aricidea abranchiata				1			1
Aricidea tetrabranchiata			1				1
Aurospio dibranchiata	1				1	1	3
Capitellidae spp. juv.	2				1		3
Capitella spp. complex		1	1				2
Exogone sp. 1					1		1
Kesun gravieri			1				1
Poecilochaetus fulgoris						1	1
Phyllochaetopterus sp. 1						1	1
Prionospio sp. 6					1		1
Prionospio sp. 20				1			1
Spiophanes sp. 1					1		1
Trochochaeta watsoni	1						1
MOLLUSCA							
Gastropoda							
Nystiella nitida		1					1
ARTHROPODA							
Isopoda							
Gnathia sp. 2	1		2	1	2	1	7
Tanaidacea							
Agathotanis cf. hanseni			1			1	1
Pseudotanis sp. 1						1	1
MISCELLANEOUS							
Asipodosphion zinni	1			1	1		3
Dicarpa simplex	4	3	1		2		10
Nemertea sp. 5					1		1
Golfingia improvisa					1		1
Priapulus cauvatus	1			2			3
TOTAL							
Individuals	11	5	7	6	12	5	46
Species	7	3	6	5	10	5	36

recruitment (e.g., Williams, 1980; Eckman, 1983; Gallagher et al., 1983). In the deep sea, however, such direct manipulations of the seafloor generally are not possible. Thus, for the past 15 years, shallow, rectangular boxes filled with defaunated sediments have been placed directly on the seabed to allow estimation of rates of recolonization in the deep sea (Grassle, 1977). Such experiments are complicated by the fact that the boxes must be deployed and recovered with the lids securely sealing the sediments for transit through the water column. This is easy with a submersible such as Alvin because the manipulator arm can open and close the boxes. However, because a submersible cannot be used for all deep-sea studies, free-vehicle arrays containing sediment trays have been designed and deployed with various levels of success (Smith et al., 1979; Desbruyeres et al., 1980; Levin and Smith, 1984).

The free vehicles in the studies cited above and the free vehicles previously used by the present investigators had sediment trays with lids attached along one side of the tray and held vertical to the sediment surface during collections. The lids opened by means of corrosible magnesium links and closed by time-released weights. This arrangement was not always successful (e.g., Levin and Smith, 1984) and this, coupled with concern that the vertical lid could significantly alter the flow across the sediment tray, depending on the flow speed and direction, resulted in a new lid design for the present study. The new lid arrangement (Figure 36) allows a free exchange of fluid across the whole sediment tray surface and offers no spatially varying flow disturbances. The height of the lid was designed so that relatively fast-falling particles (biological or nonbiological) would not be impeded by the "shadow" of the lid; i.e., so trajectories of particles that would normally intercept the sediment tray surface would not be first intercepted by the lid. Relatively slow-falling particles are not a concern because they essentially follow the flow and are not affected by the lid unless the flow is affected.

The free-vehicle array deployed during the present study is a considerable improvement over the previous design. However, a growing awareness of the role of near-bed flow processes in benthic ecology (e.g., Jumars and Nowell, 1984) prompted a detailed laboratory flume study and theoretical analysis of the possible effects of this structure on the natural near-bed flow regime. This analysis was conducted by C.A. Butman of the Ocean Engineering Dept., WHOI, and resulted in a complete redesign of the free-vehicle array to minimize potential flow artifacts. Both designs have been subsequently deployed

at both U.S. Mid-Atlantic and North Atlantic stations. The results of the flow analysis were presented in the interim report on the North Atlantic study (Maciolek et al., 1986b).

The differences in the fauna in the one-year trays are very likely due to the differences in the percentages of sand in the sediments in those trays. At Station 2, the percentage of sand in the sediments was about six times higher than in the one-year trays deployed at Station 4. There were no differences in levels of trace metals in the tray sediments compared to the range of values obtained at the slope stations where the sediment was originally collected (Bothner et al., 1987).

The experiments with sediment trays confirm previous results in other areas (Grassle, 1977; Desbruyeres et al., 1985), namely that larval colonization rates are generally slow in the deep sea. Differences in abundance of relatively opportunistic species such as spionids and Capitella-like polychaetes occurred in subsequent years; however, the unusual increase in opportunists in a single experiment such as that observed by Desbruyeres et al. (1985) was not seen in this study. An aggregation of organic material or other major disturbance in the vicinity of the trays would be likely to result in large numbers of capitellids and spionids. The present results are in keeping with the more normal sequence of events observed south of New England (Grassle, 1977; Grassle and Morse-Porteous, in press).

CHAPTER 6. EPIFAUNA

INTRODUCTION

The primary objective of the epifaunal portion of the U.S. Mid-Atlantic monitoring program was to assess the potential effects of exploratory drilling discharges on the larger components of the benthic fauna. The specific questions addressed were whether megafaunal populations change in the vicinity of, and downcurrent of, the exploratory drill site in Block 372, and whether these changes were related to drilling activity. To accomplish this task, towed camera-sled transects were initially conducted prior to spudding the well (April-May 1984), and were then repeated two months (August 1984) and 14 months (August 1985) after drilling had been completed. The first post-drilling transects were conducted to assess possible short-term changes in epifaunal composition; whereas the second post-drilling transects addressed possible longer-term changes.

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. 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 underestimation 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 sampling design was configured to assess megafaunal populations at various distances from the drill site (Figure 38). The first transect (drill site) was positioned to survey the immediate vicinity of the drill site, as well as downcurrent and upcurrent areas. This 44-km-long transect passed through the drill site, starting 35 km in the downcurrent direction (SW) and ending 9 km upcurrent (NE). The second transect circumscribed a circle with a radius of 2.3 km around the drill site. This 17.3-km-long transect surveyed areas both upslope and downslope from the drill site, as well as in downcurrent and upcurrent directions. With this sampling configuration, nearfield effects were addressed by both the circle transect and the portion of the drill site transect that was adjacent to the drill site; far-field effects were addressed by the remaining portions of the drill site transect.

Photography

The photographs were taken with the towed camera sled BERNEI (Benthic Equipment for Reptant and Natant Epifaunal Imaging). The camera was oriented facing forward at an angle of 13.5° 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.

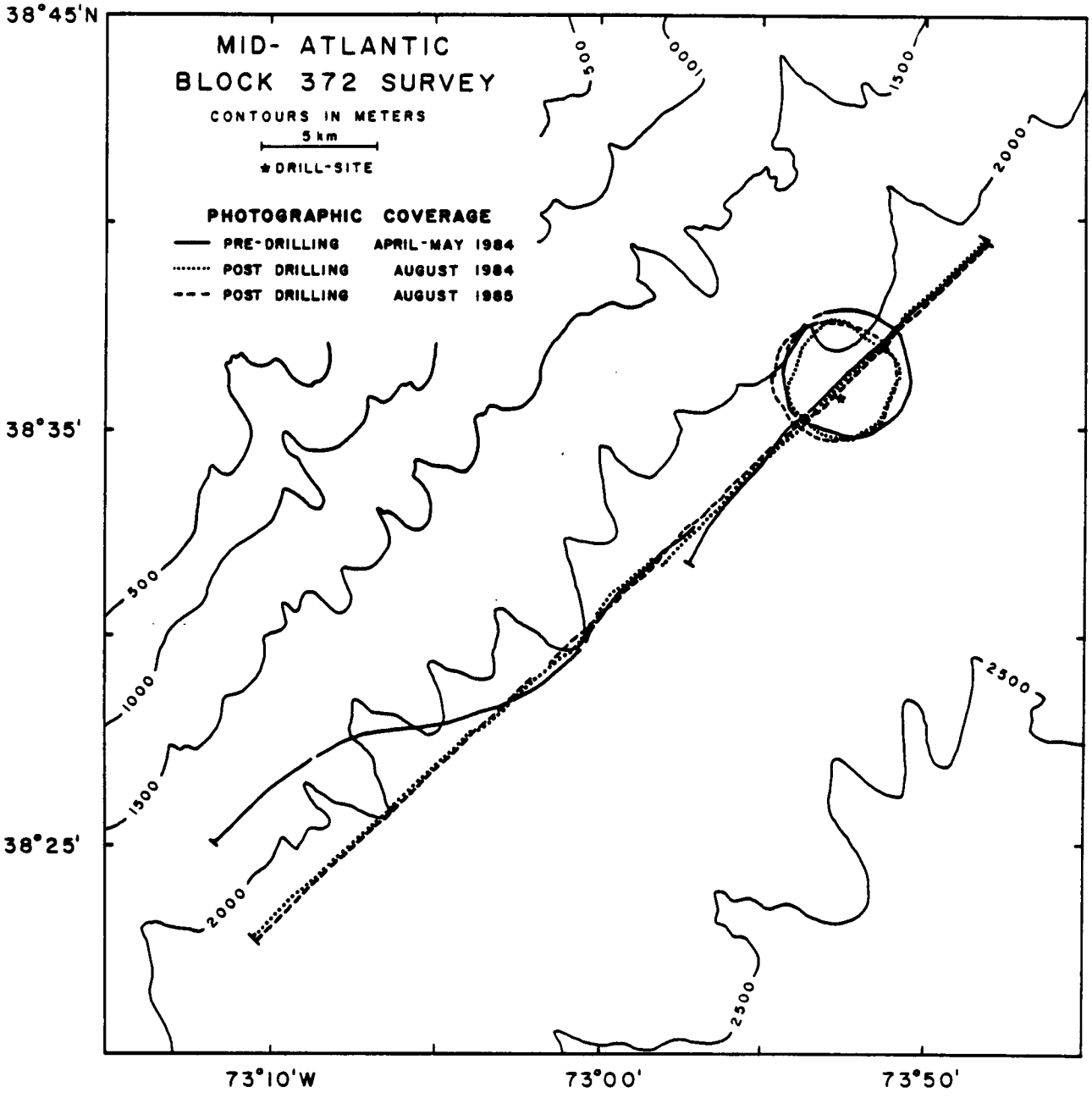

Figure 38. Photographic Coverage from Nine Camera-Sled Tows in the Vicinity of The Block 372 Drill Site.

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. This covered 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, species occurrence, and abundances. The number of square meters viewed was measured by photographing quadrates corrected for the refractive index of seawater. 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. 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 on photographs.

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 also not included because it was impossible to determine whether they were inhabited. General taxonomic categories (i.e., anemone, fish, sea pen) 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 information was 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 by the viewer. 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, then the entire film was rechecked and corrected for those inconsistencies.

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 85 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 nine camera tows were conducted during this study; the circle transect consisted of one camera tow and the drill-site transect consisted of two contiguous camera tows (see Chapter 2, this report). Each transect was initially surveyed prior to drilling activity (April-May 1984), and was repeated two months (August 1984) and fourteen months (August 1985) after drilling had been completed. Because of difficulties in maintaining steerage at 1 kn, the camera tows did not always cover exactly the same area (Figure 38). This problem was most pronounced during the pre-drilling tow at the start of the drill-site transect.

A total of 90,282 m^2 of the seafloor, spanning a depth range of 1756 to 2353 m, was viewed for this study. The 44-km-long drill-site transect was centered along the 2100-m isobath, and traversed a series of valleys and ridges covering a depth range of 1901 to 2353 m. Depths above 1901 m were covered only during the pre-drilling tow that veered

upslope of the transect line. The shallowest region covered during all three cruises was a ridge located 16 km southwest of the drill site; the deepest was the axis of Lindenkohl Canyon at the northeast end of the transect. The drill site was located at 2195 m on the southwest flank of a flat ridge. The circle transect covered the valley upslope and downslope of the drill site, as well as the upcurrent and downcurrent ridges on either side. The depth range covered by the circle transect extended from 1950 to 2324 m. Depths obtained from the transducer on the camera sled were generally 50 m deeper than those obtained from the shipboard depth recorder. The depths reported in this chapter are those obtained from the transducer on the camera sled.

Photographic coverage was patchiest down steep slopes because of the inability of the camera sled to maintain bottom contact. Surficial sediment encountered in most of the areas consisted of a fine-textured mud. Occasionally, isolated glacial erratics were encountered on the upper flanks of ridges, and outcrops ranging from low-relief ledges to sheer cliffs were encountered on the lower walls of valleys. No evidence of drill cuttings or piles was observed in the vicinity of the drill site, possibly because the tows passed slightly west of the drill site. However, a discarded plastic pipe casing and a pipe protruding from the sediment were observed in the first post-drilling tow.

Clam Area

One particularly interesting area was found between 2100 and 2200 m at the base of a high ridge 17 km southwest of the drill site. This area, which was exceptionally steep, was characterized by numerous low-relief outcrops and massive pieces of talus. Glacial erratics and ripple marks were also seen on the seafloor in this area. The seafloor throughout this area was strewn with numerous disarticulated valves of a large clam. Near the base of the slope these clam shells were so dense that they completely carpeted the seafloor. Dredge samples from this area yielded approximately 30 valves, many of which were imbedded in a stiff semi-consolidated clay. These valves were identified as a species belonging to the genus Calyptogena (R. Turner, pers. comm.). All of the clams in this area appeared to be dead. Age-dating of two shells, by a gas ^{14}C technique, indicated that these shells were approximately 1300 years old (R. Stoenner, pers. comm.).

Faunal Abundance and Depth Distribution

The density of total megafauna with depth and the relative proportion contributed by each of five selected species are shown in Figure 39. Together, these five species accounted for the majority of the fauna seen throughout the depths surveyed (1756 to 2353 m). Faunal density was high between 1800 and 1900 m (5.3 to 5.7 individuals per m^2) and gradually decreased between 1900 and 2350 m (from 3.8 to 2.4 individuals per m^2). Two species, the ophiuroid Ophiomusium lymani and a cerianthid anemone, accounted for approximately 75 percent of the total megafauna found above 2100 m. Both species exhibited maximum densities (2.2 and 1.8 individuals per m^2, respectively) between 1800 and 1900 m, but were found in relatively high abundances as deep as 2250 m. Two other species, the sea pen Kophobelemnon stelliferum and the urchin Echinus affinis, became increasingly abundant below 2200 m. Both of these species were found in highest densities between 2300 and 2350 m, with K. stelliferum accounting for 1 individual per m^2 and E. affinis accounting for 0.4 individuals per m^2. A fifth species, the soft coral Acanella arbuscula, was present in low densitites throughout most of the depth range surveyed, and showed a peak in abundance of 0.3 individuals per m^2 between 2000 and 2150 m. A variety of other taxa accounted for the remaining fauna seen.

Transect Analysis

Continuous plots of depth, trophic type, and faunal density along the transects were used to examine shifts in faunal composition with changes in local topography and between pre- and post-drilling surveys (Figures 40 to 45). With few exceptions, all organisms seen in the photographs were assigned to one of three trophic categories. Designations of carnivore/scavenger, deposit feeder, or filter/suspension feeder 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 relative proportion of deposit feeders. Carnivores represented less than 3 percent of the epifauna

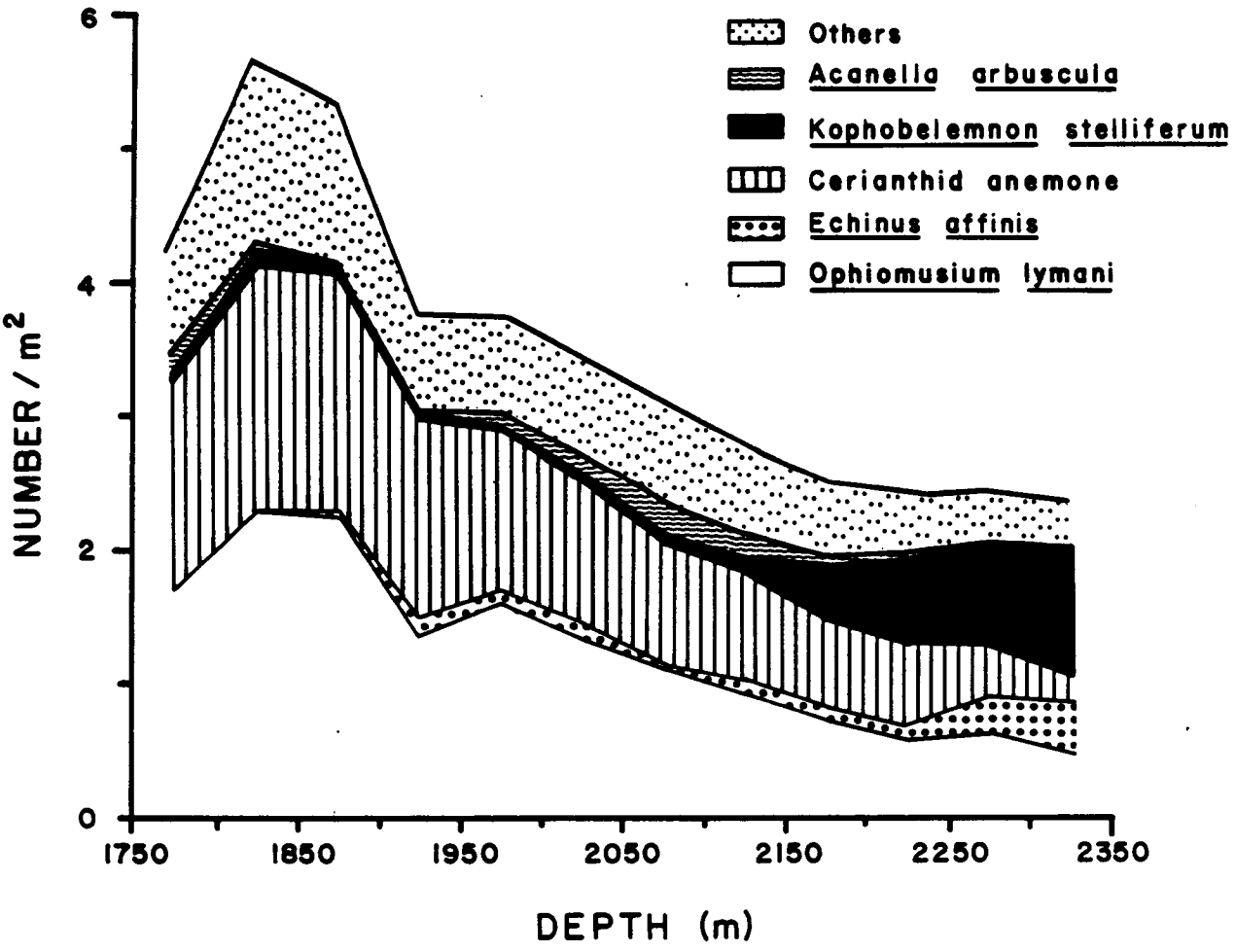

Figure 39. Density of Total Megafauna and Five Selected Species With Depth.

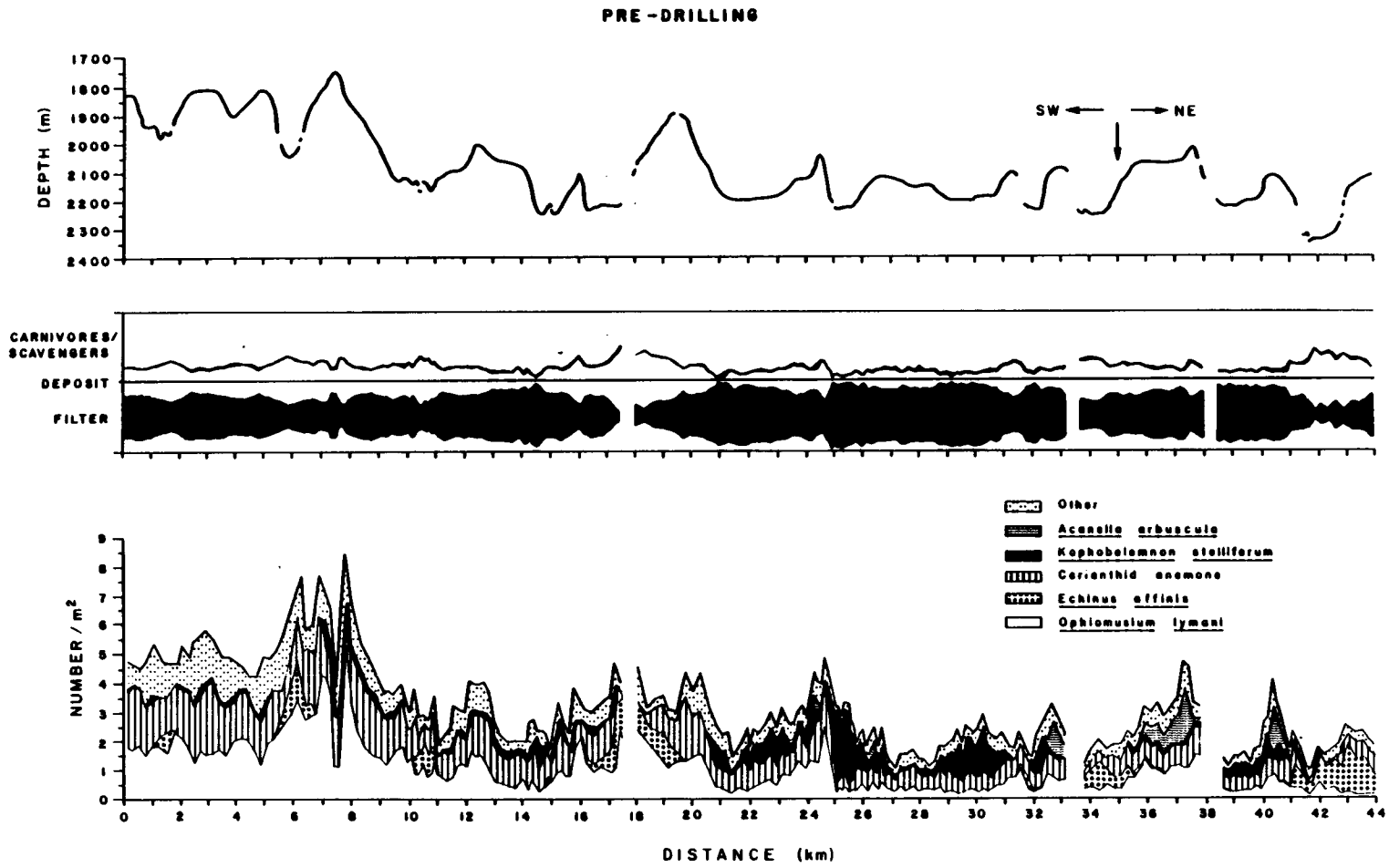

Figure 40. Depth, Trophic Type, and Abundance of Total Megafauna and Five Selected Species From the Two Pre-Drilling Camera-Sled Tows Along the Drill-Site Transect. The Relative Proportion of Deposit Feeders Is Represented by the Clear Envelope Around the Center Line; the Relative Proportions of Carnivores/Scavengers and Filter Feeders Are Represented by the Shaded Areas Above and Below the Line, Respectively. The Arrow Marks the Location of the Drill Site.

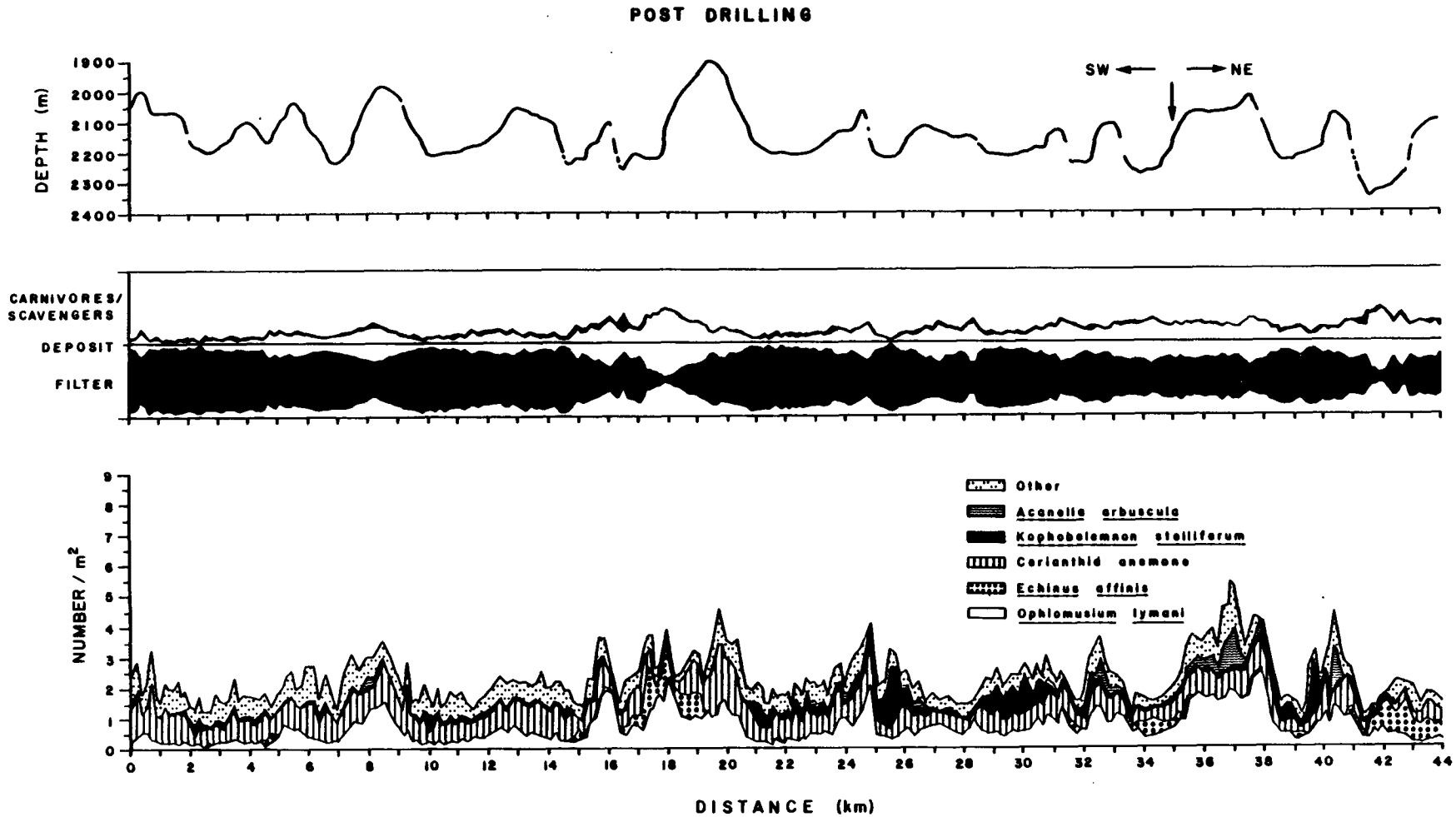

Figure 41. Depth, Trophic Type, and Abundance of Total Megafauna and Five Selected Species from the Camera-Sled Tows Taken Along the Drill Site Transect 2 Months After Drilling. The Relative Proportion of Deposit Feeders Is Represented by the Clear Envelope Around the Center Line; the Relative Proportions of Carnivores/Scavengers and Filter Feeders Are Represented by the Shaded Areas Above and Below the Line, Respectively. The Arrow Marks the Location of the Drill Site.

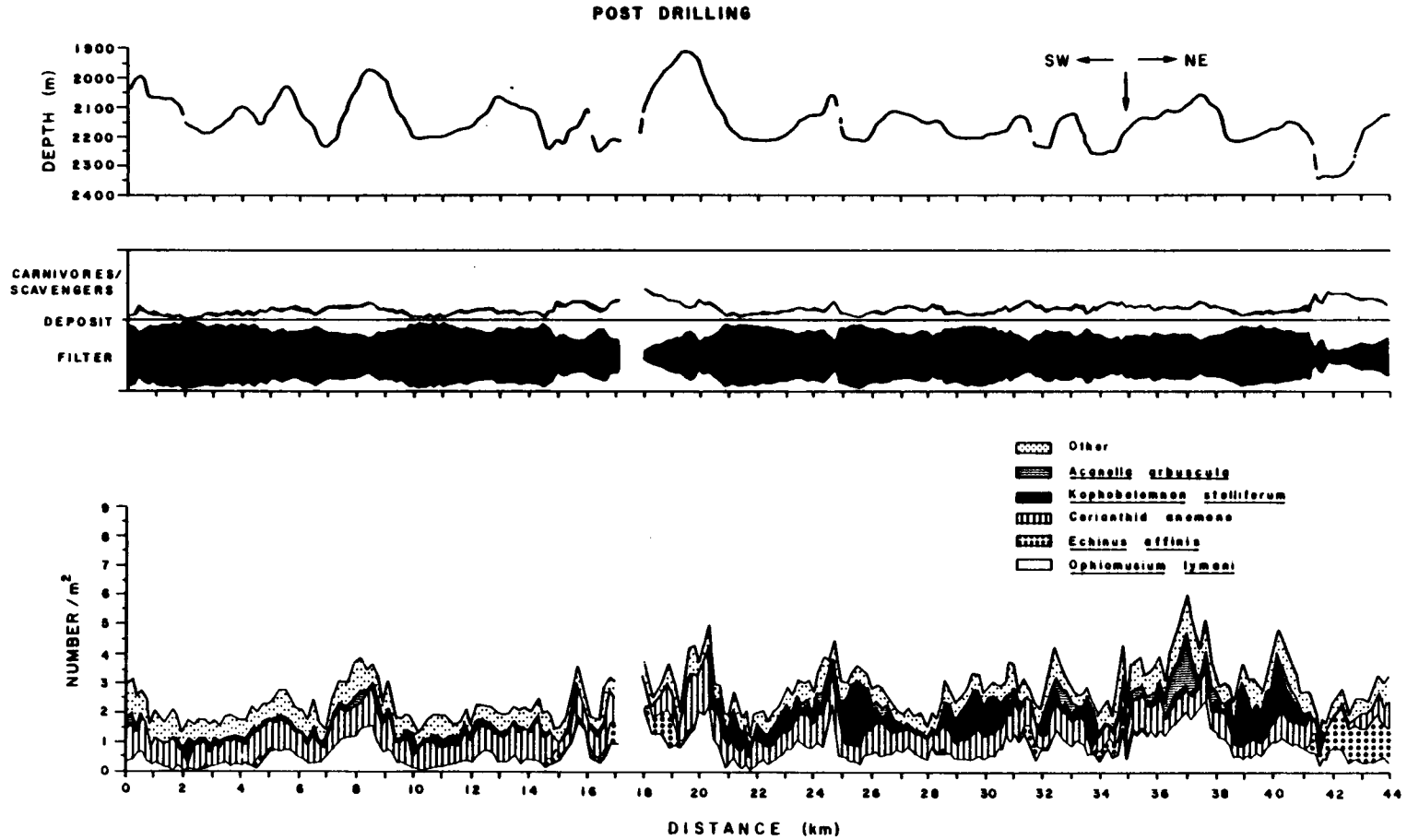

Figure 42. Depth, Trophic Type, and Abundance of Total Megafauna and Five Selected Species from the Camera-Sled Tows Taken Along the Drill-Site Transect 14 Months After Drilling. The Relative Proportion of Deposit Feeders Is Represented by the Clear Envelope Around the Center Line; the Relative Proportions of Carnivores/Scavengers and Filter Feeders Are Represented by the Shaded Areas Above and Below the Line, Respectively. The Arrow Marks the Location of the Drill Site.

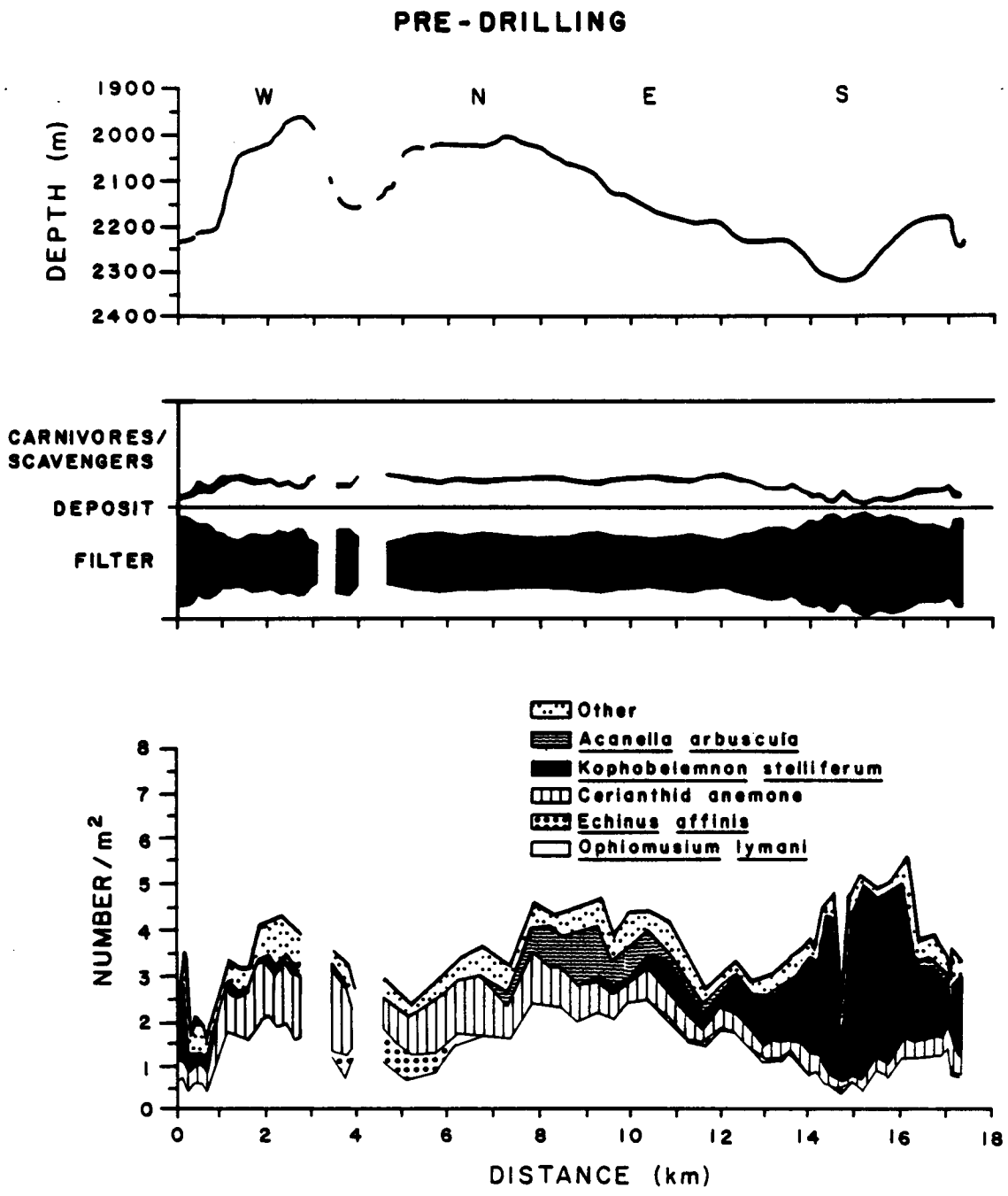

Figure 43. Depth, Trophic Type, and Abundance of Total Megafauna and Five Selected Species from the Pre-Drilling Camera-Sled Tow Along the Circle Transect. The Relative Proportion of Deposit Feeders Is Represented by the Clear Envelope Around the Center Line; the Relative Proportions of Carnivores/Scavengers and Filter Feeders Are Represented by the Shaded Areas Above and Below the Line, Respectively. Directions Above the Depth Plot Correspond to Direction From the Drill Site.

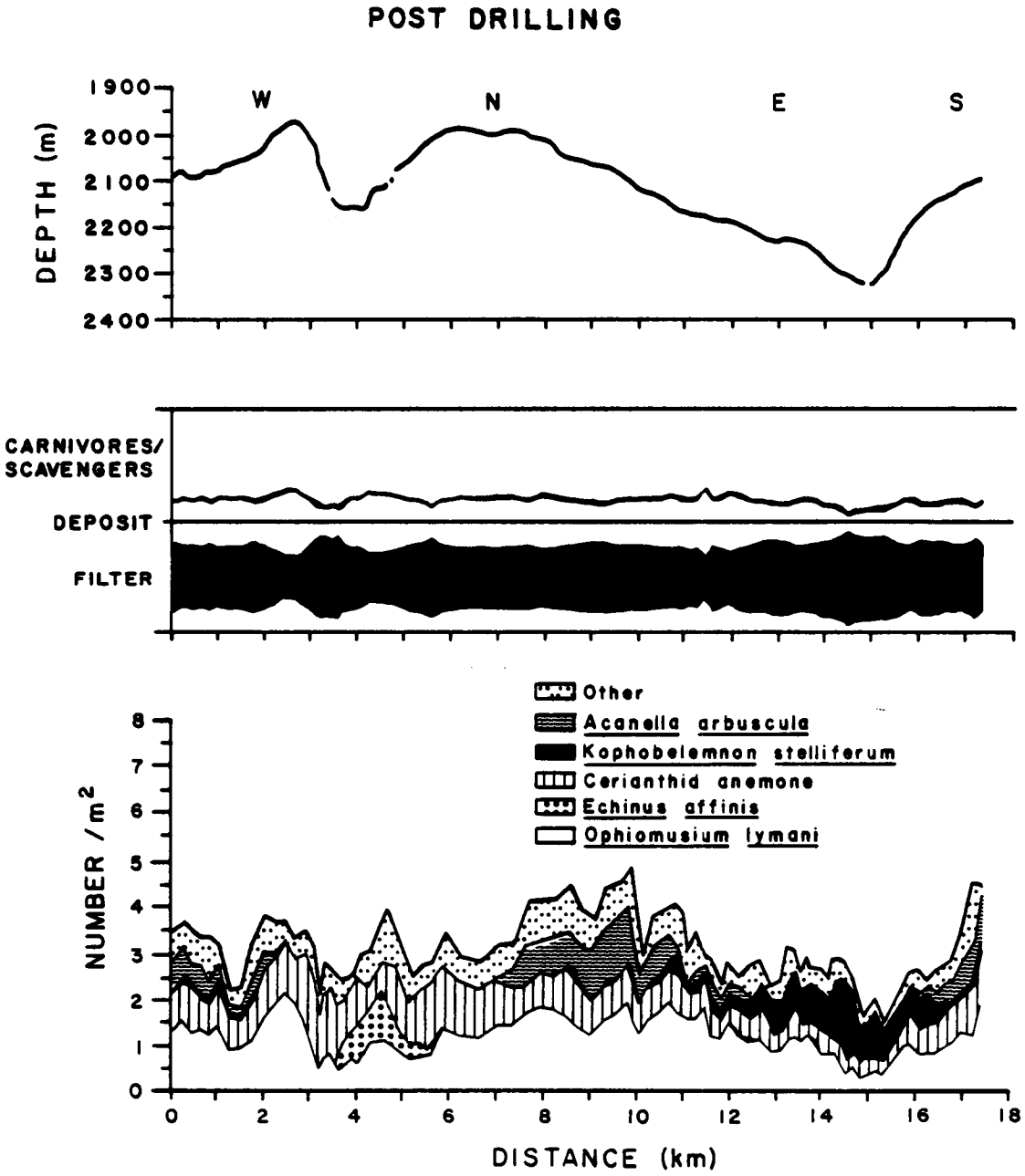

Figure 44. Depth, Trophic Type, and Abundance of Total Megafauna and Five Selected Species from the Camera-Sled Tow Taken Along the Circle Transect 2 Months After Drilling. The Relative Proportion of Deposit Feeders Is Represented by the Clear Envelope Around the Center Line; the Relative Proportions of Carnivores/Scavengers and Filter Feeders Are Represented by the Shaded Areas Above and Below the Line, Respectively. Directions Above the Depth Plot Correspond to Direction From the Drill Site.

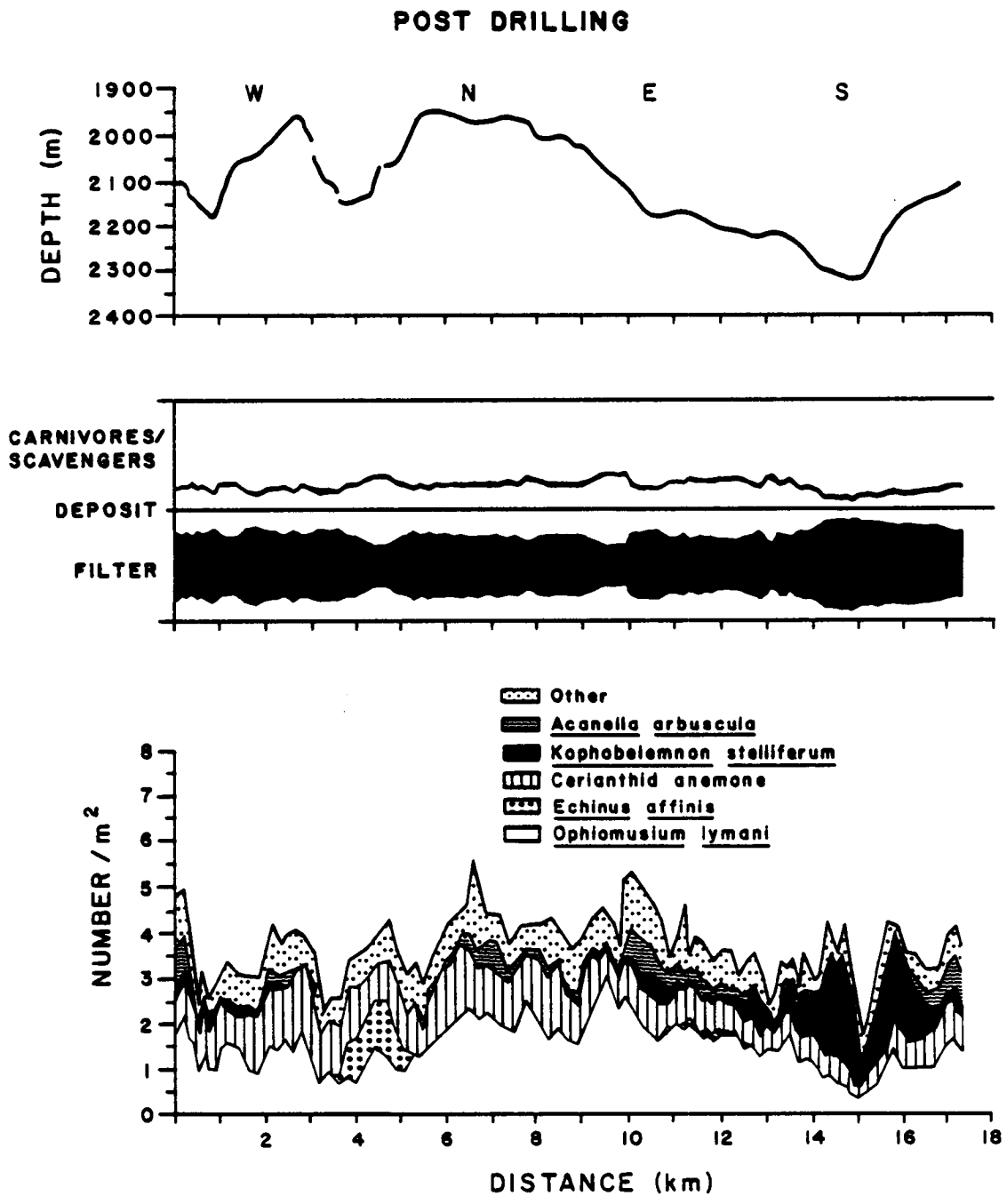

Figure 45. Depth, Trophic Type, and Abundance of Total Megafauna and Five Selected Species from the Camera-Sled Tow Taken Along the Circle Transect 14 Months After Drilling. The Relative Proportion of Deposit Feeders Is Represented by the Clear Envelope Around the Center Line; the Relative Proportions of Carnivores/Scavengers and Filter Feeders Are Represented by the Shaded Areas Above and Below the Line, Respectively. Directions Above the Depth Plot Correspond to Direction From the Drill Site.

inhabiting the surveyed areas. Together, filter feeders and deposit feeders accounted for 97 to 100 percent of the fauna seen, with filter feeders slightly more abundant than deposit feeders. Shifts in the relative proportion of these two feeding types followed the general pattern of higher proportions of filter feeders on ridges and in flat valleys, and higher proportions of deposit feeders on steep slopes and valleys. Faunal densities also varied with topography and followed the general pattern of highest abundances on shallow ridges and in flat valleys, and lowest abundances on steep slopes and in deep valleys. Shifts in the abundance of several species were responsible for most of the observed patterns. Detailed examination of the individual transects elucidated the taxa responsible for the observed shifts in faunal composition.

Drill-Site Transect

Depth, trophic composition, and faunal density along the drill-site transect were plotted for the three sampling periods (Figures 40, 41, and 42). The similarity in the three depth plots indicates that the camera sled covered essentially the same path along most of the transect. One notable exception occurred between the 0- and 14-km marks on the pre-drilling transect (Figure 40), where the camera-sled tow veered considerably upslope of the transect line. A less noticeable difference occurred between the 33- and 41-km marks on the second post-drilling transect (Figure 42), where the camera tow veered slightly downslope of the two preceding tows.

The trophic pattern was generally quite consistent among the three sampling periods. Most of the fauna consisted of filter feeders and deposit feeders, with filter feeders being slightly more abundant than deposit feeders. Proportional increases in one feeding type over the other were found in the same places during each of the sampling periods. Deposit feeders showed marked increases in deeply incised valleys and on steep slopes (at the marks for 10.5, 16, 18, and 42 km), and filter feeders showed marked increases in flatter areas (at 14.5, 21, 25 to 30, 32, and 39 km). The higher proportion of deposit feeders found in the first 14 kilometers of the pre-drilling transect merely reflects differences in the fauna inhabiting the shallower depths surveyed (Figure 40).

The density of five selected species, and the proportion each contributed to the total fauna, is shown on the third plot of each of the figures. Throughout most of the

transect, the densities were generally similar among each of the sample periods. Density of total megafauna was highest on topographic highs and lowest in valleys. Peaks in density frequently reflected the abundance of one or two of the five most common species. Two species, the deposit-feeding ophiuroid Ophiomusium lymani and the filter-feeding cerianthid anemone, were common throughout most of the areas surveyed by this transect. Both of these species were found in highest densities on topographic highs. The three remaining species, the deposit-feeding urchin Echinus affinis, and two filter-feeders, the sea pen Kophobelemnon stelliferum and the soft coral Acanella arbuscula, showed more restricted distributions. These three species appeared to be largely responsible for the observed shifts in trophic structure with variations in topography. E. affinis was most abundant in steep areas, K. stelliferum preferred flat areas of intermediate depth, and A. arbuscula preferred shallower flat ridges. As was found with the density of total fauna, no consistent differences in the density of these five species that may be attributable to drilling activity were discerned.

Circle Transect

Similar plots of depth, trophic composition, and faunal density for the tows along the circle transect are shown in Figures 43, 44, and 45. This transect started southwest of the drill site and circumscribed a clockwise circle around it. The shallow valley and the second deeper valley on the depth plots depict the same feature upslope and downslope of the drill site, respectively. Examination of the depth plots indicated that each tow followed a slightly different path. This divergence resulted from difficulties encountered while trying to maneuver the ship at the slow speeds (1 kn) required to keep the sled on the seafloor. Despite the minor differences in the areas surveyed during each of the tows, the pre- and post-drilling faunal patterns were quite similar. The fauna on the ridges on either side of the drill site and in the upslope valley consisted of an equal proportion of filter feeders and deposit feeders, whereas filter feeders dominated the fauna in the downslope valley. This trophic pattern was similar during each of the three sampling periods, with the exception that the dominance of filter-feeders in the downslope valley was more pronounced during the pre-drilling tow (Figure 43).

Faunal abundance was highest on the ridges and in the valleys, and lowest on the steep walls of the valleys. With the exception of the downslope valley, faunal abundance generally mirrored the density of O. lymani, which was highest on the ridges. The cerianthid anemone was also found in highest abundances on the ridges. These two species accounted for the nearly equal mix of deposit feeders and filter feeders found throughout most of each tow. E. affinis was found in appreciable abundances only in the valley upslope of the drill site; in contrast, A. arbuscula was common only on the flatter portions of the ridges. In general, the density of these four species did not appear to differ appreciably among the sampling periods. A. arbuscula was found in higher densities during the pre- and first post-drilling tows. However, because the second post-drilling tow covered a slightly steeper area than the two preceding tows, this difference was probably not related to drilling activity. There was one major difference in faunal density between the pre- and post-drilling surveys. K. stelliferum was most abundant in the downslope valley prior to drilling (Figure 43) and least abundant two months after drilling (Figure 44). Because all three tows overlapped considerably in this region (Figure 39), it is possible that this faunal difference may have been related to the drilling activity or to a mass movement of sediment (see Chapter 8, this report).

Community Analysis

Drill-Site Transect

Classification analysis of the data obtained from the camera-sled tows along the drill-site transect defined three major clusters (Figure 46). The range of mean depths of areas within each cluster overlaps considerably, with cluster 1 ranging from 2174 to 2259 m, cluster 2 ranging from 1761 to 2343 m, and cluster 3 ranging from 2003 to 2345 m. Each of these clusters further breaks down into groups of areas with greater than 70 percent faunal similarity. Since the clusters and the major groups within each cluster are composed of areas surveyed during each of the three cruises, it is unlikely that the cluster structure reflects drilling-related changes. Most of the areas in clusters 1 and 2 were characterized by soft substrate, but most of the areas in cluster 3 had extensive exposures of hard substrate.

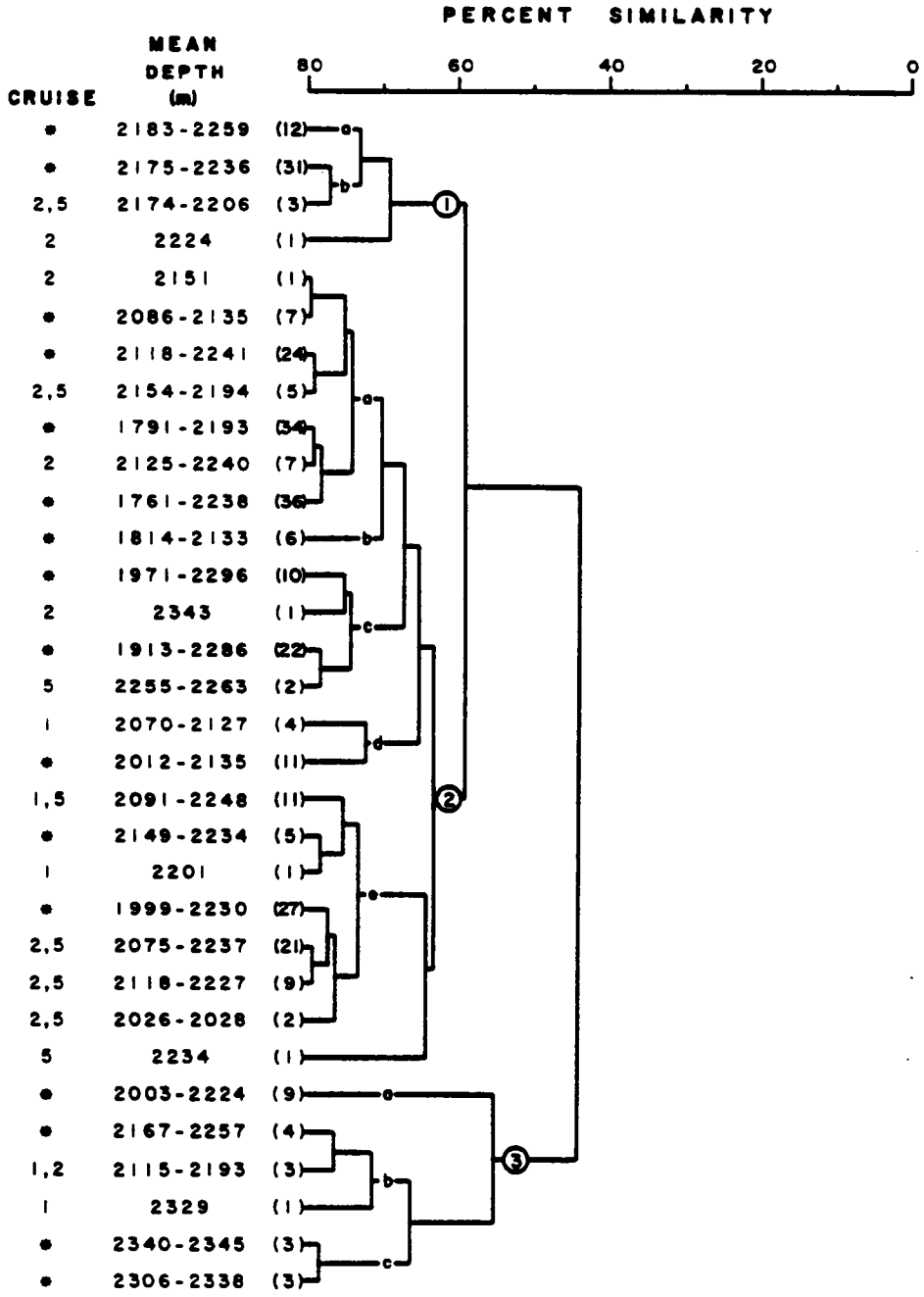

Figure 46. Hierarchical Classification of Sample Areas from Camera-Sled Tows Along the Drill-Site Transect. The Circled Numbers and Corresponding Letters Represent Major Clusters and Groups of Areas, Respectively. The Following Information Is Presented for the Areas in Each Leg of the Dendrogram: Cruise (1=Pre-Drilling, 2=2 Months After Drilling, 5=14 Months After Drilling, and *=All Three Cruises), Depth Refers to the Range of Mean Depths of the Sample Areas, and the Number in Parentheses Represents the Number of Sample Areas Included in the Leg.

Figure 47 shows the clusters plotted along the depth profiles of the camera-sled tows. Careful examination of these plots revealed that the cluster structure reflects differences in topography and depth. These differences are summarized in the physical characteristics portion of Table 32. The areas in clusters 1 and 3 are indicative of extreme flat and steep regions, respectively, and those in cluster 2 encompass the range between the two extremes. Depth and topographic differences among the groups of areas within each cluster can also be discerned. The flat regions defined by cluster 1 center around the 2200-m isobath and are exclusively located in valleys, with group 1a areas on the floors of valleys and group 1b areas at the base of slopes. In the steep regions defined by cluster 3 the three groups of areas separate by depth and location. The shallow (3a) areas are located on the lower southwest flank of a high ridge (18-km mark), the slightly deeper (3b) areas are located on the walls of Lindenkohl Canyon (between the 41- and 44-km marks), and the deep (3c) areas are located on the floor of the same canyon. A combination of depth and topography also separates the remaining areas (cluster 2) into five groups. The majority of the areas in cluster 2 are in groups 2a and 2e. Both of these groups are indicative of slopes and ridges, with group 2a areas being slightly more exposed and group 2e areas frequently being shadowed by topographic highs. The tops and flanks of higher ridges are characteristic of areas in groups 2b and 2d, with the areas in 2d being located on flatter ridges. The areas in group 2c are located on the floors of valleys and on steep slopes that frequently have moderate exposures of hard substrate.

The taxa most indicative of the faunal differences among the clusters and groups of areas are also presented in Table 32. The clusters and groups of areas differ mainly in the relative density of one or two of the five common species. The flat areas included in cluster 1 are the only areas that support high densities of the sea pen Kophobelemnon stelliferum; whereas the steep areas in cluster 3 are the only areas that support high densities of the urchin Echinus affinis. The shallower areas in cluster 3 (3a) also support high densities of Ophiomusium lymani. The deepest areas in cluster 3 (3c) differ from all the other areas in that they support fewer cerianthid anemones. The groups of areas in cluster 2 differ from each other in the relative proportion of all five of the common species. The majority of the areas in cluster 2 (groups 2a and 2e) differ from those in clusters 1 and 3 in that they support moderately low densities of K. stelliferum and very low densities of E. affinis. These two groups differ from each other in that the shallower

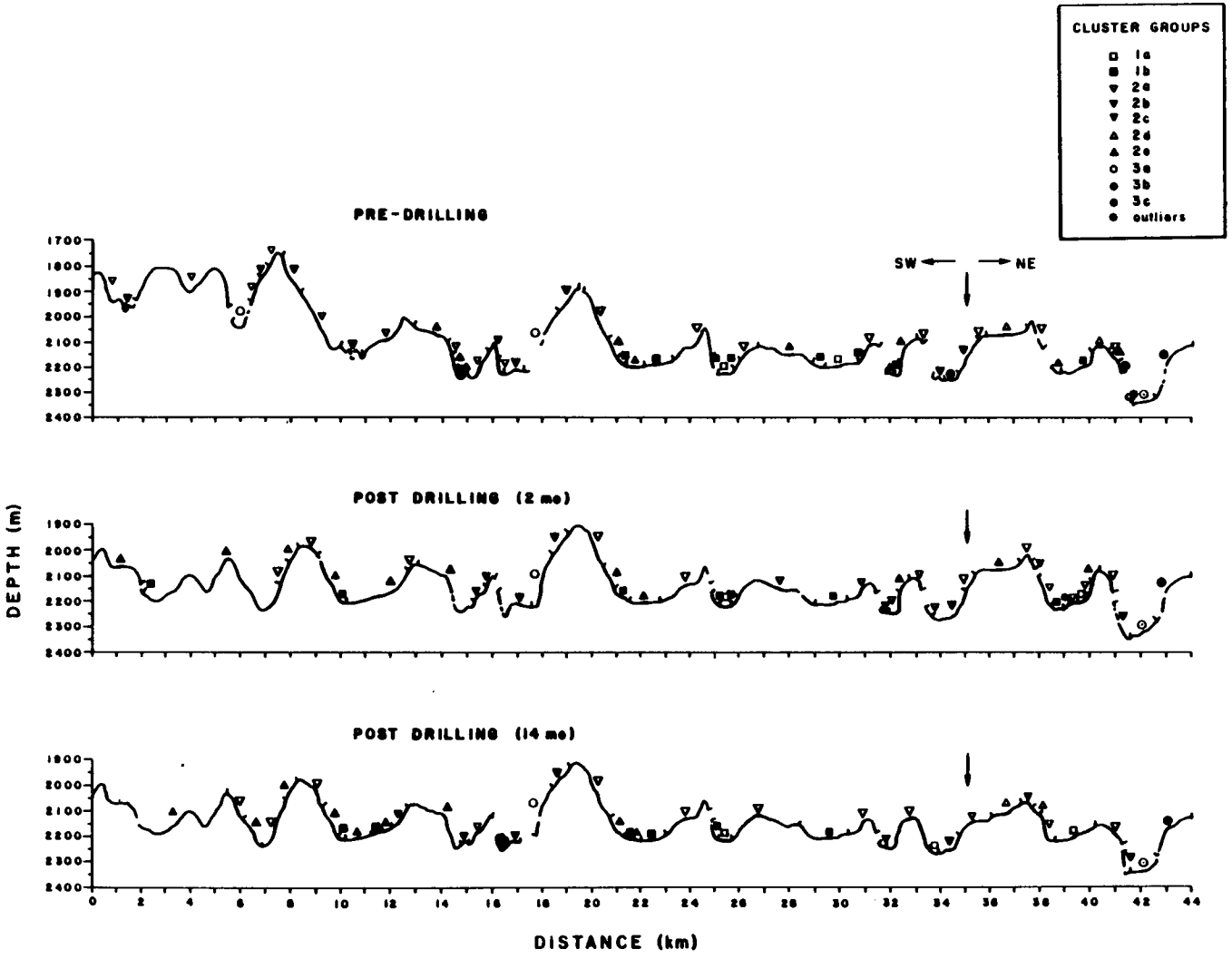

Figure 47. Plot of Cluster Groups on Depth Profiles of the Camera-Sled Tows Along the Drill-Site Transect. The Arrow Marks the Location of the Drill Site.

TABLE 32. PHYSICAL CHARACTERISTICS AND DENSITY PER M^2 OF DOMINANT EPIFAUNAL SPECIES IN THE CLUSTERS AND GROUPS OF AREAS DEFINED BY CLASSIFICATION ANALYSIS OF THE DRILL-SITE TRANSECT TOWS.

Cluster	1		2					3		
Group	a	b	a	b	c	d	e	a	b	c
Topography	Flat Valley		Ridge & Slope	Upper Slope	Valley & Steep Slope	Flat Ridge	Ridge Slope	Steep Slope and Valley		
Substrate	Mud	Mud	Mud	Mud	Outcrop	Mud	Mud	Outcrop	Outcrop	Outcrop
Mean Depth (m) ± SD	2213 ± 18	2200 ± 15	2097 ± 105	1999 ± 131	2179 ± 112	2087 ± 35	2149 ± 63	2100 ± 79	2194 ± 67	2330 ± 16
Ophiomusium lymani	46.3 ± 22.1	41.6 ± 18.2	107.8 ± 52.7	278.3 ± 117.0	78.5 ± 33.2	112.7 ± 34.2	32.9 ± 16.0	194.5 ± 50.7	23.6 ± 9.4	47.1 ± 15.0
Cerianthid sp.	46.8 ± 12.2	61.8 ± 14.9	94.8 ± 40.7	108.8 ± 41.5	66.0 ± 26.8	72.1 ± 9.5	82.2 ± 20.2	33.6 ± 33.0	45.1 ± 19.7	10.9 ± 5.5
Acanella arbuscula	1.7 ± 1.5	2.0 ± 1.7	7.1 ± 9.7	12.6 ± 13.7	0.3 ± 0.8	78.9 ± 37.7	2.1 ± 4.4	-	-	-
Echinus affinis	1.4 ± 4.0	0.7 ± 2.0	3.1 ± 6.8	4.5 ± 4.7	57.6 ± 33.3	0.8 ± 0.9	3.2 ± 7.3	89.0 ± 33.3	79.0 ± 29.0	91.5 ± 26.0
Kophobelemnon stelliferum	140.3 ± 27.8	70.9 ± 24.9	19.8 ± 18.2	5.1 ± 2.7	4.7 ± 5.1	15.5 ± 11.9	15.1 ± 10.3	0.3 ± 0.4	2.3 ± 3.9	1.4 ± 1.2

SD = Standard Deviation
- = Absent

areas (group 2a) support high densities of O. lymani; whereas the deeper areas (group 2c) do not. The tops and flanks of ridges (2b and 2d) support moderate to high densities of O. lymani, with the steeper areas (2b) also supporting high densities of the cerianthid anemone and the flatter areas (2d) supporting high densities of Acanella arbuscula. The steeper areas in cluster 2 (group 2c) differ from those in cluster 3 in that they support fewer E. affinis.

Minor differences in the cluster designation of several areas do occur among the pre- and post-drilling tows (Figure 47). These differences are usually attributable to the camera sled traversing slightly different areas of the same topographic features. Prior to drilling, the slope below the drill site clustered into group 2e, and the valley floor clustered into group 3b. Two months after drilling, both of these areas clustered into group 2e. The faunal differences between these two groups are minor, and it is likely that this change merely reflects slight differences in the path of the camera sled rather than drilling-related impacts. In many instances the areas clustered most closely with the same area from the other tows.

The ordination analysis of the data from the drill site transect is shown in Figure 48. The lack of discrete clusters of areas is not surprising in view of the high faunal similarities found in the classification analysis. The first axis appears to represent a combined steepness and substrate gradient, with the muddy, flatter areas (cluster 1 and most of cluster 2) having low values and the steeper, outcrop areas (cluster 3 and group 2c) having high values. The areas within the clusters appear to separate along axis 2 on the basis of depth and topography. Areas with high values on axis 2 are located on the shallower ridges (2d); whereas areas with low values on axis 2 are located in deeper valleys (groups 1a, 1b, and 3c). The high degree of overlap in the ordination space occupied by each of the clusters suggests a pattern of gradual faunal transition between the extremes, rather than well-defined boundaries between areas. Areas included in groups 2a and 2e appear to be regions of transition between flat valleys (cluster 1) and the tops and flanks of ridges (groups 2b and 2d). Areas in group 2c appear to be regions of transition between ridges and steep slopes and valleys (cluster 3).

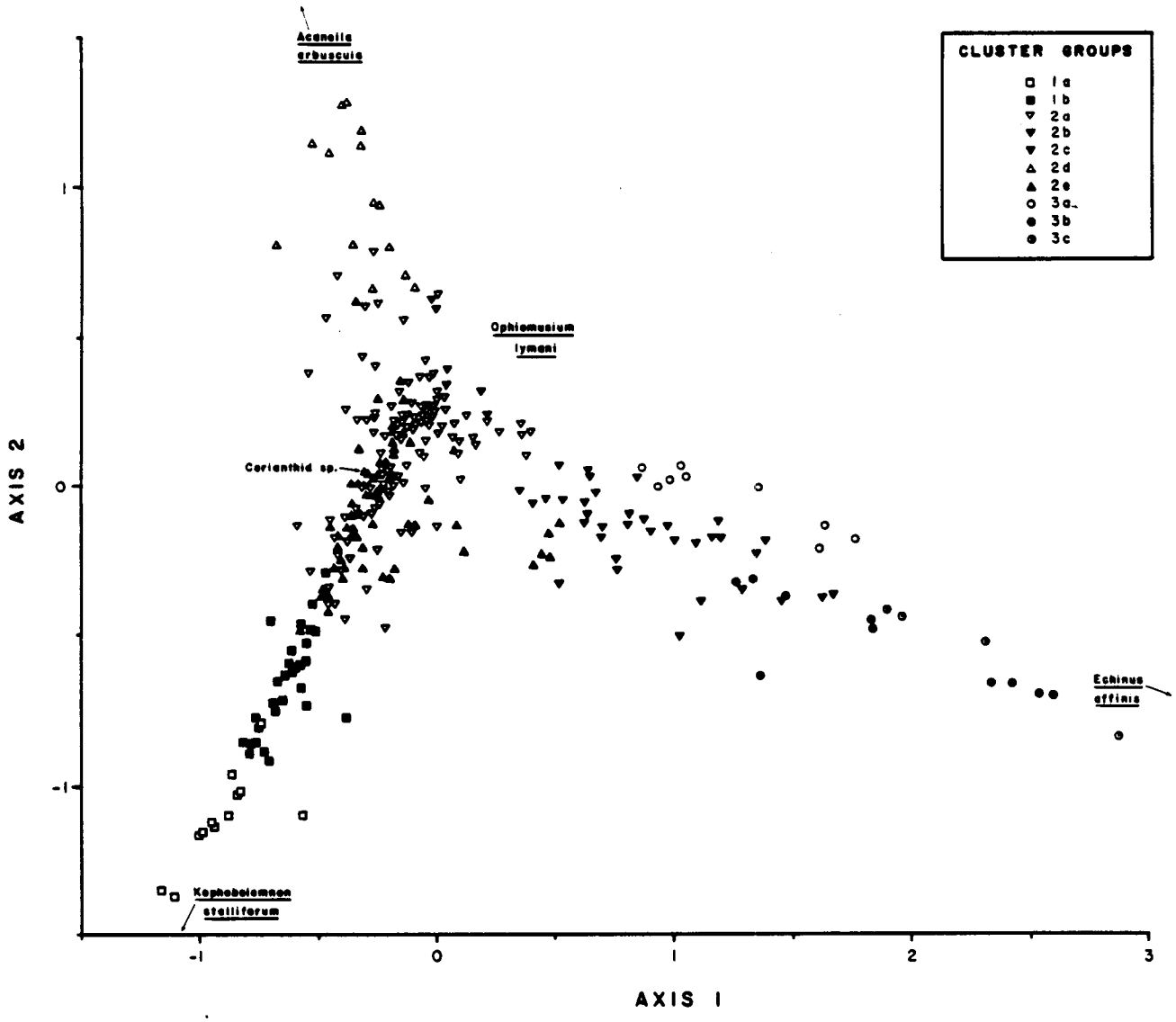

Figure 48. Ordination by Reciprocal Averaging of the Drill-Site Transect Sample Areas and Species. Symbols Represent Areas Within Cluster Groups Defined by Classification. Dominant Species Responsible for the Ordination Pattern Are Also Shown.

Circle Transect

Classification analysis of the data from camera-sled tows along the circle transect defined two major clusters (Figure 49). The mean depths of areas within these clusters overlap slightly, with cluster 1 ranging from 1963 to 2262 m and cluster 2 ranging from 2198 to 2314 m. Areas within the first cluster further subdivide into groups of areas with faunal similarities higher than 74 percent. The major groups formed by the classification analysis are all composed of areas from each of the three cruises. No consistent differences in substrate characteristics among the groups could be discerned.

Figure 50 shows the clusters plotted along the depth profiles of the camera-sled tows. Examination of these plots revealed that the cluster structure reflects differences in depth and location, with most of the cluster 1 areas (groups 1a and 1e) being located on the ridges on either side and in the valley upslope of the drill site and cluster 2 and group 1f areas being located in the valley downslope of the drill site. Table 33 summarizes the location, depth, and faunal differences among the groups within each cluster. The most striking faunal difference between the two clusters is that the areas in cluster 2 support higher densities of K. stelliferum than do the areas in cluster 1.

The six groups of areas in cluster 1 differ in that they each support slightly different abundances of one or two species. The areas in the valley upslope of the drill site (groups 1a and 1b) differ from the other areas in cluster 1 in that they support fewer O. lymani. Additionally, they differ from each other in that the areas on the floor of the valley and on the northeast slope (group 1a) support higher densities of E. affinis and lower densities of the cerianthid anemone, than the areas on the southwest slope (group 1b). The areas on the ridges on either side of the drill-site (groups 1c, 1d, and 1e) all support high densities of O. lymani. The shallower of these areas (group 1c) also support high densities of the cerianthid anemone; whereas the areas slightly deeper (group 1d) support high densities of A. arbuscula. The deeper areas on the ridges (group 2e) support fewer cerianthid anemones; whereas the areas on the walls of the valley downslope of the drill-site (group 1f) support moderate densities of K. stelliferum. The areas in cluster 2 are all located in the valley downslope of the drill-site. These areas all support relatively high densities of K. stelliferum and low densities of the other species. No consistent differences between pre-and post-drilling tows were discernable.

The ordination analysis of the data from the circle transect is shown in Figure 51. Axis 1 appears to reflect a depth gradient, with the shallower ridge and upslope valley

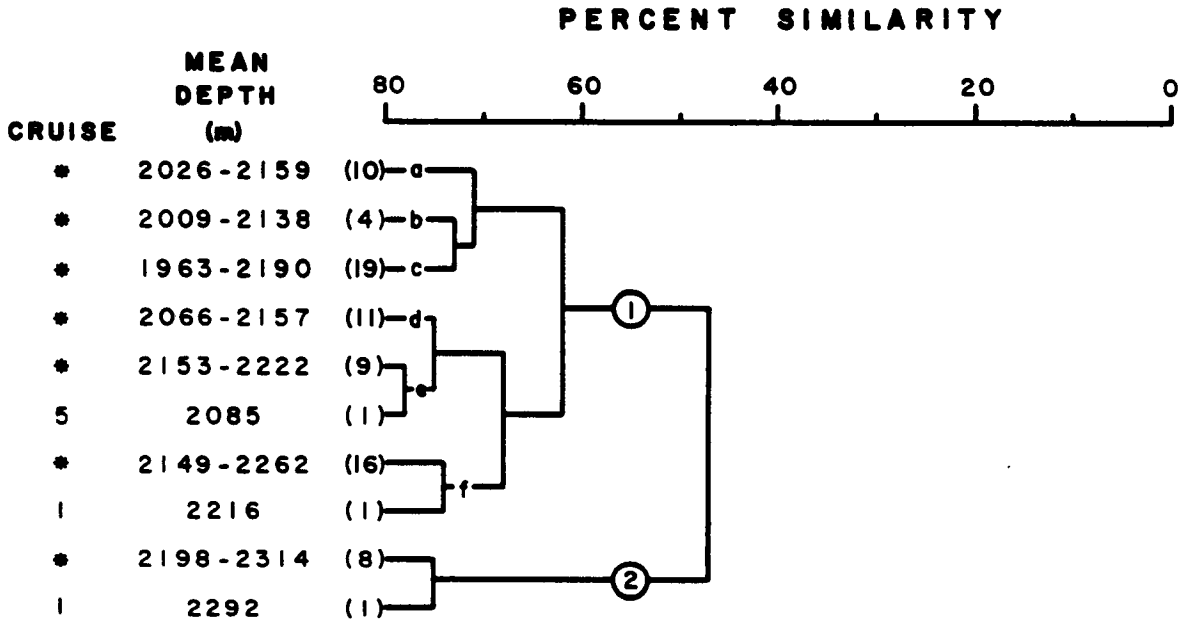

Figure 49. Hierarchical Classification of Sample Areas from Camera-Sled Tows Along the Circle Transect. The Circled Numbers and Corresponding Letters Represent Major Clusters and Groups of Areas, Respectively. The Following Information Is Presented for the Areas in Each Leg of the Dendrogram: Cruise (1=Pre-Drilling, 2=2 Months after Drilling, 5=14 Months After Drilling, and *=All Three Cruises), Depth Refers to the Range of Mean Depths of the Sample Areas, and the Number in Parentheses Represents the Number of Sample Areas Included in the Leg.

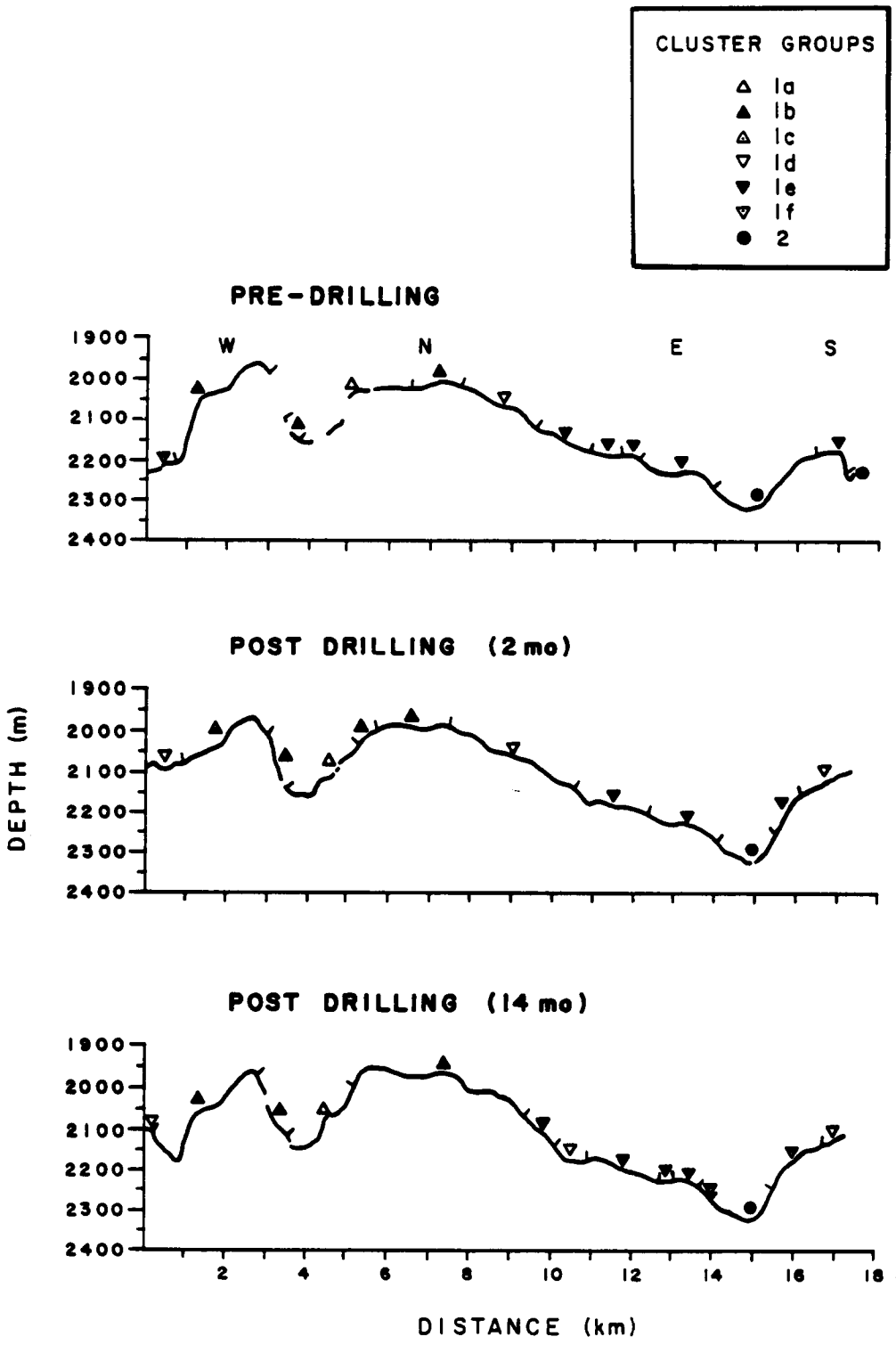

Figure 50. Plot of Cluster Groups on Depth Profiles of the Camera-Sled Tows Along the Circle Transect. Directions Above the Depth Plot Correspond to Direction From the Drill Site.

TABLE 33. PHYSICAL CHARACTERISTICS AND DENSITY PER 100 M^2 OF DOMINANT EPIFAUNAL SPECIES IN THE CLUSTERS AND GROUPS OF AREAS DEFINED BY CLASSIFICATION ANALYSIS OF THE "CIRCLE" TRANSECT TOWS.

Cluster	1						2
Group	a	b	c	d	e	f	
Topography	Upslope Valley		Ridge			Down Slope	
Mean Depth (m) ± SD	2097 ± 49	2082 ± 48	2028 ± 66	2104 ± 38	2182 ± 39	2218 ± 30	2278 ± 37
Ophiomusium lymani	94.1 ± 26.5	80.5 ± 11.8	153.6 ± 42.8	146.7 ± 38.8	168.4 ± 40.2	125.1 ± 21.8	74.9 ± 21.9
Cerianthid sp.	96.0 ± 16.1	145.0 ± 22.0	116.6 ± 28.1	79.1 ± 11.6	55.8 ± 12.8	48.7 ± 8.3	43.0 ± 13.5
Acanella arbuscula	-	0.7 ± 0.7	10.7 ± 9.3	63.6 ± 22.3	18.0 ± 14.8	5.2 ± 6.2	0.3 ± 0.4
Echinus affinis	65.4 ± 26.1	8.5 ± 6.0	0.7 ± 0.9	0.5 ± 0.6	4.0 ± 2.8	1.2 ± 1.0	0.7 ± 0.8
Kophobelemnon stelliferum	1.2 ± 1.1	1.8 ± 0.4	4.3 ± 3.7	16.8 ± 12.9	26.6 ± 10.5	84.4 ± 33.2	185.7 ± 77.7

SD = Standard Deviation
- = Absent

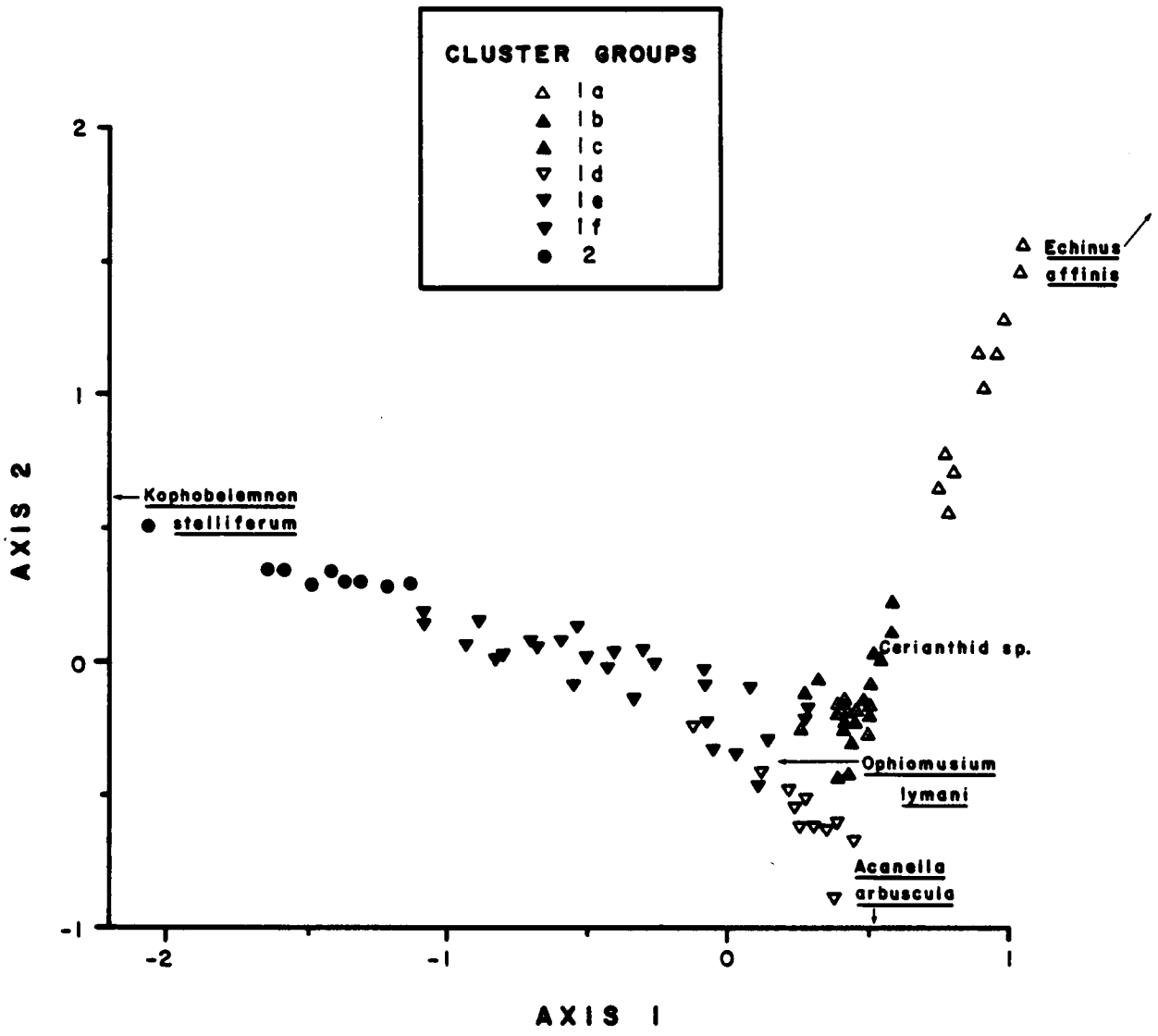

Figure 51. Ordination by Reciprocal Averaging of the Circle Transect Sample Areas and Species. Symbols Represent Area Within Cluster Groups Defined by Classification. Dominant Species Responsible for the Ordination Pattern Are Also Shown.

areas (groups 1a through 1e) having high values and the deeper downslope valley areas (group 1f and cluster 2) having low values. The upslope valley and ridge areas separate along axis 2, with the areas in the floor of the valley (group 1a) having the highest values and the areas furthest from the valley (group 1d) having the lowest values. The position of the species in the ordination space suggests that the fauna on the ridges is dominated by O. lymani and the cerianthid anemone; whereas the fauna in the upslope valley is dominated by E. affinis and the fauna in the downslope valley is dominated by K. stelliferum. The lack of a clear separation between the deeper ridge areas (group 1e) and the shallower downslope valley areas (group 1f) indicates a gradual transition in the faunal composition between those locations.

DISCUSSION

The results of the transect and community analyses suggest trends in epifaunal trophic structure and species composition that appear to be related to a combination of depth and topography. These trends reflect shifts in the relative abundance of the five most common species on the lower slope: the ophiuroid Ophiomusium lymani, a cerianthid anemone, the soft coral Acanella arbuscula, the urchin Echinus affinis, and the sea pen Kophobelemnon stelliferum. The distribution of each of these species appears to be controlled by slightly different environmental parameters, with species overlapping in some areas but not in others. Some evidence of faunal change, which may have been related to the drilling activity or to a mass movement of sediment, was observed in the valley downslope of the drill site.

The brittle star O. lymani was the most abundant species encountered in this survey. This observation agrees with results obtained from previous studies indicating that O. lymani is the dominant megafaunal constituent of the lower slope assemblage (Rowe and Menzies, 1969; Haedrich et al., 1980; Hecker et al., 1983; Blake et al., 1987). This species is a nonselective deposit feeder (Pearson and Gage, 1984) and was present in highest abundances between 1800 and 1900 m. Topographically, O. lymani occurred in higher densities on the tops and upper flanks of ridges than on lower slopes or in valleys.

The second most abundant species was a filter-feeding cerianthid anemone. The taxonomy of these burrowing anemones is poorly known, but they appear to be the same

species that is common at lower slope depths all along the east cost of the U.S. (Hecker et al., 1983). Although cerianthid anemones were found in relatively high abundances throughout most of the areas surveyed, they occurred in highest concentrations on upper southwest slopes.

The other three species occurred in much lower overall abundances, but showed high local densities. The filter-feeding sea pen K. stelliferum was the most abundant of these three species. Although it was found throughout the depth range surveyed, it only occurred in appreciable abundances below 2150 m. Topographically, K. stelliferum was found in highest densities in flat depressions. The deposit-feeding urchin E. affinis and the filter-feeding soft coral A. arbuscula both showed broad depth ranges and very localized peaks in density. A. arbuscula had an optimum depth range of 2000 to 2150 m and was most abundant at the summit of flat topographic highs. In contrast, E. affinis was found in appreciable densities only on steep northeast slopes and in deeply incised valleys.

The observed trophic pattern reflects the differing depth and topography optima of these five species. Carnivore/scavengers accounted for less than 3 percent of the fauna seen. The remaining 97 percent of the fauna consisted of a mixture of filter feeders and deposit feeders, with filter feeders being slightly more abundant. Deviations from this trend occurred in flat regions where filter feeders completely dominated the fauna, and in steep regions where deposit feeders accounted for more than half of the fauna. The two most common species, O. lymani and the cerianthid anemone, accounted for the presence of both trophic types throughout most of the areas surveyed. The observed shifts in dominant trophic type reflect highly localized peaks in density of the other three species: A. arbuscula on the crests of ridges, K. stelliferum in flat depressions, and E. affinis in steep valleys characterized by outcrop.

These shifts in trophic types, and the underlying changes in fauna, may result from the interaction of bottom topography and currents affecting nutrient input to the various areas. The prevailing bottom current in this region is the Western Boundary Undercurrent, which flows southwesterly along the isobaths (Heezen et al., 1966). As a result of this along-slope flow, it is expected that the tops of ridges and flatter areas would experience higher current velocities and concomitantly greater suspended particulate matter for the support of filter-feeders, than deeply incised valleys. Of the

filter feeders, the cerianthid anemones are the smallest and thus are restricted to the sediment-water interface. The high abundances of this anemone on upper southwest slopes may be related to stronger near-bottom currents where the undercurrent impinges on the upcurrent side of ridges. In contrast, the two corals A. arbuscula and K. stelliferum, which protrude higher into the water column, would not be as restricted to high current areas to receive adequate food. Decreased shear forces over topographic lows could result in the settling of suspended particles, providing increased food supplies for deposit feeders on upper northeast slopes, and in deeply incised valleys. This may explain the observed high densities of E. affinis in valleys. Additionally, sediment instability in steep areas may discourage settlement of the sessile filter-feeders.

The community analyses also indicate differences in faunal composition between topographic highs and lows. Faunal similarity values suggest that all of the areas had a relatively high proportion of shared species. The main faunal differences between the clusters defined by hierarchial classification were the presence or absence of one or two species. No distinct faunal boundaries between the different types of areas were defined by ordination analysis. While some of the groups defined by classification occupied a discrete space in the ordination analysis, other groups appear to serve as transition areas. Hence, the fauna inhabiting this area of the lower slope may best be viewed as an assemblage of loosely-related taxa, with each species responding to slightly different environmental parameters, rather than as a cohesive faunal community.

The clam area located 17-km southwest of the drill site is very intriguing for several reasons. Based on the density and size of the Calyptogena shells, it is highly unlikely that they are indicative of normal, nutrient-limited deep-sea conditions. Turner (1985) postulates that species belonging to this genus are restricted to environments that support chemosynthetic productivity. Examples of these types of areas are hydrothermal vents and hypersaline, sulfide seeps (Hecker, 1985). The presence of the Calyptogena shells suggests that seepage of reduced compounds capable of supporting chemosynthesis has occurred in this region in the past, and may still be occurring in nearby regions today. Geological evidence for such discharges has been found along a portion of the southern U.S. coast (Manheim, 1974) and specifically in this Mid-Atlantic region (Manheim and Hall, 1976). Persistence of the shells over the last 1300 years is surprising, unless they were previously buried and are only now being excavated. Evidence for erosional

processes in this area is the presence of ripple marks, indicating strong current activity, and numerous blocks of jagged-edged talus, indicating erosion of the outcrops.

Only one major change in epifauna that may have been related to the drilling activity in Block 372 was discerned. The valley 2 km downslope of the drill site supported a very high abundance of K. stelliferum prior to drilling. Two months after drilling had been completed, very reduced densities of this sea pen were found in the same area, and 14 months later somewhat higher abundances were found. Since the paths of all three camera-sled tows overlapped in this area, it is possible that the observed decline in the abundance of K. stelliferum during the first post-drilling tow was related to the drilling activity. However, this observed difference may be attributable to several other factors. Data on sediment texture (Chapter 8, this report) indicate that a mass movement of sediment occurred between the pre- and first post-drilling cruises in the area upslope of this region. This event may have buried many of the sea pens or clogged their filtering apparatuses, thereby accounting for the observed decrease in their abundance. If the decrease in K. stelliferum in the valley downslope of the drill site was indeed related to drilling activity, it appears to have been relatively short-lived, since higher densities were found 14 months after drilling had been completed. Other faunal changes between the post-drilling tows were minor, and were usually related to slight variations in the paths of the tows. In conclusion, with the possible exception of the valley downslope of the drill site, it does not appear that the exploratory drilling in Block 372 had a significant impact on the epifaunal composition of the surrounding area.

CHAPTER 7. CHEMICAL ANALYSIS OF SEDIMENTS, TISSUES AND DRILLING DISCHARGES

INTRODUCTION

An integral part of the U.S. Mid-Atlantic monitoring program strategy was the determination of the fate of discharged drilling muds, cuttings, and other platform discharges, as well as the potential of bioaccumulation of discharged chemicals in benthic animals. The technical approach of the chemistry component of the program involved the analysis of bottom sediments for hydrocarbons and selected benthic epifauna for hydrocarbons and trace metals, and analysis of source materials from the drilling ship. The study of Bothner et al. (1985a, 1985b, 1987) on the trace metal content of bottom sediments complements the work presented in this chapter.

The objectives of the analytical chemistry program were to establish a pre-drilling biogeochemical data set for sediments and tissues (Cruise Mid-1), and to evaluate any drilling-related changes in the benthic chemical environment (Cruises Mid-2 through Mid-6). As part of meeting the second objective, the hydrocarbon composition of drilling muds and cuttings collected at Blocks 93 and 372 during drilling operations was characterized to establish a basis for "source-matching" between platform discharges and post-drilling sediment and biota samples. The methods of the sediment, tissue, and drilling mud analyses that are presented here were also presented in the first two interim reports for this project (Maciolek-Blake et al., 1985; Maciolek et al., 1986a). Results from all six surveys 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 all stations on Cruises Mid-1 and Mid-2, but only from a selected subset of five or six stations on Cruises Mid-3 through Mid-6 (Table 34). The stations chosen for continuing study were selected because of their proximity to the drilling sites in Block 372 (Stations 1, 2, and 3) and Block 93 (Station 13). Station 10 was chosen because it could have received input of drilling materials from either of the two drill sites.

TABLE 34. STATIONS SAMPLED FOR SEDIMENT HYDROCARBON ANALYSIS.

Cruise	Stations
Mid-1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
Mid-2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Mid-3	1, 2, 3, 10, 13
Mid-4	1, 2, 3, 10, 13
Mid-5	1, 2, 3, 10, 13
Mid-6	1, 2, 3, 10, 13, 14

ANALYTICAL METHODS

Hydrocarbon Analysis

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 52). The extracts were first screened for petroleum residues by synchronous scanning UV/fluorescence spectrofluorometry (UV/F). The UV/F methodology 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 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 use of the technique in this study was to provide some 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 the saturates and capillary gas chromatography/mass spectrometry (GC/MS) for the aromatics.

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 a targeted suite of trace metals. The data were interpreted in light of drilling activities and possible transport of drilling discharges to the benthos. The details of the analytical methods used are presented below.

Extractions

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, 30 min each) followed by a 1:9 methanol:methylene chloride (2:1 solvent volume: wet

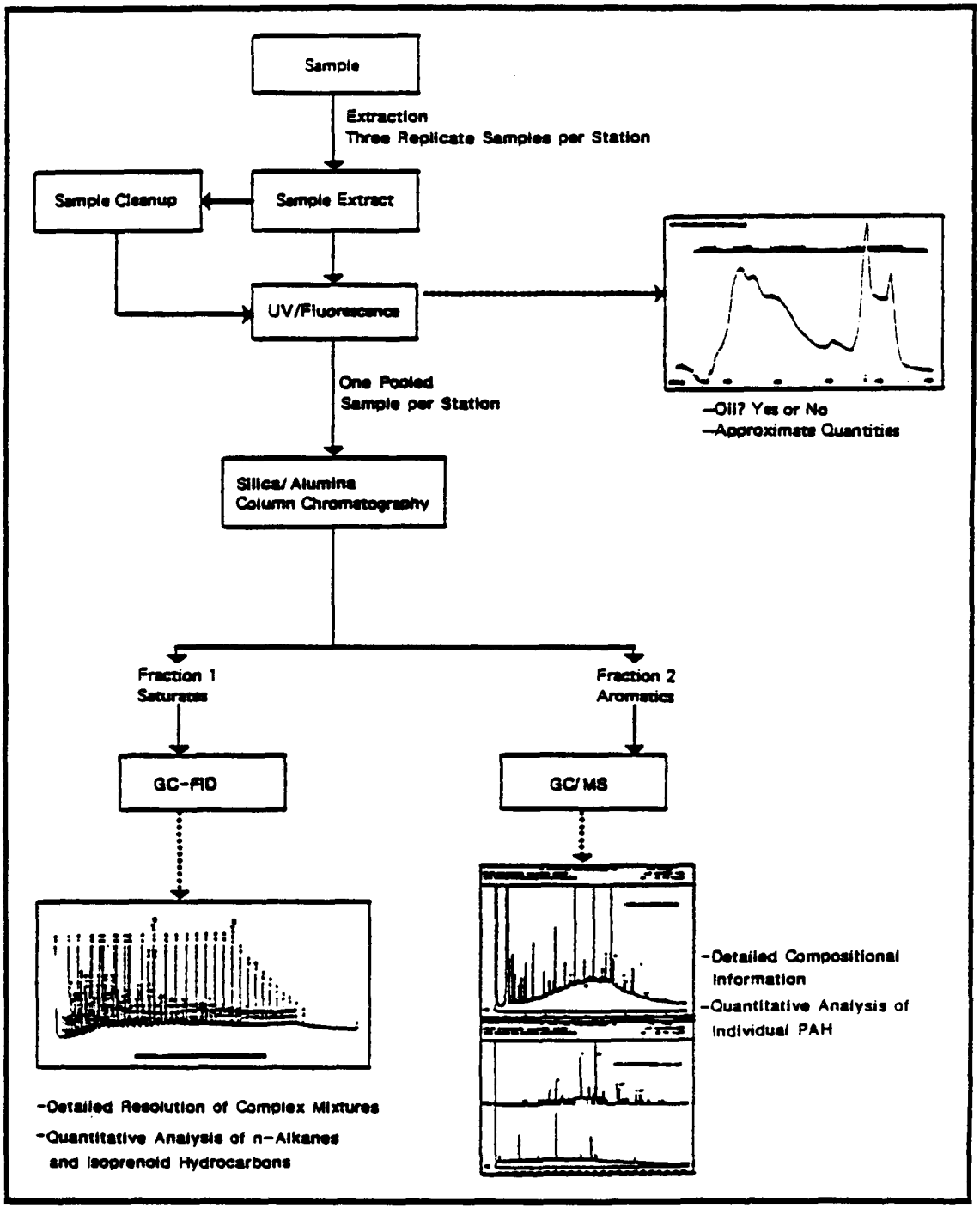

Figure 52. Analytical Scheme for Hydrocarbons in Sediments and Tissues.

weight) mixture (three times, 8 hr 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. Two species were targeted for tissue analyses: the brittle star Ophiomusium lymani and the sea urchin Echinus affinis. Whole brittle stars, including exoskelton and soft tissues, were analyzed because separation of soft tissue was not possible for this species. Soft tissues and fluids were, however, isolated from the sea urchins. Six to 12 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 hr. For Cruise Mid-1 and Mid-2 samples, the digested mixture was transferred to a 100- or 250-ml separatory funnel and neutralized with 6N HCl; three extractions were performed with hexane (3:1 sample to solvent volume). For Cruise Mid-5 samples, extraction was carried out three times by adding ether directly to the digestate in the centrifuge bottle. The extracts were dried over Na_2SO_4 and concentrated on a rotary evaporator to near dryness in preparation for alumina precolumn cleanup.

Drilling Muds and Cuttings. Samples of drilling muds and cuttings were supplied by Shell Offshore, Inc. and represented composites of samples from Block 372 and Block 93. A total of four mud and cuttings samples were analyzed. Samples from each block were pooled as follows:

Block 372

- three mud samples
- three cuttings samples

Block 93

- 12 mud samples
- 12 cuttings samples

Each pooled sample was mixed with an equal amount of Na_2SO_4 to ensure efficient drying and extraction, followed by the extraction procedure employed for sediments.

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 from Cruises Mid-5 and Mid-6 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 saturates and aromatics 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 hydrocarbon 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 dibenzothiophene 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 Digestion

Frozen specimens of brittle stars and sea urchins were manually separated, placed in plastic bags, and freeze-dried for 24 hr. Because of the expected low metal concentrations, all handling of tissue samples was conducted in a laminar flow hood to limit atmospheric contamination. Technicians wore talc-free plastic gloves when handling samples. Additionally, all equipment was acid-cleaned by soaking for 1 hr 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 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.

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

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

Quality Control

Hydrocarbon Analyses

Analytical quality control procedures included a wide range of activities such as daily calibration of all instruments, verification of instrument 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 control. 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. This solution was replaced by a combined aromatic and alkane spiking solution prepared at Battelle during the analysis of the Cruise Mid-5 and Mid-6 samples. Concentrations of individual compounds were calculated relative to an external standard and compared to the added amounts in order to evaluate recovery efficiencies 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 crude oil. The extraction process was repeated, the extracts were reanalyzed and the amount of oil present was quanitified 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.

Drilling Muds and Cuttings. One procedural blank was analyzed with these samples. In addition, one drilling mud sample was analyzed in triplicate to evaluate analytical precision.

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 standard reference materials 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 concentrations in sediments collected on Cruises Mid-1 through Mid-6 are listed in Tables I-1 to I-6 in Appendix I. The concentrations, expressed in Arabian crude oil equivalents, are reported as the mean ± one standard deviation based on triplicate analyses at three emission wavelengths (312, 355, and 425 nm) corresponding to maxima in the fluorescence spectrum of reference Arabian Light crude oil. These wavelengths also roughly correspond to fluorescence maxima of 2-ring, 3-ring, and 4- plus 5-ring PAH respectively, although fluorescence intensity at any given emission wavelength is the product of the fluorescence of many compounds. The UV/F concentrations revealed that all sediments varied between 7.11 and 131 µg/g dry weight and the data were generally quite reproducible between sampling times. Concentrations generally increased with increasing emission wavelength, possibly reflecting the greater abundance of more highly condensed fluorescing species (e.g., 4- and 5-ring PAH) in the extracts relative to the reference crude oil. The variance among replicates at a given station, expressed as the coefficient of variation (SD (100/$\bar{x}$)), ranged from ± 5 percent to ± 42 percent and exhibited no correlation with emission wavelength. The highest values exhibited throughout the survey were found at Stations 5, 11, 13, and 14.

Typical UV/F spectra for surface sediment, drilling muds, and cuttings are presented in Figure 53. The spectra of all of the sediment samples were dominated by broad spectral bands centering at approximately 312 nm (2-rings), 355 nm (3-rings), and 425 nm (4-rings). In contrast, the spectra of the drilling muds and cuttings were dominated by spectral bands at 312 nm and 355 nm because of the prevalence of the lower molecular weight aromatic compounds in these samples. These differences in UV/F characteristics can, therefore, potentially be used to diagnose additions of drilling mud to environmental samples.

Hydrocarbon concentrations and values for selected saturated hydrocarbon parameters as determined gravimetrically and by GC/FID in Cruise Mid-1 through Mid-6 sediments are shown in Appendix I, Tables I-7 to I-12. Total hydrocarbon concentrations ranged between 2.9 and 52.9 µg/g dry weight, with roughly comparable contributions from saturated and aromatic hydrocarbons exhibited at most stations. The highest concentrations occurred at Station 13, but elevated values were also found at Stations 5 and 11. The lowest concentrations of hydrocarbons were found at Stations 2, 10, and 12.

Four representative GC/FID chromatograms for Station 9 for Cruises Mid-1 and Mid-2 and for Stations 2 and 13 from Cruise Mid-6 are presented in Figures 54 and 55. As illustrated in the sample chromatograms, the saturated hydrocarbon profiles from all stations were generally similar in composition, within and between cruises, with major differences only in the concentration of individual components. Although components of the Unresolved Complex Mixture (UCM) could be found in both saturated and aromatic fractions, the unresolved components were more prevalent among the saturated hydrocarbons. For all sediment samples analyzed by GC/FID, the UCM or "hump" feature was limited to the higher molecular weight region of the GC/FID chromatograms. The Odd-Even Preference Index (OEPI) is an indicator of the relative abundance of odd- versus even-carbon-number normal alkanes in a sample. The OEPI in the samples ranged between 1.32 and 4.40. This parameter can range from approximately 1.0 in crude oil to values greater than 5.0 where the composition is dominated by terrigenous, biogenic alkanes. A low OEPI generally indicates a petroleum source. However, in this study the low OEPI probably reflects the extremely low levels of all hydrocarbons at a particular station rather than petroleum contamination. Other hydrocarbon parameters, including diagnostic ratios of isoprenoid alkanes (pristane and phytane) to each other and to normal alkanes, are listed in Appendix I, Tables I-7 to I-12.

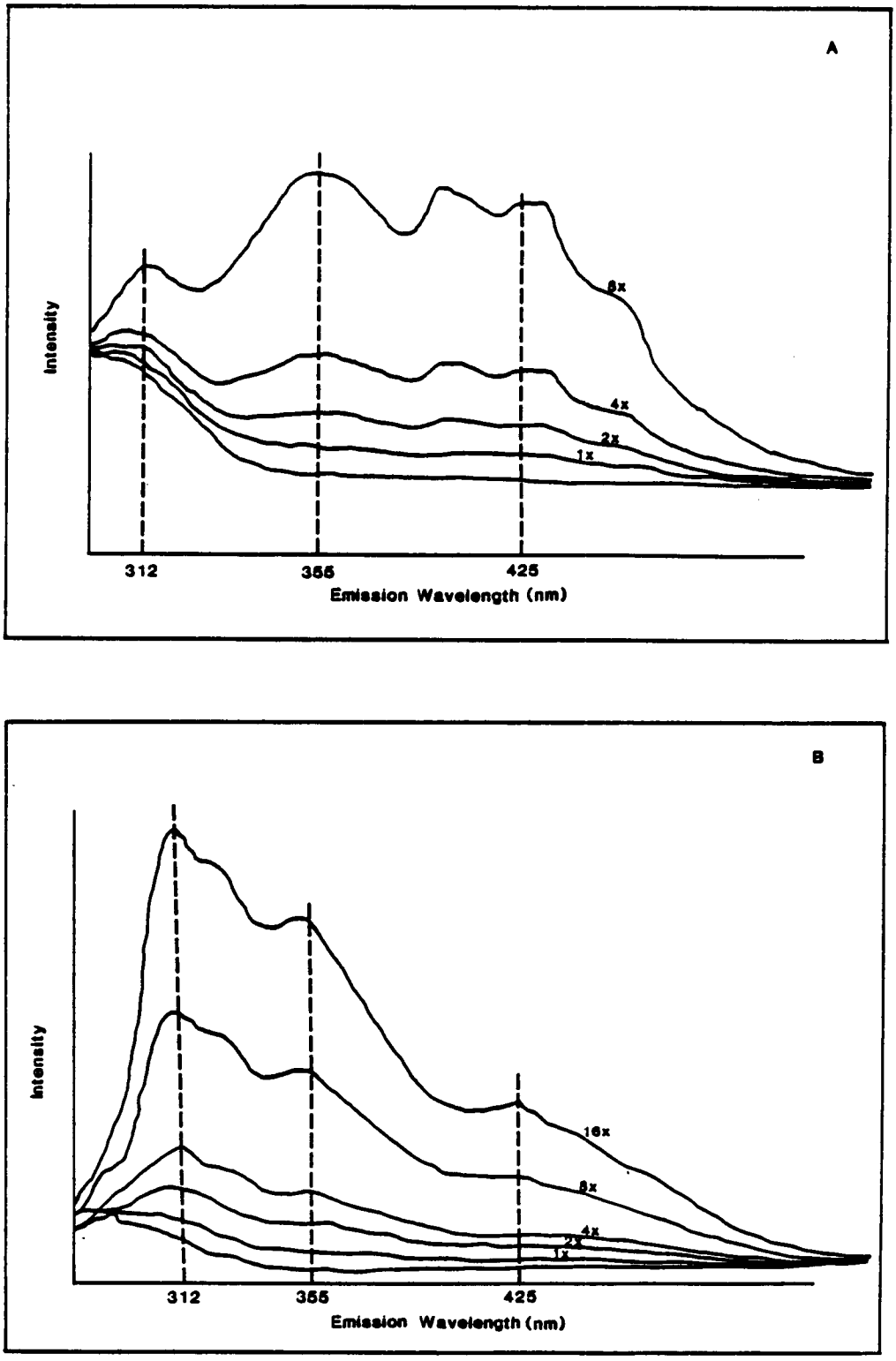

Figure 53. Representative UV/F Spectra of Sediment, Drilling Mud, and Drill Cutting Samples: A. Sediments from Station 7, Cruise Mid-1. B. Composite of Drilling Muds Discharged at Block 372.

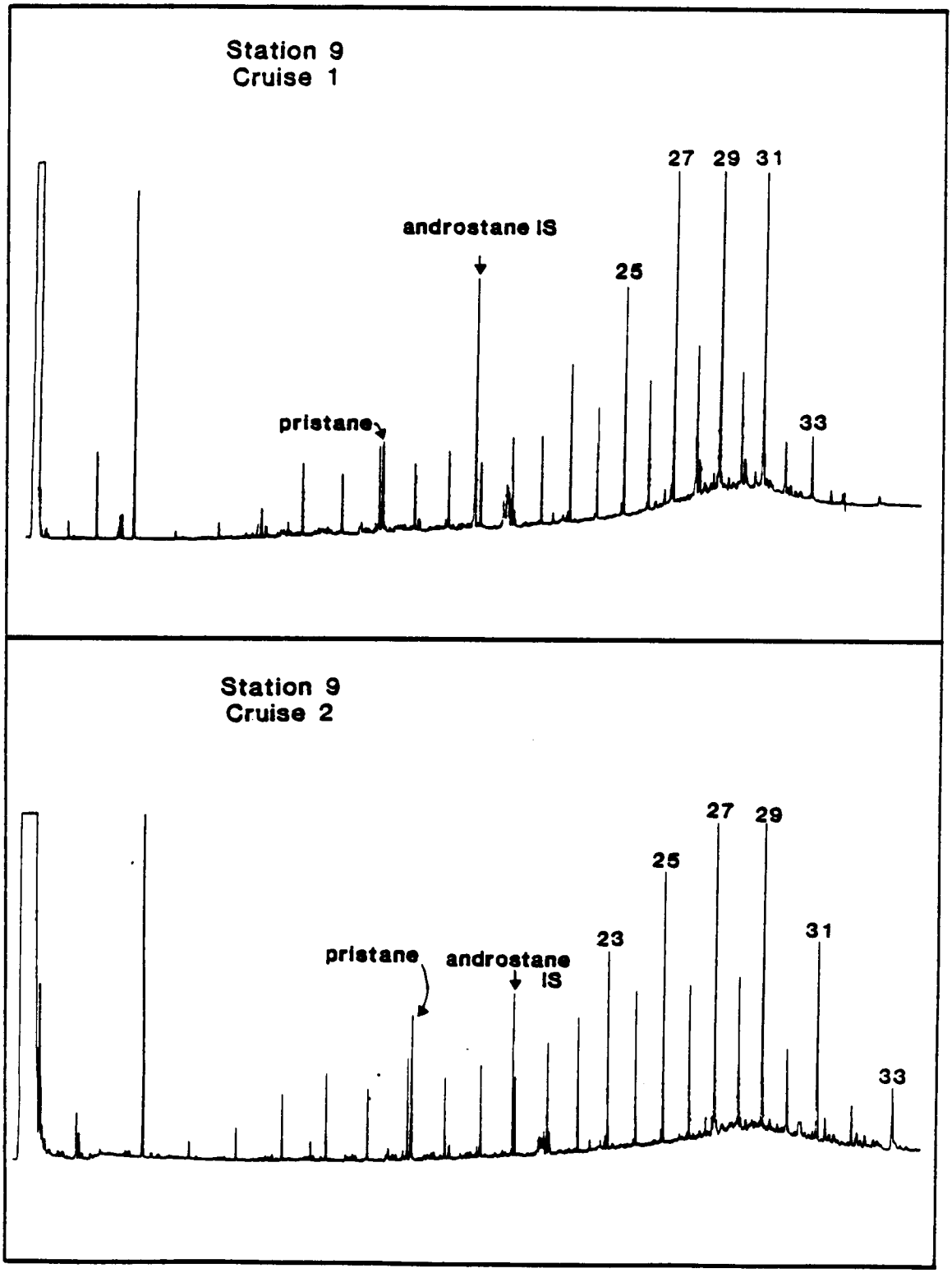

Figure 54. GC/FID Chromatograms of Saturated Hydrocarbons in Surface Sediments at Station 9, Cruises Mid-1 and Mid-2.

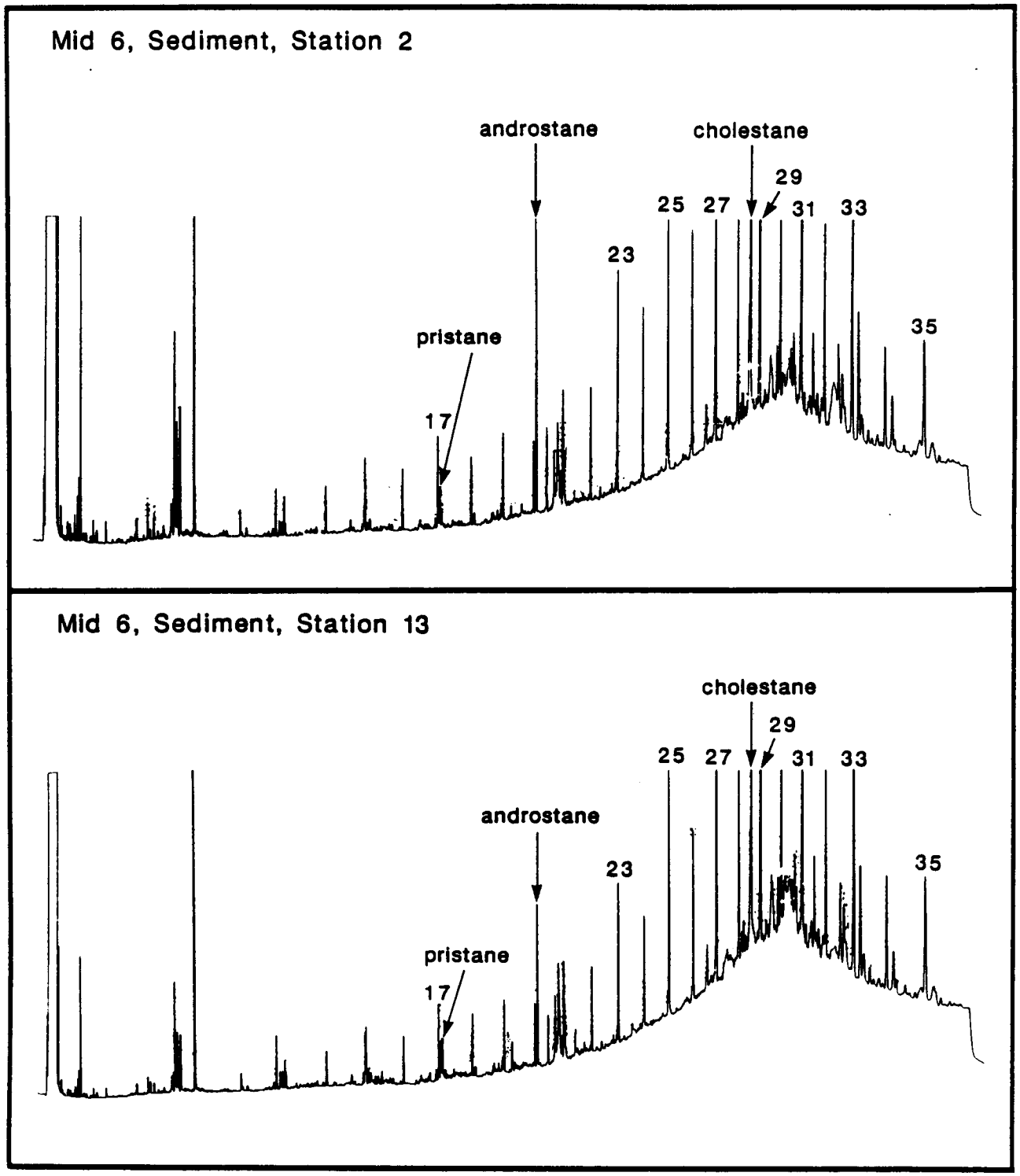

Figure 55. GC/FID Chromatograms of Saturated Hydrocarbons in Surface Sediments at Stations 2 and 13, Cruise Mid-6.

Note that, for most samples, the gravimetrically determined total hydrocarbon concentrations agreed with the UV/F-determined "oil equivalents" concentrations at 312 nm. The concentration trends found by UV/F at all wavelengths agreed well with the trends observed in the gravimetric measurements.

Concentrations of selected 2- to 5-ring PAH as determined by GC/MS are listed in Tables I-13 to I-18. Total PAH concentrations (the sum of the 27 compounds or alkyl homologue groups) ranged between 66 and 1157 ng/g dry weight and, in general, paralleled the total hydrocarbon concentrations, with the lowest values found at Stations 10 and 12 and the highest values corresponding to Stations 11, 13, and 14.

Compositionally, the naphthalene, fluorene, and dibenzothiophene series contributed minimally to the total concentrations, with the phenanthrene series and the 4- and 5-ring compounds accounting for the majority of the total. A notable exception was the PAH distribution at Station 13 on Cruise Mid-1 and, to a lesser extent, at Stations 5 and 11, where greater concentrations of naphthalenes and fluorenes were detected. A Fossil Fuel Pollution Index (FFPI), useful for differentiating PAH distributions originating from fossil fuel (i.e., oil and coal) from combustion sources (Boehm and Farrington, 1984), was calculated for these sediments (Tables I-13 to I-18). Values ranged from 17 to 53 on a scale in which 0 indicates the absence of fossil fuel PAH (i.e., all PAH present are of a combustion origin), and 100 indicates that all the PAH are derived from fossil fuel. The highest FFPI values were consistently found at Stations 5, 6, and 13, where the FFPI reached 40-50. These levels are not considered to be environmentally significant given the generally low concentrations of hydrocarbons at all stations. Inspection of the FFPI in the sediment samples will not reveal the source of petroleum contamination (i.e., coal vs. oil) without more specific PAH distributions of source material.

Tissues -- Cruises Mid-1, Mid-2, and Mid-5

Brittle stars Ophiomusium lymani and sea urchins Echinus affinis were collected from the following stations on Cruise Mid-1: Station 1 (brittle star), Station 4 (brittle star, sea urchin), and Stations 7 and 8 (pooled brittle star samples collected at the two stations). On Cruise Mid-2, only Station 4 (brittle star, sea urchin) was sampled. On Cruise Mid-5, brittle stars were collected and analyzed at Stations 1 and 4, whereas urchins were sampled from Station 4 only.

Hydrocarbon Analysis. Hydrocarbon concentrations in bottom fauna ranged between 27.4 and 163.1 µg/g wet weight (Table 35). For Cruise Mid-1 and Mid-2 samples, the saturated components were roughly twice as high as the unsaturated/aromatic compounds; whereas for Cruise Mid-5 samples, unsaturates/aromatics predominated by weight. The change in the relative amount of the unsaturates/aromatic components may have resulted from the change in the tissue extraction procedure (see section in Extractions). The use of ether as an extraction solvent may be more effective in the extraction of unresolved unsaturated compounds.

In the faunal tissues examined, the unsaturate/aromatic fraction was always dominated by unsaturated components of biogenic origin rather than aromatic hydrocarbons. However, the saturated hydrocarbon data appeared consistent throughout the survey. Most samples exhibited a significant unresolved feature in GC/FID chromatograms (Figure 56). Unresolved saturates ranged from 23 to 87 percent; as in the sediments, these components were limited to the higher molecular weight range. Pristane/phytane ratios were high in all tissue samples, consistent with the prevalence of pristane in tissues of marine organisms.

GC/MS analyses of the six faunal samples revealed no detectable PAH compounds in any Cruise Mid-1 or Mid-2 samples. However, use of a larger sample size for analysis of Cruise Mid-5 samples allowed the lowering of detection limits for individual PAH. The results of the Cruise Mid-5 aromatics analyses are presented in Table 36. The levels of PAH in these samples were uniformly low, with the 4- and 5-ring aromatics dominating the aromatic composition.

Trace Metal Analysis. The same suite of benthic faunal samples analyzed for hydrocarbons was also analyzed in duplicate for trace metal content (Table 37). The analyses of Cruise Mid-1 and Mid-2 samples were repeated to correct the problem of matrix interferences with Cu and Pb values reported in the first interim report (Maciolek-Blake et al., 1985). Therefore, the data presented in this report for tissue samples from Cruises Mid-1 and Mid-2 were not presented earlier.

The analyses of brittle stars and sea urchins represent whole body analysis and, therefore, the elevated Al, Fe, and Mn concentrations reported in tissues may represent some material associated with ingested sediment. With the exception of Al, Fe, and Zn, the elements present in the tissue samples analyzed were quite low and approached method detection limits for Ba, Cd, Cr, Cu, Ni, V, and Hg.

TABLE 35. HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS IN BENTHIC FAUNA COLLECTED DURING CRUISES MID-1 AND MID-2.

Species	Cruise	Station	Total Hydrocarbons[b] (µg/g wet weight)	Saturates[b,c] (µg/g wet weight)	Unsaturates/ Aromatics[b] (µg/g wet weight)	Resolved[d] Saturates (%)	Unresolved[d] Saturates (%)	Pristane/ Phytane[d]	Phytane/ n-C18[d]
Ophiomusium lymani	1	1	36.4	25.3 (19.1)	11.1	41	59	>100	NC
O. lymani	1	4	53.0	34.7 (21.8)	18.3	13	87	>100	NC
Echinus affinis	1	4	28.2	16.2 (21.2)	12.0	47	53	17.8	3.64
O. lymani	1	7-8	44.3	28.7 (22.9)	15.6	43	57	>100	NC
E. affinis[a]	2	4	40.4 ± 10.9	23.0 ± 6.2 (21.5)	17.4 ± 5.4	47 ± 2	53 ± 2	28.7 ± 9.1	3.14 ± 0.82
O. lymani	2	4	27.4	19.3 (35.6)	8.1	27	73	105	0.73
O. lymani	5	1	92.3	21.5	70.8	71	29	59.3	2.0
O. lymani	5	4	163.1	51.8	111.3	77	23	92.0	NC
E. affinis	5	4	129.8	30.0	99.8	75	25	40.5	5.6

[a]Triplicate analyses.
[b]Gravimetrically determined.
[c]Numbers in parentheses are GC/FID-determined saturate concentrations.
[d]GC/FID data.
NC = Not calculated due to the low relative abundance of phytane.

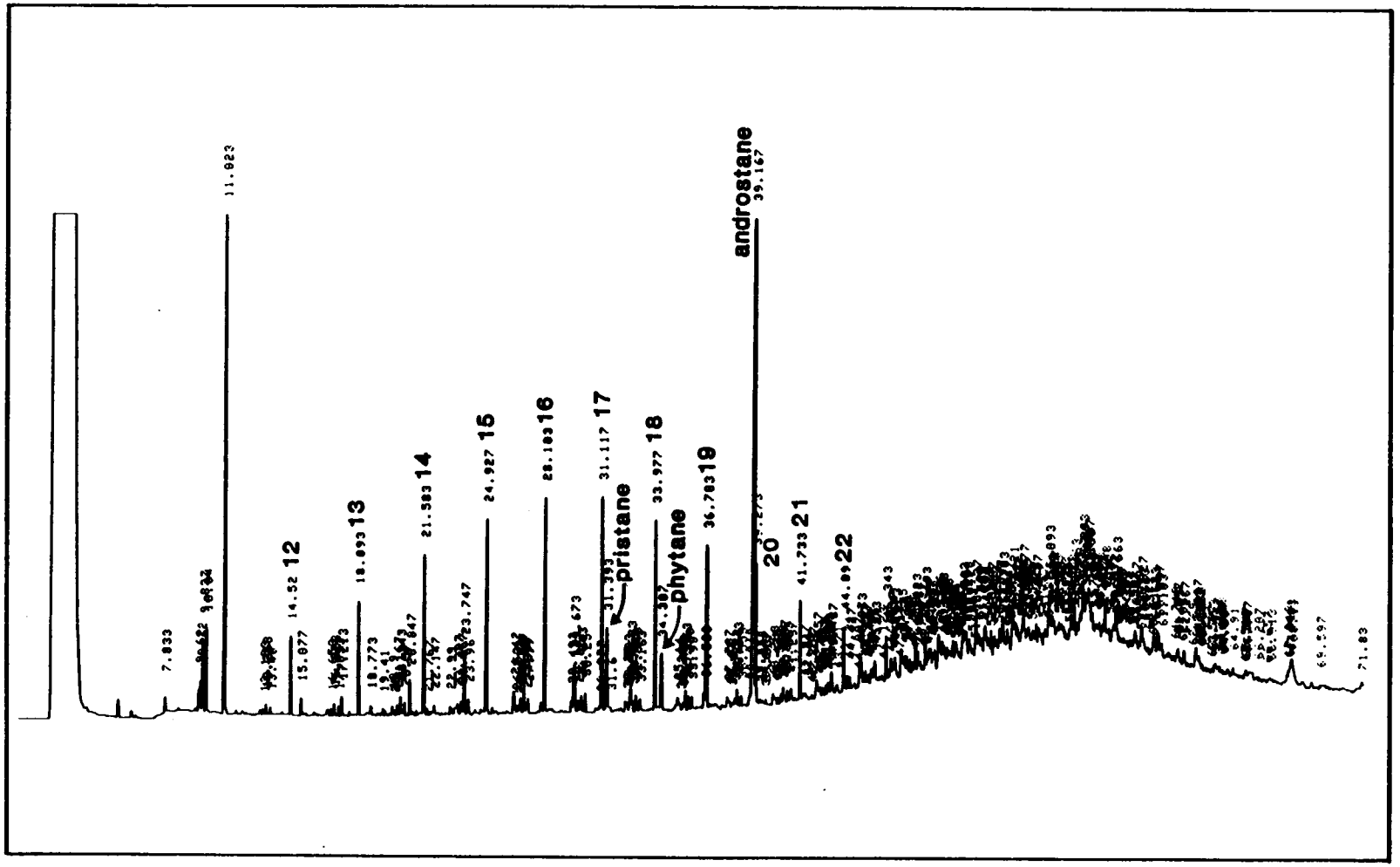

Figure 56. GC/FID Chromatogram of Saturated Hydrocarbons of Sea Urchin Sample, Station 4, Cruise Mid-2.

TABLE 36. TISSUE POLYCYCLIC AROMATIC HYDROCARBON (PAH) CONCENTRATIONS FOR SAMPLES COLLECTED ON CRUISE MID-5. CONCENTRATIONS ARE IN ng/g WET WEIGHT.

Compound	Ophiomusium lymani Sta. 1	Ophiomusium lymani Sta. 4	Echinus affinis Sta. 4
Naphthalene	1.0	1.7	1.6
C1-Napthalene	0.7	1.8	1.4
C2-Napthalene	0.7	0.7	1.4
C3-Napthalene	0.4	0.4	0.2
C4-Napthalene	ND	ND	ND
Biphenyl	0.7	1.5	0.6
Fluorene	0.6	1.3	0.6
C1-Fluorene	ND	0.4	ND
C2-Fluorene	ND	ND	ND
C3-Fluorene	ND	ND	ND
Phenanthrene	2.3	4.3	2.3
C1-Phenanthrene	0.8	1.2	0.7
C2-Phenanthrene	1.2	1.6	2.9
C3-Phenanthrene	ND	ND	0.1
C4-Phenanthrene	ND	ND	ND
Dibenzothiphene	0.9	2.3	ND
C1-Dibenzothiophene	1.4	0.1	ND
C2-Dibenzothiophene	ND	ND	ND
C3-Dibenzothiophene	ND	ND	ND
Fluoranthene	1.5	2.6	1.9
Pyrene	1.4	4.7	1.5
Benzoanthracene	2.8	3.9	1.5
Chrysene	4.1	7.2	2.2
Benzofluoranthene	1.2	2.6	2.9
Benzo(e)pyrene	1.8	1.6	2.0
Benzo(a)pyrene	10.1	8.3	2.5
Perylene	10.2	11.5	2.2
Total PAH	41.7	59.7	28.5

ND=Not detected.

TABLE 37. TRACE METAL CONCENTRATIONS IN BENTHIC FAUNA COLLECTED DURING CRUISES MID-1, MID-2, AND MID-5. CONCENTRATIONS ARE GIVEN IN µg/g WET WEIGHT.

Species	Cruise	Station	Al	Ba	Cd	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn	Hg
Ophiomusium lymani	1	1	189	NA	2.3	0.5	1.2	134	7.7	1.3	0.4	NA	155	0.03
O. lymani	1	1	286	11.8	2.1	0.5	0.8	107	6.6	1.6	0.4	<0.1	127	0.12
O. lymani	1	4	216	21.8	3.1	0.8	1.9	243	17.3	1.4	0.5	<0.5	249	0.05
O. lymani	1	4	266	10.2	3.3	1.0	2.1	345	18.3	1.89	0.5	3.2	247	0.04
O. lymani	1	7-8	268	NA	1.8	0.5	1.6	169	8.8	0.9	0.3	NA	169	0.14
O. lymani	1	7-8	446	23.3	1.6	.4	1.3	265	12.4	1.4	0.4	<0.1	202	0.05
Echinus affinis	1	1	1202	13.8	11.8	4.1	3.5	2061	66.2	1.9	2.2	2.6	74.2	0.14
E. affinis	1	1	1245	NA	16.6	3.7	3.2	1806	62.2	3.6	1.8	NA	81.3	0.14
E. affinis	1	4	2508	28.4	1.6	7.5	5.0	3878	94.0	5.2	4.4	8.0	49.8	0.11
E. affinis	1	4	1520	27.4	1.0	4.1	2.7	2092	59.1	2.8	2.6	8.4	30.3	0.10
E. affinis	1	7-8	1321	83.4	1.7	3.9	4.3	1887	70.0	1.7	2.5	3.3	33.0	0.13
E. affinis	1	7-8	1859	57.3	1.7	5.4	4.9	3089	72.2	3.9	2.8	16.0	38.1	0.14
O. lymani	2	4	391	12.3	1.5	0.4	0.9	66	7.9	0.9	0.3	<.5	113	0.03
O. lymani	2	4	297	12.8	2.1	0.7	1.6	186	9.0	1.0	0.5	0.5	159	0.03
E. affinis	2	4	1017	40.2	1.7	2.6	2.7	647	70.1	1.4	0.6	9.3	34.5	0.14
E. affinis	2	4	1437	46.4	1.7	4.8	2.5	1986	74.3	2.8	1.8	7.2	34.5	0.12
O. lymani	5	1	417	14.1	1.8	0.7	1.4	233	7.5	1.2	0.4	<0.5	162	0.10
O. lymani	5	1	534	22.3	1.6	0.9	1.1	322	7.2	1.4	0.5	1.3	161	0.08
O. lymani	5	4	2260	<5.0	2.8	0.6	1.6	218	13.1	1.2	0.4	1.9	212	0.11
O. lymani	5	4	2574	18.7	3.0	0.9	1.7	714	14.5	0.9	0.8	0.7	223	0.11
E. affinis	5	4	1497	33.1	2.0	4.1	3.0	2119	82.4	1.7	1.9	5.1	46.7	0.12
E. affinis	5	4	1543	23.7	1.8	4.2	3.0	2327	82.1	1.9	2.5	2.6	42.9	0.09

NA = Not analyzed.

Drilling Muds and Cuttings

Petroleum concentrations in drilling muds and cuttings determined by UV/F are listed in Table 38. Concentrations in the drilling muds were greater than those in the sediments, and ranged between 73.8 and 646 µg/g dry weight. The variation in concentration at the three emission wavelengths also differed from that found in the sediments, because of differences in the UV/F spectra of drilling muds and sediments (Figure 53). UV/F-determined petroleum concentrations in cuttings were even greater than in drilling muds. The concentrations determined for the Block 93 composite were two to five times greater than in the muds and ranged between 1.1 and 2.5 mg/g dry weight. Variations in concentration at the three emission wavelengths for the mud showed a marked decrease with increasing wavelength.

Total hydrocarbon concentrations and hydrocarbon parameters in both muds and cuttings are listed in Table 39. Concentrations of total hydrocarbons were higher than in the sediments, ranging between 91.9 and 918 µg/g dry weight, and were dominated by saturated components. The OEPI for these samples was also near unity, which is characteristic of n-alkanes originating from a petroleum source. The GC/FID results also clearly indicated that the samples were composed of a low boiling distillate petroleum fraction and a large high molecular weight UCM (Figure 57).

Concentration of PAH in muds and cuttings (Table 40) also indicated the presence of petroleum hydrocarbons. In contrast to the sediments, the PAH distributions in these samples were dominated by the naphthalene, phenanthrene, and dibenzothiophene alkyl homologue series, with significant quantities of fluorenes also present. Within each series, concentrations increased with increasing alkyl substitution, a distribution characteristic of petroleum and its byproducts. The FFPI for these samples varied between and 89 and 93, which is consistent with a distribution originating from petroleum. The composition of these samples showed the dibenzothiophene compounds characteristic of petrogenic inputs. Dibenzothiophenes were not detected to any significant extent in sediment or tissue samples.

TABLE 38. UV/F ANALYSES OF COMPOSITED DRILLING MUDS AND CUTTINGS FROM BLOCK 372 AND BLOCK 93. CONCENTRATIONS ARE GIVEN IN μg/g DRY WEIGHT[a].

Emission Wavelength (nm)	Block 372 Drilling Muds	Block 372 Cuttings	Block 93 Drilling Muds	Block 93 Cuttings
312	210	233	477 ± 43[b]	2450
355	91.4	141	507 ± 33[b]	1330
425	73.8	138	646 ± 34[b]	1160

[a]Concentrations are reported as petroleum equivalents calculated at three emission wavelengths using light Arabian crude as a reference oil.

[b]Triplicate analysis.

TABLE 39. HYDROCARBON CONCENTRATIONS (μg/g DRY WEIGHT) AND SATURATED HYDROCARBON PARAMETERS FOR DRILLING MUDS AND CUTTINGS FROM BLOCK 372 AND BLOCK 93.

	Block 372 Drilling Muds	Block 372 Cuttings	Block 93[a] Drilling Muds	Block 93 Cuttings
Total Hydrocarbons[b]	245	91.9	398±10	918
Saturates	170	63.7	255±14	527
Aromatics	75.2	28.2	143±8	391
Saturated Hydrocarbon Parameters[c]				
Resolved Saturates (%)	28	44	42±14	21
Unresolved Saturates (%)	72	56	58±14	79
OEPI[d]	1.27	0.97	1.14±0.31	1.37
Pristane/phytane	1.38	1.21	1.36±0.04	1.27
Phytane/n-C_{18}	0.44	0.53	0.53±0.01	0.85
Pristane/n-C_{17}	0.55	0.68	0.72±0.01	1.17

[a]Triplicate analysis.
[b]Gravimetric concentration.
[c]GC/FID data.
[d]Odd-Even Preference Index = $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2\,(n\text{-}C_{28}) + n\text{-}C_{30}}$

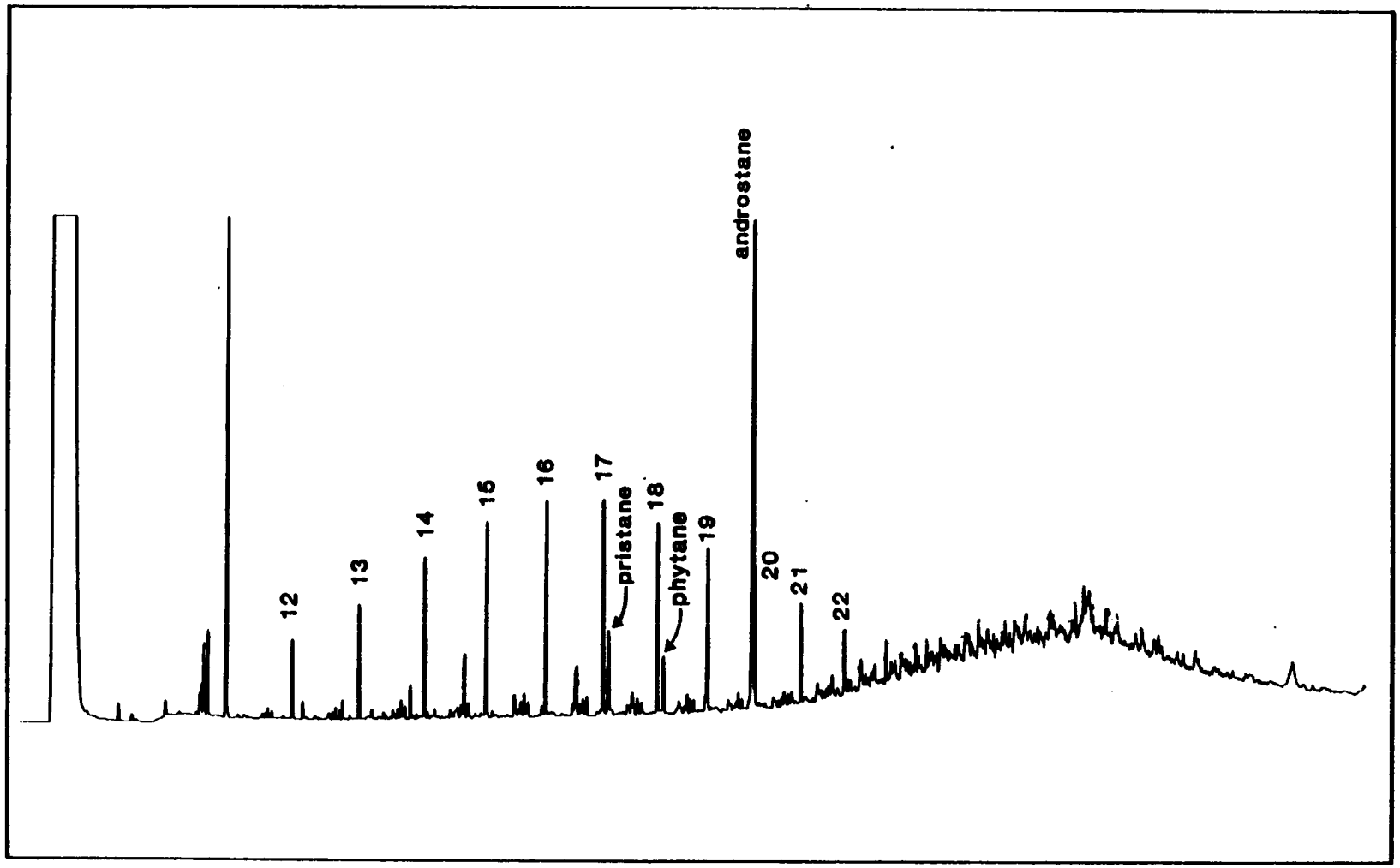

Figure 57. GC/FID Chromatograms of Saturated Hydrocarbon Fraction of Drilling Muds; Composite Sample from Block 372.

TABLE 40. CONCENTRATION (ng/g DRY WEIGHT) OF POLYCYCLIC AROMATIC HYDROCARBONS (PAH) IN DRILLING MUDS AND CUTTINGS FROM BLOCK 372 AND BLOCK 93.

Compound	Block 372 Muds	Block 372 Cuttings	Block 93[a] Drilling Muds	Block 93 Cuttings
Napthalene	13	33	140 ± 19	480
C1-Naphthalene	52	122	426 ± 43	1200
C2-Naphthalene	163	194	558 ± 45	1169
C3-Naphthalene	239	180	607 ± 38	1020
C4-Naphthalene	137	85	231 ± 33	233
Biphenyl	12	9	18 ± 2	46
Fluorene	11	21	79 ± 6	118
C1-Fluorene	28	34	137 ± 9	300
C2-Fluorene	46	39	109 ± 14	196
C3-Fluorene	16	36	45 ± 23	36
Phenanthrene	70	44	242 ± 6	469
C1-Phenanthrene	159	91	459 ± 10	919
C2-Phenanthrene	194	93	364 ± 3	638
C3-Phenanthrene	96	44	212 ± 12	343
C4-Phenanthrene	0	8	ND	ND
Dibenzothiophene	11	7	16 ± 1	23
C1-Dibenzothiophene	61	30	59 ± 4	78
C2-Dibenzothiophene	113	57	77 ± 7	105
C3-Dibenzothiophene	101	52	49 ± 14	92
Fluoranthene	33	18	86 ± 6	159
Pyrene	41	30	80 ± 7	151
Benz(a)anthracene	18	8	48 ± 10	93
Chrysene	21	11	56 ± 14	117
Benzfluoranthene	42	23	137 ± 44	242
Benzo(e)pyrene	19	10	92 ± 31	168
Benzo(a)pyrene	19	9	82 ± 28	135
Perylene	31	11	459 ± 154	594
Total PAH	1,750	1,300	4870 ± 41	9,200
FFPI[b]	80	85	71 ± 2	

[a]Triplicate analysis.
[b]Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).
ND = Not detected.

Quality Control

The results of the analyses performed to determine the precision of the instruments used in this study are given in Table 41. The results of the triplicate analyses made to determine analytical variability are given in Table 42. As a comparison, the coefficient of variation (CV) determined by triplicate analysis of sediments collected on Cruise Mid-1 ranged from 5 to 42 percent.

Most procedural blanks analyzed by the UV/F technique indicated the absence of petroleum. These procedural blanks reflect the amount of UV fluorescing material resulting from sample processing. In the present case, this material represented the trace fluorescing material associated with 180 ml methanol, 270 ml methylene chloride, and 50 g sodium chloride, plus that associated with the manipulative process of sample extraction and processing. The procedural blanks ranged from 0.5 to 2.3 µg/g dry weight (at 355 nm) for all cruises. Comparing the worst blank, i.e., the one with the highest amount of fluorescing material, to the lowest UV/F-determined hydrocarbon concentration in a sediment sample, the blank represented 18 percent of the total signal. In the majority of samples, the procedural blank represented less than 10 percent of the total signal.

In order to relate the potential contribution and magnitude of contaminants associated with blanks to actual samples, absolute concentrations of blank components were divided by a mean sample weight (calculated from actual data) to arrive at a contaminant "concentration" which can be contrasted with sample concentrations. For example, those UV/F blanks exhibiting a measurable response correspond to comparable petroleum concentrations between 0.5 and 2.3 µg/g dry weight, which are relatively minor in comparison to sample concentrations. Saturated and aromatic hydrocarbon fractions corresponding to blanks were not analyzed gravimetrically. However, similar estimates of total saturate concentrations in blanks determined by GC/FID (sum of resolved components) ranged between <0.1 and 2.9 µg/g dry weight, also within an acceptable range. The resolved material generally consisted of some contaminant interfering with the analysis of n-C_{11}, and phthalates eluting between n-C_{25} and n-C_{30}. There were no quantifiable unresolved materials found in any of the procedural blanks analyzed. Blank aromatic fractions analyzed by GC/MS occasionally revealed the presence of some PAH (primarily naphthalenes and phenanthrenes) at concentrations comparable to 1 to 3 µg/g dry weight in samples.

TABLE 41. PRECISION OF INSTRUMENTAL METHODS.

Method	Analyte	Coefficient of Variation[a] (percent)
UV/Fluorescence Spectroscopy	355 nm[b]	19[c]
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	5
	phenanthrene	9
	perylene	21

[a]n=7 for UV/F, n=5 for GC-FID, n=11 for GC/MS.

[b]Quantified against Arabian Light crude oil standard.

[c]Coefficient of variation (CV) for instrument range setting is 0.1. The majority of samples for all cruises were run at this setting. Approximately one-half of Cruise Mid-1 samples were run at range setting 1.0. The CV in this range is 10.

TABLE 42. ANALYTICAL VARIABILITY.

Method	Analyte	Coefficient of Variation (percent)
UV/Fluorescence Spectroscopy[a]	355 nm[c]	6
Gas chromatography-flame ionization detection[b]	$n\text{-}C_{20}$	21
	$n\text{-}C_{30}$	41
Gas chromatography/mass spectrometry[b]	naphthalene	9
	phenanthrene	1
	perylene	24

[a]Triplicate analysis of laboratory homogenized marine sediment, Cruise Mid-4, Station 3.

[b]Triplicate analysis of interim reference material, Duwamish 3 marine sediment.

[c]Quantified against Arabian Light crude oil standard.

Fortified blanks, processed with initial batches of sediment samples, yielded absolute recoveries between 20 and 70 percent for individual components, with the lesser recoveries corresponding to volatile constituents such as naphthalenes. Fortified blanks processed with sample sets from Cruises Mid-2, Mid-3, and Mid-4 showed improved recoveries of the volatile hydrocarbons, with 80 to 100 percent absolute recoveries for naphthalene. Recoveries of fortified blanks processed with Cruise Mid-5 and Mid-6 sediments are presented in Table 43. Note that recoveries were calculated in absolute terms (i.e., relative to an external standard added prior to GC/FID or GC/MS analysis rather than relative to an internal standard, as were most sample concentrations). Recovery calculations based on internal standards would be higher.

UV/F determination of the petroleum concentrations in previously extracted sediments, fortified with Arabian crude oil at a concentrations of approximately 200 µg/g dry weight, yielded recoveries of 104 to 141, 123 to 137, and 125 to 129 percent at emission wavelengths 312, 355, and 425 nm, respectively. These data indicate that this technique produces accurate results.

Additionally, during the course of the Cruise Mid-3 analyses, Battelle participated in a laboratory intercalibration exercise sponsored by the Minerals Management Service, Alaska OCS Region. The intercalibration exercise consisted of the analysis of sediment (Duwamish 3) and tissue homogenate for alkane and aromatic hydrocarbons by GC/FID and GC/MS, respectively. The results of Battelle's analysis of the test material and comparative test results are presented in Boehm et al. (1986).

Results of method blank and standard reference material analyses in support of the metals analytical program are presented in Table 44. A 5-g wet weight sample was assumed for the purpose of reporting the results of the analysis of method blanks. Except for Cr values which are present in the blank near the levels found in the brittle star samples, the analysis of method blanks with the tissue metals analysis revealed no significant contamination of any element. The two elements that are subject to the most contamination in the laboratory (Pb and Zn) were not detectable in the blanks. Results of analysis of NBS reference material were also satisfactory. Pb levels in blank samples were higher than the reported values for tissue samples. However, for the amount of material analyzed, these levels are near the analytical detection limit and, therefore, subject to greater error than other reported laboratory values.

TABLE 43. PERCENT RECOVERY OF SPIKED ANALYTES, BLANK SPIKE EXPERIMENTS, SEDIMENT PROCEDURE.

Saturated Hydrocarbon Analytes					
n-C_{14}	n-C_{15}	n-C_{24}	n-C_{25}	n-C_{32}	n-C_{34}
122	97	117	120	122	113
43	50	88	93	81	69

Aromatic Hydrocarbon Analytes[a]						
N	C1-N	P	DBT	Pyr	Chry	Pery
55	77	103	95	105	76	90
58	66	84	80	86	74	72

[a]N = naphthalene
C1-N = 1-methylnaphthalene
P = phenanthrene
DBT = dibenzothiophene
Pyr = pyrene
Chry = chrysene
Pery = perylene

TABLE 44. TRACE METAL ANALYTICAL RESULTS, METHODS BLANKS, AND REFERENCE MATERIALS. CONCENTRATIONS ARE GIVEN IN μg/g.

	Al	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Zn	V	Ba
Method Blank[a]	.18	.005	1.27	<.05	<.5	<.05	<2	.028	<2		
	.08	<.001	1.71	<.05	<.5	<.05	<2	.012	<2		
NBS 1577[a]											
Laboratory Analysis				148	186	10.6	.248	112			
				142	186	10.3	.366	106			
Reported Value				158	194	9.9	.135	123			
Reported SD				7	20	.8	.015	8			
NBS 1566											
Laboratory Analysis										2.39	
Reported Value										2.3	
Reported SD										.3	
NBS 1632											
Laboratory Analysis										34.8	336
Reported Value										35.0	342
Reported SD										3.0	20
NBS 1572											
Laboratory Analysis											19.9
Reported Value											21.0
Reported SD											3.0

[a]Assumes 5 g wet weight sample.

DISCUSSION

Sediment Analyses

Hydrocarbon concentrations in sediments collected during this study appear similar to, but higher than, values found in earlier studies in the same geographic area (Farrington and Tripp, 1977; Smith et al., 1979) and are also higher than concentrations found in sediments at similar depth regimes on the U.S. North Atlantic slope and rise (Maciolek et al., 1986b). However, the sediment hydrocarbon composition and temporal trends show no indication that the relatively higher levels on the U.S. Mid-Atlantic slope and rise were the result of petroleum exploration activities. The total hydrocarbon concentrations (gravimetric) in sediments collected during Cruises Mid-1 through Mid-6 ranged from 2.9 to 52.9 µg/g dry weight. There are no investigations of similar magnitude of the U.S. Mid-Atlantic slope and rise with which to compare the data. Geographically, the most comparable data sets include the work of Farrington and Tripp (1977) for sediments collected in 200-300 m depths off the western North Atlantic continental margin, and those reported by Smith et al. (1979) for Mid-Atlantic continental shelf sediments. These authors reported sediment hydrocarbon concentrations of 5.3 to 10.5 µg/g dry weight, and 0.02 to 3.0 µg/g dry weight, respectively. However, the latter values are GC/FID data for resolved hydrocarbons only and thus are not directly comparable. However, Boehm and Requejo (1986) estimate from the data of Smith et al. (1979) that if unresolved components accounted for 40 percent of the total (from visual comparisons), the total hydrocarbons in the Mid-Atlantic shelf sediments would be 0.05 to 7.5 µg/g dry weight. This estimate would be consistent with the proportions of unresolved saturated components reported for this study which, with few exceptions, ranged from 40 to 70 percent. The absolute concentrations of sediment hydrocarbons in this study compare most closely with those reported by Maciolek et al. (1986b) for sediments of the U.S. North Atlantic slope and rise where values ranged from 2.8 to 16.2 µg/g and with those reported by Boehm and Requejo (1986) for depositional areas of the Gulf of Maine where values ranged from 10 to 20 µg/g.

UV/F, GC/FID, and GC/MS data for the stations for which there are six sets of samples indicate that there was no change in hydrocarbon concentrations over time.

UV/F data are the statistically most reliable data because there were three replicate samples analyzed for each station per cruise. Linear regression of mean UV/F data at 355 nm with time indicates that there was no statistically significant linear correlation of concentration with time ($r = -0.56, +0.10, -0.39$ for Stations 1, 10, and 13, respectively). Results of UV/F analyses (Tables 45, 46, 47) indicate that the variability in mean hydrocarbon concentration at given stations between cruises was similar to the variability between replicate analyses for a single cruise. For example, the mean UV/F-determined hydrocarbon concentrations at 355 nm for Station 13 sediments was 70.5 ± 11.9 with a CV of 16.9 percent; whereas the CV from the analysis of field triplicates ranged from 8.2 (Cruise 1) to 30.7 percent (Cruise 3). The variability of mean UV/F-determined hydrocarbon concentrations at Stations 1 and 10 also fell within the range of the field replicate variability at those stations. Although there were no discernible temporal increases in UV/F-determined hydrocarbon concentrations in the sediments, it is apparent from the data that, given the limited sample set, sediment hydrocarbon concentrations would have to increase by 40 percent to be statistically significant.

Similarly, there were no apparent geographic variations in total hydrocarbon concentrations that might be attributable to drilling activities (Tables 48, 49, and 50). The total hydrocarbon concentration (mean concentration 39 μg/g) found at Station 13, situated 2 km southwest of the drill site in Block 93, is higher than those found at other stations (e.g., Station 10, 16.9 μg/g). However, elevated hydrocarbon concentrations were also detected in Cruise Mid-1 samples obtained prior to any drilling activity (Table 50). These elevations most likely reflect variations in sedimentological properties with higher concentrations associated with fine-grained sediments having higher TOC levels.

The hydrocarbon concentrations at all of the other locations (Tables I-1 to I-6) were also relatively uniform from cruise to cruise and from station to station, with the exception of Station 5, which had higher concentrations than other stations. This station is situated downcurrent of the EPA 106-Mile Dumpsite and may receive anthropogenic inputs related to disposal activities.

Sediment hydrocarbon concentrations determined gravimetrically at Stations 1, 10, and 13 also did not increase throughout the period of time of the sampling cruises (Tables 48, 49, 50). Similarly, saturated hydrocarbon parameters reveal no trends that might indicate that there was a large variation in the influx of saturated hydrocarbons to the

TABLE 45. RESULTS OF UV/F ANALYSES OF SEDIMENTS COLLECTED AT STATION 1. CONCENTRATIONS ARE GIVEN IN µg/g DRY WEIGHT[a].

Emission Wavelength (nm)	Cruise						$\bar{X}^b$	SD^b
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6		
312	19.8 ± 5.8	16.2 ± 2.3	20.5 ± 2.7	22.1[c]	17.1 ± 5.7	21.4 ± 7.2	19.5	2.4
355	41.2 ± 9.4	31.7 ± 6.2	36.1 ± 3.9	40.1 ± 8.7	36.0 ± 10.5	26.4 ± 9.4	35.3	5.5
425	64.5 ± 17.7	45.4 ± 7.6	46.5 ± 8.3	54.9 ± 9.9	41.4 ± 11.1	29.5 ± 13.5	47.0	11.9

[a]Concentrations are reported as mean ± one standard deviation petroleum equivalents calculated at three emission wavelengths using light Arabian crude. They are based on analysis of triplicate sediment grabs collected at each station.

[b]Mean and standard deviation of mean values determined for each cruise.

[c]Only one sediment sample analyzed at 312 nm.

TABLE 46. RESULTS OF UV/F ANALYSES OF SEDIMENTS COLLECTED AT STATION 10. CONCENTRATIONS ARE GIVEN IN µg/g DRY WEIGHT[a].

Emission Wavelength (nm)	Cruise						$\bar{X}$[b]	SD[b]
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6		
	Concentration (µg/g dry weight)[b]							
312	11.1 ± 2.4	9.0 ± 1.8	10.9[c]	14.4 ± 2.6	14.1 ± 3.3	11.4 ± 2.4	11.8	2.1
355	21.9 ± 3.6	19.7 ± 3.9	17.5 ± 6.2	29.0 ± 1.5	27.4 ± 9.5	16.8 ± 3.6	22.1	5.1
425	32.5 ± 4.2	32.3 ± 3.0	34.8 ± 11.2	41.8 ± 4.2	29.0 ± 11.3	18.2 ± 4.6	31.4	7.8

[a]Concentrations are reported as mean ± one standard deviation petroleum equivalents calculated at three emission wavelengths using light Arabian crude. They are based on analysis of triplicate sediment grabs collected at each station.

[b]Mean and standard deviation of mean values determined for each cruise.

[c]Only one sediment sample analyzed at 312 nm.

TABLE 47. RESULTS OF UV/F ANALYSES OF SEDIMENTS COLLECTED AT STATION 13. CONCENTRATIONS ARE GIVEN IN µg/g DRY WEIGHT[a].

Emission Wavelength (nm)	Cruise						$\bar{X}^b$	SD^b
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6		
312	43.7 ± 10.0	32.4 ± 3.1	59.9 ± 61.7	43.3 ± 3.6	42.0 ± 13.8	33.9 ± 5.2	42.5	9.8
355	79.5 ± 6.5	63.0 ± 5.5	72.7 ± 22.3	88.2 ± 11.7	56.4 ± 7.8	63.1 ± 7.5	70.5	11.9
425	121.0 ± 9.0	86.3 ± 9.4	119.3 ± 21.5	131.3 ± 16.9	63.9 ± 4.8	81.1 ± 10.8	100.5	27.0

[a]Concentrations are reported as mean ± one standard deviation petroleum equivalents calculated at three emission wavelengths using light Arabian crude. They are based on analysis of triplicate sediment grabs collected at each station.

[b]Mean and standard deviation of mean values determined for each cruise.

TABLE 48. SEDIMENT HYDROCARBON CONCENTRATIONS (µg/g DRY WEIGHT) AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED AT STATION 1.

	Cruise								
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6	$\bar{X}$	SD	CV
Total Hydrocarbons[a]	19.5	14.9	18.1	9.0	15.7	27.6	17.5	6.1	35
Saturates	9.5	7.1	8.6	4.8	9.4	16.2	9.3	3.8	41
Aromatics	10.0	7.8	9.5	4.2	6.3	11.4	8.2	2.6	32
Saturated Hydrocarbon Parameters[b]									
Resolved Saturates (%)	32	51	30	50	68	79			
Unresolved Saturates (%)	68	49	70	45	32	21			
OEPI[c]	3.68	3.11	2.90	4.0	3.3	2.0			
Pristane/Phytane	4.00	8.84	NC	3.4	3.1	2.4			
Phytane/n-C_{18}	1.18	0.22	NC	0.2	0.3	0.3			
Pristane/n-C_{17}	0.50	0.68	0.47	0.8	0.6	0.5			

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index = $\dfrac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2(n\text{-}C_{28}) + n\text{-}C_{30}}$

NC = Not calculated due to low relative abundance of phytane.

TABLE 49. SEDIMENT HYDROCARBON CONCENTRATIONS (µg/g DRY WEIGHT) AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED AT STATION 10.

	Cruise								
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6	$\bar{X}$	SD	CV
Total Hydrocarbons[a]	7.0	9.2	8.6	10.8	26.9	15.1	16.9	16.7	99
Saturates	3.7	4.5	5.0	3.5	24.1	7.0	11.9	17.6	148
Aromatics	3.3	4.7	3.6	7.3	2.8	8.1	5.0	2.2	44
Saturated Hydrocarbon Parameters[b]									
Resolved Saturates (%)	26	81	43	32	100	75			
Unresolved Saturates (%)	74	19	57	68	0	25			
OEPI[c]	2.32	3.13	3.84	1.32	3.0	2.3			
Pristane/Phytane	2.08	3.74	3.34	3.99	3.3	3.4			
Phytane/n-C_{18}	0.21	0.22	0.25	0.20	0.2	0.2			
Pristane/n-C_{17}	0.39	0.66	0.66	0.77	0.5	0.7			

[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 50. SEDIMENT HYDROCARBON CONCENTRATIONS (µg/g DRY WEIGHT) AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED AT STATION 13.

	Cruise								
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6	$\bar{X}$	SD	CV
Total Hydrocarbons[a]	46.5	37.1	52.9	20.4	31.0	46.9	39.1	12.0	31
Saturates	27.7	19.9	29.0	10.0	2.2	23.4	18.7	10.6	57
Aromatics	18.8	17.2	23.9	10.4	28.8	23.6	20.5	6.4	31
Saturated Hydrocarbon Parameters[b]									
Resolved Saturates (%)	24	35	16	37	58	51			
Unresolved Saturates (%)	76	65	84	63	42	49			
OEPI[c]	3.24	4.26	3.03	1.60	2.1	2.6			
Pristane/Phytane	2.62	1.80	1.47	4.32	3.5	3.7			
Phytane/n-C_{18}	0.32	0.26	0.51	0.18	0.2	0.2			
Pristane/n-C_{17}	0.68	0.38	0.60	0.68	0.6	0.7			

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index = $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2(n\text{-}C_{28}) + n\text{-}C_{30}}$

sediments during the period of the study. The OEPI for the sediments from the study area is comparable to those reported by Farrington and Tripp (1977) and Boehm (1984) and Boehm and Requejo (1986) for Georges Bank and western North Atlantic sediments, and also to those reported for the OCS areas in Alaska (Venkatesan and Kaplan, 1982; Shaw et al., 1979) and the Gulf of Mexico (Gearing et al., 1976). The other saturated hydrocarbon parameters, such as the isoprenoid/n-alkane ratios, that might reveal seasonal hydrocarbon input to the sediment show no consistent seasonal variability. The pristane/phytane ratios were generally similar at Stations 1, 10, and 13, suggesting a rather constant contribution from marine and terrestrial sources throughout the survey area. The gas chromatograms of many of the sediment samples analyzed display a significant UCM component also reported by Boehm and Requejo (1986) for U.S. Mid-Atlantic OCS sediments. This component suggests anthropogenic contamination in addition to biogenic hydrocarbon sources throughout the sampling area.

The most sensitive potential marker of drilling muds and cuttings, however, appears to be the aromatic hydrocarbon content and composition. The PAH data from this study represent the first data reported for the U.S. Mid-Atlantic continental slope and rise. The compositional differences between the sediments and the drilling muds and cuttings appear to reside in 1) the relative abundance of the 312- and 355-nm UV/F spectral bands versus the 425-nm band; and 2) the PAH composition as indicated by the FFPI and by the presence of the dibenzothiophene homologous series. The dominance of 4- and 5-ring PAH compounds in sediments collected on all cruises is characteristic of a high temperature pyrolytic (combustion of fossil fuels) rather than petroleum origin (Tripp et al., 1981). Some evidence for the occurence of PAH originating from a petroleum source is apparent from the higher concentrations of naphthalenes detected at Station 5 (Cruises Mid-1 and Mid-2), Station 13 (all cruises), and Station 14 (Cruise Mid-1). However, the calculated FFPI values for these sediments indicate that PAH contributions from petroleum sources were minor.

There appear to be no increases in the concentrations of sediment aromatic hydrocarbons during the course of the study. The levels found are similar to those reported previously by Bieri et al. (1978) for the Mid-Atlantic region. Concentrations of individual PAH compounds reported by these authors range from 1 to 25 ng/g dry weight on the adjacent shelf area. This range is somewhat less than the range of values shown in

Tables I-13 to I-18 for slope and rise sediments. The values from stations for which there are data from all six cruises show that the total PAH concentrations were quite constant for that period of time (Tables 51 to 53). Similarly, there was no systematic increase in FFPI values which might indicate an input of petroleum associated with oil and gas development on the slope and rise. The highest FFPI value of 53 was found at Station 5 for samples collected on Cruise Mid-2.

Sediment aromatic hydrocarbon concentrations are positively correlated with sediment total organic carbon. Additionally, sediment PAH concentrations at the shallower stations (Stations 11 and 13) were relatively enhanced compared to concentrations found at the deeper stations.

Tissue Analyses

The limited variety of suitable benthic species and the associated sampling difficulties restricted the choice of benthic species for tissue analysis. Only a small set of tissue samples was analyzed since it was possible to obtain pre-drilling and post-drilling samples at only one station for three cruises and one station for two cruises. Among the samples analyzed, there was little evidence for the presence of petroleum hydrocarbons. PAH were detected at low levels in tissue samples from Cruise Mid-5. However, total PAH did not exceed 0.06 ppm in any sample and there was no indication that the limited PAH concentrations were the result of contamination from discharges attributed to oil and gas exploration activities. Levels of all hydrocarbons were higher in samples collected during Cruise Mid-5 than those collected earlier. However, it appears that the difference is not related to an actual change in background hydrocarbon levels, but perhaps is the result of procedural changes that allowed for the improved analysis of hydrocarbons at the extreme low levels found in the samples.

Pristane was the single major resolved component in many saturated hydrocarbon fractions. The data in Table 42 indicate that the saturated hydrocarbons in some brittle star samples consisted mainly of unresolved hydrocarbon material. However, several gas chromatograms of tissue hydrocarbons showed a pattern of n-alkanes from n-C25 to n-C34, similar to those hydrocarbons found in the sediments. A UCM feature characteristic of weathered petroleum in GC/FID chromatograms similar to that found in the sediments

TABLE 51. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBON (PAH) CONCENTRATIONS (ng/g DRY WEIGHT) AT STATION 1.

Compound	Cruise						$\bar{X}$	SD	CV
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6			
Naphthalene	ND	5	3	2	4	4	3	1	46
C1-Naphthalenes	1	7	4	3	6	6	5	2	50
C2-Naphthalenes	5	8	7	6	7	8	7	1	17
C3-Naphthalenes	5	4	8	5	5	8	6	2	30
C4-Naphthalenes	ND	ND	1	ND	1	2	1	<1	24
Biphenyl	ND	2	1	1	2	2	2	1	27
Fluorene	1	3	2	1	2	2	2	1	41
C1-Fluorenes	1	2	2	1	3	3	2	1	44
C2-Fluorenes	ND	ND	3	ND	3	4	2	1	61
C3-Fluorenes	ND	ND	ND	ND	2	5	2	2	87
Phenathrene	28	24	19	15	13	18	20	6	29
C1-Phenanthrenes[a]	24	24	12	48	9	12	22	15	67
C2-Phenanthrenes[a]	16	11	12	41	6	10	16	13	79
C3-Phenanthrenes[a]	3	1	9	10	2	5	5	4	74
C4-Phenanthrenes[a]	ND	ND	7	ND	1	1	2	2	122
Dibenzothiophenes	1	1	1	1	2	2	1	1	38
C1-Dibenzothiophenes	ND	ND	1	1	1	2	1	<1	34
C2-Dibenzothiophenes	ND	ND	1	ND	1	3			
C3-Dibenzothiophenes	ND	ND	1	ND	ND	1	1	-	-
Fluoranthene	37	29	26	24	18	24	26	6	24
Pyrene	27	22	19	16	15	19	20	4	22
Benz(a)anthracene	8	7	9	7	8	11	8	2	18
Chrysene	15	12	14	14	12	13	13	1	9
Benzofluoranthene	53	31	38	52	33	59	44	12	27
Benzo(e)pyrene	16	11	13	15	13	23	15	4	28
Benzo(a)pyrene	10	7	9	12	14	13	11	3	24
Perylene	10	8	10	11	16	20	13	5	36
Total PAH (sum of above)	261	219	232	286	199	278	246	35	14
FFPI[b]	23	31	33	35	24	23	28	5	19

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene + fluorene + 1/2 (phenanthrene + C1-phenanthrenes) + dibenzothiophenes}}{\text{PAH}}$$

TABLE 52. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBON (PAH) CONCENTRATIONS (ng/g DRY WEIGHT) AT STATION 10.

Compound	Cruise						$\bar{X}$	SD	CV
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6			
Naphthalene	3	4	1	1	2	2	2	1	53
C1-Naphthalenes	5	4	2	2	4	4	4	1	30
C2-Naphthalenes	6	5	2	4	5	4	4	1	35
C3-Naphthalenes	5	4	6	3	5	5	5	1	23
C4-Naphthalenes	ND	ND	3	ND	1	1	2	2	87
Biphenyl	1	5	2	1	1	1	2	1	58
Fluorene	1	1	1	1	1	1	1	0	0
C1-Fluorenes	2	1	1	1	2	2	2	1	36
C2-Fluorenes	2	1	1	ND	3	3	2	2	73
C3-Fluorenes	ND	1	ND	ND	3	2	2	1	55
Phenanthrene	15	17	10	12	11	10	13	3	23
C1-Phenanthrenes[a]	16	22	9	36	5	7	16	12	74
C2-Phenanthrenes[a]	14	16	10	29	7	7	14	8	60
C3-Phenanthrenes[a]	5	4	6	9	3	3	5	2	46
C4-Phenanthrenes[a]	ND	ND	1	ND	1	1	1	-	-
Dibenzothiophenes	1	1	1	1	1	1	1	0	0
C1-Dibenzothiophenes	ND	1	ND	ND	1	1	1	-	-
C2-Dibenzothiophenes	ND	ND	ND	ND	2	1	<1	-	-
C3-Dibenzothiophenes	ND	ND	ND	ND	2	1	<1	-	-
Fluoranthene	15	28	14	17	14	15	17	5	32
Pyrene	12	21	11	14	11	12	84	4	28
Benz(a)anthracene	4	7	7	5	6	6	6	1	21
Chrysene	10	16	12	10	9	9	10	4	35
Benzofluoranthene	30	36	27	35	31	31	32	3	11
Benzo(e)pyrene	8	13	9	11	11	13	11	2	19
Benzo(a)pyrene	5	7	8	7	9	8	7	1	19
Perylene	8	12	12	10	12	15	12	2	20
Total PAH (sum of above)	168	227	156	209	164	166	181	29	16
FFPI[b]	36	26	28	35	25	22	29	6	20

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene} + \text{fluorene} + 1/2\,(\text{phenanthrene} + \text{C1-phenanthrenes}) + \text{dibenzothiophenes}}{\text{PAH}}$$

TABLE 53. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBON (PAH) CONCENTRATIONS (ng/g DRY WEIGHT) AT STATION 13.

Compound	Cruise								
	Mid-1	Mid-2	Mid-3	Mid-4	Mid-5	Mid-6	$\bar{X}$	SD	CV
Naphthalene	2	6	4	4	6	5	4	1	32
C1-Naphthalenes	4	5	6	7	12	11	8	3	43
C2-Naphthalenes	16	9	14	15	22	16	15	4	27
C3-Naphthalenes	24	10	22	16	22	14	18	6	31
C4-Naphthalenes	13	1	11	3	5	2	6	5	86
Biphenyl	2	8	2	2	3	2	4	2	60
Fluorene	4	3	4	5	5	5	4	1	19
C1-Fluorenes	6	3	7	6	11	5	6	3	42
C2-Fluorenes	31	1	14	7	14	7	12	10	84
C3-Fluorenes	17	1	10	2	12	9	9	6	72
Phenathrene	59	42	42	48	45	38	46	7	16
C1-Phenanthrenes[a]	67	36	32	126	38	22	54	38	72
C2-Phenanthrenes[a]	98	266	41	108	26	18	53	40	75
C3-Phenanthrenes[a]	44	6	21	56	10	6	24	21	89
C4-Phenanthrenes[a]	5	ND	10	3	2	1	4[c]	3[c]	83[c]
Dibenzothiophenes	3	3	3	4	4	3	4	1	30
C1-Dibenzothiophenes	5	3	6	5	5	4	4	1	28
C2-Dibenzothiophenes	14	2	20	8	6	6	9	7	72
C3-Dibenzothiophenes	2	ND	22	1	2	1	5[c]	8[c]	174[c]
Fluoranthene	87	51	58	64	54	52	61	14	22
Pyrene	67	37	42	49	44	41	47	11	23
Benz(a)anthracene	28	12	23	31	18	17	22	7	33
Chrysene	ND	24	29	38	33	28	30[c]	5[c]	18[c]
Benzofluoranthene	160	65	67	100	110	96	100	35	35
Benzo(e)pyrene	50	23	26	28	37	35	33	10	30
Benzo(a)pyrene	32	16	17	31	26	24	24	7	28
Perylene	30	15	20	25	23	24	23	5	22
Total PAH (sum of above)	870	408	573	792	598	493	720	177	24
FFPI[b]	41	31	44	40	28	24	35	8	23

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene + fluorene + 1/2 (phenanthrene + C1-phenanthrenes) + dibenzothiophenes}}{\text{PAH}}$$

[c] N=5

was also observed (Figure 58). Because of low PAH levels, it is unlikely that traces of sediment present in the organisms were responsible for these features and also unlikely that petrogenic inputs from exploration-related discharges accounted for the observed distribution.

A comparison of the total hydrocarbon concentrations in the brittle star Ophiomusium lymani and the sea urchin Echinus affinis collected at Stations 1 and 4 before and after drilling at Block 372 reveals a large degree of variability: the range of total hydrocarbon concentrations was 27.4 to 163.1 µg/g wet weight. However, saturated hydrocarbon concentrations exhibited a narrower range (16.2 to 51.8 µg/g wet weight) and the relatively larger variability in total hydrocarbon concentrations was the result of increased (gravimetric) unsaturated hydrocarbon content in the unsaturate/aromatic fraction. As discussed earlier, this increase in gravimetric concentration appears related to a change in procedure that allowed a more complete extraction of the tissue sample, rather than to a change in actual hydrocarbon levels. Station 4 is situated more than 20 km from the Block 372 drilling site and analysis of the sediments at this location showed little change in hydrocarbon composition between pre-and post-drilling samples (Cruises Mid-1 and Mid-2, respectively). The natural temporal variation in the biogenic hydrocarbon content of deep-sea benthic fauna is not well known and the variations reported here are, therefore, difficult to interpret in relation to offshore activities.

The presence of trace amounts of sediment in the tissues might account for the high Al, Fe, and Mn values and the high variability of these elements. Pb, Cr, Ni, and V also varied in a manner similar to the mineral elements. Hg, Cd, Cu, and Zn, which would tend to concentrate in the tissues, were present in low levels and showed little variation. With the exception of Ba, Cd, Hg, and Zn, sea urchins appeared to have higher tissue concentrations for most of the trace metals analyzed than did the brittle stars. For both species, the analyses represented whole body burdens. The high variability of the analyses for most elements makes it difficult to assess the temporal variation of the samples. However, there appear to be no systematic increases in metal concentrations between pre- and post-drilling samples.

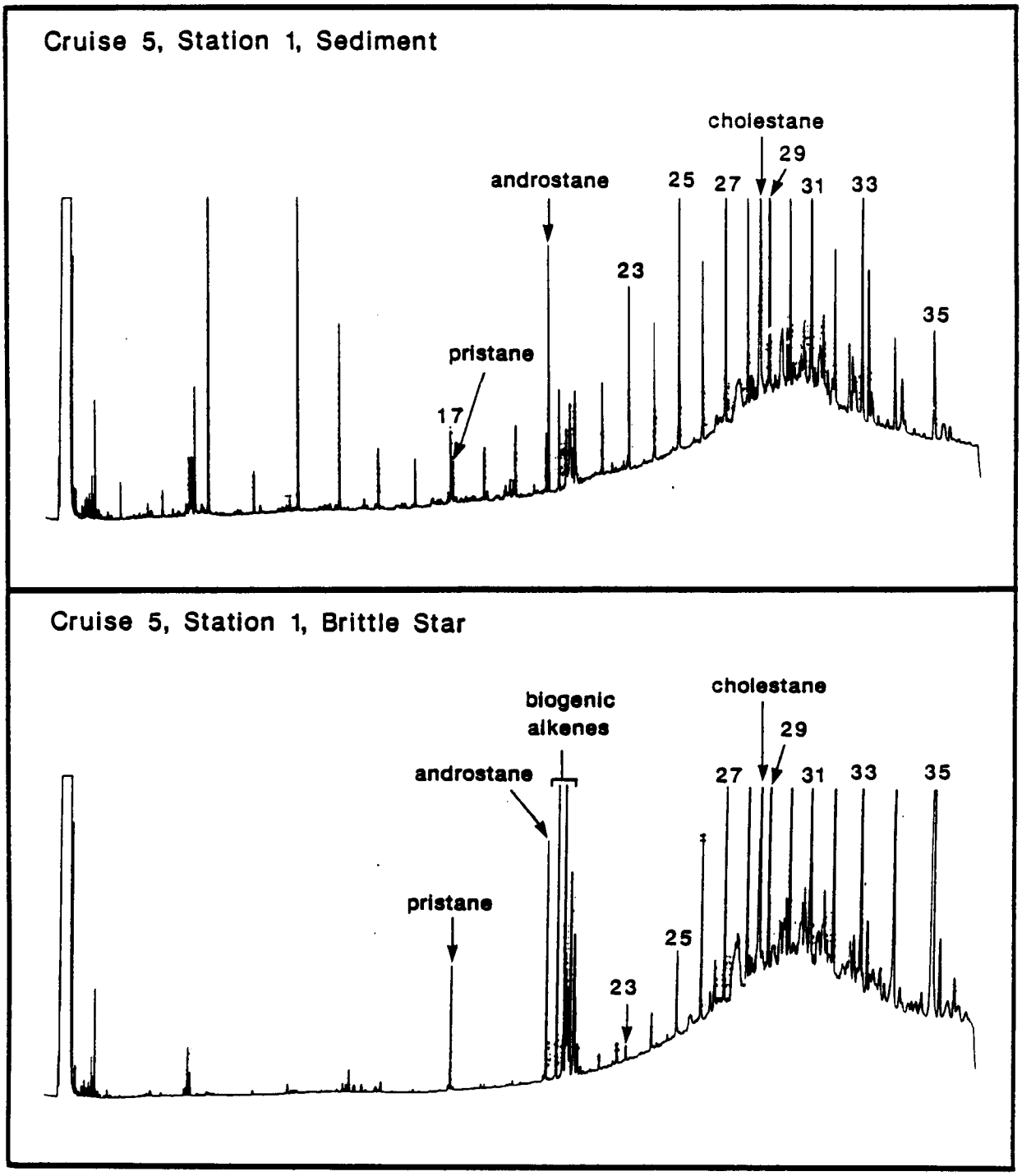

Figure 58. GC/FID Chromatograms of Brittle Star and Sediment at Station 1, Cruise Mid-5.

Drilling Muds and Cuttings

UV/F-determined petroleum concentrations were significantly greater in muds and cuttings than in sediments. Moreover, the variation in concentration with emission wavelength exhibited a trend opposite to that observed in the sediments (i.e., decreasing concentrations with increasing wavelength). This latter trend was probably due to the greater relative abundance of 2- and 3-ring PAH in the muds and cuttings in comparison with the sediments, and is highly significant because it suggests that an increase in UV/F petroleum concentration (calculated at 312-nm emission wavelength) might serve as a sensitive basis by which to screen samples for the occurrence of petroleum hydrocarbons originating from discharged drilling muds or cuttings. Although this method has not previously been used to monitor petroleum contamination from drilling muds and cuttings, similar methods have been used to trace spilled oil in the marine environment (Boehm and Fiest, 1982; Boehm et al., 1982).

Total hydrocarbon concentrations and PAH distributions confirm the presence of petroleum hydrocarbons in the muds and cuttings analyzed. Total hydrocarbon concentrations ranged from 92 to 918 µg/g dry weight, with the principal n-alkanes in the C_{14} to C_{22} range exhibiting an odd/even ratio near unity. The OEPI calculated for n-alkanes over the highest molecular weight range was also close to 1.0 (Table 50), which is characteristic of petroleum. PAH distributions were dominated by naphthalenes, with significant concentrations of fluorenes and dibenzothiophenes also evident. The FFPI of these samples varied between 70 and 90, indicating that the PAH in the muds and cuttings were predominately of petroleum origin. These results indicate that the occurrence of significant quantities of naphthalenes, fluorenes, and dibenzothiophenes in sediments and biota would be a useful indicator of exploration-related discharges, depending on the fate of these materials following discharge. However, no marked increases in these marker compounds were noted in the sediment samples analyzed in the present study.

CHAPTER 8. SEDIMENT CHARACTERISTICS: GRAIN SIZE AND CHN

INTRODUCTION

Sediment grain size is an important correlate with the occurrence of certain infaunal species. Although other physical parameters may be important, variability in patterns of species distribution can be linked to differences in grain-size composition. This relationship was demonstrated, for example, for the amphipod Erichthonius fasciatus on Georges Bank (Maciolek-Blake et al., 1984) and several of the dominant species reported in this study (see Chapter 3, this report).

Concentrations of organic carbon, hydrogen, and nitrogen in sediments may reflect the food supply available to benthic animals that filter particles from the water or ingest sediments. 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.

Most of the sediment-bound metal and organic contaminants 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. In addition, nonpolar organic contaminants such as petroleum hydrocarbons tend to be bound selectively to the organic fraction of the sediment. Therefore, information about sediment grain size and total organic carbon is essential for interpreting data on contaminant concentrations and distributions in sediment.

Documentation of these sediment parameters and their variability in time within-station and on local and regional spatial scales provides insight on periodicity and importance of sedimentological processes that directly affect sediments and their biota. Ongoing sedimentological processes recognized as important on the continental slope of the U.S. Mid-Atlantic bight include sediment spillover at the shelf break, mass wasting and downslope transport principally in the vicinity of submarine canyons, and hemipelagic sedimentation on the middle and lower slope (Knebel, 1984). In addition to existing natural variability ascribed to these processes, changes in sediment characteristics related to the disposal of drilling material were monitored in this study. Analyses were made on bulk samples taken from the top 2 cm of sediment, a scale relevant to the

majority of benthic species. Given region-wide estimates of average sedimentation rates from 0.07 (McGregor et al., 1984) to 0.22 mm/yr (Doyle et al., 1979), measurable changes in the top 2 cm of sediment were considered to reflect relatively significant sedimentological events that might occur at the sediment/water interface.

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 were 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 were 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 hr. Dried material was ground by a mortar and pestle to a fine homogenous powder. All glassware was previously fired at 550°C for 24 hr 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 hr.

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 component organic matter and selected grain-size measures among stations and cruises were each tested by use of a one-way analysis of variance (ANOVA). For significant ANOVAs, multiple comparisons of sediment characteristics were examined more closely:

1. Differences in sediment characteristics among stations of a priori interest for each time sampled (i.e., cruise) were tested using a planned comparison contrast procedure using the t statistic with alpha = 0.05.

2. Differences in sediment characteristics among times at each station and among along-slope Stations 1 through 10 at each time were tested using the Student-Newman-Keuls least significant range procedure and the more conservative Scheffé range procedure (Keppel, 1982). All comparisons used an experiment-wise alpha = 0.05.

The Student-Newman-Keuls (SNK) procedure employs range values scaled to potential subset size in comparisons of different subsets. The Scheffé procedure uses a single range value based on the ANOVA F statistic for all comparisons; it is therefore more appropriate for all possible comparisons for group means, including cases with unequal sample sizes of unequal variances.

Transformations were applied to reduce variance heterogeneity among samples. Results of multiple comparisons were similar for both raw and transformed data sets; therefore, for simplicity, only untransformed values are discussed. The degree to which the ANOVA assumption of homogeneity of variance among means was violated in these analyses was measured by Cochran's C (maximum variance/sum of variances) and a maximum/minimum variance ratio. Cochran's C may be compared to tabulated values to test the assumption of variance equality among group means. Most comparisons were made within the limits of test assumptions, except those involving stations with a wide range of replicate values (discussed below). Tests become effectively more conservative in these cases; that is, they accept the hypothesis that a measure is similar among

stations or times when, in fact, it is different. The consensus is to ignore the problem of unequal variances with this caveat in mind (Underwood, 1981), or to rely on the more conservative Scheffé multiple comparisons procedure (Neter and Wasserman, 1974).

The coefficient of variation was calculated for selected parameters. This value is calculated as

$$CV = \frac{\text{Standard Deviation}}{\text{Mean}}$$

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

Data from sediment grain-size analyses for all stations and cruises are presented in Appendix J. Summary grain-size measures, including station means and standard deviations, are presented in Appendix K. Carbon, hydrogen, and nitrogen data are presented in Appendix L. Summary CHN data, including station means and standard deviations for each cruise, are presented in Table 54. Carbon data represent total organic carbon (TOC). In the following discussion, values for sediment characteristics are averages for a station at a sampling time (cruise), unless otherwise noted.

Sediment grain-size composition for all samples is presented in Figure 59. Sediments ranged in size from a sandy mud (Station 12: 42-60 percent foraminiferal sand, or "clayey nannofossil ooze" of Dean et al., 1985) to clayey muds (Stations 1, 5 through 9,

TABLE 54. PERCENT CARBON, HYDROGEN, NITROGEN CONTENT IN SEDIMENTS OF U.S. MID-ATLANTIC STATIONS 1-14, CRUISES 1-6.

Station	Cruise	Mean Percent Carbon	Mean Percent Hydrogen	Mean Percent Nitrogen
1	1	1.49 ± 0.14	0.68 ± 0.05	0.19 ± 0.02
	2	1.51 ± 0.04	0.65 ± 0.03	0.22 ± 0.04
	3	1.58 ± 0.06	0.65 ± 0.03	0.19 ± 0.02
	4	1.39 ± 0.02	0.78 ± 0.08	0.18 ± 0.01
	5	1.30 ± 0.08	0.59 ± 0.04	0.14 ± 0.04
	6	1.22 ± 0.37	0.65 ± 0.08	0.16 ± 0.05
2	1	1.15 ± 0.24	0.62 ± 0.12	0.13 ± 0.03
	2	0.99 ± 0.14	0.61 ± 0.06	0.12 ± 0.03
	3	1.19 ± 0.08	0.65 ± 0.01	0.18 ± 0.02
	4	1.03 ± 0.40	0.71 ± 0.20	0.13 ± 0.06
	5	1.17 ± 0.13	0.56 ± 0.09	0.13 ± 0.01
	6	1.12 ± 0.13	0.85 ± 0.08	0.13 ± 0.01
3	1	1.08 ± 0.10	0.54 ± 0.08	0.13 ± 0.02
	2	0.64 ± 0.14	0.41 ± 0.10	0.08 ± 0.02
	3	1.03 ± 0.18	0.47 ± 0.07	0.11 ± 0.02
	4	0.67 ± 0.24	0.39 ± 0.13	0.09 ± 0.03
	5	0.96 ± 0.03	0.49 ± 0.05	0.14 ± 0.01
	6	1.18 ± 0.27	0.59 ± 0.20	0.15 ± 0.03
4	1	0.99 ± 0.13	0.57 ± 0.09	0.13 ± 0.02
	2	1.21 ± 0.14	0.57 ± 0.06	0.14 ± 0.01
	3	0.97 ± 0.12	0.56 ± 0.06	0.14 ± 0.02
	4	1.16 ± 0.06	0.65 ± 0.26	0.13 ± 0.01
	5	1.11 ± 0.06	0.62 ± 0.01	0.18 ± 0.01
	6	1.16 ± 0.09	0.77 ± 0.05	0.14 ± 0.02
5	1	1.49 ± 0.01	0.70 ± 0.04	0.18 ± 0.01
	2	1.51 ± 0.08	0.71 ± 0.07	0.18 ± 0.01
	3	1.49 ± 0.04	0.67 ± 0.02	0.19 ± 0.01
	4	1.42 ± 0.07	0.83 ± 0.08	0.17 ± 0.02
	5	1.31 ± 0.06	0.67 ± 0.11	0.17 ± 0.01
	6	1.27 ± 0.11	0.67 ± 0.07	0.16 ± 0.01
6	1	1.37 ± 0.05	0.67 ± 0.02	0.18 ± 0.00
	2	1.22 ± 0.08	0.65 ± 0.01	0.16 ± 0.02
	3	1.32 ± 0.12	0.64 ± 0.06	0.16 ± 0.01
	4	1.25 ± 0.11	0.82 ± 0.09	0.15 ± 0.02
	5	1.37 ± 0.07	0.66 ± 0.04	0.17 ± 0.01
	6	1.28 ± 0.08	0.67 ± 0.10	0.18 ± 0.02
7	1	1.57 ± 0.12	0.71 ± 0.03	0.19 ± 0.01
	2	1.56 ± 0.17	0.77 ± 0.03	0.19 ± 0.02
	3	1.53 ± 0.04	0.67 ± 0.04	0.20 ± 0.01
	4	1.23 ± 0.36	0.88 ± 0.29	0.16 ± 0.06
	5	1.52 ± 0.19	0.81 ± 0.06	0.20 ± 0.02
	6	1.34 ± 0.08	0.70 ± 0.08	0.18 ± 0.01

TABLE 54. (Continued).

Station	Cruise	Mean Percent Carbon	Mean Percent Hydrogen	Mean Percent Nitrogen
8	1	1.56 ± 0.09	0.73 ± 0.05	0.20 ± 0.01
	2	1.44 ± 0.14	0.66 ± 0.08	0.19 ± 0.02
	3	1.81 ± 0.21	0.78 ± 0.03	0.22 ± 0.03
9	1	1.77 ± 0.16	0.80 ± 0.02	0.23 ± 0.03
	2	1.52 ± 0.06	0.76 ± 0.04	0.20 ± 0.01
	3	1.62 ± 0.08	0.78 ± 0.00	0.21 ± 0.01
	4	1.64 ± 0.03	0.83 ± 0.03	0.19 ± 0.01
	5	1.49 ± 0.05	0.71 ± 0.11	0.20 ± 0.00
	6	1.73 ± 0.02	0.90 ± 0.05	0.20 ± 0.03
10	1	0.90 ± 0.21	0.64 ± 0.10	0.11 ± 0.04
	2	0.90 ± 0.15	0.59 ± 0.18	0.11 ± 0.02
	3	1.20 ± 0.16	0.58 ± 0.02	0.13 ± 0.00
	4	1.05 ± 0.07	0.68 ± 0.12	0.13 ± 0.01
	5	0.96 ± 0.01	0.69 ± 0.03	0.14 ± 0.01
	6	0.94 ± 0.15	0.60 ± 0.08	0.12 ± 0.02
11	1	1.82 ± 0.06	0.70 ± 0.09	0.23 ± 0.01
	2	1.71 ± 0.10	0.68 ± 0.04	0.21 ± 0.03
	3	1.62 ± 0.25	0.62 ± 0.10	0.20 ± 0.03
	4	1.68 ± 0.21	0.75 ± 0.02	0.21 ± 0.03
	5	1.67 ± 0.05	0.69 ± 0.09	0.22 ± 0.01
	6	1.19 ± 0.24	0.75 ± 0.04	0.15 ± 0.03
12	1	0.56 ± 0.05	0.60 ± 0.13	0.08 ± 0.01
	2	0.52 ± 0.03	0.38 ± 0.07	0.06 ± 0.01
	3	0.53 ± 0.11	0.36 ± 0.04	0.08 ± 0.01
	4	0.62 ± 0.06	0.95 ± 0.10	0.08 ± 0.01
	5	0.58 ± 0.05	0.48 ± 0.04	0.08 ± 0.01
	6	0.52 ± 0.07	0.37 ± 0.08	0.06 ± 0.02
13	1	2.00 ± 0.15	0.59 ± 0.35	0.25 ± 0.02
	2	1.89 ± 0.07	0.71 ± 0.09	0.23 ± 0.01
	3	1.93 ± 0.14	0.78 ± 0.01	0.24 ± 0.02
	4	1.85 ± 0.35	0.70 ± 0.09	0.22 ± 0.04
	5	1.93 ± 0.07	0.84 ± 0.03	0.23 ± 0.01
	6	2.00 ± 0.15	0.82 ± 0.02	0.25 ± 0.02
14	1	1.76 ± 0.12	0.76 ± 0.01	0.22 ± 0.02
	4	1.70 ± 0.12	0.89 ± 0.07	0.20 ± 0.02
	5	1.70 ± 0.12	0.76 ± 0.04	0.23 ± 0.02
	6	1.76 ± 0.25	0.83 ± 0.02	0.22 ± 0.06

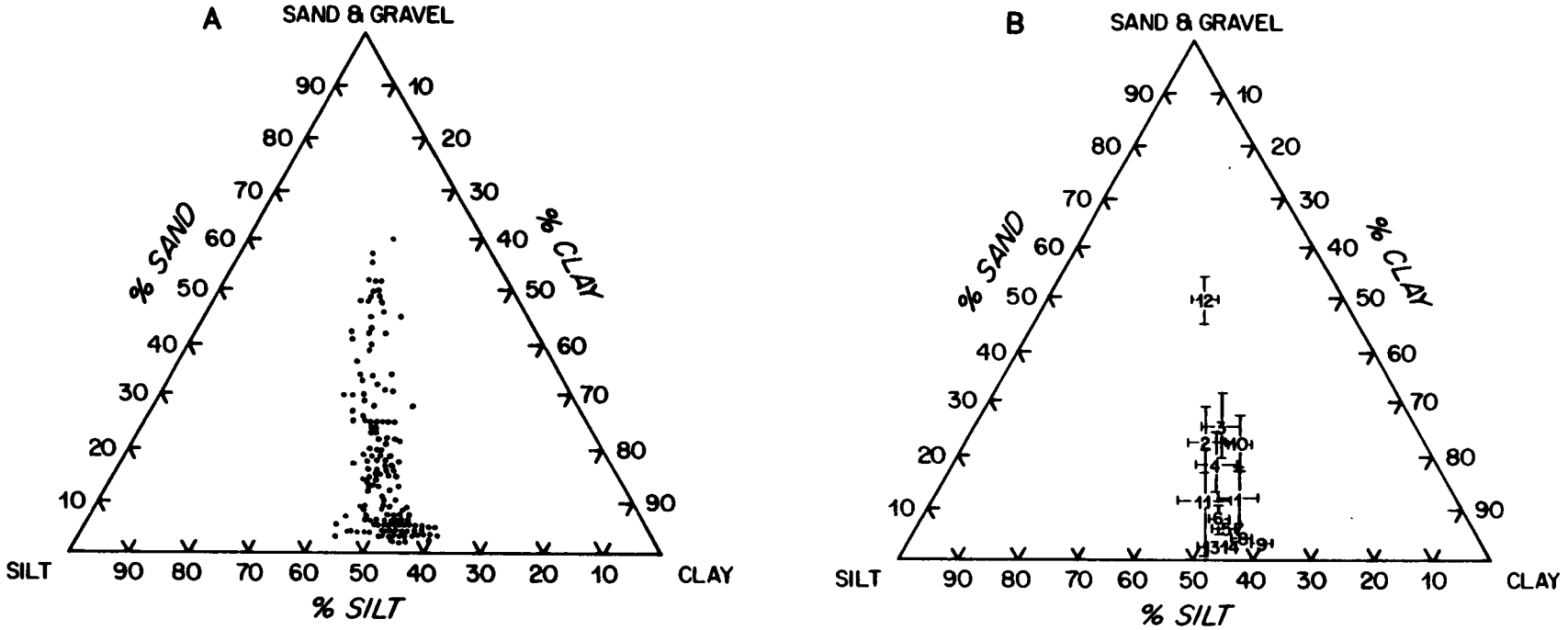

Figure 59. Ternary Diagram of Sediment Grain Size (Sand-Silt-Clay Content) for U.S. Mid-Atlantic Stations 1-14, Cruises 1-6. A) All Replicates, B) Station Averages Over All Cruises ± 1 SD Sand and Silt/Clay Contents.

11, 13, and 14: generally less than 10 percent sand and over 50 percent clay, "nannofossil-diatom bearing clay" of Dean et al., 1985). Sediments of intermediate texture were found at Stations 2, 3, 4, and 10.

All sediments were olive-gray to dark olive-gray in color (5Y 3.5/2 in Munsell, 1975). All sediments were poorly sorted (region-wide, time-averaged phi sorting of 2.86 ± 0.44 ∅) and only slightly coarse-to-fine skewed (region-wide, time-averaged phi skewness of 0.03 ± 0.24). Both sorting and skewness decreased with grain size (Figures 60 and 61). Average phi sorting values plotted with mean phi values further distinguished the textural groups described above. Sediments become increasingly fine-skewed (development of coarse-tail) with decreasing mean phi grain size. This trend represents the admixture of larger particles (planktonic foraminiferal and diatom tests) in otherwise typical silt-clay muds of Station 12.

Carbon content ranged from 0.52 percent (Station 12, Cruise Mid-6) to 2.00 percent (Station 13, Cruises Mid-1 and Mid-6). Hydrogen content ranged from 0.36 percent (Station 12, Cruise Mid-3) to 0.90 percent (Station 9, Cruise Mid-6). Nitrogen content ranged from 0.06 percent (Station 12, Cruises Mid-2 and Mid-6) to 0.25 percent (Station 13, Cruises Mid-1 and Mid-6). Water content ranged from 48.63 percent (Station 12, Cruise Mid-1) to 74.50 percent (Station 13, Cruise Mid-1).

In general, the organic and water content correlated significantly with the silt-plus-clay content (Figure 62). Pearson moment correlation coefficients (r) for this relationship, computed from average log-transformed values for each station and each cruise, ranged from 0.85 to 0.98 for carbon and 0.88 to 0.97 for nitrogen. These values were similar or higher when computed for Stations 1 through 10 only (all 2100-m stations). Average log-transformed hydrogen content showed considerably more scatter (r = -0.29 to 0.95) when compared with silt-plus-clay content for all stations. Values were only slightly better for the 2100-m stations (r = 0.29 to 0.96). Average water content showed a strong correlation with sediment grain-size for all stations (r = 0.78 to 0.95).

Carbon/nitrogen ratios for all stations over all cruises averaged 7.95 ± 0.62; all values fell between 6 and 10 (Figure 63).

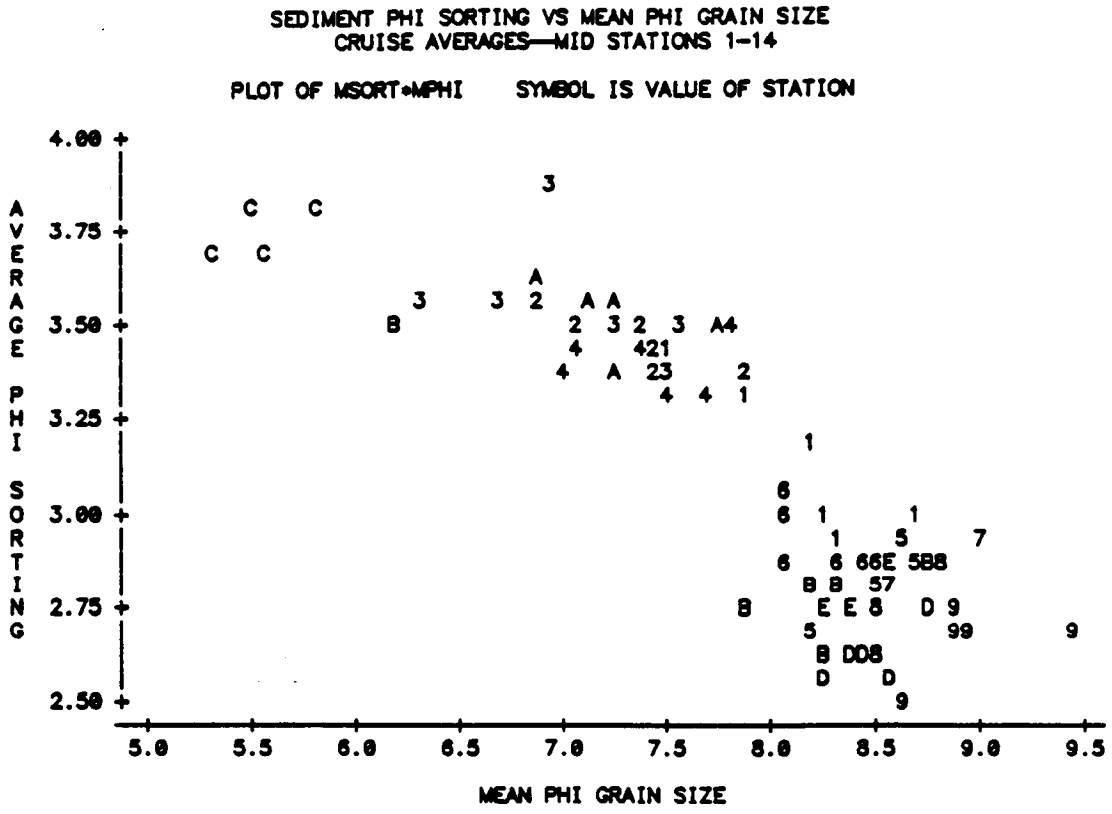

Figure 60. Scatter Plot of Sediment Phi Sorting and Mean Phi Grain Size. Values Plotted are Station Averages for Each Cruise. Symbols Plotted Represent Stations 1 Through 14 (A Through E Represent 10 Through 14, Respectively).

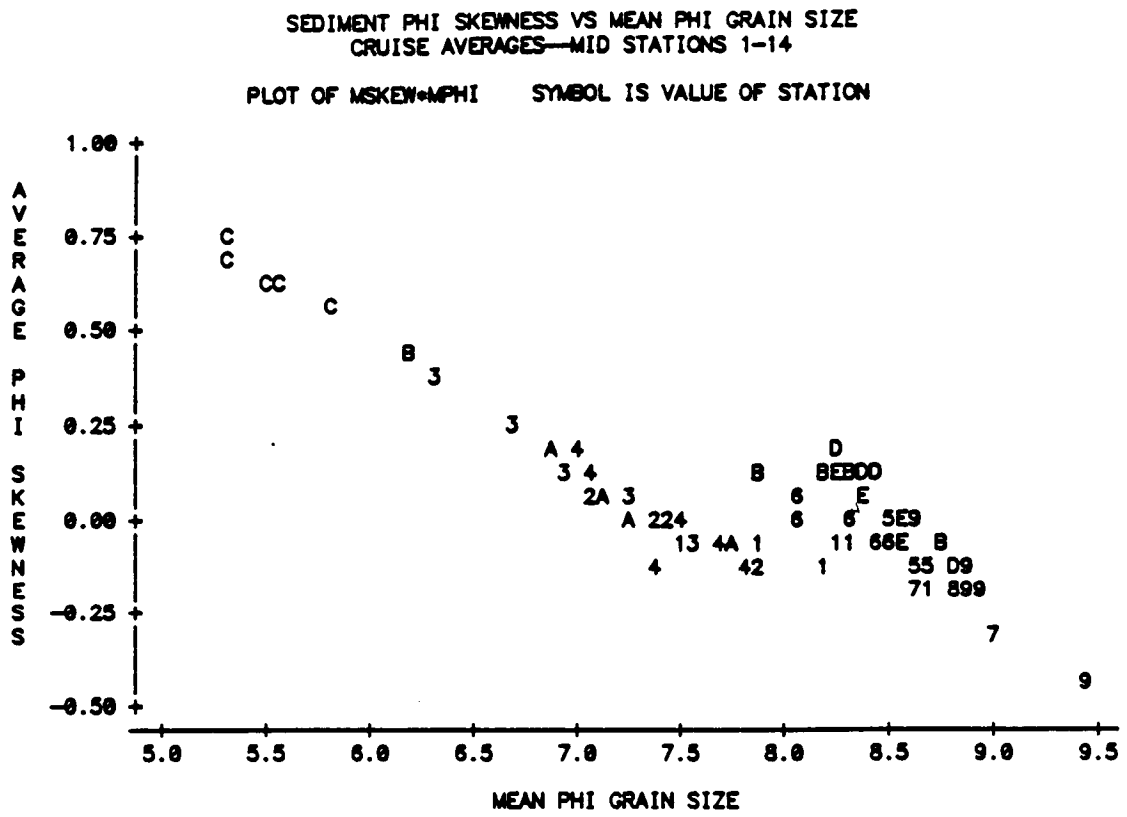

Figure 61. Scatter Plot of Sediment Phi Skewness and Mean Phi Grain Size. Values Plotted Are Station Averages for Each Cruise. Symbols Plotted Represent Stations 1 through 14 (A Through E Represent 10 Through 14, Respectively).

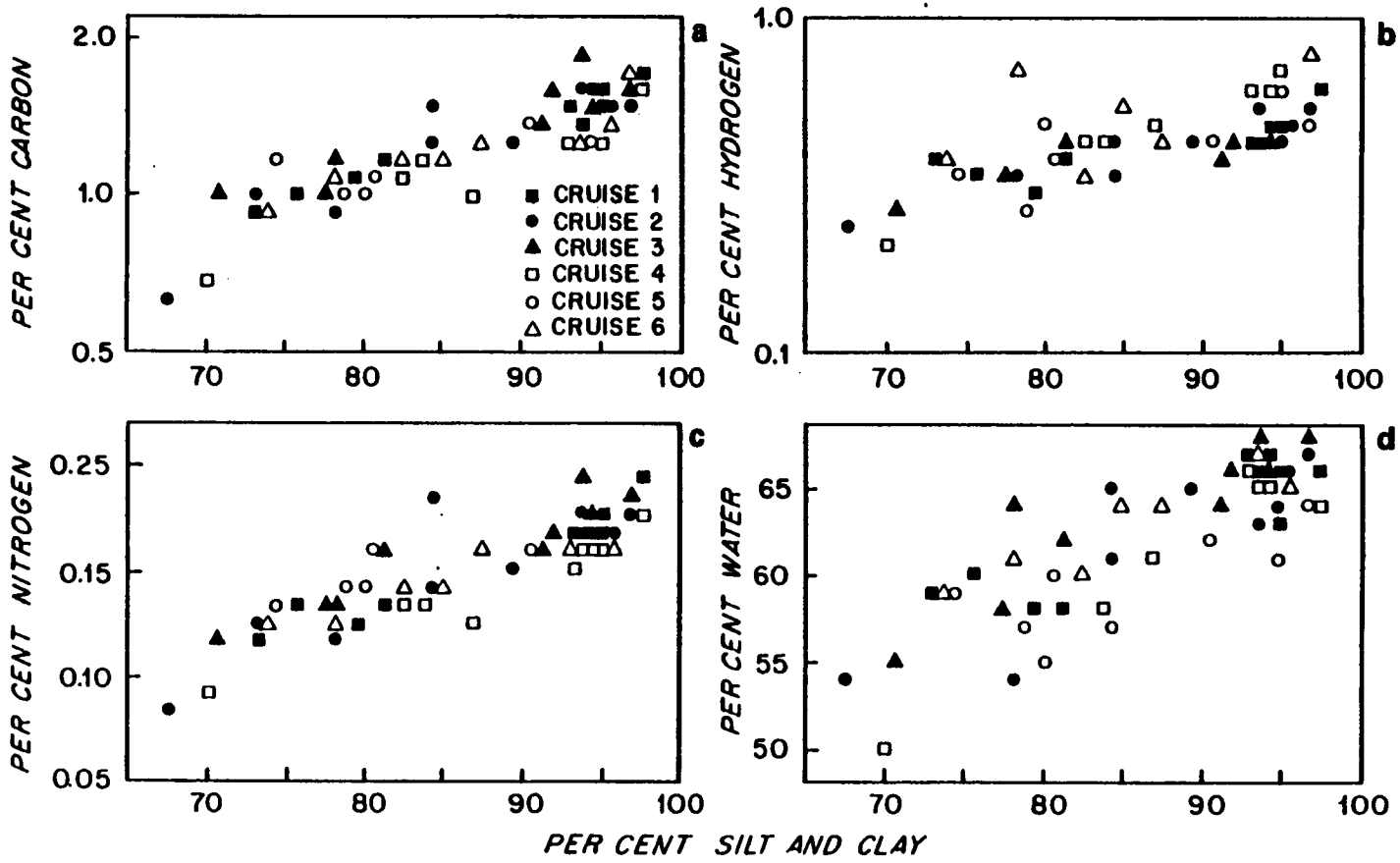

Figure 62. Sediment Organic and Water Contents vs. Silt Plus Clay Content for U.S. Mid-Atlantic Stations 1-14, Cruises 1-6. Plotted Values Are Cruise Averages for Each Station. Semilogarithmic Plots of a) Percent Carbon, b) Percent Hydrogen, c) Percent Nitrogen and Arithmetic Plot of d) Percent Water.

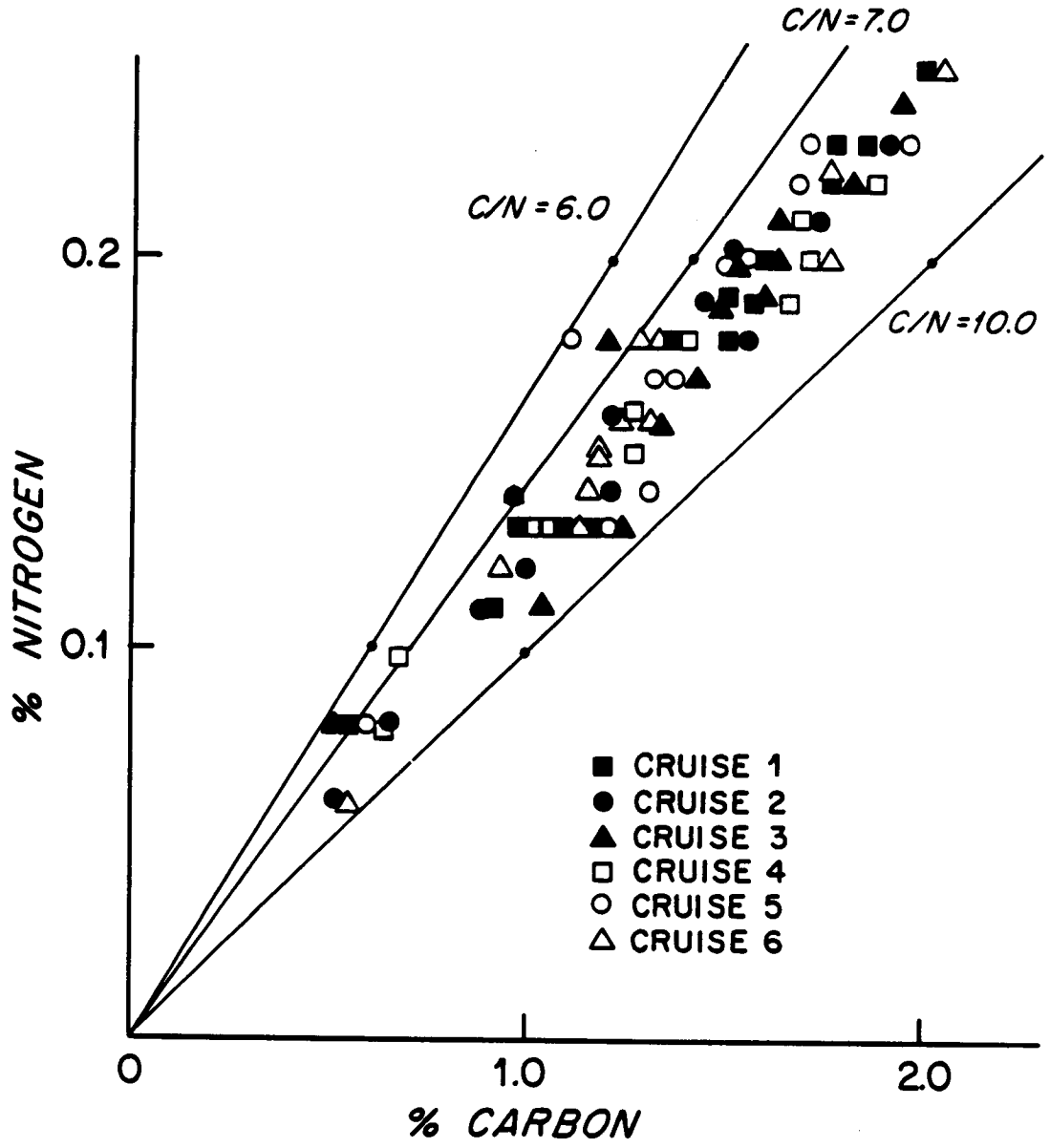

Figure 63. Percent Nitrogen vs. Percent Carbon in Sediments of U.S. Mid-Atlantic Stations 1-14, Cruises 1-6. Plotted Values Are Cruise Averages for Each Station.

Within-Station Variability in Sediment Characteristics

Sediments of Stations 2, 3, 4, and 10 exhibited a wide range of textures (e.g., 10 to 40 percent sand) among replicates from all cruises. Examination of plots of coefficients of variation (CV) vs. mean values for selected sediment parameters (Figures 64 through 67) revealed times of maximum disparity, or "patchiness," among station replicates. In general, coefficients of variation amounted to less than 50 percent of average sand content and less than 20 to 25 percent for average silt/clay ratios and carbon and nitrogen contents. Moreover, CVs generally increased slightly with decreasing parameter value.

Notable exceptions to these trends were the striking homogeneity of sand content among replicates of Stations 5 and 7 from Cruises Mid-4 and Mid-5 and Stations 8 and 9 from Cruises Mid-1 and Mid-2. Also, sand content varied widely among replicates of Station 1 at the times of Cruises Mid-1, Mid-2, and Mid-6 (e.g., Cruise Mid-2, 5.1 to 25.2 percent); among replicates of Station 2 at the time of Cruise Mid-2 (18.5 to 37.4 percent); among replicates of Station 4 at the time of Cruise Mid-1 (13.3 to 42.1 percent); and among replicates of Station 11 at the times of Cruises Mid-3 and Mid-4 (e.g., Cruise Mid-3, 3.9 to 18.4 percent) (Appendix J).

Sediments at Station 13 showed a wide range of silt/clay ratios among replicates collected on Cruises Mid-3, Mid-5, and Mid-6 (e.g., Cruise Mid-3, 0.80 to 1.28).

Sediments at Station 1 showed a wide range of carbon and nitrogen contents at the time of Cruise Mid-6. Stations 2, 3, and 7 exhibited disparate carbon and nitrogen values at the time of Cruise Mid-4 (Appendix L).

These ranges probably reflect natural variability within the sampling area of a station. Samples were generally collected within a radius of 0.1 nmi of the reference Loran time delays, but some exceptions did occur; e.g., Replicate 3 at Station 4 on Cruise Mid-1 (Figure B-4, Appendix B).

Statistical analyses involving these stations were confounded by wide-ranging values and potential inequality of variances for compared sample populations.

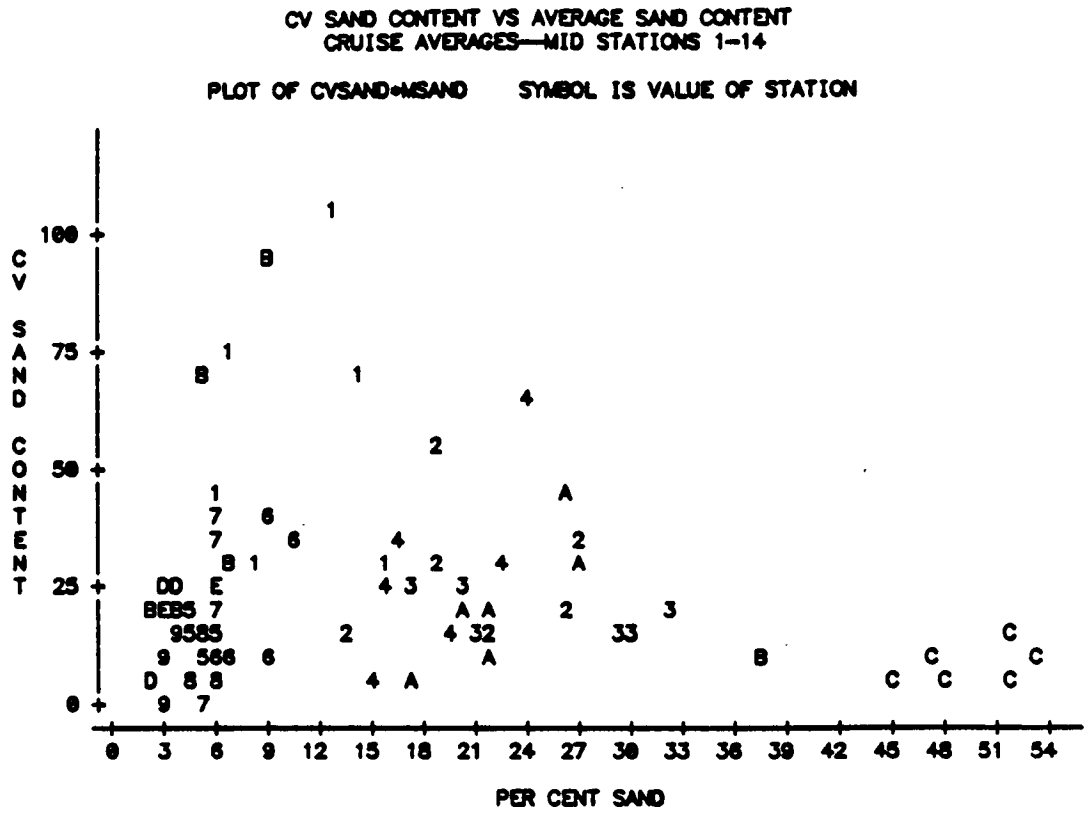

Figure 64. Coefficient of Variation ($CV=SD/\bar{x}$) vs. Average Sand Content for U.S. Mid-Atlantic Stations 1-14, Cruises 1-6. CV Expressed as Percent of Average Value. Plotted Symbol Is Value of Station; A=10, B=11, C=12, D=13, E=14.

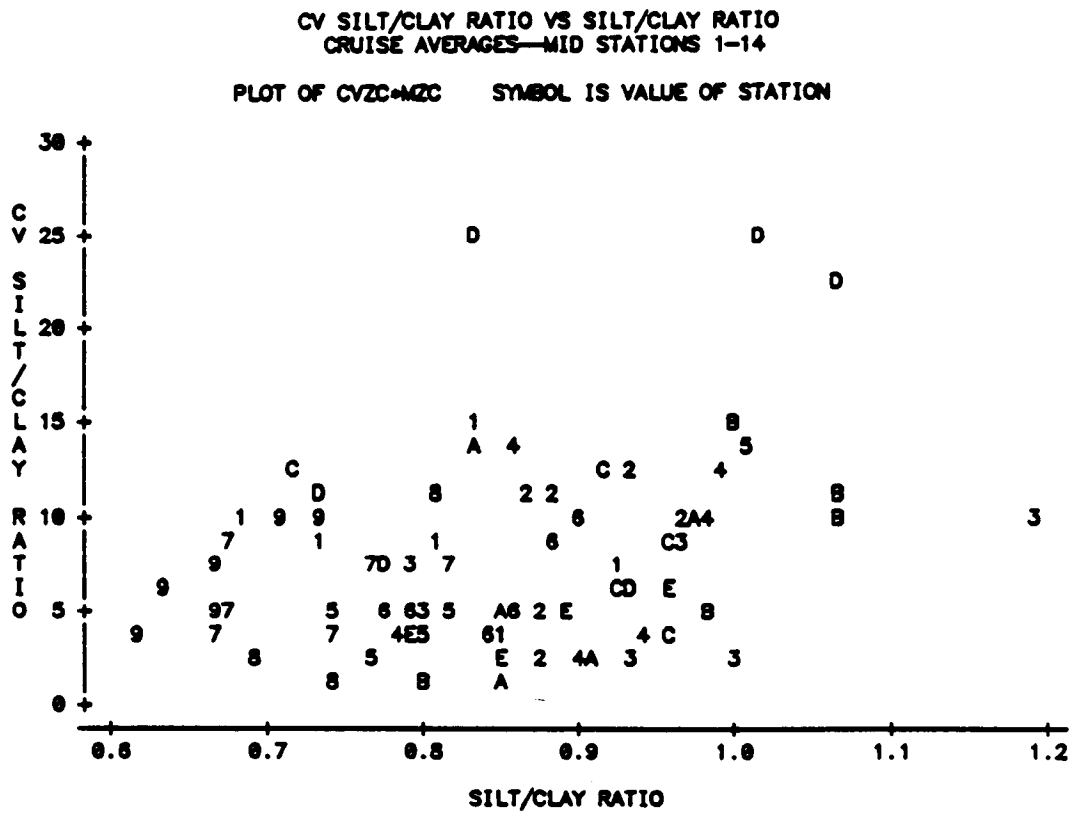

Figure 65. Coefficient of Variation (CV=SD/$\bar{x}$) vs. Silt/Clay Ratio for U.S. Mid-Atlantic Stations 1-14, Cruises 1-6. CV Expressed as Percent of Average Value. Plotted Symbol Is Value of Station ; A=10, B=11, C=12, D=13, E=14.

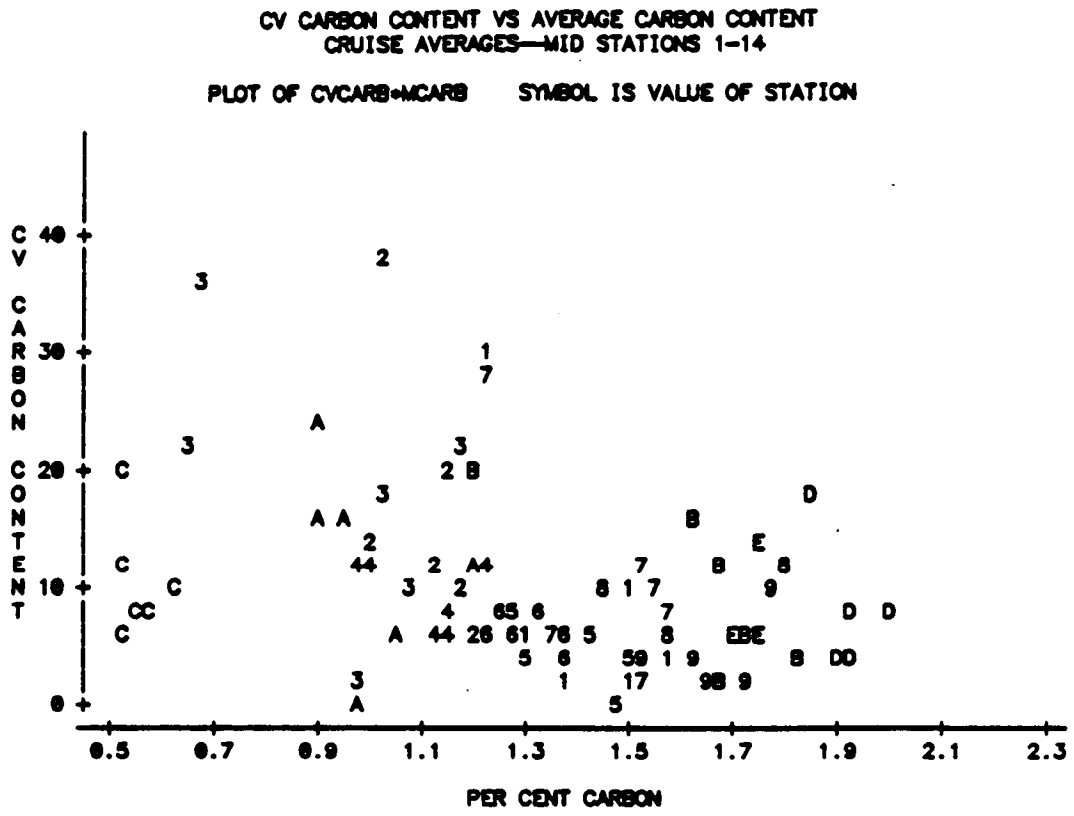

Figure 66. Coefficient of Variation ($CV=SD/\bar{x}$) vs. Carbon Content for U.S. Mid-Atlantic Stations 1-14, Cruises 1-6. CV Expressed as Percent of Average Value. Plotted Symbol Is Value of Station ; A=10, B=11, C=12, D=13, E=14.

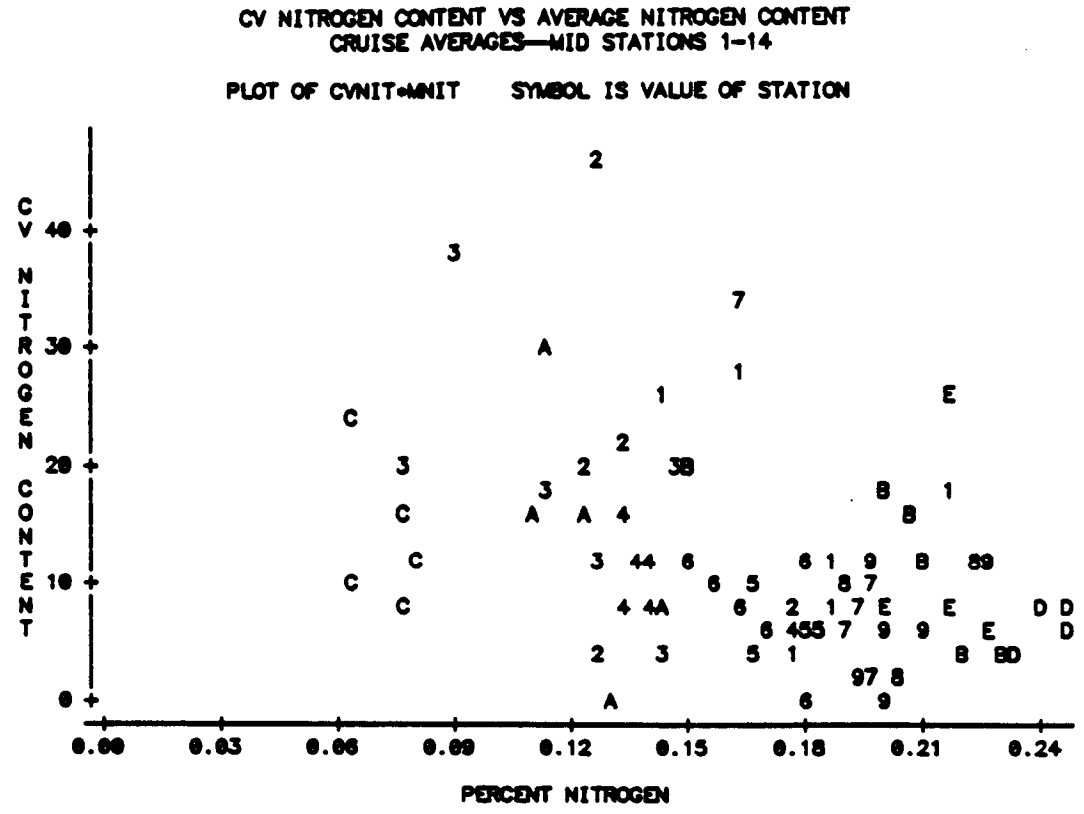

Figure 67. Coefficient of Variation ($CV=SD/\bar{x}$) vs. Nitrogen Content for U.S. Mid-Atlantic Stations 1-14, Cruises 1-6. CV Expressed as Percent of Average Value. Plotted Symbol Is Value of Station ; A=10, B=11, C=12, D=13, E=14.

Local Variability in Sediment Characteristics with Depth

Grain Size. Stations 7 and 8 were closely adjacent stations that differed in overlying water depth by 50 m. Stations 13 and 14, while located 2 km apart, differed in depth by 113 m. These two pairs of stations were used as the basis for planned statistical contrasts. Analyses and data are summarized in Tables 55 and 56 and Figures 68 through 74.

Sand content was slightly greater at Station 14 (1500 m) than at Station 13 (1613 m), approximately 2 km to the southwest. This difference was statistically significant for Cruise Mid-4 (4.83 ± 1.02 percent vs. 2.40 ± 0.17 percent) and Cruise Mid-6 (5.37 ± 0.81 percent vs. 3.07 ± 0.67 percent) (Table 55). Station 14 was not sampled on Cruises Mid-2 or Mid-3. Visual inspection of the sand fractions revealed only the typical foraminiferal-diatom assemblage; no exotic particles such as drill cuttings were seen at either station at any time.

Sediment grain-size measures did not vary significantly between the closely adjacent Stations 7 and 8 (2100 m and 2150 m, respectively) at times of Cruises Mid-1 through Mid-3. Station 8 was not sampled after Cruise Mid-3.

Organic Matter (CHN). Neither carbon nor nitrogen contents varied significantly between Stations 13 and 14 or closely adjacent Stations 7 and 8 at times of simultaneous samplings (Table 56). However, hydrogen content was slightly greater at Station 14 (0.89 ± 0.07 percent) than at Station 13 (0.70 ± 0.09 percent) at the time of Cruise Mid-4. This difference was reversed during Cruise Mid-5 (0.76 ± 0.04 percent vs. 0.84 ± 0.03 percent, respectively). Moreover, hydrogen content differed significantly between Stations 7 and 8 for Cruise Mid-3 (0.67 ± 0.04 percent vs. 0.78 ± 0.04 percent, respectively).

Variability in Sediment Characteristics with Depth

Grain Size. Stations 11, 1, 2, and 12 form a transect downslope from 1515 to 2505 m in the vicinity of Lindenkohl Canyon. Stations 13 and 10 are farther to the southwest at 1613 and 2095 m, respectively. These stations were contrasted using the t-statistic; analyses and data are summarized in Tables 55 and 56 and Figures 68 through 74.

TABLE 55. SUMMARY OF t-TEST CONTRASTS OF SEDIMENT GRAIN-SIZE CHARACTERISTICS.

Cruise	Contrasted Stations	Percent Sand	Mean Phi Grain-Size	Silt/Clay Ratio	Percent Silt/Mode
1	11 vs. 1, 2 vs. 12	*	*	*	*
	13 vs. 10	*	*	*	
	14 vs. 13				
	7 vs. 8				
	13 vs. 11				
	10 vs. 2, 3 vs. 6	*	*		
2	11 vs. 1, 2 vs. 12	*	*		
	13 vs. 10	*	*		
	7 vs. 8				
	13 vs. 11				
	10 vs. 2, 3 vs. 6	*	*		
3	11 vs. 1, 2 vs. 12	*	*		*
	13 vs. 10	*	*		
	7 vs. 8				
	13 vs. 11				
	10 vs. 2, 3 vs. 6	*			
4	11 vs. 1, 2 vs. 12	*	*		
	13 vs. 10	*	*		
	14 vs. 13	*			
	13 vs. 11				
	10 vs. 2, 3 vs. 6	*	*		*
5	11 vs. 1, 2 vs. 12	*	*		*
	13 vs. 10	*	*		
	14 vs. 13				
	13 vs. 11				
	10 vs. 2, 3 vs. 6	*	*		
6	11 vs. 1, 2 vs. 12			*	*
	13 vs. 10				
	14 vs. 13	*			
	13 vs. 11	*	*		
	10 vs. 2, 3 vs. 6				

* Indicates statistically significant differences among contrasted mean values at alpha = 0.05.

TABLE 56. SUMMARY OF t-TEST CONTRASTS OF SEDIMENT CHN CONTENT.

Cruise	Contrasted Stations	Percent Carbon	Percent Hydrogen	Percent Nitrogen
1	11 vs. 1, 2 vs. 12	*	*	*
	13 vs. 10	*		*
	14 vs. 13			
	7 vs. 8			
	13 vs. 11	*		*
	10 vs. 2, 3 vs. 6	*		*
2	11 vs. 1, 2 vs. 12	*	*	*
	13 vs. 10	*		*
	7 vs. 8			
	13 vs. 11			
	10 vs. 2, 3 vs. 6			
3	11 vs. 1, 2 vs. 12	*	*	*
	13 vs. 10	*	*	*
	7 vs. 8		*	
	13 vs. 11			
	10 vs. 2, 3 vs. 6			
4	11 vs. 1, 2 vs. 12	*	*	*
	13 vs. 10	*	*	*
	14 vs. 13		*	
	13 vs. 11			
	10 vs. 2, 3 vs. 6			
5	11 vs. 1, 2 vs. 12	*	*	*
	13 vs. 10	*	*	
	14 vs. 13		*	
	13 vs. 11			
	10 vs. 2, 3 vs. 6	*		*
6	11 vs. 1, 2 vs. 12	*	*	*
	13 vs. 10	*	*	*
	14 vs. 13			
	13 vs. 11	*		*
	10 vs. 2, 3 vs. 6	*		*

* Indicates statistically significant differences among contrasted mean values at alpha = 0.05.

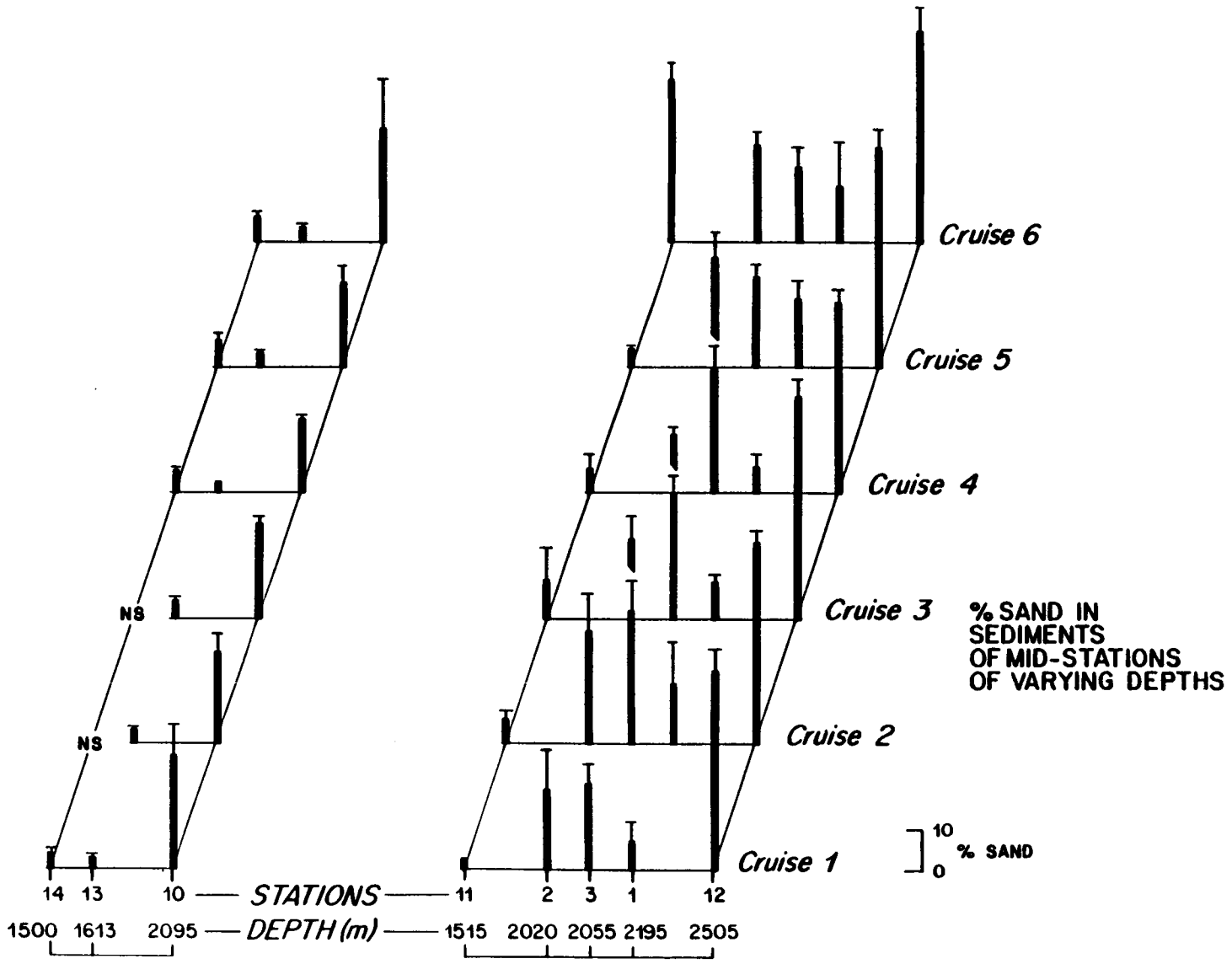

Figure 68. Sediment Sand Content vs. Depth for Selected U.S. Mid-Atlantic Stations Sampled on Each of Six Cruises. Plotted Values Are Cruise Averages + 1 SD.

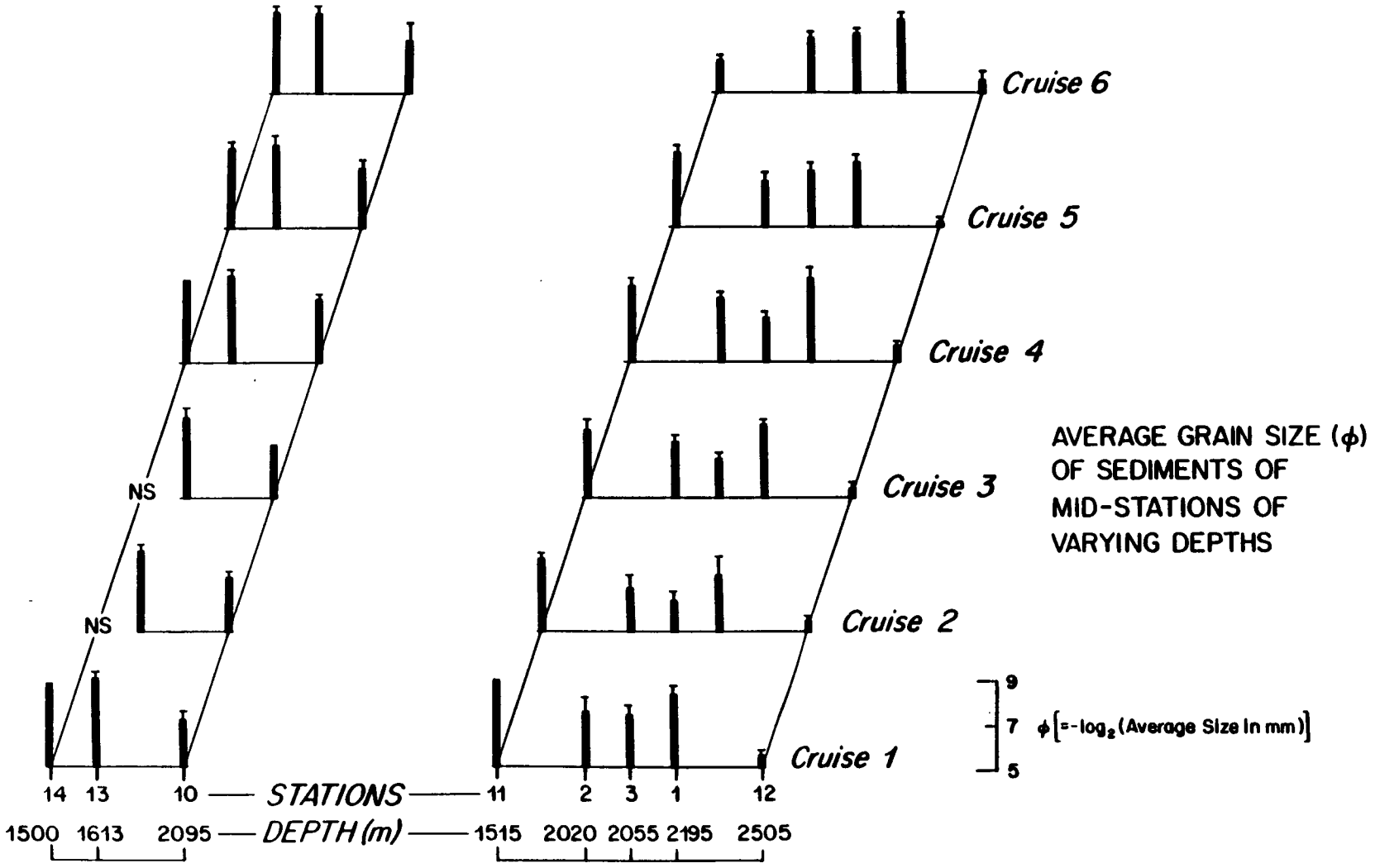

Figure 69. Sediment Mean Phi Grain-Size vs. Depth for Selected U.S. Mid-Atlantic Stations Sampled on Each of Six Cruises. Plotted Values Are Cruise Averages + 1 SD.

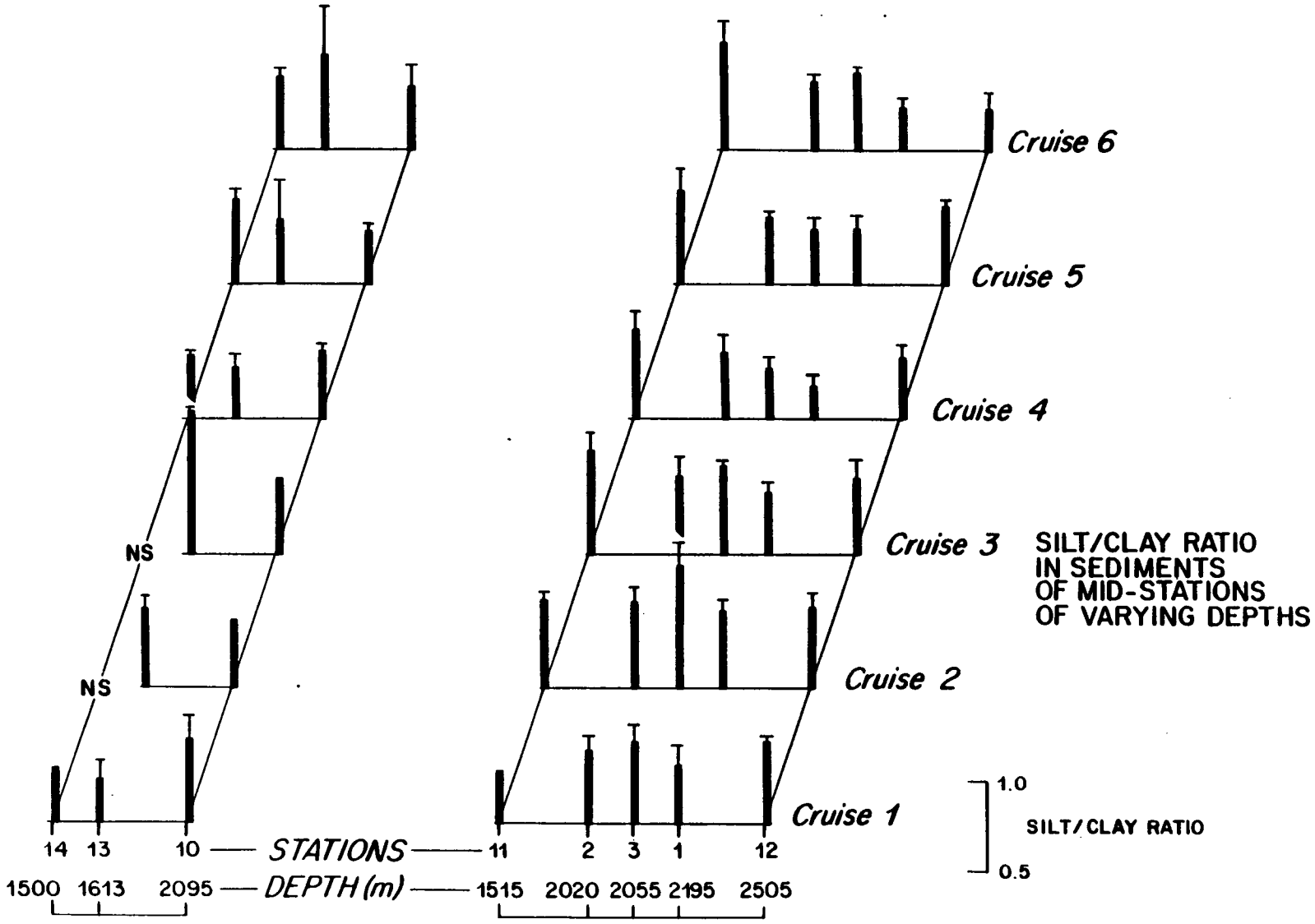

Figure 70. Sediment Silt/Clay Ratio vs. Depth for Selected U.S. Mid-Atlantic Stations Sampled on Each of Six Cruises. Plotted Values Are Cruise Averages + 1 SD.

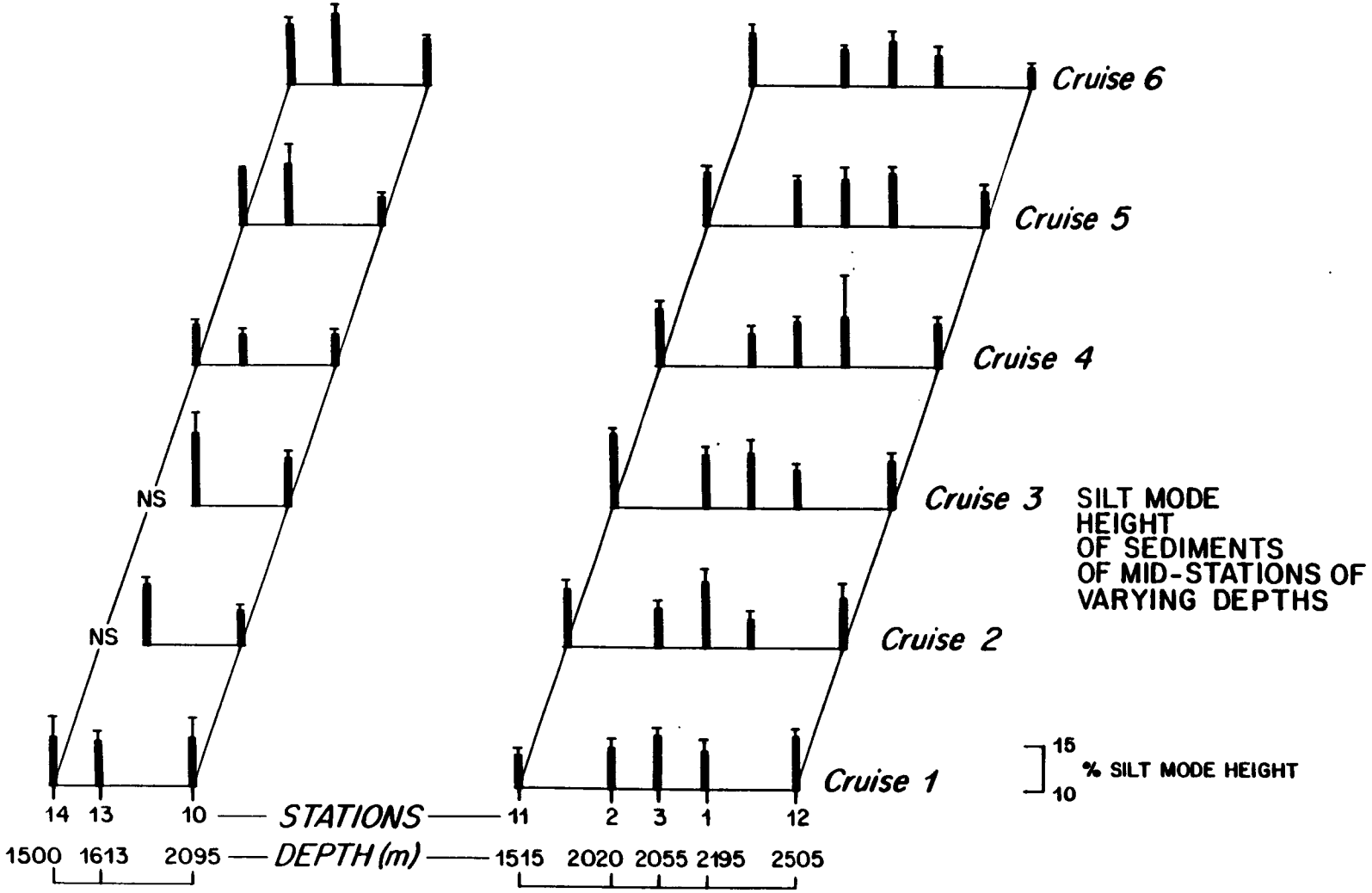

Figure 71. Sediment Silt-Mode Height vs. Depth for Selected U.S. Mid-Atlantic Stations Sampled on Each of Six Cruises. Plotted Values Are Cruise Averages + 1 SD.

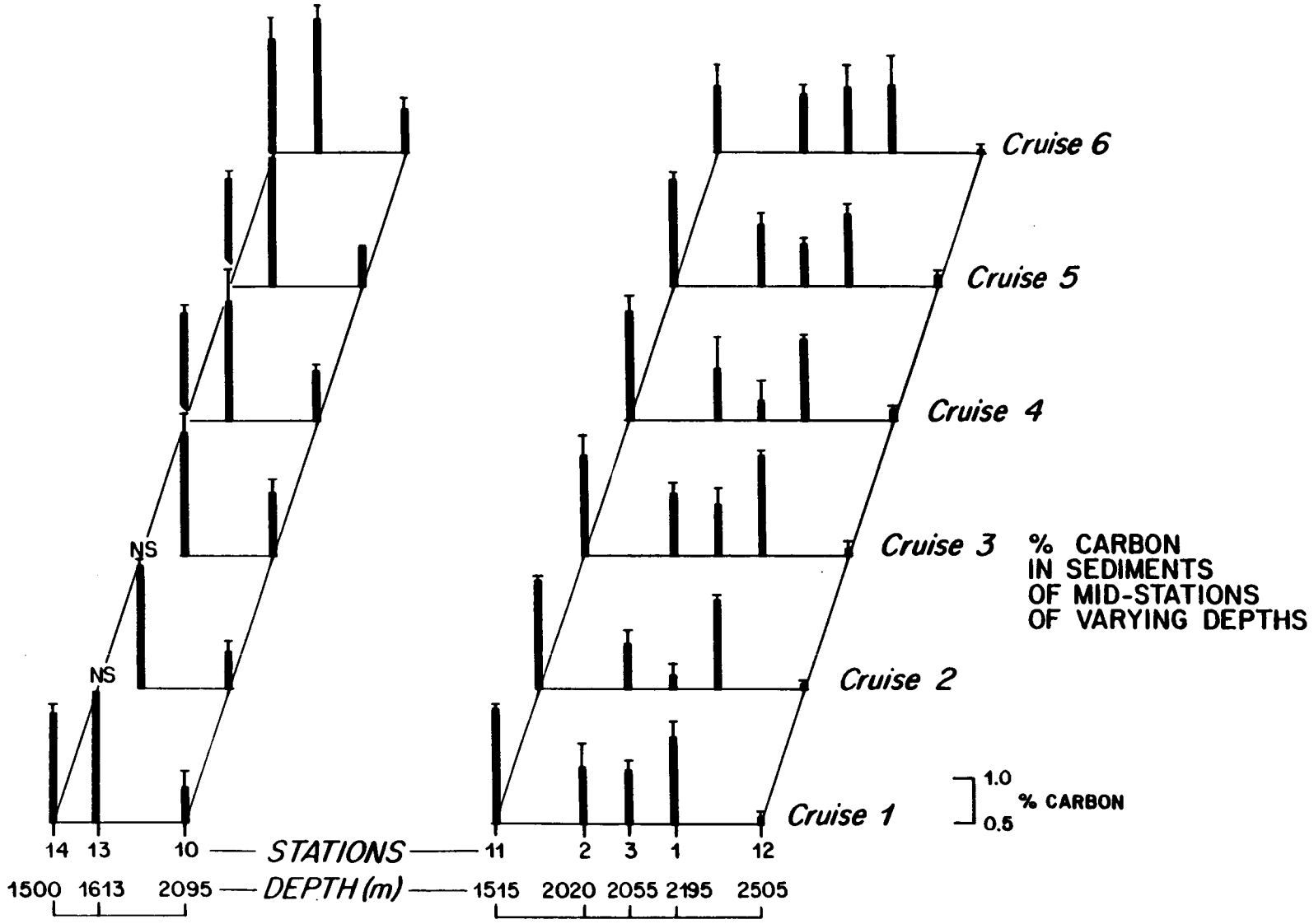

Figure 72. Sediment Carbon Content vs. Depth for Selected U.S. Mid-Atlantic Stations Sampled on Each of Six Cruises. Plotted Values are Cruise Averages + 1 SD.

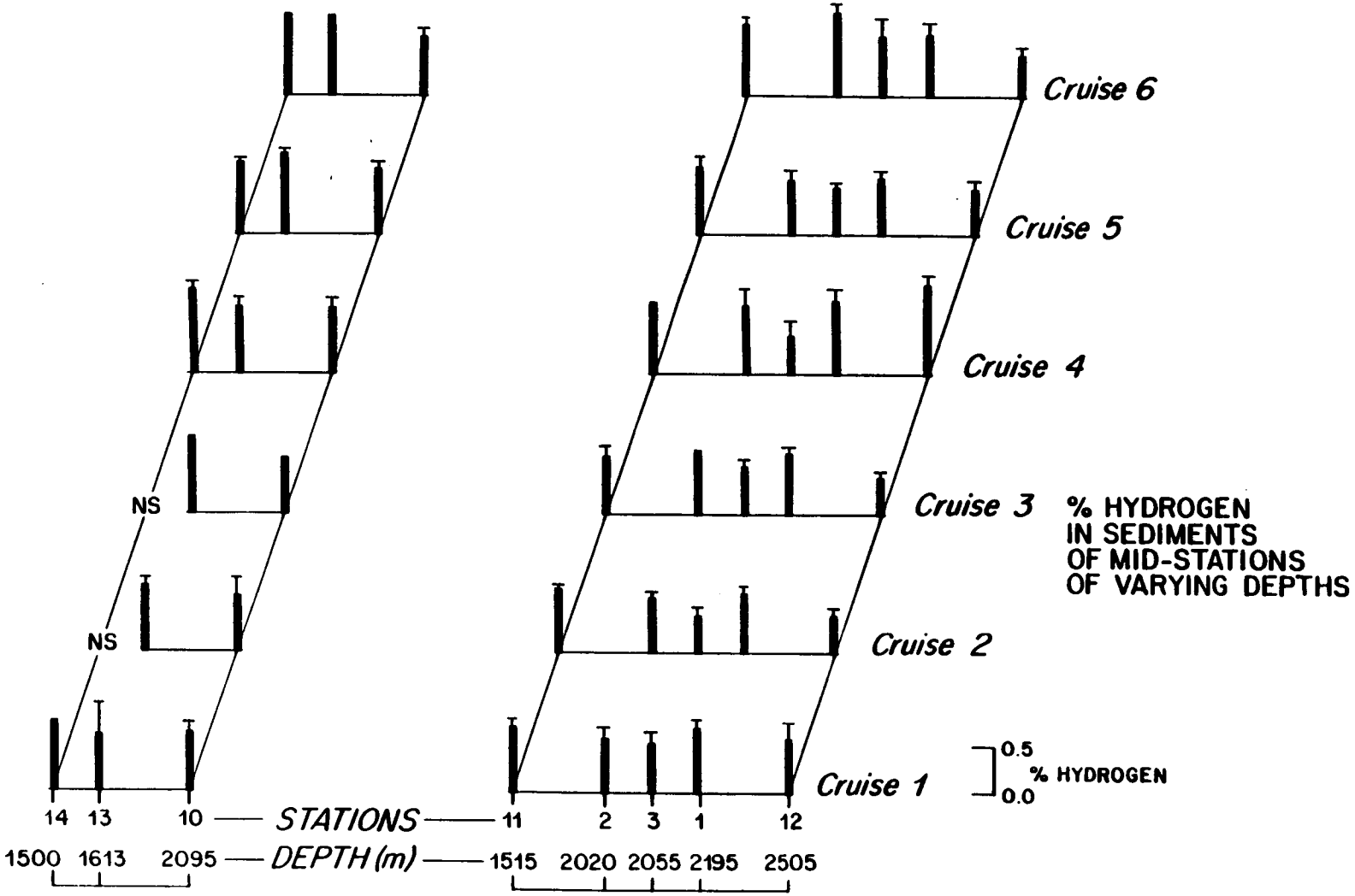

Figure 73. Sediment Hydrogen Content vs. Depth for U.S. Mid-Atlantic Stations Sampled on Each of Six Cruises. Plotted Values Are Cruise Averages + 1 SD.

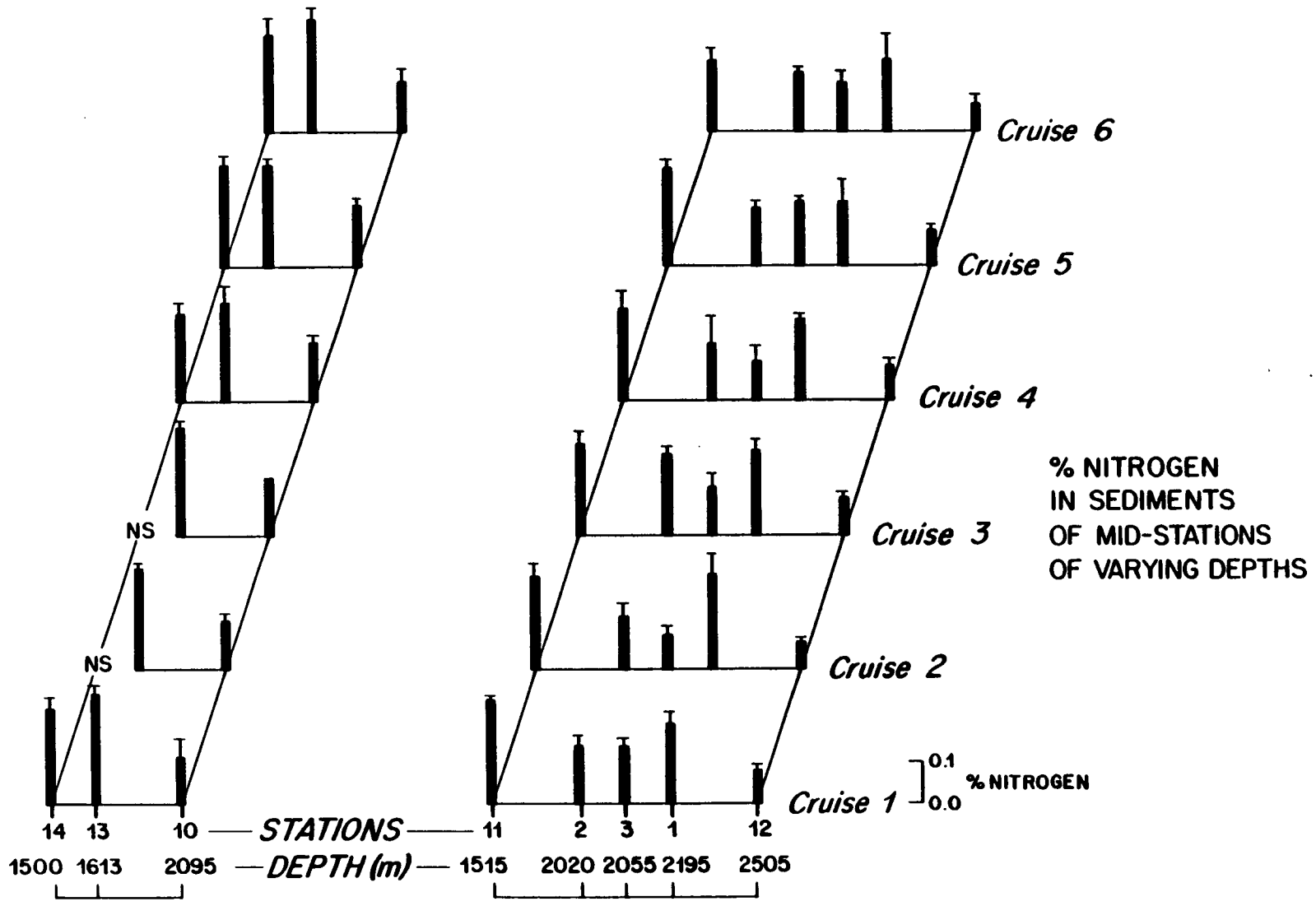

Figure 74. Sediment Nitrogen Content vs. Depth for U.S. Mid-Atlantic Stations Sampled on Each of Six Cruises. Plotted Values Are Cruise Averages + 1 SD.

A statistically significant increase in sand content was seen from Station 11 (e.g., Cruise Mid-1, 2.37 ± 0.45 percent) to Station 12 (Cruise Mid-1, 47.40 ± 4.71 percent) and from Station 13 (e.g., Cruise Mid-1, 2.67 ± 0.71 percent) to Station 10 (Cruise Mid-1, 26.90 ± 8.09 percent). This trend was seen for samples collected on each of the first five sampling occasions. Mean phi grain size showed a similar trend. A large increase in the sand content of Station 11 sediments at the time of Cruise Mid-6 confounded this pattern (see discussion under Changes in Sediment Characteristics with Time.)

Silt/clay ratios increased in a statistically significant manner from Station 11 (0.80 ± 0.01) to Station 12 (0.96 ± 0.04) at the time of Cruise Mid-1, decreased at the time of Cruise Mid-6 (1.06 ± 0.02 to 0.72 ± 0.09, respectively), and were similar at intermediate sampling times. Statistically significant differences in silt/clay ratios were seen between Station 13 (0.73 ± 0.09) and Station 10 (0.97 ± 0.10) for Cruise Mid-1, but were not significant at other times.

A statistically significant increase in silt-mode height from Station 11 (13.77 ± 0.46 percent) to Station 12 (15.67 ± 0.49 percent) occurred at the time of Cruise Mid-1; this parameter decreased significantly with depth at the time of Cruises Mid-3, Mid-5, and Mid-6. For example, values for Cruise Mid-5 were 15.60 ± 0.70 percent at Station 11 and 13.57 ± 0.40 percent at Station 12. Silt-mode height appears to decrease with depth from Stations 13 to Station 10, but the decrease was statistically significant only during Cruise Mid-2, (when values were 16.27 ± 0.83 percent vs. 13.57 ± 0.45 percent, respectively).

Organic Matter (CHN). On all cruises, carbon, hydrogen, and nitrogen contents decreased significantly with depth from Station 11 (e.g., Cruise Mid-1: 1.82 ± 0.56 percent, 0.70 ± 0.09 percent, 0.23 ± 0.01 percent, respectively) to Station 12 (Cruise Mid-1: 0.82 ± 0.05 percent, 0.56 ± 0.00 percent, 0.07 ± 0.01 percent, respectively). A similar trend was seen from Station 13 (e.g., Cruise Mid-1: 2.00 ± 0.15 percent, 0.79 ± 0.02 percent, 0.25 ± 0.02 percent, respectively) to Station 10 (Cruise Mid-1: 1.10 ± 0.11 percent, 0.62 ± 00.7, 0.10 ± 0.03 percent, respectively). Exceptions included hydrogen content at the time of Cruise Mid-2 and nitrogen content at the time of Cruise Mid-5 at Stations 13 and 10. It is also worth noting that this apparent trend followed the grain-size gradient established above and was not clearly related to depth.

Along-Slope Variability in Sediment Characteristics

Placement of Stations 11 and 13 and Stations 1 through 10 allowed contrasts of a priori interest as well as multiple comparisons of sediment characteristics. Analyses and data are summarized in Tables 55 and 56 and in Figures 68 through 74.

Grain Size. Stations 11 (1515 m) and 13 (1613 m) did not differ significantly in grain size from Cruises Mid-1 through Mid-5 (< 10 percent sand). A 34.0 percent increase in sand content of sediments at Station 11 at the time of Cruise Mid-6 contributed to a significant difference in sand content and mean phi grain size between the two stations.

Contrasts of Stations 10 vs. 2 and 3 vs. 6 suggest a regional decrease in sand content and average phi grain size from Station 10 (e.g., Cruise Mid-1: 26.90 ± 8.09 percent sand, 6.85 ± 0.61 ∅) northeastward along-slope to Station 6 (Cruise Mid-1: 6.03 ± 0.64 percent sand, 8.49 ± 080 ∅). This trend was statistically significant for samples collected on Cruises Mid-1 through Mid-5 and remained apparent at the time of Cruise Mid-6.

Silt/clay ratio and silt-mode height were not significantly different among contrasted stations.

Organic Matter (CHN). Stations 11 and 13 did not differ significantly in organic content from Cruises Mid-1 through Mid-5. However, significant differences in percent carbon and nitrogen between these two stations at the time of Cruise Mid-6 (1.19 ± 0.24 percent vs. 2.00 ± 0.15 percent TOC and 0.15 ± 0.03 percent vs. 0.25 ± 0.02 percent N, respectively) were probably associated with the increase in coarse material observed at Station 11. Hydrogen content did not vary significantly between these stations at any sampling time.

Percent carbon and nitrogen increased significantly northeastward along-slope in sediments of Stations 10 vs. 2 and 3 vs. 6 at the times of Cruises Mid-1, Mid-5, and Mid-6 and apparently so at the times of Cruises Mid-2, Mid-3, and Mid-4 (e.g., Cruise Mid-1, 0.90 ± 0.21 percent vs. 1.37 ± 0.05 percent TOC; 0.11 ± 0.04 percent vs. 0.18 ± 0.00 percent N). Hydrogen content did not vary significantly among these contrasted stations at any sampling time.

Multiple Comparisons of Sediment Characteristics of 2100-m Stations

Inspection of Figures 68 through 74 reveals that along-slope variation in sediment characteristics of the 2100-m Stations 1 through 10 was not a simple east-west regional gradient. For example, there was an approximately 10-fold change in sand content and a two-fold change in organic content between southwestern-most Stations 9 and 10 (e.g., Cruise Mid-1: 2.6 percent sand, 1.77 percent TOC, and 0.23 percent N for Station 9, and 26.9 percent sand, 0.90 percent TOC, and 0.11 N for Station 10). Multiple comparisons generate groups of stations that are statistically significantly different in respective sediment characteristics (Tables 57 through 63). In general, among Stations 1 through 10, the groups described above can be discerned: fine-grained, relatively organic-rich muds at Stations 1 and 5 through 9 (2 to 15 percent sand, 0.60 to 0.90 silt/clay ratio, mean phi $\geq$ 8, 1.22 to 1.81 percent TOC, and 0.15 to 0.23 percent N), compared with relatively sandier, organic-poor muds at Stations 2, 3, 4, and 10 (15 to 32 percent sand, 0.85 to 1.20 silt/clay ratio, mean phi $\leq$ 8, 0.64 to 1.21 percent TOC, and 0.08 to 0.16 percent N). These groups were most readily defined for Cruises Mid-1 and Mid-3. Note, too, that although these groups varied in depth (Stations 1 and 5 through 9: 2065-2195 m vs. Stations 2, 3, 4, and 10: 2020-2095 m), this consideration may be initially discounted by the nonsignificance of sediment contrasts of closely-spaced Stations 7 and 8.

It is emphasized that these groups are generalizations and neglect much of the additional information presented in Tables 57 through 63. There was much overlap between groups, particularly among Stations 1, 2, 4, 5, 6, and 10. This overlap may be interpreted as a shifting gradient between the two sediment groups. There was also subset partitioning within each of the groups.

For example, at the time of Cruise Mid-2, Station 3 sediments were distinctly high in silt content and low in organic content when compared with all other 2100-m stations. Sand content reached a station maximum at this time but showed a similarity with Stations 2 and 10. During Cruises Mid-3 and Mid-4, sediments at Station 3 were distinct in having a high sand content and low hydrogen content. Both carbon and nitrogen contents were low at these times but were similar to values recorded at other coarse-grained stations.

TABLE 57. MULTIPLE COMPARISONS OF SEDIMENT SAND CONTENT AT U.S. MID-ATLANTIC STATIONS 1 THROUGH 10.

Cruise Mid-1	Station	9	5	8	6	7	1	2	3	4	10
F ratio=5.609	% Sand	2.63	4.67	4.83	6.03	6.37	6.57	18.87	20.37	24.27	26.90
DF=(9, 20)											
C=0.5242*	SNK										
Var ratio=72817.0											
	Scheffé										
Cruise Mid-2	Station	9	5	8	7	6	1	4	10	2	3
F ratio=10.302	% Sand	2.90	4.57	4.97	6.27	10.80	14.40	15.70	21.83	26.77	32.40
DF=(9, 20)											
C=0.3412	SNK										
Var ratio=1467.0											
	Scheffé										
Cruise Mid-3	Station	9	7	5	8	1	6	2	10	4	3
F ratio=20.047	% Sand	3.20	5.80	5.87	6.23	8.23	8.97	18.77	21.63	22.53	29.60
DF=(9, 20)											
C=0.3821	SNK										
Var ratio=1108.2											
	Scheffé										
Cruise Mid-4	Station	9	7	5	1	6	2	4	10	3	
F ratio=33.441	% Sand	2.27	5.30	5.60	5.97	6.80	13.40	16.33	21.63	30.10	
DF=(8, 18)											
C=0.4670	SNK										
Var ratio=2906.3											
	Scheffé										
Cruise Mid-5	Station	9	7	5	6	1	4	10	3	2	
F ratio=21.766	% Sand	3.40	5.20	5.60	9.17	15.83	19.23	20.07	21.13	25.97	
DF=(8, 18)											
C=0.3728	SNK										
Var ratio=3152.3											
	Scheffé										
Cruise Mid-6	Station	9	7	6	5	1	4	3	2	10	
F ratio=4.984	% Sand	3.10	4.70	6.10	6.87	12.63	19.23	17.53	21.60	26.13	
DF=(8, 18)											
C=0.4760*	SNK										
Var ratio=5602.1											
	Scheffé										

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 58. MULTIPLE COMPARISONS OF SEDIMENT MEAN PHI GRAIN SIZE AT U.S. MID-ATLANTIC STATIONS 1 THROUGH 10.

Cruise Mid-1	Station	10	4	3	2	1	6	5	7	8	9
F ratio=9.101	Mean Phi	6.85	7.02	7.25	7.44	8.30	8.49	8.62	8.63	8.79	8.86
DF=(9, 20)											
C=0.3799	SNK										
Var ratio=321.7											
	Scheffé										
Cruise Mid-2	Station	3	2	10	4	1	6	5	7	8	9
F ratio=9.852	Mean Phi	6.29	6.90	7.27	7.52	7.57	8.09	8.48	8.52	8.52	8.86
DF=(9, 20)											
C=0.5550*	SNK										
Var ratio=8804.3											
	Scheffé										
Cruise Mid-3	Station	3	4	10	2	6	5	1	8	7	9
F ratio=24.823	Mean Phi	6.71	7.09	7.22	7.44	8.03	8.20	8.26	8.49	8.55	8.61
DF=(9, 20)											
C=0.5314*	SNK										
Var ratio=107.8											
	Scheffé										
Cruise Mid-4	Station	3	10	4	2	6	5	1	7	9	
F ratio=30.264	Mean Phi	6.93	7.73	7.82	7.89	8.32	8.70	8.71	8.97	9.45	
DF=(8, 18)											
C=0.3479	SNK										
Var ratio=260.1											
	Scheffé										
Cruise Mid-5	Station	2	4	3	10	1	6	5	7	9	
F ratio=35.589	Mean Phi	7.06	7.39	7.53	7.53	7.88	8.09	8.70	8.79	8.89	
DF=(8, 18)											
C=0.2881	SNK										
Var ratio=229.0											
	Scheffé										
Cruise Mid-6	Station	10	2	3	4	1	5	6	7	9	
F ratio=6.960	Mean Phi	7.14	7.35	7.53	7.71	8.18	8.30	8.44	8.83	8.96	
DF=(8, 18)											
C=0.5465*	SNK										
Var ratio=249.11											
	Scheffé										

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 59. MULTIPLE COMPARISONS OF SEDIMENT SILT/CLAY RATIO U.S. MID-ATLANTIC STATIONS 1 THROUGH 10.

Cruise Mid-1	Station	8	9	5	7	6	1	2	3	10	4
F ratio=6.038	Silt/Clay	0.69	0.71	0.76	0.76	0.78	0.83	0.88	0.96	0.97	0.99
DF=(9, 20)											
C=0.2393	SNK										
Var ratio=63.0											
	Scheffé										
Cruise Mid-2	Station	9	5	8	7	6	10	1	4	2	3
F ratio=13.424	Silt/Clay	0.66	0.80	0.81	0.82	0.84	0.85	0.92	0.94	0.97	1.19
DF=(9, 20)											
C=0.2961	SNK										
Var ratio=129.0											
	Scheffé										
Cruise Mid-3	Station	9	8	7	1	6	10	2	4	3	5
F ratio=5.585	Silt/Clay	0.73	0.74	0.74	0.85	0.90	0.91	0.94	0.99	1.00	1.01
DF=(9, 20)											
C=0.2960	SNK										
Var ratio=193.0											
	Scheffé										
Cruise Mid-4	Station	9	7	1	5	4	3	10	2	6	
F ratio=7.735	Silt/Clay	0.62	0.67	0.68	0.74	0.78	0.80	0.85	0.87	0.88	
DF=(8,18)											
C=0.3170	SNK										
Var ratio=13.9											
	Scheffé										
Cruise Mid-5	Station	9	7	5	3	10	1	4	6	2	
F ratio=5.151	Silt/Clay	0.67	0.68	0.74	0.79	0.80	0.81	0.86	0.86	0.87	
DF=(8, 18)											
C=0.4732*	SNK										
Var Ratio=22.7											
	Scheffé										
Cruise Mid-6	Station	9	7	1	6	5	10	2	4	3	
F ratio=10.990	Silt/Clay	0.64	0.67	0.73	0.79	0.82	0.83	0.87	0.90	0.93	
DF=(8, 18)											
C=0.4756*	SNK										
Var ratio=27.8											
	Scheffé										

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 60. MULTIPLE COMPARISONS OF SEDIMENT SILT-MODE HEIGHT AT U.S. MID-ATLANTIC STATIONS 1 THROUGH 10.

Cruise Mid-1	Station	8	5	7	9	6	1	2	10	4	3
F ratio=2.834	% Silt-Mode	12.50	12.60	13.10	13.37	13.43	13.93	14.20	14.87	15.63	15.90
DF= (9,20)											
C=0.4628*	SNK										
Var ratio=174.1											
	Scheffé										
Cruise Mid-2	Station	5	1	9	6	10	7	8	2	4	3
F ratio=5.390	% Silt Mode	12.73	13.17	13.17	13.23	13.57	13.80	13.93	14.03	14.77	17.13
DF=(9, 20)											
C=0.3907	SNK										
Var ratio=27.8											
	Scheffé										
Cruise Mid-3	Station	7	6	1	4	10	8	2	3	9	5
F ratio=2.659	% Silt-Mode	13.57	13.83	14.03	14.30	14.83	15.20	15.30	15.57	15.77	17.20
DF=(9, 20)											
C=0.2724	SNK										
Var ratio=39.3											
	Scheffé										
Cruise Mid-4	Station	4	2	10	5	3	1	6	7	9	
F ratio=4.173	% Silt-Mode	12.20	12.80	13.10	14.57	14.77	15.27	15.83	16.17	20.60	
DF=(8,18)											
C=0.5836*	SNK										
Var ratio=77.8											
	Scheffé										
Cruise Mid-5	Station	10	7	9	3	5	2	6	4	1	
F ratio=1.839	% Silt-Mode	12.73	12.77	13.57	14.40	14.57	14.67	14.80	14.90	15.07	
DF=(8, 18)											
C=0.2898	SNK										
Var Ratio=33.9											
	Scheffé										
Cruise Mid-6	Station	7	1	6	9	2	5	4	3	10	
F ratio=1.668	% Silt-Mode	12.57	12.80	13.17	13.17	13.73	14.00	14.13	14.33	14.50	
DF=(8, 18)											
C=0.3367	SNK										
Var ratio=28.4											
	Scheffé										

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 61. MULTIPLE COMPARISONS OF SEDIMENT CARBON CONTENT AT U.S. MID-ATLANTIC STATIONS 1 THROUGH 10.

Cruise Mid-1	Station	10	4	3	2	6	5	1	8	7	9
F ratio=12.696	% C	0.90	0.99	1.08	1.15	1.37	1.49	1.49	1.56	1.57	1.77
DF= (9,20)											
C=0.2853	SNK										
Var ratio=421.0											
	Scheffé										
Cruise Mid-2	Station	3	10	2	4	6	8	5	1	9	7
F ratio=20.686	% C	0.64	0.90	0.99	1.21	1.22	1.44	1.51	1.51	1.52	1.56
DF=(9, 20)											
C=0.1955	SNK										
Var ratio=15.0											
	Scheffé										
Cruise Mid-3	Station	4	3	2	10	6	5	7	1	9	8
F ratio=14.574	% C	0.97	1.03	1.19	1.20	1.32	1.49	1.53	1.58	1.62	1.81
DF=(9, 20)											
C=0.2937	SNK										
Var ratio=26.7											
	Scheffé										
Cruise Mid-4	Station	3	2	10	4	7	6	1	5	9	
F ratio=5.52	% C	0.67	1.03	1.04	1.16	1.23	1.25	1.39	1.42	1.64	
DF=(8,18)											
C=0.4338	SNK										
Var ratio=374.4											
	Scheffé										
Cruise Mid-5	Station	3	10	4	2	1	5	6	9	7	
F ratio=15.253	% C	0.96	0.96	1.11	1.17	1.30	1.31	1.37	1.49	1.52	
DF=(8, 18)											
C=0.4882*	SNK										
Var Ratio=1101.0											
	Scheffé										
Cruise Mid-6	Station	10	2	4	3	1	5	6	7	9	
F ratio=4.481	% C	0.94	1.12	1.16	1.18	1.22	1.27	1.28	1.34	1.73	
DF=(8, 18)											
C=0.4815	SNK										
Var ratio=336.1											
	Scheffé										

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) from compared population means.

TABLE 62. MULTIPLE COMPARISONS OF SEDIMENT HYDROGEN CONTENT AT U.S. MID-ATLANTIC STATIONS 1 THROUGH 10.

Cruise Mid-1	Station	3	4	2	10	6	1	5	7	8	9
F ratio=3.885	% H	0.54	0.57	0.62	0.64	0.67	0.68	0.70	0.71	0.73	0.80
DF= (9,20)											
C=0.2987	SNK										
Var ratio=44.4											
	Scheffé										
Cruise Mid-2	Station	3	4	10	2	1	6	8	5	9	7
F ratio=5.305	% H	0.41	0.57	0.59	0.61	0.65	0.65	0.66	0.71	0.76	0.77
DF=(9, 20)											
C=0.4976*	SNK										
Var ratio=309.0											
	Scheffé										
Cruise Mid-3	Station	3	4	10	6	1	2	7	5	9	8
F ratio=14.162	% H	0.47	0.56	0.58	0.64	0.65	0.65	0.67	0.67	0.78	0.78
DF=(9, 19)											
C=0.3139	SNK										
Var ratio=52.0											
	Scheffé										
Cruise Mid-4	Station	3	4	10	2	1	6	5	9	7	
F ratio=2.458	% H	0.39	0.65	0.68	0.71	0.78	0.82	0.83	0.83	0.88	
DF=(8,18)											
C=0.3399	SNK										
Var ratio=88.2											
	Scheffé										
Cruise Mid-5	Station	3	2	1	4	6	5	10	9	7	
F ratio=5.411	% H	0.49	0.56	0.59	0.62	0.66	0.67	0.69	0.71	0.81	
DF=(8, 18)											
C=0.2908	SNK										
Var Ratio=367.0											
	Scheffé										
Cruise Mid-6	Station	3	10	1	5	6	7	4	2	9	
F ratio=3.651	% H	0.59	0.60	0.65	0.67	0.67	0.70	0.77	0.85	0.90	
DF=(8, 18)											
C=0.4695	SNK										
Var ratio=19.5											
	Scheffé										

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 63. MULTIPLE COMPARISONS OF SEDIMENT NITROGEN CONTENT AT U.S. MID-ATLANTIC STATIONS 1 THROUGH 10.

Cruise Mid-1	Station	10	3	2	4	5	6	1	7	8	9
F ratio=10.163	% N	0.11	0.13	0.13	0.13	0.18	0.18	0.19	0.19	0.20	0.23
DF= (9,20)											
C=0.2913	SNK										
Var ratio=37.0											
	Scheffé										
Cruise Mid-2	Station	3	10	2	4	6	5	8	7	9	1
F ratio=16.718	% N	0.08	0.11	0.12	0.14	0.16	0.18	0.19	0.19	0.20	0.22
DF=(9, 20)											
C=0.3874	SNK										
Var ratio=14.3											
	Scheffé										
Cruise Mid-3	Station	3	10	4	6	2	1	5	7	9	8
F ratio=16.763	% N	0.11	0.13	0.14	0.16	0.18	0.19	0.19	0.20	0.21	0.22
DF=(9, 19)											
C=0.2836	SNK										
Var ratio=19.0											
	Scheffé										
Cruise Mid-4	Station	3	2	4	10	6	7	5	1	9	
F ratio=3.051	% N	0.09	0.13	0.13	0.13	0.15	0.16	0.17	0.18	0.19	
DF=(8,18)											
C=0.4023	SNK										
Var ratio=103.0											
	Scheffé										
Cruise Mid-5	Station	2	1	3	10	5	6	4	7	9	
F ratio=6.640	% N	0.13	0.14	0.14	0.14	0.17	0.17	0.18	0.20	0.20	
DF=(8, 18)											
C=0.5890*	SNK										
Var Ratio=43.0											
	Scheffé										
Cruise Mid-6	Station	10	2	4	3	1	5	7	6	9	
F ratio=3.299	% N	0.12	0.13	0.14	0.15	0.16	0.16	0.18	0.18	0.20	
DF=(8, 18)											
C=0.4351	SNK										
Var ratio=67.0											
	Scheffé										

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) from compared population means.

Also at the time of Cruise Mid-3, Stations 8 and 9 formed a pair measurably higher in hydrogen content than the other 2100-m stations. At the time of Cruise Mid-4, Station 9 sediments were unique in mean phi grain size and silt-mode height. Moreover, at the time of Cruise Mid-5, sediments of Station 9 were similar to those at Stations 5, 6, and 7 in sand content and mean phi grain size. And finally, at the time of Cruise Mid-6, Station 9 sediments were significantly higher in carbon content than those of all other 2100-m stations.

Changes in Sediment Characteristics with Time

Analyses of variance and multiple comparisons of sediment characteristics of each station over time revealed the range and dynamic nature of changes in sediments. Analyses and data are summarized in Tables 64 through 70 and Figures 66 through 81. Notable changes included the following:

Station 1--Gravel- and sand-sized plate-like fragments of a yellow marl were found in samples collected on Cruise Mid-2. Subsequent X-ray diffraction analysis revealed the fragments to be 53 percent layered silicates, 31 percent calcite, and a trace of zeolites, with the remainder composed of poorly crystalline X-ray opaque minerals (L. Poppe, USGS, pers. comm.). Upon visual inspection of sand fractions of Stations 1, 2, 3, and 10 (for distant comparison) grains of this material were readily observable in sand fractions of sediments from Stations 1, 2, and 3, but not Station 10. Sediments of Station 1 also showed an increase in silt/clay ratio from 0.83 to 0.92; although not statistically significant, this increase was concurrent with appearance of the exotic material and an increase in grain size at Station 3 described below.

Station 2--Marl fragments similar to those observed at Station 1 were found in the sand fraction of samples collected on Cruise Mid-2. There were apparent increases in sediment sand content and silt/clay ratio and a decrease in carbon content between Cruise Mid-1 and Cruise Mid-2. Parameters returned to original levels by Cruise Mid-4. None of these differences were statistically significant.

TABLE 64. SUMMARY OF MULTIPLE COMPARISONS OF EACH U.S. MID-ATLANTIC STATION EXHIBITING CHANGES IN SEDIMENT SAND CONTENT OVER CRUISES MID-1 THROUGH MID-6.

Station 3	Cruise	6	1	5	3	4	2
F ratio=5.048	% Sand	17.5	20.4	21.1	29.6	30.1	32.4
DF= (5,12)							
C=0.3559	SNK						
Var ratio=4.9							
	Scheffé						
Station 11	Cruise	1	5	4	2	3	6
F ratio=30.109	% Sand	2.4	3.8	5.2	6.4	8.8	37.8
DF= (5,12)							
C=0.6433*	SNK						
Var ratio=342.3							
	Scheffé						

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 65. SUMMARY OF MULTIPLE COMPARISONS OF EACH U.S. MID-ATLANTIC STATION EXHIBITING CHANGES IN MEAN PHI GRAIN SIZE CONTENT OVER CRUISES MID-1 THROUGH MID-6.

Station 3	Cruise	2	3	4	1	6	5
F ratio=7.244	Mean Phi	6.29	6.71	6.93	7.25	7.53	7.53
DF= (5,12)							
C=0.3605	SNK						
Var ratio=7.2							
	Scheffé						
Station 5	Cruise	3	6	2	1	4	5
F ratio=10.624	Mean Phi	8.20	8.30	8.48	8.62	8.70	8.70
DF= (5,12)							
C=0.4798	SNK						
Var ratio=273.0							
	Scheffé						
Station 7	Cruise	2	3	1	5	6	4
F ratio=5.972	Mean Phi	8.52	8.55	8.63	8.79	8.83	8.97
DF= (5,12)							
C=0.4303	SNK						
Var ratio=94.2							
	Scheffé						
Station 9	Cruise	3	1	2	5	6	4
F ratio=20.443	Mean Phi	8.61	8.86	8.86	8.89	8.96	9.45
DF= (5,12)							
C=0.3269	SNK						
Var ratio=7.8							
	Scheffé						
Station 11	Cruise	6	3	2	5	4	1
F ratio=30.758	Mean Phi	6.21	7.88	8.19	8.27	8.30	8.73
DF= (5,12)							
C=0.3156	SNK						
Var ratio=55.2							
	Scheffé						

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 66. SUMMARY OF MULTIPLE COMPARISONS OF EACH U.S.MID-ATLANTIC STATION EXHIBITING CHANGES IN SEDIMENT SILT/CLAY RATIO SIZE CONTENT OVER CRUISES MID-1 THROUGH MID-6.

Station 1	Cruise	4	6	5	1	3	2
F ratio=3.946	Silt/Clay	0.68	0.73	0.81	0.83	0.85	0.92
DF= (5,12)							
C=0.4253	SNK						
Var ratio=11.3							
	Scheffé						
Station 3	Cruise	5	4	6	1	3	2
F ratio=15.015	Silt/Clay	0.79	0.80	0.93	0.96	1.00	1.19
DF= (5,12)							
C=0.4968	SNK						
Var ratio=24.2							
	Scheffé						
Station 5	Cruise	4	5	1	2	6	3
F ratio=7.362	Silt/Clay	0.74	0.74	0.76	0.80	0.82	1.01
DF= (5,12)							
C=0.7699*	SNK						
Var ratio=82.7							
	Scheffé						
Station 7	Cruise	6	4	5	3	1	2
F ratio=4.957	Silt/Clay	0.67	0.67	0.68	0.74	0.76	0.82
DF= (5,12)							
C=0.3079	SNK						
Var ratio=6.8							
	Scheffé						
Station 12	Cruise	6	4	3	5	1	2
F ratio=4.325	Silt/Clay	0.72	0.85	0.92	0.93	0.96	0.96
DF= (5,12)							
C=0.3688	SNK						
Var ratio=8.9							
	Scheffé						

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 67. SUMMARY OF MULTIPLE COMPARISONS OF EACH U.S. MID-ATLANTIC STATION EXHIBITING CHANGES IN SEDIMENT SILT-MODE HEIGHT SIZE CONTENT OVER CRUISES MID-1 THROUGH MID-6.

Station 5	Cruise	1	2	6	4	5	3
F ratio=9.662	% Silt-Mode	12.6	12.7	14.0	14.6	14.6	17.2
DF= (5,12)							
C=0.3500	SNK	———					———
Var ratio=11.4							
	Scheffé	———			———		
Station 6	Cruise	6	2	1	3	5	4
F ratio=5.257	% Silt-Mode	13.2	13.2	13.4	13.8	14.8	15.8
DF= (5,12)							
C=0.3146	SNK	———				———	
Var ratio=9.8							
	Scheffé	———				———	
Station 9	Cruise	2	6	1	5	3	4
F ratio=18.183	% Silt-Mode	13.2	13.2	13.4	13.6	15.8	20.6
DF= (5,12)							
C=0.4266	SNK	———					———
Var ratio=12.1							
	Scheffé	———					———
Station 11	Cruise	1	4	6	5	2	3
F ratio=7.622	% Silt-Mode	13.8	15.1	15.2	15.6	16.3	17.6
DF= (5,12)							
C=0.3953	SNK	———			———		
Var ratio=21.8							
	Scheffé	———			———		
Station 12	Cruise	6	5	4	3	2	1
F ratio=5.744	% Silt-Mode	11.7	13.6	14.5	14.8	15.1	15.7
DF= (5,12)							
C=0.6690*	SNK	———					
Var ratio=25.8							
	Scheffé	———			———		

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 68. SUMMARY OF MULTIPLE COMPARISONS OF EACH U.S. MID-ATLANTIC STATION EXHIBITING CHANGES IN SEDIMENT CARBON CONTENT OVER CRUISES MID-1 THROUGH MID-6.

Station 3	Cruise	2	4	5	3	1	6
F ratio=4.723	% C	0.64	0.67	0.96	1.03	1.08	1.18
DF= (5,12)							
C=0.3741	SNK						
Var ratio=112.0							
	Scheffé						
Station 5	Cruise	6	5	4	1	3	2
F ratio=6.697	% C	1.27	1.31	1.42	1.49	1.49	1.51
DF= (5,12)							
C=0.4227	SNK						
Var ratio=90.3							
	Scheffé						
Station 9	Cruise	5	2	3	4	6	1
F ratio=5.576	% C	1.49	1.52	1.62	1.64	1.73	1.77
DF= (5,11)							
C=0.6763	SNK						
Var ratio=66.1							
	Scheffé						
Station 11	Cruise	6	3	5	4	2	1
F ratio=4.971	% C	1.19	1.62	1.67	1.68	1.71	1.82
DF= (5,12)							
C=0.3572	SNK						
Var ratio=30.1							
	Scheffé						

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 69. SUMMARY OF MULTIPLE COMPARISONS OF EACH U.S. MID-ATLANTIC STATION EXHIBITING CHANGES IN SEDIMENT HYDROGEN CONTENT OVER CRUISES MID-1 THROUGH MID-6.

Station 6	Cruise	3	2	5	1	6	4
F ratio=3.361	% H	0.64	0.65	0.66	0.67	0.67	0.82
DF= (5,12)							
C=0.4042	SNK						
Var ratio=96.3							
	Scheffé						
Station 9	Cruise	5	2	3	1	4	6
F ratio=3.868	% H	0.71	0.76	0.78	0.80	0.83	0.90
DF= (5,11)							
C=0.7140*	SNK						
Var ratio=40.8							
	Scheffé						
Station 12	Cruise	3	6	2	5	1	4
F ratio=22.712	% H	0.36	0.37	0.38	0.48	0.60	0.95
DF= (5,11)							
C=0.3905	SNK						
Var ratio=9.9							
	Scheffé						

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

TABLE 70. SUMMARY OF MULTIPLE COMPARISONS OF EACH U.S. MID-ATLANTIC STATION EXHIBITING CHANGES IN SEDIMENT NITROGEN CONTENT OVER CRUISES MID-1 THROUGH MID-6.

Station 3	Cruise	2	4	3	1	5	6
F ratio=4.892	% N	0.08	0.09	0.11	0.13	0.14	0.15
DF= (5,12)							
C=0.4045	SNK						
Var ratio=36.0							
	Scheffé						
Station 4	Cruise	1	4	3	2	6	5
F ratio=3.720	% N	0.13	0.13	0.14	0.14	0.14	0.18
DF= (5,12)							
C=0.3250	SNK						
Var ratio=4.3							
	Scheffé						
Station 11	Cruise	6	3	2	4	5	1
F ratio=3.479	% N	0.15	0.20	0.21	0.21	0.22	0.23
DF= (5,12)							
C=0.2975	SNK						
Var ratio=12.0							
	Scheffé						

Contrasted values are cruise averages; underlined stations represent groups whose mean values are not statistically significantly different at experimentwise alpha = 0.05. SNK = Student-Newman-Keuls least significant range procedure. Scheffé = Scheffé Procedure. F ratio indicates significance of ANOVA with shown degrees of freedom (DF). C = Cochran's C (Maximum Variance/Sum of Variances) for compared population means. An asterisk (*) following a value indicates statistically significant inequality of compared population variances. Var Ratio = (Maximum Variance/Minimum Variance) for compared population means.

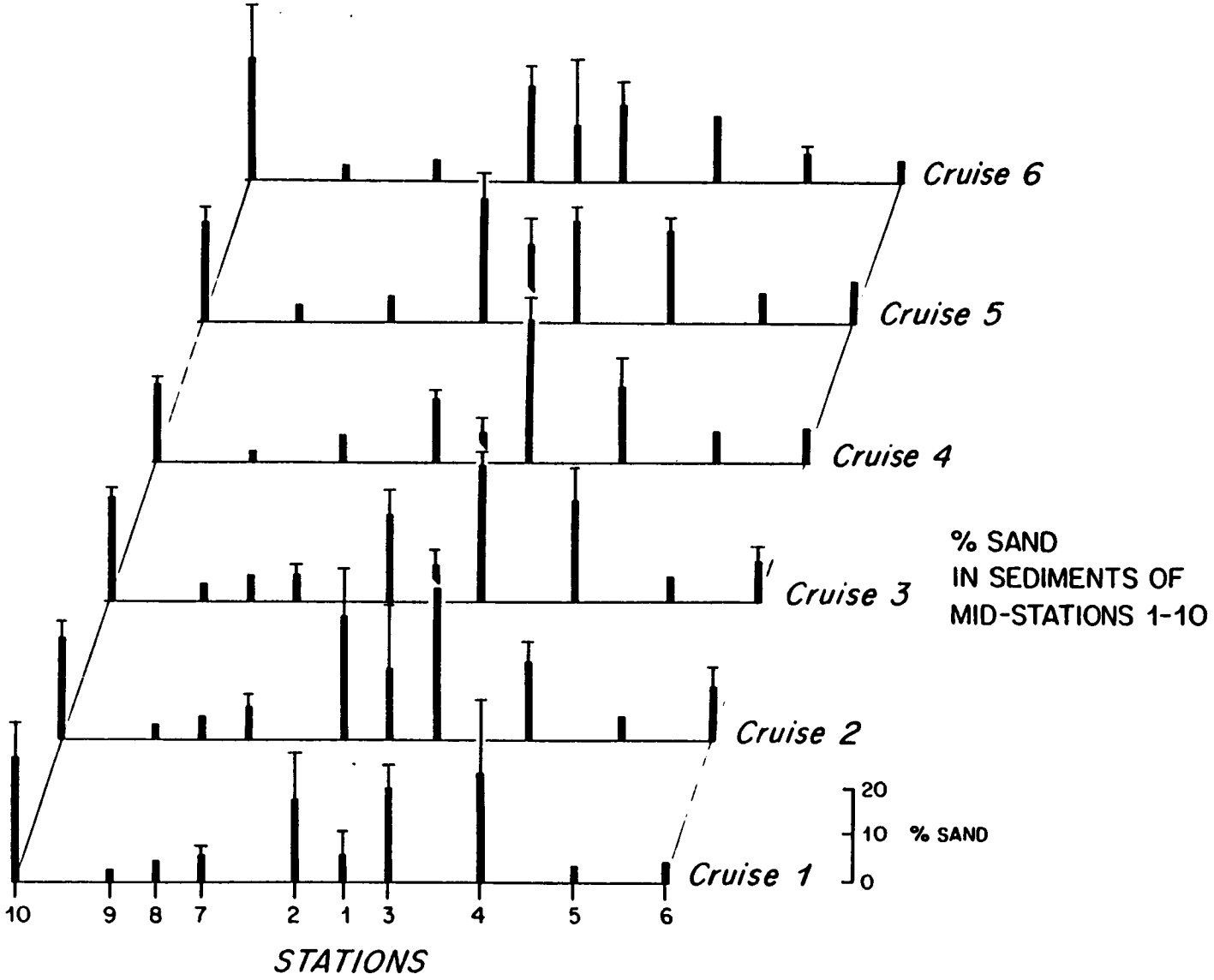

Figure 75. Sediment Sand Content for U.S. Mid-Atlantic Stations 1 Through 10 for Each of the Six Cruises. Values Shown Are Cruise Averages + 1 SD for Respective Stations. Horizontal Axis Not to Scale.

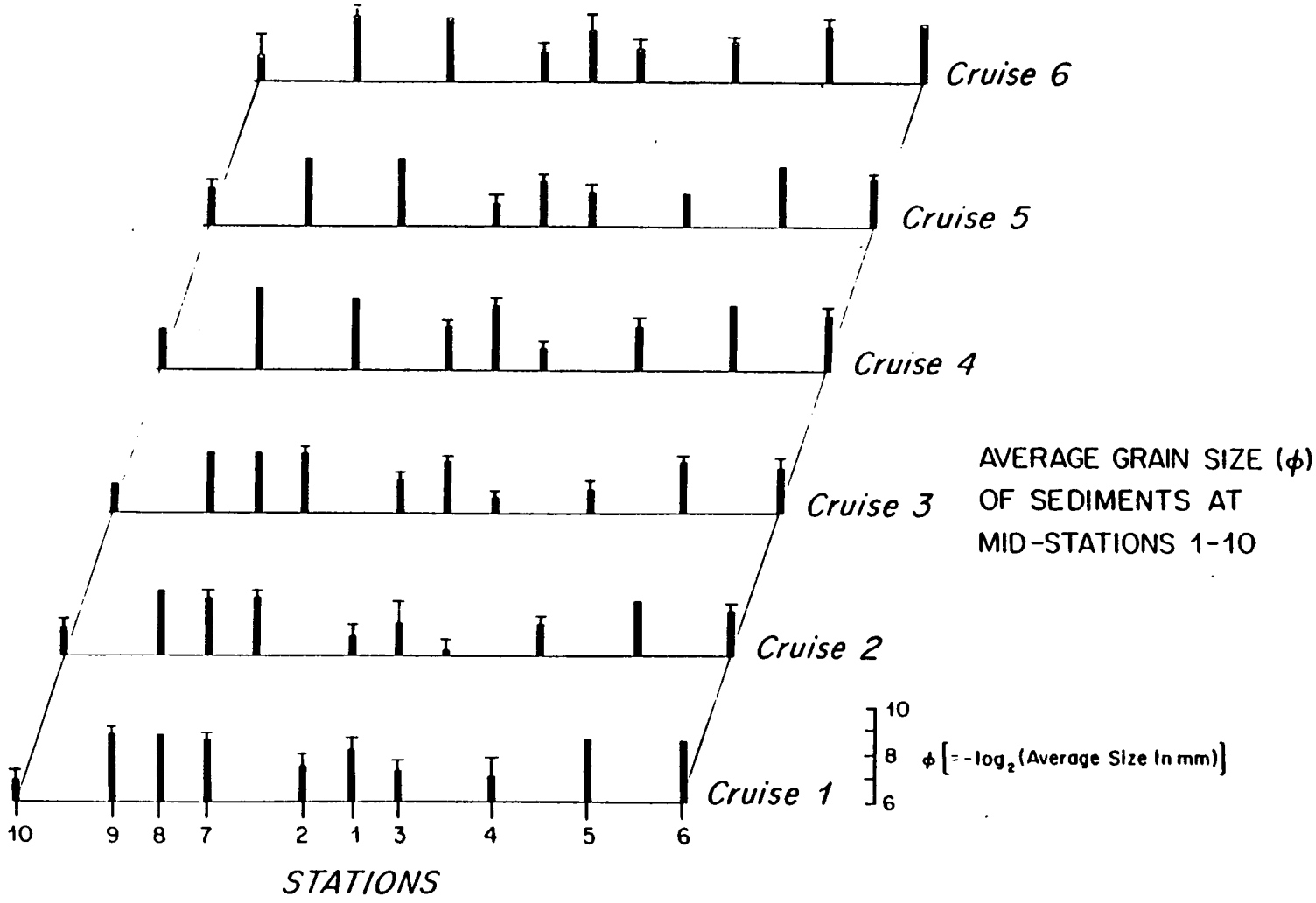

Figure 76. Sediment Mean Phi Grain Size for U.S. Mid-Atlantic Stations 1 Through 10 for Each of the Six Cruises. Values Shown Are Cruise Averages + 1 SD for Respective Stations. Horizontal Axis Not to Scale.

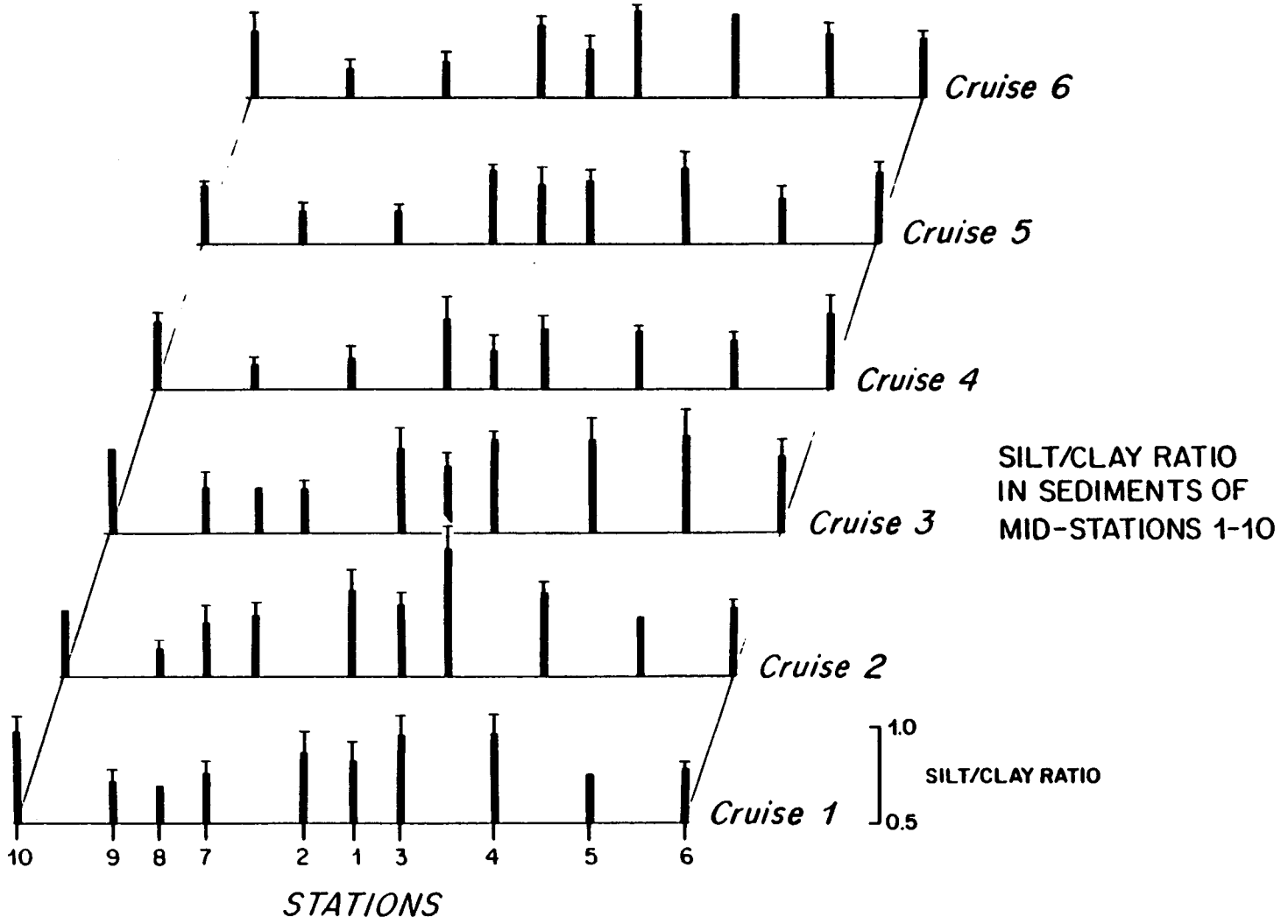

Figure 77. Sediment Silt/Clay Ratio for U.S. Mid-Atlantic Stations 1 Through 10 for Each of the Six Cruises. Values Shown Are Cruise Averages + 1 SD for Respective Stations. Horizontal Axis Not to Scale.

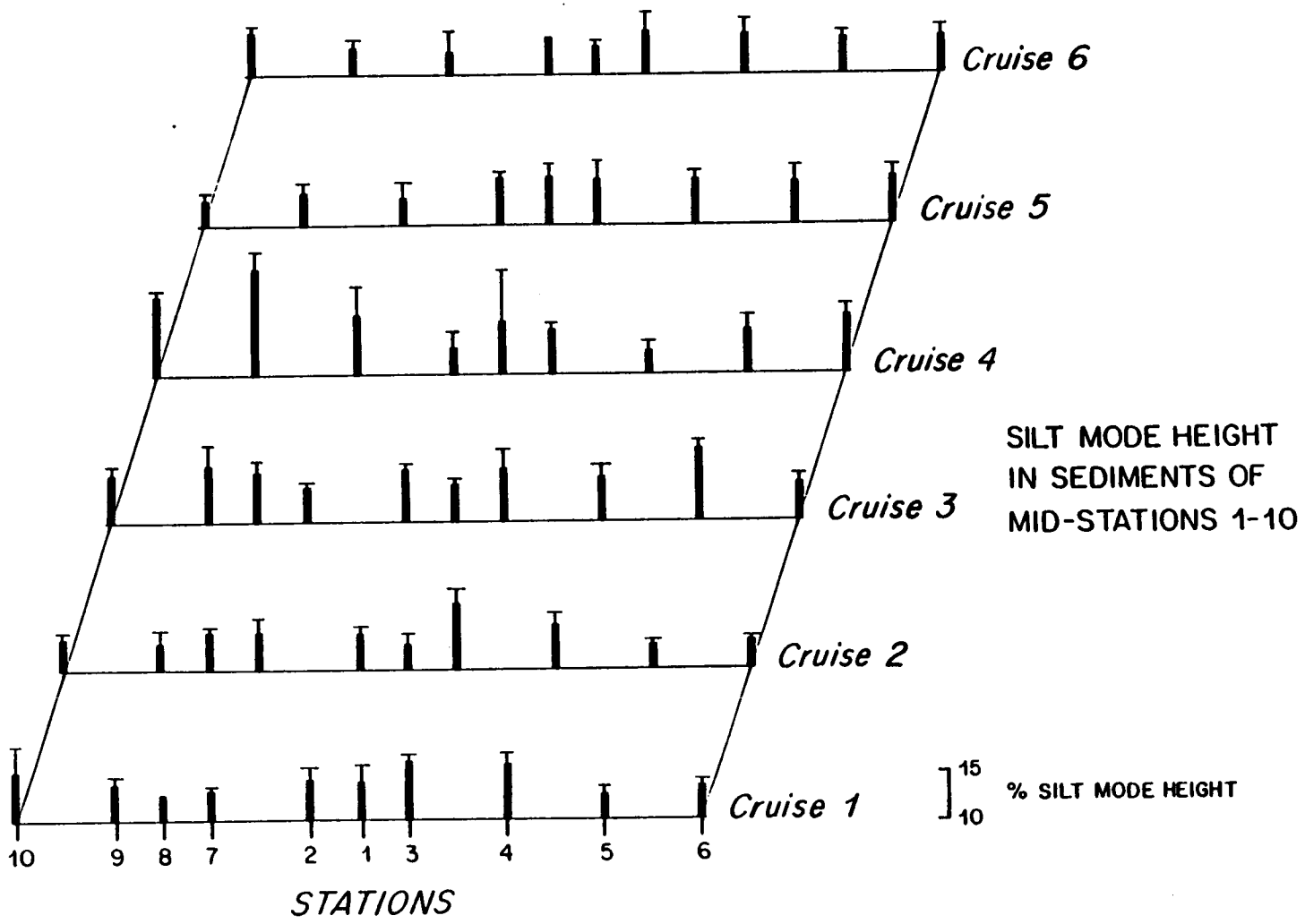

Figure 78. Sediment Silt-Mode Height for U.S. Mid-Atlantic Stations 1 Through 10 for Each of the Six Cruises. Values Shown Are Cruise Averages + 1 SD for Respective Stations. Horizontal Axis Not to Scale.

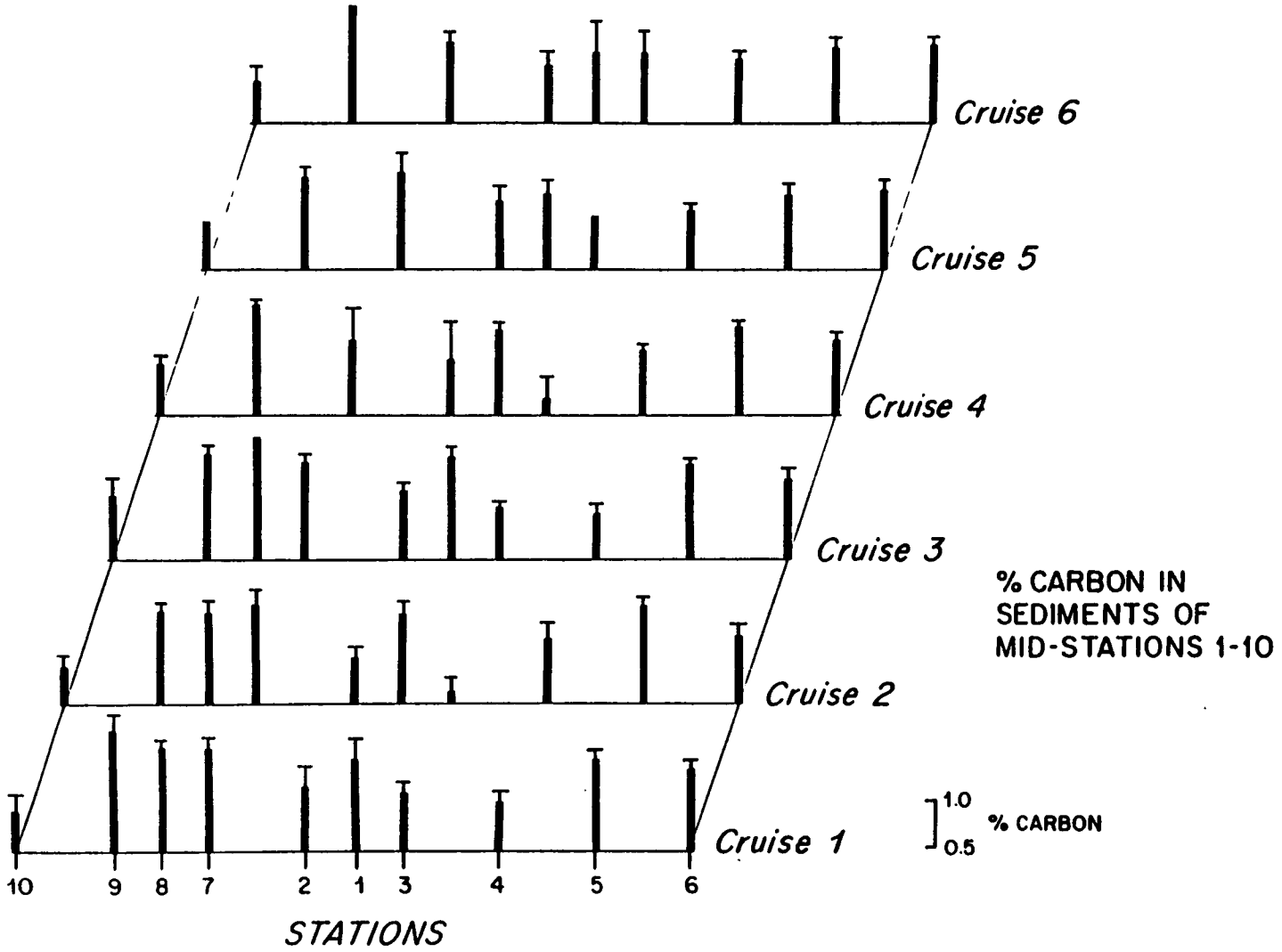

Figure 79. Sediment Carbon Content for U.S. Mid-Atlantic Stations 1 Through 10 for Each of the Six Cruises. Values Shown Are Cruise Averages + 1 SD for Respective Stations. Horizontal Axis Not to Scale.

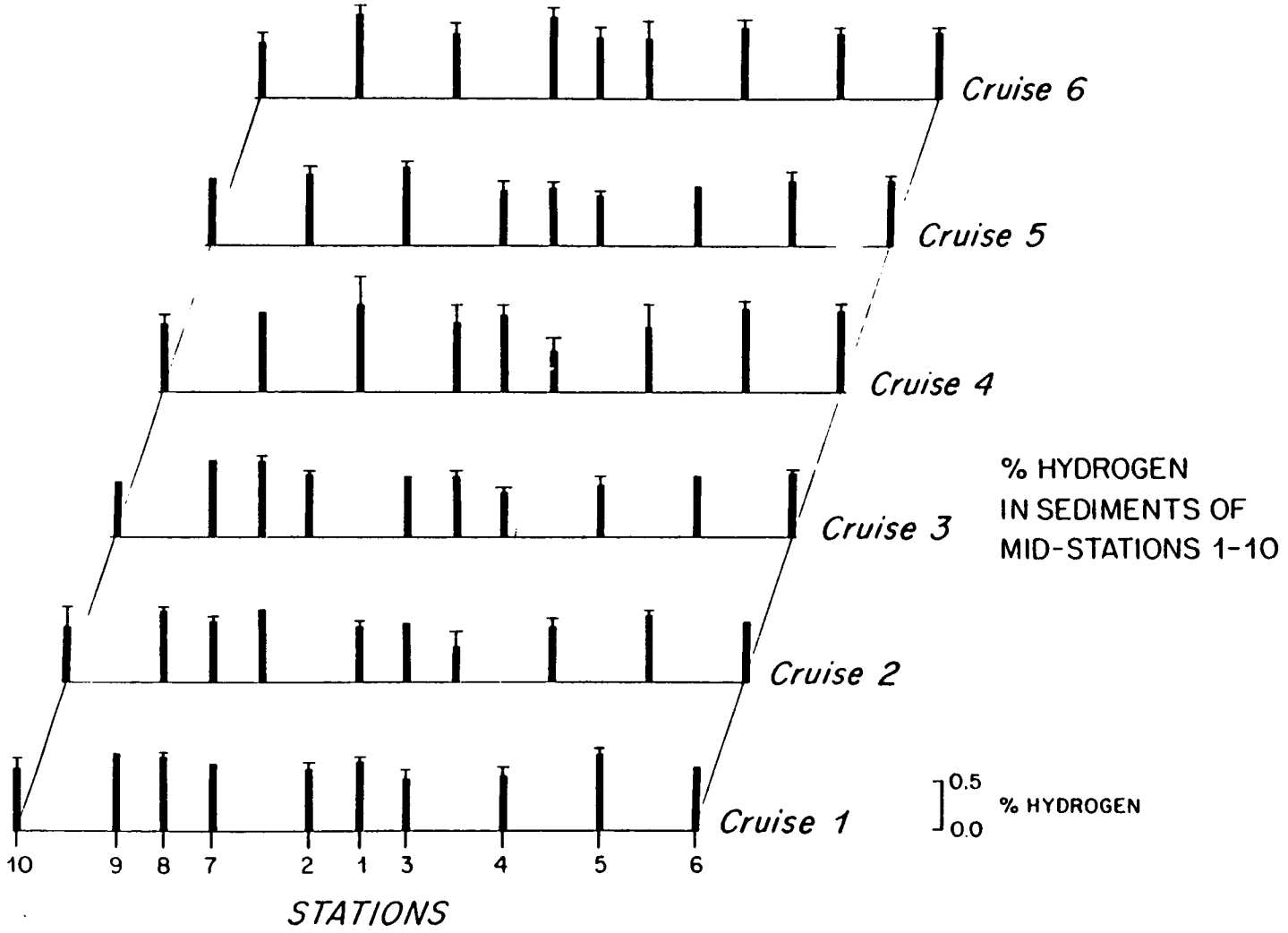

Figure 80. Sediment Hydrogen Content for U.S. Mid-Atlantic Stations 1 Through 10 for Each of the Six Cruises. Values Shown Are Cruise Averages + 1 SD for Respective Stations. Horizontal Axis Not to Scale.

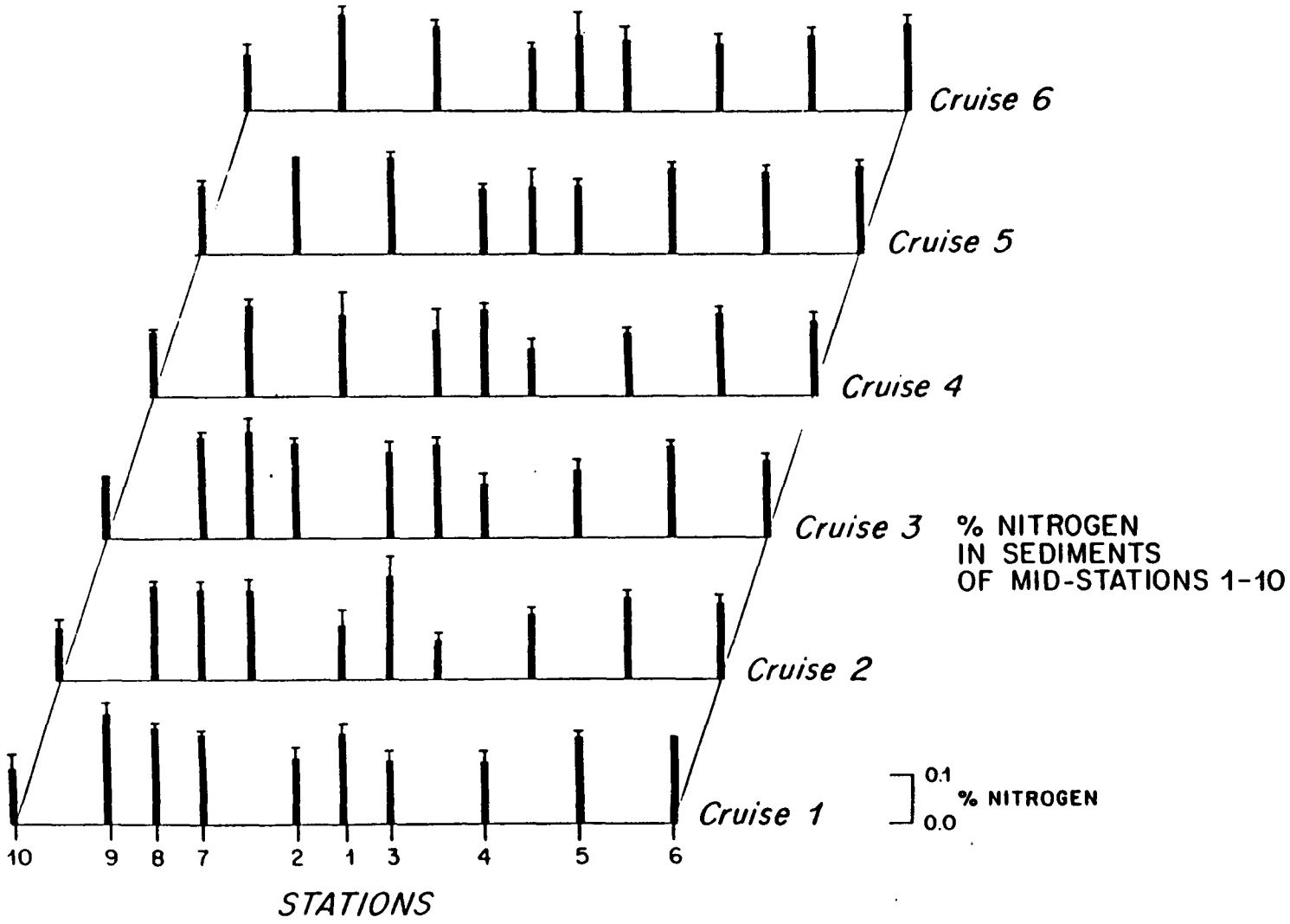

Figure 81. Sediment Nitrogen Content for U.S. Mid-Atlantic Stations 1 Through 10 for Each of the Six Cruises. Values Shown Are Cruise Averages + 1 SD for Respective Stations. Horizontal Axis Not to Scale.

Station 3--A significant increase in mean grain size occurred between Cruises Mid-1 and Mid-2. These changes amounted to a 12.0 percent increase in sand content and an increase in silt/clay ratio from 0.96 to 1.19. Visual inspection of sand fractions revealed a simultaneous appearance of marl fragments similar to those observed at Stations 1 and 2. Percent carbon and nitrogen decreased proportionately (TOC: 1.08 ± 0.10 percent to 0.64 ± 0.14 percent, and N: 013 ± 0.02 percent to 0.08 ± 0.02 percent) over this time. These changes were sufficient to distinguish Station 3 sediments from those of the other 2100-m stations; they persisted through Cruise Mid-3 and into the second year of sampling when values returned to Cruise Mid-1 levels.

Station 4--There was an apparent decrease in average silt/clay ratio from year 1 (0.94 to 0.99) to year 2 (0.78 to 0.90); however, this trend was not statistically significant. Also, there was a maximum in nitrogen content at the time of Cruise Mid-5 (0.18 ± 0.01 percent).

Station 5--Well-defined maxima in silt/clay ratio (1.01 ± 0.14) and silt-mode height (17.20 ± 0.70 percent) were observed in samples from Cruise Mid-3; moreover, there was a general decrease in percent carbon from year 1 to year 2 (1.49 to 1.51 percent vs. 1.27 to 1.42 percent).

Station 6--A subtle maximum in silt-mode height (15.83 ± 0.91 percent) and a minimum hydrogen content (0.15 ± 0.02 percent) occurred at the time of Cruise Mid-4.

Station 7--There was a general decrease in silt/clay ratios (0.74 to 0.76 vs. 0.67 to 0.68) and average grain size from year 1 to year 2; organic content did not change.

Station 8--There were no notable changes in sediment characteristics.

Station 9--A maximum in silt-mode height (20.20 ± 1.44 percent) and a minimum in mean phi grain size (9.45 ± 10 Ø) were observed at the time of Cruise Mid-4. At that time, Station 9 sediments were distinct from all other 2100-m stations in these measures.

Station 10--There was an apparent increase in the silt/clay ratio from year 1 (0.97 to 0.91) to year 2 (0.80 to 0.85).

Station 11--There was an apparent increase in the average value and scatter among replicate silt/clay ratios between Cruise Mid-1 (0.80 ± 0.01) and Cruises Mid-2 through Mid-6 (0.98 ± 0.10 to 1.07 ± 0.10). Also, there was an approximately 34.0 percent increase in sand content between Cruises Mid-5 and Mid-6 (thus affecting mean phi grain size proportionately). Visual inspection of the sand fraction revealed that the sand collected on Cruise Mid-6 was composed primarily of sub-spherical dark green glauconite grains instead of the more typical foraminiferal and diatom test assemblage. Percent carbon and nitrogen decreased from Cruise Mid-5 to Cruise Mid-6 (TOC: 1.67 ± 0.06 percent to 1.19 ± 0.24 percent, N: 0.22 ± 0.01 percent).

Station 12--A general decrease in silt/clay ratio from year 1 to year 2 (0.92 to 0.96 and 0.72 to 0.93, respectively) was observed. This was accompanied by a somewhat more subtle decrease in silt-mode height. A distinct maximum in hydrogen content was recorded for samples collected on Cruise Mid-4 (0.95 ± 0.10 percent).

Station 13--There was an apparent increase in average values and scatter among replicate silt/clay ratios from Cruise Mid-1 (0.73 ± 0.09) to the times of Cruises Mid-2, Mid-3, Mid-5, and Mid-6 (0.83 ± 0.21 to 1.07 ± 0.25). These changes were not statistically significant, however.

Station 14--An apparent increase in silt/clay ratio from the time of Cruise Mid-1 (0.79 ± 0.03) to the times of Cruises Mid-4, Mid-5, and Mid-6 (0.85 to 0.96) was observed. This change was not statistically significant, however.

DISCUSSION

Sediment characteristics of the silt-clay muds reported here are in general agreement with regional studies of sediment texture (Hathaway, 1971; Hollister, 1973), organic content (Hathaway, 1971), and sand fraction composition (Milliman, 1972; Milliman et al., 1972).

Variability in sediment characteristics among samples collected at a single station (within 0.1 nmi of each other) was typically low; however, at some stations the within-station range of sediment parameters equaled that observed on regional scales. The implications for single point measurement of any parameter that may show a correlation with grain size are significant (e.g., biota, fine-grained reactive pollutants).

In general, the increase in sand content with depth shown by comparison of Stations 11, 1, 2, 3, and 12 (1515 m to 2505 m) and Stations 13 and 10 (1613 m to 2095 m) may reflect diminishing down-slope transport of terrigenous fine-grained material and increasing relative importance of pelagic sedimentation of sand-sized foraminiferal tests. Driscoll et al. (1985) reported increases in sand content and silt/clay ratio from depths of 4000 m to 4100 m on the Nova Scotian lower continental rise. They attributed this zonation to increasing average and peak speeds of regional geostrophic currents with depth. Current meter data suggest that environments on the lower continental slope of the Mid-Atlantic bight are dominated by the slow, southwestwardly flow of the Western Boundary Undercurrent (Scientific Applications International Corporation, pers. comm.). Temperature and salinity measurements made as part of this study agree with this observation (see Chapter 9, this report).

Alternatively, differences in textural characteristics may reflect fortuitous placement of stations in different canyon and near-canyon depositional environments. Although no significant differences in sediments were found between closely spaced stations that differed in overlying water depth by 50 m, Maciolek et al. (1986b, 1987) reported changes in sediment grain size between closely spaced stations located in gully and nongully environments at 1300 m on the continental slope off New England. Both McGregor et al. (1984), in summarizing a wide range of observations, and Stanley et al. (1986), in reporting petrologic and foraminiferal evidence, concluded that canyons on the slope of the Mid-Atlantic bight serve as conduits for periodic transport of quartzose sands and shallow-water foraminiferal tests derived from the upper slope and shelf. Finer-grained sediments at mid-slope depths may represent overbank deposition; whereas stations on the lower slope in various near-canyon locations show accumulation of sands. X-radiographs of the top 15 cm of sediments at Stations 1 and 12 show extensively bioturbated muds with no preservation of sedimentary structures; however, at Station 1, pebbles (0.5 to 1.0 cm in diameter) were visible in the sediments at 2 to 5-cm depth (Dade, unpublished).

An extreme variation in sediment texture along-slope is demonstrated by a 10-fold increase in sand content between Stations 9 (2 to 4 percent) and 10 (17 to 27 percent). This range in sediment grain size most certainly reflects placement of stations in different depositional environments with respect to sediment transport in and around canyons.

Organic content of bottom sediments varies inversely with grain size. Fine-grained material and organic matter generally settle through the seawater column at similar rates. Moreover, organic matter is readily adsorbed onto the surfaces of clay minerals. Fractionation of fine-grained particles probably occurs during settling through slow flows typical of the deep sea (McCave and Swift, 1976). Thus, stations with greater fine-grained and organic material represent lower energy depositional environments. The resulting correlation between accumulating fine-grained sediments and organic matter is best shown here by organic carbon and nitrogen (Figure 62). This trend is similar to that reported by Emery and Uchupi (1972) for western Atlantic sediments in general and by Maciolek et al. (1987) for sediments of the slope and rise off New England.

Marine organic matter, principally derived from phytoplankton, is typically 6.5 parts carbon to 1 part nitrogen by weight. This C/N ratio increases to between 6 and 10 in surficial sediments of the bottom as a result of oxidation of less refractory nitrogen compounds (Emery and Uchupi, 1972, 1984). The present data are in complete agreement with these observations. No extreme deviations were noted during the course of the study.

The apparent increase in organic content of sediments with depth is probably related to grain size. However, a comparison of sediments of similar texture from Station 13 (1613 m, 3 percent sand) and Station 9 (2105 m, 3 percent sand) shows that the former station had greater TOC (1.85 to 2.00 percent) and nitrogen content (0.22 to 0.25 percent) than did the latter (1.49 to 1.73 percent TOC; 0.19 to 0.21 percent N). Emery and Uchupi (1984) concluded that sediment organic content decreases slightly for Western North Atlantic sediments in water depths greater than 1 km.

Sediment grain size increased at Station 1 (Block 372 drill site) between pre-drilling and post-drilling conditions (from 6.57 percent to 14.40 percent sand and from 0.83 to 0.92 silt/clay ratio). Neither change was statistically significant, however. Concurrent with this change was the appearance of gravel- and sand-sized plate-like particles of yellow

chalk in one replicate. These particles, initially suspected of being drill cuttings, also appeared in the sand fractions of Stations 2 and 3 in samples collected on post-drilling Cruise Mid-2. These particles were very likely from a "calcareous claystone" of Eocene age that is presently exposed in outcrops along much of the continental slope of the Mid-Atlantic bight (Robb et al., 1982). Concurrent increases in sand content and silt/clay ratios at Stations 2, 3, and 11 from Cruise Mid-1 to Cruise Mid-2 suggest a sediment transport event in the vicinity of Lindenkohl Canyon over this time period. Data reported by Scientific Applications International Corporation (SAIC) from current meters moored approximately 80 and 275 m above the bottom at Station 1 over this time period showed maximum current speeds of about 20 cm/sec and 40 cm/sec, respectively. Resuspension of deep-sea sediments at the HEBBLE site on the Nova Scotian rise can result from geostrophic currents flowing at speeds measured above the benthic boundary layer of about 20 cm/sec (10 cm/sec at 1 mab) (Grant et al., 1985). It is suggested here that between the time of Cruises Mid-1 and Mid-2, coarse sediments derived from recently eroded outcrops of Eocene age were transported into the area of Stations 1, 2, and 3. This event probably contributed to an increase in silt/clay ratio at Station 11 farther upslope and notable decreases in organic content and patchiness of sediment characteristics at these stations. It is worth noting in this regard that a decrease in filter-feeding epifauna at topographic lows in the vicinity of Station 1 occurred over this same time period (Chapter 6, this report). At Station 3, at least, the effects on sediment texture of the top 2 cm of sediment persisted into the summer of year 2 (Cruise Mid-5).

A clearly significant increase in sand content at Station 11 from Cruise Mid-5 to Cruise Mid-6 (from 4 to 38 percent sand) probably represented a localized sediment transport event similar to that described above. The composition of the sand fraction changed from a typical foraminiferal-diatom test assemblage to one dominated by grains (glauconite) characteristic of shelf and some slope sediments of the Mid-Atlantic bight (Milliman et al., 1972).

There were apparent increases in silt/clay ratios and patchiness among sediment parameters from pre-drilling to post-drilling conditions at Stations 13 and 14 (both in the vicinity of Block 93 drill site). For example, at Station 14, silt/clay increased from 0.79 to 0.85 to 0.96. These changes were not statistically significant, however, and may or may not be related to drilling.

CHAPTER 9. HYDROGRAPHY

INTRODUCTION

Dissolved oxygen concentration, salinity, and temperature of the near-bottom water were measured during this study. These hydrographic parameters are important since they may influence the distribution and abundances of the 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

Reversing thermometers, two protected and one unprotected, were used to measure the near-bottom temperature on all six sampling cruises. The temperatures recorded on the reversing thermometers were first corrected for the individual thermometer by using the method established by the U.S. Naval Oceanographic Office (1975). The actual depth (z) of the hydrocast was calculated by

$$z = \frac{(Tu-Tw)}{(rho)\,(Q)}$$

where Tu is the corrected temperature of the unprotected thermometer, Tw is the corrected temperature of the protected thermometer, rho is the mean density of the water column above the estimated depth, and Q is the pressure-response coefficient for the unprotected thermometer.

The dissolved oxygen concentrations were determined on board ship by the Winkler titration method. The salinity samples were measured at WHOI using an Autosal conductivity probe. On Cruise Mid-2, a Neal Brown Mark III CTD was used to provide additional temperature and salinity data. The temperature and salinity were recorded at intervals of one meter, thereby providing a vertical profile at each station.

RESULTS

The mean of the temperatures recorded by the two protected thermometers at each station on each cruise is presented in Table 71. The depths are the values calculated to be the depth at which the temperature readings were actually made. The salinity and dissolved oxygen concentration data, including station means and standard deviations, are presented in Tables 72 and 73, respectively. Mean values for each parameter represent averages of the replicate measurements of a single sample; within-station variability is not represented here. The CTD plots of temperature and salinity versus depth for each station are in Appendix M.

The salinity and dissolved oxygen concentrations varied little between stations and cruises. The only anomaly common to both parameters was at Station 2 on Cruise Mid-3; the lowest dissolved oxygen concentration (5.33 mg/l) was recorded and the salinity was near its highest value (35.2 o/oo). Temperature decreased with depth fairly consistently. Station 12 (2500 m) had the lowest mean temperature on all sampling occasions except Cruise Mid-4. The 1500-m stations (11, 13, and 14) had the highest mean temperature except on Cruises Mid-2 and Mid-4. Station 10 had a lower mean temperature than the other 2100-m stations except on Cruise Mid-4, when it had the highest temperature of these stations. For Cruise Mid-4, northernmost Stations 1 through 5 at 2100 m were slightly cooler than all other stations.

The near-bottom CTD data for salinity were extremely uniform for all stations. If the CTD plots were superimposed, there would be no difference in salinity for the near-bottom water at any station. There was a sharp decrease in salinity and temperature in the top 500 m of water. The temperature at the 2500-m station (Station 12) decreased more slowly with depth than it did at the 1500-m stations (Stations 11 and 13). The near-bottom temperatures obtained from the CTD casts were consistently higher than the temperatures recorded from the reversing thermometers (Table 74). Salinity as measured for samples collected from the Niskin bottles showed slight differences between stations but was fairly consistent with the CTD data (Table 74).

A plot of temperature versus salinity is presented in Figure 82. Average temperature-salinity curves for Norwegian Sea Overflow Water (NSOW) and North Atlantic Deep Water (NADW) are shown for comparison.

TABLE 71. TEMPERATURE (°C) OF NEAR-BOTTOM WATER AT U.S. MID-ATLANTIC MONITORING PROGRAM STATIONS FOR SAMPLING CRUISES MID-1 THROUGH MID-6.

Station	MID-1		MID-2		MID-3		MID-4		MID-5		MID-6	
	°C	Depth (m)	°C	Depth (m)	°C	Depth (m)	°C	Depth (m)	°C	Depth (m)	°C	Depth (m)
1		*	3.29	2807.4	3.41	2094.5	3.57	2186.6	3.46	2103.2	3.57	2047.2
2		**	3.48	1915.7	3.61	1949.6	3.61	1996.6	3.58	1988.5	3.57	2048.5
3	3.39	1981.0	3.47	1967.6	3.52	1960.5	3.58	2052.9	3.64	1936.6	3.50	2057.0
4	3.55	2012.6	3.38	2015.5		**	3.60	2071.4	3.65	2015.6	3.56	2050.7
5	1.11	2215.9	3.28	2038.8		**	3.59	2076.9	3.66	2003.4	3.64	2040.2
6	3.46	***	3.36	1990.9	3.64	***		**	3.53	1993.1	3.55	2043.9
7	3.50	2003.8	3.47	2002.3		**	3.95	2055.5	3.52	2012.7	3.57	2039.9
8	3.42	2065.9	3.16	2075.7	3.59	2059.4		**		**		**
9	3.46	2008.1	3.44	2011.7	4.09	1987.4	3.95	2474.0	3.43	2023.0	3.61	2050.6
10	9.58	1352.3	3.36	1992.6		**	3.96	2011.2	3.29	1963.7	3.39	2066.2
11	3.76	1443.2	3.97	1435.0	4.06	1439.6	3.96	1601.6	3.79	1568.8	3.92	1516.0
12	2.63	2393.9	2.85	2391.0	2.86	2390.8	3.91	2366.7	2.96	2358.4	2.88	2514.0
13	3.86	1546.8	3.43	1591.5	4.07	1205.2	3.93	1577.2	3.78	1548.6	3.88	1609.0
14		*		**		**	3.96	1479.7	3.82	1428.4	4.02	1489.0

*Bottle tripped near surface.
**Sample not collected.
***Equipment failure.
+Suspect values.

TABLE 72. SALINITY (0/00) OF NEAR-BOTTOM WATER AT U.S. MID-ATLANTIC MONITORING PROGRAM STATIONS FOR SAMPLING CRUISES MID-1 THROUGH MID-6.

Station	Replicate	MID-1 (5/84)	MID-2 (8/84)	MID-3 (11/84)	MID-4 (5/85)	MID-5 (8/85)	MID-6 (11/85)
1	1	35.01	34.96	34.96	34.98	34.97	34.96
	2	34.92	34.96	34.97	34.98	35.00	34.96
	3	34.94	34.97	*	34.99	34.98	34.96
	$\bar{x}$	34.96	34.96	34.96	34.98	34.98	34.96
	SD	0.05	0.01	0.01	0.01	0.02	0.00
2	1	*	34.99	35.20	34.98	34.91	34.34
	2	*	34.98	35.19	35.01	34.93	34.32
	3	*	34.98	*	34.98	34.92	34.35
	$\bar{x}$		34.98	35.20	34.99	34.92	34.34
	SD		0.01	0.01	0.02	0.01	0.02
3	1	34.96	34.97	34.92	35.53	35.00	34.90
	2	35.00	34.97	34.96	35.45	35.00	34.35
	3	34.98	34.97	*	35.50	34.99	34.32
	$\bar{x}$	34.98	34.97	34.94	35.49	35.00	34.36
	SD	0.02	0.00	0.03	0.04	0.01	0.04
4	1	34.97	34.97	*	35.08	34.90	34.33
	2	34.97	35.02	*	36.39	34.39	34.31
	3	34.98	35.01	*	35.74	34.38	34.93
	$\bar{x}$	34.97	35.00		35.90	34.39	34.36
	SD	0.01	0.03		0.92	0.01	0.06
5	1	34.98	34.97	*	34.97	34.89	34.33
	2	35.14	34.96	*	34.98	34.93	34.34
	3	34.97	34.94	*	34.98	34.90	34.35
	$\bar{x}$	35.03	34.96		34.98	34.91	34.34
	SD	0.10	0.02		0.01	0.02	0.01
6	1	*	34.97	34.94	34.32	34.88	34.93
	2	*	34.97	34.96	34.32	34.90	34.33
	3	*	34.97	*	34.34	34.89	34.34
	$\bar{x}$		34.97	34.95	34.33	34.89	34.37
	SD		0.00	0.01	0.01	0.01	0.06
7	1	34.97	34.97	34.97	34.38	34.95	34.95
	2	34.96	34.98	34.97	35.10	34.96	34.35
	3	34.96	34.97	*	34.97	34.96	34.35
	$\bar{x}$	34.96	34.97	34.97	34.98	34.96	34.38
	SD	0.01	0.01	0.00	0.11	0.01	0.06

TABLE 72. (Continued)

Station	Replicate	MID-1 (5/84)	MID-2 (8/84)	MID-3 (11/84)	MID-4 (5/85)	MID-5 (8/85)	MID-6 (11/85)
8	1	34.97	34.98	34.94			
	2	34.97	35.03	34.95	**	**	**
	3	34.99	34.97	*			
	$\bar{x}$	34.98	34.99	34.94			
	SD	0.01	0.03	0.01			
9	1	35.00	34.96	34.96	34.98	35.01	34.97
	2	34.96	34.96	34.92	35.02	35.00	34.98
	3	34.96	34.96	*	35.00	34.99	35.04
	$\bar{x}$	34.97	34.96	34.94	35.00	35.00	35.00
	SD	0.02	0.00	0.03	0.02	0.01	0.04
10	1	34.96	34.97	*	34.96	34.96	34.96
	2	34.97	34.96	*	34.96	34.96	34.96
	3	34.97	34.96	*	34.97	34.96	34.96
	$\bar{x}$	34.97	34.96		34.96	34.96	34.96
	SD	0.01	0.01		0.01	0.00	0.01
11	1	34.97	34.98	34.98	34.78	34.78	34.86
	2	34.98	35.11	34.96	34.99	34.76	34.72
	3	34.96	35.03	*	35.00	34.78	34.83
	$\bar{x}$	34.97	35.04	34.97	34.92	34.77	34.80
	SD	0.01	0.06	0.01	0.12	0.01	0.07
12	1	35.00	34.95	34.98	34.94	34.96	34.93
	2	34.96	34.95	34.96	34.96	34.89	34.65
	3	34.94	34.94	*	34.93	34.90	34.81
	$\bar{x}$	34.97	34.95	34.97	34.94	34.92	34.80
	SD	0.03	0.01	0.01	0.02	0.04	0.14
13	1	34.71	34.98	34.95	35.00	34.88	34.99
	2	34.72	34.97	34.94	35.00	34.88	34.83
	3	34.75	34.97	*	34.99	34.88	35.08
	$\bar{x}$	34.73	34.97	34.94	35.00	34.88	34.97
	SD	0.02	0.01	0.01	0.01	0.00	0.13
14	1	*			34.85	34.90	34.98
	2	*	**	**	34.93	34.90	34.86
	3	*			34.77	34.89	35.00
	$\bar{x}$				34.85	34.90	34.95
	SD				0.08	0.01	0.08

*No data.
**No samples collected.

TABLE 73. DISSOLVED OXYGEN CONTENT (MG/L) OF NEAR-BOTTOM WATER AT U.S. MID-ATLANTIC MONITORING PROGRAM STATIONS FOR SAMPLING CRUISES MID-1 THROUGH MID-6. VALUES DETERMINED BY WINKLER TITRATION.

Station	Replicate	MID-1 (5/84)	MID-2 (8/84)	MID-3 (11/84)	MID-4 (5/85)	MID-5 (8/85)	MID-6 (11/85)
1	1	9.44	8.28	8.30	8.71	8.38	8.44
	2	8.67	8.31	8.43	N.D.	8.40	8.41
	3	8.65	8.38	8.14	8.49	8.41	8.38
	$\bar{x}$	8.92	8.32	8.29	8.60	8.40	8.41
	SD	0.45	0.05	0.14	0.16	0.02	0.03
2	1	*	8.26	5.06	8.40	8.46	8.37
	2	*	8.47	5.75	8.41	8.47	8.56
	3	*	8.41	5.17	8.51	8.57	8.60
	$\bar{x}$		8.38	5.33	8.44	8.50	8.51
	SD		0.11	0.37	0.06	0.06	0.12
3	1	8.73	8.50	8.64	7.26	8.44	8.41
	2	8.76	8.55	8.63	7.30	8.47	8.64
	3	8.75	8.50	8.65	7.40	8.52	8.61
	$\bar{x}$	8.75	8.52	8.64	7.32	8.48	8.55
	SD	0.02	0.03	0.01	0.07	0.04	0.12
4	1	8.47	8.26	*	8.49	8.42	8.48
	2	8.55	9.22	*	8.62	8.51	8.44
	3	8.49	9.40	*	8.52	8.57	8.50
	$\bar{x}$	8.50	8.96		8.54	8.50	8.47
	SD	0.04	0.61		0.07	0.08	0.03
5	1	8.44	8.70	*	7.62	8.49	8.23
	2	8.53	8.55	*	8.55	8.58	8.16
	3	8.54	8.62	*	8.49	8.41	8.41
	$\bar{x}$	8.50	8.62		8.22	8.49	8.27
	SD	0.06	0.08		0.52	0.08	0.13
6	1	8.74	8.36	8.39	8.14	8.34	8.52
	2	8.65	8.44	8.47	8.18	8.52	8.66
	3	8.64	8.44	8.43	8.18	8.23	8.60
	$\bar{x}$	8.68	8.41	8.43	8.17	8.36	8.59
	SD	0.06	0.05	0.04	0.02	0.15	0.07
7	1	8.65	8.76	8.64	8.13	8.30	8.49
	2	8.64	8.59	8.64	8.11	8.53	8.40
	3	8.67	8.40	8.58	8.18	8.49	8.37
	$\bar{x}$	8.65	8.58	8.62	8.14	8.44	8.42
	SD	0.02	0.18	0.03	0.04	0.12	0.06

TABLE 73. (Continued)

Station	Replicate	MID-1 (5/84)	MID-2 (8/84)	MID-3 (11/84)	MID-4 (5/85)	MID-5 (8/85)	MID-6 (11/85)
8	1	8.65	8.56	8.60			
	2	8.57	8.60	8.57			
	3	8.84	8.60	8.54	**	**	**
	$\bar{x}$	8.69	8.59	8.57			
	SD	0.14	0.02	0.03			
9	1	8.59	8.62	8.58	8.59	8.49	8.30
	2	8.75	8.53	8.49	8.83	8.54	8.44
	3	8.72	8.58	9.55	8.65	8.58	8.42
	$\bar{x}$	8.69	8.58	8.87	8.69	8.54	8.39
	SD	0.08	0.04	0.59	0.12	0.04	0.08
10	1	8.68	8.34	*	8.58	8.37	8.27
	2	8.54	8.33	*	8.52	8.47	8.08
	3	8.68	8.36	*	8.59	8.48	8.27
	$\bar{x}$	8.63	8.34		8.56	8.44	8.21
	SD	0.08	0.02		0.04	0.06	0.11
11	1	8.64	8.38	8.35	8.12	8.44	8.39
	2	8.55	8.47	8.34	8.34	8.39	8.37
	3	8.40	8.45	8.21	9.26	8.42	8.35
	$\bar{x}$	8.53	8.43	8.30	8.57	8.48	8.37
	SD	0.12	0.04	0.08	0.60	0.09	0.02
12	1	8.86	8.67	8.56	8.55	8.43	8.56
	2	8.77	8.72	8.68	8.60	8.36	8.37
	3	8.79	8.71	8.61	8.62	8.40	8.63
	$\bar{x}$	8.81	8.70	8.62	8.59	8.40	8.52
	SD	0.05	0.03	0.06	0.04	0.04	0.13
13	1	8.76	8.41	8.60	8.25	8.36	8.73
	2	8.80	8.51	8.58	8.24	8.39	8.35
	3	8.65	8.47	8.60	8.28	8.46	8.40
	$\bar{x}$	8.74	8.46	8.59	8.26	8.40	8.49
	SD	0.08	0.05	0.01	0.02	0.05	0.21
14	1	8.68			8.57	8.32	8.65
	2	8.53	**	**	8.57	8.49	8.42
	3	8.54			8.58	8.49	8.44
	$\bar{x}$	8.58			8.57	8.43	8.50
	SD	0.08			0.06	0.10	0.13

*No data.
**No samples collected.

TABLE 74. NEAR-BOTTOM TEMPERATURE AND SALINITY MEASUREMENTS TAKEN AT U.S. MID-ATLANTIC STATIONS DURING CRUISE MID-2.

Station	Hydrocast/CTD Depth (m)	Hydrocast Temp (°C)	CTD Temp (°C)	Hydrocast Salinity (o/oo)	CTD Salinity (o/oo)
1	2161*	3.29	3.28	34.96	34.94
2	1915	3.48	3.64	34.98	34.94
3	1967	3.47	3.56	34.97	34.96
4	2015	3.38	3.45	35.00	34.96
5	2038	3.28	3.46	34.96	34.96
6	1990	3.36	3.60	34.97	34.96
7	2002	3.47	3.63	34.97	34.94
8	2075	3.16	3.53	34.99	34.93
9	2011	3.44	3.52	34.96	34.93
10	1992	3.36	3.41	34.96	34.93
11	1435	3.97	3.98	35.04	34.94
12	2391	2.85	2.98	34.95	34.90
13	1591	3.43	3.90	34.97	34.95

*Depth derived from CTD rather than reversing thermometers.

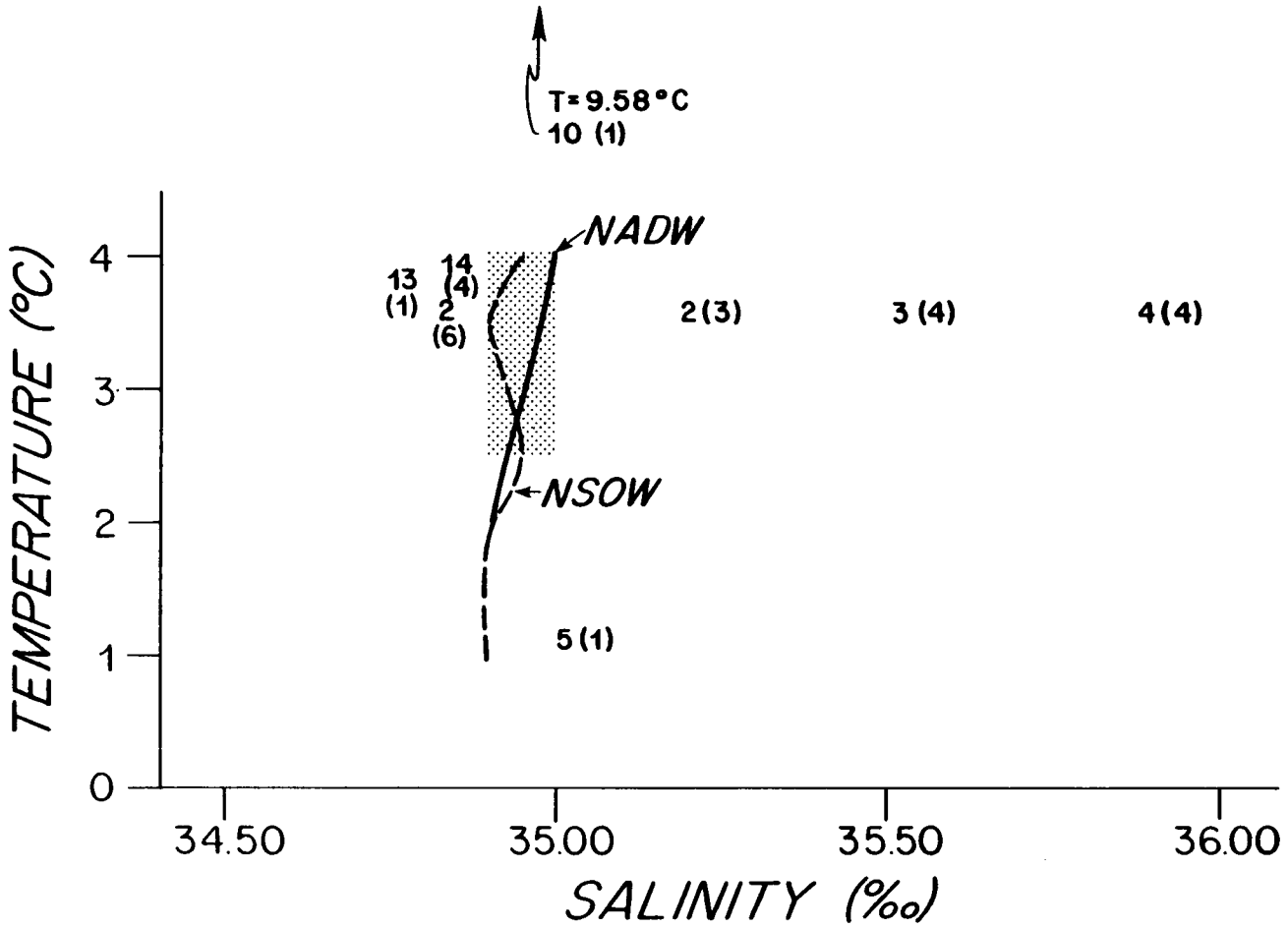

Figure 82. Temperature vs. Salinity of Near-Bottom Waters of Stations 1 Through 14. Hatched Area Shows Range of 64 T-S Measurements. Others Are Designated by Station (Cruise), e.g., 2(3) = Station 2, Cruise Mid-3. Average T-S Curves for Norwegian Sea Overflow Water (NSOW) and North Atlantic Deep Water (NADW) Redrawn from Emery and Uchupi (1972, Figure 241, p. 288) for Comparison.

DISCUSSION

It is not possible to fully characterize the U.S. Mid-Atlantic slope and rise water with the few data available. Hydrographic data were not collected at every station on every cruise because of inclement weather or other obstacles encountered in field sampling. The temperature data were even more scattered than those for the other two parameters because of the vulnerability of the thermometers to physical damage.

Temperature and salinity recorded for the near-bottom waters gave strong evidence that these waters were mixtures to varying degrees of Norwegian Sea Overflow Water (NSOW) and North Atlantic Deep Water (NADW). Both of these water masses are important components of the Western Boundary Undercurrent, which flows in a southwesterly direction along the lower slope and continental rise of the eastern North American margin (Volkmann, 1962; Emery and Uchupi, 1972). The influence of this circulation system was reflected in the average flow speeds of 3 cm/sec to the SSW that were recorded by current meters moored 100 m above bottom in the vicinity of Block 372 drill site during the summer of 1984 (Scientific Applications International Corporation, pers. comm.). The only notable changes over time were the relatively lower temperatures observed at northeasternmost Stations 1 through 5 in May 1985 (Cruise Mid-4); these observations may reflect an incursion of deeper, cooler water at these sites.

Values of dissolved oxygen concentrations reported here were uniformly higher than those typically observed for western North Atlantic deep water masses. However, Emery and Uchupi (1972), summarizing the work of Worthington and Wright (1970), showed tongues of water of high oxygen content associated with NSOW along the eastern North American slope.

Outlier values reported above, not readily assigned to known water masses, are suspect (Tables 71-74, Figure 82). For example, anomalous values of both salinity and dissolved oxygen concentration at Station 2 on Cruise Mid-3 suggest contamination with highly variable slope water. Mechanical failure of the reversing thermometers was the prevalent reason for any outlying temperature values.

CHAPTER 10. DISCUSSION OF BIOLOGICAL PROCESSES ON THE U.S. MID-ATLANTIC CONTINENTAL SLOPE AND RISE

The design of the present study allowed an examination of both temporal and spatial changes in the benthic fauna of the U.S. Mid-Atlantic continental slope and rise. Sampling at the majority of stations was carried out six times over a two-year period, and data on benthic infauna, sediment texture, and geochemistry were developed for three replicate samples at each station. Phototransects for the characterization of epifauna were occupied during three of the six cruises. A study of the recolonization of defaunated sediments was also carried out and measurements of ash-free dry weight biomass were made for six samples. The data have yielded a number of interesting insights into the structure of benthic infaunal and epifaunal communities on the U.S. Mid-Atlantic slope and rise, as well as providing an evaluation of the potential impacts due to oil and gas exploratory operations in deep water.

PHYSICAL SETTING

Physical Oceanography

The study area lies within the western part of a distinct area termed "slope water" by Iselin (1936) and the "Slope Sea" by recent authors (Csanady and Hamilton, 1987; Science Applications International Corporation (SAIC), 1987). Although the Slope Sea and the Gulf Stream have been studied since the 1930s (Rossby, 1936), it is only recently that a synthesis of the circulation has been made and some of the supposed features confirmed (Csanady and Hamilton, 1987; SAIC, 1987).

The most recent study of the physical oceanography in the study area was the Mid-Atlantic Slope and Rise (MASAR) Physical Oceanography Study performed by SAIC for the Department of the Interior, Minerals Management Service (SAIC, 1987). The underlying circulation of the Slope Sea, as described below, has been derived from historical hydrographic data and supported by data from the MASAR study (SAIC, 1987; Csanady and Hamilton, 1987).

The Gulf Stream, part of the western boundary current system of the North Atlantic Ocean, has a profound influence on the circulation over this area. The Gulf Stream leaves the continental margin near Cape Hatteras, and flows into progressively deeper water. Between Cape Hatteras and the New England Seamount Chain, it is generally a well-defined jet that separates the Sargasso Sea on the south from the slope water mass on the north. Clockwise-rotating gyres, called warm-core rings, may pinch off from the Gulf Stream and move northward, bringing parcels of warmer, more saline water into the slope area. An average of five to eight warm-core rings may pass through the western Slope Sea annually (Fitzgerald and Chamberlin, 1983; Brown et al., 1986). The Gulf Stream itself may occasionally be displaced northward from its normal position (SAIC, 1987).

A western gyre, variable in size and strength depending on the configuration of the Gulf Stream, the strength of the inflow from the Labrador Sea, and the strength of the large-scale wind forcing, is present about 85 percent of the time (SAIC, 1987). The evidence for this gyre and its variability is largely empirical, and the detailed dynamics are not well established. Large perturbations such as warm-core rings and upper-slope eddies are essentially superimposed on this basic circulation pattern.

Earlier studies of patterns of water movement in the area indicate a general drift to the southwest, but due to strong density fronts, wind regimes, and seasonal temperature fluctuations in near-surface waters, currents often were seen to vary by an order of magnitude (Ingham et al., 1977; Bisagni, 1981; Flagg et al., 1982; NOAA, 1983). With the aid of radio-direction-finding buoy measurements, Bisagni (1981) identified two major currents, both presumably wind-driven. A slow (less than 26 cm/s) southwest drift from the 106-Mile Deepwater Disposal Site was measured in near-surface water. Warm-core rings result in a strong northeasterly component. In the MASAR study, two lines of moored current meters were deployed for a two-year period. The nearshore current meters observed a relatively weak (10 cm/s) mean flow to the southwest; whereas at the farthest mooring offshore, current meters at 200 m below the surface recorded either Gulf Stream velocities (100 cm/s to the east) or light-variable flow with only a very weak southwestward component.

Currents measured at 100 m off the bottom at depths of 1000 to 2000 m were consistently to the southwest at speeds of approximately 2 to 8 cm/sec (SAIC, 1987). When both historical and MASAR data are considered together, there is a suggestion that

currents are marginally slower at 1000 m than at 2000 m (see Figure 4.5-2 in SAIC, 1987), although this distinction was not made by SAIC (1987). This flow is part of the Western Boundary Undercurrent (WBUC), which is formed by the sinking of cold Arctic water in the region of the Denmark Strait and has been traced as far south as 27°N. Bottom currents on the continental rise are somewhat stronger than at 2000 m depth. Strong fluctuating currents (20 to 60 cm/s) due to planetary wave motions thought to be generated by the meandering Gulf Stream also may be found near the bottom. These waves are known as Topographic Rossby Waves (TRWs) and are characterized by fluctuating currents that increase in magnitude from about 1000 m depth towards the ocean floor (Rhines, 1971; Luyten, 1977; Hamilton, 1984).

Geology and Chemistry of Sediments

The U.S. Mid-Atlantic continental slope is a steep, narrow area paralleling the shelf and extending from the shelf break to depths of about 2000 m. The slope encompasses roughly the eastern third of the Baltimore Canyon Trough, a deep structural basin. The upper slope has gradients ranging from about 30 m/km to 240 m/km and is highly dissected by canyons and valleys. Twichell and Roberts (1982) demonstrated that the spacing of the canyons correlates well with the general gradient of the slope: canyons are spaced 1.5 to 4 km apart where the gradient is greater than 6° (e.g., between Lindenkohl and Wilmington Canyons), they are 2 to 10 km apart where the gradient is between 3 and 5° (e.g., between Lindenkohl and Mey Canyons), and absent where the gradient is less than 3°. Canyons are generally V-shaped in cross section, and are continuous from their heads to the base of the slope, where some stop but others continue as channels onto the continental rise.

Submarine canyons may originate in one of two ways: (1) as a result of riverine erosional processes during glacial periods when the sea level was much lower, or (2) as a result of mass wasting of shelf-edge sediments. With the possible exception of Block, Hudson, and Wilmington Canyons, the canyons in the U.S. Mid-Atlantic region appear to have formed as a result of the second, rather than the first, process. Long-range sidescan sonar data have demonstrated that the morphology of the canyons is much more complex, especially on the upper and mid-slope, than previously indicated by traditional

bathymetric mapping or shallow seismic investigations. Twichell et al. (1980) found many previously unknown canyons, some with secondary gullies, in the region between Hudson and Baltimore Canyons. McGregor et al. (1982) used midrange sidescan sonar to elucidate gullies and small channels that feed into some of the canyons on the slope, such as South Wilmington and North Heyes Canyons. Detailed surveys by Robb et al. (1981, 1983) also revealed a complex pattern of canyons, valleys, and sidewall gullies in the area between Lindenkohl and South Toms Canyon.

The most common types of mass sediment movements observed in the Mid-Atlantic region include slumps, slides, and debris flows. Large features of these types appear to be more common near the major canyon systems than near the smaller canyons. The timing of these movements is not clear; many of them probably represent events now inactive. Robb et al. (1983) concluded that large mass movements of sediments are not common on the upper slope between Lindenkohl and South Toms Canyons. However, small-scale slumps and slides do occur within those canyons and canyon systems. A large mass movement feature south of Hudson Canyon and some smaller features near Wilmington and Baltimore Canyons were noted by Keer and Cardinell (1981). Debris flow deposits are often associated with such sediment movements and may be found on the upper rise of the Mid-Atlantic region.

The middle and lower continental rise are generally smooth and geologically more uniform than the upper rise. These areas are beyond the influence of mass wasting found near the base of the continental slope and instead are shaped by the downslope flow of turbidity currents and the along-isobath flow of bottom currents such as the Western Boundary Undercurrent (WBUC) (e.g., Heezen et al., 1966; Heezen, 1975). Currents that follow contours are probably responsible for smoothing the channels and levees developed by the turbidity currents (Tucholke, 1987).

Detailed patterns of sediment accumulation are poorly known for the continental slope. Average sedimentation rates in the region range from 0.07 (McGregor et al., 1984) to 0.22 mm/yr (Doyle et al., 1979). Accumulation rates on the upper continental rise may be similar, but probably decrease with increasing water depth.

Most of the continental shelf is covered with sands and patches of gravel mixed with sand (Milliman et al., 1972). Fine-grained materials tend to be winnowed out and moved either shoreward into estuaries or off the shelf and into canyons on the continental slope.

North of Cape Hatteras, the sediments of the continental slope are mainly silty clays or clayey silts with local sandy patches. Most of the sand in this region is biogenic in origin, although patches of terrigenous sand occur in the axes of some canyons (Hathaway, 1971; Keller et al., 1973). On the continental rise, surface sediments are almost invariably silty clays and clayey silts. Mean grain size probably is slightly greater near major channels crossing the rise (Bennett et al., 1980).

The majority of stations in the present program were between 2020 and 2195 m water depth; three stations were at 1500 to 1613 m depth and one station was at 2505 m. Sediments were dominated by silts and clays, and were generally similar at the majority of stations. However, nearly 50 percent of the sediment at the 2500-m station was sand, which was composed of foraminiferal tests. Both McGregor et al. (1984), in summarizing a wide variety of observations, and Stanley at al. (1986), in reporting petrologic and foraminiferal evidence, concluded that canyons on the slope of the Mid-Atlantic Bight serve as conduits for periodic transport of quartzose sands and shallow-water foraminiferal tests derived from the upper slope and shelf. The range of sediment textures found at the other stations probably reflects placement of stations in different depositional environments with respect to sediment transport in and around canyons.

The concentrations of 12 metals (aluminum, barium, cadmium, chromium, copper, iron, mercury, manganese, nickel, lead, vanadium, and zinc) in sediments were measured six times over a two-year period at the same stations sampled for the present study (Bothner et al., 1987). Mean values for each of the metals were the same or lower than values reported for average shales from various locations around the world (Krauskopf, 1967). The variation in concentrations measured by Bothner et al. was small, generally within a factor of 2 over the entire study area. Metal concentrations were shown to be highly correlated with sediment texture: fine sediments with a high percentage of silt and/or clay had the highest metal concentrations.

Samples from 4 of the 14 stations were split into 2-cm intervals in order to examine change in metal concentration with depth in the sediment (Bothner et al., 1987). The concentrations of lead and manganese were consistently higher in the upper few centimeters than deeper in the sediment. The upper 5 to 10 cm typically contained as much as 2 to 3 times more lead than did sediments 25 to 30 cm below the sediment-water interface. The highest values measured in these cores was 31 ppm at about 4 cm depth;

this value is slightly higher than the 20-ppm world-average value for shales reported by Krauskopf (1967). Enrichment of lead in surficial sediments may be related to an increased use of leaded gasolines in coastal metropolitan areas; however, the origin of this lead is not known for certain. The penetration of lead to a depth of 10 cm is probably related to biological reworking of the sediments.

Levels of total hydrocarbons in the sediments were measured during the present study. Samples were fractionated to isolate saturated and aromatic hydrocarbons, and individual compounds were also quantified. Total hydrocarbon concentrations ranged between 2.9 and 52.9 µg/g (parts per million) dry weight, with roughly comparable contributions from saturated and aromatic hydrocarbons at most stations. The highest concentrations were found at the mid-slope Station 13, but elevated concentrations also occurred at Stations 2, 10, 12. Total concentrations of polyaromatic hydrocarbons (PAH) ranged between 66 and 1157 ng/g (parts per billion) dry weight, and, in general, paralleled the total hydrocarbons concentrations, with the lowest values found at the sandy Stations 10 and 12 and the highest values corresponding to mid-slope Stations 11, 13, and 14. These concentrations appear similar to, but higher than, values found in earlier studies in the same geographic area (Farrington and Tripp, 1977; Smith et al., 1979) and are also higher than concentrations found in sediments in similar depth regimes in the U.S. North Atlantic (Maciolek et al., 1987).

BIOLOGICAL PROCESSES

Infaunal

The characteristics of the infaunal benthos of the continental slope and rise were virtually unknown until the mid-1960s, when methods to study the small macrofauna living in the sediments were developed. Hessler and Sanders (1967) and Sanders (1968) found a high diversity of species in each 1- to 2-km swath (0.81-m trawl width) sampled on a transect between Gay Head, Massachusetts, and Bermuda. Numerous taxonomic studies of material collected on the fine-mesh (0.42-mm) screens used by Sanders and Hessler have confirmed the initial reports of high diversity for several portions of the fauna (e.g., polychaetes: Hartman, 1965; Hartman and Fauchald, 1971; Maciolek, 1981, 1985, 1987;

isopods: Hessler, 1967, 1968, 1970a, 1970b; Wilson and Hessler, 1974, 1980, 1981; Thistle and Hessler, 1976, 1977; Wilson, 1976, 1980a, 1980b, 1981; Siebenaller and Hessler, 1977, 1981; Thistle, 1980; Kensley, 1982; bivalves: Allen and Sanders, 1966, 1969, 1973; Sanders and Allen, 1973, 1977; Allen and Turner, 1974; Allen and Morgan, 1981). Prior to the present series of studies on the U.S. Atlantic continental slope and rise, however, macrofaunal species had been completely analyzed from fewer than 100 quantitative samples and, of these, most are from depths ≯5000 m in the extremely depauperate mid-Pacific gyre. This lack of quantitative samples from which all of the infauna has been identified has led at least one author (Nybakken, 1982) to argue that despite the evidence from qualitative samples, without data on the actual density of species "the idea of a highly diverse deep-sea fauna must remain speculative."

In the present study, a total of 233 box cores taken at 14 stations over a two-year period were fully analyzed for infauna, thus providing an extensive quantitative database on which statements about faunal composition and diversity can be based. Stations were placed at depths ranging from 1515 to 2500 m, with the majority of stations placed along a 176-km transect at depths between 2020 and 2195 m. A total of 862 species representing 16 phyla were identified from the box core samples. Of these, 489 species (56.7 percent) are undescribed. The largest percentage of new species recorded in major phyla were arthropods: 139 species (68 percent) are new to science. Sixty-four percent (236 species) of the polychaetes are undescribed. Within several polychaete families that have a high number of species, such as the Dorvilleidae, Cirratulidae, Spionidae, Flabelligeridae, and Terebellidae, the percentage of new species ranged from 75 to 93 percent. Five new species of oligochaetes were also found out of the 18 species recorded. Forty-two species, or 36.5 percent, of the molluscs are new to science. Additional undescribed species were found in the phyla Porifera (4), Cnidaria (22), Nemertea (23), Echiurida (4), Bryozoa (3), Brachiopoda (2), Echinodermata (5), and Hemichordata (4). In many cases, these new species represent 100 percent of the species recorded in the particular phylum.

In the companion programs to this study, Blake et al. (1987) reported 1202 species identified from 76 box cores taken on the U.S. South Atlantic slope and rise, and Maciolek et al. (1987) reported 1019 species identified from 193 samples taken on the U.S. North Atlantic slope and rise. In both studies, the percentage of new or undescribed taxa was

similar to that reported for the Mid-Atlantic study area. The recognition that approximately half of the species collected are undescribed is important when comparing results of diversity and species composition with results of any other study of deep-sea benthos. The correct identification of the taxa composing the benthic communities is made substantially more difficult when the species are not documented in the published literature. A lower level of recognition of separate taxa would result in lower estimates of diversity.

The phylogenetic composition of infaunal communities in the Mid-Atlantic study area is generally similar to that reported for other continental slope and rise depths (Blake et al., 1987; Maciolek et al., 1987) and also to the majority of continental shelf communities (Maciolek-Blake, et al., 1985b). Annelids accounted for nearly 45 percent of all species recorded and were represented in the present study by 367 species of polychaetes in 46 families and 18 species of oligochaetes. The Spionidae, Ampharetidae, Paraonidae, Cirratulidae, and Dorvilleidae were the best-represented polychaete families, with 33, 27, 24, 24, and 23 species, respectively. These same families were also important in the benthic communities on both the U.S. South and North Atlantic slope, although the polychaete family Phyllodocidae, with 26 species, was also dominant in the South Atlantic samples.

The phylum Arthropoda was an important component of the fauna, and accounted for 23.4 percent of all species recorded. The orders Isopods, Amphipoda, Tanadaicea, and Cumacea were the dominant arthropod groups. Approximately 13.3 percent of the species were molluscs, including bivalves, gastropods, aplacophorans, and scaphopods. The remaining phyla were relatively less common, and included groups that are typical of deep sea (rather than coastal or shelf) fauna, such as sipunculans and pogonophorans.

The majority of dominant species at any depth interval were polychaetes, which comprised a total of 11 to 13 of the top 20 species. The spionid polychaete Aurospio dibranchiata was the top dominant at the 11 stations deeper than 2020 m. This species was also dominant in the U.S. North Atlantic samples from similar depths, but was replaced by another small polychaete, Microrbinia linea, south of Cape Lookout (Maciolek et al., 1987; Blake et al., 1987). At the shallower (1500-1600 m) stations, the communities were dominated by the sipunculan Aspidosiphon zinni and the aplacophoran mollusc Prochaetoderma yongei. These same species also dominated mid-slope communities in the

U.S. North Atlantic study area (Maciolek et al. 1987), and were found in the U.S. South Atlantic study area as far south as Cape Lookout (Blake et al., 1987). The dominance of these large burrowing forms in mid-slope depths may be related to marginally slower water currents, which may result in a greater deposition of organic material to support these organisms than is seen in areas with faster currents.

The actual percent contribution of individual species to each station varied very little among stations. For example, abundances of the most common species, A. dibranchiata, ranged from 6 to 8 percent of the total individuals at all ten 2100-m stations, and the successively less common species had abundances of 2-7 percent, 3-5 percent, 2-5 percent, 2-3 percent, 1-4 percent, 2-4 percent, and 2-3 percent, respectively. The ninth and tenth most common species accounted for an average of 2 percent of individuals at every station. In disturbed deep-sea environments, the most abundant species may represent more than half the individuals. For example, Thistle et al. (1985) found that the polychaete Paedampharete acutiseries made up 50-64 percent of the fauna in an area where the currents may be 20-25 cm/s for periods of several days. Smith et al. (1986) reported abundances of 67 percent of the polychaete Levinsenia oculata in background samples in an area characterized by dense concentrations of megafaunal mounds. Artificial mounds also produced similar proportions of the same species after 50 days. Grassle and Morse-Porteous (in press) found that the polychaete Ophryotrocha sp. A comprised 38 percent of the individuals in cores dominated by decomposing Sargassum weed from a depth of 3600 m off New England. Another member of the same genus, O. akessoni, accounted for more than 90 percent of the individuals in sediments affected by hydrothermal venting (Grassle et al., 1985).

Species diversity was evaluated by several methods, including Hurlbert rarefaction, species accumulation over increasing area, and Shannon-Wiener diversity. As a group, the shallower (1500 to 1600 m) stations were more diverse than the deeper stations. A similar result was obtained in the U.S. North Atlantic study area (Maciolek et al., 1987) where the mid-slope stations at 1220 to 1350 m exhibited higher diversities than either shallower (250 to 550 m) or deeper (2100 m) stations. The expected number of species per 1000 individuals at the mid-slope Mid-Atlantic stations ranged from 176 to 184; whereas at the remaining Mid-Atlantic stations the same parameter ranged from 144 to 171 species per 1000 individuals. Exceptions to this pattern were seen in the U.S. South Atlantic, where

stations at 600, 2000, and 3000 m exhibited very high diversities (Blake et al., 1987). However, the highest diversity recorded in the entire U.S. Atlantic slope and rise program was at a station at 800 m off Charleston, SC, where the expected number of species per 1000 individuals was 223 (Blake et al., 1987). These results do not agree with the conclusions reached by Rex (1983), who reviewed patterns of diversity for several major faunal groups. In Rex's review, he reported that diversities increased with depth to a maximum at about 2000 to 3000 m. However, most of the data that Rex used were based on qualitative epibenthic sled samples; whereas the present results are based on detailed quantitative date.

Biomass measurements were made for three samples collected from each of two stations, the northernmost Station 6 and the southernmost Station 10. Total wet weight, dry weight, and ash-free dry weight (AFDW) at Station 10 were approximately 5, 6, and 2 times higher, respectively, than the same parameters at Station 6. There was a great deal of variability among replicates: at Station 6, for example, AFDW ranged between 0.133 and 0.188 g/m^2; whereas the range at Station 10 was between 0.168 and 0.779 g/m^2. Similar variability was also observed in samples analyzed from the U.S. South and North Atlantic study areas (Blake et al., 1987; Maciolek et al., 1987). High variability of biomass among samples is not restricted to slope and rise environments, but has also been observed on continental shelf areas such as Georges Bank (Maurer and Wigley, 1984; Brown, 1985). This high variability results from the presence of a few large, heavy-bodied animals, usually molluscs or echinoderms, in one of the replicates.

The data developed for the Mid-Atlantic stations are directly comparable with values generated for stations at similar depths in both the U.S. South and North Atlantic study areas. The Mid-Atlantic biomass values appear to be most similar to values from the two South Atlantic stations; whereas mean values from the two North Atlantic stations are an order of magnitude higher than mean values from the other four stations sampled. These measurements represent the first measurements of AFDW for continental slope environments. Other investigators have reported only wet weight or dry weight (e.g., Khripounoff et al., 1980; Rowe, 1983; Dinet et al., 1985). The wet weight and dry weight measurements developed for the present samples are generally comparable to, although higher than, those made by other investigators, despite some differences in sample collection and processing methods.

The results of the present study indicate that the species composition and abundance of benthic infauna is remarkably homogeneous at depths of 2020 to 2195 m along the 176-km long transect sampled. This high similarity along depth contours was also seen in the U.S. North Atlantic samples (Maciolek et al., 1987) but is in sharp contrast to the remarkable heterogeneity reported by Blake et al. (1987) for the slope and rise south of Cape Hatteras. In the Mid-Atlantic study area, the mean NESS similarity (m = 50) of adjacent pairs of stations is 0.83 + .05 (95 percent confidence limits) for the six northernmost stations (Stations 1-6), and 0.79 + .05 between the most distant stations (Stations 6 and 10). The NESS similarities (m = 200) for all samples from the ten 2100-m stations were greater than 0.85 when a cluster analysis using a group average sorting was performed.

Because these similarities were so high, the entire fauna was considered to represent a single community and allowed calculation of species accumulation and rarefaction curves based on 125 of the samples from the 2020- to 2195-m depth interval. This calculation indicated an extremely diverse fauna with many more species to be added with additional sampling. The curve did not reach an asymptote, but continues to climb, adding on the order of 30 species for every 10,000 individuals added (see Figure 4). The five qualitative trawl samples for which all of the fauna has been analyzed (Hessler and Sanders, 1967) had 185-364 species for 4000 to 25,000 individuals. These samples fall well below the diversity curves for the present samples, in part because the epibenthic sled used by Hessler and Sanders captured only the surface fauna, and in part because there have been major developments in systematics of deep-sea invertebrates in the intervening 20 years. Shallow-water communities outside of tropical areas have relatively few species. The best-studied communities are from intertidal areas or coastal embayments where the number of species per number of individuals collected reaches an asymptote at less than 100 species (e.g., Hessler and Sanders, 1967). Communities on the continental shelf are more diverse than communities in shallow-water embayments, but 70 samples taken from a station at 80-m water depth on Georges Bank indicated that an asymptote was reached at about 200 species (Maciolek-Blake et al., 1985b).

The characterization of diversity in any area is a difficult problem because results depend heavily on the numbers and kinds of samples. For species-area and species-individual relationships, the spacing of samples must be considered. This is particularly

true where regional diversity and measurement of the total species pool are of prime interest. Because deep-sea communities have been demonstrated not to have sharp boundaries (Grassle et al., 1979; Jumars and Eckman, 1983; this study), any sampling plan represents a compromise betyween local and regional coverage.

Local diversity measurements are important because this is the spatial scale on which interactions among species take place. However, local species diversity is heavily influenced by the total species pool and the rate of species recruitment to each area. Few barriers to dispersal exist in the deep sea, so that geographically widespread, open populations contribute heavily to local diversity. Local processes that maintain local species richness are important, but cannot be considered in isolation from processes operating on a regional scale (Ricklefs, 1987).

Results of the recolonization experiments indicate that recruitment to defaunated sediments may be very similar between stations over the same time period, but may be very different at the same station between years. For example, the polychaete Paramphinome jeffreysii was common in 1984 and absent in 1985. This species is much less abundant at 2100 m (where the experimental trays were placed) than at 1500 m, implying that successful recruitment may depend on transport of larvae down-slope by currents. Small differences in sediment texture, with concomitant differences in organic content, may also result in different numbers of opportunistic species being recruited. Spionid polychaetes and Capitella-like species were both much more common in 1984 than in 1985. Because these groups favor organic-rich sediments, the differences in abundance might be explained by small differences in the sediments used in the trays in subsequent years. However, the results of the present study confirm previous results in other areas (Grassle, 1977; Desbruyeres et al., 1985), namely, that larval colonization rates are generally slow in the deep sea.

The patch dynamics of resources and disturbance, as well as interactions among species, maintain the number and relative proportion of deep-sea species (Grassle and Morse-Porteous, in press). Bottom mounds (Jumars, 1976; Smith et al., 1986), vacant burrows (Aller and Aller, 1986), activities of scavengers (Smith, 1986), input of wood (Turner, 1973; 1977), and sunken patches of seaweed or salp blooms that have accumulated in topographic depressions (Grassle and Morse-Porteous, in press) are all important sources of heterogeneity, either through disturbance of existing populations or input of

patchy and ephemeral resources, or both. Although their effects have not been clearly demonstrated in the deep sea, stalks of sessile animals protruding above the sediment, abandoned shells, the presence and activities of megafaunal animals, and the potential hosts of symbionts and parasites are other sources of habitat heterogeneity (Grassle and Sanders, 1973).

Epifauna

Previous studies of the megafauna of the continental slope have included both observations from manned submersibles (e.g., Grassle et al., 1975) and data based on photographs (e.g., Rowe and Menzies, 1969; Haedrich et al., 1980; Hecker et al., 1983). The megafauna is generally too sparsely distributed to be adequately sampled by grabs or box cores. 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 megafaunal abundances (Barham et al., 1967). Uzmann et al. (1977) found that densities obtained from photographic techniques underestimated benthopelagic species in comparison to densities obtained from trawls. Burrowing organisms tend to be underestimated by both trawls and photography. In the present study, a towed camera sled system designed specifically to obtain continuous coverage of long transects along the ocean floor was used. Depths photographed ranged from 1756 to 2353 m and included two transects: one transect extended 44 km along the 2100-m isobath, and a second, circular 17.3-km-long transect that surveyed areas both upslope and downslope of the drill site at 2195 m.

The present analyses of epifaunal distributions and abundances suggest that the trends seen in trophic structure and species composition are related to a combination of depth and topography. These trends reflect shifts in the relative abundances of the five most common species found in the study area: the ophiuroid Ophiomusium lymani, an unnamed cerianthid anemone, the soft coral Acanella arbuscula, the urchin Echinus affinis, and the sea pen Kophobelemnon stelliferum. The distribution of each of these species appears to be controlled by slightly different environmental parameters, with species overlapping in some areas but not in others.

The brittle star O. lymani was the most abundant species encountered in this survey. This observation agrees with results of previous studies along the U.S. Atlantic slope and rise, in which this species has been recorded as a dominant megafaunal constituent of the lower slope assemblage (Rowe and Menzies, 1969; Haedrich et al., 1980; Hecker et al., 1983; Blake et al., 1987; Maciolek et al., 1987). This nonselective deposit feeder was present in highest abundances between 1800 and 1900 m, and occurred in higher densities on the tops and upper flanks of ridges than on lower slope or in valleys.

Carnivores and scavengers accounted for less than 3 percent of the fauna seen. Of the five most common species, three are filter feeders (cerianthid anemone, K. stelliferum, A. arbuscula) and two are deposit feeders (O. lymani and E. affinis). In general, filter feeders were slightly more abundant than deposit feeders. Deviations from this trend occurred in flat regions where filter feeders completely dominated the fauna, and in steep regions where deposit feeders accounted for more than half the species. Observed shifts in dominant trophic types reflect the differing depth and topography optima of the five most common species.

These shifts in trophic type, and the underlying changes in the fauna, may result from the interaction of bottom topography and currents, which can affect nutrient input. As a result of the along-slope flow of the WBUC, tops of ridges and flatter areas may experience higher current velocities and concomitantly greater suspended particulate matter than would deeply incised valleys. Higher numbers of filter feeders would therefore be supported in such areas. Conversely, decreased flow rates over topographic lows could result in the settling of suspended particles, therefore providing increased food supplies for deposit feeders. This situation could explain the high densities of E. affinis observed in valleys.

CHAPTER 11. IMPACTS OF DRILLING

The major objective of this program was to determine the impacts, if any, of exploratory drilling operations, in particular, the discharge of drilling muds and drill cuttings, on the benthic fauna of the U.S. Mid-Atlantic slope and rise. Two exploratory wells had been drilled in Blocks 586 and 587, approximately 60 km southwest of Block 372, before the start of the monitoring program. Drilling started in Block 372 in 2120 m of water on May 26, 1984, and the monitoring effort was centered around that site. The well was plugged and abandoned on July 9, 1984, having been completed to a depth of 4679 ft (1426 m) below the mud line. The drill ship, Discoverer Seven Seas, then moved to Block 93 in 1528 m of water and began drilling there on July 12, 1984. Drilling in Block 93 continued to a depth of 12,727 ft (3879 m) below the mud line. The well was plugged and abandoned on November 4, 1984. In the series of six cruises, one pre-drilling and five post-drilling sample sets were collected at Block 372. One pre-drilling, one during-drilling, and four post-drilling sample sets were collected at Station 13 in Block 93, and one pre-drilling and three post-drilling sample sets were collected at Station 14.

PHYSICAL IMPACTS

A total of 4144 barrels (668,843 L) of drilling mud and 540.84 barrels (85,987 L) of drill cuttings were discharged from the drill ship during drilling of the well in Block 372. The drilling mud inventory for this well contained 511 metric tons (mt) of drilling mud solids, representing nine major drilling mud ingredients. Included were 96.5 mt of barite (18.9 percent of mud solids) and 1.75 mt of chrome lignosulfonate. Probably no more than 50 percent of the total solids in the drilling mud inventory were actually discharged to the ocean. The remainder was either retained on board the ship or left in the hole.

A total of 40,387 barrels (6,421,020 L) of drilling mud and 2506.2 barrels (398,454 L) of drill cuttings were discharged from the drill ship during drilling of the well in Block 93. The drilling mud inventory for this well was not available from the operator, but probably was qualitatively similar to the inventory for the Block 372 well.

Physical evidence of drilling-related activities was minimal in the vicinity of the Block 372 drill site. No cuttings piles were noted in the photographic analysis, although

discarded plastic pipe casings were seen in the post-drilling (Cruise Mid-2) camera tow. One sediment grain-size sample collected at Station 1 on Cruise Mid-2 contained large flakes of a brittle, pale-yellow material that at first was thought to be drill cuttings. Visual inspection of replicates from Stations 2, 3, and 10 revealed the presence of this material at Stations 2 and 3, in addition to Station 1. This material is now believed to be a calcareous claystone derived from recently eroded outcrops of Eocene age.

CHEMICAL IMPACTS

There was little variation in the concentrations of heavy metals in surficial sediments among stations or at any station for the first four sampling cruises, with one exception (Bothner et al., 1987). In one replicate sample from Station 1 on Cruise Mid-3 (November/December 1984), the concentration of barium was as much as 13 percent higher in the top 4 cm than in the deeper core sediments. In one replicate from Cruise Mid-6, the top sediments were 20 percent higher in barium concentration. Barium, because it is usually abundant in drilling muds and is both dense and very insoluble, is frequently used as a tracer of the environmental fate of discharged drilling muds. Bothner et al. (1987) presented several lines of evidence in support of the premise that the elevation in the concentration of barium in sediments at Station 1 after drilling was due to the accumulation of drilling mud solids. However, the increase in barium concentration was small, from a pre-drilling mean of 422 ppm to a concentration of 493 ppm in the one Cruise Mid-3 replicate sample and 555 ppm in one Cruise Mid-6 sample, and these values are within the 580 ppm worldwide average for marine shales (Krauskopf, 1967). The concentrations of barium or other metals in sediments did not increase between pre- and post-drilling surveys at any other station along the two transects through the Block 372 drill site. In addition, there was no change in the concentrations of barium or other metals in surficial sediments at the two stations near the Block 93 drill site, despite the fact that nearly 10 times more drilling mud and cuttings were discharged at Block 93 than at Block 372. The strongest chemical signal from drilling mud was the collection of discrete particles of barite in several sediment traps placed within the upper 850 m of the water column at a mooring 2.8 km southwest of Station 1 (Bothner et al., 1987).

Given the great depth (>2000 m) of the water and the rate of sinking of barite-sized particles, most of the drilling mud solids discharged from the ship were expected to be transported tens of kilometers away before settling on the bottom. However, during drilling of the surface hole (spudding in) and setting of the surface casing, the riser system is not in place and drilling mud is not returned to the ship for recycling down-hole. Instead, the spud mud and drill cuttings are discharged directly to the bottom. Because spud mud may contain up to 50 lb barite per barrel (Ayers et al., 1983), it is possible that the barium that accumulated in surficial sediments at Station 1 was derived from spud mud discharged directly to the bottom. Conversely, the sediment traps deployed by Bothner et al. (1987) were set out for a period of 99 days beginning June 21, 1984. This time period included the last 18 days of the drilling operations at Block 372. Bothner et al. (1987) concluded that large particles of barite fell individually through the water column at speeds predicted by a model based on Stokes Law; the presence of fine-grained barite is more difficult to explain, but presumably these particles could have been transported after incorporation into copepod fecal pellets.

Samples of drilling muds and cuttings were collected from the drill ship during drilling operations at both Block 93 and Block 372. The hydrocarbon composition of these samples was determined and compared to the hydrocarbon composition of the natural sediments. The concentration of total hydrocarbons in the samples of drilling muds and cuttings ranged from 91.9 to 918 ppm as measured gravimetrically. Hydrocarbon concentrations in the surficial sediments ranged from 5.7 to 52.9 ppm as measured gravimetrically. The highest concentrations in sediments occurred at Station 13, but elevated values were also found at Stations 5 and 11. The lowest concentrations of hydrocarbons in sediments were found at Stations 2, 10, and 12. The gas chromatograms of the alkane and aromatic hydrocarbon fractions of the sediment extracts revealed that a majority of the hydrocarbons present were of biogenic or pyrogenic origin and not from petroleum. There were no geographic or temporal trends in sediment concentrations of total hydrocarbons or resolved polycyclic aromatic hydrocarbons (the best markers of petroleum discharges) that could be attributed to drilling discharges.

Samples for heavy metal and hydrocarbon analysis of the brittle star Ophiomusium lymani and the sea urchin Echinus affinis were collected from three stations on Cruise Mid-1, from one station on Cruise Mid-2, and from two stations on Cruise Mid-5. With the

exception of aluminum, iron, and zinc, the elements present in the tissue samples were quite low and approached the detection limits for the methods used. Concentrations of barium, chromium, or other metals did not increase in the tissues of the sea urchins or brittle stars from either Stations 1 or 4 between the pre-drilling and the post-drilling cruises. There was no consistent relationship between the concentration of any metal in sediments from a particular station at a particular sampling time and the concentration of that metal in the tissues of echinoderms residing in that sediment.

Hydrocarbon concentrations in the tissues of these animals ranged between 27.4 and 163.1 µg/g wet weight. The gas chromatograms (GC) of hydrocarbons in the tissue extracts were dominated by high molecular weight saturates of biogenic orgin. There was no clear relationship between the concentration of hydrocarbons in the tissues of the echinoderms and in the sediments in which they resided. There was no evidence of bioaccumulation of either heavy metals or hydrocarbons from discharged drilling mud and cuttings.

BIOLOGICAL IMPACTS

The biological parameters measured in this program were the community structure of the infaunal benthos and the composition of the epifaunal megabenthos. The deep-sea benthic infauna are thought to be very sensitive to burial (Jumars, 1981). Therefore, the accumulation of even a small amount of drilling mud and cuttings solids (a millimeter or so) on the sediment surface might be expected to have a deleterious effect on the fauna. Several measures of diversity were evaluated, including Hurlbert rarefaction and the Shannon-Wiener index. Diversity at all stations was uniformly high over all sampling seasons. It was hypothesized that any sudden, unnatural disturbance of the deep-sea communities would result in a sharp drop in diversity; such a decrease was not seen at any station. The changes in diversity that were seen, e.g., at Station 1, were small and are not considered to be significant. At Station 1, the Shannon diversity values increased from 6.16 on the pre-drilling Cruise Mid-1 to 6.24 on Cruise Mid-6. The Hurlbert rarefaction values decreased from 154 to 150 species per 1000 individuals over the same time period. At Station 14, the Shannon diversity dropped from 6.34 on Cruise Mid-1 to 6.01 on Cruise Mid-6, but the Hurlbert rarefaction values did not change over the same time period.

Based on both the NESS and Bray-Curtis similarity measures, samples collected at Station 1 on the first, pre-drilling, cruise clustered separately from samples collected on the post-drilling cruises. These results may be due to differences in the abundances of certain species over time. For example, the density of the polychaete Tharyx sp. 1 was significantly lower in Cruise Mid-4 (post-drilling) samples than in Cruise Mid-1 (pre-drilling) samples. However, the density of this species was not significantly different from densities recorded at the majority of stations on any particular sampling date. Similarly, the polychaete Aurospio dibranchiata had significantly different densities at Station 14, the drill site station in Block 93, in May 1984 and May 1985. The abundance of this species, which is dominant at the majority of stations along the 2100-m isobath, increased between the two sampling dates, and the change is not considered to be a harmful effect of drilling.

Pre-drilling samples collected at Station 14, the drill site in Block 93, were highly similar to samples collected a year later (Cruise Mid-4). Samples collected on Cruise Mid-6, however, were highly dissimilar to other replicates collected at this station; this dissimilarity was apparent when only the polychaete fauna was evaluated as well as when the total fauna was evaluated. No statistically significant changes in sediment grain-size composition were detected at Station 14; therefore, it is difficult to account for the dissimilarity of this one sample set.

A much larger amount of drilling mud and cutting solids accumulated in surficial sediments near the drilling site in Block 312 in 80 m of water on Georges Bank, as indicated by increases in the concentration of barium in surfical sediments (Bothner et al., 1985b). In that study, as in this one, there were no measurable changes in the benthic infaunal community structure that could be attributed to the drilling discharges (Maciolek-Blake et al., 1985b).

Trays filled with azoic sediment were placed at Stations 2 and 4 in order to determine the rate of recolonization of disturbed sediments. The experiment was designed to determine if there were any differences in recolonization rates between stations near the drill site (Station 2) and up-current of the site (Station 4). After the first six-month period, the faunal recolonization was very similar at both stations, but after one year, significantly greater numbers of individuals had settled at Station 4 in comparison with Station 2. This difference is most likely due to the different percentages

of sand in the sediments in the trays. At Station 2, the percentage of sand in the one-year trays was about six times higher than in the one-year trays from Station 4. There were no differences in levels of trace metals in the tray sediments compared to the range of values obtained at the slope stations where the sediment was originally collected (Bothner et al., 1987).

Transect and classification analysis of data collected from camera-sled tows indicated trends in epifaunal trophic structure and species composition that were related to a combination of depth and topography. With one exception, only minor localized faunal differences between pre- and post-drilling transects were discerned. The one change in epifauna that may have been related to the drilling activity in Block 372 was seen in the valley 2 km downslope of the drill site. This area supported a very high abundance of the sea pen Kophobelemnon stelliferum prior to drilling. Two months after drilling had been completed, very reduced densities of this organism were found in the same area, but 14 months later somewhat higher abundances were found. Because the paths of all three camera-sled tows overlapped in this area, it is possible that the observed decline in the abundance of K. stelliferum during the first post-drilling tow was related to the drilling activity. However, this observed difference may be attributable to another factor unrelated to drilling. Data on sediment texture developed during the present study indicate that a mass movement of sediment occurred between the pre-drilling and first post-drilling cruises in the area upslope of this region. This event may have buried many of the sea pens or clogged their filtering apparatuses, thereby accounting for the observed decrease in their abundance. If the decrease in K. stelliferum in the valley downslope of the drill site was indeed related to drilling activity, it appears to have been relatively short-lived, because higher densities were found 14 months after drilling had been completed. Other faunal changes between the post-drilling tows were minor, and were usually related to slight variations in the paths of the tows. In conclusion, with the possible exception of a small area downslope of the drill site, it does not appear that the exploratory drilling in Block 372 had a significant impact on the epifaunal composition of the surrounding area.

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LITERATURE CITED

Allen, J.A. and R.E. Morgan. 1981. The functional morphology of Atlantic deep water species of the families Cuspidariidae and Poromyidae (Bivalvia): an analysis of the evolution of the septibranch condition. Phil. Trans. Royal Soc. London 294:413-546.

Allen, J.A. and H.L. Sanders. 1966. Adaptations to abyssal life as shown by the bivalve, Abra profundorum (Smith). Deep-Sea Res. 13:1175-1184.

Allen, J.A. and H.L. Sanders. 1969. Nucinella serrei Lamy (Bivalvia:, Protobranchia), a monomyarian solemyid and possible living actinodont. Malacologia 7:381-396.

Allen, J.A. and H.L. Sanders. 1973. Studies on deep-sea Protobranchia. The families Siliculidae and Lametilidae. Bull. Mus. Comp. Zool. Harv. 145:.263-310.

Allen, J.A. and J.F. Turner. 1974. On the functional morphology of the family Verticordiidae (Bivalvia) with descriptions of new species from the abyssal Atlantic. Phil. Trans. R. Soc. London B 268:401-536.

Aller, J.Y. and R.C. Aller. 1986. Evidence for localized enhancement of biological activity associated with tube and burrow structures in deep-sea sediments at the HEBBLE site, western North Atlantic. Deep-Sea Res. 33:755-790.

Ayers, R.C., Jr., T.C. Sauer, Jr., and P.W. Anderson. 1983. The generic mud concept for offshore drilling for NPDES permitting. Proc. IADC/SPE 1983 Drilling Conference, New Orleans, LA. Society of Petroleum Engineers, Dallas, TX. No. 11399, pp. 327-336.

Barham, E.G., N.J. Ayer, and R.E. Boyce. 1967. Macrobenthos of the San Diego Trough: photographic census and observations from bathyscaphe Trieste. Deep-Sea Res. 14:773-784.

Battelle, Woods Hole Oceanographic Institution, and Lamont-Doherty Geological Observatory. 1984. Study of biological processes on the U.S. Mid-Atlantic slope and rise. Cruise Report, MMS Mid-2, R/V GYRE, 31 Jul-9 Aug, 1984. Prepared for U.S. Department of the Interior, Minerals Management Service, Washington, D.C. under Contract No. 14-12-0001-30064. 32 pp. + Appendices 1-3.

Bennett, R.H., G.L. Freeland, D.N. Lambert, W.B. Sawyer, and G.H. Keller. 1980. Geotechnical properties of surficial sediments in a mega-corridor: U.S. Atlantic continental slope, rise, and deep sea basin. Mar. Geol. 38:123-140.

Bieri, R.H., M.K. Cueman, C.L. Smith, and C. Su. 1978. Polynuclear aromatic and polycyclic aliphatic hydrocarbons in sediments from the Atlantic outer continental shelf. Int. J. Environ. Anal. Chem. 5:293-310.

Bisagni, J.J. 1981. Movement of the two drogue buoys deployed at Deepwater Dumpsite 106 tracked by satellite. Coast. Ocean Pollut. Assessm. News 1(2):26.

Blake, J.A., B. Hecker, J.F. Grassle, N. Maciolek-Blake, B. Brown, M. Curran, B. Dade, S. Freitas and R.E. Ruff. 1985. Study of Biological Processes on the U.S. South Atlantic Slope and Rise. Phase 1. Benthic Characterization Study. Final Report. Prepared for U.S. Department of the Interior, Minerals Management Service, Washington, D.C. under Contract No. 14-12-0001-30064. 142 pp. + Appendices 1-4.

Blake, J.A., B. Hecker, J.F. Grassle, B. Brown, M. Wade, P.D. Boehm, E. Baptiste, B. Hilbig, N. Maciolek, R. Petrecca, R.E. Ruff, V. Starczak, and L. Watling. 1987. Study of biological processes on the U.S. South Atlantic slope and rise. Phase 2. Final Report prepared for U.S. Dept. of the Interior, Minerals Management Service, Washington, D.C. 414 pp. + Appendices A-M.

Boehm, P.D. 1983. Estuarine-continental shelf and benthic-water column coupling of organic pollutants in the New York Bight Region. Can. J. Fish. Aquat. Sci. 40(Suppl. 2):262.

Boehm, P.D. 1984. Aspects of saturated hydrocarbon geochemistry of recent sediments in the Georges Bank Region. Org. Geochem. 7:11-23.

Boehm, P.D. and D.L. Fiest. 1982. Subsurface distributions of petroleum from an offshore well blowout. The Ixtoc I blowout, Bay of Campeche. Environmental Sci. and Technol. 16:67-74.

Boehm, P.D., D.L. Fiest, P. Hirtzer, L. Scott, R. Norstrom, and R. Engelhardt. 1982. A biogeochemical assessment of the BIOS experimental spills: Transport pathways and fates of petroleum in benthic animals. In: Proceedings of the Fifth Arctic Marine Oil Spill Program Technical Seminar, Environmental Protection Service, Ottawa, Canada, pp. 581-618

Boehm, P.D., A.D. Wait, D.L. Fiest, and D. Pilson. 1982. Chemical assessment hydrocarbon analyses. In: IXTOC Spill Assessment, P.D. Boehm (ed.), Final Report to Bureau of Land Management, Contract No. AA851-CTO-71. Bureau of Land Management, New Orleans, LA., pp. 23-153.

Boehm, P.D. and J.W. Farrington. 1984. Aspects of the polycyclic aromatic hydrocarbon geochemistry of recent sediments in the Georges Bank region. Environ. Sci. Technol. 18:840-845.

Boehm, P.D., E. Crecelius, W. Steinhauer, M. Steinhauer, and C. Tuckfield. 1986. Beaufort Sea Monitoring Program: Analysis of Trace Metals and Hydrocarbons from Outer Continental Shelf (OCS) Activities. Draft Annual Report prepared for the Minerals Management Service, Anchorage, AK under Contract No. 14-12-0001-30163. 243 pp.

Boehm, P.D. and A.G. Requejo. 1986. Overview of the recent sediment hydrocarbon geochemistry of Atlantic and Gulf Coast outer continental shelf environments. Estuarine Coastal and Shelf Science 23:29-58.

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. U. S. Department of Commerce, NTIS PB-269 604. EPA-60013-77-033. 114 pp.

Bothner, M.H., E.Y. Campbell, G.P. DiLisio, C.M. Parmenter, M.W. Doughten, R.G. Johnson, J.R. Gillison, and N. Rait. 1985a. Analysis of trace metals in bottom sediments in support of deepwater biological processes studies on the U. S. Mid-Atlantic Continental Slope and Rise. First Interim Report submitted to U.S. Department of the Interior, Minerals Management Service, March 15, 1985. Interagency Agreement No. 14-12-0001-30197. 42 pp.

Bothner, M.H., R.R. Rendigs, E. Y. Campbell, M.W. Doughten, C.M. Parmenter, C.H. O'Dell, G.P. DiLisio, R.G. Johnson, J.R. Gillison, and N. Rait. 1985b. The Georges Bank Monitoring Program: Analysis of trace metals in bottom sediments during the third year of monitoring. Final report submitted to the U.S. Department of the Interior, Minerals Management Service under Interagency Agreement No. 14-12-0001-30153. 99 pp.

Bothner, M.H., E.Y. Campbell, G.P. DiLisio, C.M. Parmeter, R.R. Rendigs, J.R. Gillison, W. Dangelo and J.A. Commeau. 1987. Analysis of trace metals in bottom sediments in support of deepwater biological processes studies on the U.S. Mid-Atlantic Continental Slope and Rise. Final Report submitted to U.S. Department of the Interior, Minerals Management Service, March 31, 1987. Interagency Agreement No. 14-12-0001-31097. 82 pp.

Brown, B. 1985. Ch. 4. Biomass. In: Georges Bank Benthic Infauna Monitoring Program Final Report, prepared for the U.S. Dept. of Interior, Minerals Management Service by Battelle New England Marine Research Laboratory and Woods Hole Oceanographic Institution, pp. 97-120.

Brown, D.W., L.S. Ramos, A.J. Friedman, and W.D. MacLeod. 1979. Analysis of trace levels of petroleum hydrocarbons in marine sediments using a solvent/slurry extraction procedure. In: Trace organic analysis: a new frontier in analytical chemistry, National Bureau of Standard Special Publication 519. Washington, D.C. pp. 161-167.

Brown, D.W., L.S. Ramos, M.Y. Vyeda, A.J. Friedman, and W.D. MacLeod, Jr. 1980. Ambient temperature extraction of hydrocarbons from marine sediment: comparison with boiling solvent extractions. In: Petroleum in the Marine Environment, L. Petrakis and F.T. Weiss (eds.), Adv. Mar. Chem. Ser. No. 185. American Chemical Society, Washington, D.C., pp. 313-326.

Brown, O.B., P.C. Cornillon, S.R. Emmerson, and H.M. Carle. 1986. Warm Core Rings: A statistical study of their behavior. Deep-Sea Res. 33:1459-1474.

Crisp, D.J. 1984. Ch. 9: Energy flow measurements. In: Methods for the Study of Marine Benthos, 2nd Ed., N.A. Holme and A.D. McIntyre (eds.), Blackwell Sci. Publ., Oxford, pp. 284-372.

Csanady, G.T. and P. Hamilton. 1987. Circulation of slopewater. Manuscript submitted to Continental Shelf Research.

Desbruyeres, D., J.Y. Bervas, and A. Khripounoff. 1980. Un cas de colonisation rapide d'un sediment profond. Oceanologia Acta 3:285-291.

Desbruyeres, D., J.W. Deming, A. Dinet and A. Khripounoff. 1985. Ch. 11. Reactions de l'ecosysteme benthique profund aux perturbations: nouveaux resultats experimentaux. In: Peuplements profonds du Grolfe de Gascogne -Campagnes Biogas, L. Laubier and C. Monniot (eds.), IFREMER, Brest, pp. 193-208.

Dean, W.E., M. Leinan, and D.A.V. Stow. 1985. Classification of deep-sea, fine grained sediments. J. Sed. Pet. 55(2):250-256.

Dinet, A., D. Desbruyeres, and A. Khripounoff. 1985. Ch. 6. Abondance des peuplements macro- et meiobenthiques: repartition et strategie d'enchantillonnage. In: Peuplements profonds du Golfe de Gascogne - Campagnes Biogas, L. Laubier, and C. Monniot (eds.), IFREMER, Brest, pp. 121-142.

Doyle, L.J., O.H. Pilkey, and C.C. Woo. 1979. Sedimentation on the eastern United States continental slope. Soc. Econ. Paleontol. Mineral., Spec. Publ. 27:119-129.

Driscoll, M.L., B.E. Tucholke, and I. N. McCave. 1985. Seafloor zonation in sediment texture on the Nova Scotian lower continental rise. Mar. Geol. 66:25-41.

Eckman, J.E. 1983. Hydrodynamic processes affecting benthic recruitment. Limnol. Oceanogr. 28:241-257.

Emery, K.O., and E. Uchupi. 1972. Western North Atlantic Ocean. AAPG Memoir 17. Tulsa, Oklahoma. 532 pp.

Emery, K.O., and E. Uchupi. 1984. The Geology of the Atlantic Ocean. Springer-Verlag, Inc., New York. 925 pp.

Erwin, T.L. 1983. Beetles and other insects of tropical forest canopies at Manaus, Brazil, sampled by insecticidal fogging. In: Tropical Rain Forest, S.L. Sutton, T.C. Whitmore and A.C. Chadwick (eds.), Ecology and Management Sp. Publ. No. 2, British Ecological Society.

Farrington, J.W. and B.W. Tripp. 1977. Hydrocarbons in western North Atlantic surface sediments. Geochim. et Cosmochim. Acta 41:1627-1641.

Fitzgerald, J.L. and J.L. Chamberlin. 1983. Anticyclonic warm core Gulf Stream eddies off the northeastern United States in 1980. Annal. Biol. 37:41-47.

Flagg, C.N., B.A. Magnell, D. Frye, J.J. Cura, S.E. McDowell, and R.I. Scarlet. 1982. Interpretation of the physical oceanography of Georges Bank. EG&G Environmental Consultants report to Bureau of Land Management. 2 volumes.

Folk, R.L. 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Company, Austin, Texas. 182 pp.

Gallagher, E.D., P.A. Jumars, and D.D. Trueblood. 1983. Facilitation of soft-bottom benthic succession by tube builders. Ecology 64:1200-1216.

Gaufin, A.R., E.K. Harris and H.J. Walter. 1956. A statistical evaluation of stream bottom sampling data obtained from three standard samplers. Ecology 37: 643-648.

Gearing, P., J.N. Gearing, T.F. Lytle, and J.S. Lytle. 1976. Hydrocarbons in 60 northeast Gulf of Mexico shelf sediments: a preliminary study. Geochim. et Cosmochim. Acta 40:1005-1017.

Gibbs, R.J. 1977. Effect of combustion temperature and time, and of the oxidation agent used in organic carbon and nitrogen analyses of sediments and dissolved organic material. J. Sediment. Petrol. 47(2):547-550.

Gordon, D.C., P.D. Keizer, W.R. Hardstaff, and D.G. Aldous. 1976. Fate of crude oil spilled in seawater contained in outdoor tanks. Env. Sci. Tech. 10:580-585.

Grant, W.B., A.J. Williams, III, and T.F. Gross. 1985. A description of the bottom boundary layer at the HEBBLE site: Low-frequency forcing, bottom stress and temperature structure. Mar. Geol. 66:219-241.

Grassle, J.F. 1977. Slow recolonisation of deep-sea sediment. Nature 265:618-619.

Grassle, J.F. and H.L. Sanders. 1973. Life histories and the role of disturbance. Deep-Sea Res. 20:643-659.

Grassle, J.F., H.L. Sanders, R.R. Hessler, G.T. Rowe and T. McLellan. 1975. Pattern and zonation: a study of the bathyal megafauna using the research submersible Alvin. Deep-Sea Res. 22:457-481.

Grassle, J.F. and W.L. Smith. 1976. A similarity measure sensitive to the contribution of rare species and its use in investigation of variation in marine benthic communities. Oecologia 25:13-22.

Grassle, J.F., H.L. Sanders, and W.K. Smith. 1979. Faunal changes with depth in the deep-sea benthos. Ambio Spec. Rep. 6:47-50.

Grassle, J.F., L.S. Brown-Leger, L. Morse-Porteous, R. Petrecca, and I. Williams. 1985. Deep-sea fauna of sediments in the vicinity of hydrothermal vents. Biol. Soc. Washington Bull. 6:443-452.

Grassle, J.F. and L. Morse-Porteous. In press. Macrofaunal colonization of disturbed deep-sea environments and the structure of deep-sea benthic communities. Deep-Sea Res.

Haedrich, R.L., G.T. Rowe and P.T. Polloni. 1975. Zonation and faunal composition of epibenthic populations on the continental slope south of New England. J. Mar. Res. 33:191-212.

Haedrich, R.L., G.T. Rowe, and P.T. Polloni. 1980. The megabenthic fauna in the deep sea south of New England, U.S.A. Mar. Biol. 57:165-179.

Hamilton, P. 1984. Topographic and inertial waves on the continental rise of the Mid-Atlantic Bight. J. Geophys. Res. 89:695-710.

Hannan, C.A. 1981. Polychaete larval settlement: Correspondence of patterns in suspended jar collectors and in the adjacent natural habitat in Monterey Bay, California. Limnol. Oceanogr. 26:159-171.

Hannan, C.A. 1984. Planktonic larvae may act like passive particles in turbulent near-bottom flows. Limnol. Oceanog. 29:1108-1116.

Hartman, O. 1965. Deep-water benthic polychaetous annelids off New England to Bermuda and other North Atlantic areas. Allan Hancock Occas. Paper 28: 1-378.

Hartman, O. and K. Fauchald. 1971. Deep-water benthic polychaetous annelids off New England to Bermuda and other North Atlantic areas. Part II. Allan Hancock Monogr. Mar. Biol. 6:1-327.

Hathaway, J.C. 1971. Data file continental margin program, Atlantic coast of the United States. Woods Hole Oceanographic Institution, Ref. No. 71-15, 2: 1-496.

Hecker, B. 1985. Fauna from a cold sulfur-seep in the Gulf of Mexico: Comparison with hydrothermal vent communities and evolutionary implications. Bull. Biol. Soc. Wash. 6:465-473.

Hecker, B., D.T. Logan, F.E. Gandarillas, and P.R. Gibson. 1983. Megafaunal assemblages in Lydonia Canyon, Baltimore Canyon, and selected slope areas. In: Canyon and Slope Processes Study, Final Report prepared for the U.S. Department of the Interior, Minerals Management Service, Washington, D.C. under Contract No. 14-12-001-29178.

Heezen, B.C. 1975. Photographic reconnaissance of Continental Slope and upper Continental Rise. In: NOAA, May 1974 Baseline Investigation of Deepwater Dumpsite 106, pp. 17-32. NOAA Dumpsite Evaluation Report 75-1, Rockville, MD. 388 p.

Heezen, B.C., C.D. Hollister, and W.F. Ruddiman. 1966. Shaping of the continental rise by deep geostrophic contour currents. Science 152:502-508.

Hessler, R.R. 1967. A record of Serolidae (Isopoda) from the North Atlantic Ocean. Crustaceana 12:.159-162.

Hessler, R.R. 1968. The systematic position of Dactylostylis Richardson (Isopoda, Asellota). Crustaceana 14:143-146.

Hessler, R.R. 1970a. A new species of Serolidae (Isopoda) from bathyal depths of the equatorial Atlantic Ocean. Crustaceana 18:227-232.

Hessler, R.R. 1970b. The Desmosomatidae (Isopoda, Assellota) of the Gay Head - Bermuda Transect. Bull. Scripps Inst. Oceanogr. 15: 1-185.

Hessler, R.R. and H.L. Sanders. 1967. Faunal diversity in the deep sea. Deep-Sea Res. 14: 65-78.

Hessler, R.R. and P.A. Jumars. 1974. Abyssal community analysis from replicate box cores in the central North Pacific. Deep-Sea Res. 21: 185-209.

Hill, M.O. 1973. Reciprocal averaging: an eigenvector method of ordination. J. Ecol. 61:237-249.

Hill, M.O. 1974. Correspondence analysis: a neglected multivariate method. J. Royal Stat. Soc., Ser. C. 23:340-354.

Hill, M.O. 1979. DECORANA - a FORTRAN program for detrended correspondence analysis and reciprocal averaging. Cornell University, Ithaca, NY.

Hollister, C.D. 1973. Atlantic continental shelf and slope of the United States - texture of surface sediments from New Jersey to southern Florida. U.S. Geol. Surv., Prof. Paper 529-M: 1-23.

Hurlbert, S.H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52:577-586.

Ingham, M.C., J.J. Bisagni, and D. Mizenko. 1977. The general physical oceanography of deepwater dumpsite 106. In: Baseline Report of Environmental Conditions in Deepwater Dumpsite 106 (Volume1), pp. 29-86. NOAA Dumpsite Evaluation Report 77-1, Rockville, MD.

Iselin, C. O'D. 1936. A study of the circulation of the western North Atlantic. Papers in Phys. Oceanogr. Meteorol. 4(4):101.

Jumars, P.A. 1976. Deep-sea species diversity: does it have a characteristic scale? Jour. Mar. Res. 34:217-246.

Jumars, P.A. 1981. Limits in predicting and detecting benthic community responses to manganese module mining. Marine Mining 3:213-229.

Jumars, P.A. and E.D. Gallagher. 1982. Ch. 10. Deep-sea community structure: three plays on the benthic proscenium: In: The Environment of the Deep Sea, W.G. Ernst and J.G. Morin (eds.), Prentice-Hall, Inc., Englewood Cliffs, New Jersey, pp. 217-255.

Jumars, P.A. and J.E. Eckman. 1983. Spatial structure within deep-sea benthic communities. Chapter 10. In: The Sea, G.T. Rowe (ed.), J. Wiley and Sons, Inc., New York.

Jumars, P.A. and A.R.M. Nowell. 1984. Fluid and sediment dynamic effects on marine benthic community structure. Amer. Zool. 24:45-55.

Keer, F.R. and A.P. Cardinell. 1981. Potential geologic hazards and constraints for blocks in proposed Mid-Atlantic OCS Oil and Gas Lease Sale 59. U.S. Geol. Surv. Open-File Rep. 81-725:109.

Keller, G.H., D. Lambert, G. Rowe, and N. Staresinic. 1973. Bottom currents in the Hudson Canyon. Science 180:181-183.

Keppel, G. 1982. Design and Analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 669 pp.

Khripounoff, A., D. Desbruyeres, and P. Chardy. 1980. Les peuplements benthiques de la faille Vema: donnees quantitatives et bilan d'energie en milieu abyssal. Oceanologica Acta 3: 187-198.

Khripounoff, A. and G.T. Rowe. 1985. Les apports organiques et leur transformation en milieu abyssal a l' interface eau-sediment dans l'Ocean Atlantique tropical. Oceanologia Acta 8: (submitted).

Knebel, H.J. 1984. Sedimentary processes on the Atlantic continental slope of the United States. Mar. Geol. 61:43-74.

Krauskopf, K.B. 1967. Introduction to Geochemistry. McGraw-Hill, New York. 721 pp.

Levin, L.A. and C.R. Smith. 1984. Response of background fauna to disturbance and enrichment in the deep sea: a sediment tray experiement. Deep-Sea Res. 31:1271-1285.

Lloyd, J.B.F. 1971. The nature and edidential value of the luminescence of automobile engine oils and related materials. J. Forensic Sci. Soc., 11:83-94, 153-210, 235.

Luyten, J.R. 1977. Scales of motion in the deep Gulf Stream and across the continental rise. J. Mar. Res. 35:49-74.

Maciolek, N.J. 1981. A new genus and species of Spionidae (Annelida:.Polychaeta) from the north and south Atlantic. Proc. Biol. Soc. Wash. 94(1):228-239.

Maciolek, N.J. 1983. Systematics of Atlantic Spionidae (Annelida:Polychaeta) with special reference to deep-water species. Ph.D. Thesis. Boston University, Boston, MA, pp. 1-400.

Maciolek, N.J. 1987. New species records of Scolelepis (Polychaeta:Spionidae) from the East Coast of North America, with a review of the subgenera. Bull. Biol. Soc. Wash. 7:16-40.

Maciolek-Blake, N., J.F. Grassle, J.A. Blake, and J.M. Neff. 1984. Georges Bank Benthic Infauna Monitoring Program: Final Report for the Second Year of Sampling. Prepared for U.S. Department of the Interior, Minerals Management Service, Washington, D.C. under Contract No. 14-12-0001-29192. 315 pp.

Maciolek-Blake, N., P.D. Boehm, B. Hecker, J.F. Grassle, D. McGrath, A.G. Requejo, B. Brown, C.M. Cetta, B. Dade, S. Freitas, and R. Petrecca. 1985a. Study of biological processes on the U.S. Mid-Atlantic slope and rise. First Interim Report to the U.S. Department of the Interior, Minerals Management Service, Washington, D.C. under Contract No. 14-12-0001-30064. 99 pp + Appendices 1-4.

Maciolek-Blake, N., J.M. Neff, and J.F. Grassle (eds.). 1985b. Georges Bank Benthic Infauna Monitoring Program: Final Report for the Third Year of Sampling. Prepared for U.S. Department of the Interior, Minerals Management Service, Washington, D.C. under contract No. 14-12-0001-29192. ii + 333 pp.

Maciolek, N., J.F. Grassle, P.D. Boehm, B. Dade, B. Brown, W.G. Steinhauer, C.A. Butman, R.E. Ruff, R. Petrecca, and E. Baptiste. 1986a. Study of biological processes on the U.S. Mid-Atlantic slope and rise. Second Interim Report to the U.S. Department of the Interior, Minerals Management Service, Washington, D.C. under contract No. 14-12-0001-30064. 118 pp. + Appendices 1-6.

Maciolek, N., B. Hecker, C.A. Butman, J.F. Grassle, W.B. Dade, P.D. Boehm, W.G. Steinhauer, V. Starczk, E. Baptiste, R.E. Ruff, and B. Brown. 1986b. Study of biological processes on the U.S. North Atlantic slope and rise. Interim Report prepared for the U.S. Department of the Interior, Minerals Management Service, Washington, D.C. under Contract No. 14-12-0001-30064. 201 pp + Appendices 1-6.

Maciolek, N.J., J.F. Grassle, B. Hecker, B. Brown, J.A. Blake, P.D. Boehm, R. Petrecca, S. Duffy, E. Baptiste, and R.E. Ruff. 1987. Study of biological processes on the U.S. North Atlantic slope and rise. Final Report prepared for U.S. Dept. of the Interior, Minerals Management Service, Washington, D.C., 358 pp. + Appendices A-L.

Manheim, F.T. 1974. Evidence for submarine discharge of water on the Atlantic Continental slope of the southern United States, and suggestions for further search. Trans. NY Acad. Sci. Geol. Sec.: 839-853.

Manheim, F.T. and R.E. Hall. 1976. Deep evaporitic strata off New York and New Jersey - Evidence from interstitial water chemistry of drill cores. J. Res. U.S. Geol. Survey 4(6): 697-702.

Maurer, D. and R.L. Wigley. 1984. Biomass and density of macrobenthic invertebrates on the U.S. continental shelf off Martha's Vineyard, MA., in relation to environmental factors. NOAA Tech. Rpt., NMFS SSRF-783. 24 pp.

McCave, I.N. and S.A. Swift. 1976. A physical model for the rate of deposition of fine-grained sediments in the deep sea. Bull. Geol. Soc. Am. 87:541-546.

McGregor, B.A., J.C. Hampson, Jr., and W.B.F. Ryan. 1982. Sidescan data collected in the Wilmington Canyon area during 1980, Gyre cruise 80-G-8B. U.S. Geol. Surv. Open-File Rep. 82-499:4.

McGregor, B.A., T.A. Nelson, W.L. Stubblefield, and G.F. Merrill. 1984. The role of canyons in late Quaternary deposition of the United States Mid-Atlantic continental rise. In: D.A.V. Stow and D.J.W. Piper (eds.), Fine-Grained Sediments. Geol. Soc. Am. Sp. Pub. No. 15:319-330.

Milliman, J.D. 1972. Atlantic continental shelf and slope of the United States -petrology of the sand fraction of sediments, northern New Jersey to southern Florida. U.S. Geol. Surv., Prof. Paper 529-J: 1-40.

Milliman, J.D., O.H. Pilkey, and D.A. Ross. 1972. Sediments on the continental margin off the eastern United States. Bull. Geol. Soc. Am. 83:1315-1334.

Munsell. 1975. Munsell Soil Color Charts. Kollmorgen Corp., Baltimore, Maryland.

Neter J. and W. Wasserman. 1974. Applied Linear Statistical Models. R.D. Irwin, Inc., Homewood, Illinois. 842 pp.

NOAA. 1983. 106-Mile Site Characterization Update. NOAA Technical Memorandum NMFS-F/NEC-26.

Nybakken, J.W. 1982. Marine Biology. An ecological approach. Harper and Row, New York.

Pearson, M. and J.D. Gage. 1984. Diets of some deep-sea brittle stars in the Rockall Trough. Mar. Biol. 82:247-258.

Rex, M.A. 1973. Deep-sea species diversity: decreased gastropod diversity at abyssal depths. Science 181: 1051-1053.

Rex, M.A. 1983. Geographic patterns of species diversity in the deep-sea benthos. In: The Sea, Vol. 8, G.T. Rowe (ed.), John Wiley and Sons, pp. 453-472.

Rhines, P. 1971. A note on long-period motions at Site D. Deep-Sea Res. 18:21-26.

Ricklefs, R.E. 1987. Community diversity: Relative roles of local and regional processes. Science 235:167-171.

Robb, J.M., J.R. Kirby, and J.C. Hampson, Jr. 1981. Bathymetric map of the continental slope and uppermost continental rise between Lindenkohl Canyon and South Toms Canyon, offshore eastern United States. U.S. Geol. Surv. Misc. Field Studies Map MF-1270. 1 sheet.

Robb, J.M., J.R. Kirby, J.C. Hampson, Jr., P.R. Gibson, and B. Hecker. 1982. Furrowed outcrops of Eocene chalk on the lower continental slope offshore New Jersey. Geology 11:182-186.

Robb, J.M., J.C. Hampson, Jr., and J.R. Kirby. 1983. Ch. 5: Surficial geologic studies of the continental slope in the northern Baltimore Canyon Trough area - techniques and findings. In: Environmental geologic studies on the United States mid- and north-Atlantic outer continental shelf area 1980-1982. Vol. II. Mid-Atlantic region, B.A. McGregor (ed.), Final report submitted to the U.S. Bureau of Land Management under Memorandum of Understanding AA851-MUO-18 and Interagency Agreements AA851-IA1-17 and AA851-IA2-26. pp. 1-30.

Rossby, C.G. 1936. Dynamics of steady ocean currents in the light of experimental fluid mechanics. PPOM, 5, Woods Hole Oceanographic Institution, pp. 1-43.

Rowe, G.T. 1983. Ch. 3. Biomass and production of the deep-sea macrobenthos. In: Deep-Sea Biology, G.T. Rowe (ed.), John Wiley & Sons, New York, pp. 97-121.

Rowe, G.T. and R.J. Menzies. 1969. Zonation of large benthic invertebrates in the deep-sea off the Carolinas. Deep-Sea Res. 16:531-537.

Sanders, H.L. 1968. Marine benthic diversity: a comparative study. Am. Nat. 102:243-282.

Sanders, H.L. and J.A. Allen. 1973. Studies on deep-sea Protobranchia (Bivalvia), Prologue and the Pristoglomidae. Bull. Mus. Comp. Zool. 145:237-262.

Sanders, H.L. and J.A. Allen. 1977. Studies on deep-sea Protobranchia (Bivalvia), the family Tindariidae and the genus Pseudotindaria. Bull. Mus. Comp. Zool. Vol. 148:23-59.

Sanders, H.L. and R.R. Hessler. 1969. Ecology of deep-sea benthos. Science 163: 1419-1424.

Science Applications International Corporation (SAIC). 1987. Study of physical processes on the U.S. Mid-Atlantic continental slope and rise. Final report. Volume II: Technical. Prepared for Minerals Management Service, Atlantic OCS, Department of Interior under Contract No. 14-12-0001-30066.

Shaw, D.G., D.J. McIntosh, and E.R. Smith. 1979. Arene and alkane hydrocarbons in nearshore Beaufort Sea sediments. Estuar. Coast. Mar. Sci. 9:435-449.

Siebenaller, J.F. and R.R. Hessler. 1977. The Nannoniscidae (Isopoda, Asellota): Hebefustis n. gen. and Nannoniscoides Hansen. Trans. San Diego Soc. Nat. Hist. 19:17-44.

Siebenaller, J.F. and R.R. Hessler. 1981. The genera of the Nannoniscidae (Isopoda, Asellota). Trans. San Diego Soc. Nat. Hist. 19:227-250.

Smith C.L., C.W. Su, and W.G. MacIntyre. 1979. Hydrocarbon distribution and concentration, Chapt. 14, Section 1, Vol. IIB. In: Middle Atlantic Outer Continental Shelf Environmental Studies, Chemical and Biological Benchmark Studies, Final Report. Contract No. AA550-CT6-62, Bureau of Land Management, New York OCS Office, New York.

Smith, C.R. 1986. Nekton falls, low-intensity disturbance and community structure of infaunal benthos in the deep sea. Jour. Mar. Res. 44:567-600.

Smith C.R., P.A. Jumars, and D.J. DeMasters. 1986. In situ studies of megafaunal mounds indicate rapid sediment turnover and community response at the deep-sea floor. Nature 323:251-253.

Smith, K.L., Jr., G.A. White, M.B. Laver, R.R. McConnaughey, and J.P. Meador. 1979. Free vehicle capture of abyssopelagic animals. Deep-Sea Res. 26:57-64.

Smith, W.L. and J.F. Grassle. 1977. Sampling properties of a family of diversity measures. Biometrics 33:283-291.

Smith, W.L., J.F. Grassle, and D. Kravitz. 1979. Measures of diversity with unbiased estimates. In: Ecological Diversity in Theory and Practice, J.F. Grassle, G.P. Pitil, W.L. Smith and C. Taille (eds.), International Cooperative Publishing House, Fairland, Maryland, pp. 177-191.

Sokal, R.R. and P.H.A. Sneath. 1963. Principles of Numerical Taxonomy. Freeman Press, San Francisco. 573 pp.

Sokal, R.R. and F.J. Rohlf. 1969. Biometry. Freeman Press, San Francisco. 776 pp.

Stanley, D.J., S.J. Culver and W.L. Stubblefield. 1986. Petrologic and foraminiferal evidence for active downslope transport in Wilmington Canyon. Mar. Geol. 69: 207-218.

Thistle, D. 1980. A revision of Ilyarachna (Crustacea, Isopoda) in the Atlantic with four new species. Jour. Nat. Hist. 14:111-143.

Thistle, D. and R. R. Hessler. 1976. Origin of a deep-sea family, the Ilyarachnidae (Crustacea: Isopoda). Sys. Zool. 25:110-116.

Thistle, D. and R.R. Hessler. 1977. A revision of Betamorpha (Isopoda: Asellota) in the world ocean with three new species. Zool. J. Linn. Soc. 60:273-295.

Thistle, D., J.Y. Yingst, and K. Fauchald. 1985. A deep-sea benthic community exposed to strong near-bottom currents on the Scotian Rise (western Atlantic). Mar. Geol. 66:91-112.

Tripp, B.W., J.W. Farrington, and J.M. Teal. 1981. Unburned coal as a source of hydrocarbons in surface sediments. Mar. Pollut. Bull. 12:122-126.

Tucholke, B.E. 1987. Submarine geology. In: The Marine Environment of the U.S. Atlantic Continental Slope and Rise, J.D. Milliman and W.R. Wright (eds.), pp. 56-113. Jones and Bartlett Publishers, Ltd., Boston.

Turner, R.D. 1973. Wood-boring bivalves, opportunistic species in the deep sea. Science 180:1377-1379.

Turner, R.D. 1977. Wood, mollusks, and deep-sea food chains. Bull. Amer. Malacol. Un. 1976, pp. 13-19.

Turner, R.D. 1985. Notes on mollusks of deep-sea vents and reducing sediments. Am. Malacol. Bull., Spec. Ed. 1: 23-34.

Twichell, D.C., D.G. Roberts, and P.G. Teleki. 1980. Long-range sidescan sonar views of the continental margin seaward of the Baltimore Canyon Trough. Abs. Geol. Soc. Am. 12(7):538-539.

Twichell, D.C. and D.G. Roberts. 1982. Morphology, distribution, and development of submarine canyons on the United States Atlantic continental slope between Hudson and Baltimore Canyons. Geology 10:408-412.

Underwood, A.J. 1981. Techniques of analysis of variance in experimental marine biology and ecology. Oceanogr. Mar. Biol. Ann. Rev. 19: 513-605.

U.S. Naval Oceanographic Office. 1975. Instruction Manual for obtaining Oceanographic Data. Publication No. 607. 14 pp.

Uzmann, J.R., R.A. Cooper, R.B. Theroux and R.L. Wigley. 1977. Synoptic comparison of three sampling techniques for estimating abundance and distribution of selected megafauna: submersible vs. camera sled vs. otter trawl. Mar. Fish. Rev. 39(12):11-19.

Venkatesan, M.I. and I.R. Kaplan. 1982. Distribution and transport of hydrocarbons in surface sediments of the Alaskan outer continental shelf. Geochim. et Cosmochim. Acta 46:2135-2150.

Volkmann, G. 1962. Deep current observations in the western North Atlantic. Deep-Sea Res. 9: 493-500.

Wakeham, S.G. 1977. Synchronous fluorescence spectroscopy and its application to indigenous and petroleum-derived hydrocarbons in lacustrine sediments. Env. Sci. Tech. 11:272-276.

Whittaker, R.H. and C.W. Fairbanks. 1958. A study of plankton copepod communities in the Columbia Basin, southeastern Washington. Ecol. 54: 46-65.

Williams, W.T. 1971. Principles of clustering. Ann. Rev. Ecol. Syst. 2:303-326.

Williams, J.G. 1980. The influence of adults on the settlement of spat of the clam, Tapes japonica. J. Mar. Res. 38:729-741.

Wilson, G.D. 1976. The systematics and evolution of Haplomunna and its relatives (Isopoda, Haplomunnidae, new family). J. Nat. Hist. 10:569-580.

Wilson, G.D. 1980a. New insights into the colonization of the deep sea: systematics and zoogeography of the Munnidae and Pleurogoniidae comb. nov. (Isopoda: Janiroidea). Jour. Nat. Hist. 14:215-236.

Wilson, G.D. 1980b. Systematics of a species complex in the deep-sea genus Eurycope, with a revision of six previously described species (Crustacea, Isopoda, Eurycopidae). Bull. Scripps Inst. Oceanogr. 25:1-64.

Wilson, G.D. 1981. Taxonomy and postmarsupial development of a dominant deep-sea eurycopid isopod (Crustacea). Proc. Biol. Soc. Wash. 94:276-294.

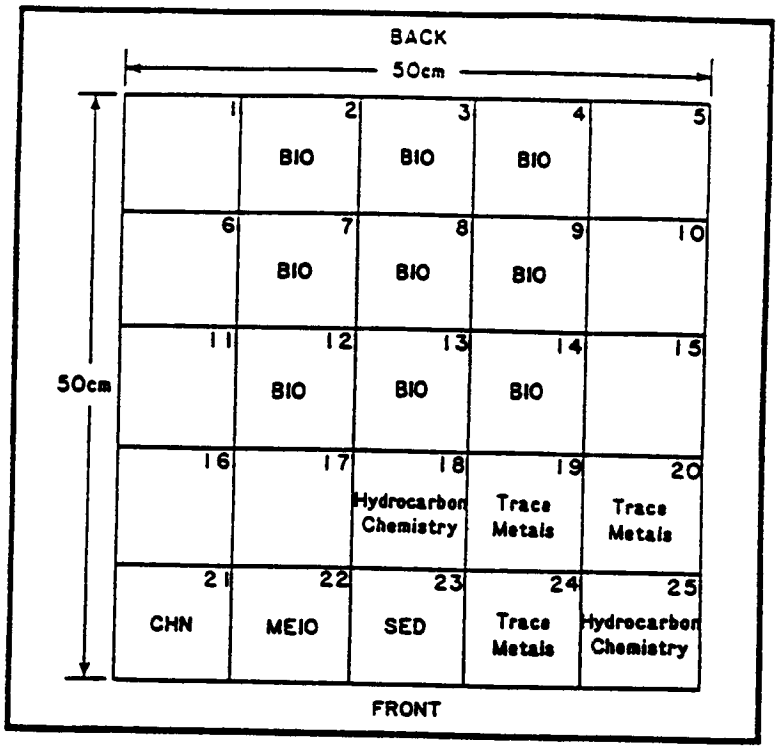
Wilson, G.D. and R.R. Hessler. 1974. Some unusual Parselloidea (Isopoda, Asellota) from the deep benthos of the Atlantic. Crustaceana 27:47-67.

Wilson, G.D. and R. R. Hessler. 1980. Taxonomic characters in the morphology of the genus Eurycope (Crustacea, Isopoda) with a redescription of E. cornuta Sars 1864. Cah. Biol. Mar. 21:241-263.

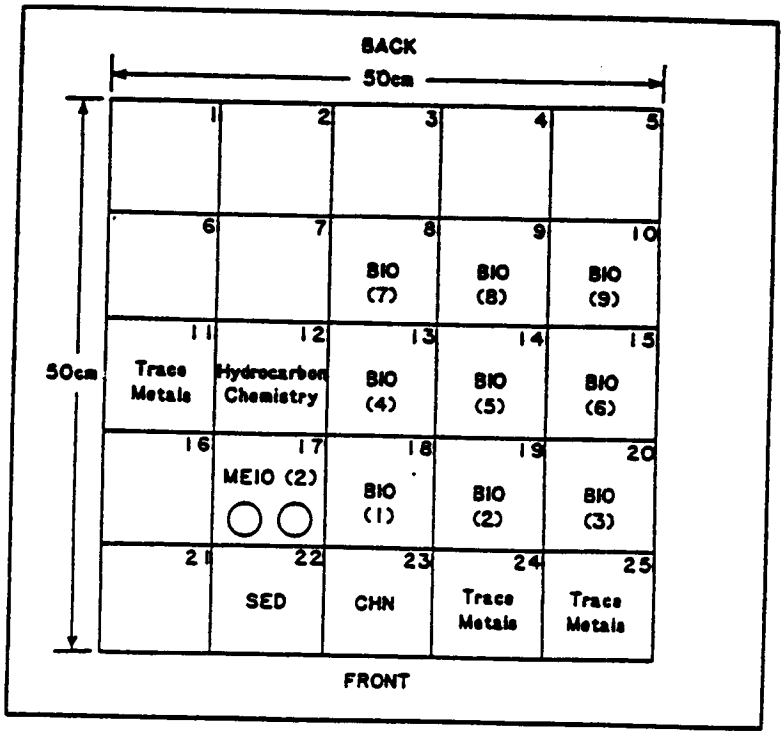
Wilson, G.D. and R.R. Hessler. 1981. A revision of the genus Eurycope (Isopoda, Asellota) with descriptions of three new genera. J. Crust. Biol. 21:401-423

Worthington, L.V. and W.R. Wright. 1970. North Atlantic Ocean Atlas of potential temperature and salinity in the deep water including temperature, salinity and oxygen profiles from the Erika Dan cruise of 1962. WHOI Atlas No. 2. 50 pp.

APPENDIX A

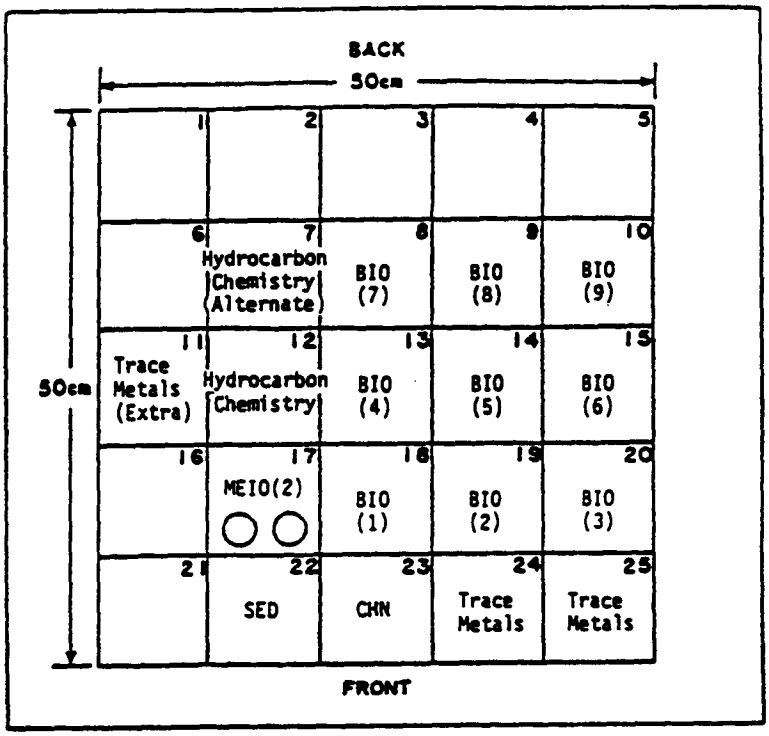


A

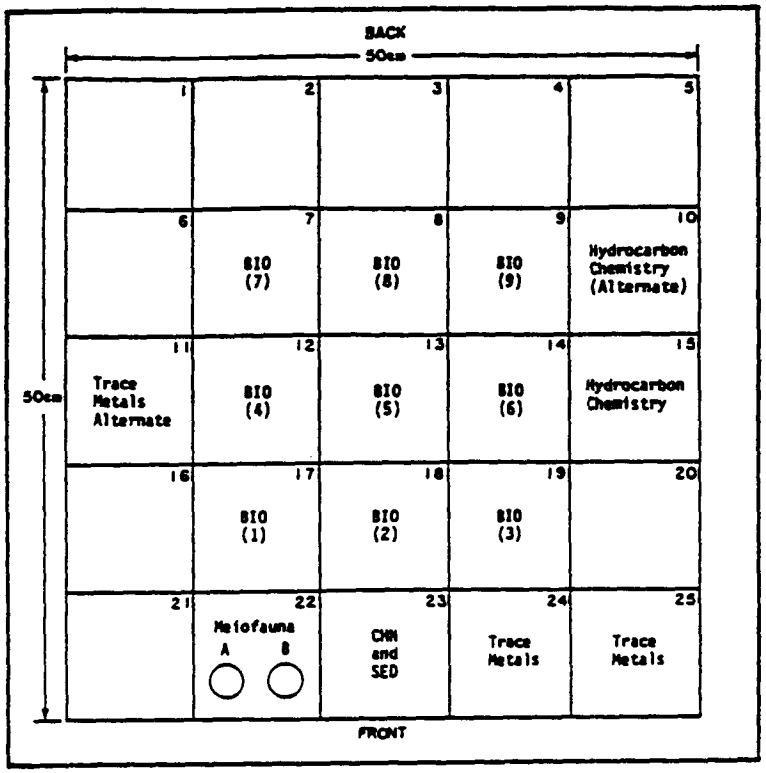


B

Figure A-1. Designation of subcores from the 0.25-m^2 box core for Cruise Mid-1, Leg 1 (A) and Cruise Mid-1, Leg 2 (B).

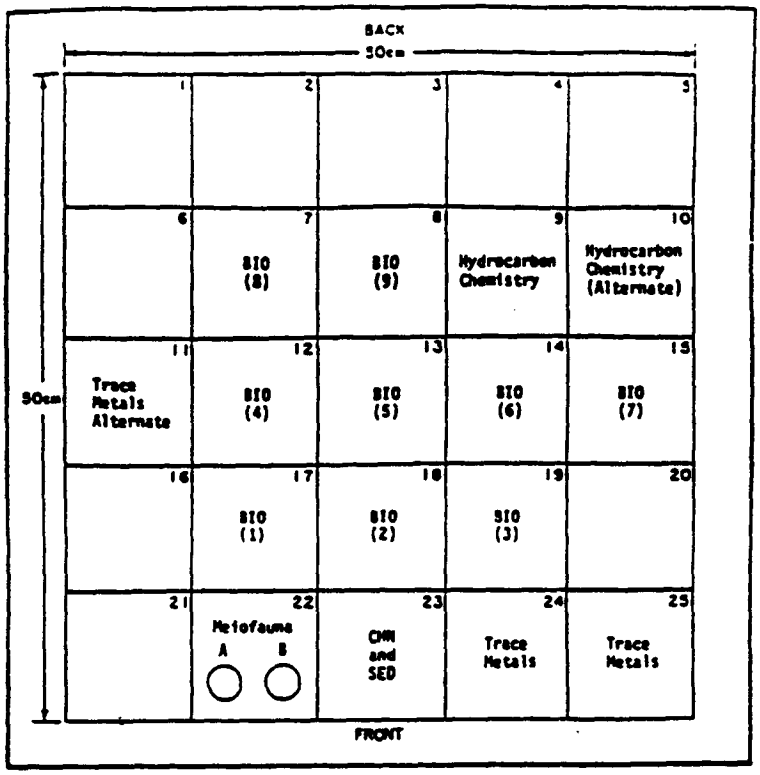


A

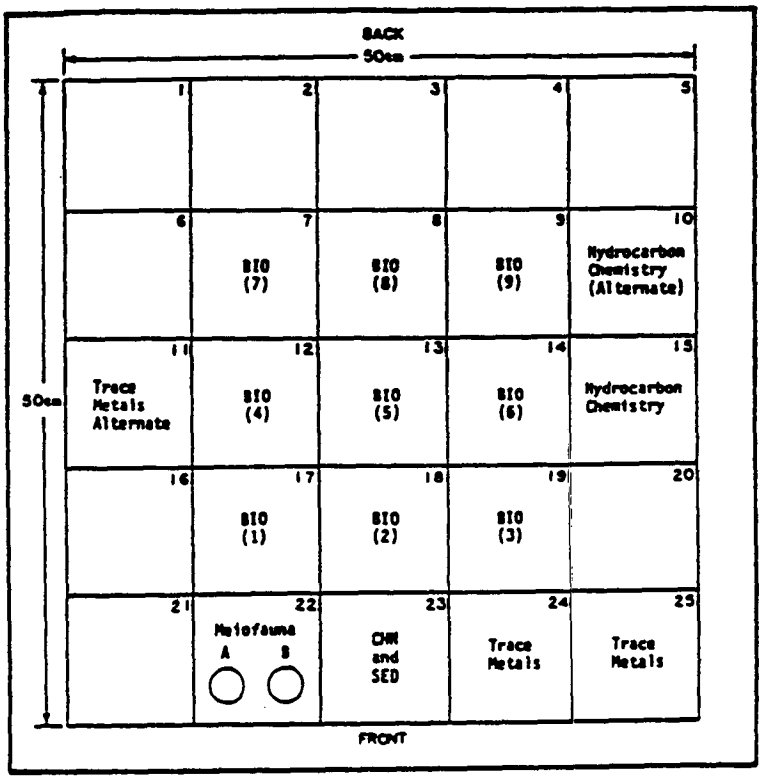


B

Figure A-2. Designation of subcores from the 0.25-m^2 box core for Cruise Mid-2 (A) and Mid-3 (B).

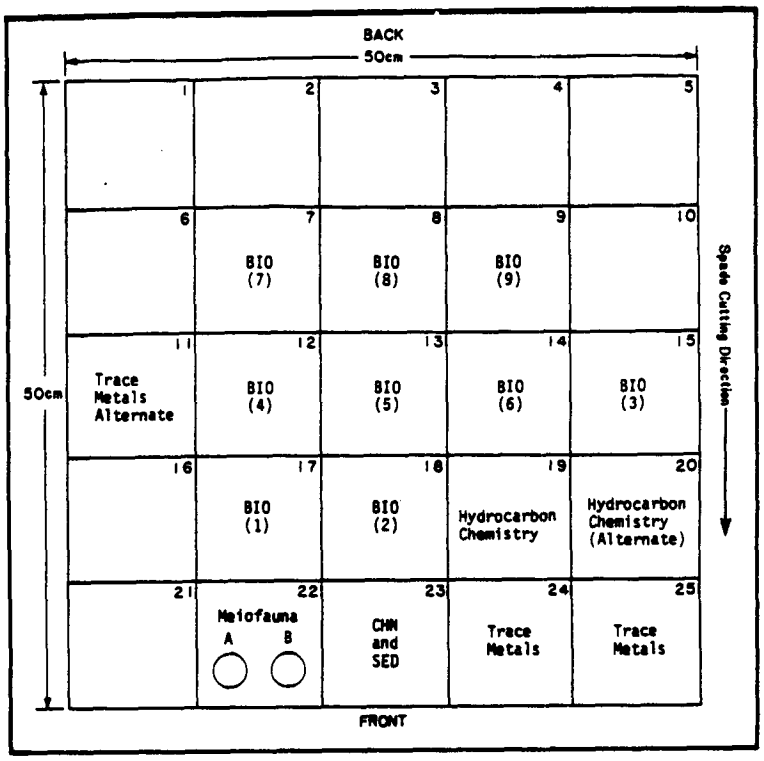


A

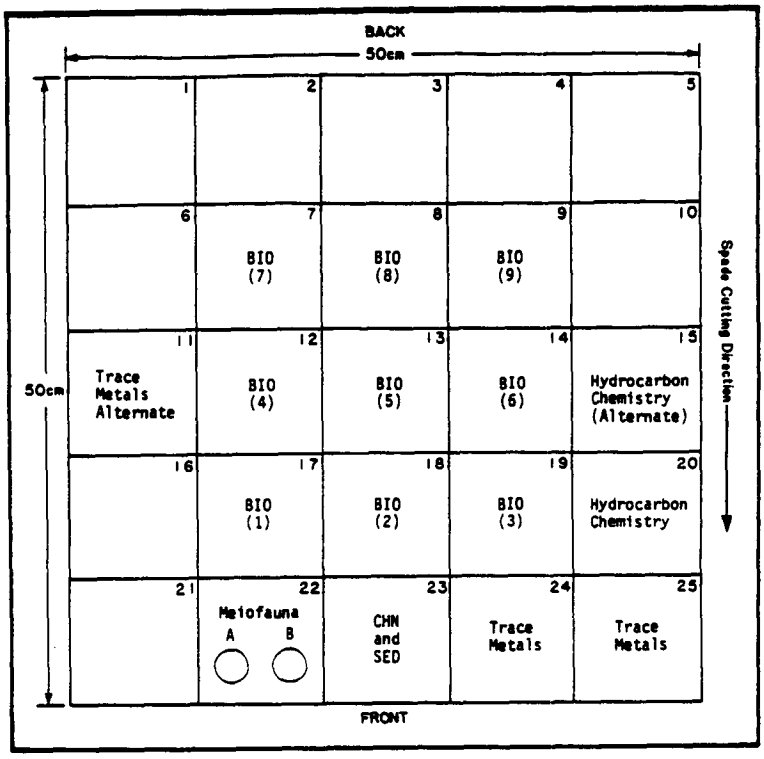


B

Figure A-3. Designation of subcores from the 0.25-m^2 box core for Cruise Mid-4. Arrangement shown in part A was used for Stations 1, 2, 3, 10, and 13; arrangement shown in part B was used for Stations 4-7, 9, 11, 12, and 14.



A



B

Figure A-4. Designation of subcores from the 0.25-m^2 boxcore for Cruises Mid-5 and Mid-6. Arrangement shown in Part A was used for Stations 1, 2, 3, 10, and 13; arrangement shown in Part B was used for Stations 4-7, 9, 11, 12, and 14.

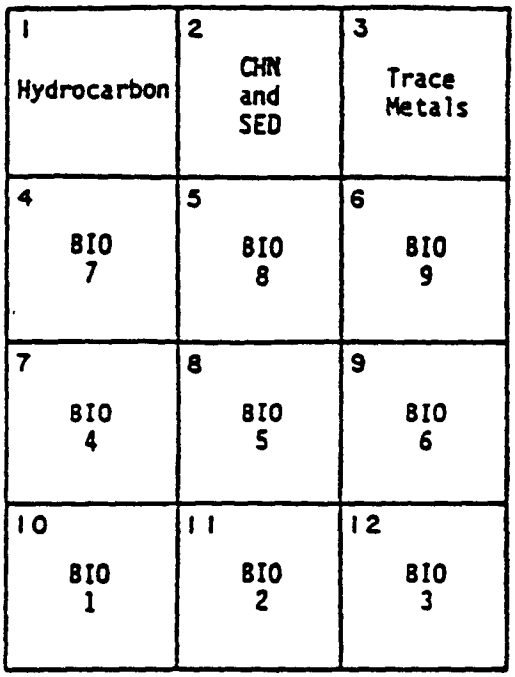


Figure A-5. Allocation of subcores taken from recolonization trays. Each subcore has a surface area of 0.1 m^2.

APPENDIX B

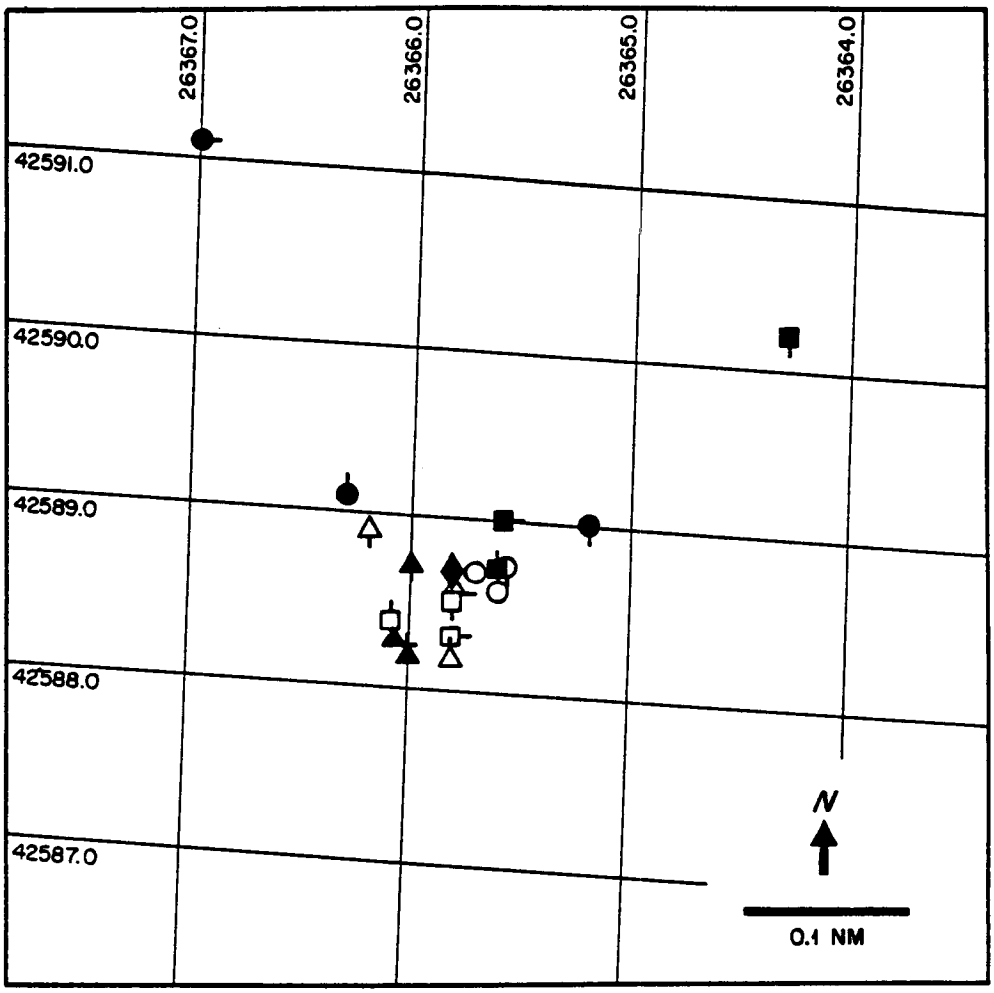


Figure B-1. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 1.

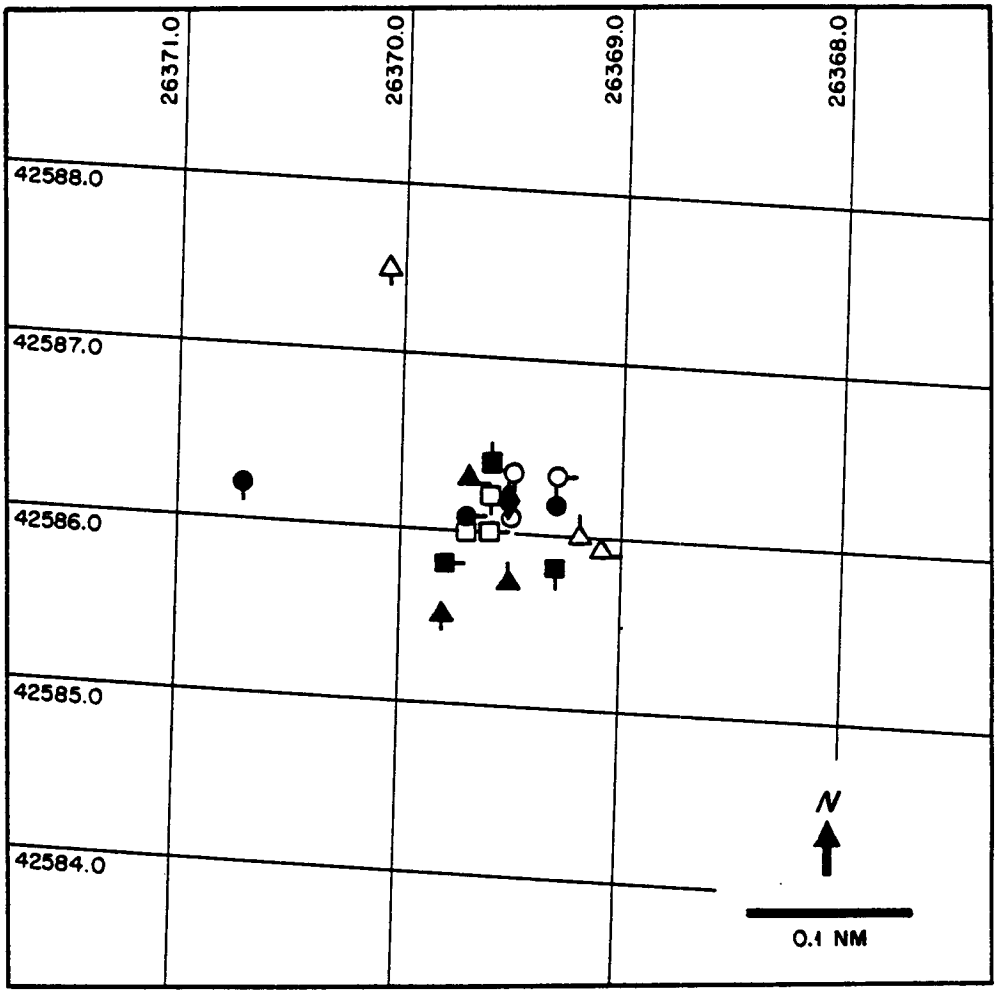


Figure B-2. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 2.

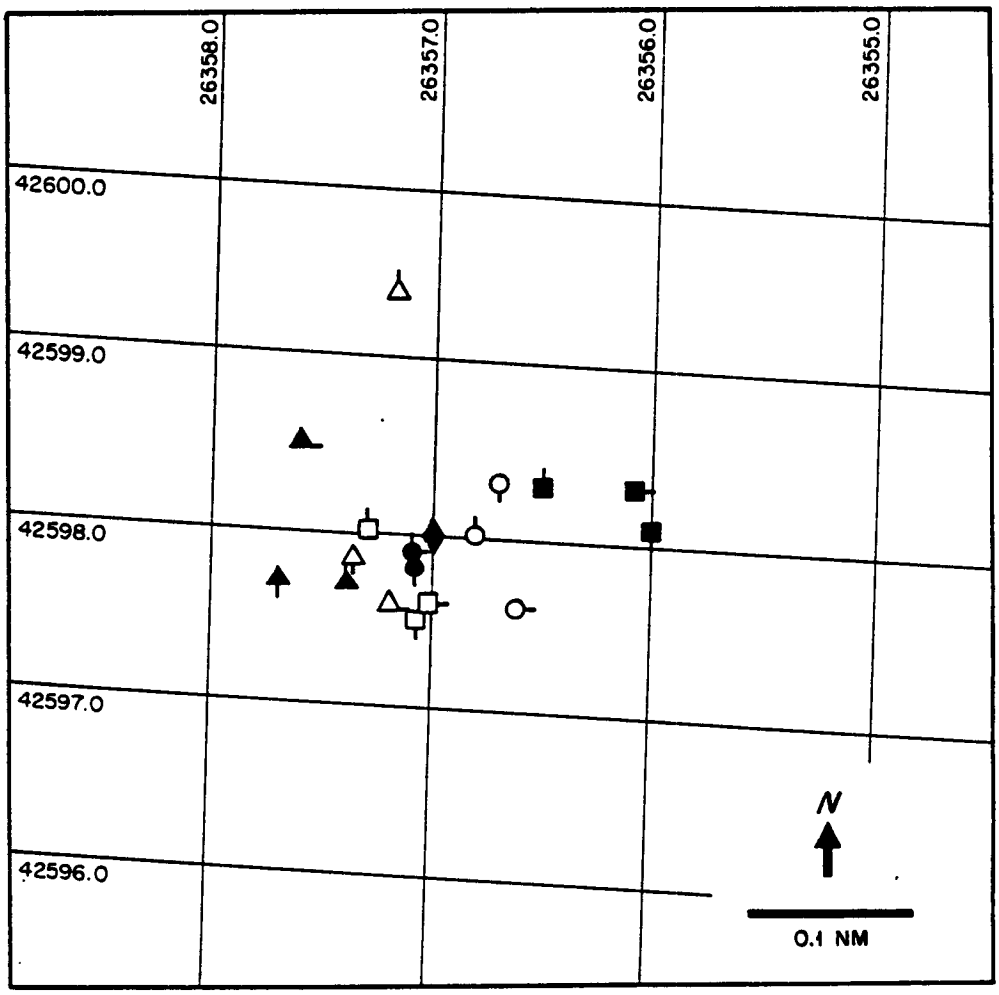


Figure B-3. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 3.

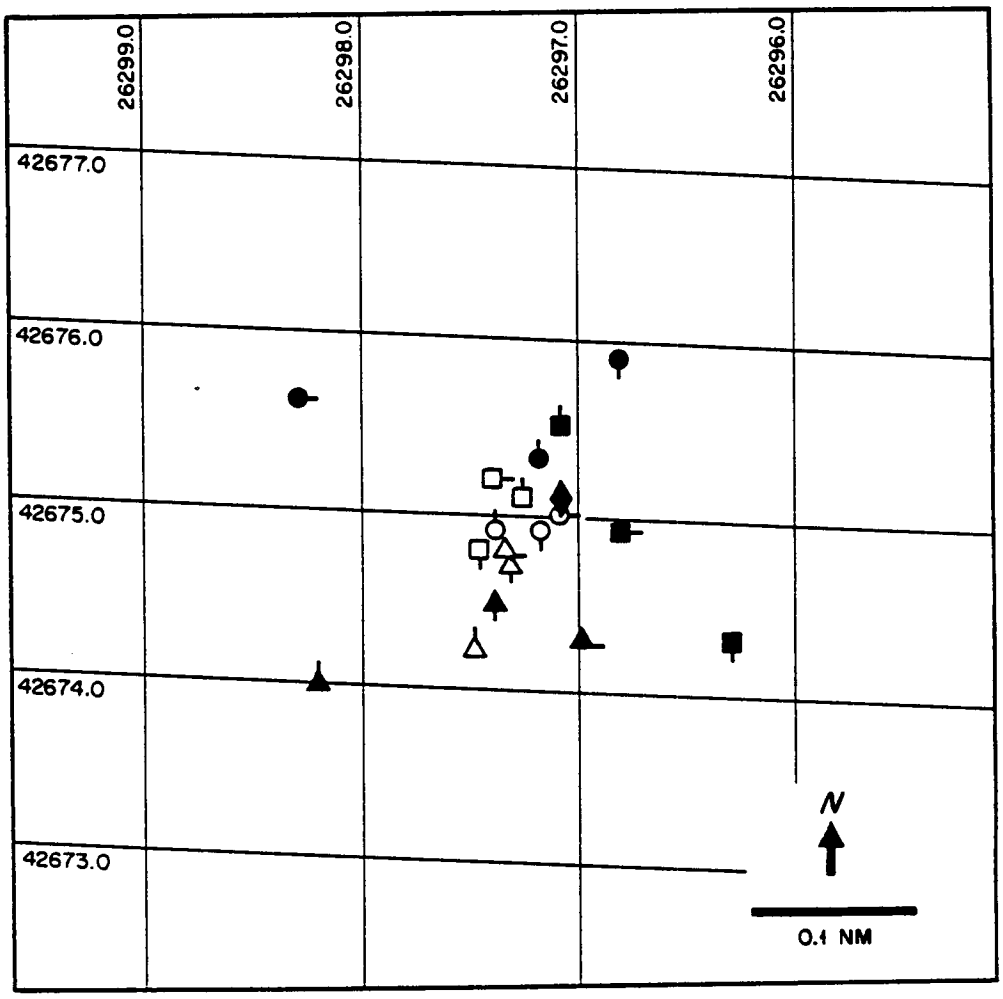


Figure B-4. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 4.

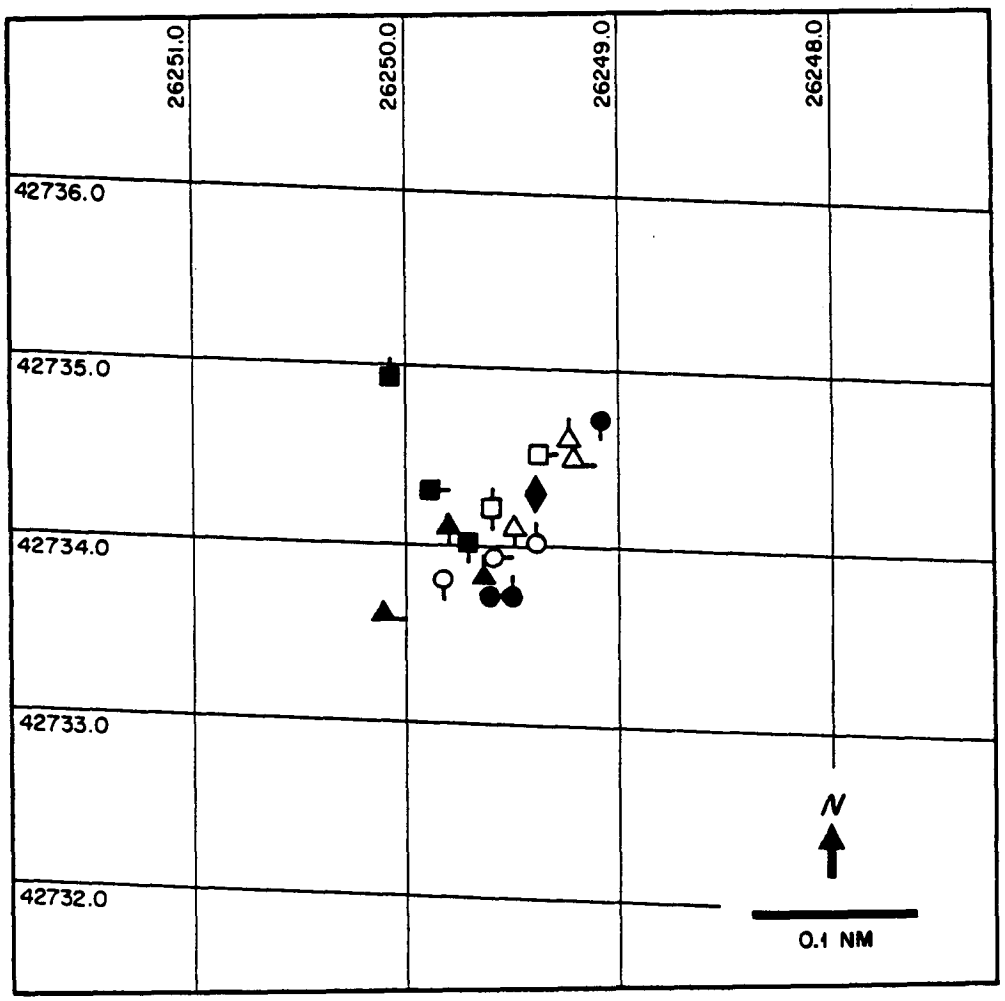


Figure B-5. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 5.

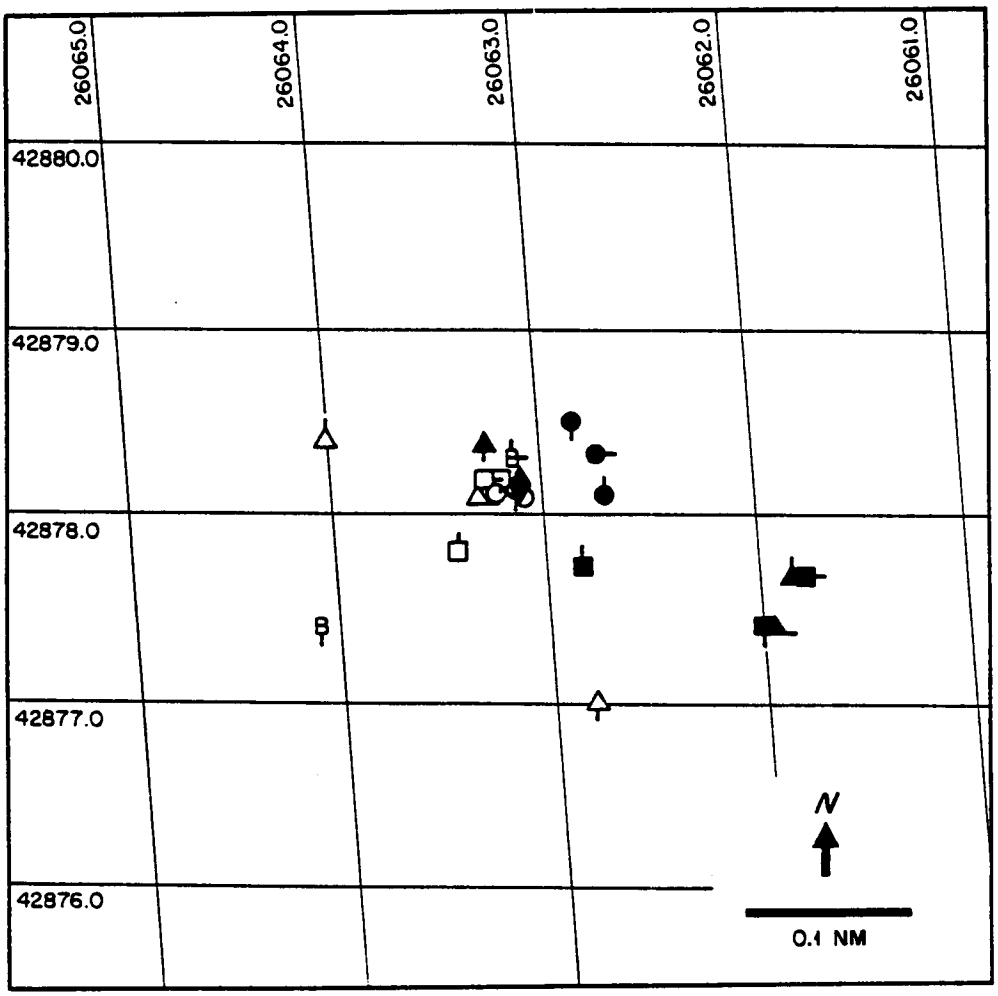


Figure B-6. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 6.

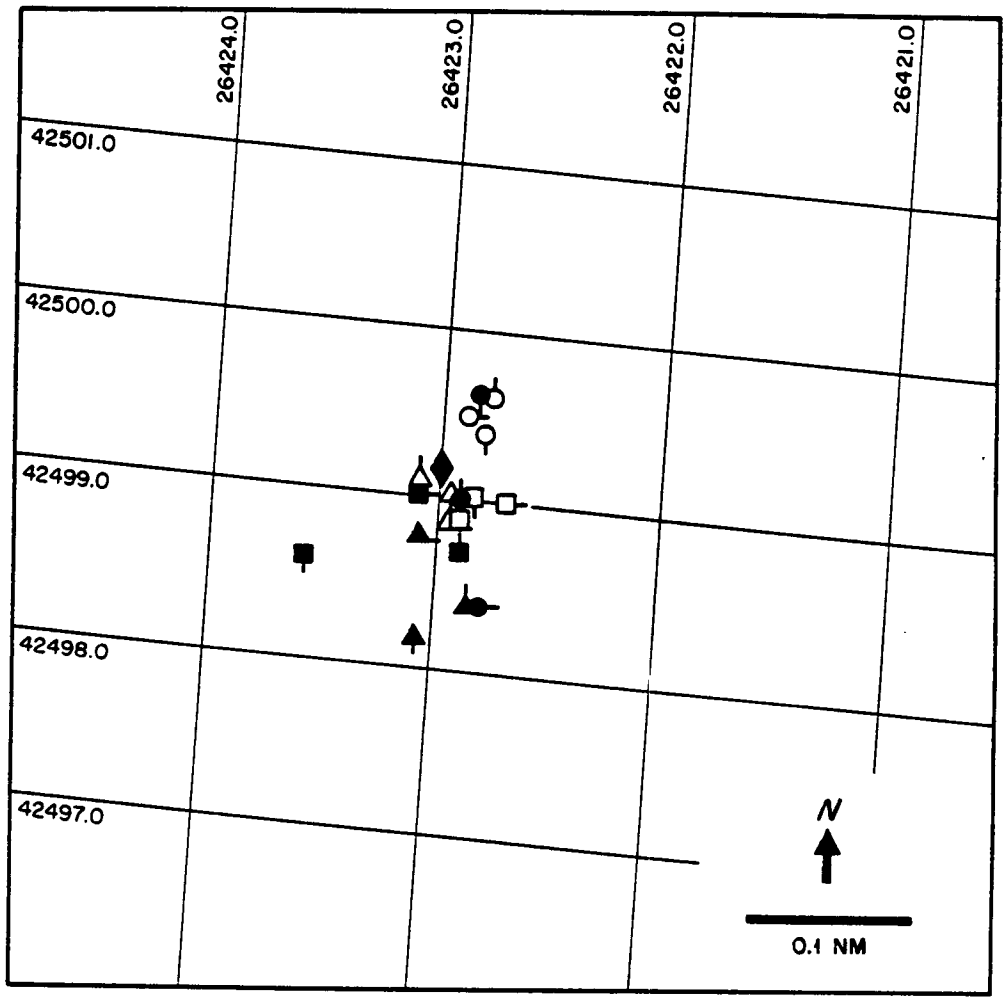


Figure B-7. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 7.

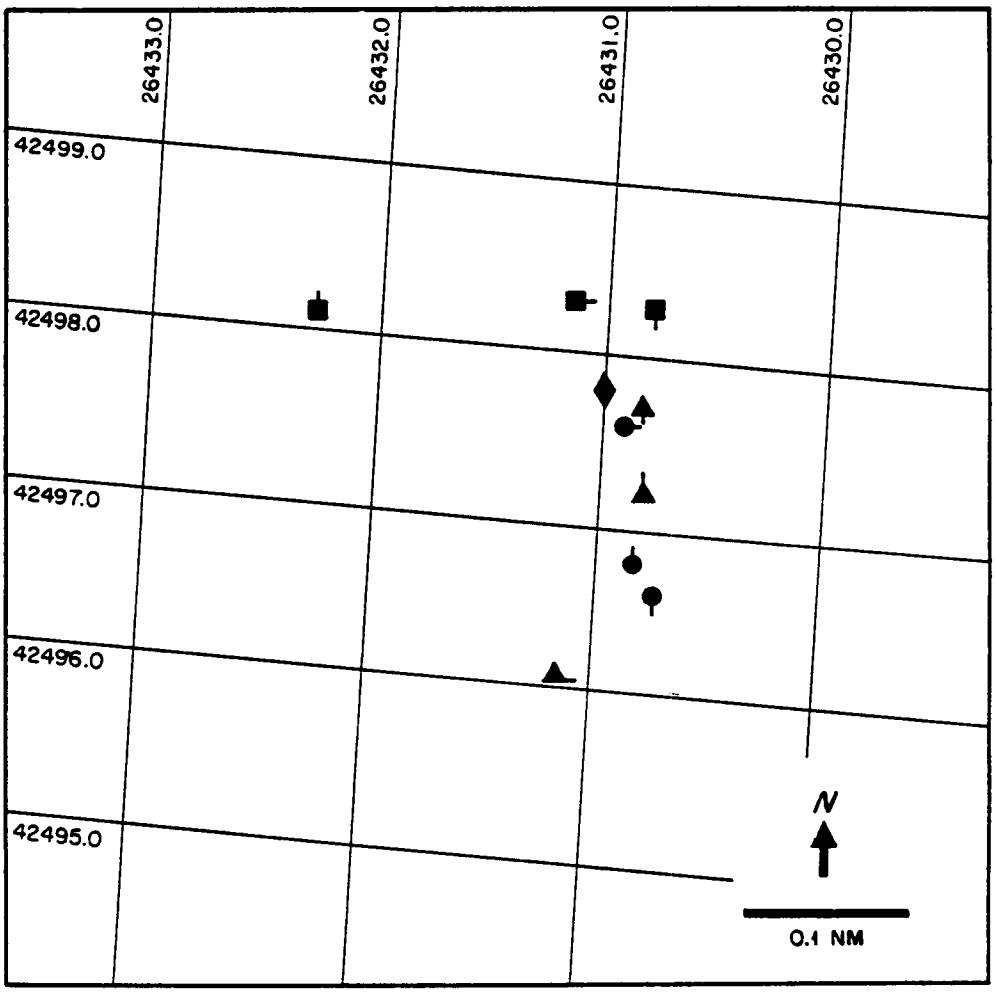


Figure B-8. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 8.

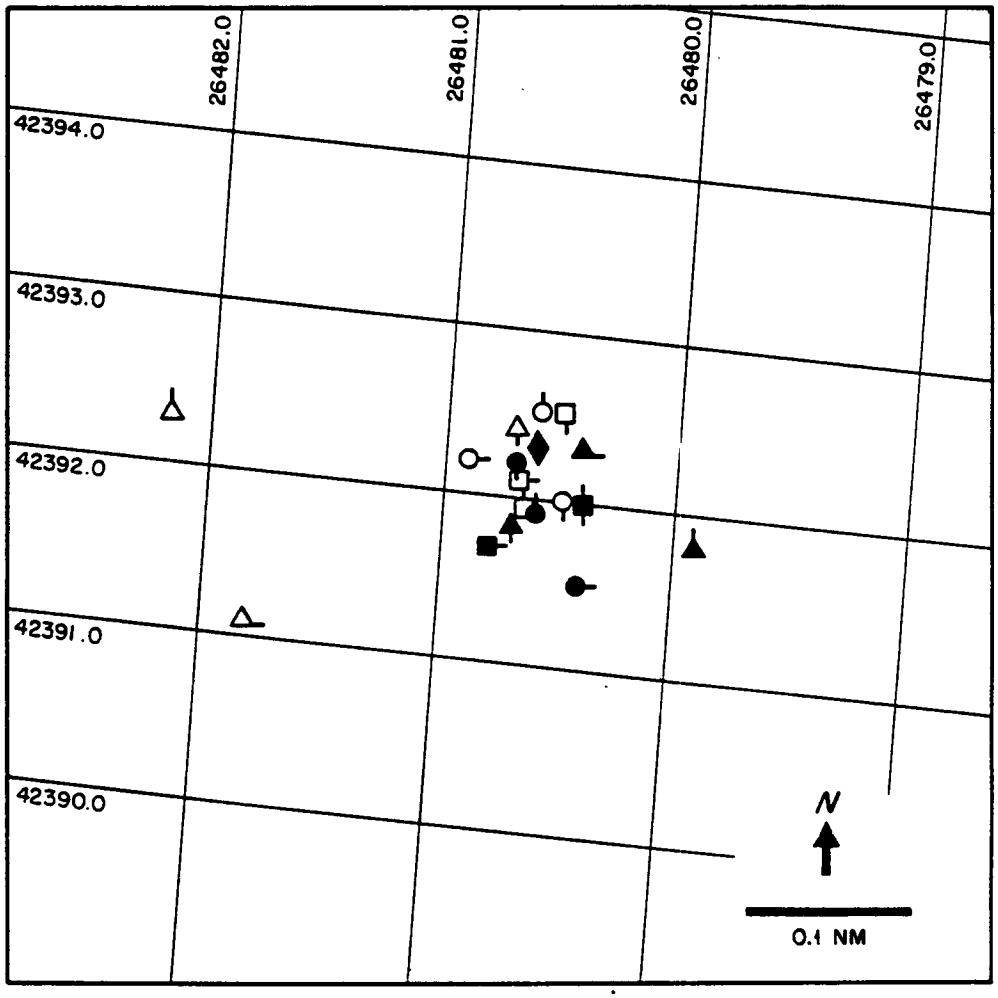


Figure B-9. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 9.

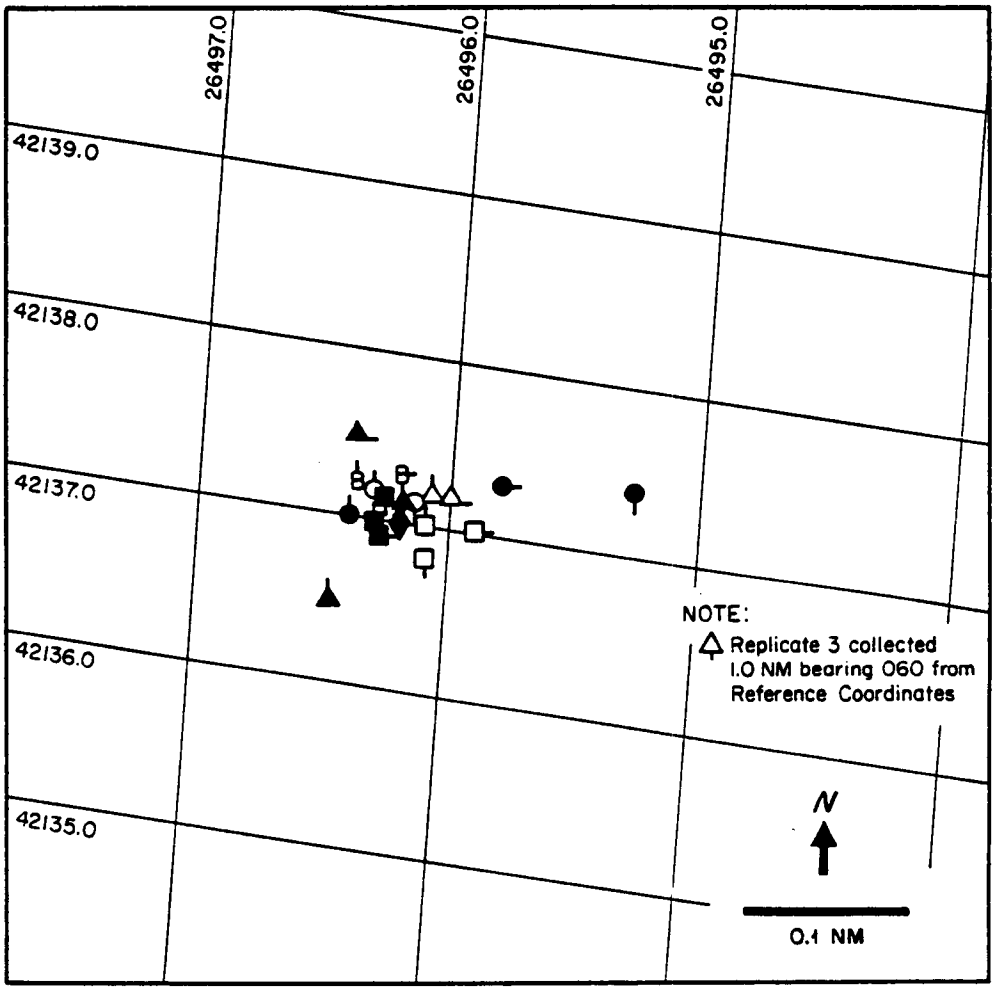


Figure B-10. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 10.

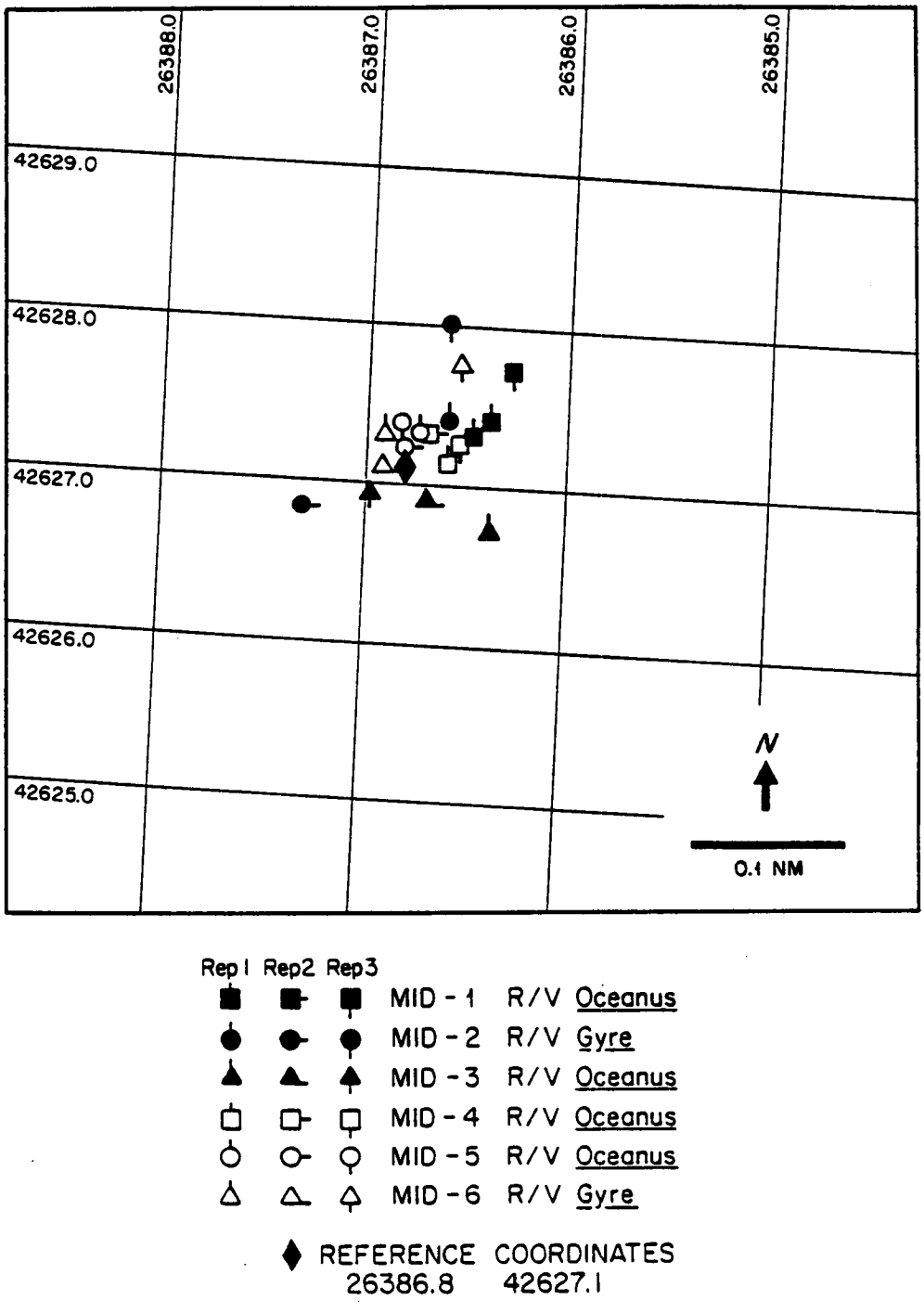


Figure B-11. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 11.

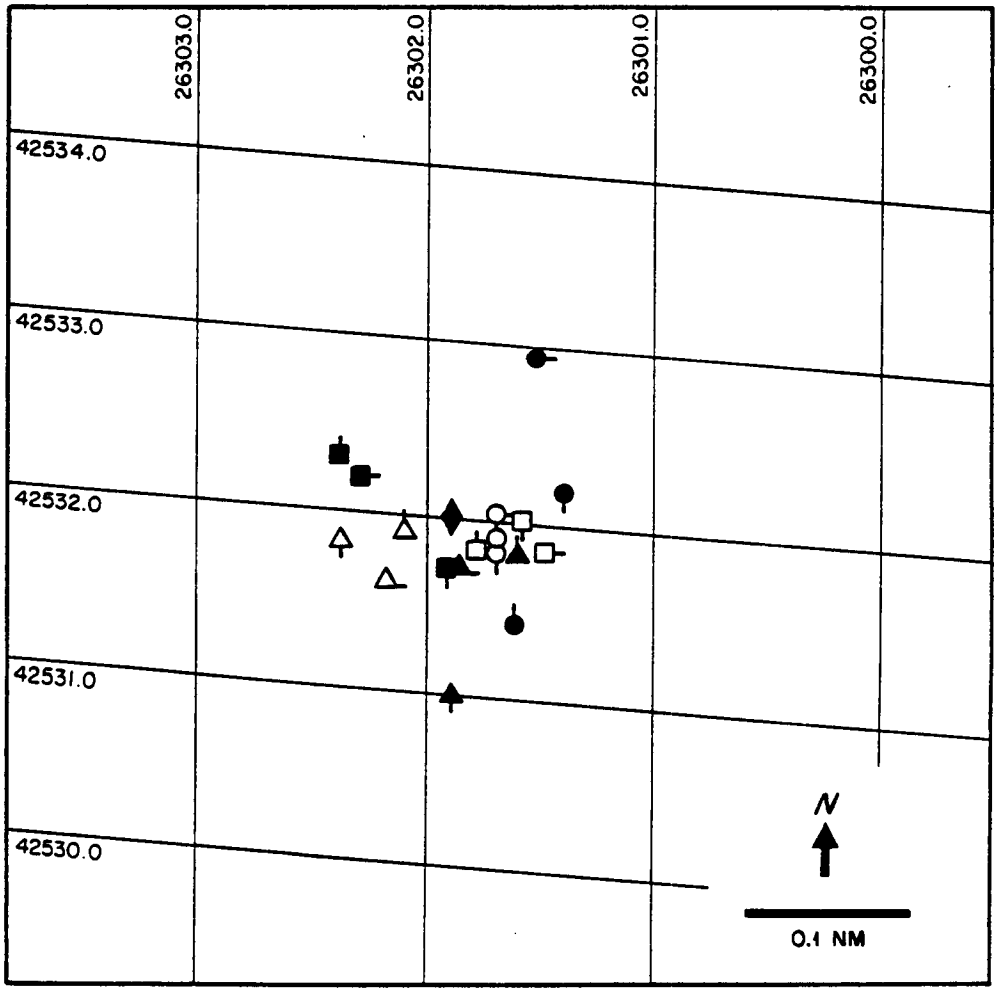


Figure B-12. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 12.

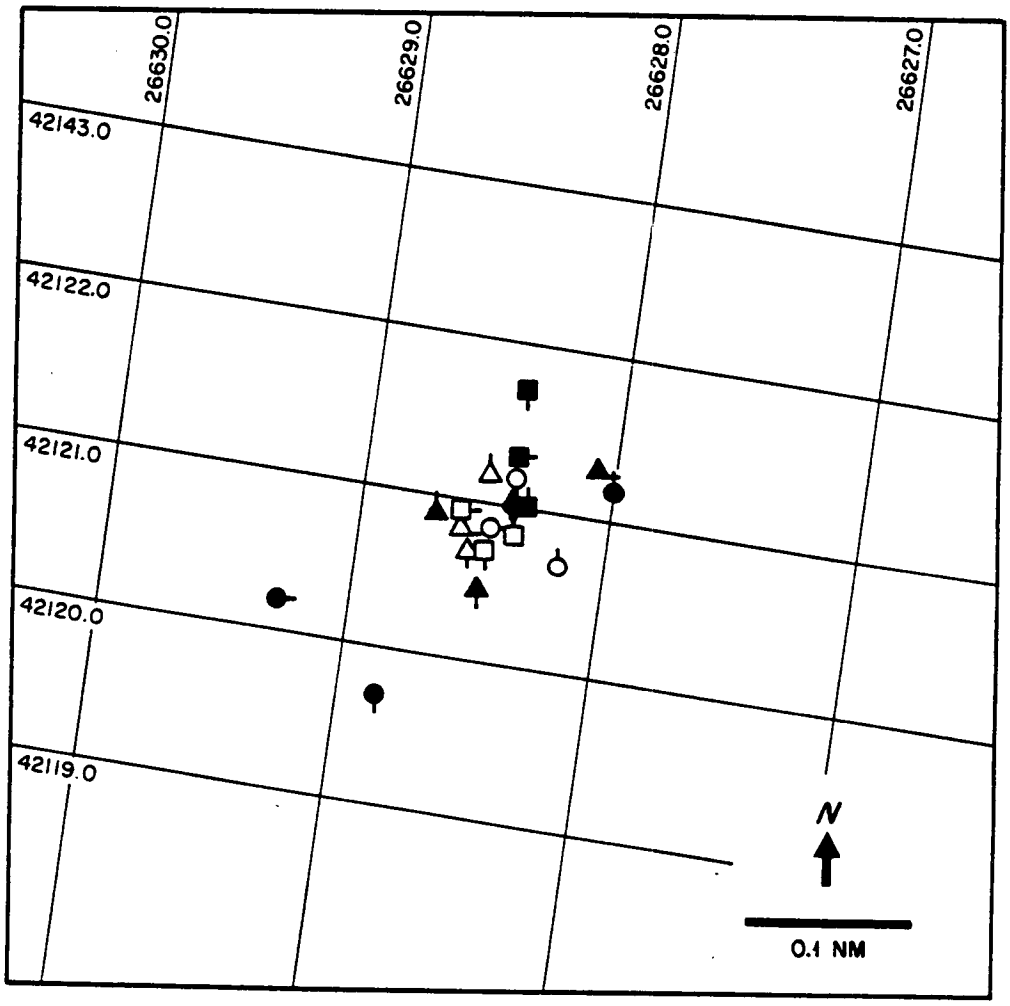


Figure B-13. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 13.

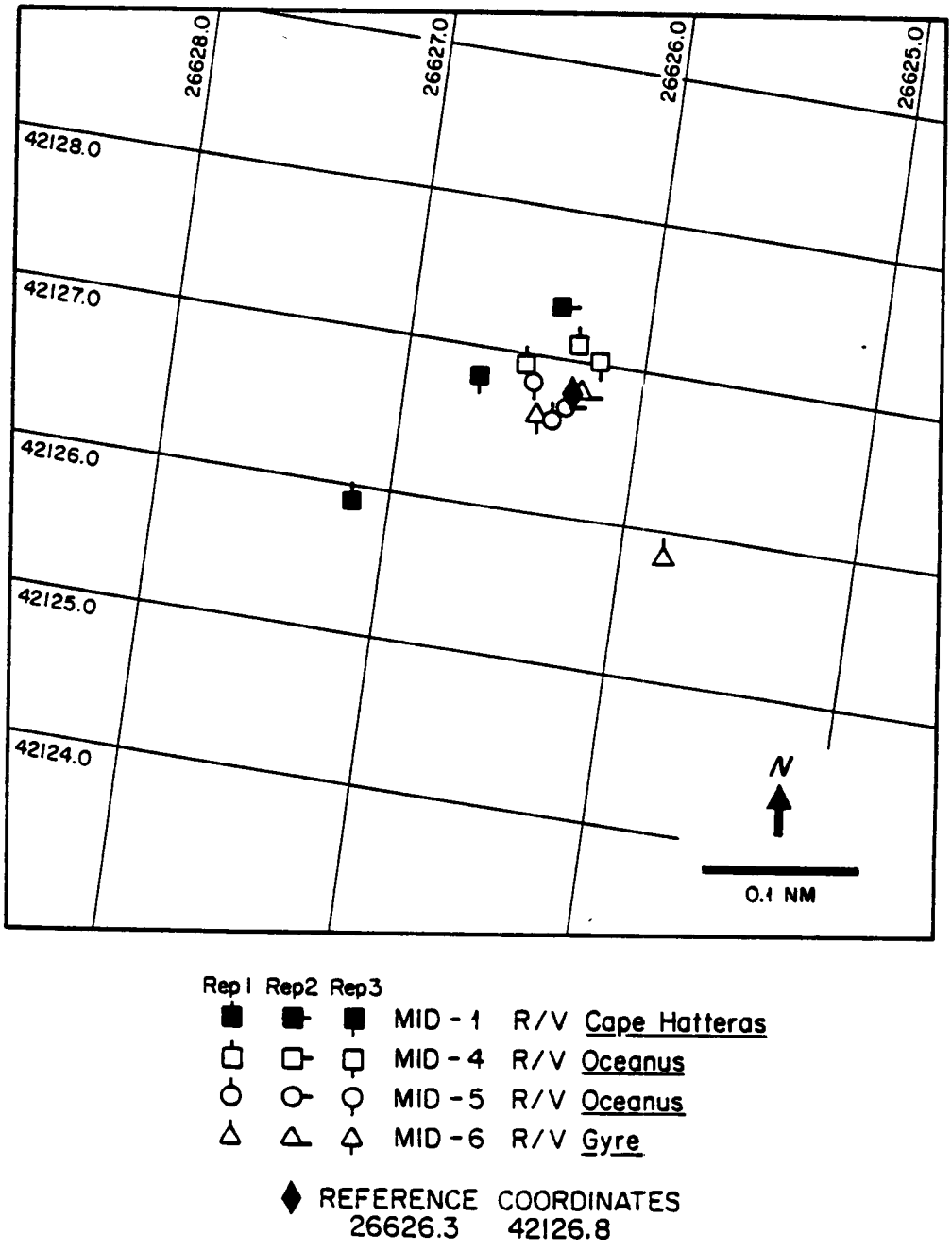


Figure B-14. Positions of replicate box cores taken at U.S. Mid-Atlantic Station 14.

APPENDIX C

TABLE C-1. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 1.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°35.90'N 72°53.12'W	26365.8 42588.7	2195
Mid-1	31 Mar 84 1620	Box Core 1	38°35.98'N 72°52.86'W	26365.6 42588.7	2195
Mid-1	31 Mar 84 2022	Box Core 2	38°36.01'N 72°52.96'W	26365.6 42589.0	2195
Mid-1	31 Mar 84 2345	Box Core 3	38°36.11'N 72°52.71'W	26364.3 42590.2	2143 *
Mid-2	3 Aug 84 1147	Box Core 1	38°36.12'N 72°53.06'W	26366.3 42590.1	2209
Mid-2	3 Aug 84 1317	Box Core 2	38°36.21'N 72°52.96'W	26365.7 42591.1	2179
Mid-2	3 Aug 84 1446	Box Core 3	38°35.99'N 72°52.87'W	26365.2 42589.0	2194
Mid-3	2 Dec 84 2058	Box Core 1	38°35.92'N 72°53.03'W	26366.0 42588.1	2165
Mid-3	2 Dec 84 2254	Box Core 2	38°35.94'N 72°53.04'W	26366.1 42588.4	2175
Mid-3	3 Dec 84 0210	Box Core 3	38°35.97'N 72°53.01'W	26366.0 42588.7	2185
Mid-4	17 May 85 0316	Box Core 1	38°35.88'N 72°53.18'W	26366.1 42588.4	2200
Mid-4	17 May 85 0542	Box Core 2	38°35.87'N 72°53.13'W	26365.8 42588.4	2180
Mid-4	17 May 85 0716	Box Core 3	38°35.88'N 72°53.13'W	26365.8 42588.5	2195
Mid-5	5 Aug 85 1149	Box Core 1	38°35.90'N 72°53.11'W	26365.7 42588.7	2185
Mid-5	5 Aug 85 1332	Box Core 2	38°35.90'N 72°53.11'W	26365.8 42588.7	2185
Mid-5	5 Aug 85 1512	Box Core 3	38°35.91'N 72°53.10'W	26365.6 42588.7	2185
Mid-6	13 Nov 85 0155	Box Core 1	38°35.85'N 72°53.14'W	26365.8 42588.2	2194
Mid-6	13 Nov 85 0427	Box Core 2	38°35.89'N 72°53.12'W	26365.8 42588.6	2199
Mid-6	13 Nov 85 0642	Box Core 3	38°35.93'N 72°53.19'W	26366.2 42588.9	2194

* Depth questionable due to superimposed noise.

TABLE C-2. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 2.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°35.78'N 72°53.65'W	26369.5 42586.2	2020
Mid-1	1 Apr 84 0304	Box Core 1	38°35.78'N 72°53.65'W	26369.6 42586.4	2013
Mid-1	1 Apr 84 0440	Box Core 2	38°35.71'N 72°53.69'W	26369.8 42585.8	2018
Mid-1	1 Apr 84 0700	Box Core 3	38°35.71'N 72°53.61'W	26369.3 42585.8	2033
Mid-2	3 Aug 84 1840	Box Core 1	38°35.77'N 72°53.58'W	26369.3 42586.5	2019
Mid-2	3 Aug 84 2015	Box Core 2	38°35.74'W 72°53.68'N	26369.7 42586.1	2014
Mid-2	3 Aug 84 2156	Box Core 3	38°35.76'N 72°53.81'W	26370.6 42586.2	2004
Mid-3	2 Dec 84 1423	Box Core 1	38°35.69'N 72°53.63'W	26369.5 42585.6	2015
Mid-3	2 Dec 84 1626	Box Core 2	38°35.75'N 72°53.67'W	26369.9 42586.2	2010
Mid-3	2 Dec 84 1803	Box Core 3	38°35.68'N 72°53.69'W	26369.8 42585.6	2015
Mid-4	17 May 85 1401	Box Core 1	38°35.66'N 72°53.81'W	26369.7 42586.0	2010
Mid-4	17 May 85 1519	Box Core 2	38°35.66'N 72°53.80'W	26369.7 42586.0	2011
Mid-4	17 May 85 1712	Box Core 3	38°35.68'N 72°53.79'W	26369.6 42586.2	2012
Mid-5	5 Aug 85 1820	Box Core 1	38°35.68'N 72°53.79'W	26369.6 42586.2	2010
Mid-5	5 Aug 85 2020	Box Core 2	38°35.70'N 72°53.75'W	26369.4 42586.4	2008
Mid-5	5 Aug 85 2158	Box Core 3	38°35.69'N 72°53.78'W	26369.6 42586.4	2005
Mid-6	13 Nov 85 1042	Box Core 1	38°35.66'N 72°53.71'N	26369.2 42586.0	2024
Mid-6	13 Nov 85 1226	Box Core 2	38°35.65'N 72°53.70'W	26369.1 42585.9	2024
Mid-6	13 Nov 85 1430	Box Core 3	38°35.83'N 72°53.91'W	26370.3 42587.5	1994

TABLE C-3. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 3.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°36.84'N 72°51.35'W	26356.0 42597.8	2055
Mid-1	5 May 84 1427	Box Core 1	38°36.88'N 72°51.41'W	26356.5 42598.3	2055
Mid-1	5 May 84 1752	Box Core 2	38°36.88'N 72°51.34'W	26356.1 42598.3	2055
Mid-1	5 May 84 1931	Box Core 3	38°36.86'N 72°51.29'W	26356.0 42598.1	2060
Mid-2	3 Aug 84 0517	Box Core 1	38°36.85'N 72°51.46'W	26357.1 42597.9	2059
Mid-2	3 Aug 84 0645	Box Core 2	38°36.87'N 72°51.45'W	26357.1 42597.9	2049
Mid-2	3 Aug 84 0948	Box Core 3	38°36.84'N 72°51.46'W	26357.1 42597.8	2056
Mid-3	3 Dec 84 0447	Box Core 1	38°36.84'N 72°51.50'W	26357.3 42597.8	2050
Mid-3	3 Dec 84 0619	Box Core 2	38°36.91'N 72°51.55'W	26357.7 42598.5	2050
Mid-3	3 Dec 84 0759	Box Core 3	38°36.81'N 72°51.55'W	26357.6 42597.5	2050
Mid-4	16 May 85 2006	Box Core 1	38°36.79'N 72°51.63'W	26357.3 42598.0	2045
Mid-4	16 May 85 2137	Box Core 2	38°36.75'N 72°51.57'W	26357.0 42597.7	2055
Mid-4	16 May 85 2310	Box Core 3	38°36.75'N 72°51.60'W	26357.1 42597.6	2052
Mid-5	5 Aug 85 0533	Box Core 1	38°36.79'N 72°51.54'W	26356.8 42598.0	2050
Mid-5	5 Aug 85 0709	Box Core 2	38°36.75'N 72°51.52'W	26356.6 42597.7	2058
Mid-5	5 Aug 85 0846	Box Core 3	38°36.82'N 72°51.54'W	26356.8 42598.4	2050
Mid-6	12 Nov 85 0330	Box Core 1	38°36.73'N 72°51.62'W	26357.2 42599.4	2064*
Mid-6	12 Nov 85 0549	Box Core 2	38°36.75'N 72°51.61'W	26357.2 42597.6	2064
Mid-6	12 Nov 85 2025	Box Core 3	38°36.77'N 72°51.64'W	26357.4 42597.8	2056

* Some core surfaces disturbed.

TABLE C-4. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 4.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°44.47'N 72°41.09'W	26297.1 42675.1	2100
Mid-1	8 May 84 0520	Box Core 1	38°44.48'N 72°41.09'W	26297.1 42675.2	2100
Mid-1	8 May 84 0604	Box Core 2	38°44.45'N 72°41.04'W	26296.8 42674.9	2108
Mid-1	8 May 84 0857	Box Core 3	38°44.36'N 72°40.97'W	26296.3 42674.3	2115
Mid-2	1 Aug 84 1731	Box Core 1	38°44.48'N 72°41.05'W	26297.2 42675.3	2124
Mid-2	1 Aug 84 1857	Box Core 2	38°44.53'N 72°41.23'W	26298.3 42675.3	2114
Mid-2	1 Aug 84 2348	Box Core 3	38°44.54'N 72°40.95'W	26296.8 42675.9	2099
Mid-3	5 Dec 84 0842	Box Core 1	38°44.36'N 72°41.21'W	26298.1 42674.0	2105
Mid-3	5 Dec 84 1027	Box Core 2	38°44.38'N 72°41.00'W	26296.9 42674.3	2110
Mid-3	5 Dec 84 1213	Box Core 3	38°44.40'N 72°41.08'W	26297.4 42674.5	2105
Mid-4	16 May 85 1038	Box Core 1	38°44.44'N 72°41.24'W	26297.3 42675.1	2100
Mid-4	16 May 85 1223	Box Core 2	38°44.45'N 72°41.26'W	26297.5 42675.2	2091
Mid-4	16 May 85 1546	Box Core 3	38°44.41'N 72°41.28'W	26297.6 42674.8	2100
Mid-5	3 Aug 85 1057	Box Core 1	38°44.43'N 72°41.24'W	26297.4 42675.0	2095
Mid-5	3 Aug 85 1237	Box Core 2	38°44.44'N 72°41.22'W	26297.2 42675.1	2095
Mid-5	3 Aug 85 1416	Box Core 3	38°44.41'N 72°41.21'W	26297.2 42674.9	2095
Mid-6	11 Nov 85 1422	Box Core 1	38°44.34'N 72°41.27'W	26297.5 42674.2	2112
Mid-6	11 Nov 85 2021	Box Core 2	38°44.40'N 72°41.25'W	26297.4 42674.8	2106
Mid-6	11 Nov 85 2220	Box Core 3	38°44.40'N 72°41.26'W	26297.4 42674.7	2105

TABLE C-5. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 5.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°50.49'N 72°33.01'W	26249.4 42734.3	2065
Mid-1	8 May 84 1244	Box Core 1	38°50.54'N 72°33.18'W	26250.1 42734.9	2055
Mid-1	4 May 84 0058	Box Core 2	38°50.53'N 72°33.10'W	26249.9 42734.3	2065
Mid-1	8 May 84 1406	Box Core 3	38°50.46'N 72°33.14'W	26249.7 42734.0	2080
Mid-2	1 Aug 84 1010	Box Core 1	38°50.42'N 72°33.03'W	26249.5 42733.7	2089
Mid-2	1 Aug 84 1145	Box Core 2	38°50.42'N 72°33.05'W	26249.6 42733.7	2089
Mid-2	1 Aug 84 1337	Box Core 3	38°50.52'N 72°32.96'W	26249.1 42734.7	2074
Mid-3	5 Dec 84 1427	Box Core 1	38°50.42'N 72°33.04'W	26249.6 42733.7	2085
Mid-3	5 Dec 84 1600	Box Core 2	38°50.40'N 72°33.12'W	26250.1 42733.6	2090
Mid-3	5 Dec 84 1726	Box Core 3	38°50.47'N 72°33.07'W	26249.7 42734.2	2070
Mid-4	16 May 85 0237	Box Core 1	38°50.46'N 72°33.23'W	26249.7 42734.2	2080
Mid-4	16 May 85 0439	Box Core 2	38°50.48'N 72°33.19'W	26249.5 42734.5	2080
Mid-4	16 May 85 0641	Box Core 3	38°50.46'N 72°33.21'W	26249.6 42734.3	2075
Mid-5	3 Aug 85 0437	Box Core 1	38°50.44'N 72°33.13'W	26249.4 42734.1	2077
Mid-5	3 Aug 85 0649	Box Core 2	38°50.42'N 72°33.24'W	26249.7 42733.9	2080
Mid-5	3 Aug 85 0821	Box Core 3	38°50.42'N 72°33.24'W	26249.8 42733.9	2081
Mid-6	11 Nov 85 0431	Box Core 1	38°50.49'N 72°33.17'W	26249.3 42734.6	2084
Mid-6	11 Nov 85 0659	Box Core 2	38°50.49'N 72°33.17'W	26249.3 42734.5	2079
Mid-6	11 Nov 85 0924	Box Core 3	38°50.44'N 72°33.20'W	26249.5 42734.1	2089

TABLE C-6. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 6.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		39°05.54'N 72°02.97'W	26063.1 42878.2	2090
Mid-1	3 May 84 1156	Box Core 1	39°05.61'N 72°02.98'W	26062.8 42877.7	2090
Mid-1	3 May 84 1108	Box Core 2	39°05.63'N 72°03.00'W	26063.0 42877.8	2088
Mid-1	3 May 84 1518	Box Core 3	39°05.59'N 72°03.00'W	26063.0 42877.6	2090
Mid-2	1 Aug 84 0039	Box Core 1	39°05.65'N 72°02.97'W	26062.7 42878.1	2084
Mid-2	1 Aug 84 0225	Box Core 2	39°05.68'N 72°02.99'W	26062.7 42878.3	2084
Mid-2	1 Aug 84 0408	Box Core 3	39°05.69'N 72°02.99'W	26062.8 42878.5	2084
Mid-3	28 Nov 84 0259	Box Core 1	39°05.58'N 72°02.81'W	26061.7 42877.4	2090
Mid-3	28 Nov 84 0439	Box Core 2	39°05.57'N 72°02.83'W	26061.9 42877.3	2090
Mid-3	28 Nov 84 0621	Box Core 3	39°05.65'N 72°03.08'W	26063.3 42878.4	2085
Mid-4	15 May 85 1639	Box Core 1	39°05.61'N 72°03.26'W	26063.5 42877.9	2090
Mid-4	15 May 85 1830	Box Core 2	39°05.66'N 72°03.25'W	26063.3 42878.3	2045
Mid-4	15 May 85 2044	Box Core 3	39°05.65'N 72°03.22'W	26063.2 42878.3	2085
Mid-5	2 Aug 85 0205	Box Core 1	39°05.65'N 72°03.22'W	26063.1 42878.2	2080
Mid-5	2 Aug 85 1139	Box Core 2	39°05.64'N 72°03.24'W	26063.3 42878.2	2080
Mid-5	2 Aug 85 1339	Box Core 3	39°05.65'N 72°03.22'W	26063.1 42878.3	2080
Mid-5	2 Aug 85 1533	Box Core Biomass 1	39°05.65'N 72°03.23'W	26063.2 42878.2	2080
Mid-5	2 Aug 85 1728	Box Core Biomass 2	39°05.66'N 72°03.19'W	26063.0 42878.3	2080
Mid-5	2 Aug 85 1949	Box Core Biomass 3	39°05.56'N 72°03.38'W	26064.1 42877.4	2080
Mid-6	10 Nov 85 1643	Box Core 1	39°05.67'N 72°03.36'W	26064.0 42878.4	2089
Mid-6	10 Nov 85 1910	Box Core 2	39°05.63'N 72°03.25'W	26063.3 42878.1	2091
Mid-6	10 Nov 85 2130	Box Core 3	39°05.51'N 72°03.16'W	26062.8 42877.0	2092

TABLE C-7 BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 7.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°27.36'N 73°03.44'W	26423.0 42499.2	2100
Mid-1	6 May 84 0138	Box Core 1	38°27.32'N 73°03.45'W	26422.9 42498.8	2110
Mid-1	6 May 84 0334	Box Core 2	38°27.30'N 73°03.43'W	26422.9 42498.7	2100
Mid-1	6 May 84 0527	Box Core 3	38°27.34'N 73°03.48'W	26423.1 42499.0	2100
Mid-2	5 Aug 84 1651	Box Core 1	38°27.34'N 73°03.41'W	26422.9 42499.0	2104
Mid-2	5 Aug 84 1847	Box Core 2	38°27.32'N 73°03.38'W	26522.8 42498.9	2104
Mid-2	5 Aug 84 2015	Box Core 3	38°27.39'N 73°03.39'W	26422.8 42499.6	2099
Mid-3	2 Dec 84 1651	Box Core 1	38°27.28'N 73°03.38'W	26422.7 42498.6	2110 *
Mid-3	2 Dec 84 1847	Box Core 2	38°27.31'N 73°03.44'W	26423.1 42498.8	2110 *
Mid-3	2 Dec 84 0626	Box Core 3	38°27.25'N 73°03.44'W	26423.1 42498.2	2110
Mid-4	18 May 85 1038	Box Core 1	38°27.26'N 73°03.55'W	26422.9 42498.9	2100
Mid-4	18 May 86 1205	Box Core 2	38°27.27'N 73°03.52'W	26422.8 42499.0	2105
Mid-4	18 May 85 1330	Box Core 3	38°27.27'N 73°03.55'W	26422.9 42499.0	2102
Mid-5	7 Aug 85 0949	Box Core 1	38°27.34'N 73°03.53'W	26422.8 42450.0	2085
Mid-5	7 Aug 985 1207	Box Core 2	38°27.32'N 73°03.54'W	26422.9 42499.5	2095
Mid-5	7 Aug 85 1347	Box Core 3	38°27.31'N 73°03.54'W	26422.8 42499.4	2088
Mid-6	14 Nov 85 1706	Box Core 1	38°27.29'N 73°03.58'W	26423.1 42499.1	2096
Mid-6	14 Nov 85 1953	Box Core 2	38°27.27'N 73°03.56'W	26422.9 42498.9	2002
Mid-6	14 Nov 85 2211	Box Core 3	38°27.28'N 73°03.54'W	26422.9 42499.0	2104

* Rough recovery, disturbed surfaces.

TABLE C-8. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 8.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°27.31'N 73°04.87'W	26431.0 42497.8	2150
Mid-1	6 May 84 0819	Box Core 1	38°27.36'N 73°05.09'W	26432.3 42498.1	2148
Mid-1	6 May 84 0942	Box Core 2	38°27.36'N 73°04.88'W	26431.2 42498.3	2150
Mid-1	6 May 84 1107	Box Core 3	38°27.36'N 73°04.81'W	26430.8 42498.3	2150
Mid-2	5 Aug 84 2337	Box Core 1	38°27.21'N 73°04.79'W	26430.8 42496.8	2159
Mid-2	6 Aug 84 0103	Box Core 2	38°27.29'N 73°04.80'W	26430.9 42497.6	2159
Mid-2	6 Aug 84 0221	Box Core 3	38°27.18'N 73°04.78'W	26430.7 42496.6	2159
Mid-3	1 Dec 84 1430	Box Core 1	38°27.25'N 73°04.79'W	26430.8 42497.2	2155 *
Mid-3	1 Dec 84 1634	Box Core 2	38°27.13'N 73°04.87'W	26431.2 42496.0	2150 *
Mid-3	1 Dec 84 2303	Box Core 3	38°27.30'N 73°04.79'W	26430.8 42497.7	2155 *

* All reps very dense clay; surface disturbed.

TABLE C-9. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 9.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°17.28'N 73°14.51'W	26480.6 42392.3	2105
Mid-1	6 May 84 1615	Box Core 1	38°17.24'N 73°14.51'W	26480.4 42392.0	2105
Mid-1	6 May 84 1910	Box Core 2	38°17.22'N 73°14.56'W	26480.8 42391.7	2108
Mid-1	6 May 84 2035	Box Core 3	38°17.23'N 73°14.60'W	26480.9 42391.7	2108
Mid-2	6 Aug 84 0700	Box Core 1	38°17.24'N 73°14.51'W	26480.6 42391.9	2109
Mid-2	6 Aug 84 0833	Box Core 2	38°17.26'N 73°14.49'W	26480.7 42392.2	2114
Mid-2	6 Aug 84 1143	Box Core 3	38°17.19'N 73°14.46'W	26480.4 42391.5	2114
Mid-3	30 Nov 84 2018	Box Core 1	38°17.20'N 73°14.38'W	26479.9 42391.7	2110
Mid-3	30 Nov 84 2340	Box Core 2	38°17.28'N 73°14.47'W	26480.4 42392.3	2105
Mid-3	1 Dec 84 0805	Box Core 3	38°17.23'N 73°14.50'W	26480.6 42391.8	2107
Mid-4	18 May 85 1904	Box Core 1	38°17.19'N 73°14.66'W	26480.6 42392.0	2100
Mid-4	18 May 85 2042	Box Core 2	38°17.20'N 73°14.65'W	26480.7 42392.2	2105
Mid-4	18 May 85 2202	Box Core 3	38°17.24'N 73°14.62'W	26480.5 42392.5	2100
Mid-5	8 Aug 85 2220	Box Core 1	38°17.24'N 73°14.63'W	26480.6 42392.6	2100
Mid-5	8 Aug 85 2354	Box Core 2	38°17.21'N 73°14.69'W	26480.9 42392.2	2100
Mid-5	9 Aug 85 0136	Box Core 3	38°17.19'N 73°14.63'W	26480.6 42392.0	2100
Mid-6	16 Nov 85 2343	Box Core 1	38°17.24'N 73°14.92'W	26482.2 42392.3	2108
Mid-6	17 Nov 85 1416	Box Core 2	38°17.12'N 73°14.88'W	26481.8 42391.1	2109
Mid-6	17 Nov 85 1641	Box Core 3	38°17.23'N 73°14.65'W	26480.7 42392.4	2104

TABLE C-10. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 10.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		37°51.80'N 73°19.84'W	26496.2 42137.0	2095
Mid-1	7 May 84 0318	Box Core 1	37°51.52'N 73°17.57'W	26496.3 42137.0	2095
Mid-1	7 May 84 0603	Box Core 2	37°51.80'N 73°19.96'W	26496.3 42136.9	2095
Mid-1	7 May 84 0729	Box Core 3	37°51.83'N 73°19.94'W	26496.3 42137.1	2095
Mid-2	7 Aug 84 1218	Box Core 1	37°51.82'N 73°19.91'W	26496.4 42137.0	2099
Mid-2	7 Aug 84 1337	Box Core 2	37°51.83'N 73°19.79'W	26495.8 42137.3	2099
Mid-2	7 Aug 84 1504	Box Core 3	37°51.83'N 73°19.70'W	26495.3 42137.4	2104
Mid-3	30 Nov 84 1159	Box Core 1	37°51.76'N 73°19.94'W	26496.5 42136.4	2100
Mid-3	30 Nov 84 1357	Box Core 2	37°51.58'N 73°19.91'W	26496.4 42137.4	2100
Mid-3	30 Nov 84 1552	Box Core 3	37°51.80'N 73°19.85'W	26496.2 42137.0	2100
Mid-4	19 May 85 0258	Box Core 1	37°51.76'N 72°20.01'W	26496.1 42137.0	2095
Mid-4	19 May 85 0435	Box Core 2	37°51.75'N 73°19.97'W	26496.0 42137.0	2095
Mid-4	19 May 85 0609	Box Core 3	37°51.73'N 73°20.01'W	26496.2 42136.8	2095
Mid-5	9 Aug 85 0639	Box Core 1	37°51.76'N 73°20.04'W	26496.3 42137.1	2095
Mid-5	9 Aug 85 0812	Box Core 2	37°51.77'N 73°20.06'W	26496.4 42137.1	2093
Mid-5	9 Aug 85 0949	Box Core 3	37°51.78'N 73°20.04'W	26496.3 42137.2	2093
Mid-5	9 Aug 85 1323	Box Core Biomass 1	37°51.75'N 73°20.05'W	26496.3 42136.9	2095
Mid-5	9 Aug 85 1457	Box Core Biomass 2	37°51.76'N 73°20.05'W	26496.3 42137.0	2090
Mid-5	9 Aug 85 1628	Box Core Biomass 3	37°51.77'N 73°20.02'W	26496.2 42137.1	2095
Mid-6	16 Nov 85 0918	Box Core 1	37°51.77'N 73°20.01'W	26496.1 42137.2	2104
Mid-6	16 Nov 85 1115	Box Core 2	37°51.76'N 73°20.00'W	26496.0 42137.2	2104
Mid-6	16 Nov 85 1348	Box Core 3	37°52.18'N 73°18.93'W	26490.7 42142.5	2114

TABLE C-11. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 11.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°40.17'N 72°56.37'W	26386.8 42627.1	1515
Mid-1	7 May 84 1434	Box Core 1	38°40.16'N 72°56.82'W	26386.4 42627.4	1515
Mid-1	7 May 84 1546	Box Core 2	38°40.19'N 72°56.31'W	26386.5 42627.3	1520
Mid-1	7 May 84 1656	Box Core 3	38°40.22'N 72°56.27'W	26386.3 42627.7	1520
Mid-2	4 Aug 84 2245	Box Core 1	38°40.20'N 72°56.30'W	26386.6 42627.4	1514
Mid-2	5 Aug 84 0026	Box Core 2	38°40.14'N 72°56.41'W	26387.3 42626.8	1509
Mid-2	5 Aug 84 0134	Box Core 3	38°40.25'N 72°56.24'W	26386.6 42628.0	1504
Mid-3	4 Dec 84 1233	Box Core 1	38°40.13'N 72°56.27'W	26386.5 42626.9	1540
Mid-3	4 Dec 84 1431	Box Core 2	38°40.14'N 72°56.31'W	26386.7 42626.9	1520
Mid-3	4 Dec 84 1620	Box Core 3	38°40.14'N 72°56.35'W	26387.3 42626.9	1520
Mid-4	17 May 85 2012	Box Core 1	38°40.10'N 72°56.43'W	26386.6 42627.2	1510
Mid-4	17 May 85 2125	Box Core 2	38°40.12'N 72°56.44'W	26386.7 42627.3	1510
Mid-4	17 May 85 2232	Box Core 3	38°40.11'N 72°56.44'W	26386.7 42627.2	1510
Mid-5	6 Aug 85 1542	Box Core 1	38°40.12'N 72°56.45'W	26386.7 42627.3	1505
Mid-5	6 Aug 85 1657	Box Core 2	38°40.12'N 72°56.47'W	26386.8 42627.2	1502
Mid-5	6 Aug 85 1814	Box Core 3	38°40.14'N 72°56.46'W	26386.8 42627.4	1502
Mid-6	13 Nov 85 1843	Box Core 1	38°40.13'N 72°56.48'W	26386.9 42627.3	1504
Mid-6	13 Nov 85 2102	Box Core 2	38°40.11'N 72°56.48'W	26386.9 42627.1	1504
Mid-6	13 Nov 85 2350	Box Core 3	38°40.06'N 72°56.41'W	26386.5 42626.7	1519 *

* Cores a bit sloped, uneven hit.

TABLE C-12. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 12.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		38°29.30'N 72°42.15'W	26301.9 42532.0	2505
Mid-1	7 May 84 2212	Box Core 1	38°29.34'N 72°42.23'W	26302.4 42532.3	2501
Mid-1	7 May 84 2341	Box Core 2	38°29.33'N 72°42.19'W	26302.3 42532.2	2500
Mid-1	8 May 84 0142	Box Core 3	38°29.33'N 72°42.24'W	26302.3 42532.2	2500
Mid-2	5 Aug 84 0810	Box Core 1	38°29.23'N 72°42.04'W	26301.6 42531.4	2509
Mid-2	5 Aug 84 1005	Box Core 2	38°29.39'N 72°42.01'W	26301.5 42532.9	2504
Mid-2	5 Aug 84 1140	Box Core 3	38°29.31'N 72°42.00'W	26301.4 42532.1	2514
Mid-3	4 Dec 84 2004	Box Core 1	38°29.29'N 72°42.05'W	26301.7 42531.9	2510
Mid-3	4 Dec 84 2222	Box Core 2	38°29.28'N 72°42.11'W	26302.0 42531.8	2507
Mid-3	5 Dec 84 0030	Box Core 3	38°29.22'N 72°42.13'W	26302.1 42531.3	2505
Mid-4	18 May 85 0229	Box Core 1	38°29.22'N 72°42.22'W	26301.8 42531.9	2505
Mid-4	18 May 85 0435	Box Core 2	38°29.22'N 72°42.17'W	26301.5 42531.8	2505
Mid-4	18 May 85 0613	Box Core 3	38°29.24'N 72°42.20'W	26301.7 42532.1	2505
Mid-5	7 Aug 85 0041	Box Core 1	38°29.23'N 72°42.21'W	26301.7 42532.0	2495
Mid-5	7 Aug 85 0239	Box Core 2	38°29.25'N 72°42.22'W	26301.8 42532.0	2495
Mid-5	7 Aug 85 0434	Box Core 3	38°29.23'N 72°42.22'W	26301.8 42531.9	2495
Mid-6	14 Nov 85 0606	Box Core 1	38°29.23'N 72°42.27'W	26302.1 42531.9	2506
Mid-6	14 Nov 85 0904	Box Core 2	38°29.20'N 72°42.29'W	26302.2 42531.6	2504
Mid-6	14 Nov 85 1110	Box Core 3	38°29.22'N 72°42.33'W	26302.4 42531.8	2499

TABLE C-13. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 13.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		37°53.33'N 73°45.09'W	26628.4 42121.0	1613
Mid-2	7 Aug 84 2156	Box Core 1	37°53.35'N 73°45.01'W	26628.0 42121.2	1614
Mid-2	7 Aug 84 2340	Box Core 2	37°53.28'N 73°45.26'W	26629.3 42120.2	1619
Mid-2	8 Aug 84 0232	Box Core 3	37°53.22'N 73°45.17'W	26628.8 42119.7	1619
Mid-3	30 Nov 84 0347	Box Core 1	37°53.32'N 73°45.10'W	26628.5 42120.9	1615
Mid-3	30 Nov 84 0548	Box Core 2	37°53.35'N 73°45.00'W	26628.1 42121.3	1615
Mid-3	30 Nov 84 0750	Box Core 3	37°53.29'N 73°45.11'W	26628.5 42120.4	1612
Mid-4	19 May 85 1043	Box Core 1	37°53.26'N 73°45.25'W	26628.4 42120.8	1615
Mid-4	19 May 85 1152	Box Core 2	37°53.29'N 73°45.30'W	26628.7 42121.0	1607
Mid-4	19 May 85 1348	Box Core 3	37°53.27'N 73°45.27'W	26628.5 42120.8	1605
Mid-5	9 Aug 85 2149	Box Core 1	37°53.26'N 73°45.21'W	26628.2 42120.8	1607
Mid-5	9 Aug 85 2310	Box Core 2	37°53.27'N 73°45.28'W	26628.5 42120.9	1605
Mid-5	10 Aug 85 0020	Box Core 3	37°53.30'N 73°45.27'W	26628.5 42121.1	1608
Mid-6	15 Nov 85 2250	Box Core 1	37°53.31'N 73°45.27'W	26628.5 42121.2	1609
Mid-6	16 Nov 85 0036	Box Core 2	37°53.27'N 73°45.30'W	26628.6 42120.8	1611
Mid-6	16 Nov 85 0231	Box Core 3	37°53.23'N 73°45.27'W	26628.5 42120.5	1607

TABLE C-14. BOX CORE POSITIONS AT MMS MID-ATLANTIC STATION 14.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Loran Time Delays	Depth (m)
	Reference Coordinates		37°53.91'N 73°44.62'W	26626.3 42126.8	1500
Mid-1	2 Apr 84 1422	Box Core 1	37°53.79'N 73°44.78'W	26627.2 42125.9	1503
Mid-1	2 Apr 84 1533	Box Core 2	37°53.91'N 73°44.62'W	26626.4 42127.3	1493
Mid-1	2 Apr 84 1722	Box Core 3	37°53.86'N 73°44.68'W	26626.7 42126.8	1503
Mid-4	19 May 85 1456	Box Core 1	37°53.81'N 73°44.81'W	26626.5 42126.9	1490
Mid-4	19 May 85 1631	Box Core 2	37°53.83'N 73°44.76'W	26626.3 42127.1	1492
Mid-4	19 May 85 1735	Box Core 3	37°53.82'N 73°44.76'W	26626.3 42127.0	1490
Mid-5	10 Aug 85 0201	Box Core 1	37°53.79'N 73°44.78'W	26626.4 42126.7	1490
Mid-5	10 Aug 85 0313	Box Core 2	37°53.79'N 73°44.79'W	26626.4 42126.7	1490
Mid-5	10 Aug 85 0425	Box Core 3	37°53.79'N 73°44.79'W	26626.5 42126.8	1490
Mid-6	15 Nov 85 1548	Box Core 1	37°53.69'N 73°44.69'W	26625.8 42125.8	1515
Mid-6	15 Nov 85 1823	Box Core 2	37°53.80'N 73°44.74'W	26626.4 42126.8	1494
Mid-6	15 Nov 85 2033	Box Core 3	37°53.77'N 73°44.77'W	26626.4 42126.6	1499

TABLE C-15. STARTING AND ENDING POSITIONS OF OTTER TRAWLS AND DAY DREDGES TAKEN IN THE U.S. MID-ATLANTIC.

Cruise	Date and Time (EST)	Sample	Latitude/ Longitude	Time Delays	Depth (m)	Comments
Mid-1	4 May 84 1536-2100	Otter Trawl	38°48.16'N 72°37.14'W to 38°42.94'N 72°46.69'W	26273.8 42711.3 to 26330.3 42658.3	2170 to 2120	Northeast to Southwest
Mid-1	4 May 84 2301 to 5 May 84 0205	Otter Trawl	38°36.27'N 72°56.25'W to 38°35.90'N 72°53.98'W	26326.3 42595.3 to 26371.4 42587.5	2375 to 2165	East to West
Mid-1	9 May 84 2230	Otter Trawl	38°28.12'N 73°12.64'W to 38°26.74'N 73°01.74'W	26476.3 42500.3 to 26413.2 42496.4	1850 to 2100	East to West
Mid-2	2 Aug 84 0304-0730	Otter Trawl	38°45.8'N 72°39.1'W to 38°41.1'N 72°45.3'W	26285.0 42689.0 to 26322.0 42642.0	2110 to 2180	Northeast to Southwest
Mid-3	8 Dec 84 0100-0600	Otter Trawl	39°39.80'N 70°54.30'W to 39°38.67'N 70°57.53'W	14559.2 43153.4 to 14578.6 43145.6	2165 to 2165	Northeast - Southwest
Mid-5	4 Aug 85 1440-1550	Otter Trawl	38°45.78'N 72°39.20'W to 38°43.46'N 72°42.26'W	26285.3 42688.5 to 26303.3 42665.5	2110 to 2160	Northeast to Southwest
Mid-5	5 Aug 85 2240 to 6 Aug 85 0052	Otter Trawl	38°36.82'N 72°51.73'W to 38°35.55'N 72°53.58'W	26357.9 42598.2 to 26368.4 42585.0	2036 to 2035	Northeast-Southwest
Mid-5	7 Aug 85 1900-1950	Otter Trawl	38°27.62'N 73°03.07'W to 38°26.45'N 73°04.63'W	26420.3 42502.7 to 26428.8 42490.3	2110 to 2210	Northeast-Southwest Net hung up on incline; was full of soft sediment.
Mid-5	10 Aug 85 1211-1239	Day Dredge 1	38°29.76'N 73°00.98'W to 38°29.99'N 73°00.68'W	26409.2 42524.9 to 26407.5 42527.3	2100 to 1880	Southwest-Northeast
Mid-5	10 Aug 85 1547-1622	Day Dredge 2	38°29.32'N 73°01.58'W to 38°29.75'N 73°00.86'W	26412.5 42520.2 to 26408.5 42524.8	2175 to 1990	Southwest-Northeast

APPENDIX D

APPENDIX D

SPECIES RECORDED FROM U.S. MID-ATLANTIC SLOPE AND RISE INFAUNAL SAMPLES

(Species marked with an * were not included in statistical analysis)

PORIFERA

*Calcarea sp. 2, sp. 3
*Porifera sp. 1, sp. 2
*Porifera olynthus sp. 2

CNIDARIA

Hydrozoa

*Cunina octonaria McCrady, 1857
Dahlgrenella farcta Miles, 1937
*Campanularia sp. 1
*Diphyes spp. indeterminate
*Egmundella superba Stechow, 1921
*Eucuspidella sp. 1
*Monobrachium parasitum Mereschkowsky, 1877
*Obelia dichotoma Linné, 1758
*Obelia nr. hyalina Clarke, 1879
*Obelia longissima Pallas, 1766
*Plumularia profunda Nutting, 1900
*Tubiclava cornucopiae Norman, 1864
Athecata sp. A
*Campanulinidae sp. 1
*Hypolitidae sp. 1, sp. 2
*Lafoeidae sp. 1
Tubularidae sp. 1
Hydrozoa sp. 1, sp. 2*, sp. 3, sp. 5*, sp. 7*, sp. 8*, sp. 11

Anthozoa

*Acanella arbuscula (Johnson, 1862)
Epizoanthus incrustatus (Duben & Koren, 1847)
Halcampa duodecimcirrata (Sars, 1851)
Kophobelemnon stelliferum (Müller, 1776)
Octocorallia sp. A
Paraedwardsia arenaria (Carlgren, 1905)
Protoptilum carpenteri Koelliker, 1872
Scleroptilum grandiflorum Koelliker, 1880
Cerianthidae sp. 1
Anthozoa sp. 1*, sp. 2, sp. 4, sp. 5, sp. 6

Scyphozoa

*Periphyla periphyla (Peron & Lesueur, 1809)
Coronatae polyp
*Scyphozoa spp. indeterminate

PLATYHELMINTHES

*Turbellaria

NEMERTEA

*Cerebratulus sp. 1
Lineus sp. 1, sp. 2
Micrura sp. 1, sp. 2
Nemertea sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 7, sp. 9, sp. 10, sp, 12, sp. 13, sp. 14, sp. 15, sp. A, sp. E, sp. F, sp. Q, sp. R, sp. S

PRIAPULIDA

Priapulopsis bicaudatus (Danielssen, 1868)
Priapulus caudatus deLamarck, 1816

ANNELIDA

Polychaeta

Acrocirridae

Flabelligella cirrata Hartman & Fauchald, 1971
Flabelligella macrochaeta (Fauchald, 1972)

Ampharetidae

Amage sp. 1
Ampharete arctica Malmgrem, 1866
Amphicteis gunneri (Sars, 1835)
Amphicteis tricophora Hartman, 1965
Amphicteis vestis Hartman, 1965
Anobothrus gracilis (Malmgren, 1866)
Anobothrus sp. 1, sp. 2
Auchinoplax crinita Ehlers, 1887
Eclysippe sp. 1, sp. 3
Glyphanostomum sp. 2
Hypaniola sp. 1
Lysippe labiata Malmgren, 1866
Melinna sp. 1
Melinnata sp. 2
Melinnampharete cf. gracilis Hartman, 1969
Mugga wahrbergi Eliason, 1955
Sabellides sp. 2
Sosanides sp. 1
Sosanopsis wireni Hessle, 1917
Ampharetidae sp. 3, sp. 7, sp. 8, sp. 11 sp. 12, sp. 13, sp. 14

Amphinomidae

Paramphinome jeffreysii (McIntosh, 1868)

Aphroditidae

Antinoana fusca Hartman & Fauchald, 1971
Aphrodite spp. juvenile

Apistobranchidae

Apistobranchus tullbergi (Théel, 1879)

Arabellidae

Drilonereis longa Webster, 1879

Capitellidae

Barantolla sp. 1, sp. 3, sp. 5
Capitella spp. complex
Dasybranchus sp. 1
Heteromastus sp. 1, sp. 2, sp. 3, sp. 4
Notomastus latericeus Sars, 1851
Notomastus cf. tenuis Moore, 1909

Notomastus teres Hartman, 1965
Notomastus sp. 2, sp. 3
Pseudocapitella cf. incerta Fauvel, 1914
Capitellidae sp. 4, sp. 5, sp. 7, sp. 8, sp. 9

Chaetopteridae
Phyllochaetopterus sp. 1

Chrysopetalidae
Dysponetus sp. 1, sp. 3, sp. 4, sp. 5, sp. 6

Cirratulidae
Caulleriella sp. 1, sp. 2, sp. 8
Chaetozone gayheadia Hartman, 1965
Chaetozone setosa Malmgren, 1867
Chaetozone sp. 1, sp. 2, sp. 4,
sp. 5, sp. 6, sp. 8, sp. 10, sp. 14
Tharyx annulosus Hartman, 1965
Tharyx dorsobranchialis (Kirkegaard, 1959)
Tharyx cf. marioni (Saint-Joseph,1894)
Tharyx nr. monilaris Hartman, 1960
Tharyx sp. 1, sp. 2, sp. 5, sp. 6, sp. 7,
sp. 8, sp. 9, sp. 11
Cirratulidae sp. 1

Cossuridae
Cossura longocirrata
Webster & Benedict, 1887
Cossura sp. 1

Dorvilleidae
Dorvillea sp. 1, sp. 2, sp. 3
Exallopus cropion Jumars, 1974
Exallopus sp. 1, sp. 2, sp. 3
Meiodorvillea minuta (Hartman, 1965)
Meiodorvillea sp. 1, sp. 2
Ophryotrocha sp. 1, sp. 2, sp. 3, sp. 4, sp. 5,
sp. 6, sp. 8
Parophryotrocha sp. 1
Pettiboneia sp. 1
Schistomeringos anoculata
(Hartman, 1965)
Schistomeringos caeca
(Webster & Benedict, 1884)
Schistomeringos sp. 3
Dorvilleidae sp. 1, sp. 2

Fauveliopsidae
Fauveliopsis brevis (Hartman, 1965)
Fauveliopsis glabra (Hartman, 1960)
Fauveliopsis olgae
Hartmann-Schroder, 1983

Flabelligeridae
Flabelligera sp. 1
Flabelligeridae sp. 3, sp. 5, sp. 13,
sp. 14, sp. 16, sp. 17

Glyceridae
Glycera capitata Ørsted, 1843
Glycera robusta Ehlers, 1868

Goniadidae
Glycinde profunda
Hartman & Fauchald, 1971
Goniada brunnea Treadwell, 1906
Goniada norvegica Ørsted, 1845

Hesionidae
Microphthalmus sczelkowii
Metschnikow, 1865
Nereimyra punctata (Müller, 1788)
Nereimyra sp. 1
Hesionidae sp. 2, sp. 3, sp. 4

Heterospionidae
Heterospio nr. longissima Ehlers, 1874

Lacydoniidae
Lacydonia cirrata
(Hartman & Fauchald, 1971)

Lumbrineridae
Augeneria bidens (Ehlers, 1887)
Lumbrineris nr. coccinea (Renier, 1804)
Lumbrineris fragilis (Müller, 1776)
Lumbrineris impatiens (Claparède, 1868)
Lumbrineris latreilli
Audouin & Milne Edwards, 1834
Lumbrineris sp. 1, sp. 2, sp. 3, sp. 6
Ninoe nr. brevipes (McIntosh, 1903)

Maldanidae
Asychis cf. biceps (Sars, 1861)
Clymenopsis sp. 1
Clymenura lankesteri (McIntosh, 1885)
Clymenura polaris (Théel, 1879)
Lumbriclymene sp. 1
Maldane sp. 2
Maldane glebifex Grube, 1860
Maldanella sp. 1
Notoproctus nr. abyssus
Hartman & Fauchald, 1971
Notoproctus nr. oculatus Arwidsson, 1907
Praxillella gracilis (Sars, 1861)
Praxillella praetermissa (Malmgren, 1866)
Praxillura cf. longissima Arwidsson, 1907
Rhodine gracilior Tauber, 1879
Maldanidae sp. 1, sp. 2, sp. 3, sp. 5,
sp. 7, sp. 8, sp. 10

Nephtyidae
- Aglaophamus sp. 1, sp. 2
- Nephtys paradoxa Malm, 1874

Nereididae
- Ceratocephale nr. abyssorum (Hartman & Fauchald, 1971)
- Ceratocephale loveni (Malmgren, 1867)
- Nereis caecoides Hartman, 1965
- Nereididae sp. 1

Onuphidae
- Hyalinoecia sp. 3
- Onuphis geophiliformis (Moore, 1903)
- Onuphis opalina (Verrill, 1873)
- Onuphis rullieriana (Amoureux, 1977)
- Onuphis sp. 1, sp. 3, sp. 4
- Paradiopatra glutinatrix Ehlers, 1887
- Sarsonuphis hartmanae (Kirkegaard, 1980)
- Sarsonuphis nr. quadricuspis (Sars, 1872)

Opheliidae
- Kesun gravieri (McIntosh, 1908)
- Ophelina abranchiata Støp-Bowitz, 1948
- Ophelina aulogastrella (Hartman & Fauchald, 1971)
- Ophelina cylindricaudata (Hansen, 1878)
- Tachytrypane cf. jeffreysii McIntosh, 1879
- Opheliidae sp. 1

Orbiniidae
- Califia schmitti (Pettibone, 1957)
- Leitoscoloplos nr. kerguelensis (McIntosh, 1885)
- Microrbina linea Hartman, 1965
- Orbinia sp. 1
- Orbiniella sp. 1, sp. 2
- Scoloplos sp. 1

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 n. gen. n. sp. 2

Paralacydoniidae
- Paralacydonia paradoxa Fauvel, 1913

Paraonidae
- Aricidea abranchiata Hartman, 1965
- Aricidea catherinae Laubier, 1967
- Aricidea nr. claudiae Laubier, 1967
- Aricidea neosuecica Hartman, 1965
- Aricidea quadrilobata Webster & Benedict, 1887
- Aricidea tetrabranchia Hartman & Fauchald, 1971
- Aricidea sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 7, sp. 9
- Levinsenia sp. 1, sp. 2, sp. 6, sp. 7, sp. 8
- Paradoneis abranchiata Hartman, 1965
- Paradoneis brevicirratus (Strelzov, 1973)
- Paradoneis lyra (Southern, 1914)
- Paradoneis sp. 2
- Paraonella sp. 1
- Sabidius cornatus (Hartman, 1965)

Pholoidiidae
- Pholoe anoculata Hartman, 1965

Phyllodocidae
- Eulalia sp. 1, sp. 2
- Eumida sp. 2, sp. 3
- Genetyllis sp. 1
- Mystides caeca Langerhans, 1879
- Mystides dayi Hartmann-Schröder, 1983
- Mystides nr. limbata Saint-Joseph, 1888
- Mystides punctata (Hartman, 1965)
- Mystides rarica (Uschakov, 1958)
- Paranaitis wahlbergi (Malmgren, 1865)
- Phyllodoce sp. 2, sp. 3
- Protomystides anoculata (Hartman & Fauchald, 1971)
- Protomystides occidentalis (Ditlevsen, 1917)
- Protomystides sp. 1, sp. 2
- Steggoa sp. 1

Pilargidae
- Ancistrosyllis nr. groenlandica McIntosh, 1879
- Ancistrosyllis jonesi Pettibone, 1966
- Sigambra sp. 1
- Synelmis sp. 1

Poecilochaetidae
Poecilochaetus fulgoris Claparède, 1875

Polynoidae
Antinoella sarsi (Malmgren, 1865)
Hermadion acanellae (Verrill, 1881)
Macellicephalinae sp. 1

Protodrilidae
Protodrilus sp. 1

Sabellariidae
Monorchos sp. 1

Sabellidae
Chone sp. 3, sp. 4
Desdemona sp. 1
Euchone hancocki Banse, 1970
Euchone incolor Hartman, 1965
Euchone papillosa (Sars, 1851)
Euchone scotiarum Hartman, 1978
Euchone sp. 3
Fabricia sp. 1
Jasmineira bermudensis Hartman, 1965
Jasmineira filiformis Hartman, 1965
Jasmineira sp. 2
Potamilla sp. 1
Sabellidae sp. 2, sp. 3, sp. 5

Scalibregmatidae
Oligobregma sp. 1
Pseudoscalibregma parvum (Hansen, 1878)
Scalibregma sp. 1
Sclerobregma branchiata Hartman, 1965

Sigalionidae
Leanira minor Hartman, 1965
Leanira sp. 2, sp. 3
Neoleanira tetragona (Ørsted, 1845)

Sphaerodoridae
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

Spionidae
Aurospio dibranchiata Maciolek, 1981
Laonice sp. 1, sp. 2, sp. 6, sp. 8, sp. 9, sp. M
Microspio sp. 1
Polydora spp. juvenile
Prionospio ehlersi Fauvel, 1928
Prionospio sp. 1, sp. 2, sp. 3, sp. 6, sp. 11, sp. 14, sp. 15, sp. 19, sp. 20, sp. 21, sp. 22
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. 3, n. gen. n. sp. 5, n. gen. n. sp. 6, n. gen. n. sp. 9, n. gen. n. sp. 10

Syllidae
Autolytus sp. 1
Braniella nr. palpata Hartman, 1967
Exogone verugera profunda Hartman, 1965
Exogone sp. 1
Sphaerosyllis sp. 1, sp. 2, sp. 3
Syllis sp. 1

Terebellidae
Lysilla sp. 1, sp. 2
Pista cristata (Muller, 1776)
Polycirrus sp. 3, sp. 4, sp. 6, sp. 7
Streblosoma sp. 1, sp. 2, sp. A
Terebellidae sp. 1, sp. 2, sp. 6, sp. 9

Trichobranchidae
Terebellides sp. 1, sp. 2, sp. 4, sp. 5, sp. 6
Trichobranchus sp. 1
Trichobranchidae sp. 2, sp. 5

Trochochaetidae
Trochochaeta watsoni (Fauvel, 1916)

Uncispionidae
Uncispionidae n. gen. n. sp. 2

Unassigned
Polychaeta sp. 2, sp. 5, sp. 6

Oligochaeta

Adelodrilus fimbriatus Erséus, 1983
Adelodrilus voraginus Cook, 1970
Bathydrilus asymetricus Cook, 1970
Bathydrilus atlanticus Erséus, 1979
Bathydrilus sandersi Erséus, 1983
Grania atlantica Coates & Erséus, 1985
Grania sp. 2
Limnodriloides medioporus Cook, 1969
Limnodriloides monothecus Cook, 1974
Limnodriloides rubicundus Erséus, 1982
Phallodrilus biparis Erséus, 1983
Phallodrilus grasslei Erséus, 1984
Phallodrilus sp. 3, sp. 4
Tubificoides aculeatus Cook, 1976
Tubificoides maureri (complex)
Brinkhurst & Baker, 1979
Tubificoides sp. 3, sp. 4

ECHIURA

Bonellidae sp. 1
Echiura sp. 1, sp. 2, sp. 3

SIPUNCULA

Apionsoma murinae Cutler, 1969
Aspidosiphon zinni Cutler, 1969
Golfingia elongata (Keferstein, 1862)
Golfingia improvisa (Théel, 1905)
Golfingia margaritacea (Sars, 1851)
Nephasoma abyssorum (Herubel, 1925)
Nephasoma bulbosum (Southern, 1913)
Nephasoma cf. capilleforme (Murina, 1973)
Nephasoma diaphanes (Gerould, 1913)
Nephasoma eremita (Sars, 1851)
Nephasoma flagriferum (Selenka, 1885)
Onchnesoma steenstrupi
Koren & Danielssen, 1875
Phascolion lutense Selenka, 1885
Phascolion strombus (Montagu, 1804)
Sipunculus norvegicus
Koren & Danielssen, 1875

POGONOPHORA

Diplobrachia floridiensis Southward, 1971
Diplobrachia similis
Southward & Brattegard, 1968
Lamellisabella nr. coronata
Southward, 1969
Nereilinum nr. punctatum Nielsen, 1965
Oligobranchia nr. floridana Nielsen, 1965
Nielsen, 1965
Polybranchia lepida
Southward & Brattegard, 1968
Siboglinum angstum
Southward & Brattegard, 1968
Siboglinum baveri Southward, 1971
Siboglinum ekmani Jaegersten, 1956
Sibloglinum longicollum
Southward & Brattegard, 1968
Siboglinum pholidotum
Southward & Brattegard, 1968
Siboglinum sp. 2, sp. 11

MOLLUSCA

Bivalvia

Abra longicallis americana
Verrill & Bush, 1898
Catillopecten eucymatus (Dall, 1898)
Cuspidaria obesa (Lovén, 1846)
Cuspidaria parva Verrill & Bush, 1898
Dacrydium sp. 1, sp. 2
Kelleilla sp. 2
Lametila abyssorum Allen & Sanders, 1973
Limatula subauriculata (Montagu, 1808)
Limopsis tenella Jeffreys, 1876
Lyonsiella abyssicola (Sars, 1872)
Malletia johnsoni Clarke, 1961
Neilonella subovata (Verrill & Bush, 1897)
Nucula cancellata Jeffreys, 1881
Nucula granulosa Verrill, 1884
Nucula subovata Verrill & Bush, 1898
Periploma sp. 1
Pristogloma alba Sanders & Allen, 1973
Pristogloma nitens (Jeffreys, 1876)
Solemya 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 (Orbigny, 1846)
Thyasira sp. 6, sp. 13, sp. 14
Tindaria sp. 2

Verticordia nr. triangularis Locard, 1898
Xyloredo sp. 1
Yoldiella curta (Verrill & Bush, 1898)
Yoldiella frigida (Torell, 1859)
Yoldiella inconspicua Verrill & Bush, 1898
Yoldiella lucida (Lovén, 1846)
Cuspidaridae sp. 3
Mytilidae sp. 1
Bivalvia sp. 7, sp. 8

Gastropoda
Aclis walleri (Jeffreys, 1884)
*Acteocina spp. indeterminate
Benthomangelia macra (Watson, 1881)
Cerithiella whiteavesii Verrill, 1880
*Clione limacina (Phipps, 1774)
Colus caelatus (Verrill & Smith, 1880)
Colus pygmaeus Gould, 1841
Crenilabrum exilis Jeffreys, 1871
*Creseis aciculata (Rang, 1828)
Cylichna alba (Brown, 1827)
Cylichna occulta Mighels & Adams, 1842
Cylichna vortex (Dall, 1881)
Diaphana spp. juvenile
Epitonium nitidum (Verrill & Smith, 1885)
Gymnobela aquilarium (Watson, 1881)
Haliella stenostoma (Jeffreys, 1858)
*Limacina inflata (Orbigny, 1836)
*Limacina retroversa (Fleming, 1823)
Lissospira sp. 1
Lunatia pallida (Broderip & Sowerby, 1829)
Odostomia eburnea (Stimpson, 1851)
Oenopota graphica (Locard, 1897)
Oenopota ovalis (Friele, 1877)
Omalogyra densicostata (Jeffreys, 1884)
Omalogyra sp. 1
*Paedoclione doliiformis Danforth, 1907
Philine sagra Orbigny, 1841
Philine sp. 1
Retusa obtusa (Montagu, 1807)
Solutiscala pyrrhias Watson, 1886
Torellia vestita Jeffreys, 1867
Turbonilla bushiana Verrill, 1882
Naticidae sp. 1
Nudibranchiata spp.
Nystiellinae sp. 1
*Pyramidellidae spp. juvenile

Scaphopoda
Antalis sp. A
Cadulus atlanticus Henderson, 1920
Cadulus nr. minusculus Dall, 1889
Cadulus pandionis Verrill & Smith, 1880
Cadulus sp. 5
Entalina platamodes (Watson, 1879)
Fissendentalium nr. meridionale (Pilsbry & Sharp, 1897)
Pulsellum affine (Sars, 1864)
Pulsellum verrilli (Henderson, 1920)

Aplacophora
Chaetoderma sp. 3, sp. 7, sp. 9, sp. 10
Falcidens sp. 2, sp. 4
Neomenia carinata Tullberg, 1875
Prochaetoderma yongei Scheltema, 1985
Spathoderma clenchi Scheltema, 1985
Uncimenia sp. 1
Lepidomeniidae sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 9, sp. 11
Neomeniidae sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6
*Wireniidae spp.

ARTHROPODA
Arachnida
*Acarina

Crustacea
Ostracoda
*Myodocopa

Malacostraca
Mysidacea
*Meterythrops robustum Smith, 1879
*Mysidacea sp. 1, sp. 2, sp. 5

Decapoda
Lucifer sp. 1
Pandalus spp. indeterminate
Sergestidae sp. 1

Cumacea
Atlantocuma n. sp. 1
Campylaspis paucinodosa Jones, 1973
Campylaspis selvakuramani (Bacescu & Muradian, 1974)
Cumella sp. 1, sp. 2
Diastylis spp. indeterminate
Eudorella hispida Sars, 1871
Eudorella pusilla Sars, 1871
Eudorella sp. 1
Hemilamprops cristatus Sars, 1870
Leptostylis macrura Sars, 1869
Leptostylis sp. 1, sp. 2
Leucon siphonatus Calman, 1904
Leucon tener Hansen, 1920
Leucon sp. 3, sp. 5, sp. 7, sp. 8

Makrokylindrus costatus (Bonnier, 1896)
Makrokylindrus tubulicauda (Calman, 1905)
Makrokylindrus sp. 2, sp. 3
Platycuma sp. 1
Vemakylindrus hastatus (Hansen, 1920)
Vaunthompsoniinae n. gen. A n. sp. 1

Tanaidacea
Agathotanais cf. hanseni Lang, 1970
Anarthrura cf. simplex G.O. Sars, 1882
Collettea cf. cylindrata (G.O. Sars, 1882)
Cryptocope cf. abbreviata (G.O. Sars, 1868)
Leptognathia cf. armata Hansen , 1913
Leptognathia breviremus (Lilljeborg, 1864)
Leptognathia indivisa (Hansen, 1913)
Leptognathia uncinata Hansen, 1913
Leptognathia sp. 5, sp. 7, sp. 12, sp. 22, sp. 28, sp. 40, sp. 41
Leptognathiella spinicauda Bird & Holdich, 1985
Leptognathiella sp. 2
Leviapseudes gracillimus (Hansen, 1913)
Macrinella sp. 2
Neotanais affinis Wolff, 1956
Neotanais sandersi Gardiner, 1975
Paragathotanais cf. typicus Lang, 1970
Paranarthrura cf. insignis Hansen, 1913
Pseudotanais sp. 1, sp. 2, sp. 3, sp. 4
Siphonolabrum sp. 2
Sphyrapus sp. 1
Stenotanais sp. 1, sp. 4
Typhlotanais nr. spinicauda Hansen, 1913
Typhlotanais trispinosus Hansen, 1913
Typhlotanais sp. 1, sp. 2, sp. 3, sp. 8, sp. 9, sp. 10, sp. 11, sp. 16
Anarthuridae sp. 1, sp. 2
Leptognathiidae sp. 1, sp. 2

Isopoda
Betamorpha fusiformis (Barnard, 1920)
Chelator insignis (Hansen, 1916)
Chelator verecundus Hessler, 1970
Chelator sp. 4
Dendrotion sp. 2
Disconectes cf. phallangium (Sars, 1864)
Disconectes sp. 1, sp. 7, sp. 20
Eugerda fulcimandibulata Hessler, 1970
Eugerda latipes (Hansen, 1916)
Eugerda tetarta Hessler, 1970
Eurycope cf. alia Wilson, 1982
Eurycope grasslei Wilson, 1982
Eurycope longiflagrata Wilson, 1983
Eurycope cf. producta G.O. Sars, 1865
Eurycope sandersi Wilson, 1982
Eurycope sp. 8, sp. 16, sp. 17
Exiliniscus clipeatus (Siebenaller & Hessler, 1981)
Gnathia sp. 1, sp. 2, sp. 3
Haplomesus sp. 2
Ilyarachna hirticeps (G.O. Sars, 1870)
Ilyarachna longicornis (G.O. Sars, 1864)
Ilyarachna sp. 1
Ischnomesus sp. 2, sp. 3, sp. 6, sp. 7
Janirella sp. 1
Macrostylis sp. 1, sp. 2
Menneurycope cf. nodifrons (Hansen, 1916)
Mirabilicoxa gracilipes (Hansen, 1916)
Mirabilicoxa similis (Hansen, 1916)
Mirabilicoxa sp. 1
Momedossa sp. 1
Munna cf. acanthifera Hansen, 1916
Munnopsis sp. 2
Munnopsurus sp. 1
Nannoniscus minutus Hansen, 1916
Nannoniscus sp. 2, sp. 3, sp. 4
Oecidiobranchus plebejum (Hansen, 1916)
Panetela wolffi (Siebenaller & Hessler, 1981)
Paramunnopsis sp. 1
Prochelator lateralis (G.O. Sars, 1899)
Pseudomesus sp. 1
Rapaniscus crassipes (Hansen, 1916)
Rapaniscus n. sp. 1
Thambema sp. 1
Whoia angusta (G.O. Sars, 1899)
Eurycopidae n. gen. M sp. 1, n. gen. Y sp. 1, n. gen. Z sp. 1

Amphipoda
Aceroides sp. 1
Amphilochus sp. 1
Astyra sp. 1
Bathymedon sp. 2, sp. 3, sp. 4, sp. 5, sp. 6
Byblis brachycephala Mills, 1971
Caleidoscopis sp. 1
Carangolia sp. 1
Cressa sp. 1
Dulichia sp. 1
*Eusirus sp. 1
Gitana sp. 1

Haploops setosa (Boeck, 1871)
Haploops sp. 2
Harpinia clivicola (Watling, 1981)
Harpinia propinqua (G.O. Sars, 1891)
Harpinia sp. 2, sp. 10
Lembos nr. megacheir (G.O. Sars, 1895)
Lepidepecreum sp. 1
Leptophoxus sp. 1
Liljeborgia sp. 1, sp. 2
Monoculodes sp. 2
Oradarea sp. 1
Pardaliscella ? symmetrica Barnard, 1959
*Protoaeginella muriculata Laubitz & Mills, 1972
*Rhachotropis sp. 1, sp. 2
Synchelidium sp. 1
Syrrhoe sp. 1
Syrrhoites sp. 1
Unciola sp. 2
Caprellidae sp. 4
*Eusiridae sp. 4, sp. 5
Liljeborgiidae n. gen. n. sp. 1
Lysianassidae sp. 1, sp. 7, sp. 10, sp. 15, sp. 16, sp. 18
Melphidippidae sp. 1
Oedicerotidae n. gen. n. sp. 1, sp. 8, sp. 9, sp. 10, sp. 11, sp. 13
Pardaliscidae sp. 4
Stenothoidae sp. 1, sp. 4, sp. 6
*Synopiidae sp. 2
Amphipoda sp. 2, sp. 5, sp. 6, sp. 7, sp. 9, sp. 10*

Pycnogonida
Nymphon spp. juvenile

BRYOZOA
Aethozoon pellucida Hayward, 1978
*Bugula sp. 1
*Ctenostomata sp. 2
*Arachnidiidae sp. 1

BRACHIOPODA
Brachiopoda sp. 3, sp. 4

ECHINODERMATA
Echinoidea
Brissopsis sp. 1
Pourtalesia sp. 1
Echinoidea sp. 1, sp. 2, sp. 3, sp. 4, sp. 5, sp. 6, sp. 7 (all juveniles)

Ophiuroidea
Amphilepis ingolfiana (Mortensen, 1933)
Amphiura palmeri (Lyman, 1882)
Ophiomusium lymani Wyv. Thomson, 1874
Ophiura ljungmani (Lyman, 1882)
Ophiura sp. 1 (juvenile)
Amphiuridae sp. 1, sp. 2, sp. 3 (all juveniles)
Ophiacanthidae sp. 1, sp. 2
Ophiuroidea sp. 2, sp. 7, sp. 9, sp. 12, sp. 13, sp. 15 (all juveniles)

Asteroidea
Pectinaster sp. 1
Porcellanaster caeruleus (Thompson, 1877)
Astropectinidae sp. 1 (juvenile)

Holothuroidea
Acanthotrochus mirabilis Danielssen & Koren, 1879
Chiridota laevis (Fabricius, 1780)
Hedingia albicans (Théel, 1886)
Labidoplax buskii (McIntosh, 1866)
Molpadia blakei (Théel, 1886)
Molpadia musculus (Risso, 1826)
Myriotrochus bathybius Clark, 1920
Myriotrochus vitreus (Sars, 1866)
Myriotrochinae sp. 1 (juvenile)
Holothuroidea sp. 2, sp. 6 (both juveniles)

HEMICHORDATA
Enteropneusta sp. 1, sp. 2, sp. 3, sp. 4

CHAETOGNATHA
*Chaetognatha spp. indeterminate

CHORDATA
*Cyclothone signata Garman, 1899
*Diaphus effulgens (Goode & Bean, 1895)
Dicarpa simplex Millar, 1955
*Myctophum affine Lütken, 1892
*Salpa fusiformis Cuvier, 1804
*Larvacea spp. indeterminate
*Thaliacea spp. indeterminate

APPENDIX E

TABLE E-1. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 1.

Species	Total Raw Count	Percent Total Fauna
1. Aurospio dibranchiata (Polychaeta)	475	6.2
2. Tharyx sp. 1 (Polychaeta)	396	5.2
3. Spathoderma clenchi (Aplacophora)	390	5.1
4. Tubificoides aculeatus (Oligochaeta)	283	3.7
5. Pholoe anoculata (Polychaeta)	268	3.5
6. Oecidiobranchus plebejum (Isopoda)	266	3.5
7. Prionospio sp. 2 (Polychaeta)	191	2.5
8. Prochaetoderma yongei (Aplacophora)	184	2.4
9. Fauvelopsis brevis (Polychaeta)	174	2.3
10. Glycera capitata (Polychaeta)	162	2.1
11. Aricidea tetrabranchia (Polychaeta)	154	2.0
12. Prionospio sp. 11 (Polychaeta)	147	1.9
13. Nemertea sp. 5 (Nemertea)	144	1.9
14. Sabidius cornatus (Polychaeta)	141	1.9
15. Thyasira subovata (Bivalvia)	136	1.8
16. Macrostylis sp. 2 (Isopoda)	123	1.6
17. Chaetozone sp. 1 (Polychaeta)	112	1.5
18. Kesun gravieri (Polychaeta)	105	1.4
19. Levinsenia sp. 1 (Polychaeta)	102	1.3
20. Nemertea sp. 2 (Nemertea)	97	1.3
	Total Cumulative Percent	53.1

TABLE E-2. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 2.

Species	Total Raw Count	Percent Total Fauna
1. Aurospio dibranchiata (Polychaeta)	601	6.9
2. Pholoe anoculata (Polychaeta)	457	5.3
3. Aricidea tetrabranchia (Polychaeta)	269	3.1
4. Prionospio sp. 2 (Polychaeta)	267	3.1
5. Aricidea abranchiata (Polychaeta)	266	3.1
6. Tharyx sp. 1 (Polychaeta)	257	3.0
7. Prochaetoderma yongei (Aplacophora)	241	2.8
8. Spathoderma clenchi (Aplacophora)	188	2.2
9. Haplomesus sp. 2 (Isopoda)	180	2.1
10. Nemertea sp. 5 (Nemertea)	166	1.9
11. Grania atlantica (Oligochaeta)	165	1.9
12. Glycera capitata (Polychaeta)	153	1.8
13. Kesun gravieri (Polychaeta)	144	1.7
14. Chelator insignis (Isopoda)	143	1.6
15. Euchone sp. 3 (Polychaeta)	139	1.6
16. Sabidius cornatus (Polychaeta)	133	1.5
17. Fauveliopsis brevis (Polychaeta)	125	1.4
18. Tubificoides aculeatus (Oligochaeta)	115	1.3
19. Lumbrineris latreilli (Polychaeta)	115	1.3
20. Notomastus latericeus (Polychaeta)	112	1.3
	Total Cumulative Percent	48.9

TABLE E-3. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 3.

Species	Total Raw Count	Percent Total Fauna
1. Aurospio dibranchiata (Polychaeta)	530	7.5
2. Pholoe anoculata (Polychaeta)	322	4.6
3. Prionospio sp. 2 (Polychaeta)	217	3.1
4. Tharyx sp. 1 (Polychaeta)	205	2.9
5. Prochaetoderma yongei (Aplacophora)	196	2.8
6. Aricidea tetrabranchia (Polychaeta)	185	2.6
7. Poecilochaetus fulgoris (Polychaeta)	169	2.4
8. Glycera capitata (Polychaeta)	165	2.3
9. Grania atlantica (Oligochaeta)	152	2.2
10. Nemertea sp. 5 (Nemertea)	145	2.1
11. Tubificoides aculeatus (Oligochaeta)	138	2.0
12. Spathoderma clenchi (Aplacophora)	131	1.9
13. Kesun gravieri (Polychaeta)	131	1.9
14. Chelator insignis (Isopoda)	124	1.8
15. Fauveliopsis brevis (Polychaeta)	117	1.7
16. Notomastus latericeus (Polychaeta)	114	1.6
17. Aricidea abranchiata (Polychaeta)	112	1.6
18. Levinsenia sp. 1 (Polychaeta)	98	1.4
19. Haplomesus sp. 2 (Isopoda)	92	1.3
20. Chaetozone sp. 1 (Polychaeta)	91	1.3
	Total Cumulative Percent	49.0

TABLE E-4. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 4.

	Species	Total Raw Count	Percent Total Fauna
1.	Aurospio dibranchiata (Polychaeta)	578	7.0
2.	Pholoe anoculata (Polychaeta)	511	6.2
3.	Tharyx sp. 1 (Polychaeta)	370	4.5
4.	Spathoderma clenchi (Aplacophora)	268	3.3
5.	Prionospio sp. 2 (Polychaeta)	261	3.2
6.	Prochaetoderma yongei (Aplacophora)	250	3.1
7.	Tubificoides aculeatus (Oligochaeta)	203	2.5
8.	Sabidius cornatus (Polychaeta)	191	2.3
9.	Oecidiobranchus plebejum (Isopoda)	183	2.2
10.	Fauveliopsis brevis (Polychaeta)	172	2.1
11.	Macrostylis sp. 2 (Isopoda)	169	2.1
12.	Dicarpa simplex (Chordata)	162	2.0
13.	Nemertea sp. 5 (Nemertea)	153	1.9
14.	Kesun gravieri (Polychaeta)	148	1.8
15.	Levinsenia sp. 1 (Polychaeta)	147	1.8
16.	Aricidea tetrabranchia (Polychaeta)	143	1.7
17.	Glycera capitata (Polychaeta)	142	1.7
18.	Haplomesus sp. 2 (Isopoda)	138	1.7
19.	Notomastus latericeus (Polychaeta)	123	1.5
20.	Grania atlantica (Oligochaeta)	117	1.4
		Total Cumulative Percent	54.0

TABLE E-5. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 5.

Species	Total Raw Count	Percent Total Fauna
1. Pholoe anoculata (Polychaeta)	563	7.4
2. Aurospio dibranchiata (Polychaeta)	438	5.7
3. Spathoderma clenchi (Aplacophora)	383	5.0
4. Tharyx sp. 1 (Polychaeta)	345	4.5
5. Prochaetoderma yongei (Aplacophora)	323	4.2
6. Tubificoides aculeatus (Oligochaeta)	240	3.1
7. Grania atlantica (Oligochaeta)	236	3.1
8. Prionospio sp. 2 (Polychaeta)	216	2.8
9. Glycera capitata (Polychaeta)	177	2.3
10. Aspidosiphon zinni (Sipuncula)	175	2.3
11. Aricidea tetrabranchia (Polychaeta)	168	2.2
12. Kesun gravieri (Polychaeta)	160	2.1
13. Fauveliopsis brevis (Polychaeta)	149	1.9
14. Lumbrineris latreilli (Polychaeta)	136	1.8
15. Nemertea sp. 5 (Nemertea)	122	1.6
16. Notomastus latericeus (Polychaeta)	114	1.5
17. Levinsenia sp. 1 (Polychaeta)	109	1.4
18. Chelator insignis (Isopoda)	106	1.4
19. Sabidius cornatus (Polychaeta)	103	1.3
20. Nemertea sp. 2 (Nemertea)	93	1.2
	Total Cumulative Percent	53.8

TABLE E-6. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 17 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 6.

Species	Total Raw Count	Percent Total Fauna
1. Aurospio dibranchiata (Polychaeta)	373	6.7
2. Pholoe anoculata (Polychaeta)	303	5.4
3. Spathoderma clenchi (Aplacophora)	241	4.3
4. Tharyx sp. 1 (Polychaeta)	227	4.1
5. Tubificoides aculeatus (Oligochaeta)	204	3.7
6. Sabidius cornatus (Polychaeta)	181	3.2
7. Prochaetoderma yongei (Aplacophora)	176	3.2
8. Prionospio sp. 2 (Polychaeta)	156	2.8
9. Notomastus latericeus (Polychaeta)	148	2.7
10. Nemertea sp. 5 (Nemertea)	125	2.2
11. Aspidosiphon zinni (Sipuncula)	113	2.0
12. Kesun gravieri (Polychaeta)	111	2.0
13. Oecidiobranchus plebejum (Isopoda)	101	1.8
14. Glycera capitata (Polychaeta)	99	1.8
15. Fauveliopsis brevis (Polychaeta)	97	1.7
16. Levinsenia sp. 1 (Polychaeta)	92	1.7
17. Aricidea tetrabranchia (Polychaeta)	84	1.5
18. Thyasira subovata (Bivalvia)	81	1.5
19. Grania atlantica (Oligochaeta)	79	1.4
20. Chaetozone sp. 1 (Polychaeta)	75	1.3
	Total Cumulative Percent	**55.0**

TABLE E-7. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 17 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 7.

	Species	Total Raw Count	Percent Total Fauna
1.	Aurospio dibranchiata (Polychaeta)	418	6.5
2.	Spathoderma clenchi (Aplacophora)	262	4.1
3.	Tubificoides aculeatus (Oligochaeta)	232	3.6
4.	Prionospio sp. 2 (Polychaeta)	198	3.1
5.	Tharyx sp. 1 (Polychaeta)	153	2.4
6.	Prochaetoderma yongei (Aplacophora)	147	2.3
7.	Pholoe anoculata (Polychaeta)	147	2.3
8.	Nemertea sp. 5 (Nemertea)	145	2.3
9.	Sabidius cornatus (Polychaeta)	133	2.1
10.	Aricidea tetrabranchia (Polychaeta)	128	2.0
11.	Glycera capitata (Polychaeta)	121	1.9
12.	Fauveliopsis brevis (Polychaeta)	118	1.8
13.	Haplomesus sp. 2 (Isopoda)	109	1.7
14.	Prionospio sp. 11 (Polychaeta)	99	1.5
15.	Chaetozone sp. 1 (Polychaeta)	95	1.5
16.	Kesun gravieri (Polychaeta)	93	1.4
17.	Chelator insignis (Isopoda)	90	1.4
18.	Prochelator lateralis (Isopoda)	87	1.4
19.	Malletia johnsoni (Bivalvia)	84	1.3
20.	Levinsenia sp. 1 (Polychaeta)	79	1.2
		Total Cumulative Percent	47.2

TABLE E-8. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 8 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 8.

	Species	Total Raw Count	Percent Total Fauna
1.	Auropsio dibranchiata (Polychaeta)	155	5.8
2.	Spathoderma clenchi (Aplacophora)	124	4.6
3.	Tharyx sp. 1 (Polychaeta)	94	3.5
4.	Tubificoides aculeatus (Oligochaeta)	90	3.4
5.	Prionospio sp. 2 (Polychaeta)	88	3.3
6.	Fauveliopsis brevis (Polychaeta)	73	2.7
7.	Nemertea sp. 5 (Nemertea)	68	2.5
8.	Pholoe anoculata (Polychaeta)	65	2.4
9.	Sabidius cornatus (Polychaeta)	60	2.2
10.	Aricidea tetrabranchia (Polychaeta)	55	2.1
11.	Prionospio sp. 11 (Polychaeta)	53	2.0
12.	Chaetozone sp. 1 (Polychaeta)	46	1.7
13.	Chelator insignis (Isopoda)	46	1.7
14.	Haplomesus sp. 2 (Isopoda)	45	1.7
15.	Prochaetoderma yongei (Aplacophora)	45	1.7
16.	Kesun gravieri (Polychaeta)	44	1.6
17.	Harpinia sp. 2 (Amphipoda)	40	1.5
18.	Glycera capitata (Polychaeta)	39	1.5
19.	Notomastus latericeus (Polychaeta)	35	1.3
20.	Lumbrineris latreilli (Polychaeta)	33	1.2
		Total Cumulative Percent	48.5

TABLE E-9. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 9.

	Species	Total Raw Count	Percent Total Fauna
1.	Aurospio dibranchiata (Polychaeta)	377	6.0
2.	Spathoderma clenchi (Aplacophora)	269	4.3
3.	Tubificoides aculeatus (Oligochaeta)	251	4.0
4.	Pholoe anoculata (Polychaeta)	198	3.1
5.	Tharyx sp. 1 (Polychaeta)	179	2.8
6.	Prochaetoderma yongei (Aplacophora)	167	2.6
7.	Prionospio sp. 2 (Polychaeta)	152	2.4
8.	Sabidius cornatus (Polychaeta)	138	2.2
9.	Aricidea tetrabranchia (Polychaeta)	131	2.1
10.	Glycera capitata (Polychaeta)	131	2.1
11.	Nemertea sp. 5 (Nemertea)	128	2.0
12.	Lumbrineris latreilli (Polychaeta)	122	1.9
13.	Fauveliopsis brevis (Polychaeta)	117	1.9
14.	Kesun gravieri (Polychaeta)	110	1.7
15.	Oecidiobranchus plebejum (Isopoda)	104	1.7
16.	Prionospio sp. 11 (Polychaeta)	104	1.7
17.	Levinsenia sp. 1 (Polychaeta)	101	1.6
18.	Dicarpa simplex (Chordata)	98	1.6
19.	Chelator insignis (Isopoda)	95	1.5
20.	Malletia johnsoni (Bivalvia)	94	1.5
		Total Cumulative Percent	48.7

TABLE E-10. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 10.

Species	Total Raw Count	Percent Total Fauna
1. Aurospio dibranchiata (Polychaeta)	616	7.6
2. Aricidea abranchiata (Polychaeta)	573	7.1
3. Prionospio sp. 2 (Polychaeta)	272	3.4
4. Spathoderma clenchi (Aplacophora)	256	3.2
5. Haplomesus sp. 2 (Isopoda)	215	2.7
6. Tharyx sp. 1 (Polychaeta)	213	2.6
7. Glycera capitata (Polychaeta)	188	2.3
8. Sabidius cornatus (Polychaeta)	181	2.2
9. Tubificoides aculeatus (Oligochaeta)	173	2.1
10. Ischnomesus sp. 2 (Isopoda)	168	2.1
11. Grania atlantica (Oligochaeta)	163	2.0
12. Notomastus latericeus (Polychaeta)	159	2.0
13. Nemertea sp. 5 (Nemertea)	148	1.8
14. Pholoe anoculata (Polychaeta)	138	1.7
15. Euchone sp. 3 (Polychaeta)	134	1.7
16. Eugerda latipes (Isopoda)	131	1.6
17. Pseudotanais sp. 2 (Tanaidacea)	125	1.6
18. Thyasira pygmaea (Bivalvia)	119	1.5
19. Nemertea sp. 2 (Nemertea)	118	1.5
20. Anobothrus sp. 1 (Polychaeta)	105	1.3
	Total Cumulative Percent	52.1

TABLE E-11. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 17 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 11.

	Species	Total Raw Count	Percent Total Fauna
1.	Prochaetoderma yongei (Aplacophora)	529	6.7
2.	Aurospio dibranchiata (Polychaeta)	520	6.6
3.	Lumbrineris latreilli (Polychaeta)	317	4.0
4.	Aricidea tetrabranchia (Polychaeta)	309	3.9
5.	Pholoe anoculata (Polychaeta)	309	3.9
6.	Tharyx sp. 1 (Polychaeta)	246	3.1
7.	Kesun gravieri (Polychaeta)	244	3.1
8.	Glycera capitata (Polychaeta)	213	2.7
9.	Prionospio sp. 11 (Polychaeta)	169	2.1
10.	Prionospio sp. 2 (Polychaeta)	158	2.0
11.	Euchone sp. 3 (Polychaeta)	149	1.9
12.	Bathydrilus asymetricus (Oligochaeta)	149	1.9
13.	Nucula granulosa (Bivalvia)	143	1.8
14.	Nemertea sp. 5 (Nemertea)	140	1.8
15.	Leptognathiella spinicauda (Tanaidacea)	130	1.7
16.	Tubificoides aculeatus (Oligochaeta)	118	1.5
17.	Aspidosiphon zinni (Sipuncula)	98	1.2
18.	Lumbrineris sp. 3 (Polychaeta)	91	1.2
19.	Dysponetus sp. 4 (Polychaeta)	84	1.1
20.	Ophelina abranchiata (Polychaeta)	74	0.9
		Total Cumulative Percent	53.1

TABLE E-12. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 12.

	Species	Total Raw Count	Percent Total Fauna
1.	Aurospio dibranchiata (Polychaeta)	586	10.1
2.	Tharyx sp. 1 (Polychaeta)	402	7.0
3.	Prionospio sp. 2 (Polychaeta)	327	5.7
4.	Myriochele sp. 1 (Polychaeta)	236	4.1
5.	Paradoneis abranchiata (Polychaeta)	191	3.3
6.	Phallodrilus grasslei (Oligochaeta)	162	2.8
7.	Glycera capitata (Polychaeta)	137	2.4
8.	Pholoe anoculata (Polychaeta)	128	2.2
9.	Nemertea sp. 5 (Nemertea)	123	2.1
10.	Aspidosiphon zinni (Sipuncula)	105	1.8
11.	Spathoderma clenchi (Aplacophora)	96	1.7
12.	Fauveliopsis brevis (Polychaeta)	90	1.6
13.	Tubificoides aculeatus (Oligochaeta)	84	1.5
14.	Chaetozone sp. 1 (Polychaeta)	77	1.3
15.	Dacrydium sp. 1 (Bivalvia)	77	1.3
16.	Sabellidae sp. 5 (Polychaeta)	73	1.3
17.	Notomastus latericeus (Polychaeta)	73	1.3
18.	Aricidea tetrabranchia (Polychaeta)	69	1.2
19.	Euchone sp. 3 (Polychaeta)	65	1.1
20.	Nucula cancellata (Bivalvia)	60	1.0
		Total Cumulative Percent	**54.8**

TABLE E-13. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 18 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 13.

Species	Total Raw Count	Percent Total Fauna
1. Aspidosiphon zinni (Sipuncula)	745	8.6
2. Prochaetoderma yongei (Aplacophora)	537	6.2
3. Glycera capitata (Polychaeta)	369	4.3
4. Aricidea tetrabranchia (Polychaeta)	344	4.0
5. Pholoe anoculata (Polychaeta)	285	3.3
6. Kesun gravieri (Polychaeta)	263	3.0
7. Tharyx sp. 1 (Polychaeta)	258	3.0
8. Aurospio dibranchiata (Polychaeta)	242	2.8
9. Tubificoides aculeatus (Oligochaeta)	202	2.3
10. Leptognathiella spinicauda (Tanaidacea)	197	2.3
11. Prionospio sp. 11 (Polychaeta)	158	1.8
12. Lumbrineris latereilli (Polychaeta)	136	1.6
13. Prionopsio sp. 2 (Polychaeta)	132	1.5
14. Nemertea sp. 5 (Nemertea)	121	1.4
15. Chaetozone sp. 1 (Polychaeta)	121	1.4
16. Anthozoa sp. 5 (Anthozoa)	101	1.2
17. Spathoderma clenchi (Aplacophora)	100	1.2
18. Dysponetus sp. 4 (Polychaeta)	98	1.1
19. Paranarthrura cf. insignis (Tanaidacea)	98	1.1
20. Nemertea sp. 2 (Nemertea)	97	1.1
	Total Cumulative Percent	53.2

TABLE E-14. DOMINANT SPECIES AND THEIR CONTRIBUTION TO THE TOTAL FAUNA RECORDED IN 12 REPLICATES TAKEN AT U.S. MID-ATLANTIC STATION 14.

Species	Total Raw Count	Percent Total Fauna
1. Aspidosiphon zinni (Sipuncula)	712	11.5
2. Prochaetoderma yongei (Aplacophora)	374	6.1
3. Paranarthrura cf. insignis (Tanaidacea)	183	3.1
4. Aurospio dibranchiata (Polychaeta)	183	3.1
5. Kesun gravieri (Polychaeta)	166	2.7
6. Aricidea tetrabranchia (Polychaeta)	162	2.6
7. Glycera capitata (Polychaeta)	144	2.3
8. Leptognathiella spinicauda (Tanaidacea)	139	2.3
9. Prionospio sp. 11 (Polychaeta)	136	2.2
10. Poecilochaetus fulgoris (Polychaeta)	110	1.8
11. Tharyx sp. 1 (Polychaeta)	98	1.6
12. Pholoe anoculata (Polychaeta)	98	1.6
13. Nephasoma diaphanes (Sipuncula)	83	1.3
14. Nemertea sp. 5 (Nemertea)	83	1.3
15. Harpinia propinqua (Amphipoda)	74	1.2
16. Dysponetus sp. 4 (Polychaeta)	73	1.2
17. Priapulus caudatus (Priapulida)	70	1.1
18. Chaetozone sp. 1 (Polychaeta)	60	1.0
19. Agathotanais cf. hanseni (Tanaidacea)	60	1.0
20. Nemertea sp. 2 (Nemertea)	59	1.0
	Total Cumulative Percent	**50.0**

APPENDIX F

TABLE F-1. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 1.

April/May 1984	August 1984	November 1984
Tharyx sp. 1	Aurospio dibranchiata	Tharyx sp. 1
Aurospio dibranchiata	Tharyx sp. 1	Spathoderma clenchi
Pholoe anoculata	Pholoe anoculata	Aurospio dibranchiata
Spathoderma clenchi	Spathoderma clenchi	Tubificoides aculeatus
Tubificoides aculeatus	Tubificoides aculeatus	Pholoe anoculata
Prochaetoderma yongei	Oecidiobranchus plebejum	Fauveliopsis brevis
Fauveliopsis brevis	Prionospio sp. 11	Nemertea sp. 5
Aricidea tetrabranchia	Nemertea sp. 5	Prionospio sp. 2
Haplomesus sp. 2	Glycera capitata	Oecidiobranchus plebejum
Glycera capitata	Fauveliopsis brevis	Prochaetoderma yongei
Thyasira subovata	Prochaetoderma yongei	Glycera capitata
Prionospio sp. 2	Thyasira subovata	Prionospio sp. 11
Levinsenia sp. 1	Aricidea tetrabranchia	Macrostylis sp. 2
Dicarpa simplex	Sabidius cornatus	Sabidius cornatus
Prionospio sp. 11	Prionospio sp. 2	Chaetozone sp. 1
Euchone sp. 3	Kesun gravieri	Levinsenia sp. 1
Kesun gravieri	Euchone sp. 3	Thyasira subovata
Nemertea sp. 5	Chaetozone sp. 1	Aricidea tetrabranchia
Paranarthrura cf. insignis	Macrostylis sp. 2	Euchone sp. 3
Mirabilicoxa similis	Malletia johnsoni	Chaetozone sp. 10
May 1985	**August 1985**	**November 1985**
Spathoderma clenchi	Oecidiobranchus plebejum	Aurospio dibranchiata
Oecidiobranchus plebejum	Aurospio dibranchiata	Spathoderma clenchi
Tubificoides aculeatus	Spathoderma clenchi	Tharyx sp. 1
Aurospio dibranchiata	Anarthruridae sp. 2	Tubificoides aculeatus
Tharyx sp. 1	Aricidea tetrabranchia	Pholoe anoculata
Pholoe anoculata	Tharyx sp. 1	Prionospio sp. 2
Prionospio sp. 2	Prionspio sp. 2	Chaetozone sp. 1
Prochaetoderma yongei	Fauveliopsis brevis	Glycera capitata
Chaetozone sp. 1	Pholoe anoculata	Prochaetoderma yongei
Anarthruridae sp. 2	Prochaetoderma yongei	Kesun gravieri
Sabidius cornatus	Tubificoides aculeatus	Sabidius cornatus
Glycera capitata	Sabidius cornatus	Thyasira subovata
Nemertea sp. 2	Nemertea sp. 5	Nemertea sp. 5
Macrostylis sp. 2	Prionospio sp. 11	Prionospio sp. 11
Fauveliopsis brevis	Kesun gravieri	Fauveliopsis brevis
Haplomesus sp. 2	Euchone sp. 3	Macrostylis sp. 2
Aricidea tetrabranchia	Glycera capitata	Notomastus latericeus
Thyasira subovata	Notomastus latericeus	Malletia johnsoni
Nemertea sp. 5	Macrostylis sp. 2	Yoldiella curta
Prochelator lateralis	Thyasira subovata	Aricidea tetrabranchia

TABLE F-2. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 2.

April/May 1984	August 1984	November 1984
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Pholoe anoculata	Pholoe anoculata	Pholoe anoculata
Prionospio sp. 2	Aricidea tetrabranchia	Prionospio sp. 2
Aricidea tetrabranchia	Prionospio sp. 2	Aricidea abranchiata
Haplomesus sp. 2	Haplomesus sp. 2	Aricidea tetrabranchia
Aricidea abranchiata	Aricidea abranchiata	Tharyx sp. 1
Tharyx sp. 1	Prochaetoderma yongei	Chelator insignis
Prochaetoderma yongei	Spathoderma clenchi	Prochaetoderma yongei
Glycera capitata	Chelator insignis	Nemertea sp. 5
Euchone sp. 3	Tharyx sp. 1	Kesun gravieri
Grania atlantica	Sabidius cornatus	Glycera capitata
Nemertea sp. 2	Nemertea sp. 5	Lumbrineris latreilli
Prionospio sp. 11	Euchone sp. 3	Aspidosiphon zinni
Tubificoides aculeatus	Myriochele sp. 1	Grania atlantica
Sabidius cornatus	Dicarpa simplex	Euchone sp. 3
Poecilochaetus fulgoris	Prionospio sp. 11	Spathoderma clenchi
Nemertea sp. 5	Kesun gravieri	Levinsenia sp. 1
Spathodermi clenchi	Yoldiella curta	Mirabilicoxa similis
Levinsenia sp. 1	Notomastus latericeus	Haplomesus sp. 2
Anobothrus sp. 1	Thyasira subovata	Typhlotanais sp. 3
May 1985	**August 1985**	**November 1985**
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Pholoe anoculata	Pholoe anoculata	Pholoe anoculata
Aricidea abranchiata	Prochaetoderma yongei	Prionospio sp. 2
Tharyx sp. 1	Aricidea abranchiata	Tharyx sp. 1
Prochaetoderma yongei	Tharyx sp. 1	Glycera capitata
Aricidea tetrabranchia	Prionospio sp. 2	Haplomesus sp. 2
Spathoderma clenchi	Aricidea tetrabranchia	Aricidea tetrabranchia
Prionospio sp. 2	Mirabilicoxa similis	Notomastus latericeus
Grania atlantica	Grania atlantica	Grania atlantica
Kesun gravieri	Spathoderma clenchi	Nucula cancellata
Paranarthrura cf. insignis	Sabidius cornatus	Nemertea sp. 5
Lumbrineris latreilli	Nemertea sp. 5	Euchone sp. 3
Nemertea sp. 5	Fauveliopsis brevis	Thyasira pygmaea
Levinsenia sp. 1	Chelator insignis	Nemertea sp. 2
Nemertea sp. 2	Lumbrineris latreilli	Poecilochaetus fulgoris
Haplomesus sp. 2	Thyasira ferruginea	Kesun gravieri
Thyasira ferruginea	Glycera capitata	Tubificoides aculeatus
Sabidius cornatus	Kesun gravieri	Fauveliopsis brevis
Fauveliopsis brevis	Prionospio sp. 11	Sabidius cornatus
Euchone sp. 3	Tubificoides aculeatus	Aricidea abranchiata

TABLE F-3. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 3.

April/May 1984	August 1984	November 1984
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Tharyx sp. 1	Poecilochaetus fulgoris	Prochaetoderma yongei
Pholoe anoculata	Aricidea tetrabranchia	Poecilochaetus fulgoris
Aricidea tetrabranchia	Prionospio sp. 2	Glycera capitata
Prionospio sp. 2	Aricidea abranchiata	Aricidea tetrabranchia
Glycera capitata	Glycera capitata	Euchone sp. 3
Tubificoides aculeatus	Pholoe anoculata	Spathoderma clenchi
Grania atlantica	Nemertea sp. 5	Nemertea sp. 5
Prochaetoderma yongei	Fauveliopsis brevis	Kesun gravieri
Kesun gravieri	Prochaetoderma yongei	Tubificoides aculeatus
Spathoderma clenchi	Tharyx sp. 1	Grania atlantica
Levinsenia sp. 1	Levinsenia sp. 1	Fauveliopsis brevis
Fauveliopsis brevis	Sclerobregma branchiata	Pholoe anoculata
Chelator insignis	Trochochaeta watsoni	Prionospio sp. 2
Poecilochaetus fulgoris	Maldanidae sp. 3	Chelator insignis
Thyasira ferruginea	Notomastus latericeus	Thyasira subovata
Aricidea abranchiata	Kesun gravieri	Chaetozone sp. 1
Dysponetus sp. 4	Chelator insignis	Sabidius cornatus
Nemertea sp. 5	Falcidens sp. 4	Agathotanais cf. hanseni
Anobothrus sp. 1	Thyasira ferruginea	Tharyx sp. 1

May 1985	August 1985	November 1985
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Pholoe anoculata	Pholoe anoculata	Prionospio sp. 2
Prionospio sp. 2	Grania atlantica	Pholoe anoculata
Tharyx sp. 1	Mirabilicoxa similis	Nemertea sp. 5
Prochaetoderma yongei	Prionospio sp. 2	Prochaetoderma yongei
Aricidea tetrabranchia	Chelator insignis	Tharyx sp. 1
Spathoderma clenchi	Poecilochaetus fulgoris	Kesun gravieri
Grania atlantica	Tubificoides aculeatus	Chaetozone sp. 1
Typhlotanais sp. 1	Nemertea sp. 5	Notomastus latericeus
Euchone sp. 3	Glycera capitata	Tubificoides aculeatus
Glycera capitata	Phallodrilus grasslei	Chelator insignis
Notomastus latericeus	Notomastus latericeus	Aricidea tetrabranchia
Fauveliopsis brevis	Aricidea tetrabranchia	Haplomesus sp. 2
Aricidea abranchiata	Lepidomeniidae sp. 1	Spathoderma clenchi
Tubificoides aculeatus	Tharyx sp. 1	Nucula cancellata
Poecilochaetus fulgoris	Prochaetoderma yongei	Grania atlantica
Kesun gravieri	Kesun gravieri	Glycera capitata
Aspidosiphon zinni	Chaetozone sp. 1	Sabidius cornatus
Chelator insignis	Aspidosiphon zinni	Nemertea sp. 2
Nemertea sp. 5	Levinsenia sp. 1	Levinsenia sp. 1

TABLE F-4. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 4.

April/May 1984	August 1984	November 1984
Aurospio dibranchiata	Pholoe anoculata	Aurospio dibranchiata
Tharyx sp. 1	Tharyx sp. 1	Prionospio sp. 2
Pholoe anoculata	Aurospio dibranchiata	Tharyx sp. 1
Spathoderma clenchi	Prochaetoderma yongei	Oecidiobranchus plebejum
Prionospio sp. 2	Tubificoides aculeatus	Haplomesus sp. 2
Prochaetoderma yongei	Spathoderma clenchi	Dicarpa simplex
Fauveliopsis brevis	Sabidius cornatus	Nemertea sp. 5
Oecidiobranchus plebejum	Fauveliopsis brevis	Kesun gravieri
Levinsenia sp. 1	Prionospio sp. 2	Pholoe anoculata
Haplomesus sp. 2	Aricidea tetrabranchia	Spathoderma clenchi
Tubificoides aculeatus	Levinsenia sp. 1	Grania atlantica
Grania atlantica	Nemertea sp. 5	Aricidea tetrabranchia
Kesun gravieri	Macrostylis sp. 2	Glycera capitata
Glycera capitata	Nucula cancellata	Tubificoides aculeatus
Macrostylis sp. 2	Pulsellum verrilli	Euchone sp. 3
Sabidius cornatus	Glycera capitata	Fauveliopsis brevis
Aricidea tetrabranchia	Prionospio sp. 11	Nemertea sp. 2
Nemertea sp. 2	Neilonella subovata	Macrostylis sp. 2
Euchone sp. 3	Dicarpa simplex	Prochaetoderma yongei
Nemertea sp. A	Thyasira subovata	Prionospio sp. 11

May 1985	August 1985	November 1985
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Pholoe anoculata	Pholoe anoculata	Pholoe anoculata
Tharyx sp. 1	Tharyx sp. 1	Prionospio sp. 2
Spathoderma clenchi	Spathoderma clenchi	Prochaetoderma yongei
Prochaetoderma yongei	Sabidius cornatus	Macrostylis sp. 2
Sabidius cornatus	Tubificoides aculeatus	Oecidiobranchus plebejum
Dicarpa simplex	Prionospio sp. 2	Spathoderma clenchi
Fauveliopsis brevis	Prochaetoderma yongei	Tharyx sp. 1
Macrostylis sp. 2	Dicarpa simplex	Nemertea sp. 2
Prionospio sp. 2	Oecidiobranchus plebejum	Chaetozone sp. 1
Notomastus latericeus	Nemertea sp. 5	Nemertea sp. 5
Kesun gravieri	Fauveliopsis brevis	Sabidius cornatus
Tubificoides aculeatus	Macrostylis sp. 2	Notomastus latericeus
Glycera capitata	Levinsenia sp. 1	Tubificoides aculeatus
Aricidea tetrabranchia	Glycera capitata	Nucula cancellata
Oecidiobranchus plebejum	Thyasira subovata	Haplomesus sp. 2
Levinsenia sp. 1	Notomastus latericeus	Levinsenia sp. 1
Nemertea sp. 5	Prionospio sp. 11	Paranarthrura cf. insignis
Lumbrineris latreilli	Grania atlantica	Glycera capitata
Grania atlantica	Kesun gravieri	Kesun gravieri

TABLE F-5. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 5.

April/May 1984	August 1984	November 1984
Pholoe anoculata	Pholoe anoculata	Pholoe anoculata
Tharyx sp. 1	Tharyx sp. 1	Aurospio dibranchiata
Aurospio dibranchiata	Spathoderma clenchi	Spathoderma clenchi
Spathoderma clenchi	Prochaetoderma yongei	Prochaetoderma yongei
Prochaetoderma yongei	Aurospio dibranchiata	Prionospio sp. 2
Grania atlantica	Tubificoides aculeatus	Tubificoides aculeatus
Tubificoides aculeatus	Glycera capitata	Glycera capitata
Aricidea tetrabranchia	Aspidiosiphon zinni	Tharyx sp. 1
Prionospio sp. 2	Grania atlantica	Grania atlantica
Fauveliopsis brevis	Aricidea tetrabranchia	Fauveliopsis brevis
Glycera capitata	Nemertea sp. 5	Lumbrineris latreilli
Kesun gravieri	Kesun gravieri	Aricidea tetrabranchia
Levinsenia sp. 1	Prionospio sp. 2	Levinsenia sp. 1
Lumbrineris latreilli	Malletia johnsoni	Chelator insignis
Notomastus latericeus	Notomastus latericeus	Aspidosiphon zinni
Chelator insignis	Fauveliopsis brevis	Typhlotanais sp. 3
Chaetozone sp. 1	Prionospio sp. 11	Nemertea sp. 2
Nemertea sp. 5	Lumbrineris latreilli	Kesun gravieri
Aspidosiphon zinni	Nucula cancellata	Sabidius cornatus
Paramphinome jeffreysii	Ophelina abranchiata	Nucula cancellata

May 1985	August 1985	November 1985
Pholoe anoculata	Prochaetoderma yongei	Aurospio dibranchiata
Spathoderma clenchi	Spathoderma clenchi	Pholoe anoculata
Aurospio dibranchiata	Aurospio dibranchiata	Tharyx sp. 1
Tharyx sp. 1	Pholoe anoculata	Prionospio sp. 2
Prochaetoderma yongei	Grania atlantica	Grania atlantica
Aspidosiphon zinni	Tharyx sp. 1	Spathoderma clenchi
Tubificoides aculeatus	Kesun gravieri	Prochaetoderma yongei
Grania atlantica	Prionospio sp. 2	Aspidosiphon zinni
Haliella stenostoma	Tubificoides aculeatus	Tubificoides aculeatus
Fauveliopsis brevis	Lumbrineris latreilli	Kesun gravieri
Glycera capitata	Notomastus latericeus	Aricidea tetrabranchia
Aricidea tetrabranchia	Aspidosiphon zinni	Notomastus latericeus
Prionospio sp. 2	Aricidea tetrabranchia	Glycera capitata
Chelator insignis	Nemertea sp. 5	Fauveliopsis brevis
Mirabilicoxa similis	Yoldiella curta	Chaetozone sp. 1
Sabidius cornatus	Nemertea sp. 2	Nemertea sp. 2
Lumbrineris latreilli	Prionospio sp. 11	Nemertea sp. 5
Augeneria bidens	Fauveliopsis brevis	Levinsenia sp. 1
Kesun gravieri	Sabidius cornatus	Sabidius cornatus
Nemertea sp. 5	Glycera capitata	Nemertea sp. A

TABLE F-6. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 6.

April/May 1984	August 1984	November 1984
Pholoe anoculata	Spathoderma clenchi	Aurospio dibranchiata
Aurospio dibranchiata	Aurospio dibranchiata	Pholoe anoculata
Tharyx sp. 1	Tharyx sp. 1	Tubificoides aculeatus
Spathoderma clenchi	Pholoe anoculata	Spathoderma clenchi
Prochaetoderma yongei	Tubificoides aculeatus	Sabidius cornatus
Tubificoides aculeatus	Prochaetoderma yongei	Prochaetoderma yongei
Prionospio sp. 2	Notomastus latericeus	Prionospio sp. 2
Notomastus latericeus	Nemertea sp. 5	Tharyx sp. 1
Aspidosiphon zinni	Oecidiobranchus plebejum	Notomastus latericeus
Glycera capitata	Glycera capitata	Aspidosiphon zinni
Sabidius cornatus	Sabidius cornatus	Levinsenia sp. 1
Levinsenia sp. 1	Aspidosiphon zinni	Thyasira subovata
Kesun gravieri	Aricidea tetrabranchia	Kesun gravieri
Fauveliopsis brevis	Kesun gravieri	Fauveliopsis brevis
Chaetozone sp. 1	Prionospio sp. 2	Chelator insignis
Aricidea abranchiata	Nucula cancellata	Grania atlantica
Nemertea sp. 5	Prochelator lateralis	Glycera capitata
Aricidea tetrabranchia	Fauveliopsis brevis	Aricidea tetrabranchia
Prionospio sp. 11	Prionospio sp. 11	Prionospio sp. 11
Oecidiobranchus plebejum	Dicarpa simplex	Nemertea sp. 5
May 1985	**August 1985**	**November 1985**
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Pholoe anoculata	Sabidius cornatus	Pholoe anoculata
Spathoderma clenchi	Tubificoides aculeatus	Tharyx sp. 1
Prionospio sp. 2	Spathoderma clenchi	Spathoderma clenchi
Sabidius cornatus	Prochaetoderma yongei	Tubificoides aculeatus
Nemertea sp. 5	Tharyx sp. 1	Prochaetoderma yongei
Tharyx sp. 1	Pholoe anoculata	Thyasira subovata
Tubificoides aculeatus	Notomastus latericeus	Chaetozone sp. 1
Oecidiobranchus plebejum	Kesun gravieri	Nemertea sp. 5
Notomastus latericeus	Prionospio sp. 2	Prionospio sp. 2
Fauveliopsis brevis	Grania atlantica	Sabidius cornatus
Dicarpa simplex	Nemertea sp. 5	Nemertea sp. 2
Aricidea abranchiata	Aspidosiphon zinni	Oecidiobranchus plebejum
Aspidosiphon zinni	Malletia johnsoni	Grania atlantica
Levinsenia sp. 1	Thyasira subovata	Notomastus latericeus
Kesun gravieri	Glycera capitata	Kesun gravieri
Prochaetoderma yongei	Aricidea abranchiata	Glycera capitata
Aricidea tetrabranchia	Levinsenia sp. 1	Nucula cancellata
Glycera capitata	Oecidiobranchus plebejum	Aricidea tetrabranchia
Chaetozone sp. 1	Aricidea tetrabranchia	Levinsenia sp. 1

TABLE F-7. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 7.

April/May 1984	August 1984	November 1984
Tubificoides aculeatus	Aurospio dibranchiata	Aurospio dibranchiata
Aurospio dibranchiata	Spathoderma clenchi	Spathoderma clenchi
Spathoderma clenchi	Pholoe anoculata	Prionospio sp. 2
Prochaetoderma yongei	Sabidius cornatus	Tubificoides aculeatus
Tharyx sp. 1	Nemertea sp. 5	Aricidea tetrabranchia
Prionospio sp. 2	Tubificoides aculeatus	Prochaetoderma yongei
Prionospio sp. 11	Prochaetoderma yongei	Sabidius cornatus
Glycera capitata	Prionospio sp. 2	Nemertea sp. 5
Nemertea sp. 5	Prionospio sp. 11	Prionospio sp. 11
Chaetozone sp. 1	Aricidea tetrabranchia	Haplomesus sp. 2
Pholoe anoculata	Fauveliopsis brevis	Aspidosiphon zinni
Kesun gravieri	Myriotrochinae sp. 1 (juv.)	Pholoe anoculata
Sabidius cornatus	Chaetozone sp. 1	Fauveliopsis brevis
Haplomesus sp. 2	Tharyx sp. 1	Tharyx sp. 1
Anobothrus sp. 1	Mirabilicoxa similis	Grania atlantica
Levinsenia sp. 1	Glycera capitata	Galathowenia sp. 1
Agathotanais cf. hanseni	Kesun gravieri	Malletia johnsoni
Paranarthrura cf. insignis	Levinsenia sp. 1	Augeneria bidens
Nemertea sp. 2	Aspidosiphon zinni	Kesun gravieri
Falcidens sp. 4	Malletia johnsoni	Glycera capitata

May 1985	August 1985	November 1985
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Spathoderma clenchi	Spathoderma clenchi	Prionospio sp. 2
Tubificoides aculeatus	Prochelator lateralis	Spathoderma clenchi
Prionospio sp. 2	Tubificoides aculeatus	Tharyx sp. 1
Chaetozone sp. 1	Aricidea tetrabranchia	Chelator insignis
Fauveliopsis brevis	Pholoe anoculata	Tubificoides aculeatus
Agathotanais cf. hanseni	Fauveliopsis brevis	Nemertea sp. 5
Notomastus latericeus	Nemertea sp. 5	Thyasira pygmaea
Haliella stenostoma	Glycera capitata	Pholoe anoculata
Chaetozone sp. 10	Prionospio sp. 2	Glycera capitata
Aricidea tetrabranchia	Prochaetoderma yongei	Myriotrochinae sp. 1 (juv.)
Haplomesus sp. 2	Haplomesus sp. 2	Chaetozone sp. 1
Glycera capitata	Sabidius cornatus	Sabidius cornatus
Tharyx sp. 1	Malletia johnsoni	Typhlotanais sp. 1
Pholoe anoculata	Tharyx sp. 1	Haplomesus sp. 2
Sabidius cornatus	Kesun gravieri	Prochelator lateralis
Myriotrochinae sp. 1 (juv.)	Chelator insignis	Grania atlantica
Dysponetus sp. 4	Paramphinome jeffreysii	Kesun gravieri
Levinsenia sp. 1	Prionospio sp. 11	Nemertea sp. 2
Malletia johnsoni	Thyasira pygmaea	Paranarthrura cf. insignis

TABLE F-8. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 8.

April/May 1984	August 1984	November 1984
Spathoderma clenchi	Aurospio dibranchiata	Aurospio dibranchiata
Aurospio dibranchiata	Spathoderma clenchi	Spathoderma clenchi
Prionospio sp. 2	Tharyx sp. 1	Chaetozone sp. 1
Tubificoides aculeatus	Fauveliopsis brevis	Tubificoides aculeatus
Tharyx sp. 1	Prionospio sp. 2	Nemertea sp. 5
Haplomesus sp. 2	Tubificoides aculeatus	Pholoe anoculata
Chelator insignis	Nemertea sp. 5	Fauveliopsis brevis
Prionospio sp. 11	Pholoe anoculata	Aricidea tetrabranchia
Sabidius cornatus	Aricidea tetrabranchia	Prionospio sp. 2
Nemertea sp. 2	Sabidius cornatus	Tharyx sp. 1
Harpinia sp. 2	Kesun gravieri	Sabidius cornatus
Pholoe anoculata	Prochaetoderma yongei	Prochaetoderma yongei
Nemertea sp. 5	Prochelator lateralis	Kesun gravieri
Chaetozone sp. 1	Prionospio sp. 11	Malletia johnsoni
Thyasira ferruginia	Lumbrineris latreilli	Prionospio sp. 20
Glycera capitata	Notomastus latericeus	Prionospio sp. 11
Fauveliopsis brevis	Levinsenia sp. 1	Harpinia sp. 2
Aricidea tetrabranchia	Chelator insignis	Notomastus latericeus
Thyasira subovata	Nucula cancellata	Lumbrineris sp. 3
Malletia johnsoni	Glycera capitata	Falcidens sp. 4
May 1985	**August 1985**	**November 1985**
No Samples Collected	No Samples Collected	No Samples collected.

TABLE F-9. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 9.

April/May 1984	August 1984	November 1984
Spathoderma clenchi	Auropsio dibranchiata	Aurospio dibranchiata
Tubificoides aculeatus	Pholoe anoculata	Pholoe anoculata
Auropsio dibranchiata	Spathoderma clenchi	Spathoderma clenchi
Tharyx sp. 1	Tubificoides aculeatus	Tubificoides aculeatus
Pholoe anoculata	Nemertea sp. 5	Tharyx sp. 1
Prochaetoderma yongei	Prochaetoderma yongei	Chaetozone sp. 1
Glycera capitata	Prionospio sp. 2	Lumbrineris latreilli
Sabidius cornatus	Chelator insignis	Prochaetoderma yongei
Flabelligella cirrata	Agathotanais cf. hanseni	Aricidea tetrabranchia
Aricidea tetrabranchia	Glycera capitata	Fauveliopsis brevis
Prionospio sp. 11	Tharyx sp. 1	Flabelligella cirrata
Fauveliopsis brevis	Fauveliopsis brevis	Prionospio sp. 2
Nemertea sp. 5	Malletia johnsoni	Chaetozone sp. 10
Levinsenia sp. 1	Oecidiobranchus plebejum	Nemertea sp. 5
Prionospio sp. 2	Kesun gravieri	Kesun gravieri
Ophelina abranchiata	Lumbrineris latreilli	Glycera capitata
Chelator insignis	Aricidea tetrabranchia	Sabidius cornatus
Nemertea sp. A	Sabidius cornatus	Prionospio sp. 11
Thyasira croulinensis	Anarthruridae sp. 2	Paramphinome jeffreysii
Malletia johnsoni	Prochelator lateralis	Notomastus latericeus

May 1985	August 1985	November 1985
Aurospio dibranchiata	Aurospio dibranchiata	Tubificoides aculeatus
Prionospio sp. 2	Spathoderma clenchi	Spathoderma clenchi
Spathoderma clenchi	Tubificoides aculeatus	Prochaetoderma yongei
Tharyx sp. 1	Nemertea sp. 5	Aurospio dibranchiata
Oecidiobranchus plebejum	Prionospio sp. 2	Pholoe anoculata
Tubificoides aculeatus	Prochelator lateralis	Glycera capitata
Aricidea tetrabranchia	Pholoe anoculata	Tharyx sp. 1
Sabidius cornatus	Sabidius cornatus	Sabidius cornatus
Kesun gravieri	Kesun gravieri	Dicarpa simplex
Prochelator lateralis	Chelator insignis	Fauveliopsis brevis
Levinsenia sp. 1	Aricidea tetrabranchia	Lumbrineris latreilli
Nemertea sp. 2	Lumbrineris latreilli	Malletia johnsoni
Dicarpa simplex	Prochaetoderma yongei	Nemertea sp. 5
Pholoe anoculata	Levinsenia sp. 1	Chaetozone sp. 1
Prionospio sp. 11	Oecidiobranchus plebejum	Chaetozone sp. 10
Myriotrochinae sp. 1 (juv.)	Glycera capitata	Prionospio sp. 2
Fauveliopsis brevis	Notomastus latericeus	Levinsenia sp. 1
Lumbrineris latreilli	Ophiura sp. 1 (juv.)	Aricidea tetrabranchia
Prochaetoderma yongei	Tharyx sp. 1	Thyasira tortuosa
Galathowenia sp. 1	Dicarpa simplex	Augeneria bidens

TABLE F-10. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 10.

April/May 1984	August 1984	November 1984
Aricidea abranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Aurospio dibranchiata	Aricidea abranchiata	Aricidea abranchiata
Spathoderma clenchi	Prionospio sp. 2	Prionospio sp. 2
Prionospio sp. 2	Spathoderma clenchi	Spathoderma clenchi
Grania atlantica	Haplomesus sp. 2	Nemertea sp. 5
Haplomesus sp. 2	Tharyx sp. 1	Myriochele sp. 1
Tharyx sp. 1	Nemertea sp. 5	Tubificoides aculeatus
Glycera capitata	Grania atlantica	Nemertea sp. 2
Notomastus latericeus	Glycera capitata	Ischnomesus sp. 2
Sabidius cornatus	Ischnomesus sp. 2	Haplomesus sp. 2
Nemertea sp. 2	Sabidius cornatus	Glycera capitata
Tubificoides aculeatus	Pholoe anoculata	Notomastus latericeus
Aricidea tetrabranchia	Euchone sp. 3	Tharyx sp. 1
Malletia johnsoni	Pseudotanais sp. 2	Thyasira pygmaea
Levinsenia sp. 1	Eugerda latipes	Anobothrus sp. 1
Euchone sp. 3	Sabellidae sp. 5	Pseudotanais sp. 2
Ischnomesus sp. 2	Prionospio sp. 11	Grania atlantica
Eugerda latipes	Notomastus latericeus	Paranarthrura cf. insignis
Anobothrus sp. 1	Prochaetoderma yongei	Eugerda latipes
Pseudotanais sp. 2	Sclerobregma branchiata	Sabidius cornatus

May 1985	August 1985	November 1985
Aricidea abranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Aurospio dibranchiata	Aricidea abranchiata	Aricidea abranchiata
Sabidius cornatus	Ophryotrocha sp. 2	Tharyx sp. 1
Haplomesus sp. 2	Spathoderma clenchi	Prionospio sp. 2
Prionospio sp. 2	Glycera capitata	Tubificoides aculeatus
Ischnomesus sp. 2	Thyasira pygmaea	Haplomesus sp. 2
Spathoderma clenchi	Tharyx sp. 1	Euchone sp. 3
Tubificoides aculeatus	Prionospio sp. 2	Spathoderma clenchi
Tharyx sp. 1	Pseudotanais sp. 2	Sabidius cornatus
Glycera capitata	Euchone sp. 3	Pholoe anoculata
Eugerda latipes	Notomastus latericeus	Notomastus latericeus
Pholoe anoculata	Haplomesus sp. 2	Nemertea sp. 5
Grania atlantica	Pholoe anoculata	Nemertea sp. 2
Notomastus latericeus	Grania atlantica	Grania atlantica
Thyasira subovata	Ischnomesus sp. 2	Glycera capitata
Oecidiobranchus plebejum	Nemertea sp. 5	Prochaetoderma yongei
Aricidea tetrabranchia	Dicarpa simplex	Paranarthrura cf. insignis
Nemertea sp. 5	Tubificoides aculeatus	Fauveliopsis brevis
Prochaetoderma yongei	Aricidea tetrabranchia	Dicarpa simplex
Galathowenia sp. 1	Mirabilicoxa similis	Eugerda latipes

TABLE F-11. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 11.

April/May 1984	August 1984	November 1984
Prochaetoderma yongei	Aurospio dibranchiata	Prochaetoderma yongei
Tharyx sp. 1	Prochaetoderma yongei	Aurospio dibranchiata
Aurospio dibranchiata	Aricidea tetrabranchia	Pholoe anoculata
Lumbrineris latreilli	Lumbrineris latreilli	Aricidea tetrabranchia
Aricidea tetrabranchia	Prionospio sp. 11	Kesun gravieri
Pholoe anoculata	Pholoe anoculata	Bathydrilus asymmetricus
Kesun gravieri	Kesun gravieri	Glycera capitata
Glycera capitata	Glycera capitata	Lumbrineris latreilli
Tubificoides sp. 4	Tharyx sp. 1	Prionospio sp. 2
Prionospio sp. 2	Bathydrilus asymmetricus	Tharyx sp. 1
Prionospio sp. 11	Nucula granulosa	Aspidosiphon zinni
Tubificoides aculeatus	Nemertea sp. 5	Nucula granulosa
Euchone sp. 3	Lumbrineris sp. 3	Leptognathiella spinicauda
Bathydrilus asymmetricus	Prionospio sp .2	Prionospio sp. 11
Nucula granulosa	Terebellidae sp. 2	Euchone sp. 3
Nemertea sp. 5	Euchone sp. 3	Chaetozone sp. 1
Galathowenia sp. 1	Eugerda tetarta	Nemertea sp. 5
Dicarpa simplex	Ophelina abranchiata	Dysponetus sp. 4
Fauveliopsis olgae	Leptognathiella spinicauda	Nemertea sp. 2
Dysponetus sp. 4	Paramphinome jeffreysii	Lumbrineris sp. 3
May 1985	**August 1985**	**November 1985**
Prochaetoderma yongei	Aurospio dibranchiata	Pholoe anoculata
Aurospio dibranchiata	Prochaetoderma yongei	Auropsio dibranchiata
Lumbrineris latreilli	Aricidea tetrabranchia	Lumbrineris latreilli
Tharyx sp. 1	Lumbrineris latreilli	Aricidea tetrabranchia
Pholoe anoculata	Kesun gravieri	Lysilla sp. 1
Aricidea tetrabranchia	Euchone sp. 3	Kesun gravieri
Kesun gravieri	Leptognathiella spinicauda	Prochaetoderma yongei
Glycera capitata	Glycera capitata	Glycera capitata
Leptognathiella spinicauda	Tharyx sp. 1	Nemertea sp. 5
Euchone sp. 3	Prionospio sp. 11	Leptognathia sp. 40
Tubificoides aculeatus	Nemertea sp. 5	Prionospio sp. 2
Bathydrilus asymmetricus	Pholoe anoculata	Aspidosiphon zinni
Prionospio sp. 11	Nucula granulosa	Poecilochaetus fulgoris
Prionospio sp. 2	Tubificoides aculeatus	Prionospio sp. 11
Nucula granulosa	Prionospio sp. 2	Tubificoides sp. 4
Dysponetus sp. 4	Bathydrilus asymmetricus	Collettea cf. cylindrata
Ophelina abranchiata	Aspidosiphon zinni	Tharyx sp. 1
Dicarpa simplex	Lumbrineris sp. 3	Sclerobregma branchiata
Nemertea sp. 2	Ophelina abranchiata	Micrura sp. 1
Lumbrineris sp. 3	Dicarpa simplex	Nemertea sp. 2

TABLE F-12. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 12.

April/May 1984	August 1984	November 1984
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Tharyx sp. 1	Prionospio sp. 2	Myriochele sp. 1
Prionospio sp. 2	Tharyx sp. 1	Tharyx sp. 1
Myriochele sp. 1	Myriochele sp. 1	Prionospio sp. 2
Paradoneis abranchiata	Glycera capitata	Paradoneis abranchiata
Tubificoides aculeatus	Phallodrilus grasslei	Glycera capitata
Glycera capitata	Paradoneis abranchiata	Aspidosiphon zinni
Pholoe anoculata	Nemertea sp. 5	Notomastus latericeus
Nemertea sp. 5	Pholoe anoculata	Phallodrilus grasslei
Sclerobregma branchiata	Tubificoides aculeatus	Nemertea sp. 5
Aspidosiphon zinni	Spathoderma clenchi	Notomastus sp. 3
Sabidius cornatus	Ophiura sp. 1 (juv.)	Aricidea tetrabranchia
Grania atlantica	Aricidea tetrabranchia	Spathoderma clenchi
Notomastus latericeus	Dacrydium sp. 1	Bathydrilus asymmetricus
Phallodrilus grasslei	Fauveliopsis brevis	Nemertea sp. 2
Chaetozone sp. 10	Notomastus latericeus	Dacrydium sp. 1
Aricidea tetrabranchia	Nephasoma cf. capilleforme	Pholoe anoculata
Exogone sp. 1	Euchone sp. 3	Sabellidae sp. 5
Euchone sp. 3	Sabidius cornatus	Fauveliopsis brevis
Fauveliopsis brevis	Sclerobregma branchiata	Lepidomeniidae sp. 1

May 1985	August 1985	November 1985
Aurospio dibranchiata	Aurospio dibranchiata	Aurospio dibranchiata
Tharyx sp. 1	Prionospio sp. 2	Tharyx sp. 1
Prionospio sp. 2	Tharyx sp. 1	Prionospio sp. 2
Phallodrilus grasslei	Phallodrilus grasslei	Myriochele sp. 1
Pholoe anoculata	Paradoneis abranchiata	Paradoneis abranchiata
Paradoneis abranchiata	Sabellidae sp. 5	Chaetozone sp. 1
Spathdoerma clenchi	Nemertea sp. 5	Sabellidae sp. 5
Nucula cancellata	Aspidosiphon zinni	Tubificoides aculeatus
Aspidosiphon zinni	Myriochele sp. 1	Phallodrilus grasslei
Fauveliopsis brevis	Pholoe anoculata	Pholoe anoculata
Sabellidae sp. 2	Fauveliopsis brevis	Nemertea sp. 5
Notomastus latericeus	Glycera capitata	Glycera capitata
Glycera capitata	Nucula cancellata	Fauveliopsis brevis
Nemertea sp. 5	Euchone sp. 3	Aspidosiphon zinni
Lepidomeniidae sp. 1	Notomastus latericeus	Dacrydium sp. 1
Dacrydium sp. 1	Dacrydium sp. 1	Spathoderma clenchi
Nemertea sp. 2	Myriochele cf. heeri	Sabidius cornatus
Aricidea tetrabranchia	Aricidea tetrabranchia	Prionospio sp. 20
Sclerobregma branchiata	Spathoderma clenchi	Leptognathia breviremus
Sabidius cornatus	Pseudotanais sp. 2	Nemertea sp. 2

TABLE F-13. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 13.

April/May 1984	August 1984	November 1984
Aspidosiphon zinni	Prochaetoderma yongei	Aspidosiphon zinni
Prochaetoderma yongei	Aspidosiphon zinni	Prochaetoderma yongei
Glycera capitata	Aricidea tetrabranchia	Glycera capitata
Aricidea tetrabranchia	Glycera capitata	Aricidea tetrabranchia
Pholoe anoculata	Aurospio dibranchiata	Pholoe anoculata
Anthozoa sp. 5	Tharyx sp. 1	Tharyx sp. 1
Tharyx sp. 1	Pholoe anoculata	Kesun gravieri
Tubificoides aculeatus	Kesun gravieri	Tubificoides aculeatus
Kesun gravieri	Prionospio sp. 11	Aurospio dibranchiata
Prionospio sp. 11	Nemertea sp. 5	Leptognathiella spinicauda
Dysponetus sp. 4	Prionospio sp. 2	Prionospio sp. 11
Leptognathiella spinicauda	Lumbrineris latreilli	Prionospio sp. 2
Aurospio dibranchiata	Tubificoides aculeatus	Lumbrineris latreilli
Paranarthrura cf. insignis	Anthozoa sp. 5	Thyasira subovata
Lumbrineris latreilli	Chaetozone sp. 1	Dysponetus sp. 4
Thyasira tortuosa	Spathoderma clenchi	Spathoderma clenchi
Nemertea sp. 5	Lucifer sp. 1	Nemertea sp. 5
Prionospio sp. 2	Leptognathiella spinicauda	Nemertea sp. 2
Nucula granulosa	Nucula granulosa	Paranarthrura cf. insignis
Harpinia propingua	Trichobranchidae sp. 5	Siboglinum angstum

May 1985	August 1985	November 1985
Aspidosiphon zinni	Aspidosiphon zinni	Aspidosiphon zinni
Glycera capitata	Prochaetoderma yongei	Prochaetoderma yongei
Aricidea tetrabranchia	Glycera capitata	Aurospio dibranchiata
Prochaetoderma yongei	Pholoe anoculata	Aricidea tetrabranchia
Aurospio dibranchiata	Aricidea tetrabranchia	Tharyx sp. 1
Leptognathiella spinicauda	Kesun gravieri	Kesun gravieri
Kesun gravieri	Tubificoides aculeatus	Pholoe anoculata
Nephasoma diaphanes	Aurospio dibranchiata	Glycera capitata
Prionospio sp. 2	Leptognathiella spinicauda	Leptognathiella spinicauda
Spathoderma clenchi	Tharyx sp. 1	Tubificoides aculeatus
Thyasira tortuosa	Chaetozone sp. 1	Chaetozone sp. 1
Tubificoides aculeatus	Nemertea sp. 2	Lumbrineris latreilli
Tharyx sp. 1	Lumbrineris latreilli	Nemertea sp. 2
Paramphinome jeffreysii	Prionospio sp. 11	Prionospio sp. 11
Pholoe anoculata	Nucula granulosa	Maldanidae sp. 3
Paranarthrura cf. insignis	Priapulus caudatus	Nemertea sp. 5
Euchone sp. 3	Maldanidae sp. 3	Prionospio sp. 2
Dysponetus sp. 4	Levinsenia sp. 1	Spathoderma clenchi
Priapulus caudatus	Nemertea sp. 5	Harpinia clivicola
Chaetozone sp. 1	Paramphinome jeffreysii	Paramphinome jeffreysii

TABLE F-14. DOMINANT SPECIES AT U.S. MID-ATLANTIC STATION 14.

April/May 1984	August 1984	November 1984
Aspidosiphon zinni	No Samples Collected.	No Samples Collected.
Prochaetoderma yongei		
Pholoe anoculata		
Aricidea tetrabranchia		
Kesun gravieri		
Glycera capitata		
Tharyx sp. 1		
Prionospio sp. 11		
Aurospio dibranchiata		
Paranarthrura cf. insignis		
Priapulus caudatus		
Poecilochaetus fulgoris		
Galathowenia sp. 1		
Leptognathiella spinicauda		
Agathotanais cf. hanseni		
Dysponetus sp. 4		
Harpinia propinqua		
Prochelator lateralis		
Dicarpa simplex		
Nephasoma diaphanes		
May 1985	**August 1985**	**November 1985**
Prochaetoderma yongei	Aspidosiphon zinni	Aspidosiphon zinni
Aspidosiphon zinni	Prochaetoderma yongei	Prochaetoderma yongei
Panarthrura cf. insignis	Aurospio dibranchiata	Leptognathiella spinicauda
Aurospio dibranchiata	Paranarthrura cf. insignis	Kesun gravieri
Glycera capitata	Prionospio sp. 11	Auropsio dibranchiata
Kesun gravieri	Poecilochaetus fulgoris	Aricidea tetrabranchia
Aricidea tetrabranchia	Aricidea tetrabranchia	Paranarthrura cf. insignis
Poecilochaetus fulgoris	Kesun gravieri	Glycera capitata
Leptognathiella spinicauda	Nemertea sp. 5	Prionspio sp. 11
Prionospio sp. 11	Glycera capitata	Tubificoides aculeatus
Tharyx sp. 1	Harpinia propinqua	Nephasoma diaphanes
Pholoe anoculata	Leptognathia sp. 28	Heteromastus sp. 2
Dysponetus sp. 4	Leptognathiella spinicauda	Nemertea sp. 5
Nephasoma diaphanes	Ophelina abranchiata	Chaetozone sp. 1
Spathoderma clenchi	Agathotanais cf. hanseni	Tharyx sp. 1
Aricidea sp. 3	Levinsenia sp. 1	Maldanidae sp. 3
Chaetozone sp. 1	Anthozoa sp. 5	Yoldiella curta
Nemertea sp. 5	Nephasoma diaphanes	Nemertea sp. 2
Priapulus caudatus	Lepidomeniidae sp. 1	Priapulus caudatus
Levinsenia sp. 1	Tharyx sp. 1	Pholoe anoculata

APPENDIX G

TABLE G-1. BENTHIC COMMUNITY PARAMETERS FOR U.S. MID-ATLANTIC STATIONS, CALCULATED SEPARATELY FOR EACH CRUISE AND REPLICATE.

Station	Cruise/ Replicate	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
1	1-1	771	134	33.4	51.8	83.7	6.09	0.862
	1-2	275	79	29.8	46.4	75.6	5.45	0.865
	1-3	313	86	29.6	46.2	76.5	5.46	0.849
	2-1	414	94	31.4	47.5	74.9	5.73	0.874
	2-2	290	78	30.4	46.0	73.0	5.52	0.879
	2-3	430	98	32.3	49.8	78.9	5.82	0.880
	3-1	335	80	29.3	44.3	70.3	5.46	0.864
	3-2	335	89	30.0	46.8	77.7	5.54	0.855
	3-3	426	97	31.9	48.7	77.4	5.80	0.878
	4-1	360	76	30.7	45.5	67.6	5.59	0.894
	4-2	506	93	29.7	44.8	70.6	5.58	0.854
	4-3	378	94	32.7	50.5	79.8	5.85	0.892
	5-1	406	91	31.1	46.8	73.0	5.68	0.873
	5-2	330	77	30.4	46.5	70.0	5.50	0.878
	5-3	433	95	31.5	48.6	76.4	5.73	0.872
	6-1	350	94	33.5	52.2	81.7	5.87	0.896
	6-2	291	91	32.8	51.4	84.4	5.79	0.889
	6-3	450	102	33.0	50.7	79.9	5.91	0.885
2	1-1	338	90	31.8	48.8	78.2	5.73	0.882
	1-2	413	102	31.3	48.9	81.0	5.76	0.864
	1-3	308	89	32.9	51.1	81.6	5.80	0.895
	2-1	458	97	33.0	50.6	78.1	5.90	0.893
	2-2	437	102	32.4	49.8	79.8	5.86	0.878
	2-3	504	106	33.5	51.4	79.7	5.97	0.888
	3-1	456	104	32.6	50.7	80.6	5.88	0.877
	3-2	549	123	34.8	54.6	88.3	6.18	0.890
	3-3	494	107	33.9	52.7	82.4	6.02	0.893
	4-1	544	107	32.2	49.3	77.2	5.86	0.869
	4-2	532	118	35.1	54.8	87.1	6.18	0.898
	4-3	360	89	30.6	47.3	76.2	5.61	0.867
	5-1	435	96	30.3	46.0	73.7	5.61	0.851
	5-2	473	104	30.6	47.7	78.2	5.69	0.849
	5-3	422	112	34.4	54.5	88.8	6.06	0.891
	6-1	429	105	33.7	53.6	85.4	5.95	0.886
	6-2	431	108	33.8	53.2	86.4	6.00	0.889
	6-3	572	134	35.7	56.9	93.9	6.30	0.892

TABLE G-1. (Continued).

Station	Cruise/ Replicate	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
3	1-1	464	105	32.6	50.1	79.6	5.88	0.876
	1-2	338	95	31.5	49.0	81.3	5.72	0.870
	1-3	381	97	33.1	51.5	81.9	5.89	0.892
	2-1	184	62	30.1	45.0	*	5.35	0.898
	2-2	266	85	33.1	51.6	82.7	5.77	0.901
	2-3	348	96	33.0	51.5	83.3	5.86	0.890
	3-1	304	79	30.8	46.5	72.3	5.56	0.881
	3-2	336	93	33.0	50.7	81.0	5.85	0.894
	3-3	120	56	32.7	50.4	*	5.41	0.931
	4-1	360	99	33.0	51.3	82.8	5.86	0.883
	4-2	546	120	34.6	54.6	87.2	6.13	0.888
	4-3	474	115	33.7	53.2	87.6	6.04	0.882
	5-1	531	108	33.4	52.2	81.8	5.98	0.885
	5-2	290	86	32.3	50.3	80.2	5.67	0.882
	5-3	441	108	33.9	53.6	85.6	6.00	0.889
	6-1	365	107	35.0	55.7	90.8	6.08	0.901
	6-2	459	114	34.3	53.8	87.4	6.07	0.888
	6-3	425	116	35.4	55.9	91.3	6.18	0.901
4	1-1	287	80	32.4	49.4	75.8	5.70	0.902
	1-2	384	85	31.6	47.6	72.9	5.70	0.890
	1-3	414	96	32.0	48.9	77.1	5.79	0.880
	2-1	500	101	30.2	46.7	75.4	5.64	0.846
	2-2	477	91	30.0	45.6	71.0	5.59	0.859
	2-3	497	87	29.6	44.1	66.8	5.52	0.856
	3-1	340	65	29.5	42.1	59.1	5.42	0.899
	3-2	415	95	31.4	47.6	75.2	5.73	0.872
	3-3	383	80	29.4	44.4	67.9	5.44	0.861
	4-1	394	85	31.2	46.5	70.7	5.65	0.882
	4-2	516	102	30.8	48.0	76.9	5.69	0.853
	4-3	491	99	32.5	49.5	76.3	5.86	0.884
	5-1	453	101	32.3	49.3	77.7	5.84	0.878
	5-2	437	83	31.5	46.5	68.4	5.69	0.892
	5-3	329	74	30.2	44.5	66.6	5.52	0.888
	6-1	375	95	32.2	49.4	79.3	5.80	0.882
	6-2	450	98	31.7	48.3	76.3	5.78	0.874
	6-3	541	112	32.6	50.1	79.5	5.91	0.868

TABLE G-1. (Continued).

Station	Cruise/ Replicate	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
5	1-1	383	90	29.7	45.6	74.0	5.52	0.850
	1-2	316	77	29.3	43.4	68.8	5.46	0.870
	1-3	409	91	29.6	44.5	72.2	5.57	0.856
	2-1	493	124	32.3	51.7	88.8	5.93	0.853
	2-2	437	101	29.8	46.6	77.8	5.60	0.840
	2-3	412	90	30.5	46.1	72.4	5.63	0.868
	3-1	387	93	30.7	47.0	76.1	5.65	0.864
	3-2	362	89	31.2	47.4	76.0	5.69	0.879
	3-3	422	95	29.6	46.2	75.7	5.55	0.845
	4-1	450	107	30.6	47.9	80.2	5.69	0.844
	4-2	431	99	31.2	48.2	78.4	5.74	0.865
	4-3	203	69	31.6	48.2	*	5.53	0.905
	5-1	505	111	33.0	51.2	83.2	5.97	0.878
	5-2	373	82	31.1	46.2	69.8	5.64	0.888
	5-3	340	96	33.0	51.3	83.8	5.87	0.891
	6-1	421	110	33.4	52.3	85.7	5.97	0.881
	6-2	449	108	31.9	49.9	82.2	5.82	0.862
	6-3	386	100	31.4	49.3	81.4	5.74	0.863
6	1-1	337	91	32.6	50.3	80.3	5.81	0.893
	1-2	333	80	29.3	44.2	70.0	5.46	0.864
	1-3	290	85	31.2	48.7	79.3	5.61	0.876
	2-1	260	74	31.4	47.0	72.8	5.59	0.901
	2-2	286	91	32.3	50.4	84.7	5.76	0.885
	2-3	331	89	31.4	48.1	77.4	5.67	0.876
	3-1	359	90	31.8	48.7	77.6	5.74	0.885
	3-2	356	95	33.9	52.9	83.5	5.94	0.905
	3-3	307	87	34.0	52.5	80.7	5.90	0.915
	4-1	313	83	32.7	49.8	76.2	5.76	0.904
	4-2	267	86	32.2	50.0	83.2	5.72	0.891
	4-3	319	86	30.8	47.5	76.7	5.60	0.872
	5-1	247	65	28.3	42.6	*	5.23	0.868
	5-2	245	68	29.2	43.7	*	5.36	0.880
	5-3	335	85	31.7	47.5	74.2	5.70	0.890
	6-1	397	104	32.2	50.2	83.1	5.84	0.871
	6-2	242	80	33.0	50.8	*	5.74	0.908
	6-3	(Replicate deleted from data analysis)						

TABLE G-1. (Continued).

Station	Cruise/ Replicate	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
7	1-1	274	97	34.1	54.8	92.7	5.92	0.897
	1-2	417	115	34.7	54.8	90.5	6.11	0.893
	1-3	349	102	33.2	52.8	87.1	5.90	0.884
	2-1	263	86	33.7	52.8	84.2	5.83	0.908
	2-2	414	106	34.3	54.2	87.5	6.04	0.898
	2-3	342	93	34.0	52.7	82.6	5.93	0.907
	3-1	266	93	37.2	58.5	90.7	6.16	0.942
	3-2	283	94	35.0	55.2	89.1	6.00	0.915
	3-3	425	101	33.3	51.0	80.8	5.93	0.891
	4-1	350	104	35.6	56.5	91.1	6.13	0.915
	4-2	168	67	34.0	51.8	*	5.66	0.934
	4-3	(Replicate deleted from data analysis)						
	5-1	363	100	33.8	53.6	86.6	5.95	0.895
	5-2	428	110	35.1	55.6	88.6	6.13	0.904
	5-3	422	109	33.0	51.5	84.9	5.94	0.877
	6-1	477	109	33.8	52.6	84.2	6.02	0.890
	6-2	458	120	36.0	57.4	93.6	6.26	0.906
	6-3	371	104	35.6	55.9	88.8	6.13	0.915
8	1-1	346	97	34.0	53.7	85.7	5.96	0.903
	1-2	287	98	37.1	59.0	93.0	6.20	0.937
	1-3	385	110	34.6	54.3	89.3	6.08	0.896
	2-1	249	82	32.3	49.7	*	5.70	0.897
	2-2	319	79	30.6	45.9	71.4	5.57	0.884
	2-3	318	96	33.5	52.4	85.9	5.90	0.896
	3-1	(Replicate deleted from data analysis)						
	3-2	390	112	35.1	56.3	92.1	6.12	0.899
	3-3	265	86	34.2	52.8	83.8	5.88	0.916
	4	No samples collected on Cruise 4						
	5	No samples collected on Cruise 5						
	6	No samples collected on Cruise 6						

TABLE G-1. (Continued).

Station	Cruise/ Replicate	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
9	1-1	308	104	35.3	56.3	94.1	6.08	0.908
	1-2	320	81	32.4	49.2	74.2	5.73	0.904
	1-3	326	88	32.7	50.4	78.8	5.79	0.896
	2-1	296	81	32.3	48.9	75.5	5.72	0.903
	2-2	363	85	32.2	47.7	72.4	5.75	0.897
	2-3	336	92	33.9	52.5	82.0	5.92	0.907
	3-1	310	90	33.6	52.0	82.2	5.87	0.905
	3-2	364	86	31.8	47.9	74.0	5.72	0.890
	3-3	320	93	33.2	51.3	82.7	5.85	0.895
	4-1	356	89	33.0	49.9	77.3	5.83	0.901
	4-2	180	63	31.5	47.7	*	5.45	0.911
	4-3	424	94	32.4	49.3	76.4	5.82	0.888
	5-1	391	104	35.8	56.6	88.8	6.16	0.919
	5-2	395	110	35.8	56.4	90.4	6.18	0.912
	5-3	440	113	35.8	56.5	90.2	6.21	0.910
	6-1	168	64	30.2	46.8	*	5.32	0.887
	6-2	270	79	32.1	49.2	76.6	5.67	0.899
	6-3	389	95	32.5	49.7	78.8	5.83	0.888
10	1-1	297	90	33.1	51.9	83.5	5.81	0.896
	1-2	469	107	31.8	49.6	80.8	5.81	0.862
	1-3	465	112	32.8	51.1	83.8	5.93	0.871
	2-1	447	95	32.1	49.0	76.8	5.81	0.884
	2-2	471	112	32.4	51.3	84.6	5.89	0.865
	2-3	365	81	30.2	45.8	70.6	5.52	0.871
	3-1	428	103	32.8	50.9	81.3	5.90	0.882
	3-2	449	115	35.9	56.7	90.5	6.22	0.909
	3-3	465	102	31.9	49.1	78.1	5.81	0.871
	4-1	558	117	33.6	52.5	85.0	6.04	0.880
	4-2	485	116	31.8	49.8	83.5	5.85	0.853
	4-3	457	103	30.8	47.7	77.9	5.71	0.854
	5-1	348	89	31.8	48.8	77.4	5.70	0.881
	5-2	524	114	33.2	52.6	85.2	5.98	0.876
	5-3	440	104	31.8	49.9	81.3	5.78	0.862
	6-1	549	111	32.7	50.5	79.7	5.93	0.872
	6-2	145	71	34.0	55.4	*	5.64	0.916
	6-3	377	96	32.8	51.6	82.1	5.82	0.884

TABLE G-1. (Continued).

Station	Cruise/ Replicate	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
11	1-1	406	119	31.8	50.4	89.2	5.88	0.852
	1-2	453	105	31.0	48.2	79.8	5.74	0.854
	1-3	496	118	33.0	51.8	85.8	5.98	0.869
	2-1	344	92	30.7	47.5	78.9	5.62	0.862
	2-2	443	111	30.5	47.9	81.9	5.71	0.840
	2-3	302	97	31.3	49.9	87.4	5.69	0.862
	3-1	392	113	33.5	53.2	90.6	5.99	0.879
	3-2	424	100	30.8	47.4	78.1	5.70	0.858
	3-3	518	104	29.8	45.6	74.9	5.64	0.842
	4-1	573	130	33.8	53.8	90.1	6.11	0.870
	4-2	464	119	34.0	53.8	89.1	6.07	0.880
	4-3	319	89	31.7	49.1	79.7	5.71	0.882
	5-1	431	110	32.7	51.4	85.2	5.91	0.871
	5-2	400	102	32.1	50.3	82.8	5.81	0.871
	5-3	496	112	32.1	50.1	82.5	5.88	0.863
	6-1	534	103	30.6	46.8	74.4	5.69	0.851
	6-2	(Replicate deleted from data analysis)						
	6-3	389	95	31.1	47.8	77.0	5.70	0.867
12	1-1	325	85	29.6	46.1	75.4	5.49	0.857
	1-2	234	83	30.7	49.9	*	5.50	0.860
	1-3	274	83	31.3	49.3	79.8	5.59	0.877
	2-1	173	63	29.0	45.5	*	5.18	0.867
	2-2	246	71	26.2	41.3	*	5.06	0.823
	2-3	246	69	28.7	43.7	*	5.27	0.863
	3-1	158	47	24.1	36.4	*	4.66	0.839
	3-2	224	67	26.4	41.8	*	4.96	0.818
	3-3	310	79	27.6	42.7	70.6	5.22	0.828
	4-1	303	74	27.6	42.0	67.5	5.22	0.840
	4-2	306	84	29.5	45.8	75.8	5.45	0.853
	4-3	306	79	28.2	43.5	71.3	5.28	0.837
	5-1	390	95	30.5	46.9	76.6	5.65	0.859
	5-2	278	75	29.7	45.2	71.5	5.42	0.871
	5-3	327	93	31.1	48.6	81.2	5.66	0.866
	6-1	317	83	29.4	45.8	74.7	5.44	0.854
	6-2	404	94	29.1	45.1	75.0	5.51	0.841
	6-3	320	85	31.2	48.3	76.8	5.64	0.880

TABLE G-1. (Continued).

Station	Cruise/ Replicate	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
13	1-1	622	134	31.0	48.6	83.5	5.85	0.828
	1-2	325	101	32.1	51.7	88.1	5.73	0.860
	1-3	435	102	31.2	48.3	79.8	5.74	0.861
	2-1	365	99	33.3	51.6	83.4	5.91	0.891
	2-2	410	90	30.0	45.9	73.3	5.57	0.858
	2-3	367	100	31.4	48.7	82.0	5.75	0.866
	3-1	544	114	30.1	46.6	77.2	5.69	0.832
	3-2	413	112	32.8	52.3	88.4	5.94	0.872
	3-3	478	107	31.0	48.2	79.7	5.75	0.854
	4-1	464	91	28.8	43.8	69.6	5.38	0.827
	4-2	401	106	32.0	51.4	86.0	5.77	0.857
	4-3	453	107	33.3	51.4	82.3	5.96	0.885
	5-1	447	115	32.7	52.0	87.4	5.92	0.865
	5-2	448	104	31.6	49.2	80.3	5.78	0.863
	5-3	454	105	31.4	49.4	80.8	5.74	0.855
	6-1	503	101	31.0	47.5	75.5	5.73	0.861
	6-2	470	115	31.2	50.0	86.2	5.78	0.844
	6-3	425	104	33.5	52.0	83.1	5.96	0.890
14	1-1	480	108	31.6	50.4	82.9	5.79	0.858
	1-2	460	119	35.5	57.0	93.8	6.22	0.901
	1-3	565	115	32.3	50.5	82.0	5.90	0.862
	2		No samples collected on Cruise 2					
	3		No samples collected on Cruise 3					
	4-1	464	116	33.6	54.1	89.7	6.02	0.878
	4-2	530	130	35.8	57.7	96.3	6.31	0.899
	4-3	390	112	33.4	53.2	90.6	5.99	0.880
	5-1	493	109	29.9	47.6	79.9	5.54	0.818
	5-2	504	120	32.6	53.1	90.0	5.89	0.852
	5-3	386	97	32.0	49.3	80.2	5.80	0.879
	6-1	602	113	28.1	45.2	75.5	5.23	0.766
	6-2	408	119	33.7	55.1	94.5	6.01	0.872
	6-3	548	126	32.9	52.4	87.3	5.97	0.856

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

APPENDIX H

TABLE H-1. BENTHIC COMMUNITY PARAMETERS FOR U.S. MID-ATLANTIC STATIONS, CALCULATED SEPARATELY FOR EACH CRUISE AND STATION (REPLICATES COMBINED).

Cruise	Station	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Species per 500 Indiv.	Species per 750 Indiv.	Species per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
1	1	1359	172	33.0	51.9	85.4	117.1	137.9	153.8	6.16	0.830
	2	1059	156	32.8	50.9	83.0	114.6	136.2	152.6	6.09	0.836
	3	1183	158	33.1	51.6	83.8	114.6	133.9	149.5	6.13	0.840
	4	1085	141	32.6	50.3	79.8	106.7	124.4	137.4	6.04	0.845
	5	1107	151	29.8	45.3	74.6	105.7	127.5	144.6	5.79	0.800
	6	960	145	31.6	49.1	80.9	111.9	132.3	*	5.96	0.830
	7	1040	166	34.7	55.8	93.1	126.5	147.8	163.8	6.33	0.858
	8	1018	166	36.5	58.4	96.2	129.5	150.1	165.1	6.50	0.882
	9	954	148	34.7	54.7	88.4	117.6	136.3	*	6.26	0.869
	10	1231	168	33.1	52.3	86.6	119.2	140.6	156.4	6.16	0.834
	11	1355	195	32.4	51.5	88.4	125.9	151.5	171.6	6.17	0.812
	12	833	156	31.6	50.9	88.6	125.9	149.9	*	5.98	0.821
	13	1382	185	31.7	50.2	85.7	121.1	145.0	163.3	6.07	0.806
	14	1505	190	34.3	55.1	92.5	127.4	150.0	166.5	6.34	0.837
2	1	1134	141	32.0	49.3	79.4	107.1	124.1	135.9	5.99	0.839
	2	1399	164	34.3	53.6	85.2	113.2	131.8	146.1	6.25	0.850
	3	798	151	33.3	52.8	87.8	122.0	146.8	*	6.13	0.847
	4	1474	154	31.0	47.8	76.4	102.3	120.2	133.4	5.89	0.810
	5	1342	171	31.3	49.2	82.9	115.6	137.1	153.4	5.99	0.808
	6	877	138	32.1	49.4	80.2	110.1	130.0	*	5.98	0.842
	7	1019	151	34.7	54.8	88.8	118.6	137.0	150.2	6.27	0.867
	8	886	137	32.6	50.7	82.9	112.1	129.7	*	6.04	0.852
	9	985	137	32.2	50.9	80.3	107.8	125.3	*	6.08	0.857
	10	1283	164	32.7	51.2	83.6	115.0	135.8	151.1	6.10	0.828
	11	1089	171	31.5	50.0	86.2	123.4	148.1	165.9	6.03	0.813
	12	665	127	29.6	46.2	78.6	111.5	*	*	5.68	0.813
	13	1142	159	32.4	50.8	84.7	117.1	137.7	152.3	6.08	0.832

TABLE H-1. (Continued)

Cruise	Station	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Species per 500 Indiv.	Species per 750 Indiv.	Species per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
3	1	1096	143	31.5	48.7	79.4	107.9	125.9	138.9	5.94	0.830
	2	1499	176	34.3	54.1	87.9	118.7	138.5	153.4	6.30	0.844
	3	760	131	33.2	51.4	81.9	110.8	130.3	*	6.05	0.860
	4	1138	136	31.2	47.1	73.5	98.8	116.2	129.7	5.86	0.827
	5	1171	152	31.0	47.7	78.1	108.2	128.2	143.4	5.91	0.815
	6	1022	140	34.0	52.9	84.4	111.4	127.5	139.1	6.17	0.866
	7	974	152	35.3	55.3	88.9	119.3	138.8	*	6.33	0.873
	8	655	137	35.3	56.3	92.1	123.8	*	*	6.28	0.884
	9	994	149	34.1	53.3	85.2	114.3	134.0	*	6.20	0.859
	10	1342	171	34.1	53.5	86.5	117.4	138.3	154.2	6.26	0.844
	11	1334	182	32.2	50.5	86.0	122.6	146.5	164.1	6.12	0.815
	12	692	119	27.8	43.5	73.2	102.9	*	*	5.45	0.791
	13	1445	190	31.9	50.3	85.9	121.8	146.2	164.7	6.11	0.807
4	1	1244	136	31.7	48.5	76.9	102.1	117.3	128.0	5.95	0.839
	2	1436	158	33.6	52.1	83.5	112.2	130.2	142.8	6.18	0.847
	3	1380	173	34.4	54.3	88.6	120.0	140.4	155.6	6.30	0.848
	4	1401	149	32.1	49.5	78.3	103.9	120.4	133.1	5.99	0.830
	5	1084	147	31.4	48.9	80.4	110.3	129.3	143.1	5.94	0.825
	6	899	135	32.5	50.2	81.4	109.8	127.2	*	6.01	0.850
	7	518	123	36.2	57.8	93.7	121.7	*	*	6.30	0.908
	9	960	135	33.4	51.5	81.8	108.6	125.0	*	6.10	0.861
	10	1500	176	32.8	51.6	85.7	117.8	138.8	154.3	6.15	0.825
	11	1356	190	34.0	54.6	93.3	130.1	153.4	170.7	6.34	0.837
	12	915	144	29.2	45.6	76.4	108.3	131.2	*	5.67	0.791
	13	1318	174	32.6	51.7	85.9	118.7	140.6	157.2	6.10	0.819
	14	1383	197	35.3	57.3	98.6	136.7	160.2	177.2	6.48	0.851

TABLE H-1. (Continued)

Cruise	Station	Total Indiv.	Total Species	Species per 50 Indiv.	Species per 100 Indiv.	Species per 250 Indiv.	Species per 500 Indiv.	Species per 750 Indiv.	Species per 1000 Indiv.	Shannon-Wiener Diversity (H')	Evenness (E)
5	1	1169	142	31.8	49.0	78.0	104.0	121.1	134.4	5.94	0.831
	2	1330	170	33.3	52.2	85.9	117.8	138.6	154.2	6.19	0.836
	3	1262	168	33.9	53.6	86.8	117.3	137.9	153.9	6.21	0.840
	4	1219	133	32.2	48.9	75.8	100.1	115.4	126.1	5.97	0.846
	5	1218	156	33.1	51.1	82.3	111.6	131.1	145.8	6.13	0.842
	6	827	128	31.2	47.7	76.7	104.4	123.2	*	5.86	0.837
	7	1213	167	34.9	55.8	92.3	124.0	143.4	157.5	6.35	0.860
	9	1226	172	36.6	58.3	94.5	126.2	146.4	161.4	6.51	0.876
	10	1312	177	33.8	53.6	88.4	121.4	143.4	160.2	6.24	0.836
	11	1327	178	33.2	52.6	88.9	123.6	145.7	161.9	6.21	0.831
	12	995	152	31.2	48.5	80.1	112.0	134.6	*	5.92	0.817
	13	1349	175	32.2	51.2	86.0	118.8	140.6	157.1	6.09	0.817
	14	1383	180	32.3	52.1	88.9	123.2	144.9	161.0	6.08	0.812
6	1	1091	154	34.2	53.8	87.3	117.1	135.7	149.6	6.24	0.858
	2	1432	169	35.0	55.8	91.2	121.7	140.3	153.4	6.36	0.859
	3	1249	170	35.5	56.6	92.2	123.9	144.1	158.8	6.41	0.864
	4	1366	152	33.2	51.1	81.0	108.3	125.9	138.7	6.12	0.844
	5	1256	168	32.9	51.8	85.6	117.6	138.8	154.8	6.15	0.831
	6	639	123	32.5	50.5	82.3	111.6	*	*	5.97	0.860
	7	1306	169	35.8	57.0	92.6	123.2	142.2	156.0	6.44	0.870
	9	827	130	32.2	49.5	79.4	107.4	125.4	*	5.97	0.850
	10	1071	160	33.4	52.4	85.5	117.2	138.8	155.7	6.15	0.840
	11	923	143	33.2	51.6	83.2	112.4	132.0	*	6.10	0.852
	12	1041	148	30.8	48.2	80.0	110.3	130.3	145.8	5.88	0.815
	13	1398	177	32.6	51.1	84.7	117.5	139.6	156.4	6.12	0.821
	14	1558	197	31.8	51.8	88.9	124.8	148.8	167.2	6.01	0.789

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

APPENDIX 1

TABLE I-1. RESULTS OF UV/F ANALYSES OF CRUISE MID-1 SEDIMENTS.

Emission Wavelength (nm)	Station 1	2	3	4	5	6	7
	Concentration (µg/g dry weight)[a]						
312	19.8 ±5.8	11.4 ±3.8	13.6 ±2.3	13.6 ±4.6	30.2 ±4.1	14.6 ±0.8	16.5 ±3.6
355	41.2 ±9.4	22.4 ±3.9	30.6 ±7.6	23.4 ±6.0	51.4 ±6.0	33.5 ±2.5	32.4 ±7.2
425	64.5 ±17.7	35.7 ±5.1	49.0 ±14.1	33.7 ±7.9	68.5 ±5.2	51.0 ±6.0	49.9 ±8.5

Emission Wavelength (nm)	Station 8	9	10	11	12	13	14
	Concentration (µg/g dry weight)[a]						
312	10.9 ±3.8	18.6 ±2.9	11.1 ±2.4	28.6 ±5.3	7.1 ±2.5	43.7 ±10.0	27.8 ±1.1
355	22.3 ±8.4	30.0 ±8.3	21.9 ±3.6	52.0 ±15.5	15.0 ±2.4	79.5 ±6.5	45.9 ±3.0
425	35.4 ±15.0	45.6 ±11.3	32.5 ±4.2	73.6 ±23.7	23.9 ±4.5	121.0±9.0	51.4 ±6.1

[a] Concentrations are reported as mean ± one standard deviation petroleum equivalents calculated at three emission wavelengths using Light Arabian Crude as a reference oil. They are based on analysis of triplicate sediment grabs collected at each station.

TABLE I-2. UV/F ANALYSES OF CRUISE MID-2 SEDIMENTS.

Emission Wavelength (nm)	Station 1	2	3	4	5	6	7
	Concentration (µg/g dry weight) [a]						
312	16.2 ±2.3	12.4 ±1.3	8.5 ± 3.3	11.2 ±2.2	20.7 ±9.8	10.8 ±2.7	9.58[b]
355	31.7 ±6.2	19.6 ±6.0	14.3 ±3.1	23.0 ±4.0	35.4 ±10.3	26.9 ±4.7	20.9 ±0.3
425	45.4 ±7.6	28.9 ±6.7	19.6 ±3.9	29.6 ±5.2	45.5 ±14.7	38.3 ±4.9	35.6 ±2.3

Emission Wavelength (nm)	Station 8	9	10	11	12	13
	Concentration (µg/g dry weight) [a]					
312	10.9 ±2.2	11.2[c]	9.0 ±1.8	20.4 ± 2.1	5.61[b]	32.4 ±3.1
355	22.0 ±4.4	16.9 ±4.3	19.7 ±3.9	41.0 ± 3.6	11.5 ±1.6	63.0 ±5.5
425	35.7 ±9.9	24.6 ±4.0	32.3 ±3.0	56.9 ± 3.2	16.4 ±1.6	86.3 ±9.4

[a]Concentrations are reported as mean ± one standard deviation petroleum equivalents calculated at three emission wavelengths using light Arabian crude. They are based on analysis of triplicate sediment grabs collected at each station.

[b]Only one sediment sample analyzed.

[c]Mean value of two replicates analyzed.

TABLE I-3. RESULTS OF UV/F ANALYSIS OF CRUISE MID-3 SEDIMENTS.

Emission Wavelength (nm)	Station				
	1	2	3	10	13
	Concentration (µg/g dry weight)				
312	20.5 ± 2.7	13.4 ± 1.6[a]	7.7 ± 0.1	10.9[b]	59.9 ± 61.7
355	36.1 ± 3.9	27.8 ± 11.3	21.0 ± 3.3	17.5 ± 6.2	72.7 ± 22.3
425	46.5 ± 8.3	41.5 ± 13.2	30.9 ± 4.9	34.8 ± 11.2	119.3 ± 21.5

[a] Two replicates only at 312 nm.
[b] One replicate only at 312 nm.

TABLE I-4. RESULTS OF UV/F ANALYSIS OF CRUISE MID-4 SEDIMENTS.

Emission Wavelength (nm)	Station				
	1	2	3	10	13
	Concentration (µg/g dry weight)				
312	22.1[a]	21.3[a]	9.2 ± 1.3	14.4 ± 2.6	43.3 ± 3.6
355	40.1 ± 8.7	39.0 ± 10.9	27.2 ± 4.5	29.0 ± 1.5	88.2 ± 11.7
425	54.9 ± 9.9	45.5 ± 13.7	39.1 ± 6.9	41.8 ± 4.2	131.3 ± 16.9

[a] One replicate only at 312 nm.

TABLE I-5. RESULTS OF UV/F ANALYSES OF CRUISE MID-5 SEDIMENTS.

Emission Wavelength (nm)	Station 1	2	3	10	13
	Concentration[a] (µg/g dry weight)				
312	17.05±5.75	18.83±4.38	14.40±2.34	14.08±3.29	42.01±13.77
355	36.01±10.46	42.54±8.42	20.71±2.73	27.44±9.53	56.44±7.79
425	41.45±11.14	49.44±9.08	24.28±3.34	29.01±11.31	63.92±4.80

[a]Concentrations are reported as mean ± standard deviation petroleum equivalents at three emission wavelengths using Arabian Light Crude Oil as a reference and are based on analysis of triplicate sediment grabs collected at each station.

TABLE I-6. RESULTS OF UV/F ANALYSES OF CRUISE MID-6 SEDIMENTS.

Emission Wavelength (nm)	Station 1	2	3	10	13	14
	Concentration[a] (µg/g dry weight)					
312	21.36±7.23	10.44±0.99	10.33±2.04	11.40±2.38	33.95±5.23	24.46±5.26
355	26.38±9.39	21.61±4.36	14.50±2.30	16.78±3.59	63.09±7.50	42.00±10.10
425	29.45±13.49	27.54±5.84	15.71±2.15	18.17±4.59	81.06±10.83	52.79±13.97

[a]Concentrations are reported as mean ± standard deviation petroleum equivalents at three emission wavelengths using Arabian Light Crude Oil as a reference and are based on analysis of triplicate sediment grabs collected at each station.

TABLE I-7. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE MID-1.

	Station													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Concentration (µg/g dry weight)													
Total Hydrocarbons [a]	19.5	13.1	18.1	17.2	25.1	20.5	23.3	13.9	18.3	7.0	35.2	6.8	46.5	2.9
Saturates	9.5	5.9	10.0	9.6	13.8	10.1	12.2	6.0	8.5	3.7	18.2	3.6	27.7	1.5
Aromatics	10.0	7.2	8.1	7.6	11.3	10.4	11.1	7.9	9.8	3.3	17.0	3.2	18.8	1.4
	Saturated Hydrocarbon Parameters[b]													
Resolved Saturates (%)	32	38	42	13	9	15	33	44	40	26	26	27	24	50
Unresolved Saturates (%)	68	62	58	87	91	85	67	56	60	74	74	73	76	50
OEPIC	3.68	3.63	3.54	3.27	3.18	2.66	2.78	4.40	3.84	2.32	3.49	1.36	3.24	1.64
Pristane/phytane	4.00	3.00	4.00	2.31	2.27	3.24	4.67	5.00	NC	2.08	5.60	NC	2.62	2.58
Phytane/n-C_{18}	0.18	0.23	0.27	0.32	0.32	0.19	0.27	0.23	NC	0.21	0.27	NC	0.32	0.26
Pristane/n-C_{17}	0.50	0.82	0.86	0.74	0.76	0.62	1.08	1.00	1.13	0.39	1.22	0.75	0.68	0.50

[a] Gravimetric concentrations.
[b] GC/FID data.
[c] Odd-Even Preference Index = $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2\,(n\text{-}C_{28}) + n\text{-}C_{30}}$

NC = Not calculated due to the low relative abundance of phytane.

TABLE I-8. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE MID-2.

	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
	Concentration (µg/g dry weight)												
Total Hydrocarbons [a]	14.9	12.4	11.5	12.8	27.5	14.5	11.9	12.7	10.0	9.2	25.8	5.7	37.1
Saturates	7.1	5.5	6.6	5.5	14.8	6.5	4.5	5.6	4.4	4.5	13.3	2.5	19.9
Aromatics	7.8	6.9	4.9	7.3	12.7	8.0	7.4	7.1	5.6	4.7	12.5	3.2	17.2
	Saturated Hydrocarbon Parameters[b]												
Resolved Saturates (%)	51	55	53	63	31	57	74	53	99	81	27	100	35
Unresolved Saturates (%)	49	45	47	37	69	43	26	47	1	19	73	0	65
OEPI[c]	3.11	2.58	1.41	2.43	2.41	3.19	3.40	2.96	2.91	3.13	3.41	3.39	4.26
Pristane/phytane	8.84	2.97	1.32	3.01	2.51	8.23	7.06	5.41	7.56	3.74	5.29	NC	1.80
Phytane/n-C_{18}	0.22	0.23	0.50	0.29	0.42	0.24	0.23	0.27	0.23	0.22	0.21	NC	0.26
Pristane/n-C_{17}	0.68	0.57	0.73	0.72	0.84	1.57	1.27	1.15	1.36	0.66	0.87	0.19	0.38

[a] Gravimetric concentrations.
[b] GC/FID data.
[c] Odd-Even Preference Index = $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2\,(n\text{-}C_{28}) + n\text{-}C_{30}}$

NC = Not calculated due to the low relative abundance of phytane.

TABLE I-9. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE MID-3.

	Station			
	1	2	10	13
	Concentration (µg/g dry weight)			
Total Hydrocarbons[a]	18.1	10.3	8.6	52.9
Saturates	8.6	5.5	5.0	29.0
Aromatics	9.5	4.8	3.6	23.9
	Saturated Hydrocarbon Parameters[b]			
Resolved Saturates (%)	30	31	43	16
Unresolved Saturates (%)	70	69	57	84
OEPI[c]	2.90	3.54	3.84	3.03
Pristane/phytane	NC	2.40	3.34	1.47
Phytane/n-C_{18}	NC	0.23	0.25	0.51
Pristane/n-C_{17}	0.47	0.42	0.66	0.60

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index = $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2\,(n\text{-}C_{28}) + n\text{-}C_{30}}$

NC = Not calculated due to the low relative abundance of phytane.

TABLE I-10. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE MID-4.

	Station			
	1	2	10	13
	Concentration (µg/g dry weight)			
Total Hydrocarbons[a]	9.0	6.7	10.8	20.4
Saturates	4.8	3.6	3.5	10.0
Aromatics	4.2	3.1	7.3	10.4
	Saturated Hydrocarbon Parameters[b]			
Resolved Saturates (%)	55	45	32	37
Unresolved Saturates (%)	45	55	68	63
OEPI[c]	3.96	3.12	1.32	1.60
Pristane/phytane	3.43	9.68	3.99	4.32
Phytane/n-C_{18}	0.23	0.22	0.20	0.18
Pristane/n-C_{17}	0.76	1.97	0.77	0.68

[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 I-11. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE MID-5.

	Station		
	1	10	13
	Concentration (µg/g dry weight)		
Total Hydrocarbons[a]	15.7	26.9	31.0
Saturates	9.4	24.1	2.2
Aromatics	6.3	2.8	28.8
	Saturated Hydrocarbon Parameters[b]		
Resolved Saturates (%)	68	100	58
Unresolved Saturates (%)	32	ND	42
OEPI[c]	3.3	3.0	2.1
Pristane/Phytane	3.1	3.3	3.5
Phytane/n-C_{18}	0.3	0.2	0.2
Pristane/n-C_{17}	0.6	0.5	0.6

[a]Gravimetric concentrations.
[b]GC/FID data.
[c]Odd-Even Preference Index = $\frac{2\,(n\text{-}C_{27} + n\text{-}C_{29})}{n\text{-}C_{26} + 2(n\text{-}C_{28}) + n\text{-}C_{30}}$

ND=Not detected.

TABLE I-12. SEDIMENT HYDROCARBON CONCENTRATIONS AND SATURATED HYDROCARBON PARAMETERS FOR SAMPLES COLLECTED ON CRUISE MID-6.

	Station				
	1	2	3	10	13
	Concentration (µg/g dry weight)				
Total Hydrocarbons[a]	27.6	23.7	17.1	15.1	46.9
Saturates	16.2	8.3	6.0	7.0	23.4
Aromatics	11.4	15.4	11.1	8.1	23.6
	Saturated Hydrocarbon Parameters[b]				
Resolved Saturates (%)	79	70	68	75	51
Unresolved Saturates (%)	21	30	32	25	49
OEPI[c]	2.0	2.5	2.3	2.3	2.6
Pristane/Phytane	2.4	3.1	2.3	3.4	3.7
Phytane/n-C_{18}	0.3	0.3	0.3	0.2	0.2
Pristane/n-C_{17}	0.5	0.6	0.5	0.7	0.7

[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 I-13. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBON (PAH) CONCENTRATIONS FOR SAMPLES COLLECTED ON CRUISE MID-1.

Compound	Station 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Concentration (ng/g dry weight)													
Naphthalene	ND	ND	ND	1	5	4	ND	ND	1	3	2	ND	2	11
C_1-Naphthalenes	1	1	ND	2	15	6	ND	ND	1	5	4	ND	4	19
C_2-Naphthalenes	5	5	4	5	19	9	2	3	6	6	13	1	16	30
C_3-Naphthalenes	5	5	5	6	19	9	2	4	6	5	13	1	24	36
C_4-Naphthalenes	ND	1	ND	ND	1	ND	ND	ND	1	ND	1	ND	13	4
Biphenyl	ND	1	ND	1	2	1	ND	ND	1	1	1	ND	2	5
Fluorenes	1	1	1	2	3	2	1	1	2	1	3	ND	4	10
C_1-Fluorenes	1	2	1	1	4	2	ND	1	1	2	3	ND	6	13
C_2-Fluorenes	ND	2	1	2	4	1	ND	1	1	2	3	ND	31	20
C_3-Fluorenes	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	17	7
Phenanthrenes	28	15	23	16	27	28	24	19	25	15	50	15	59	90
C_1-Phenanthrenes [a]	24	17	19	14	28	21	27	18	25	16	42	11	67	65
C_2-Phenanthrenes [a]	16	14	14	13	21	14	14	13	17	14	35	6	98	51
C_3-Phenanthrenes [a]	3	6	3	4	4	1	3	3	4	5	13	1	44	12
C_4-Phenanthrenes [a]	ND	1	ND	ND	ND	ND	ND	ND	1	ND	1	ND	5	18
Dibenzothiophene	1	1	1	1	1	1	ND	1	1	1	2	ND	3	7
C_1-Dibenzothiophenes	ND	1	1	1	1	1	ND	ND	1	ND	2	ND	5	11
C_2-Dibenzothiophenes	ND	1	ND	1	ND	ND	ND	ND	ND	ND	1	ND	14	11
C_3-Dibenzothiophenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2	2
Fluoranthene	37	20	30	19	25	24	38	28	36	15	72	21	87	124
Pyrene	27	15	23	14	20	18	27	19	25	12	53	17	67	106
Benz(a)anthracene	8	5	10	5	7	4	9	7	9	4	23	5	28	49
Chrysene	15	11	17	11	14	8	20	13	18	10	38	10	<1	86
Benzofluoranthene	53	32	66	35	39	19	69	44	76	30	116	30	160	201
Benzo(e)pyrene	16	9	19	10	11	4	19	11	22	8	34	7	50	76
Benzo(a)pyrene	10	6	10	6	6	2	10	5	ND	5	19	4	32	44
Perylene	10	11	10	6	5	2	12	9	17	8	19	2	30	54
Total PAH (sum of above compounds)	261	184	258	176	281	181	277	200	297	168	563	131	870	1157
FFPI [b]	23	30	19	31	45	40	17	20	23	36	25	17	41	20

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene} + \text{fluorene} + 1/2(\text{phenanthrene} + \text{C1-phenanthrenes}) + \text{dibenzothiophenes}}{\text{PAH}}$$

ND = No data.

TABLE I-14. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBON (PAH) CONCENTRATIONS FOR SAMPLES COLLECTED ON CRUISE MID-2.

Compound	Station 1	2	3	4	5	6	7	8	9	10	11	12	13
	Concentration (ng/g dry weight)												
Naphthalene	5	4	4	3	4	6	3	5	4	4	2	2	6
C_1-Naphthalenes	7	6	7	6	7	7	4	4	4	4	4	1	5
C_2-Naphthalenes	8	6	10	8	14	9	6	7	6	5	6	2	9
C_3-Naphthalenes	4	1	8	6	14	8	5	8	4	4	5	2	10
C_4-Naphthalenes	ND	ND	ND	ND	3	1	ND	1	ND	ND	ND	ND	1
Biphenyl	2	1	1	1	4	6	3	8	6	5	3	3	8
Fluorene	3	2	3	2	3	2	1	2	1	1	2	1	3
C_1-Fluorenes	2	ND	3	1	4	3	2	3	2	1	1	ND	3
C_2-Fluorenes	ND	ND	3	ND	4	3	2	4	2	1	ND	ND	1
C_3-Fluorenes	ND	ND	1	2	2	2	3	1	3	1	ND	ND	1
Phenanthrene	24	18	17	17	28	24	18	22	15	17	34	7	42
C_1-Phenanthrenes [a]	24	16	21	18	29	22	23	26	23	22	35	7	36
C_2-Phenanthrenes [a]	11	4	14	11	18	14	18	20	16	16	18	5	26
C_3-Phenanthrenes [a]	1	ND	1	1	2	2	5	6	6	4	1	1	6
C_4-Phenanthrenes [a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzothiophene	1	1	1	1	2	2	1	1	1	1	2	ND	3
C_1-Dibenzothiophenes	ND	ND	1	1	3	2	1	2	1	1	1	ND	3
C_2-Dibenzothiophenes	ND	ND	ND	ND	1	1	1	2	ND	ND	ND	ND	2
C_3-Dibenzothiophenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	29	19	17	20	20	20	30	33	29	28	57	7	51
Pyrene	22	15	12	16	15	14	23	23	22	21	43	6	37
Benz(a)anthracene	7	2	3	5	4	3	7	6	9	7	19	2	12
Chrysene	12	5	7	10	7	6	13	12	18	16	37	4	24
Benzofluoranthene	31	7	17	23	14	12	25	21	41	36	95	9	65
Benzo(e)pyrene	11	2	6	8	5	4	8	7	13	13	35	3	23
Benzo(a)pyrene	7	ND	3	5	4	2	5	4	8	7	24	2	16
Perylene	8	2	4	5	3	2	7	5	13	12	22	2	15
Total PAH (sum of above compounds)	219	111	164	170	214	177	214	234	248	227	446	66	408
FFPI [b]	31	38	45	36	53	49	34	41	31	26	18	36	31

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene} + \text{fluorene} + 1/2(\text{phenanthrene} + \text{C1-phenanthrenes}) + \text{dibenzothiophenes}}{\text{PAH}}$$

ND = No data.

TABLE I-15. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBONS (PAH) CONCENTRATIONS FOR SAMPLES COLLECTED ON CRUISE MID-3.

Compound	Station 1	Station 2	Station 10	Station 13
	Concentration (ng/g dry weight)			
Naphthalene	3	3	1	4
C_1-Naphthalenes	4	2	2	6
C_2-Naphthalenes	7	5	2	14
C_3-Naphthalenes	8	7	6	22
C_4-Naphthalenes	1	1	3	11
Biphenyl	1	1	2	2
Fluorine	2	1	1	4
C_1-Fluorenes	2	2	1	7
C_2-Fluorenes	3	3	1	14
C_3-Fluorenes	0	1	0	10
Phenanthrene	19	13	10	42
C_1-Phenanthrenes[a]	12	9	9	32
C_2-Phenanthrenes[a]	12	9	10	41
C_3-Phenanthrenes[a]	9	8	6	21
C_4-Phenanthrenes[a]	7	6	1	10
Dibenzothiophene	1	1	1	3
C_1-Dibenzothiophenes	1	1	0	6
C_2-Dibenziothiophenes	1	2	0	20
C_3-Dibenziothophenes	1	1	0	22
Fluoranthene	26	19	14	58
Pyrene	19	14	11	42
Benz(a)anthracene	9	6	7	23
Chrysene	14	11	12	29
Benzofluoranthene	38	28	27	67
Benzo(e)pyrene	13	9	9	26
Benzo(a)pyrene	9	6	8	17
Perylene	10	7	12	20
Total PAH	232	176	156	573
FFPI[b]	33	36	28	44

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene} + \text{fluorene} + 1/2(\text{phenanthrene} + \text{C1-phenanthrenes}) + \text{dibenzothiophenes}}{\text{PAH}}$$

TABLE I-16. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBONS (PAH) CONCENTRATIONS FOR SAMPLES COLLECTED ON CRUISE MID-4.

	Station			
	1	2	10	13
Compound	Concentration (ng/g dry weight)			
Naphthalene	2	1	1	4
C_1-Naphthalenes	3	2	2	7
C_2-Naphthalenes	6	4	4	15
C_3-Napthalenes	5	3	3	16
C_4-Napthalenes	0	0	0	3
Biphenyl	1	0	1	2
Fluorene	1	1	1	5
C_1-Fluorenes	1	0	1	6
C_2-Fluorenes	0	0	0	7
C_3-Fluorenes	0	0	0	2
Phenanthrene	15	12	12	48
C_1-Phenanthrenes[a]	48	36	36	126
C_2-Phenanthrenes[a]	41	27	29	108
C_3-Phenanthrenes[a]	10	6	9	56
C_4-Phenanthrenes[a]	0	0	0	3
Dibenzothiophene	1	1	1	4
C_1-Dibenzothiophene	1	0	0	5
C_2-Dibenzothiophene	0	0	0	8
C_3-Dibenzothiophene	0	0	0	1
Fluoranthene	24	17	17	64
Pyrene	16	14	14	49
Benz(a)anthracene	7	5	5	31
Chrysene	14	10	10	38
Benzofluoranthene	52	37	35	100
Benzo(e)pyrene	15	10	11	28
Benza(a)pyrene	12	7	7	31
Perylene	11	8	10	25
Total PAH (sum of above)	286	201	209	792
FFPI[b]	35	33	35	40

[a] May include some anthracene alkyl homologues.

[b] Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene} + \text{fluorene} + 1/2(\text{phenanthrene} + \text{C1-phenanthrenes}) + \text{dibenzothiophenes}}{\text{PAH}}$$

TABLE I-17. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBON (PAH) CONCENTRATIONS FOR SAMPLES COLLECTED ON CRUISE MID-5.

	Station		
	1	10	13
Compound	Concentration (ng/g dry weight)		
Naphthalene	4	2	6
C1-Naphthalenes	6	4	12
C2-Naphthalenes	7	5	22
C3-Naphthalenes	5	5	22
C4-Naphthalenes	1	1	5
Biphenyl	2	1	3
Fluorene	2	1	5
C1-Fluorenes	3	2	11
C2-Fluorenes	3	3	14
C3-Fluorenes	2	3	12
Phenanthrene	13	11	45
C1-Phenanthrenes[a]	8	5	38
C2-Phenanthrenes[a]	6	7	26
C3-Phenanthrenes[a]	2	3	10
C4-Phenanthrenes[a]	1	1	2
Dibenzothiophenes	2	1	4
C1-Dibenzothiophenes	1	1	5
C2-Dibenzothiphenes	1	2	6
C3-Dibenzothiophenes	ND	2	2
Fluoranthene	17	14	54
Pyrene	15	11	44
Benz(a)anthracene	8	6	18
Chrysene	12	9	33
Benzofluoranthene	33	31	110
Benzo(e)pyrene	13	11	37
Benzo(a)pyrene	14	9	26
Perylene	16	12	23
Total PAH (sum of above)	199	164	598
FFPI[b]	24	25	28

[a]May include some anthracene alkyl homologues.

[b]Fossil Fuel Pollution Index, defined in oehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene} + \text{fluorene} + 1/2(\text{phenanthrene} + \text{C1-phenanthrenes}) + \text{dibenzothiophenes}}{\text{PAH}}$$

TABLE I-18. SEDIMENT POLYCYCLIC AROMATIC HYDROCARBON (PAH) CONCENTRATIONS FOR SAMPLES COLLECTED ON CRUISE MID-6.

Compound	Station 1	2	3	10	13
	Concentration (ng/g dry weight)				
Naphthalene	4	3	3	2	5
C1-Naphthalenes	6	5	5	4	11
C2-Naphthalenes	8	6	5	4	16
C3-Naphthalenes	8	5	5	5	14
C4-Naphthalenes	2	2	1	1	2
Biphenyl	2	1	1	1	2
Fluorene	2	2	2	1	5
C1-Fluorenes	3	2	2	2	5
C2-Fluorenes	4	4	3	3	7
C3-Fluorenes	5	2	2	2	9
Phenathrene	18	14	12	10	38
C1-Phenanthrenes[a]	12	9	8	7	22
C2-Phenanthrenes[a]	10	7	6	7	18
C3-Phenanthrenes[a]	5	3	3	3	6
C4-Phenanthrenes[a]	1	1	1	1	1
Dibenzothiophenes	2	1	1	1	3
C1-Dibenzothiophenes	2	2	1	1	4
C2-Dibenzothiophenes	3	2	1	1	6
C3-Dibenzothiophenes	1	1	1	1	1
Fluoranthrene	24	20	16	15	52
Pyrene	19	16	13	12	41
Benz(a)anthracene	11	7	6	6	17
Chrysene	13	12	10	9	28
Benzofluoranthene	59	32	34	31	96
Benzo(e)pyrene	23	16	12	13	35
Benzo(a)pyrene	13	10	9	8	24
Perylene	20	13	11	15	24
Total PAH (sum of above)	278	196	173	166	493
FFPI[b]	23	24	23	22	24

[a]May include some anthracene alkyl homologues.

[b]Fossil Fuel Pollution Index, defined in Boehm and Farrington (1984).

$$FFPI = \frac{\text{naphthalene} + \text{fluorene} + 1/2(\text{phenanthrene} + \text{C1-phenanthrenes}) + \text{dibenzothiophenes}}{\text{PAH}}$$

APPENDIX J

TABLE J-1. SEDIMENT GRAIN SIZE DATA FOR U.S. MID-ATLANTIC MONITORING PROGRAM STATIONS.

Station	Cruise Replicate	Percent Water	Percent Gravel	Percent Sand					Percent Silt				Percent Clay		
				-1-0ϕ	0-1ϕ	1-2ϕ	2-3ϕ	3-4ϕ	4-5ϕ	5-6ϕ	6-7ϕ	7-8ϕ	8-9ϕ	9-10ϕ	> 10ϕ
1	1-1	64.5	0.0	0.0	0.4	3.1	3.5	5.2	8.5	13.7	9.3	11.5	10.4	8.9	25.6
	1-2	68.2	0.0	0.0	0.0	0.0	0.0	3.2	7.6	12.3	9.4	11.3	11.3	9.9	34.9
	1-3	68.7	0.0	0.0	0.0	0.0	0.0	4.3	6.9	12.9	10.4	12.5	10.4	10.8	31.8
	2-1	69.0	0.0	0.0	0.0	0.0	0.0	5.1	5.2	12.0	13.3	13.0	10.0	10.0	31.4
	2-2	62.8	0.0	0.0	0.9	2.9	3.9	5.2	10.6	10.9	10.6	10.3	8.7	6.8	29.2
	2-3	63.7	3.8	5.6	4.7	3.6	4.5	6.8	8.5	9.2	8.5	8.8	8.1	5.1	22.8
	3-1	68.9	0.0	0.0	0.0	0.0	0.0	9.5	5.9	12.3	11.0	13.2	10.2	7.6	30.2
	3-2	66.2	0.0	0.0	0.0	0.0	0.0	5.2	6.4	13.1	11.7	12.7	11.3	7.9	31.7
	3-3	63.3	0.0	0.0	0.4	1.9	3.2	4.5	5.5	12.3	11.5	11.0	10.2	7.9	31.6
	4-1	67.0	0.0	0.0	0.0	0.0	0.0	4.5	5.9	9.0	10.1	11.2	9.0	7.4	42.8
	4-2	62.3	0.0	0.0	0.0	0.0	0.0	9.1	8.9	7.6	1.9	10.6	8.7	7.2	36.0
	4-3	65.2	0.0	0.0	0.0	0.0	0.0	4.3	6.7	10.1	9.3	12.7	9.3	9.3	38.4
	5-1	56.5	0.0	0.0	0.0	0.0	0.0	11.4	7.9	12.2	10.0	11.4	7.9	8.7	30.6
	5-2	58.8	0.0	0.0	1.7	5.3	6.3	7.1	1.5	12.3	10.5	9.3	7.8	7.8	30.3
	5-3	56.2	0.0	0.0	0.2	2.4	4.2	8.9	3.9	13.4	9.9	10.4	8.2	9.1	29.4
	6-1	57.0	0.2	0.4	1.7	6.0	9.1	10.4	5.6	7.6	6.8	8.8	5.6	6.4	31.5
	6-2	67.3	0.0	0.0	0.0	0.0	0.0	5.4	8.2	10.7	10.7	11.8	9.7	9.0	34.5
	6-3	67.0	0.0	0.0	0.0	0.0	0.0	4.9	5.2	12.5	9.9	13.0	9.9	8.6	35.9
2	1-1	57.8	0.0	0.0	0.2	2.6	4.1	5.3	8.4	10.4	9.4	11.7	7.0	9.1	31.8
	1-2	58.6	0.0	0.0	0.1	2.9	4.7	6.0	13.5	11.0	8.6	9.9	8.3	9.4	25.5
	1-3	56.5	0.2	0.2	1.7	7.2	10.7	10.9	6.5	8.1	9.4	7.1	8.1	6.8	23.1
	2-1	54.7	0.0	0.3	1.4	8.3	14.3	13.1	9.3	9.0	6.9	7.2	6.3	3.9	20.1
	2-2	60.3	0.1	0.1	0.7	5.4	9.0	9.2	8.5	10.3	8.3	8.5	6.8	7.3	25.8
	2-3	62.9	0.0	0.1	0.3	4.1	6.4	7.6	9.5	11.2	8.8	10.2	7.8	7.5	26.5
	3-1	63.1	0.0	0.0	0.4	3.1	4.7	5.7	8.7	12.4	9.9	11.6	8.7	7.9	26.9
	3-2	59.8	0.0	0.1	0.8	7.2	8.9	7.9	1.7	12.0	9.0	10.7	8.3	7.3	26.0
	3-3	61.7	0.0	0.0	0.2	4.3	6.2	6.8	8.4	11.6	9.1	12.8	7.8	8.7	24.0
	4-1	63.2	0.0	0.0	0.3	4.1	5.4	5.4	10.8	8.6	10.4	12.1	6.9	7.8	28.1
	4-2	60.3	0.0	0.0	0.3	3.7	4.6	4.8	8.5	10.1	9.1	10.4	7.8	8.5	32.2
	4-3	58.3	0.0	0.0	0.2	2.3	3.9	5.2	10.5	10.7	8.4	10.7	7.5	7.5	33.1
	5-1	60.4	0.0	0.1	0.6	4.7	7.2	9.0	4.4	11.6	10.0	11.2	10.0	8.4	22.8
	5-2	61.9	0.0	0.2	0.9	6.2	11.5	13.5	6.0	10.1	7.5	7.9	7.1	6.4	22.8
	5-3	53.7	0.0	0.2	0.6	5.8	9.1	8.3	7.8	10.9	8.8	7.5	7.5	6.8	26.8
	6-1	58.3	0.0	0.1	0.6	5.0	8.3	10.6	9.7	10.4	7.8	8.2	7.4	7.1	24.9
	6-2	62.9	0.0	0.0	0.3	4.9	6.7	7.0	8.2	10.9	8.2	10.5	7.3	6.8	29.2
	6-3	60.3	0.0	0.1	0.4	4.7	7.7	8.4	7.1	11.0	9.4	8.3	7.5	7.5	27.9

TABLE J-1. (Continued).

Station	Cruise Replicate	Percent Water	Percent Gravel	Percent Sand					Percent Silt				Percent Clay		
				-1-0ϕ	0-1ϕ	1-2ϕ	2-3ϕ	3-4ϕ	4-5ϕ	5-6ϕ	6-7ϕ	7-8ϕ	8-9ϕ	9-10ϕ	> 10ϕ
3	1-1	53.8	0.0	0.0	1.6	7.1	8.9	8.1	12.2	12.2	5.8	7.4	6.4	4.8	25.4
	1-2	61.4	0.0	0.0	0.8	3.7	5.2	7.0	6.2	13.5	9.8	9.2	9.5	7.9	27.2
	1-3	57.5	0.0	0.0	1.0	5.2	6.5	6.0	12.3	9.7	9.0	9.4	7.1	6.8	26.9
	2-1	51.8	0.0	0.2	1.3	7.6	9.5	8.7	11.8	9.6	7.7	8.3	5.0	6.6	23.6
	2-2	55.6	0.0	0.3	1.4	8.2	10.2	9.4	13.1	10.5	8.4	7.5	7.3	5.2	18.6
	2-3	54.0	0.1	0.2	2.0	11.3	14.0	12.9	9.8	8.7	6.8	7.6	4.3	5.4	16.8
	3-1	58.5	0.2	0.2	1.3	7.0	10.8	14.0	7.0	9.6	7.0	9.2	5.7	6.1	22.0
	3-2	56.5	0.0	0.0	0.8	5.2	8.4	11.0	10.5	13.1	4.3	9.5	6.2	7.9	23.0
	3-3	51.3	0.0	0.2	0.9	5.7	10.4	12.9	9.7	10.3	7.6	7.6	7.1	4.5	23.1
	4-1	0.0	0.0	0.2	1.5	7.8	10.5	10.6	10.0	6.9	5.9	7.7	5.4	3.6	29.8
	4-2	50.4	0.1	0.2	0.8	4.9	8.5	10.9	10.8	7.5	6.4	9.3	5.8	5.8	29.0
	4-3	49.5	0.0	0.7	3.2	8.3	9.9	12.3	10.1	6.8	5.3	6.3	4.0	5.0	28.2
	5-1	60.3	0.0	0.1	0.4	3.0	5.5	9.4	4.3	10.7	8.6	10.7	7.9	8.2	31.1
	5-2	55.3	0.0	0.1	0.4	4.5	7.1	8.3	7.1	10.9	8.3	10.4	8.6	7.0	27.3
	5-3	55.3	0.0	0.0	0.5	6.5	9.0	8.6	2.0	12.4	7.9	10.9	7.6	8.2	26.4
	6-1	57.9	0.0	0.0	0.4	2.7	4.2	7.8	10.6	11.7	7.7	10.2	7.3	9.5	27.8
	6-2	59.8	0.0	0.0	0.2	2.9	4.6	7.1	10.9	11.3	9.2	10.1	8.4	7.6	27.7
	6-3	61.6	0.0	0.0	0.4	4.1	6.9	11.3	5.8	12.3	8.9	10.6	6.5	8.5	24.8
4	1-1	60.9	0.0	0.0	0.3	3.6	4.7	4.7	8.8	13.7	8.8	9.8	8.4	8.4	28.8
	1-2	62.5	0.0	0.0	0.4	3.9	6.4	6.7	10.4	14.0	8.6	10.1	8.3	7.9	23.3
	1-3	55.2	0.0	0.0	1.1	8.7	12.2	20.1	7.7	8.2	6.5	6.1	5.1	5.4	18.9
	2-1	62.5	0.0	0.0	0.4	2.9	5.0	6.0	10.6	13.3	8.3	8.7	9.5	7.6	27.7
	2-2	60.6	0.0	0.0	0.3	3.5	4.5	4.5	10.6	12.1	9.8	9.8	8.7	9.1	27.2
	2-3	61.0	0.0	0.0	0.5	4.5	7.3	7.7	10.2	11.9	7.7	9.8	8.6	8.4	23.5
	3-1	59.7	0.0	0.2	0.8	3.9	5.6	7.2	10.4	10.4	9.5	9.2	7.7	9.5	25.7
	3-2	59.1	0.0	0.0	0.4	3.7	6.2	8.7	9.7	12.0	7.7	9.7	8.4	7.7	25.8
	3-3	54.4	0.0	0.1	1.2	8.9	10.7	9.4	10.2	10.8	8.1	7.8	5.7	6.6	20.4
	4-1	56.8	0.0	0.3	1.0	4.4	5.5	5.9	9.2	9.4	9.4	9.0	6.3	7.7	31.9
	4-2	52.8	0.0	0.4	1.7	6.5	7.2	5.5	8.7	9.5	7.0	8.5	6.0	9.5	29.5
	4-3	63.0	0.0	0.0	0.0	0.0	5.3	5.3	9.6	9.2	8.8	11.8	8.5	5.5	36.0
	5-1	62.4	0.0	0.1	0.4	5.5	7.2	6.8	8.1	12.3	6.7	9.9	9.2	7.8	26.1
	5-2	56.8	0.5	1.0	2.0	5.8	6.2	6.4	1.0	11.3	10.1	10.8	9.8	9.4	25.7
	5-3	61.4	0.0	0.3	0.6	4.1	5.5	5.8	7.5	12.4	10.2	11.3	9.8	11.3	21.1
	6-1	69.2	0.0	0.1	0.6	3.1	4.5	6.1	4.6	13.7	9.6	12.5	9.1	9.1	27.0
	6-2	58.9	0.0	0.0	0.3	2.9	5.3	7.1	10.5	11.3	9.3	9.3	8.2	9.7	26.1
	6-3	64.2	0.0	0.0	0.4	3.1	4.8	6.3	9.3	11.1	9.3	10.2	7.9	7.9	29.7

TABLE J-1. (Continued).

Station	Cruise Replicate	Percent Water	Percent Gravel	Percent Sand					Percent Silt				Percent Clay		
				-1-0ϕ	0-1ϕ	1-2ϕ	2-3ϕ	3-4ϕ	4-5ϕ	5-6ϕ	6-7ϕ	7-8ϕ	8-9ϕ	9-10ϕ	> 10ϕ
5	1-1	65.3	0.0	0.0	0.0	0.0	0.0	3.6	9.3	10.7	9.3	12.0	8.9	10.2	36.0
	1-2	61.7	0.0	0.0	0.0	0.0	0.0	5.5	9.6	10.4	11.2	9.6	9.6	6.4	37.6
	1-3	63.1	0.0	0.0	0.0	0.0	0.0	4.9	6.6	12.4	9.9	12.8	8.8	10.6	34.0
	2-1	65.9	0.0	0.0	0.0	0.0	0.0	5.2	8.1	11.8	11.5	10.8	10.8	8.7	33.1
	2-2	67.6	0.0	0.0	0.0	0.0	0.0	4.0	8.2	10.9	12.8	11.2	11.2	9.4	32.2
	2-3	63.2	0.0	0.0	0.0	0.0	0.0	4.5	7.6	11.5	10.6	11.9	11.9	11.0	31.0
	3-1	66.7	0.0	0.0	0.0	0.0	0.0	6.7	7.0	15.8	11.7	15.8	9.9	7.6	25.6
	3-2	66.4	0.0	0.0	0.0	0.0	0.0	4.8	3.2	14.2	11.7	17.1	9.2	12.4	27.4
	3-3	65.5	0.0	0.0	0.0	0.0	0.0	6.1	5.6	12.9	10.8	15.7	11.8	12.2	25.0
	4-1	66.2	0.0	0.0	0.0	0.0	0.0	5.1	5.3	10.6	10.2	15.1	10.2	7.4	36.0
	4-2	64.1	0.0	0.0	0.0	0.0	0.0	6.0	6.6	9.7	10.1	12.4	8.5	8.1	38.7
	4-3	65.7	0.0	0.0	0.0	0.0	0.0	5.7	6.1	11.5	9.4	13.8	9.1	8.8	35.7
	5-1	57.7	0.0	0.0	0.0	0.0	0.0	8.9	7.1	12.0	10.3	11.7	9.2	7.4	33.3
	5-2	63.1	0.0	0.0	0.0	0.0	0.0	7.4	4.1	13.2	10.7	11.9	10.7	9.9	32.1
	5-3	65.8	0.0	0.0	0.0	0.0	0.0	7.2	3.3	13.0	10.0	15.1	8.4	9.6	33.5
	6-1	65.2	0.0	0.0	0.0	0.0	0.0	8.8	8.3	12.8	10.4	9.5	12.4	10.4	27.4
	6-2	65.4	0.0	0.0	0.0	0.0	0.0	6.8	5.6	12.7	9.6	12.7	11.1	11.1	30.4
	6-3	67.2	0.0	0.0	0.0	0.0	0.0	5.0	7.7	13.2	9.3	13.7	9.3	11.5	30.2
6	1-1	65.7	0.0	0.0	0.0	0.0	0.0	6.3	7.3	12.8	10.1	11.9	10.1	8.7	32.9
	1-2	66.1	0.0	0.0	0.0	0.0	0.0	6.5	6.3	12.9	10.9	11.3	10.0	9.6	32.6
	1-3	65.2	0.0	0.0	0.0	0.0	0.0	5.3	5.6	12.2	12.2	10.0	10.4	10.9	33.4
	2-1	62.8	0.0	0.0	0.0	0.0	5.4	10.0	8.4	10.9	9.5	9.1	9.1	7.7	29.9
	2-2	64.7	0.0	0.0	0.0	0.0	0.0	8.2	9.4	12.5	10.7	9.8	10.2	7.6	31.6
	2-3	66.2	0.0	0.0	0.0	0.0	0.0	8.8	7.8	12.0	11.6	10.5	10.1	8.6	30.6
	3-1	58.8	0.0	0.1	0.3	2.2	3.6	7.0	10.9	11.2	8.9	11.2	8.9	10.2	25.6
	3-2	64.0	0.0	0.0	0.0	0.0	0.0	6.4	7.6	13.7	9.0	10.9	11.8	9.9	30.7
	3-3	70.0	0.0	0.0	0.0	0.0	0.0	7.3	10.9	11.3	10.1	13.0	9.7	10.9	26.7
	4-1	66.7	0.0	0.0	0.0	0.0	0.0	6.1	8.3	10.6	9.2	14.7	8.3	8.7	34.0
	4-2	65.1	0.0	0.0	0.0	0.0	0.0	7.1	8.4	10.8	10.8	15.6	9.6	11.2	26.4
	4-3	66.9	0.0	0.0	0.0	0.0	0.0	7.2	8.3	10.2	9.7	13.9	10.6	10.2	30.0
	5-1	61.8	0.0	0.0	0.0	0.0	0.0	8.6	7.4	14.5	8.6	12.9	10.9	12.1	25.0
	5-2	63.4	0.0	0.0	0.0	0.0	2.5	7.6	3.8	13.3	11.9	12.9	11.5	11.9	24.5
	5-3	61.4	0.0	0.0	0.0	0.0	0.0	8.8	6.0	12.5	11.2	11.2	9.9	12.1	28.2
	6-1	67.6	0.0	0.0	0.0	0.0	0.0	5.8	6.8	11.6	10.0	11.6	12.0	10.0	32.1
	6-2	64.8	0.0	0.0	0.0	0.0	0.0	7.1	6.5	12.2	10.0	13.0	8.7	13.0	29.5
	6-3	67.5	0.0	0.0	0.0	0.0	0.0	5.4	6.0	12.5	11.5	12.5	10.5	9.5	32.0

TABLE J-1 (Continued).

Station	Cruise Replicate	Percent Water	Percent Gravel	Percent Sand					Percent Silt				Percent Clay		
				-1-0ϕ	0-1ϕ	1-2ϕ	2-3ϕ	3-4ϕ	4-5ϕ	5-6ϕ	6-7ϕ	7-8ϕ	8-9ϕ	9-10ϕ	> 10ϕ
7	1-1	67.4	0.0	0.0	0.0	0.0	0.0	5.0	6.7	11.5	10.1	12.0	7.2	9.1	38.4
	1-2	67.3	0.0	0.0	0.0	0.0	0.0	7.1	4.0	11.5	11.5	12.8	11.1	9.7	34.3
	1-3	66.1	0.0	0.0	0.0	0.0	0.0	7.0	7.3	11.3	11.3	12.3	11.1	5.9	33.7
	2-1	63.7	0.0	0.0	0.0	0.0	0.0	4.9	5.3	11.0	13.1	15.1	6.1	9.8	34.7
	2-2	65.4	0.0	0.0	0.0	0.0	0.0	4.7	6.1	11.4	11.4	11.8	10.6	9.0	35.0
	2-3	60.5	0.0	0.0	0.0	0.0	0.0	9.2	7.4	10.9	10.9	11.9	8.8	9.1	31.9
	3-1	63.9	0.0	0.0	0.0	0.0	0.0	4.6	4.0	12.9	9.5	13.2	10.5	12.0	33.2
	3-2	67.7	0.0	0.0	0.0	0.0	0.0	8.2	5.3	12.4	10.6	11.5	9.3	8.5	34.1
	3-3	65.5	0.0	0.0	0.0	0.0	0.0	4.6	5.9	11.8	10.6	12.7	14.8	8.9	30.8
	4-1	67.8	0.0	0.0	0.0	0.0	0.0	5.2	6.0	9.2	6.9	17.9	8.2	4.1	42.6
	4-2	62.3	0.0	0.0	0.0	0.0	0.0	5.4	8.3	8.7	6.5	12.3	10.1	4.7	43.9
	4-3	59.6	0.0	0.0	0.0	0.0	0.0	5.3	5.6	8.7	8.4	15.7	8.0	5.2	43.2
	5-1	61.2	0.0	0.0	0.0	0.0	0.0	5.1	5.4	10.2	10.8	10.8	10.2	10.2	37.3
	5-2	60.0	0.0	0.0	0.0	0.0	0.0	5.2	5.7	10.5	11.0	11.4	9.2	9.2	37.7
	5-3	61.4	0.0	0.0	0.0	0.0	0.0	5.3	4.4	12.1	8.5	14.1	8.9	9.3	37.5
	6-1	64.8	0.0	0.0	0.0	0.0	0.0	4.8	7.6	10.1	9.1	12.1	8.6	10.6	37.2
	6-2	67.1	0.0	0.0	0.0	0.0	0.0	4.5	6.2	9.9	10.9	10.4	9.9	8.8	39.5
	6-3	63.3	0.0	0.0	0.0	0.0	0.0	4.8	2.9	11.2	11.2	12.9	7.9	13.3	35.7
8	1-1	68.1	0.0	0.0	0.0	0.0	0.0	4.6	5.8	10.0	12.1	10.8	9.6	9.2	37.9
	1-2	64.1	0.0	0.0	0.0	0.0	0.0	4.8	5.7	10.4	10.4	11.9	9.3	9.0	38.4
	1-3	66.5	0.0	0.0	0.0	0.0	0.0	5.1	5.6	10.7	11.7	11.2	10.2	8.2	37.2
	2-1	65.3	0.0	0.0	0.0	0.0	0.0	4.7	4.2	12.1	11.5	13.9	10.6	11.5	31.5
	2-2	63.0	0.0	0.0	0.0	0.0	0.0	5.8	7.8	11.8	12.5	12.8	10.5	13.2	25.7
	2-3	64.1	0.0	0.0	0.0	0.0	0.0	4.4	5.2	10.4	11.7	13.0	8.7	9.6	36.9
	3-1	64.4	0.0	0.0	0.0	0.0	0.0	6.4	4.5	9.6	13.1	13.1	11.6	13.6	28.2
	3-2	71.0	0.0	0.0	0.0	0.0	0.0	6.3	0.5	10.1	13.8	15.4	14.4	13.8	25.6
	3-3	67.7	0.0	0.0	0.0	0.0	0.0	6.0	1.4	10.3	13.9	14.2	12.5	12.5	29.2

TABLE J-1. (Continued).

Station	Cruise Replicate	Percent Water	Percent Gravel	Percent Sand					Percent Silt				Percent Clay		
				-1-0ϕ	0-1ϕ	1-2ϕ	2-3ϕ	3-4ϕ	4-5ϕ	5-6ϕ	6-7ϕ	7-8ϕ	8-9ϕ	9-10ϕ	> 10ϕ
9	1-1	66.5	0.0	0.0	0.0	0.0	0.0	2.7	5.9	9.8	12.6	10.2	9.0	11.4	38.4
	1-2	67.7	0.0	0.0	0.0	0.0	0.0	2.6	5.2	10.3	13.9	13.5	10.3	10.3	33.8
	1-3	64.6	0.0	0.0	0.0	0.0	0.0	2.6	4.3	10.3	12.6	12.6	10.6	9.5	37.5
	2-1	67.0	0.0	0.0	0.0	0.0	0.0	2.7	3.6	10.8	10.8	11.7	14.0	9.9	36.5
	2-2	66.6	0.0	0.0	0.0	0.0	0.0	2.8	4.3	11.9	10.4	13.7	11.9	10.4	34.6
	2-3	66.2	0.0	0.0	0.0	0.0	0.0	3.2	4.8	10.0	11.1	13.0	11.9	9.6	36.3
	3-1	68.7	0.0	0.0	0.0	0.0	0.0	2.9	1.2	12.1	12.9	17.3	11.7	15.7	26.2
	3-2	68.2	0.0	0.0	0.0	0.0	0.0	3.6	2.1	8.0	14.9	13.8	13.8	17.0	26.8
	3-3	68.3	0.0	0.0	0.0	0.0	0.0	3.1	5.8	8.7	13.6	12.1	12.6	17.8	26.4
	4-1	65.0	0.0	0.0	0.0	0.0	0.0	1.9	1.3	8.0	8.4	20.6	5.5	4.6	49.8
	4-2	61.8	0.0	0.0	0.0	0.0	0.0	2.7	3.3	7.3	6.9	18.5	6.9	5.8	48.6
	4-3	65.4	0.0	0.0	0.0	0.0	0.0	2.2	3.6	6.3	6.7	21.3	8.7	6.7	44.6
	5-1	61.8	0.0	0.0	0.0	0.0	0.0	3.9	2.8	11.1	11.7	13.9	11.1	12.2	33.3
	5-2	64.3	0.0	0.0	0.0	0.0	0.0	3.2	3.8	11.9	10.3	13.0	9.7	10.8	37.3
	5-3	66.3	0.0	0.0	0.0	0.0	0.0	3.1	2.1	12.4	10.7	12.4	11.2	9.0	39.0
	6-1	64.9	0.0	0.0	0.0	0.0	0.0	2.5	2.5	10.4	11.4	13.4	10.9	11.9	37.1
	6-2	66.4	0.0	0.0	0.0	0.0	0.0	3.9	3.2	11.6	12.1	12.1	11.0	12.1	34.1
	6-3	68.6	0.0	0.0	0.0	0.0	0.0	2.9	2.5	9.9	11.3	12.8	11.8	10.4	38.5
10	1-1	60.6	0.0	0.0	0.3	6.0	7.5	4.4	9.5	11.1	8.8	9.1	7.4	7.8	28.0
	1-2	55.2	0.0	0.0	0.5	11.3	14.2	8.2	11.8	8.7	7.0	6.7	5.6	5.0	21.0
	1-3	60.5	0.0	0.0	0.6	7.9	11.3	8.5	9.4	9.4	7.8	8.3	6.7	5.0	25.2
	2-1	57.0	0.0	0.0	0.5	6.5	9.3	7.0	9.0	10.7	5.8	10.0	7.3	7.3	26.5
	2-2	50.7	0.0	0.1	0.3	4.1	7.0	5.6	11.3	10.2	7.5	8.9	8.0	9.7	27.4
	2-3	53.6	0.0	0.0	0.4	8.3	10.4	6.0	8.6	9.8	7.7	8.3	8.6	5.9	26.1
	3-1	64.3	0.0	0.0	0.3	5.0	9.1	7.5	4.7	12.2	9.4	10.2	8.2	12.2	21.2
	3-2	65.9	0.0	0.0	0.4	4.4	7.4	7.3	8.7	11.9	8.1	10.0	9.4	9.4	23.1
	3-3	63.1	0.0	0.2	0.5	5.5	9.3	8.0	6.1	10.8	8.9	10.8	8.3	8.3	23.3
	4-1	ND	0.0	0.0	0.3	3.5	6.4	6.1	8.5	9.8	8.2	11.2	7.1	6.1	32.8
	4-2	ND	0.0	0.1	0.4	4.0	6.7	7.0	8.9	9.5	8.6	10.1	7.4	5.7	31.5
	4-3	ND	0.0	0.1	0.3	3.8	6.6	6.3	10.2	9.8	8.0	11.2	6.2	5.4	32.1
	5-1	56.7	0.0	0.0	0.4	6.5	9.8	7.8	8.3	8.7	7.4	9.7	6.9	9.7	24.9
	5-2	54.0	0.0	0.0	0.4	4.0	7.0	6.4	9.1	9.4	7.1	10.1	7.7	8.4	30.3
	5-3	54.2	0.0	0.0	0.4	3.9	6.9	6.7	7.4	10.4	8.2	10.8	7.4	7.4	30.7
	6-1	55.7	0.0	0.0	0.7	13.6	16.0	9.6	8.4	8.4	6.3	6.3	5.2	3.8	21.6
	6-2	63.2	0.0	0.0	0.3	5.1	8.6	8.3	4.0	11.4	7.9	10.4	8.4	6.4	29.2
	6-3	57.9	0.0	0.1	0.3	3.8	6.2	5.8	5.7	10.5	7.7	12.4	12.4	3.8	31.2

TABLE J-1. (Continued).

Station	Cruise Replicate	Percent Water	Percent Gravel	Percent Sand					Percent Silt				Percent Clay		
				-1-0ϕ	0-1ϕ	1-2ϕ	2-3ϕ	3-4ϕ	4-5ϕ	5-6ϕ	6-7ϕ	7-8ϕ	8-9ϕ	9-10ϕ	> 10ϕ
11	1-1	64.7	0.0	0.0	0.0	0.0	0.0	2.8	6.5	13.1	12.6	11.3	9.2	8.3	36.2
	1-2	63.4	0.0	0.0	0.0	0.0	0.0	2.4	8.0	11.6	14.0	9.6	10.0	6.8	37.6
	1-3	66.4	0.0	0.0	0.0	0.0	0.0	1.9	8.0	13.2	11.3	10.8	7.5	8.5	38.7
	2-1	63.6	0.0	0.0	0.0	0.0	0.0	5.7	6.4	15.2	12.0	14.0	11.6	9.2	26.0
	2-2	64.3	0.0	0.0	0.0	0.0	0.0	4.9	5.7	14.8	12.9	12.5	9.5	8.3	31.4
	2-3	60.9	0.0	0.0	0.0	0.0	0.0	8.6	6.6	15.6	11.3	12.4	9.0	8.7	27.8
	3-1	69.2	0.0	0.0	0.0	0.0	0.0	4.0	4.8	17.0	12.7	17.0	10.1	12.2	22.3
	3-2	66.6	0.0	0.0	0.0	0.0	0.0	3.9	4.9	13.9	14.4	17.1	10.3	14.8	20.7
	3-3	65.5	0.0	0.1	0.3	2.6	5.7	9.7	2.1	12.4	14.1	11.2	9.1	12.4	20.3
	4-1	ND	0.0	0.0	0.0	0.0	0.0	3.7	5.8	13.5	14.0	15.9	10.1	9.6	27.3
	4-2	ND	0.0	0.0	0.0	0.0	0.0	2.7	6.3	10.7	14.4	14.0	9.6	8.9	33.4
	4-3	ND	0.0	0.0	0.0	0.0	0.0	9.3	9.7	11.9	12.8	11.5	7.9	7.9	28.9
	5-1	61.5	0.0	0.0	0.0	0.0	0.0	3.0	3.5	15.8	14.3	14.3	10.4	11.4	27.2
	5-2	56.0	0.0	0.0	0.0	0.0	0.0	4.4	3.3	14.2	14.2	12.6	9.8	12.6	28.9
	5-3	63.6	0.0	0.0	0.0	0.0	0.0	4.1	8.5	13.5	14.5	15.0	12.5	10.0	22.0
	6-1	61.5	0.0	0.0	0.3	3.2	18.9	10.4	4.2	9.6	9.2	10.7	7.7	6.5	19.2
	6-2	61.6	0.0	0.0	0.1	2.9	27.8	11.1	5.9	7.9	9.1	8.7	6.7	5.5	14.2
	6-3	56.7	0.0	0.1	0.7	6.6	22.4	9.0	5.8	7.9	8.6	7.9	5.8	6.2	18.9
12	1-1	49.8	0.0	0.0	1.0	14.2	22.7	9.9	7.9	6.7	5.8	5.8	4.6	5.1	16.4
	1-2	48.8	0.0	0.0	1.0	12.5	20.1	8.9	9.1	6.9	5.3	6.3	4.8	5.6	19.4
	1-3	47.3	0.0	0.1	1.0	15.4	24.7	10.7	7.7	5.9	4.5	5.2	5.2	3.2	16.5
	2-1	52.9	0.0	0.1	1.0	14.8	23.7	10.3	6.0	6.5	5.4	6.2	4.6	4.1	17.3
	2-2	47.6	0.0	0.0	1.1	14.2	22.9	9.7	8.9	6.7	4.7	6.3	4.7	5.5	15.2
	2-3	54.5	0.0	0.0	1.1	13.3	21.5	9.5	5.7	8.3	5.2	6.4	5.7	5.9	17.3
	3-1	53.1	0.0	0.0	1.4	17.1	21.9	11.8	6.7	5.9	4.4	6.7	4.8	3.8	15.4
	3-2	54.4	0.0	0.0	1.4	15.7	21.5	10.8	3.7	6.3	4.7	7.6	5.2	4.5	18.6
	3-3	51.5	0.0	0.0	2.1	18.3	25.1	11.9	6.0	5.5	3.0	6.5	2.8	4.3	14.4
	4-1	50.7	0.0	0.0	1.2	13.1	18.0	9.3	8.0	6.7	5.4	6.0	5.4	4.4	22.4
	4-2	49.9	0.0	0.0	1.0	14.6	21.6	8.9	8.3	6.2	5.1	5.3	5.3	5.1	18.5
	4-3	51.3	0.0	0.0	1.1	14.2	22.0	10.5	7.6	6.4	4.2	6.4	5.1	4.2	18.4
	5-1	52.1	0.0	0.0	1.3	16.1	21.0	10.3	6.5	6.5	5.4	6.8	5.4	5.6	15.2
	5-2	55.2	0.0	0.0	1.4	16.1	22.9	11.8	5.8	5.8	3.8	6.7	4.5	5.5	15.7
	5-3	53.4	0.0	0.0	2.2	20.1	22.6	10.1	6.1	6.1	4.1	5.8	4.1	3.8	15.1
	6-1	50.2	0.0	0.1	1.2	13.8	19.0	11.2	5.0	5.9	4.3	6.2	5.0	5.6	22.6
	6-2	49.4	0.0	0.1	2.6	21.7	24.2	11.3	4.1	3.9	4.1	4.5	4.3	3.3	16.0
	6-3	53.1	0.0	0.0	1.4	14.6	22.6	11.6	5.6	5.9	6.2	4.7	4.7	5.3	17.3

TABLE J-1. (Continued).

Station	Cruise Replicate	Percent Water	Percent Gravel	Percent Sand					Percent Silt				Percent Clay		
				-1-0ϕ	0-1ϕ	1-2ϕ	2-3ϕ	3-4ϕ	4-5ϕ	5-6ϕ	6-7ϕ	7-8ϕ	8-9ϕ	9-10ϕ	> 10ϕ
13	1-1	83.9	0.0	0.0	0.0	0.0	0.0	2.8	5.3	15.1	12.5	10.5	7.9	9.8	36.1
	1-2	79.3	0.0	0.0	0.0	0.0	0.0	3.3	6.5	13.0	14.4	7.2	8.7	10.1	36.8
	1-3	60.3	0.0	0.0	0.0	0.0	0.0	1.9	6.8	12.3	12.7	6.4	9.1	10.4	40.4
	2-1	64.3	0.0	0.0	0.0	0.0	0.0	3.1	4.7	11.2	15.1	14.8	12.3	8.9	29.9
	2-2	69.7	0.0	0.0	0.0	0.0	0.0	3.9	2.4	14.6	16.5	14.6	12.6	9.2	26.2
	2-3	67.1	0.0	0.0	0.0	0.0	0.0	2.6	3.8	12.5	14.1	15.6	11.0	11.4	28.9
	3-1	66.6	0.0	0.0	0.0	0.0	0.0	5.2	5.4	12.4	18.1	17.3	11.1	10.7	19.8
	3-2	70.5	0.0	0.0	0.0	0.0	0.0	3.3	2.6	12.6	13.4	14.3	9.1	13.0	31.7
	3-3	71.5	0.0	0.0	0.0	0.0	0.0	3.5	3.8	14.1	16.0	17.4	11.3	12.2	21.7
	4-1	67.3	0.0	0.0	0.0	0.0	0.0	2.5	6.0	12.0	12.0	12.0	12.0	6.5	37.0
	4-2	65.4	0.0	0.0	0.0	0.0	0.0	2.2	7.3	10.8	11.2	12.1	9.5	9.9	37.0
	4-3	67.1	0.0	0.0	0.0	0.0	0.0	2.5	7.1	10.7	13.5	13.1	11.5	7.9	33.7
	5-1	57.1	0.0	0.0	0.0	0.0	0.0	3.7	3.3	12.7	15.5	18.4	13.1	10.6	22.8
	5-2	63.3	0.0	0.0	0.0	0.0	0.0	2.6	4.5	13.5	11.7	11.7	10.4	14.0	31.6
	5-3	63.3	0.0	0.0	0.0	0.0	0.0	2.8	1.9	10.5	15.3	11.5	11.5	12.0	34.5
	6-1	70.2	0.0	0.0	0.0	0.0	0.0	2.5	5.2	7.8	13.0	15.6	9.1	9.1	37.7
	6-2	70.5	0.0	0.0	0.0	0.0	0.0	3.8	4.5	13.6	15.5	16.1	12.3	11.0	23.2
	6-3	71.0	0.0	0.0	0.0	0.0	0.0	2.9	5.6	13.0	17.3	17.9	11.1	9.3	22.9
14	1-1	61.7	0.0	0.0	0.0	0.0	0.0	4.1	9.9	13.0	13.0	6.3	9.4	9.4	34.9
	1-2	62.5	0.0	0.0	0.0	0.0	0.0	2.7	6.8	11.9	17.4	7.7	9.8	8.5	35.3
	1-3	75.6	0.0	0.0	0.0	0.0	0.0	3.3	9.2	12.0	13.4	7.1	10.6	8.5	36.0
	4-1	63.8	0.0	0.0	0.0	0.0	0.0	6.0	6.3	12.1	12.6	11.7	9.6	6.3	35.4
	4-2	67.8	0.0	0.0	0.0	0.0	0.0	4.1	6.3	10.5	13.5	13.9	9.3	8.4	34.0
	4-3	63.2	0.0	0.0	0.0	0.0	0.0	4.4	7.9	10.5	12.1	13.8	10.0	7.9	33.3
	5-1	62.3	0.0	0.0	0.0	0.0	0.0	5.1	1.9	15.1	14.1	15.1	11.2	9.2	28.2
	5-2	54.4	0.0	0.0	0.0	0.0	0.0	5.0	5.8	12.8	11.7	14.6	10.6	11.3	28.1
	5-3	61.6	0.0	0.0	0.0	0.0	0.0	7.6	7.4	12.7	12.3	14.5	11.0	10.1	24.5
	6-1	69.7	0.0	0.0	0.0	0.0	0.0	6.3	5.2	12.8	14.5	12.8	10.5	10.5	27.3
	6-2	59.9	0.0	0.0	0.0	0.0	0.0	4.9	5.8	11.9	11.9	14.2	9.7	10.6	31.0
	6-3	67.2	0.0	0.0	0.0	0.0	0.0	4.9	3.9	11.8	12.8	16.3	9.9	11.8	28.6

ND = No Data.

APPENDIX K

TABLE K-1. SUMMARY MEASURES (MEAN AND STANDARD DEVIATION) OF WATER CONTENT AND SEDIMENT GRAIN SIZE OF U.S. MID-ATLANTIC STATIONS.

Station	Cruise	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/Clay Ratio	Percent Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
1	1	67.13 (2.29)	0.00 (0.00)	6.57 (4.91)	42.10 (1.31)	51.33 (5.78)	0.83 (0.12)	13.93 (1.50)	8.30 (0.51)	2.93 (0.21)	-0.06 (0.04)
	2	65.17 (3.35)	1.27 (2.19)	14.40 (10.13)	40.30 (4.62)	44.03 (7.72)	0.92 (0.06)	13.17 (0.76)	7.53 (1.08)	3.42 (0.69)	-0.08 (0.08)
	3	66.13 (2.80)	0.00 (0.00)	8.23 (2.64)	42.20 (1.81)	49.53 (1.46)	0.85 (0.04)	14.03 (0.49)	8.26 (0.14)	2.98 (0.15)	-0.04 (0.12)
	4	64.83 (2.37)	0.00 (0.00)	5.97 (2.72)	38.00 (1.56)	56.03 (3.74)	0.68 (0.07)	15.27 (4.86)	8.71 (0.40)	3.01 (0.21)	-0.20 (0.12)
	5	57.17 (1.42)	0.00 (0.00)	15.83 (4.50)	37.57 (3.95)	46.00 (0.66)	0.81 (0.08)	15.07 (1.12)	7.88 (0.22)	3.30 (0.25)	-0.09 (0.12)
	6	63.77 (5.86)	0.07 (0.12)	12.63 (12.96)	36.93 (7.06)	50.37 (5.98)	0.73 (0.06)	12.80 (0.79)	8.18 (0.75)	3.21 (0.56)	-0.10 (0.01)
2	1	57.63 (1.06)	0.07 (0.12)	18.87 (10.28)	38.00 (6.17)	43.03 (4.95)	0.88 (0.10)	14.20 (1.31)	7.44 (0.65)	3.41 (0.25)	0.00 (0.15)
	2	59.30 (4.19)	0.03 (0.06)	26.77 (9.67)	35.90 (3.66)	37.33 (6.16)	0.97 (0.09)	14.03 (0.67)	6.90 (0.65)	3.55 (0.12)	0.17 (0.22)
	3	61.53 (1.66)	0.00 (0.00)	18.77 (5.61)	39.30 (5.12)	41.87 (1.52)	0.94 (0.12)	15.30 (0.82)	7.44 (0.21)	3.38 (0.17)	-0.03 (0.04)
	4	60.00 (2.46)	0.00 (0.00)	13.40 (1.80)	40.10 (1.91)	46.47 (3.18)	0.87 (0.10)	12.80 (1.30)	7.89 (0.23)	3.35 (0.03)	-0.13 (0.08)
	5	58.67 (4.37)	0.00 (0.00)	25.97 (5.61)	34.57 (2.87)	39.53 (2.80)	0.87 (0.03)	14.67 (0.32)	7.06 (0.31)	3.53 (0.16)	0.08 (0.12)
	6	60.50 (2.31)	0.00 (0.00)	21.60 (2.86)	36.57 (1.08)	41.87 (2.15)	0.87 (0.05)	13.73 (0.31)	7.35 (0.24)	3.52 (0.02)	0.02 (0.09)

TABLE K-1. (Continued).

Station	Cruise	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/Clay Ratio	Percent Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
3	1	57.57 (3.80)	0.00 (0.00)	20.37 (4.73)	38.90 (1.41)	40.67 (4.00)	0.96 (0.08)	15.90 (0.70)	7.25 (0.40)	3.51 (0.16)	0.05 (0.14)
	2	53.80 (1.91)	0.03 (0.06)	32.40 (7.01)	36.60 (3.37)	30.93 (4.35)	1.19 (0.11)	17.13 (1.27)	6.29 (0.47)	3.58 (0.08)	0.36 (0.16)
	3	55.43 (3.72)	0.07 (0.12)	29.60 (3.97)	35.13 (2.30)	35.20 (1.71)	1.00 (0.02)	15.57 (1.77)	6.71 (0.17)	3.58 (0.07)	0.24 (0.04)
	4	49.95 (0.64)	0.03 (0.06)	30.10 (4.57)	31.00 (2.78)	38.87 (1.70)	0.80 (0.04)	14.77 (0.55)	6.93 (0.28)	3.86 (0.15)	0.12 (0.06)
	5	56.97 (2.89)	0.00 (0.00)	21.13 (3.16)	34.70 (1.73)	44.10 (2.71)	0.79 (0.06)	14.40 (1.76)	7.53 (0.27)	3.48 (0.07)	-0.08 (0.07)
	6	59.77 (1.85)	0.00 (0.00)	17.53 (4.48)	39.77 (1.99)	42.70 (2.55)	0.93 (0.03)	14.33 (1.38)	7.53 (0.22)	3.35 (0.06)	0.02 (0.04)
4	1	59.53 (3.84)	0.00 (0.00)	24.27 (15.58)	37.57 (7.92)	38.17 (8.18)	0.99 (0.10)	15.63 (1.36)	7.02 (0.88)	3.40 (0.17)	0.18 (0.31)
	2	61.37 (1.00)	0.00 (0.00)	15.70 (3.80)	40.93 (1.35)	43.43 (2.54)	0.94 (0.04)	14.77 (0.81)	7.52 (0.26)	3.33 (0.06)	0.00 (0.07)
	3	57.73 (2.90)	0.00 (0.00)	22.33 (6.93)	38.50 (1.40)	39.17 (5.62)	0.99 (0.12)	14.30 (1.51)	7.09 (0.55)	3.46 (0.11)	0.10 (0.17)
	4	57.53 (5.14)	0.00 (0.00)	16.33 (5.39)	36.70 (2.86)	46.97 (2.67)	0.78 (0.03)	12.20 (0.95)	7.82 (0.43)	3.50 (0.24)	-0.15 (0.01)
	5	60.20 (2.99)	0.17 (0.29)	19.23 (2.64)	37.20 (4.10)	43.40 (1.37)	0.86 (0.12)	14.90 (0.46)	7.39 (0.02)	3.44 (0.20)	-0.12 (0.14)
	6	64.10 (5.15)	0.00 (0.00)	14.87 (0.64)	40.23 (0.29)	44.90 (0.79)	0.90 (0.02)	14.13 (1.63)	7.71 (0.12)	3.30 (0.06)	-0.07 (0.07)

TABLE K-1. (Continued).

Station	Cruise	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/Clay Ratio	Percent Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
5	1	63.37 (1.81)	0.00 (0.00)	4.67 (0.97)	41.27 (0.45)	54.03 (0.93)	0.76 (0.02)	12.60 (0.82)	8.62 (0.06)	2.92 (0.08)	-0.11 (0.03)
	2	65.57 (2.22)	0.00 (0.00)	4.57 (0.60)	42.30 (0.75)	53.10 (0.70)	0.80 (0.03)	12.73 (0.49)	8.48 (0.01)	2.84 (0.05)	-0.03 (0.02)
	3	66.20 (0.62)	0.00 (0.00)	5.87 (0.97)	47.17 (2.78)	47.03 (3.41)	1.01 (0.14)	17.20 (0.70)	8.20 (0.19)	2.72 (0.07)	0.12 (0.08)
	4	65.33 (1.10)	0.00 (0.00)	5.60 (0.46)	40.27 (1.29)	54.17 (0.98)	0.74 (0.04)	14.57 (1.35)	8.70 (0.06)	2.90 (0.06)	-0.15 (0.05)
	5	62.20 (4.12)	0.00 (0.00)	7.83 (0.93)	40.80 (0.79)	51.37 (1.40)	0.79 (0.03)	14.57 (1.57)	8.44 (0.11)	2.92 (0.08)	-0.06 (0.04)
	6	65.93 (1.10)	0.00 (0.00)	6.87 (1.90)	41.83 (1.80)	51.27 (1.22)	0.82 (0.05)	14.00 (0.40)	8.30 (0.17)	2.86 (0.04)	0.00 (0.05)
6	1	65.67 (0.45)	0.00 (0.00)	6.03 (0.64)	41.17 (1.07)	52.87 (1.61)	0.78 (0.04)	13.43 (0.47)	8.49 (0.08)	2.89 (0.04)	-0.06 (0.03)
	2	64.57 (1.70)	0.00 (0.00)	10.80 (3.99)	40.73 (2.47)	48.47 (1.53)	0.84 (0.03)	13.23 (0.35)	8.09 (0.20)	3.08 (0.15)	0.03 (0.02)
	3	64.27 (5.60)	0.00 (0.00)	8.97 (3.69)	42.90 (2.14)	48.13 (3.92)	0.90 (0.09)	13.83 (0.86)	8.03 (0.33)	2.99 (0.18)	0.02 (0.07)
	4	66.23 (0.99)	0.00 (0.00)	6.80 (0.61)	43.50 (1.85)	49.67 (2.14)	0.88 (0.08)	15.83 (0.91)	8.32 (0.17)	2.87 (0.06)	-0.00 (0.07)
	5	62.20 (1.06)	0.00 (0.00)	9.17 (0.81)	42.07 (1.26)	48.70 (1.30)	0.86 (0.05)	14.80 (1.10)	8.09 (0.11)	2.86 (0.03)	0.04 (0.04)
	6	66.63 (1.59)	0.00 (0.00)	6.10 (0.89)	41.40 (1.28)	52.43 (1.50)	0.79 (0.04)	13.17 (0.85)	8.44 (0.08)	2.85 (0.02)	-0.04 (0.03)

TABLE K-1. (Continued).

Station	Cruise	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/Clay Ratio	Percent Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
7	1	66.93 (0.72)	0.00 (0.00)	6.37 (1.18)	40.77 (1.27)	53.50 (2.43)	0.76 (0.06)	13.10 (0.46)	8.63 (0.20)	2.92 (0.03)	-0.16 (0.14)
	2	63.20 (2.49)	0.00 (0.00)	6.27 (2.54)	42.10 (2.09)	51.67 (2.57)	0.82 (0.07)	13.80 (1.85)	8.52 (0.19)	2.90 (0.09)	-0.06 (0.04)
	3	65.70 (1.91)	0.00 (0.00)	5.80 (2.08)	40.13 (0.76)	54.03 (1.94)	0.74 (0.03)	13.57 (0.31)	8.55 (0.11)	2.83 (0.12)	-0.07 (0.04)
	4	63.23 (4.18)	0.00 (0.00)	5.30 (0.10)	38.07 (2.12)	56.67 (1.91)	0.67 (0.06)	16.17 (2.97)	8.97 (0.03)	2.96 (0.05)	-0.30 (0.03)
	5	60.87 (0.76)	0.00 (0.00)	5.20 (0.10)	38.30 (0.98)	56.50 (1.06)	0.68 (0.03)	12.77 (1.87)	8.79 (0.02)	2.87 (0.02)	-0.20 (0.02)
	6	65.07 (1.91)	0.00 (0.00)	4.70 (0.17)	38.17 (0.75)	57.17 (0.93)	0.67 (0.03)	12.57 (1.11)	8.83 (0.06)	2.85 (0.08)	-0.22 (0.03)
8	1	66.23 (2.01)	0.00 (0.00)	4.83 (0.25)	38.77 (0.40)	56.33 (0.64)	0.69 (0.02)	12.50 (0.20)	8.79 (0.05)	2.88 (0.01)	-0.18 (0.03)
	2	64.13 (1.15)	0.00 (0.00)	4.97 (0.74)	42.30 (2.36)	52.73 (3.00)	0.81 (0.09)	13.93 (0.58)	8.52 (0.29)	2.77 (0.05)	-0.05 (0.11)
	3	67.70 (3.30)	0.00 (0.00)	6.23 (0.21)	39.97 (0.29)	53.80 (0.40)	0.74 (0.01)	15.20 (1.25)	8.49 (0.06)	2.65 (0.09)	-0.05 (0.03)

TABLE K-1. (Continued).

Station	Cruise	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/Clay Ratio	Percent Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
9	1	66.27 (1.56)	0.00 (0.00)	2.63 (0.06)	40.40 (2.26)	56.93 (2.27)	0.71 (0.07)	13.37 (0.81)	8.86 (0.12)	2.73 (0.04)	-0.13 (0.09)
	2	66.60 (0.40)	0.00 (0.00)	2.90 (0.26)	38.70 (1.71)	58.37 (1.82)	0.66 (0.05)	13.17 (1.07)	8.86 (0.07)	2.70 (0.03)	-0.15 (0.04)
	3	68.40 (0.26)	0.00 (0.00)	3.20 (0.36)	40.83 (2.41)	56.00 (2.12)	0.73 (0.07)	15.77 (1.91)	8.61 (0.05)	2.50 (0.06)	-0.02 (0.07)
	4	64.07 (1.97)	0.00 (0.00)	2.27 (0.40)	37.40 (1.23)	60.40 (0.78)	0.62 (0.03)	20.60 (1.44)	9.45 (0.10)	2.68 (0.05)	-0.41 (0.05)
	5	64.13 (2.25)	0.00 (0.00)	3.40 (0.44)	38.70 (0.98)	57.87 (1.30)	0.67 (0.03)	13.57 (0.86)	8.89 (0.12)	2.71 (0.04)	-0.16 (0.04)
	6	66.63 (1.86)	0.00 (0.00)	3.10 (0.72)	37.73 (1.25)	59.27 (1.83)	0.64 (0.04)	13.17 (0.55)	8.96 (0.15)	2.67 (0.04)	-0.19 (0.05)
10	1	58.77 (3.09)	0.00 (0.00)	26.90 (8.09)	35.87 (2.31)	37.23 (5.81)	0.97 (0.10)	14.87 (2.64)	6.85 (0.61)	3.63 (0.10)	0.17 (0.22)
	2	53.77 (3.15)	0.00 (0.00)	21.83 (4.20)	35.93 (1.79)	42.27 (2.47)	0.85 (0.01)	13.57 (0.45)	7.27 (0.25)	3.57 (0.11)	0.01 (0.06)
	3	64.43 (1.40)	0.00 (0.00)	21.63 (2.01)	37.27 (1.24)	41.13 (0.08)	0.91 (0.02)	14.83 (0.75)	7.22 (0.08)	3.39 (0.07)	0.01 (0.02)
	4	N.D. N.D.	0.00 (0.00)	17.20 (0.95)	38.00 (1.08)	44.77 (1.16)	0.85 (0.04)	13.10 (0.61)	7.73 (0.10)	3.50 (0.03)	-0.09 (0.03)
	5	54.97 (1.50)	0.00 (0.00)	20.07 (3.84)	35.53 (1.36)	44.47 (2.61)	0.80 (0.03)	12.73 (0.40)	7.53 (0.32)	3.52 (0.06)	-0.08 (0.08)
	6	58.93 (3.86)	0.00 (0.00)	26.13 (12.31)	33.13 (3.48)	40.67 (8.88)	0.83 (0.11)	14.50 (0.44)	7.14 (0.95)	3.58 (0.20)	0.07 (0.33)

TABLE K-1. (Continued).

Station	Cruise	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/Clay Ratio	Percent Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
11	1	64.83 (1.50)	0.00 (0.00)	2.37 (0.45)	43.33 (0.15)	54.27 (0.51)	0.80 (0.01)	13.77 (0.46)	8.73 (0.05)	2.85 (0.02)	-0.08 (0.03)
	2	62.93 (1.80)	0.00 (0.00)	6.40 (1.95)	46.47 (0.98)	47.17 (1.88)	0.99 (0.05)	16.27 (0.76)	8.19 (0.17)	2.83 (0.08)	0.12 (0.05)
	3	67.10 (1.90)	0.00 (0.00)	8.77 (8.34)	47.20 (6.44)	44.07 (2.05)	1.07 (0.10)	17.60 (0.26)	7.88 (0.38)	2.73 (0.33)	0.14 (0.15)
	4	N.D. N.D	0.00 (0.00)	5.23 (3.56)	46.83 (2.06)	47.87 (3.68)	0.98 (0.10)	15.13 (1.23)	8.30 (0.31)	2.80 (0.16)	0.10 (0.09)
	5	60.37 (3.92)	0.00 (0.00)	3.83 (0.74)	47.90 (3.60)	48.27 (3.46)	1.00 (0.15)	15.60 (0.70)	8.27 (0.24)	2.65 (0.05)	0.16 (0.11)
	6	59.93 (2.80)	0.00 (0.00)	37.83 (4.63)	31.83 (1.76)	30.23 (3.55)	1.06 (0.12)	15.23 (0.99)	6.21 (0.36)	3.48 (0.13)	0.42 (0.16)
12	1	48.63 (1.26)	0.00 (0.00)	47.40 (4.71)	25.70 (2.19)	26.93 (2.55)	0.96 (0.04)	15.67 (0.49)	5.57 (0.29)	3.71 (0.05)	0.64 (0.13)
	2	51.67 (3.61)	0.00 (0.00)	47.73 (2.25)	25.43 (1.26)	26.77 (1.87)	0.96 (0.08)	15.10 (2.05)	5.54 (0.16)	3.69 (0.06)	0.63 (0.08)
	3	53.00 (1.45)	0.00 (0.00)	53.00 (4.06)	22.33 (1.35)	24.60 (3.44)	0.92 (0.11)	14.77 (0.68)	5.29 (0.35)	3.71 (0.10)	0.73 (0.17)
	4	50.63 (0.70)	0.00 (0.00)	45.17 (3.20)	25.20 (0.79)	29.60 (2.33)	0.85 (0.04)	14.53 (0.85)	5.79 (0.25)	3.81 (0.06)	0.54 (0.10)
	5	53.57 (1.56)	0.00 (0.00)	51.97 (3.16)	23.13 (1.79)	24.97 (1.72)	0.93 (0.06)	13.57 (0.40)	5.29 (0.21)	3.69 (0.02)	0.71 (0.10)
	6	50.90 (1.95)	0.00 (0.00)	51.80 (7.43)	20.13 (3.10)	28.03 (4.84)	0.72 (0.09)	11.70 (0.70)	5.50 (0.55)	3.83 (0.10)	0.64 (0.23)

TABLE K-1. (Continued).

Station	Cruise	Percent Water	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Silt/Clay Ratio	Percent Silt Mode Height	Average Size (Phi)	Sorting (Phi)	Skewness
13	1	74.50 (12.51)	0.00 (0.00)	2.67 (0.71)	40.90 (2.61)	56.43 (3.13)	0.73 (0.09)	14.43 (1.36)	8.79 (0.15)	2.85 (0.02)	-0.13 (0.08)
	2	67.03 (2.70)	0.00 (0.00)	3.20 (0.66)	46.63 (1.27)	50.13 (1.85)	0.93 (0.06)	16.27 (0.83)	8.44 (0.12)	2.62 (0.03)	0.13 (0.06)
	3	69.53 (2.59)	0.00 (0.00)	4.00 (1.04)	49.13 (5.48)	46.87 (6.27)	1.07 (0.25)	17.30 (2.23)	8.25 (0.39)	2.55 (0.09)	0.18 (0.19)
	4	66.60 (1.04)	0.00 (0.00)	2.40 (0.17)	42.60 (1.59)	55.00 (1.71)	0.78 (0.06)	12.83 (0.84)	8.74 (0.10)	2.78 (0.02)	-0.08 (0.07)
	5	61.23 (3.58)	0.00 (0.00)	3.03 (0.59)	43.50 (5.65)	53.50 (6.14)	0.83 (0.21)	16.23 (2.64)	8.59 (0.34)	2.59 (0.09)	0.03 (0.18)
	6	70.57 (0.40)	0.00 (0.00)	3.07 (0.67)	48.37 (6.21)	48.57 (6.55)	1.02 (0.25)	17.03 (1.23)	8.40 (0.46)	2.60 (0.10)	0.13 (0.25)
14	1	66.00 (7.80)	0.00 (0.00)	3.37 (0.70)	42.57 (1.10)	54.13 (0.84)	0.79 (0.03)	15.10 (2.43)	8.59 (0.08)	2.90 (0.06)	-0.05 (0.03)
	4	64.93 (2.50)	0.00 (0.00)	4.83 (1.02)	43.73 (0.90)	51.40 (0.26)	0.85 (0.02)	14.13 (0.64)	8.54 (0.04)	2.86 (0.07)	-0.03 (0.02)
	5	59.43 (4.37)	0.00 (0.00)	5.90 (1.47)	46.00 (1.01)	48.07 (2.25)	0.96 (0.07)	15.67 (0.25)	8.24 (0.19)	2.73 (0.05)	0.11 (0.04)
	6	65.60 (5.09)	0.00 (0.00)	5.37 (0.81)	44.63 (0.76)	49.97 (1.53)	0.89 (0.05)	15.83 (1.14)	8.39 (0.14)	2.74 (0.06)	0.04 (0.06)

APPENDIX L

TABLE L-1. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 1 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
1	1		1.34	0.63	0.16	1.54	0.63	0.26	1.54	0.62	0.19
	2		1.53	0.69	0.20	1.46	0.68	0.20	1.54	0.65	0.20
	3		1.61	0.73	0.20	1.53	0.63	0.19	1.65	0.67	0.17
		$\bar{x}$	1.49	0.68	0.19	1.51	0.65	0.22	1.58	0.65	0.19
		S.D.	0.14	0.05	0.02	0.04	0.03	0.04	0.06	0.02	0.02

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
1	1		1.38	0.81	0.18	1.34	0.63	0.17	0.80	0.63	0.11
	2		1.41	0.69	0.18	1.35	0.59	0.10	1.49	0.58	0.20
	3		1.37	0.84	0.17	1.20	0.56	0.16	1.36	0.74	0.18
		$\bar{x}$	1.39	0.78	0.18	1.30	0.59	0.14	1.22	0.65	0.16
		S.D.	0.02	0.08	0.01	0.08	0.04	0.04	0.37	0.08	0.05

TABLE L-2. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 2 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
2	1		1.28	0.69	0.14	0.89	0.55	0.10	1.28	0.66	0.19
	2		1.30	0.69	0.16	0.94	0.60	0.12	1.15	0.64	0.18
	3		0.88	0.49	0.10	1.15	0.67	0.15	1.14	0.65	0.16
		$\bar{x}$	1.15	0.62	0.13	0.99	0.61	0.12	1.19	0.65	0.18
		S.D.	0.24	0.12	0.03	0.14	0.06	0.02	0.08	0.01	0.02

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
2	1		0.57	0.84	0.06	1.21	0.66	0.14	1.03	0.76	0.13
	2		1.30	0.48	0.17	1.03	0.50	0.12	1.27	0.88	0.13
	3		1.23	0.82	0.15	1.28	0.52	0.14	1.06	0.92	0.12
		$\bar{x}$	1.03	0.71	0.13	1.17	0.56	0.13	1.12	0.85	0.13
		S.D.	0.40	0.20	0.06	0.13	0.09	0.01	0.13	0.08	0.01

TABLE L-3. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 3 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.	MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
3	1	0.97	0.45	0.11	0.67	0.44	0.08	0.83	0.39	0.09
	2	1.13	0.59	0.13	0.76	0.49	0.09	1.18	0.49	0.13
	3	1.15	0.59	0.14	0.49	0.30	0.06	1.08	0.53	0.12
	$\bar{x}$	1.08	0.54	0.13	0.64	0.41	0.08	1.03	0.47	0.11
	S.D.	0.10	0.08	0.02	0.14	0.10	0.02	0.18	0.07	0.02

Sta.	Rep.	MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
3	1	0.78	0.34	0.11	0.99	0.48	0.15	1.01	0.48	0.13
	2	0.84	0.54	0.11	0.94	0.45	0.14	1.05	0.82	0.13
	3	0.40	0.30	0.05	0.96	0.55	0.14	1.49	0.47	0.18
	$\bar{x}$	0.67	0.39	0.09	0.96	0.49	0.14	1.18	0.59	0.15
	S.D.	0.24	0.13	0.03	0.02	0.05	0.01	0.27	0.20	0.03

TABLE L-4. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 4 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
4	1		1.10	0.65	0.15	1.08	0.50	0.13	1.10	0.56	0.14
	2		1.14	0.59	0.14	1.36	0.60	0.15	1.06	0.61	0.15
	3		0.85	0.48	0.11	1.20	0.61	0.14	0.84	0.50	0.12
		$\bar{x}$	0.99	0.57	0.13	1.21	0.57	0.14	0.97	0.56	0.14
		S.D.	0.13	0.09	0.02	0.14	0.06	0.01	0.12	0.06	0.02

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
4	1		1.22	0.50	0.14	1.18	0.62	0.17	1.22	0.75	0.15
	2		1.15	0.50	0.14	1.08	0.62	0.19	1.05	0.83	0.12
	3		1.10	0.95	0.12	1.08	0.63	0.17	1.20	0.73	0.15
		$\bar{x}$	1.16	0.65	0.13	1.11	0.62	0.18	1.16	0.77	0.14
		S.D.	0.06	0.26	0.01	0.06	0.01	0.01	0.09	0.05	0.02

TABLE L-5. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 5 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
5	1		1.48	0.72	0.19	1.55	0.64	0.19	1.49	0.66	0.19
	2		1.48	0.66	0.18	1.55	0.72	0.19	1.53	0.66	0.20
	3		1.50	0.73	0.17	1.42	0.78	0.17	1.45	0.70	0.18
		$\bar{x}$	1.49	0.70	0.18	1.51	0.71	0.18	1.49	0.67	0.19
		S.D.	0.01	0.04	0.01	0.08	0.07	0.01	0.04	0.02	0.01

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
5	1		1.45	0.83	0.18	1.25	0.55	0.16	1.14	0.69	0.15
	2		1.48	0.75	0.17	1.30	0.72	0.17	1.33	0.73	0.17
	3		1.34	0.91	0.15	1.37	0.75	0.17	1.33	0.59	0.17
		$\bar{x}$	1.42	0.83	0.17	1.31	0.67	0.17	1.27	0.67	0.16
		S.D.	0.07	0.08	0.02	0.06	0.11	0.01	0.11	0.07	0.01

TABLE L-6. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 6 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
6	1		1.33	0.65	0.18	.22	0.64	0.16	1.19	0.57	0.15
	3		1.43	0.69	0.18	1.14	0.65	0.14	1.39	0.67	0.17
	3		1.35	0.68	0.18	1.29	0.66	0.17	1.39	0.69	0.17
		$\bar{x}$	1.37	0.67	0.18	1.22	0.65	0.16	1.32	0.64	0.16
		S.D.	0.05	0.02	0.00	0.08	0.01	0.02	0.12	0.06	0.01

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
6	1		1.35	0.75	0.16	1.43	0.65	0.16	1.32	0.73	0.20
	2		1.27	0.79	0.16	1.38	0.70	0.18	1.33	0.73	0.18
	3		1.13	0.92	0.13	1.29	0.62	0.17	1.19	0.56	0.16
		$\bar{x}$	1.25	0.82	0.15	1.37	0.66	0.17	1.28	0.67	0.18
		S.D.	0.11	0.09	0.02	0.07	0.04	0.01	0.08	0.10	0.02

TABLE L-7. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 7 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
7	1		1.68	0.74	0.20	1.48	0.74	0.19	1.58	0.71	0.20
	2		1.45	0.69	0.19	1.75	0.78	0.21	1.52	0.66	0.20
	3		1.57	0.70	0.18	1.44	0.80	0.18	1.50	0.63	0.19
		$\bar{x}$	1.57	0.71	0.19	1.56	0.77	0.19	1.53	0.67	0.20
		S.D.	0.12	0.03	0.01	0.17	0.03	0.02	0.04	0.04	0.01

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
7	1		1.36	0.69	0.19	1.39	0.77	0.18	1.29	0.75	0.17
	2		0.83	1.21	0.10	1.74	0.88	0.22	1.30	0.73	0.17
	3		1.51	0.74	0.20	1.43	0.77	0.19	1.44	0.61	0.19
		$\bar{x}$	1.23	0.88	0.16	1.52	0.81	0.20	1.34	0.70	0.18
		S.D.	0.36	0.29	0.06	0.19	0.06	0.02	0.08	0.08	0.01

TABLE L-8. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 8 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
8	1		1.45	0.73	0.20	1.53	0.61	0.20	2.03	0.81	0.25
	2		1.66	0.78	0.21	1.52	0.75	0.20	1.78	0.75	0.22
	3		1.49	0.68	0.20	1.28	0.63	0.17	Sample lost		
		$\bar{x}$	1.56	0.73	0.20	1.44	0.66	0.19	1.90	0.78	0.24
		S.D.	0.09	0.05	0.01	0.14	0.08	0.02	0.18	0.04	0.02

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
8	1		No samples collected			No samples collected			No samples collected		
	2										
	3										
		$\bar{x}$									
		S.D									

TABLE L-9. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 9 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
9	1		1.90	0.82	0.25	1.46	0.78	0.19	1.67	0.78	0.22
	2		1.59	0.79	0.20	1.54	0.71	0.21	1.56	0.78	0.20
	3		1.83	0.79	0.23	1.57	0.78	0.20	Sample lost		
		$\bar{x}$	1.77	0.80	0.23	1.52	0.76	0.20	1.62	0.78	0.21
		S.D.	0.16	0.02	0.02	0.06	0.04	0.01	0.08	0.00	0.01

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
9	1		1.66	0.80	0.20	1.44	0.61	0.20	1.71	0.90	0.20
	2		1.61	0.84	0.19	1.52	0.70	0.20	1.73	0.85	0.17
	3		1.66	0.86	0.19	1.52	0.83	0.20	1.75	0.94	0.22
		$\bar{x}$	1.64	0.83	0.19	1.49	0.71	0.20	1.73	0.90	0.20
		S.D.	0.03	0.03	0.01	0.05	0.11	0.00	0.02	0.04	0.02

TABLE L-10. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 10 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
10	1		0.98	0.53	0.15	1.02	0.72	0.10	1.38	0.58	0.13
	2		0.66	0.66	0.08	0.95	0.66	0.13	1.09	0.60	0.13
	3		1.06	0.72	0.11	0.73	0.39	0.10	1.14	0.56	0.13
		$\bar{x}$	0.90	0.64	0.11	0.90	0.59	0.11	1.20	0.58	0.13
		S.D.	0.21	0.10	0.04	0.15	0.18	0.02	0.16	0.02	0.00

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
10	1		1.09	0.67	0.14	0.97	0.67	0.15	0.77	0.52	0.10
	2		0.97	0.80	0.12	0.96	0.73	0.13	1.03	0.62	0.14
	3		1.08	0.57	0.14	0.96	0.68	0.15	1.03	0.67	0.13
		$\bar{x}$	1.05	0.68	0.13	0.96	0.69	0.14	0.94	0.60	0.12
		S.D.	0.07	0.12	0.01	0.01	0.03	0.01	0.15	0.08	0.02

TABLE L-11. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 11 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
11	1		1.84	0.78	0.23	1.80	0.68	0.23	1.78	0.65	0.22
	2		1.75	0.60	0.22	1.74	0.72	0.22	1.75	0.71	0.22
	3		1.86	0.73	0.24	1.60	0.64	0.17	1.33	0.51	0.16
		$\bar{x}$	1.82	0.70	0.23	1.71	0.68	0.21	1.62	0.62	0.20
		S.D.	0.06	0.09	0.01	0.10	0.04	0.03	0.25	0.10	0.03

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
11	1		1.76	0.73	0.22	1.71	0.77	0.22	0.95	0.71	0.12
	2		1.45	0.74	0.18	1.62	0.70	0.23	1.42	0.74	0.18
	3		1.84	0.77	0.23	1.68	0.60	0.21	1.21	0.79	0.15
		$\bar{x}$	1.68	0.75	0.21	1.67	0.69	0.22	1.19	0.75	0.15
		S.D.	0.21	0.02	0.03	0.04	0.08	0.01	0.24	0.04	0.03

TABLE L-12. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 12 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
12	1		0.50	0.75	0.07	0.52	0.44	0.06	0.62	0.34	0.09
	2		0.59	0.52	0.08	0.55	0.30	0.07	0.55	0.41	0.08
	3		0.58	0.54	0.08	0.49	0.41	0.06	0.41	0.33	0.07
		$\bar{x}$	0.56	0.60	0.08	0.52	0.38	0.06	0.53	0.36	0.08
		S.D.	0.05	0.13	0.01	0.03	0.07	0.01	0.11	0.04	0.01

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
12	1		0.61	0.84	0.08	0.64	0.52	0.09	0.58	0.43	0.08
	2		0.57	1.00	0.07	0.55	0.44	0.07	0.53	0.28	0.06
	3		0.69	1.02	0.08	0.55	0.47	0.07	0.45	0.41	0.05
		$\bar{x}$	0.62	0.95	0.08	0.58	0.48	0.08	0.52	0.37	0.06
		S.D.	0.06	0.10	0.01	0.05	0.04	0.01	0.06	0.08	0.02

TABLE L-13. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 13 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
13	1		1.93	0.78	0.25	1.81	0.68	0.22	1.77	0.77	0.22
	2		1.90	0.77	0.23	1.92	0.81	0.23	1.99	0.79	0.24
	3		2.18	0.81	0.26	1.94	0.63	0.24	2.03	0.79	0.26
		$\bar{x}$	2.00	0.79	0.25	1.89	0.71	0.23	1.93	0.78	0.24
		S.D.	0.15	0.02	0.02	0.07	0.09	0.01	0.14	0.01	0.02

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
13	1		1.45	0.68	0.17	1.87	0.80	0.24	1.98	0.83	0.24
	2		2.07	0.80	0.24	1.92	0.85	0.24	1.86	0.80	0.23
	3		2.04	0.63	0.24	2.00	0.86	0.22	2.16	0.83	0.27
		$\bar{x}$	1.85	0.70	0.22	1.93	0.84	0.23	2.00	0.82	0.25
		S.D.	0.35	0.09	0.04	0.06	0.03	0.01	0.15	0.02	0.02

TABLE L-14. RESULTS OF CHN ANALYSES OF SAMPLES COLLECTED AT STATION 14 ON CRUISES MID-1 THROUGH MID-6.

Sta.	Rep.		MID-1 %C	MID-1 %H	MID-1 %N	MID-2 %C	MID-2 %H	MID-2 %N	MID-3 %C	MID-3 %H	MID-3 %N
14	1		1.87	0.76	0.23	No samples collected			No samples collected		
	2		1.76	0.76	0.22						
	3		1.64	0.75	0.20						
		$\bar{x}$	1.76	0.76	0.22						
		S.D.	0.12	0.01	0.02						

Sta.	Rep.		MID-4 %C	MID-4 %H	MID-4 %N	MID-5 %C	MID-5 %H	MID-5 %N	MID-6 %C	MID-6 %H	MID-6 %N
14	1		1.56	0.93	0.18	1.82	0.76	0.23	2.03	0.84	0.27
	2		1.77	0.93	0.21	1.59	0.79	0.21	1.72	0.85	0.22
	3		1.76	0.81	0.21	1.69	0.72	0.24	1.53	0.81	0.16
		$\bar{x}$	1.70	0.89	0.20	1.70	0.76	0.23	1.76	0.83	0.22
		S.D.	0.12	0.07	0.02	0.12	0.04	0.02	0.25	0.02	0.06

APPENDIX M

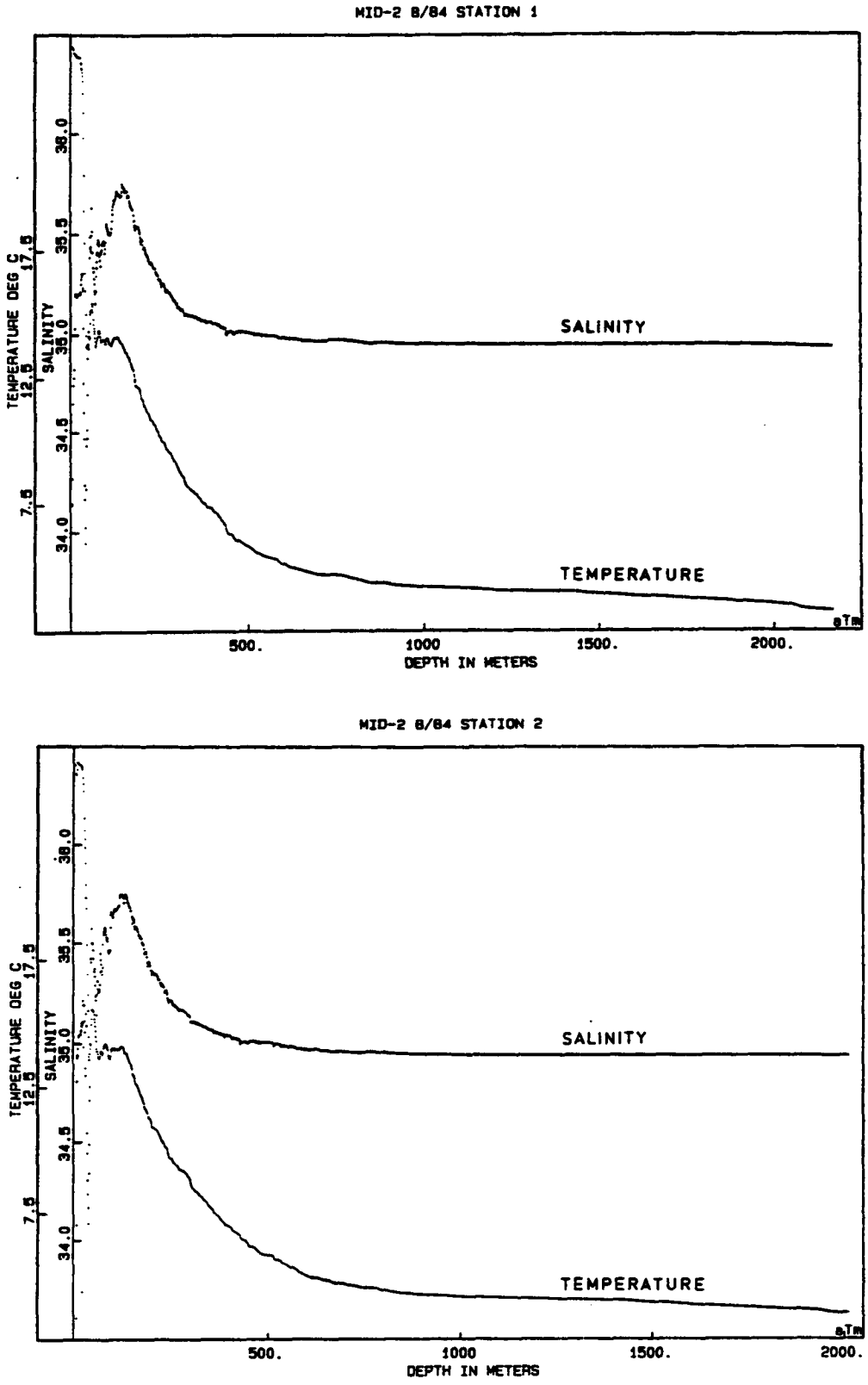
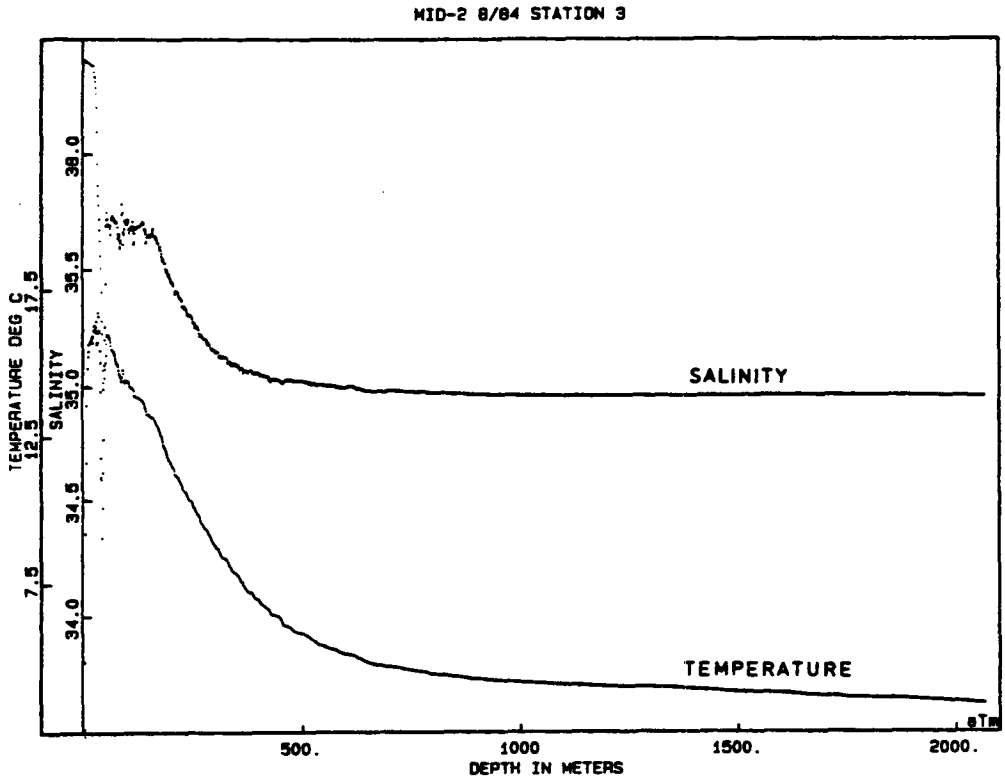


Figure M-1. Profile of temperature and salinity with depth at Station 1 (top) and Station 2 (bottom) on Cruise Mid-2.



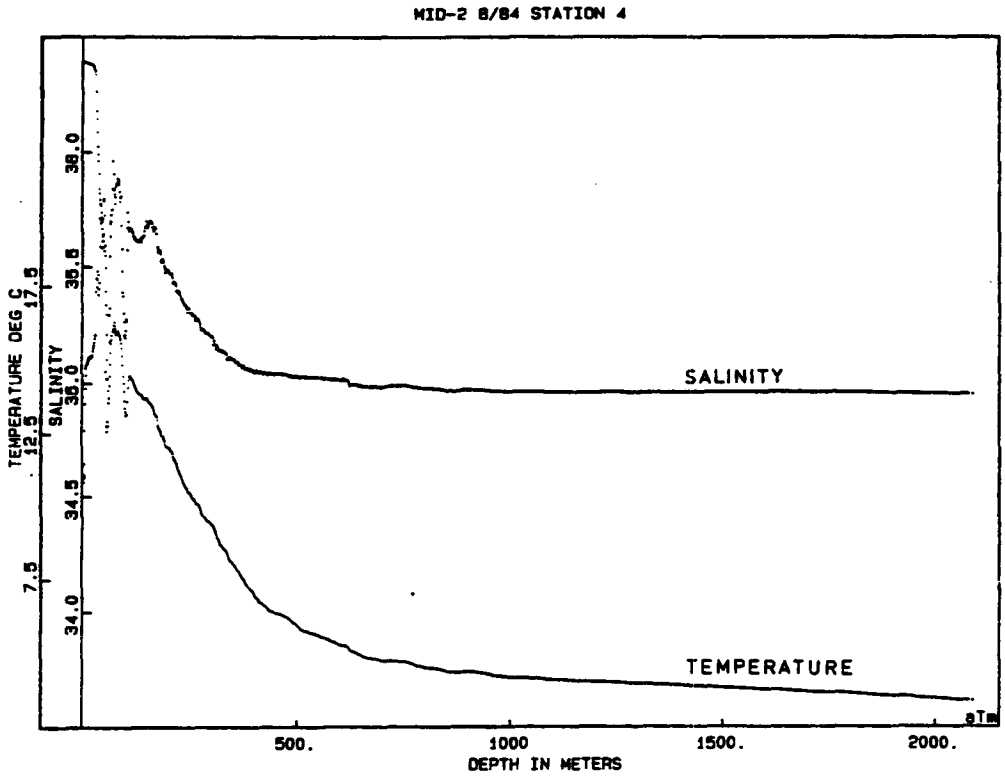


Figure M-2. Profile of temperature and salinity with depth at Station 3 (top) and Station 4 (bottom) on Cruise Mid-2.

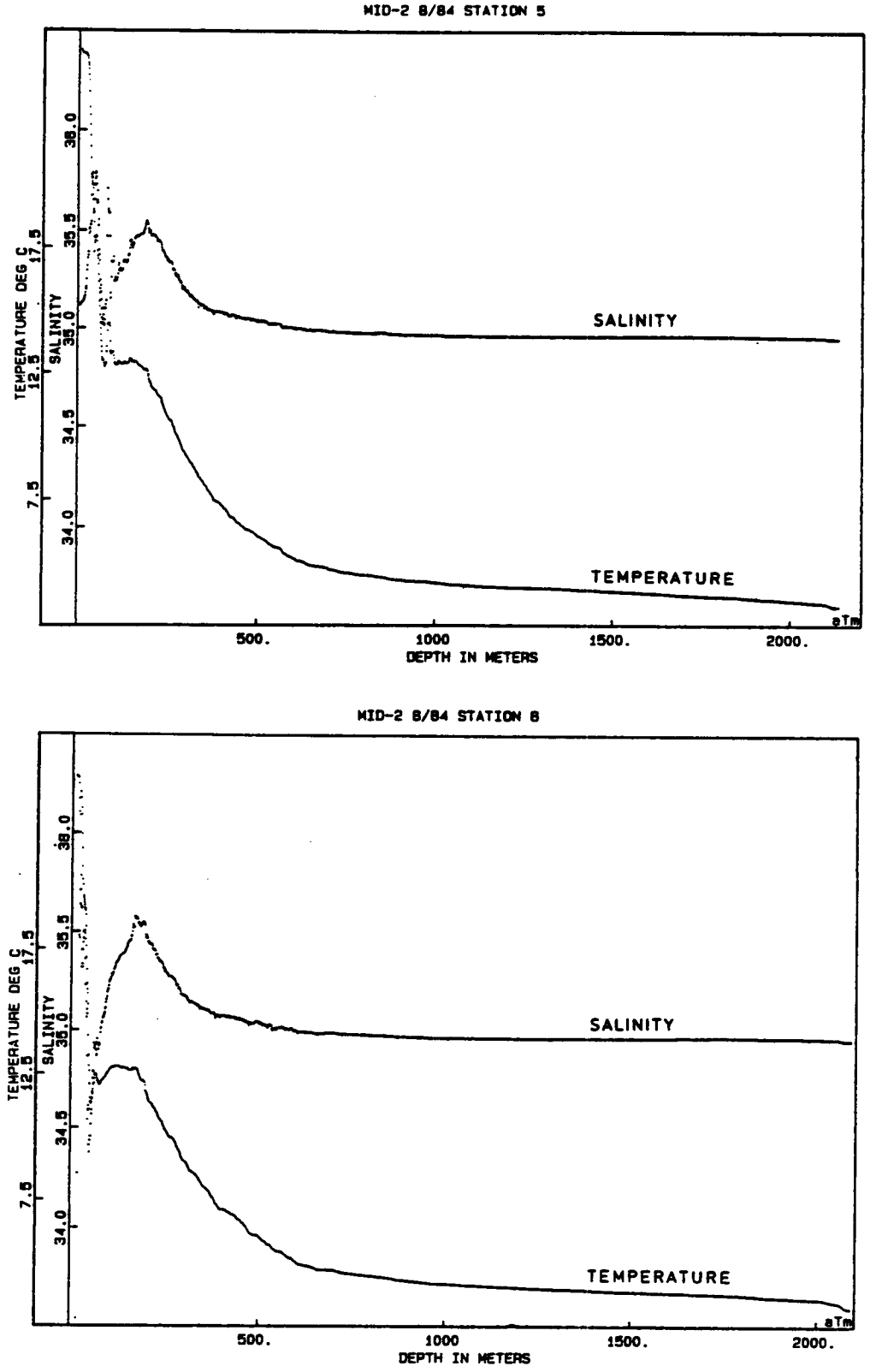
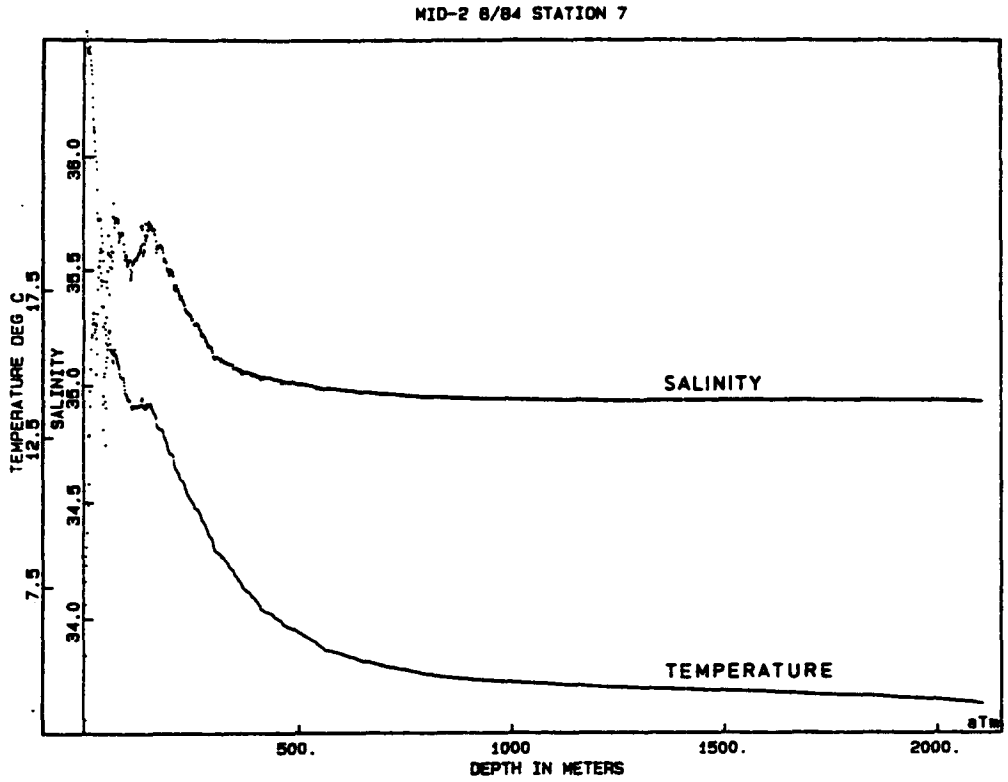


Figure M-3. Profile of temperature and salinity with depth at Station 5 (top) and Station 6 (bottom) on Cruise Mid-2.



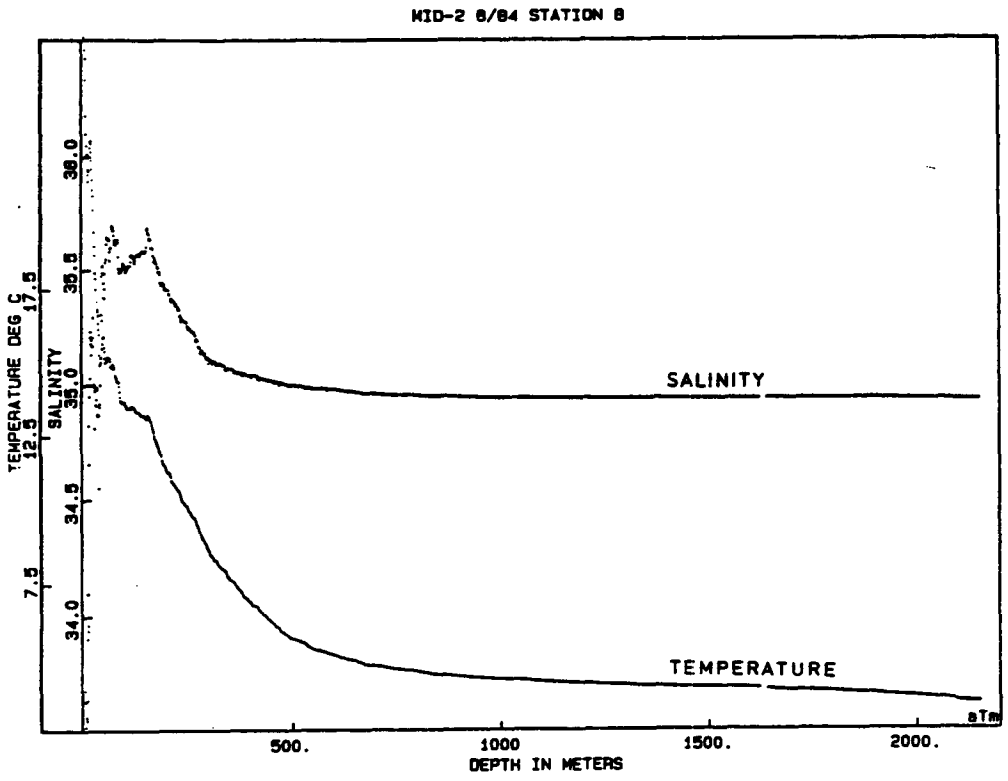


Figure M-4. Profile of temperature and salinity with depth at Station 7 (top) and Station 8 (bottom) on Cruise Mid-2.

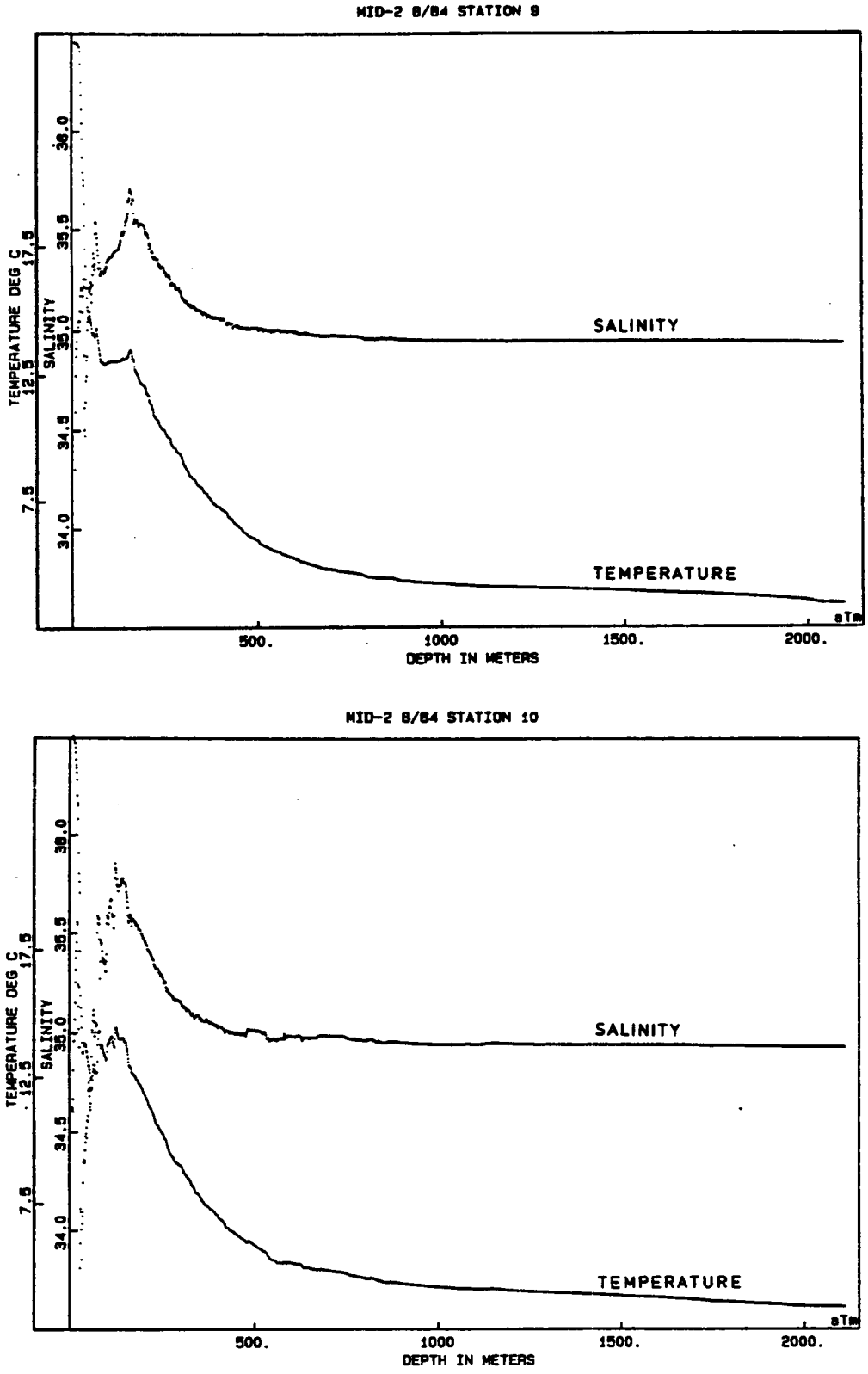


Figure M-5. Profile of temperature and salinity with depth at Station 9 (top) and Station 10 (bottom) on Cruise Mid-2.

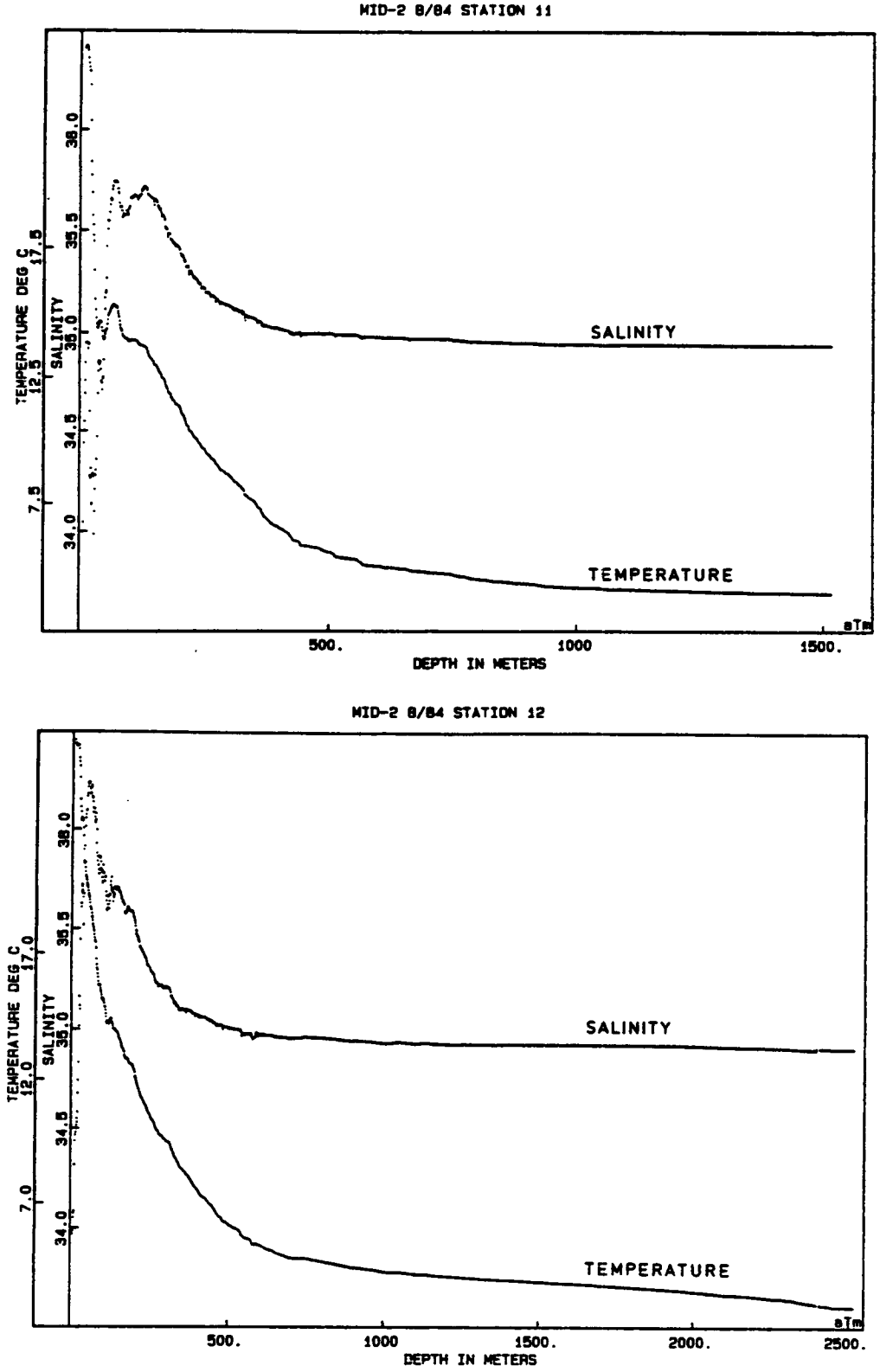


Figure M-6. Profile of temperature and salinity with depth at Station 11 (top) and Station 12 (bottom) on Cruise Mid-2.

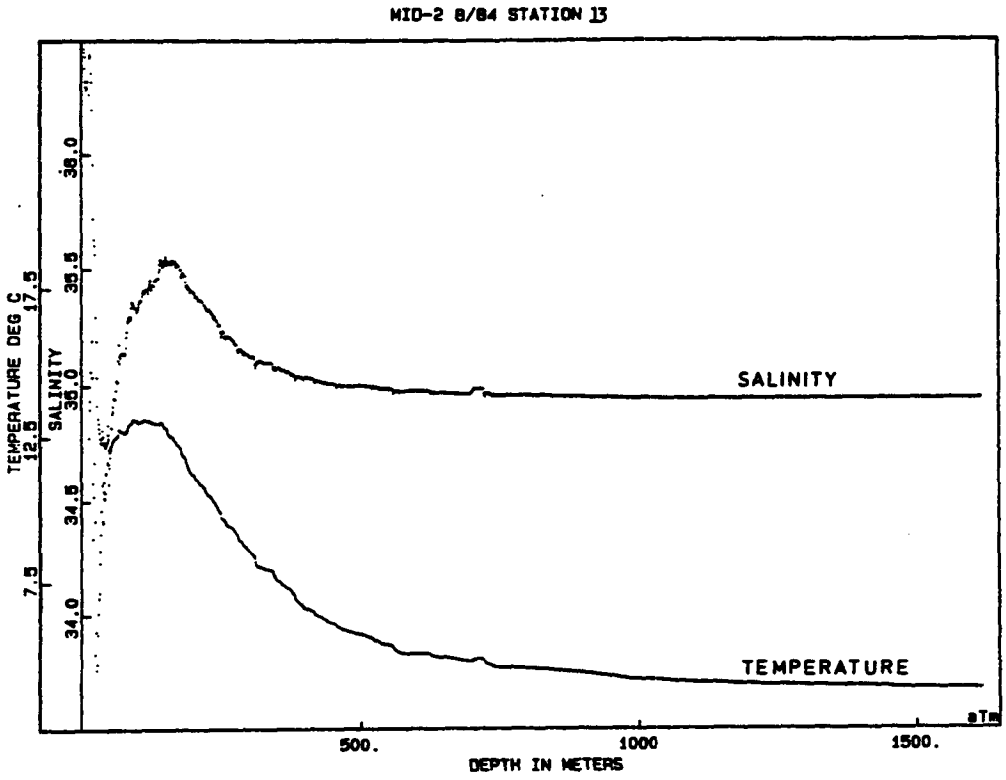


Figure M-7. Profile of temperature and salinity with depth at Station 13 on Cruise Mid-2.