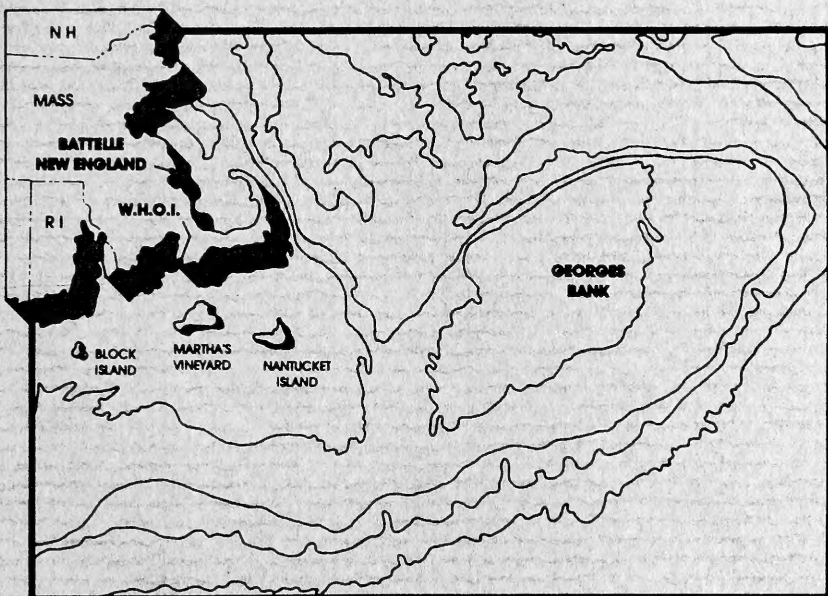
Georges Bank Benthic Infauna Monitoring Program

FINAL REPORT **YEAR I**



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GEORGES BANK BENTHIC INFAUNA MONITORING PROGRAM

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16. Abstract Concerns about the potential effects of oil and gas exploration activities on the highly productive Georges Bank off the coast of Massachusetts led to the initiation of an intensive monitoring program in July, 1981. The program includes intensive sampling of the benthic communities, collected near, upcurrent and downcurrent of the drilling rigs, analysis of bottom photographs for epifauna and microtopography, dredge and trawl collections, CHN and sediment grain size analysis. Collections of six replicate infaunal samples at each of 46 stations are made on a seasonal basis. Samples are collected with a $0.04 m^2$ modified Van Veen grab sampler and are double live-sieved through 500 μm and 300 μm screens. Twenty-nine stations are positioned in a tight radial array around 1 rig at 80 m. A second group of 3 stations are near a rig site at 145 m. The remaining stations cover a broad expanse of the Bank and nearby areas of potential deposition of drilling materials. Use of the 300 μm screen has resulted in the retention of newly settled and juvenile forms, as well as small-bodied species which are normally undersampled by larger screens. The capability of identifying the earliest juvenile stages of several species has enabled us to provide accurate counts of each species and to predict times of settlement. Results from the first 4 biological collections indicate little heterogeneity within stations, with good replication between samples. A strong relationship between faunal composition and both sediment type and depth is indicated by cluster analysis. No biological impacts which could be attributed to drilling activities have been detected to date at any station, including the site-specific array in Block 312, the 3 stations near the drill rig in Block 410, or any regional station monitored in this program.

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PREFACE

The Georges Bank Benthic Infauna Monitoring Program is the lead component of a four-part program supported by the United States Department of the Interior, Minerals Management Service: The Georges Bank Monitoring Program. Other components of this Program include:

> Analysis of Trace Metals in Bottom Sediments, performed by U.S. Department of the Interior Geological Survey, Woods Hole, MA;
>
> Analysis of Hydrocarbons in Bottom Sediments and Analysis of Hydrocarbons and Trace Metals in Benthic Fauna, performed by Science Applications, Inc., La Jolla, CA.
>
> Analysis of Historic Benthic Infaunal samples from BLM's New England Environmental Benchmark Program, performed by Taxon, Inc., Salem, MA

To the extent possible, the results of these investigations are used here as an aid to interpreting the results of the Benthic Infauna Monitoring Program.

A large number of people contributed their talents to the completion of the first year of the Georges Bank Benthic Infauna Monitoring Program. The program leaders were:

From Battelle: Jerry M. Neff, Program Manager, Nancy Maciolek-Blake, James A. Blake; and from Woods Hole Oceanographic Institution: J. Frederick Grassle, Howard L. Sanders.

Other major contributors to this program and their institutional affiliations were: **Battelle New England Marine Research Laboratory:** Paul T. Banas, Ellen Baptiste, Thomas M. Biksey, Elizabeth Broughton, Christine Brown, John Brown, Donald Cameron, James Cammarata, James Campbell, Camela Chop, Fabry Coffey, Sara Crawley, Sean Cudmore, Nancy Culpepper, Mark Curran, Dale Davis, Constance Delano, Marcia A. Desreuisseau, Diane Donovan, Deborah Driver, Suzanne Duffy, Margaret Dutch, David Farucci, Mary Jane Ferson, Sandra Freitas, Elizabeth V. Garlo, Paul Garven, Frank Gilcrist, Theresa Gilchrist, Holly Groelle, Paul Haffey, Winston Hanes, Kristen Harris, Jennifer Hillman, Robert E. Hillman, Lawrence Hufnagle, William Johnson,

Sandra Jenkins, Mary Ellen Kelley, Janet Kennedy, Bill Kennedy, Elizabeth Kitson, David Kolstad, Deborah Kohl, Janet Kwiatkowski, Ann Levandowski, Sandra Maccaferri, John Malone, Constance Masinda, Deborah McGrath, Richard A. McGrath, Steven Mellenthien, Emily Monasson, Jean Murphy, Theodore Nichols, Phillip W. Nimeskern, Margaret O'Neil-Holden, Timothy Owens, Patricia Parker, Linda Patridge, Paul Perra, Laurie Pietroski, Mary Ann Powers, Ann Reid, Margaret Richmond, Ellen Rosen, Robert Rosen, Patricia Saksa, Janet Saliba, Judy Scanlon, Julianne Sheehan, Siobhan Sheehan, George Small, Joan S. Sundstrom, Nina Vassalotti, Sandra Weiss, Robert Williams, Russell Winchell, Janette Wood, Timothy Wooster; **Woods Hole Oceanographic Institution:** Susan Brown-Leger, Catherine M. Cetta, J. Phillip Clarner, George R. Hampson, Rick Laubly, Steven Page, Rose Petrecca, John Porteous, Terri Stephen, Deborah Wiebe; **U.S. Geological Survey:** Michael H. Bothner, Bradford Butman, Carol Parmenter, Lawrence Poppe, and Rick Rendigs; **National Marine Fisheries Service:** Richard Cooper; **Lamont Doherty Geological Institute:** Michael Rawson; and **Science Applications, Inc.:** Rusty Sims and Robin Robinson.

Consultants who assisted in verifying species identifications of benthic infauna included: Robert Bullock, University of Rhode Island; John Dearborn, University of Maine, Kristian Fauchald, Smithsonian Institution, Les Watling, University of Maine. Woollcott L. Smith, Temple University, provided advice on statistical methods.

We would also like to acknowledge the active encouragement and support provided by Anthony P. Graffeo, Director, Battelle New England Marine Research Laboratory.

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I. CONCLUSIONS

• The Regional Stations analyzed for benthic infauna group consistently over all four sampling periods by depth and sediment type. Replicate samples at each station show an exceptionally high degree of homogeneity. Cluster analysis demonstrates that all of the replicates of any one regional station are more similar to each other than to replicates from any other station. When replicates at each station are summed, the samples from each of the four sampling periods fuse before any separation occurs between stations. This homogeneity should enable us to detect biological changes should they occur at these stations.

• Site-specific stations in the array around Station 5-1 have a homogeneous community structure, both spatially and temporally over most of the area. The species composition does change with the increase in the proportion of fine sand at stations located 4 and 6 km to the west of Station 5-1.

• At all stations sampled, the community structure (i.e., species composition) does not change very much with season. Although average densities of several species were observed to fluctuate seasonally, these changes probably reflect natural cycles in these populations and do not appear to be related to drilling activities.

• The only result of the chemical analyses that provides a basis for an hypothesis of an impact due to drilling activities is the gradient of barium concentrations (as a marker of accumulation of drilling muds) near the Block 410 Stations 16, 17 and 18, and Site-Specific Station 5-1.

• Drilling began in Block 410 in July, 1981 and continued until March, 1982. With the methods of analysis used thus far, no biological impacts which could be attributed to drilling activities were detected. Differences between stations were always greater than temporal differences at any one of the three stations.

• Drilling began in Block 312 on December 8, 1981 and continued until June, 1982. At the site-specific array of stations in this block, the separation of February (M3) and May (M4) samples into discrete clusters may be a result of the decline in total densities at many of the stations in February (M3), followed by a recovery in May (M4). The density declines in February (M3) may be related to changes in sediment composition or to normal seasonal population cycles. An analysis of the change in densities over time of 24 infaunal species revealed that at Stations 5-1, 5-2 and 5-8, where the greatest increment in barium concentration between July (M1) and May (M4) occurred, the densities of many species declined in November (M2) before drilling began and increased in February (M3).

- In general, no significant changes in benthic community structure which can be related to drilling activities have been detected with the methods of analysis used thus far.

2. RECOMMENDATIONS

• Sampling should continue at all long-term Regional Stations in order to establish normal seasonal patterns of population fluctuations. This will allow us to better interpret population fluctuations seen at drilling areas. The most important stations include the deeper water and canyon Stations 3, 6, 7A, 8, 9 and 12 adjacent to the proposed Lease Sale 52 area, and stations in major depositional areas (Stations 13 and 13A).

• Sampling should be continued at three stations in Block 410 (Stations 16, 17, 18). This will provide information on long-term effects at a deeper drilling site, which may be useful for predicting impacts of drilling in the Lease Sale 52 area.

• Biological and chemical sampling should continue at those stations in the Site-Specific array at which elevated concentrations of barium (a marker of drilling mud accumulation) were detected in the fine fraction of sediment on Cruise M4. First priority should be given to stations of this type two or more kilometers from the drill site. Analysis of sediment barium concentrations at an additional radial array of four to sixteen stations located about 8 and/or 10 km from the rig site would be useful for better defining the pattern and extent of movement of drilling muds away from the rig site.

• Barium should be analyzed in the fine fraction of sediments from the Secondary Site-Specific Stations for Cruises M1 through M4 to better establish the distribution of drilling muds in sediments around the rig site. If elevated concentrations of barium are detected in sediments from the Secondary Site-Specific Stations or the new far-field stations, a subset of these, including Stations 5-23, 5-24, 5-26 and 5-27 should be analyzed for benthic infauna and sediment grain size.

• Additional effort should be made to obtain more samples of Arctica islandica or other suitable macroinfaunal animals at Site-Specific Stations having elevated sediment barium concentrations, for metals and petroleum hydrocarbon analysis. This will help answer the critical question of whether materials from drilling discharges accumulating on the bottom are bioavailable.

- Because of the problems with the wet-weight biomass technique, as discussed in this report, the method for determining biomass should be reevaluated. For at least one set of samples, another technique, such as decalcified wet weights or ash-free dry weights, should be used in order to establish a better estimate of secondary productivity.

3. INTRODUCTION

The Georges Bank is a high plateau lying under 3 to 200 meters of water 80 to 325 km east-southeast of the Massachusetts coast and 150 km south of Cape Sable, Nova Scotia at the convergence of the Gulf Stream and the Labrador Current. With an area of approximately 31,000 square kilometers (12,000 square miles), within the 185 meter (100 fathom) isobath, it is slightly smaller than the states of Massachusetts and Connecticut combined. The top of the Bank, lying at a depth of 65 meters or less, has an area of 16,600 square kilometers and encloses 740 cubic kilometers of water (Hopkins and Garfield, 1981).

A unique combination of geological, chemical, and physical oceanographic features provides the conditions necessary for a very high level of biological productivity. This productive ecosystem supports one of the largest commercial marine fisheries in the world. There is also a small recreational fishery, primarily for tuna and billfish, on the Bank. However, the inshore recreational fisheries for flounder, mackerel, and scup are indirectly dependent on the Bank through recruitment from the Bank of these species to the inshore stocks.

Several proposals have been made for alternative and sometimes competing uses of Georges Bank. These include: oil and gas development; mineral extraction; sand and gravel mining of the seabed; ocean disposal of industrial and domestic sewage, dredge material and radioactive waste and construction of deep-water ports (NOAA/CZM, 1979). Substantial concern has been expressed by environmentalists and the commercial fishing industry, that proposed alternative uses of the Bank would seriously damage this complex and highly productive ecosystem.

To date, only the oil and gas development option has been pursued. Preparations for Lease Sale 42 of 206 tracts on the south-central Bank began in June, 1975, with a Call for Nominations and Comments (BLM, 1981). The sale, originally scheduled for January, 1978, was delayed by several legal suits and injunctions until December 19, 1979. Of the original 206 tracts offered, 90 were withdrawn before the Lease Sale. Seventy-three of the remaining 116 tracts were bid on and 63 of these bids were accepted and leased. Exploratory drilling began in July, 1981. To date, a total of eight exploratory wells have been drilled by five oil companies or consortia.

Two additional lease offerings are scheduled for the North Atlantic Outer Continental Shelf, including Georges Bank (Figure 1). Lease Sale 52 is scheduled for March, 1983. Another North Atlantic lease offering is scheduled for February, 1984.

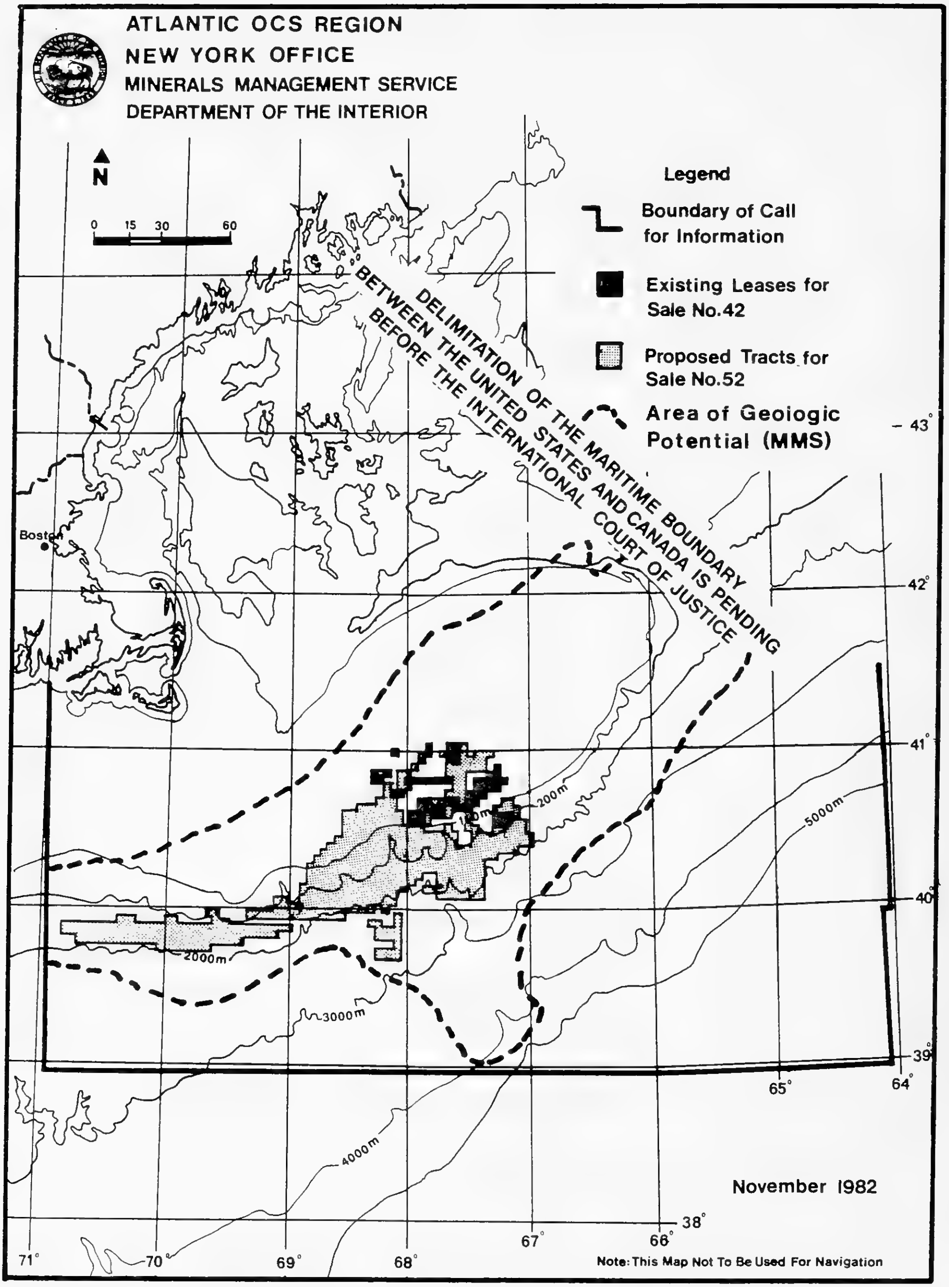


FIGURE 1. PROPOSED NO. ATLANTIC LEASE OFFERING (FEBRUARY 1984).

Because of the serious concern about the potential adverse impacts of oil exploration and development on the Georges Bank ecosystem and commercial fisheries, a Biological Task Force for OCS Lease Sale 42 was established to recommend to the Department of the Interior, Supervisor of Oil and Gas Operations in the North Atlantic, the design of environmental studies and surveys as well as periodic sampling of environmental conditions to provide warning of adverse effects of OCS oil exploration on Georges Bank (Biological Task Force, 1981). The Bureau of Land Management (now Minerals Management Service) of the U.S. Department of the Interior has implemented the monitoring program recommended by the Biological Task Force, with some modifications in sampling stations and methodology.

The primary objective of the Georges Bank Monitoring Program is to determine the fate of discharges (primarily drilling fluids and cuttings) from exploratory oil rigs in the Lease Sale 42 area and to assess the effects of these discharges on benthic species and communities of Georges Bank. The accumulation and distribution of drilling fluid-associated metals, in particular barium and chromium, in bottom sediments in the vicinity of exploratory activities are being used to trace the patterns and quantities of drilling fluid deposition around and downcurrent from drilling rigs. This research is being performed by the U.S. Geological Survey, Woods Hole, Massachusetts (Bothner et al., 1982). Concentrations of several metals are being analyzed in demersal and benthic fauna and petroleum hydrocarbons are being determined in bottom sediments and benthic/demersal animals from Georges Bank by Science Applications, Inc. (Payne et al., 1982) as a further effort to determine if drilling activities are resulting in contamination of Georges Bank. The major portion of the Monitoring Program is being performed by Battelle New England Marine Research Laboratory and Woods Hole Oceanographic Institution and addresses the question of whether benthic infaunal populations change in selected regions of the southern Georges Bank and southwestward (downcurrent) along the southern New England outer continental shelf during various stages of oil and gas exploratory activity in Lease Area 42, and whether these changes can be related to observed changes in the concentrations in the benthic environment of pollutant materials discharged from exploratory rigs. The purpose of this report is to describe and discuss the results of the first year of the Georges Bank Benthic Infaunal Monitoring Program in relation to results of the associated chemistry programs (Bothner et al., 1982; Payne et al., 1982)

3.1 Related Studies

NPDES permits issued to exploration companies by EPA set strict limits on discharges and require that specific monitoring studies be carried out by industry. These include laboratory bioassays of generic drilling muds that are used on Georges Bank and detailed monitoring and reporting of types and quantities of all drilling mud ingredients used and discharged to the ocean.

The U.S. Geological Survey, Woods Hole, Massachusetts has several recent or ongoing programs in addition to its participation in the Benthic Monitoring Program that are directly relevant to assessment of geologic and oceanographic hazards associated with oil exploration on Georges Bank. These programs include the following:

1. characterization of water currents and sediment movements in the Georges Bank region with emphasis on implications for transport of materials introduced into the area by OCS activity;

2. characterization of water currents, bottom sediment movements, and suspended sediment concentrations in Lydonia and Oceanographer Canyons and the adjacent shelf and slope. The objective is to determine the role of the canyons in transporting sediments and nutrients onto or off of the continental shelf;

3. determination of rate and direction of sand wave movement on the upper Bank;

4. identification of areas of mass movement of bottom sediments on the continental slope;

The Minerals Management Service (formerly Bureau of Land Management) has sponsored several research programs dealing with the Georges Bank environment. The New England OCS Benchmark Program was performed by ERCO, Inc. during 1977 on Georges Bank and nearby shelf and slope areas. It included measurements of petroleum hydrocarbons and metals in sediments and biota and benthic infaunal community structure at 42 stations. The analysis of the benthic infaunal samples was not completed and a subset of these samples collected near the current Benthic Infauna Monitoring Program stations were analyzed by Taxon, Inc. The purpose of this was to provide an historical perspective of the benthic fauna of the lease area to aid in interpreting results of the current monitoring program.

In addition, measurement of water currents and hydrography were made on Georges Bank from September, 1977 to October, 1979 by EG&G Environmental Consultants and Raytheon. The purpose of these studies was to develop and refine the concepts of transport, dilution and dispersion processes acting on Georges Bank.

The Canyon Assessment Study, performed by Lamont Doherty Geological Observatory, was designed to study the abundance and distribution of epibenthic and coral fauna in the Baltimore, Lydonia and Oceanographer Canyons. The canyon faunas are thought to be particularly sensitive to impacts from drilling activities.

The National Oceanic and Atmospheric Administration-National Marine Fisheries Service has several past and ongoing programs dealing with the biology and fisheries of the northwest Atlantic outer continental shelf, including Georges Bank. The Ocean Pulse Program is designed to measure several biological, biochemical, and physiological parameters in marine organisms as indices of pollutant stress and impending environmental damage. Several stations on Georges Bank are sampled periodically in the Ocean Pulse Program. Ocean Pulse is part of the Northeast Monitoring Program which includes the Manned Undersea Research and Technology (MURT) and Gulf and Atlantic Survey (GAS) Programs. The objectives of MURT are to define the geology and biology of submarine canyons and adjacent slope habitats with particular emphasis on commercially important fishery species such as crabs, lobsters and demersal fish. In the GAS Program, commercial fish and shellfish species from the OCS were analyzed for petroleum hydrocarbons, chlorinated hydrocarbons and polycyclic aromatic hydrocarbons.

In addition, the Marine Resources Monitoring, Assessment and Prediction (MARMAP) Program is being conducted on the continental shelf from the Gulf of Maine to Cape Hatteras, and includes 30 stations in the Georges Bank area. This program focuses on seasonal surveys of zooplankton-ichthyoplankton and demersal fish distribution on the OCS.

Finally the U.S. Environmental Protection Agency, the Department of Energy and the American Petroleum Institute have independently supported research programs dealing with the toxicity and environmental effects of used drilling fluids. The petroleum industry has performed several investigations of the fate and effects of drilling fluids and cuttings discharged to waters of the OCS from offshore exploratory rigs. Information from some of these studies may be useful for predicting effects of drilling mud and cuttings discharges on the Georges Bank environment.

The purpose of the combined industry and Government environmental monitoring programs is to ensure that oil and gas exploration activities do not have an adverse impact on the Georges Bank ecosystem, and particularly on its valuable fisheries. If damage is detected early, appropriate ameliorative and mitigative measures can be taken. The major concern about the exploratory phase of oil and gas development relates to possible damage, particularly to benthic and demersal populations, resulting from the discharge to the waters of the Bank of used oil well drilling fluids and cuttings. The major concern about the development and production phases of the OCS oil program relates to oil spills and their impacts on the Georges Bank ecosystem.

3.2 The Georges Bank Environment

3.2.1 Oceanography

The waters overlying Georges Bank, particularly those within the 65 meter isobath, form a discrete water mass (Hopkins and Garfield, 1981). Numerous investigations of water currents on Georges Bank have shown that there is a residual counterclockwise circulation in the Gulf of Maine and a clockwise water circulation over Georges Bank at speeds in the range of 5-10 cm/sec (Bumpus, 1976; Butman et al., 1982). The Bank circulation is defined by a southwestward flow along the southern flank, a northward flow on the eastern side of the Great South Channel, a northeastward flow on the northern edge of the Bank and an eastward, southeastward and southward flow on the northeast peak.

Superimposed on the slow clockwise gyre overlying Georges Bank are a series of strong semi-diurnal (twice per tidal day) clockwise rotary tidal currents. Maximum tidal current velocities on the Bank vary from 35 to 75 cm/sec and are higher on the shallow crest of the Bank than on the deeper slopes (Aaron et al, 1980). Water displacements associated with the semi-diurnal tidal currents typically are 10 kilometers on the crest of the Bank and a few kilometers on the flanks (Butman et al., 1982). The tidal currents cause extensive vertical mixing, especially on the crest of the Bank, so there is little or no vertical stratification.

The vertically well-mixed water over the crest of the Bank at depths of less than about 70 meters may recirculate around the Bank. The circuit time for a water particle moving along the 60 meter isobath is approximately 2 months (Butman et al., 1982). At greater depths, circuit times may be longer.

However, the gyre is not closed. Water appears to enter the Georges Bank system primarily from the Wilkinson Basin in the Gulf of Maine in the late fall and early winter (Hopkins and Garfield, 1981). Additional water influx comes from the upper shelf-slope water to the south, Scotian Shelf water to the northeast and Nantucket Shoals water to the west. On the southern flank of Georges Bank, water currents diverge south of Great South Channel, where most flow continues to the westward along the southern New England shelf, while the remainder of the flow turns northward into the Channel (Butman and Beardsley, 1982; Butman et al., 1982). Water in the westward flowing branch could easily reach the shelf south of Cape Cod in one month.

On the southern flank of Georges Bank in the vicinity of the Lease Sale 42 blocks, mean current flow in all seasons and at all depths is to the southwest approximately parallel to the local isobaths (Butman and Beardsley, 1982; Butman et al., 1982). The mean flow is strongest near the surface (typically 15 cm/sec at 10-15 meters). At 45 and 75 meters, mean current speeds are approximately 8.6 and 3.5 cm/sec, respectively. Current speed also decreases offshore. At 45 meters current speed varies seasonally from a high of about 11 cm/sec in September to a minimum of about 5 cm/sec in March. Estimates of the mean residence time of surface water over the southern flank of the Bank by Lagrangian and Eulerian methods (drogues and current meters, respectively) are in the range of 32 to 46 days (Magnell et al., 1981).

The Georges Bank region is subjected to frequent gales and northeast storms, particularly in winter. Storm waves on the Bank may be quite large. Wave heights greater than one meter occur more than 50 percent of the time on the Bank and 1-year and 100-year maximum wave heights are projected at 11-12 m and 19 m, respectively (Thompson and Harris, 1972; Neu, 1970-1972).

The combination of tide, currents, and storm waves over Georges Bank creates a high energy environment with excellent vertical and horizontal mixing. In parts of the Bank shallower than 60 m, this water turbulence may carry coarse-grained sand particles over the bottom in waves, somewhat resembling migrating sand dunes on land. These sand waves may be from 10 to 20 m high and 200-300 m long with a periodicity of 100 to 200 m.

Seawater temperatures vary seasonally and vertically with minimum temperatures in winter of 4-6°C and maximum surface temperatures in summer of 15-18°C (Colton and Stoddard, 1972). A sharp thermocline develops during the summer in deeper parts of the Bank and on the slopes where mixing is weak, but not on the crest of the Bank at depths less than about 60 meters.

Bottom sediment granularity varies substantially from one part of Georges Bank to another. Sand covers approximately 75 percent of the Bank (Wigley, 1961). Gravel sediments cover a large area in the northeast corner of the Bank and occur in small patches on the north-central Bank and in the Great South Channel. Patches of silt and clay sediment occur in deep water off the northwest corner of the Bank. It is thought that much of the fine silt/clay sediments washed off the Bank are deposited in a large muddy area south of Rhode Island sometimes called the Mud Patch (Twichell et al., 1981; Bothner et al., 1981b). Mollusc shell fragments make up to 5 to 25 percent of the coarse sand and gravel sediments along the eastern flank of the Bank. Total organic carbon concentration of the sediments varies from 0 to about 3.5 percent and tends to increase with decreasing grain size. Dominant sediment types in the Lease Sale 42 area are medium and fine sands. Total organic carbon concentration of these sediments is in the 0.1-0.5 percent range.

Concentrations of suspended particulates generally are very low in waters overlying Georges Bank, except after major storms. In the Lease Sale 42 area, total suspended particulate concentrations range from 750-800 μg/l over shallower portions to about 250 μg/l in deeper slope waters (Bothner et al., 1981a). Dominant minerals in the suspended inorganic particulates are layered silicates, quartz, and feldspar. The most abundant clay minerals are illite ($57 \pm 6\%$) and chlorite ($27 \pm 4\%$), with small amounts of kaolinite. No montmorillonite (bentonite clay) is found.

A surface deposit of fine-grained silt and clay, covering an area of approximately 13,000 square kilometers and as much as 13 meters thick, exists on the floor of the continental shelf south of Cape Cod at depths between 60 and 200 meters (Twichell et al., 1981; Bothner et al., 1981b). Evidence that this area, called the Mud Patch, is a site of active sediment deposition is provided by investigations of the vertical distribution in sediment cores of the isotopes ^{14}C and ^{210}Pb (Bothner et al., 1981b; Bothner and Johnson, 1981). The ^{14}C concentration profiles indicate that sedimentation rates were approximately 130 cm/1,000 years when deposition began and have decreased to current rates of about 25 cm/1,000 years in the central portion and about 30 cm/1,000 years at the eastern end of the deposit.

The ^{210}Pb data yielded an estimated current sedimentation rate of about 170 cm/1,000 years. This higher estimate may be due to bioturbation of near-surface sediments. Based on an average sedimentation rate of 25 cm/1,000 years, sediments are accumulating in the Mud Patch at a rate of about 84 million metric tons per year.

Because the net water current direction in this area of the continental shelf is southwestward, it is thought that these fine-grained sediments originate on Georges Bank and Nantucket Shoals. In support of this hypothesis, the clay mineralogy of sediments in the Mud Patch is similar to that of the clay-size fraction of sediments from Georges Bank (Bothner et al., 1980). Illite is predominant, with moderate amounts of chlorite and small amounts of kaolinite. Montmorillonite is absent or present only as a trace. Periodically, during storms, some fine sediments may bypass or be eroded from the Mud Patch and be transported into Long Island Sound (Bothner et al., 1981b). Thus, fine-grained materials, such as drilling fluids, discharged from drilling rigs on Georges Bank could be carried to and deposited in the Mud Patch and Long Island Sound.

Concentrations of primary nutrients in waters over Georges Bank are generally quite high. Nitrogen/phosphorous (N/P) ratios generally are low, characteristic of shallow areas where intense mixing brings nutrients up from the bottom (Riley, 1941). Dissolved oxygen concentration is usually near saturation in surface waters and rarely lower than 50 percent saturation in deeper portions of the slope.

3.2.2 Biota and Biological Productivity

The combination of strong water mixing over most of Georges Bank and nutrient upwelling caused by convergence of major ocean currents sustains a very high primary productivity throughout the year. Primary production of phytoplankton varies seasonally and reaches a maximum of about 950 mg C/m^2/day in April over shallower parts of the Bank (Riley, 1941). Annual mean phytoplankton production on Georges Bank is estimated at 400-500 g C/m^2/year. This value is as high as or higher than any value reported for any other oceanic ecosystem, including the highly productive North Sea and Grand Banks of Newfoundland.

The rich phytoplankton crop supports a large and diverse zooplankton community dominated by copepods (Sherman et al., 1978). Georges Bank is known to be a major spawning ground for at least 26 species of fish. Pelagic eggs and larvae of 29 species of fish, many of them commercially important, have been collected on the Bank (BLM, 1977; Colton and Byron, 1977). Georges Bank is a major spawning area for such species as Atlantic herring, Atlantic cod, haddock, and several species of flounder.

The benthic invertebrate fauna of Georges Bank also is very diverse and productive. This fauna contains not only some of the more economically important commercial fishery species (e.g., the sea scallop Placopecten magellanicus) but is a major source of nutrition for most of the other commercial fishery species (e.g., cod, haddock, flounder). The benthic community also is the one most likely to be adversely affected by oil and gas exploration activities on Georges Bank.

Before the present investigation, few quantitative surveys of benthic populations on Georges Bank were made. Wigley (1961, 1965, 1968) sampled once in August, 1957, and used 1 mm sieves. He estimated the average abundance of benthic macroepifauna and infauna at 1,690 individuals per m^2. The composition of Wigley's samples included 66 percent crustaceans (an average of 1,113 individuals), 20 percent annelids (334 individuals), 3 percent each molluscs and echinoderms (with 54 and 47 individuals, respectively) and 8 percent miscellaneous (142 individuals).

Another survey was the BLM-sponsored New England Environmental Benchmark Program conducted by Energy Resources Company, Inc. (ERCO). Benthic samples were collected in February/March and May/June, 1977, and sieved on 0.5 mm mesh screens. Results of the February/March, 1977 cruise indicate densities of individuals, exclusive of polychaetes, ranging from 80 to 13,319 individuals per m^2 at 42 stations and numbers of species from 60 to 330 per m^2 (Michael, 1977). When the polychaete data for this cruise (Maurer and Leathem, 1981) are considered in addition, total infaunal densities range from 432 to 20,553 individuals per m^2, with an average density of 6,413 per m^2. The densities thus recorded are of the same order of magnitude as those obtained by Wigley (1961); this is surprising in view of the fact that smaller mesh (0.5 mm) screens were used in the Benchmark Study.

More recently, Grassle (W.H.O.I., unpublished data) sampled three stations on the southern edge of Georges Bank. Using fine (0.3 mm mesh) sieves, he obtained densities of 14,000 to 17,000 per m^2 at one station, and 21,000 to 64,000 per m^2 at a second station. These generally higher densities can be attributed to the finer mesh sieve and careful handling of the samples (Grassle, unpublished observations), as well as to possible spatial differences.

In both the Benchmark survey and the recent study by Grassle, polychaetes accounted for at least 50 percent of the taxa collected, with amphipod crustaceans being the second dominant group, followed by molluscs, other crustaceans, echinoderms and other phyla (Michael, 1977; Maurer and Leathem, 1981; Grassle, unpublished data).

Ampeliscid amphipods belonging to 2 species are particularly common on Georges Bank. Byblis serrata (Smith) is more common on top of the Bank, and Ampelisca agassizi (Judd) is common in deeper waters (Dickenson and Wigley, 1981). These animals account for a high proportion of the benthic productivity and are food for commercial species of fish. Tube-building amphipods such as these are also important in stabilizing the sediment (Ekman, et al., 1981). The ampeliscid amphipods are also known to be among the species most sensitive to increased levels of hydrocarbons in marine sediments (Sanders, et al., 1980; Cabioch et al., 1978).

3.2.3 Fisheries

Georges Bank has been fished constantly for more than 300 years. Until about 1960, most fishing was for cod and mackerel by U.S. fishermen. After that date, foreign fishing effort increased dramatically so that by the 1970's the foreign catch far exceeded the U.S. commercial catch. In 1977, the total foreign catch was 456,111 metric tons compared with 65,707 tons for the U.S. (Houghton et al., 1981).

In 1968, the commercial yield of Georges Bank was 11.6 metric tons/km^2, the highest catch per unit area anywhere in the Atlantic, ranking Georges Bank over the North Sea and the Grand Banks of Newfoundland in fisheries productivity (Hennemuth, 1976; Mills, 1980). Since that date, total biomass of principal demersal fish species has declined by roughly 50 percent. The major cause of this dramatic decline was overfishing, although adverse environmental conditions, coastal pollution, and inter- and intra-specific competition also may have contributed (Clark and Brown, 1976). The Fishery Conservation Management Act was passed in an effort to protect the fishery from overexploitation and to allow fish stocks to recover. If stocks recover and are fished at or below their maximum sustainable yield, the economic value of the Georges Bank fishery over the next 20 years is estimated at $3.34 billion (1978 dollars) (NOAA/CZM, 1979). Total value of commercial landings from Georges Bank in 1978 was $167,625,000. The most valuable species were sea scallops ($99 million), cod ($17.9 million), haddock ($15.8 million) and yellowtail flounder ($10.3 million). Lobster with a market value of more than $8 million were landed from Georges Bank, primarily from the heads of submarine canyons along the southern flank of the Bank. There is some concern that drilling muds discharged from exploratory rigs in Lease Sale Area 42 may be swept into the canyons and increase suspended sediment concentrations there, possibly damaging the important filter-feeding community (mainly soft and hard corals) (Haedrich et al., 1975).

The portion of Georges Bank containing Lease Sale Area 42 produces moderately low catches of demersal fish compared to other areas of the Bank (Pikanowski, 1977). During spring and fall groundfish surveys performed by NMFS in 1972-78, average weight of groundfish per tow of an otter trawl was 30.97 and 19.34 kg., respectively, compared to 111.77 kg per tow in the most productive area on the western border of the Bank. Elasmobranchs and yellowtail flounder were the most abundant fish species taken in the lease area.

Although ocean scallops Placopecten magellanicus are most abundant in the northeastern part of Georges Bank and in the area of the Great South Channel, commercial quantities of scallops (average, 0.75 bushels per 15-minute tow) occur in the eastern part of the Lease Sale 42 area (MacKenzie et al., 1978). Lobsters Homarus americanus do not occur regularly in the Lease Sale area, but are abundant in the submarine canyons immediately to the south. However, these lobsters make shoalward migrations, possibly for spawning, in spring and summer, with a return to the edge of the shelf in fall and winter (Cooper and Uzmann, 1971). These migrations take the lobsters through the Lease Sale 42 area.

3.3 Environmental Concerns Related to Oil/Gas Exploration and Production

The major environmental concerns resulting from exploration, development, and production activities for oil and gas on Georges Bank are that intentional discharges of materials (mainly drilling fluids and cuttings) from oil platforms during normal exploratory and development activities may damage the Georges Bank marine environment and in particular the fisheries; and that accidental spills of crude oil and discharges of petroleum hydrocarbon-laden produced water during the production phase will harm the marine biota (particularly floating eggs and larvae of commercial fish) and result in tainting of fisheries species. Other concerns relate to increased ship traffic over the Bank, disruption of the bottom by pipelines and rig structures, and disturbance of migrating whales by noise. Interestingly, the major damage to fisheries reported from oil industry activities in the North Sea has resulted from damage to nets from jetsam cast overboard from rig work boats, barges, etc.

3.3.1 Drilling Fluids

A large volume of drilling fluid (also called drilling mud) is used to drill a typical offshore oil well. Between 100 and 2,000 tons of drilling fluid may be used to drill a single well (Hrudey, 1979; Ayers et al., 1980). Water-based drilling fluids, but not oil-based drilling fluids may be permitted (by NPDES Permit) for discharge to the ocean. Used drilling fluids are often discharged intermittently in small quantities, usually associated with drill cuttings, during exploratory drilling and in bulk quantities at the end of the drilling operation (McGuire, 1975; Ray, 1979; Neff, 1982). In most cases, much less drilling fluid is discharged during drilling of a production well than during drilling of an exploratory well, because in the former case it may be possible to use a single batch of mud for more than one well.

Initially it was estimated that during the remainder of the initial 5-year lease period for Lease Area 42, approximately 35 exploratory wells will be drilled (BLM, 1977). Up to 3 rigs will be operating in Lease Area 42 at any one time. If there are significant finds of oil and/or gas, between 150 and 420 development wells will be drilled during the development phase lasting 8 to 11 years. These production wells would be drilled from 11 to 28 fixed platforms (10 to 15 wells/platform). The production phase, when no drilling would take place, would last about 20 years.

To date, a total of eight exploratory wells have been drilled in the Lease Sale 42 Area. All wells were reported to be dry holes. Because of the discouraging initial results and the rapidly changing oil supply picture, it is uncertain how much additional exploration will take place in the Lease Sale 42 Area.

Drilling fluids are custom-formulated by the mud engineer on an oil rig to fulfill a variety of functions integral to the whole drilling operation. The most important of these functions are to suspend drill cuttings and carry them to the surface and to balance subsurface and formation pressures preventing a blowout. There are well over 1,000 trade-name products available for drilling mud formulation (World Oil, 1977), representing about 55 different generic materials or formulations (McMordie, 1975). Of all these materials, only about 10 to 15 are actually used for mud formulation for a typical well. Five chemicals (barite, bentonite clay, lignite, sodium hydroxide and chrome or ferrochrome lignosulfonate) make up more than 90 percent by volume of most water-based drilling muds. Other minor ingredients in a typical offshore drilling mud include cellulose polymer, sodium carbonate/bicarbonate, and lime. A variety of other ingredients may be added in small quantities as needed to solve particular down hole problems.

The quantities and types of materials used to formulate the drilling fluids used to date on Georges Bank are listed in Tables 1 and 2. The amount of drilling mud solids used per well ranged from 717.7 to 2,023.5 metric tons with a total mud useage for eight wells of 9,727.7 metric tons. Of this total, 5,727.2 metric tons were barite and 3,004.8 metric tons were bentonite (montmorillonite) clay. Not all this drilling mud was discharged to the ocean, but if it had been, it would represent 0.01 percent of the estimated 84 million metric tons of fine-grained sediments accumulating each year in the Mud Patch. Some diesel oil was used in one well (Block 312) to help free stuck pipe. Apparently, most of this oil was not discharged to the ocean (E.P. Danenberger, MMS, Hyannis, MA, personal communication)..

The two major environmental concerns relating to discharge of used drilling fluids to the oceans are that: (1) the drilling fluids may be acutely toxic or produce deleterious sublethal responses in sensitive marine species or ecosystems, and (2) metals present in some drilling fluids may be accumulated by marine organisms to concentrations that could be harmful to the organisms themselves or to consumers, including Man, of fishery products.

The fate and biological effects of used drilling fluids discharged to the ocean have been thoroughly reviewed in three recent monographs (Houghton et al., 1981; Neff, 1982; Petrazzuolo, 1981). The authors are in general agreement that a majority of the drilling fluids evaluated to date have a relatively low order of acute toxicity to all but the most sensitive species and life stages of marine organisms. Median lethal exposure concentrations at 96 hours (96 hr LC50) usually lie above 10,000 ppm drilling mud added. The most sensitive species and life stages of marine animals may show acute lethal or chronic sublethal responses to concentrations as low as 10-50 ppm. Among the most sensitive organisms tested to date are larvae and juveniles of ocean scallop Placopecten magellanicus and lobster Homarus americanus, both extremely important Georges Bank fishery species (Gerber et al., 1980; Derby and Atema, 1981; Atema et al., 1982; Gilbert, New England Aquarium, unpublished report).

Observations in the field have shown that in a dynamic high energy offshore environment, drilling fluids discharged to the ocean are diluted to "background" concentrations usually within 1,000-2,000 m downcurrent from the discharge pipe and usually within 2 hours of discharge (Ayers, et al., 1980; Ray and Meek, 1980). Because of this rapid dilution, it is unlikely that adverse impacts of drilling mud discharge will be detectable in water column organisms. However, drilling mud ingredients accumulate on

TABLE 1. TYPES AND QUANTITIES OF SOLID INGREDIENTS USED TO FORMULATE DRILLING FLUIDS USED FOR DRILLING THE EIGHT EXPLORATORY WELLS ON GEORGES BANK DURING 1981-1982. THE ACTUAL AMOUNTS OF DRILLING FLUIDS DISCHARGED TO GEORGES BANK ARE LESS THAN THE TOTALS LISTED HERE.

Solids (Metric Tons)	Well (Block Number)							
	133	975	410	312	187	145	273	357
Barite ($BaSO_4$)	507.1	351.4	509.9	1083.1	1202.5	368.4	409.3	1285.5
Bentonite Clay	225.3	231.6	582.5	320.4	500.6	312.9	257.5	574.0
Caustic Soda (NaOH)	20.0	26.1	39.5	47.9	75.6	15.9	32.2	55.8
Lignite	17.9	17.0	-	24.7	51.3	-	0.4	-
Chrome Lignosulfonate	21.3	31.9	27.6	16.3	65.5	7.0	5.2	39.2
Sodium Bicarbonate	0.8	3.7	-	-	4.2	-	0.2	-
Lime ($Ca(OH)_2$, CaO)	1.8	0.1	1.2	1.1	1.1	1.9	0.2	3.4
Sodium Acid Pyrophosphate	0.2	0.4	0.1	-	0.1	-	-	-
Nut Plug (Lost Circulation Material)	0.2	1.0	22.4	0.4	2.8	-	0.7	18.9
Mica (Lost Circulation Material)	0.7	0.9	-	-	-	-	-	8.2
Aluminum Stearate (Defoamant)	0.4	-	0.1	0.2	0.02	-	0.01	0.2
Drispac (Na Carboxymethyl Cellulose)	0.2	1.6	6.4	15.6	17.8	7.0	8.8	8.0
Soda Ash (Na_2CO_3)	0.1	6.8	1.0	3.4	1.3	4.6	5.5	2.9
Salt (NaCl)	-	64.2	-	-	4.4	-	-	-
Sulf-X11 (Zn Sulfonate-Zn Carbonate; H_2S Scavenger)	-	-	2.9	-	-	-	-	1.1
Poly RX (Lignosulfonate-Polymer-Sodium Carbonate Blend, High Temperature Thinner)	-	-	-	8.8	-	-	2.0	23.9
Spot (Weighted Ca Oleate-Asphalt Mixture; Spotting Fluid)	-	-	-	2.1	-	-	-	-
Super-Col (Beneficiated Bentonite)	-	-	-	-	31.7	-	-	-
Chemtrol-X	-	-	-	-	45.2			
Super Shale Trol 202	-	-	-	-	10.0			
XC Polymer (Xanthan Polymer; Viscosifier)	-	-	-	-	0.1	-	-	-
WO 30 (Calcium Carbonate)	-	-	-	-	0.05	-	-	-
Calcium Chloride	-	-	-	-	-	-	-	2.4
Total Solids	796.0	736.7	1193.6	1524.0	2014.2	717.7	722	2023.5

TABLE 2. TYPES AND QUANTITIES OF LIQUID INGREDIENTS (OTHER THAN MAKE-UP WATER) USED TO FORMULATE DRILLING FLUIDS USED FOR DRILLING FOUR OF THE EIGHT EXPLORATORY WELLS ON GEORGES BANK DURING 1981-1982. NO LIQUID INGREDIENTS WERE REPORTED FOR THE OTHER FOUR WELLS. THE ACTUAL AMOUNTS OF THESE MATERIALS DISCHARGED TO GEORGES BANK ARE LESS THAN THE AMOUNTS USED.

Liquids (Liters)	Well (Block Number)			
	410	312	187	273
Foam Ban (Blend of Phosphoric Acid Tributyl Ester, Alcohol and Refined Hydrocarbon Carrier; Defoamant)	113.6	-	-	-
Torque Trim (Liquid Triglycerides and Alcohol; Lubricant)	-	2,498.3	-	624.5
Lube 106 (Blend of Glycerol Mono-oleates and Mixed Long-Chain Alcohols; Lubricant)	-	605.7	-	7,005.0
MD (Modified Alkanolamid and Sodium Acid Pyrophosphate; Detergent)	-	37.9	1,722.4	-
Diesel Oil	-	16,216.7	-	-
Free Pipe (Oil-Soluble Surfactants)	-	416.4	-	-
Scale Ban (Acrylic Polymer)	-	-	56.8	-
LD-8 (Surfactant, Defoamant)	-	-	8,422.5	-
WO Defoamer	-	-	359.6	-
Aqua Spot (Water-Soluble Surfactant)	-	-	4,788.5	-
Mentor 28	-	-	1,041.0	-
Total Liquids	**113.6**	**19,775.0**	**16,390.8**	**7,629.5**

the bottom under and for as much as several thousand meters downcurrent from the discharge. This may result in outright burial of benthos or produce acute or chronic toxic effects (including metal accumulation) in surviving benthic fauna.

Elevated concentrations of barium, chromium, zinc, cadmium, and lead, presumably derived in part from discharged drilling muds, have been reported in bottom sediments in the immediate vicinity of offshore exploratory wells (Ecomar, 1978; Crippen et al., 1980; Gettleson and Laird, 1980; Mariani et al., 1980; Meek and Ray, 1980; Tillery and Thomas, 1980; Wheeler et al., 1980; EG&G Environmental Consultants, 1982). A few attempts have been made to determine whether these and other drilling mud associated metals are accumulated by benthic marine animals (Liss et al., 1980; McCulloch et al., 1980; Neff, 1980; Page et al., 1980; Rubinstein et al., 1980; Tornberg et al., 1980). Drilling mud metals showed a very limited bioavailability to all species tested. Chromium (present in drilling mud primarily associated with lignosulfonate) was the most bioavailable metal studied. Barium (from barite) was accumulated to a small extent by some species. The other metals studied showed little or no bioaccumulation potential. Small increases in the concentrations of barium and/or chromium were reported in tissues of mixed assemblages of molluscs, echinoderms and polychaetes collected from bottom sediments near an offshore exploratory rig on the mid-Atlantic OCS up to one year after completion of drilling (EG&G Environmental Consultants, 1982). There are no other reports of accumulation of metals from drilling muds by marine animals in the vicinity of offshore exploratory wells.

Because of the high energy mixing regime over most of Georges Bank, little long-term deposition of finer fractions of discharged drilling muds is likely in shallower regions of the Bank. Significant deposition and long-term retention of drilling muds is expected in the near-field of rigs deeper than 100 meters.

Normal background concentrations of barium in sediments in Lease Area 42 range from 28 to 300 mg/kg with a mean of 105 mg/kg. Bothner et al., 1982 report that from July 1981, when drilling began, to May 1982, the concentration of barium in bulk (unfractionated) surficial sediments increased by a factor of 3.5 near the rig site in Block 410 and by a factor of 2.3 near the drill site in Block 312. Post-drilling levels of Ba did not increase above pre-drilling levels at other monitoring stations. Concentration of Ba in the clay-size fraction of sediments ($< 62\,\mu m$) increased by a factor of 36 near the drill site in Block 410 and by a factor of 22 near the drill site in Block 312. Changes in concentrations of other metals in bulk sediments from Blocks 312 and 410 were within the normal background concentration range. Concentrations of Cr, Hg, Cu, and Al in the clay-size fraction of sediment at the drill site in Block 410 increased temporarily by a factor of about 2.

Deposited drilling muds may damage the benthic invertebrate community through burial and smothering, clogging with fine suspended particles of gills etc., of animals, or chemical toxicity. The extent of this damage and rate of recovery are not known. In the mid-Atlantic OCS, changes in benthic fauna were observed under and downcurrent from an exploratory rig immediately after and one year after drilling ceased (Menzie et al., 1980; EG&G Environmental Consultants, 1982). Many of the effects were attributed to predation by demersal fish and motile macroinvertebrates (crabs and starfish) attracted to the area by the increased microrelief provided by cuttings accumulation and by mussels knocked off rig structures and anchor chains. Substantial recovery had occurred within one year.

3.4 Design of the Benthic Monitoring Program

The Benthic Monitoring Program proposed by the Biological Task Force was designed to determine both the near-field short-term and regional long-term environmental impacts of oil exploration activities in the Lease Sale 42 area. A total of 46 collecting stations were established on and adjacent to Georges Bank (Figures 2 and 3, Table 3). These were of two types. A group of long-term regional stations was established to assess long-term and regional impacts of drilling activities (Figure 2). Benthic faunal distributions on the southern flank of the Bank are determined largely by water depth and sediment characteristics. Therefore, three transects of three stations each were set up perpendicular to the local isobaths, approximately in a north-south direction. The transects were located west of, east of and directly through the Lease Sale 42 blocks, with the three stations on each transect located at approximately the 60, 80 and 100 meters depths. Because net water movement over the southern flank of the Bank at all depths is toward the southwest, the eastern Transect I lies upstream and is considered a reference transect. The western Transect III lies downstream of the drilling activity where drilling discharges could accumulate and long-term effects might occur. Additional regional stations were located at sites of possible deposition of drilling muds and cuttings from the rigs. These include the heads of Lydonia and Oceanographer Canyons, the Mud Patch south of Cape Cod, an area of fine-grained sediments at the northern end of the

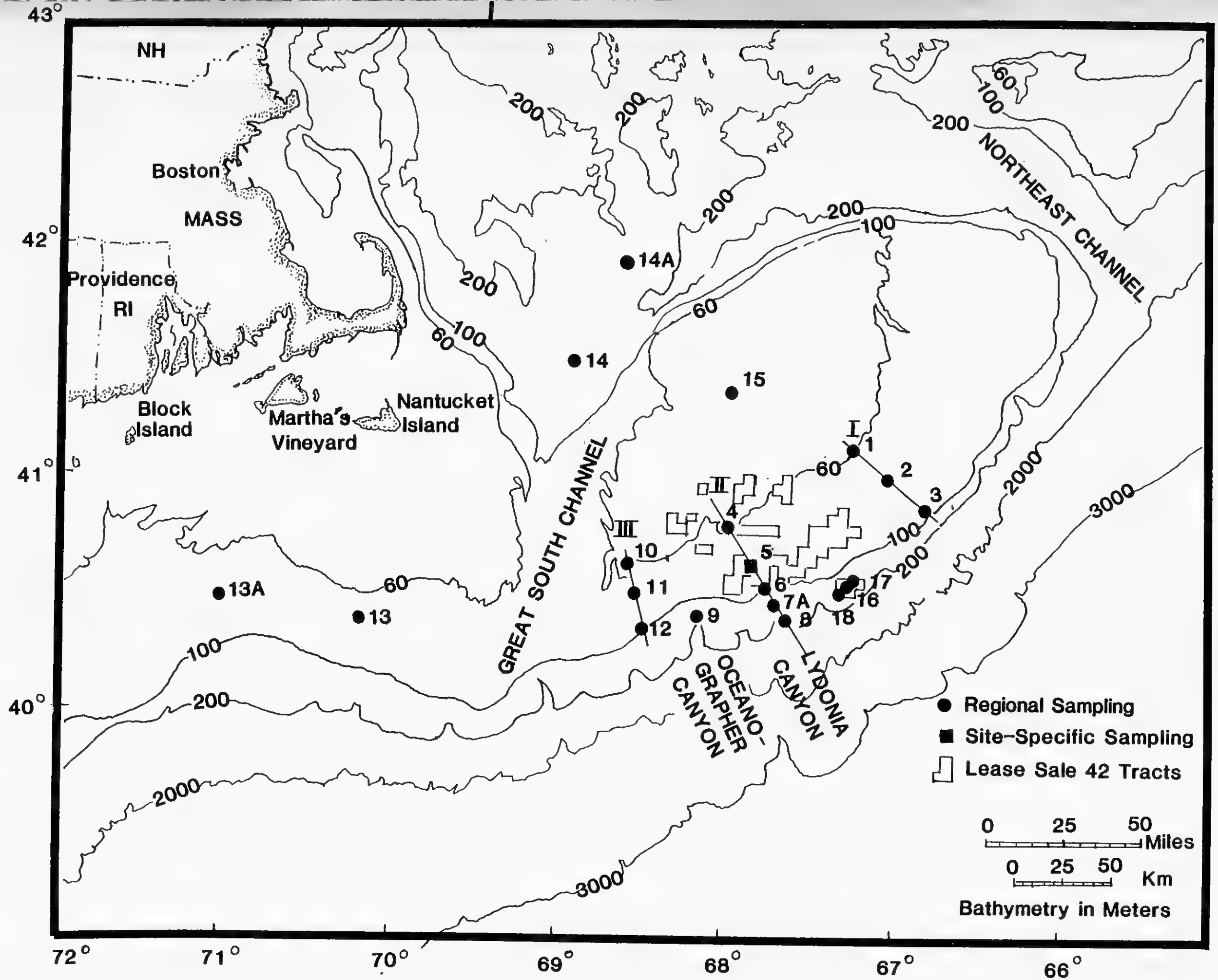


FIGURE 2. LONG-TERM REGIONAL STATIONS

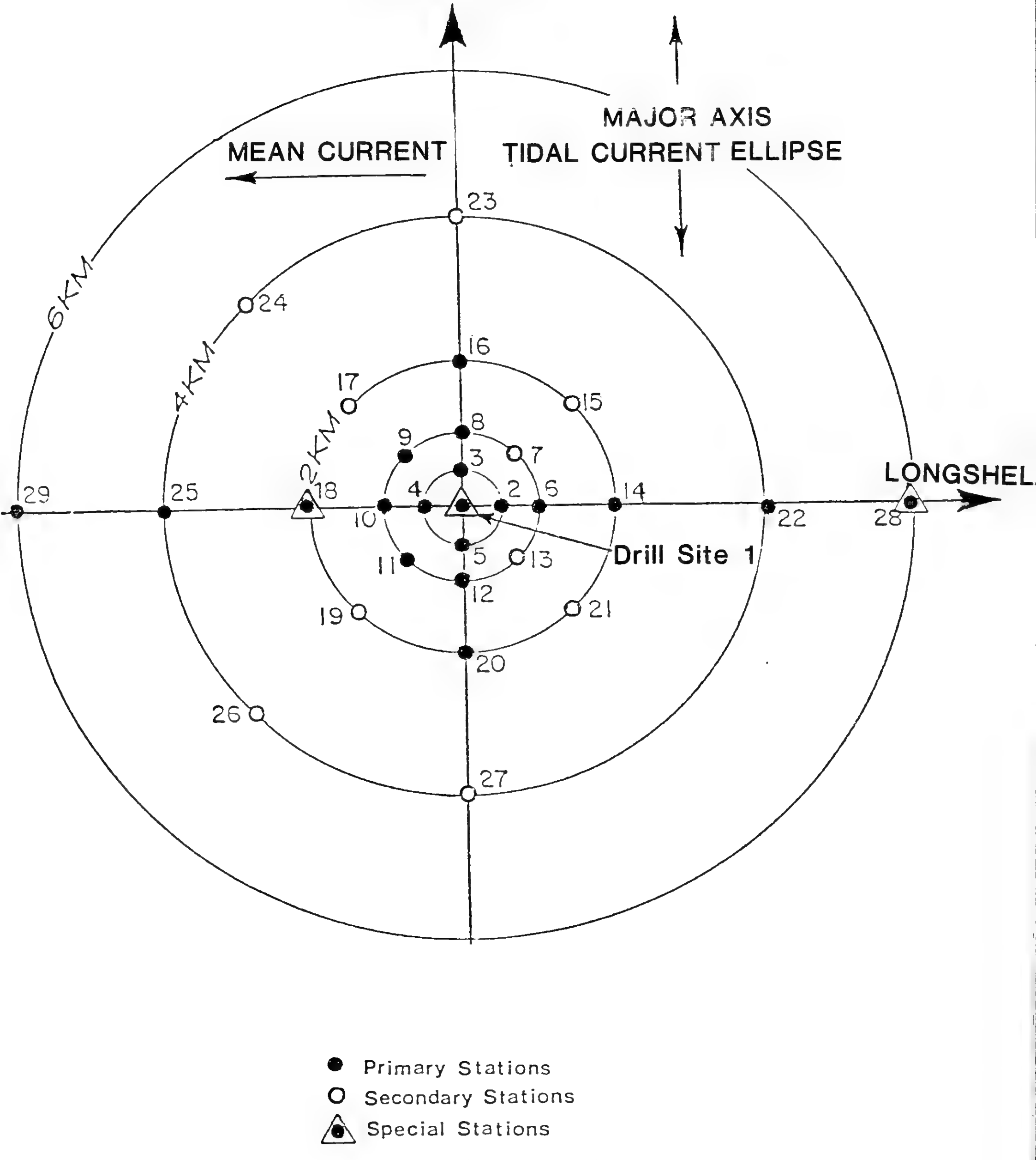


FIGURE 3. SITE-SPECIFIC STATIONS

TABLE 3. COORDINATES FOR GEORGES BANK MONITORING STATIONS

Long-Term Regional Station No.	Latitude	Longitude
1	41°13.0'N	67°15.3'W
2	40°59.0'N	66°55.8'W
3	40°53.7'N	66°46.5'W
4	40°50.7'N	68°00.2'W
5 (rig site)*	40°39.5'N	67°46.2'W
6	40°34.3'N	67°45.3'W
7	40°28.8'N	67°43.2'W
8	40°27.1'N	67°37.4'W
9	40°26.7'N	68°09.8'W
10	40°42.0'N	68°35.3'W
11	40°30.8'N	68°33.7'W
12	40°22.2'N	68°30.2'W
13	40°29.5'N	70°12.6'W
13A	40°30.0'N	71°00.5'W
14	41°34.2'N	68°59.0'W
15	41°27.5'N	68°00.7'W
16	40°34.2'N	67°12.3'W
17	40°35.0'N	67°11.7'W
18	40°33.5'N	67°13.7'W

Site-Specific Station No.	Latitude	Longitude
*5-1 (rig site)	40°39.5'N	67°46.2'W
*5-2	40°39.6'N	67°45.8'W
*5-3	40°39.8'N	67°46.1'W
*5-4	40°39.5'N	67°46.5'W
*5-5	40°39.3'N	67°46.2'W
*5-6	40°39.5'N	67°45.4'W
5-7	40°39.9'N	67°45.7'W
*5-8	40°40.1'N	67°46.1'W
*5-9	40°39.9'N	67°46.7'W
*5-10	40°39.4'N	67°46.9'W
*5-11	40°39.2'N	67°46.6'W
*5-12	40°39.0'N	67°46.1'W
5-13	40°39.2'N	67°45.6'W
*5-14	40°39.5'N	67°44.7'W
5-15	40°40.3'N	67°45.2'W
*5-16	40°40.6'N	67°46.1'W
5-17	40°40.3'N	67°47.1'W
*5-18	40°39.6'N	67°47.6'W
5-19	40°38.8'N	67°47.2'W
*5-20	40°38.5'N	67°46.1'W
5-21	40°38.8'N	67°45.1'W
*5-22	40°39.5'N	67°43.3'W
5-23	40°41.7'N	67°46.1'W
5-24	40°41.1'N	67°48.1'W
*5-25	40°39.5'N	67°49.0'W
5-26	40°38.0'N	67°48.1'W
5-27	40°37.4'N	67°46.1'W
*5-28	40°39.5'N	67°41.9'W
*5-29	40°39.5'N	67°50.4'W

*Primary Stations

Great South Channel, and just above the shelf-slope break south of the lease sale area. Another station was located in a high energy erosional area at the top of the Bank in about 35 meters of water.

Two groups of stations were located in close proximity to two exploratory drilling operations in order to assess near-field impacts of drilling discharges on the benthos. A group of three stations was located within 200 meters, and approximately 2,000 meters upcurrent and downcurrent of the drilling rig in Block 410 in about 140 meters of water. A larger site-specific array of 29 stations was located in a radial pattern around the exploratory rig in Block 312 in 79 meters of water (Figure 3). Stations were located within 200 meters and at distances of 0.5, 1, 2, 4, and 6 kilometers from the rig. An over-sampling strategy was used here. Nineteen of the stations were designated as primary stations, and all samples from these stations were analyzed. The other ten stations were designated as secondary stations, and samples from them will be analyzed if needed to aid in interpretation of impacts observed at the primary stations.

All stations are sampled four times per year on a seasonal basis. During the first year of the program, covered by this report, samples were collected in July and November 1981 and February and May 1982. At each station, six replicate biology samples and three replicate chemistry samples of undisturbed bottom sediments are collected with Van Veen grab samplers. Subsamples of these are taken for carbon-hydrogen-nitrogen (CHN) and sediment grain size analysis. Biology samples are sieved and preserved. Chemistry samples are frozen. Bottom photographs are taken at each station to document the presence of epifauna and demersal fish and in an effort to detect possible accumulations of drilling mud and/or cuttings. Measurements of water column hydrography (salinity, temperature, dissolved oxygen) are taken at all regional stations. Dredge and trawl samples are collected at up to three regional and three site-specific stations to obtain fish and mollusc samples for chemical analysis and to obtain representative specimens of epifauna and demersal fish for a voucher collection to be used in identifying species observed in bottom photographs.

All animals retained by a 0.3 mm sieve from the biological benthic grab samples are identified to lowest possible taxon, enumerated and weighed. These data are evaluated statistically to characterize the benthic communities and to compare them within and between stations over the time-course of the investigation. Relatively small changes in community parameters, possibly attributable to drilling activities, can be detected.

Chemistry samples are analyzed for several metals associated with drilling muds and for petroleum hydrocarbons. The biological and chemical data are evaluated to discern any correlations between accumulation of materials from drilling discharges and changes in community parameters in the benthic infauna.

Progress of the Program is reviewed periodically by a Scientific Review Board and by the Biological Task Force and recommendations are made for improving the program.

4. METHODS

4.1 Field Sampling

Sampling stations were located by LORAN-C (Northstar 6000), using average time delays obtained during Cruise M1. The several types of samples which were taken at each regional and site-specific station are summarized in Table 4. At each regional station, 6 replicate 0.1 m^2 Van Veen grabs and 6 replicate 0.04 m^2 Van Veen grabs were taken for infaunal analysis. Large (0.1 m^2) grab samples were taken at all regional and primary site-specific stations for trace metal and hydrocarbon analyses.

Core subsamples for CHN and sediment grain size analyses were taken from each 0.04 m^2 grab sample immediately after collection. A plastic syringe with an inside diameter of 2.54cm was used. No cores were removed from M1 samples; 4 cores were removed from each M2 sample, and 3 cores (1 for CHN, 2 for sediment grain size) were removed from each M3 and M4 sample. Cores were frozen in labelled Whirlpak bags immediately after collection. Removal of these cores therefore reduced the surface area analyzed for infauna by 5.07% (M2 samples) and 3.80% (M3 and M4 samples).

After the core subsamples were removed, each 0.04 m^2 sample was placed in a 10 qt. bucket with pour spout. Filtered seawater was added to the bucket, then decanted onto a 12 inch diameter screen with 0.3 mm mesh. This procedure was repeated as long as a low density organism fraction was obtained. The portion remaining on the screen was then transferred to a 16 oz. jar, preserved with 10% buffered formalin in seawater and labelled both inside and outside the container. The heavy sediment residue was placed in a 1-gallon plastic jar and similarly preserved and labelled. Large (0.1 m^2) grab samples were transferred to a muslin bag, stored individually in labelled 3.5 gallon buckets, with 10% buffered formalin added as a fixative. Large grab samples collected on Cruise M1 were stored in nine 30-gallon drums rather than in individual containers.

Epifaunal samples were collected at Regional Stations 2, 7, and 13 and at Site-Specific Stations 5-1, 5-18 and 5-28. Various types of sampling gear were employed including an epibenthic sled, a Blake trawl, a Day dredge and, on Cruise M4, an otter trawl. These samples were collected primarily to provide specimens for analysis of the metal and hydrocarbon content of selected tissues of particular species, but also to provide biological voucher specimens, especially to assist in the analysis of the bottom photographs.

TABLE 4. SAMPLES COLLECTED AT GEORGES BANK MONITORING STATIONS M1-M4

	Regional Stations	Site-Specific Stations Primary	Site-Specific Stations Secondary
$0.10m^2$ Van Veen Grab Samples	6 replicates	Sta. 5-1 Only	
$0.04m^2$ Van Veen Grab Samples	6 Replicates	6 Replicates	6 Replicates
CHN Subsamples	6 Replicates	6 Replicates	6 Replicates
Grain-Size Subsamples	6 Replicates	6 Replicates	6 Replicates
Epifaunal Samples	3 Stations Only	3 Stations Only	
Hydrographic Measurements	D.O. - 3 Salinity - 2 XBT - 1	1 Station Only: D.O. - 3 Salinity - 2 XBT - 1	
Bottom Still Photographs	20 Frames	20 Frames	
Geology and Geochemistry Grab Samples*	3 Replicates	3 Replicates	3 Replicates

*Collection coordinated.

Specimens for chemical analysis were removed, labelled, and frozen by the chemistry Contractors. Voucher specimens were preserved in 10% buffered formalin in seawater and transferred to Battelle for labelling and archiving.

Bottom still photographs were taken at each regional and primary site-specific station in order to record surface topography and visible epifauna. A Benthos Model[R] 372 underwater camera and strobe unit were mounted on a steel frame, which was raised and lowered using a hydrowinch. The camera was triggered by a bottom switch coupled with an auto advance. A minimum of 20 color frames were exposed at each station.

Hydrographic measurements, including dissolved oxygen, salinity and water temperature profiles were made at all regional stations. A minimum of three replicates of bottom water were collected by attaching a Nansen water sampling bottle to the winch wire of the grab sampler. When the water sample was received on deck, a portion was drawn off into a Winkler (BOD) bottle, and immediately fixed with manganous sulfate and alkaline iodide solutions. A Winkler titration was performed, using an automated burette, within 3 hours of sample collection.

Surface water samples for salinity measurements were collected using a bucket. Bottom water samples for salinity were obtained from the Nansen bottles. For Cruise M1 an AUTOSAL 8400 at W.H.O.I. was used to determine conductivity. For Cruises M3 and M4, either a Hydrolab Model IIB conductivity probe or American Optical refractometer was used to take one measurement each for surface and bottom salinity.

Temperature profiles were obtained via XBT casts. A deck-mounted launcher was used to deploy the XBT, and a strip chart recorder was used to record the temperature profile with depth.

4.2 Laboratory Processing

4.2.1 Infaunal Grab Samples. The large 0.1 m^2 grab samples collected on Cruises M1 through M4 were transferred to 70% alcohol (denatured ethanol or isopropanol) and archived at Battelle. The muslin bag containing the sample was removed from each 3.5 gallon bucket, and the bag plus sample rinsed several times in fresh water to remove the formalin. Each bag was then returned to the properly labelled bucket, and the bucket filled with 70% alcohol. Each sample was labelled inside the muslin bag, with a tag tied around the neck of the bag, and on the outside of each bucket. Samples collected on Cruise M1 were removed from the large drums and placed in individual buckets in August, 1982. Several labels had faded to the point where they could not be read.

All small (0.04 m^2) grab samples which were to be analyzed were individually logged into the Battelle laboratory when they were received, either at the start of the contract, or upon completion of each cruise. Each sample was logged on a "Sample Tracking Sheet" which can be used to determine the location of any particular sample or portion of sample at any time. These sheets were initialed by each technician who handled the sample. Each sample was resieved before sorting. All regional station samples were rescreened through a nest of 0.5 mm and 0.3 mm screens. The heavy residue from each sample was elutriated with fresh water in order to remove low density organisms which may not have been removed during shipboard handling. The two resultant fractions of each sample (0.5 and 0.3 mm) were kept separate during sorting, identification and biomass procedures. Samples from site-specific stations, with the exception of Station 5-1 which was treated as a regional station, were resieved only onto a 0.3 mm screen.

Each sample was stained with a solution of Rose Bengal at least four hours prior to sorting. All fractions of each sample were examined under a dissecting microscope and each organism or fragment thereof removed. Organisms were sorted at this point to basic taxonomic groups such as polychaete families, Amphipoda, Isopoda, other crustacea, Mollusca, Echinodermata and "miscellaneous", which includes Porifera, Cnidaria, Bryozoa, Sipunculida, Oligochaeta, and Chordata.

The majority of sample residues sorted were subjected to a quality control check before the vials containing organisms were released for final identifications. In this check, the sample residues were partly or completely reexamined by the laboratory supervisor or by a technician other than the one who originally sorted the sample. At least 10% of the samples sorted by any one technician are completely resieved and resorted. When each sample was finished, the low density or light fraction was stored in alcohol in a zip-loc bag which was then placed inside the 1 gallon jar containing the heavy sediment residue, also in 70% alcohol. All sample residues are archived at Battelle.

Identifications were made to the lowest possible taxon, usually to species. For most major taxonomic groups (i.e. Arthropoda, Mollusca, Echinodermata), a single identifier was responsible for the entire sample. However, the Polychaeta, which represents the single most complex and difficult group of organisms present in the samples, were identified by a series of individuals with experience with a particular group of families. In only a very few cases, for example with juvenile polychaetes, have we been unable to distinguish separate species and have been forced to use a category which might include 2 or more species. In some cases, these problem identifications have been worked out during the course of this program. Voucher specimens of mollusc and arthropod species were submitted for verification to Dr. Robert C. Bullock, University of Rhode Island, and Dr. Les Watling, University of Maine, respectively. Taxonomic problems were also discussed with Dr. John Dearborn, University of Maine (echinoderms) and Dr. Kristian Fauchald, Smithsonian Institution (polychaetes).

For regional station samples, counts of individuals were recorded separately for the 0.5 and 0.3 mm screen (Fig. 4). Only a total (0.3 mm screen) count was recorded for site-specific stations (with the exception of Station 5-1, which is the same as Regional Station 5). Notations were also made as to visible reproductive condition and presence of juveniles where appropriate, and size class estimates were made for a number of species.

Wet weight biomass was determined separately for each species. Weights were recorded to the nearest 0.001 gram. Hard parts of organisms were not removed prior to weighing. Therefore, the shells of molluscs and calcareou endoskeletons of echinoderms were included in the weights.

4.2.2 Epifaunal Samples. Voucher specimens from dredge and trawl collections were identified to species and stored in separately labelled glass jars or vials. No specimens were received from Cruise M1. Dredge samples from Cruise M2 were received at Battelle in February, 1982, and those collected on Cruises M3 and M4 were received at the completion of each cruise.

4.2.3 Bottom Still Photographs. Film from Cruises Ml and M2 was transferred to Battelle in March, 1982. Film from Cruises M3 and M4 was developed at W.H.O.I. after each cruise was completed. Each frame was projected onto a screen and examined for characteristics of surface topography. Visible epifauna were identified and counted, and biogenic features noted. Assuming that the trigger switch wire was 6 feet long, the area of bottom covered by each frame is slightly greater than 1 square meter.

4.2.4 CHN. Sediment samples frozen for CHN analysis were prepared at Battelle and analyzed at W.H.O.I. No samples were taken on Cruise Ml. Samples from Cruise M2 were transferred to Battelle in March, 1982. Samples from Cruises M3 and M4 were recieved at Battelle immediately after the completion of each cruise. Each sample was prepared by thawing, drying to a constant weight, and grinding in a mortar and pestle.

TAXONOMIST______________

GEORGES BANK MONITORING PROGRAM

PAGE____OF____

CRUISE ☐☐ DATE MO. DA. YR. ☐☐☐☐☐☐ STATION NO. ☐☐☐ REPLICATE ☐☐ GEAR TYPE ☐☐

Species Name	Species Code	Count 500μ	Count 300μ	Total Count	Biomass 500μ	Biomass 300μ	Total Biomass	LHS	Comments	

FIGURE 4. DATA SHEET.

Drying was accomplished by placing each sample in an aluminum tare dish in a 60°C oven for 12 hours. The dried sediment is then ground in order to provide a fine, homogeneous sample. An aliquot is placed in a properly labelled, clean, dry 1 dram vial. Samples are analyzed on a Perkin-Elmer CHN Elemental Analyzer Model 240. An on-line computer provides immediate coversion of the digital display into percentages of carbon, hydrogen and nitrogen present in the sample.

4.2.5 Sediment Grain Size. Analysis of sediment grain size of subsamples removed from the 0.04 m^2 grabs was performed by W.H.O.I. All samples were frozen upon collection and thawed just prior to analysis. The procedures followed are identical to those used by the U.S.G.S. for their analyses of Georges Bank sediment samples. A coarse sieving technique is used to separate gravel, sand, and silt-clay fractions, and the percentage each of silt and clay is determined using pipette analysis. The Rapid Sediment Analyzer is used for further analysis of the sand fractions.

4.3 Data Reduction and Analysis

Completed data sheets for data from Cruises M1 through M4 were coded at Battelle and entered into the VAX 11/780 computer at Woods Hole Oceanographic Institution by W.H.O.I. personnel. Verification of hard copy printout and correction of any errors was conducted jointly by Battelle and W.H.O.I.

Statistical treatment of the data set included an agglomerative clustering technique (Williams, 1971) to determine similarity between samples. The first step in this classification is to measure similarity between all pairwise combinations of samples, starting with the most similar pairs, and subsequently combining samples until they all combine into one large group. The similarity measure is NESS, the Normalized Expected Species Shared (Grassle and Smith, 1976), where the comparison of expected species shared is between random samples of 50 individuals from the initial collection of individuals in each grab. Since two samples of 50 drawn within each of the samples are required for normalization, samples with less than 100 individuals are excluded from the analysis. The method has also been used with m set at 200 individuals. NESS is more sensitive to the less common species than other commonly used methods. The clustering strategy is flexible sorting with β set at the commonly used value of -0.25 (Boesch, 1977;

Williams, 1971). This allows more intense clustering than the other commonly used methods, such as the group average or unweighted pair-group method. Boesch (1977) points out that intense clustering strategies are often prone to misclassifications and "one often has to choose between non-classifications due to weakly clustering strategies or misclassifications due to intensely clustering strategies". This is not the case with the data presented below. We have also used the Bray-Curtis or percent similarity coefficient (Boesch, 1977) as a similarity measure with group average sorting. The few individuals where the species identification is uncertain (juveniles, fragments, etc.) are not used in the analysis. The animals attached to hard surfaces such as rocks and shells, and the parasitic species are also excluded from the analyses.

Shannon-Wiener diversity (H') was calculated:

$$H'_{(s)} = -\sum_{j} p_j \log p_j$$

in which 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 without replacement, given a population N:

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

in which N_i is the finite population of species i; N is $(N_i, N_2, \ldots, N_k)$, a vector representing the entire finite population; and N is the total number of individuals in the finite population,

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

and S_m is the random variable denoting the number of species in a sample of size m (Smith and Grassle, 1977). For the species diversity results presented, we have used m=100 or the number of species per 100 individuals, and m= 1,000 or the number of species per 1000 individuals.

Spearman rank correlation (Siegel, 1956) was used to test the association between biological variables such as density of individual species or community similarity indices and physical variables such as sediment grain size.

5. RESULTS

5.1 Taxonomic Composition and Station Characterisation

5.1.1 Taxonomy

The species found in all infaunal grab samples analyzed from cruises M1 through M4 are listed in Appendix A. Excluding categories labelled "spp." which might represent two or more taxa which cannot be separated because of the lack of development of diagnostic characters, or damage to those characters, a total of 783 taxa have been identified. Seventy-four of the species listed, including the poriferans, hydrozoans, and ectoprocts, are entirely epifaunal; others, such as the five fish species, are also clearly not usual members of the infauna. A few species, such as the bivalve Dacrydium vitreum, and the hyperiid amphipod Parathemisto gaudichaudi are epizootic. Several molluscs are found only on hard substrates such as rocks; these include species of Crepidula and Anomia. Such species are excluded from the statistical analysis of the infaunal samples.

Polychaetes were represented by 306 species, and accounted for 39.1 percent of all taxa identified. Of these, at least 8 represent undescribed genera, and at least 30 represent undescribed species. One of the most bizzare and interesting polychaetes is a new genus and species of Phyllodocidae having an armed proboscis which has been collected from several of the deep-water stations. Of the 46 families recorded, the spionids, paraonids and syllids were the best represented, with 30, 26, and 24 species, respectively. These three families therefore accounted for 26 percent of all polychaete species recorded. The next most abundant families were maldanids (20 species), phyllodocids (18 species), ampharetids (18 species) and cirratulids (15 species). Several species were rare, with only one or two specimens collected in over 800 samples analysed. Many of these rare species, for example Malacoceros indicus, Apoprionospio dayi, Prionospio aff. cirrobranchiata and Nematonereis unicornis are previously known only from as far north as Cape Hatteras, and are found mainly at stations deeper than 100 m on the southern slope of the Bank. Two specimens of Cirrodoce cristata represent only the second and third specimens ever collected of this rare and interesting polychaete.

Arthropods are represented by 159 species, and accounted for 20.3 percent of all taxa identified. Amphipods are clearly the dominant group, with 76 species, or nearly half of all arthropod species recorded. At least two undescribed species are present in the collections, and our records constitute at least four range extensions. Arthropod species previously known only from as far north as Cape Hatteras included larvae of Ocypode quadrata and juveniles of Anoplodactylus petiolatus. The arthropods Epimeria obtusa and Janaria alta are more typical of slope depths.

Molluscs, represented by 132 species, accounted for 16.6 percent of the fauna. At least two range extensions and one new species are included in our records. Tellina agilis is the most common infaunal bivalve, and was the dominant mollusc at several stations.

Additional comments on species of interest can be found in the annotated species list in Appendix B. It is expected that additional taxa will be added to the cumulative species list when samples collected subsequent to Cruise M4 are analyzed. The relocation of Stations 7 and 14 in particular should yield new taxa.

5.1.2 Efficiency of the 0.3 mm Screen

For regional stations sampled on Cruises M1 through M4, the contents of the 0.5 mm mesh screen were identified and enumerated separately from the fraction retained by the 0.3 mm mesh screen. Results indicate that the use of the 0.3 mm mesh resulted in greater efficiency in sampling the populations of several benthic species. In particular, small syllid polychaetes such as Exogone hebes, E. verugera, and Sphaerosyllis sp. A occured in almost equal numbers on both screens. This implies that these species would be drastically undersampled if only the 0.5 mm mesh were used. Additionally, some very small species such as Paradoneis new sp. A were retained almost entirely on the 0.3 mm screen. This was the dominant species at Stations 16 and 17, and probably would not have been collected at all if only the coarser screen had been used.

The recently hatched young (first or second instar) of most of the common arthropod species were retained by the 0.3 mm mesh screen. The percentage of arthropods retained on the 0.3 mm screen varied from 21 percent in November (M2) when recently hatched young were most abundant to 3 percent in February (M3). In the fall and spring (M2 and M4), when recently hatched young were most abundant, the 0.5 mm screen undersampled arthropods by 16 to 21 percent. Long, thin, smooth species such as Tanaissus lilljeborgi and Ericthonius rubricornis were especially susceptible to slipping through the 0.5 mm screen, and were the most severely undersampled. Thirty-seven percent of the T. lilljeborgi and 17 percent of the E. rubricornis were retained on the 0.3 mm screen. Species such as Unciola inermis which has pointed coxal plates, were retained primarily on the 0.5 mm screen: only 4 percent of all U. inermis collected were found on the 0.3 mm screen.

5.1.3 Station Characterization

The dominant species at each regional station, for samples summed over all four cruises, are presented in Table 5. Stations located along the same depth interval were clearly similar to each other in terms of dominant species. The shallow Stations 1, 4, and 10, at approximately 60 m depth, were dominated by an archiannelid, Polygordius sp. A, a bivalve, Tellina agilis, and the arthropods Pseudunciola obliquua and Protohaustorius wigleyi. Bottom photographs at these stations showed large numbers of the sand dollar, Echinarachnius parma, distributed very patchily over a sandy, rippled surface. Juvenile echinoids from these stations, listed as Echinoidea sp. A, were probably E. parma.

Stations 2 and 5, at approximately 80 m depth, were dominated by syllid polychaetes and an oligochaete, Phallodrilus coeloprostratus. The amphipods Unciola inermis and Erichthonius rubricornis were dominant at Station 5, but were replaced by Byblis serrata at Station 2. The primary site-specific stations generally appeared very similar to each other in terms of species composition. Station 5-29, and to a lesser extent, Station 5-25, appeared to differ from the majority by having more species present and fewer individuals of the species which were dominant at the other site-specific stations. Station 15, at the top of the Bank, is slightly shallower than Stations 2 and 5, but was similar to them in species composition, being dominated by syllid polychaetes and P. coeloprostratus.

Station 3, at approximately 100 m depth, was similar to other stations at the same depth interval (i.e. Stations 6 and 12), but also shows some affinities with Station 11 at 80 m. Dominant species at these stations include Ampelisca agassizi, Polygordius sp. A, and Protodorvillea gaspeensis.

Station 13, at the Mud Patch, was characterised by sediments that were finer than those at most of the other regional stations. The community here was dominated by several species of polychaetes, including Cossura longicirrata, Levinsenia gracilis, and Euchone incolor, and an oligochaete, Limnodriloides medioporus. Ampelisca agassizi is the dominant arthropod at this station. Station 13 shared two dominants, L. medioporus and Ninoe nigripes, with Station 11.

The deeper stations, below 100 m on the southern slope of the Bank, include Station 7 in Lydonia Canyon, Station 8 at the shelf/slope break, Station 9 in Oceanographer Canyon, and Stations 16, 17 and 18 at 140 - 145 m. Ampelisca agassizi was dominant at Stations 8, 9, and 18, but only a few individuals occurred at Stations 7, 16 or

TABLE 5. TEN MOST ABUNDANT SPECIES AT REGIONAL STATIONS FOR ALL FOUR SEASONAL SAMPLING PERIODS. Stations are grouped according to major clusters as delimited by NESS.

	Station 1		Station 4		Station 10
1.	Polygordius sp. A	1.	Polygordius sp. A	1.	Polygordius sp. A
2.	Tellina agilis	2.	Tellina agilis	2.	Echinarachnius parma
3.	Pseudunciola obliquua	3.	Protohaustorius wigleyi	3.	Tanaissus lilljeborgi
4.	Tanaissus lilljeborgi	4.	Rhepoxynius hudsoni	4.	Protohaustorius wigleyi
5.	Echinoidea sp. A, juv.	5.	Pseudhaustorius carolinensis	5.	Rhepoxynius hudsoni
6.	Protohaustorius wigleyi	6.	Echinoidea sp. A, juv.	6.	Exogone hebes
7.	Capitella spp.	7.	Echinarachnius parma	7.	Tellina agilis
8.	Bathyporeia quoddyensis	8.	Solemya velum	8.	Echinoidea sp. A, juv.
9.	Rhepoxynius hudsoni	9.	Erichthonius rubricornis	9.	Streptosyllis varians
10.	Schistomeringos caeca	10.	Pontogeneia inermis	10.	Nemertea sp. A
11.	Spisula solidissina				

	Station 2		Station 5		Station 15
1.	Parapionosyllis longicirrata	1.	Exogone verugera	1.	Exogone hebes
2.	Exogone hebes	2.	Sphaerosyllis sp. A	2.	Spisula solidissima
3.	Exogone verugera	3.	Exogone hebes	3.	Polygordius sp. A
4.	Sphaerosyllis sp. A	4.	Unciola inermis	4.	Echinoidea sp. A, juv.
5.	Phallodrilus coeloprostratus	5.	Erichthonius rubricornis	5.	Phallodrilus coeloprostratus
6.	Byblis serrata	6.	Phallodrilus coeloprostratus	6.	Tanaissus lilljeborgi
7.	Echinoidea sp. A, juv.	7.	Parapionosyllis longicirrata	7.	Grania postclitellochaeta
8.	Streptosyllis arenae	8.	Euclymene sp. A	8.	Tharyx sp. A
9.	Syllides benedicti	9.	Arcidea (Acmira) catherinae	9.	Streptosyllis websteri
10.	Polygordius sp. A	10.	Tharyx sp. A	10.	Parapionosyllis longicirrata

TABLE 5. (continued)

	Station 3		Station 11		Station 13
1.	Notomastus latericeus	1.	Polygordius sp. A	1.	Cossura longicirrata
2.	Polygordius sp. A	2.	Aglaophamus circinata	2.	Levensenia gracilis
3.	Filograna implexa	3.	Limnodriloides medioporus	3.	Limnodriloides medioporus
4.	Ampelisca agassizi	4.	Nucula proxima	4.	Euchone incolor
5.	Protodorvillea gaspeensis	5.	Levensenia gracilis	5.	Ampelisca agassizi
6.	Arctica islandica	6.	Protodorvillea gaspeensis	6.	Ninoe nigripes
7.	Unciola inermis	7.	Echinoidea sp. A, juv.	7.	Mediomastus fragilis
8.	Erichthonius rubricornis	8.	Nucula delphinodonta	8.	Aricidea (Acmira) catherinae
9.	Paraonis n. sp. A	9.	Rhepoxynius hudsoni	9.	Aricidea (Allia) suecica
10.	Scalibregma inflatum	10	Ninoe nigripes	10.	Lumbrineris impatiens

	Station 6		Station 9		Station 12
1.	Ampelisca agassizi	1.	Ampelisca agassizi	1.	Ampelisca agassizi
2.	Erichthonius rubricornis	2.	Protodorvillea gaspeensis	2.	Polygordius sp. A
3.	Polygordius sp. A	3.	Aricidea (Acmira) catherinae	3.	Ophelina cylindricaudata
4.	Exogone hebes	4.	Eclysippe sp. A	4.	Protodorvillea gaspeensis
5.	Protodorvillea gaspeensis	5.	Polygordius sp. A	5.	Exogone hebes
6.	Notomastus latericeus	6.	Paraonis n. sp. A	6.	Notomastus latericeus
7.	Aglaophamus circinata	7.	Lumbrineris latreilli	7.	Paraonis n. sp. A
8.	Paraonis n. sp. A	8.	Tharyx marioni	8.	Aricidea (Acmira) catherinae
9.	Filograna implexa	9.	Euchone hancocki	9.	Aricidea (Allia) suecica
10.	Exogone verugera	10.	Limnodriloides medioporus	10.	Exogone naidena

TABLE 5. (continued)

	Station 7		Station 8		Station 18
1.	Lumbrineris latreilli	1.	Ampelisca agassizi	1.	Ampelisca agassizi
2.	Tubificidae sp. A	2.	Lumbrineris latreilli	2.	Tharyx annulosus
3.	Eclysippe sp. A	3.	Aricidea (Acmira) catherinae	3.	Paraonis n. sp. A
4.	Protodorvillea gaspeensis	4.	Tharyx nr. monilaris	4.	Thyasira sp. B
5.	Chone duneri	5.	Aricidea (Acmira) neosuecica	5.	Aricidea (Acmira) catherinae
6.	Polygordius sp. A	6.	Tharyx marioni	6.	Notomastus latericeus
7.	Aricidea (Acmira) neosuecica	7.	Polygordius sp. A	7.	Lumbrineris latreilli
8.	Tharyx marioni	8.	Chone duneri	8.	Aricidea (Acmira) neosuecica
9.	Aricidea (Acmira) catherinae	9.	Paraonis n. sp. A	9.	Prionospio cirrifera
10.	Tharyx acutus	10.	Nierstrassia fragile	10.	Protodorvillea gaspeensis

	Station 16		Station 17
1.	Paradoneis n. sp. A	1.	Paradoneis n. sp. A
2.	Polycirrus sp. A	2.	Notomastus latericeus
3.	Notomastus latericeus	3.	Tharyx nr. monilaris
4.	Phallodrilus coeloprostratus	4.	Phallodrilus coeloprostratus
5.	Tharyx nr. monilaris	5.	Polycirrus sp. A
6.	Tharyx marioni	6.	Polygordius sp. A
7.	Protodorvillea gaspeensis	7.	Tharyx marioni
8.	Enteropneusta sp. E	8.	Tharyx annulosus
9.	Ampelisca agassizi	9.	Aricidea (Allia) n. sp. A
10.	Polygordius sp. A	10.	Protodorvillea gaspeensis

17. Several polychaete species of paraonid and cirratulid polychaetes were common at these stations. Several species typical of the slope fauna catalogued by Hartman (1965) and Hartman and Fauchald (1971) occur at the Block 410 stations, as well as several undescribed genera and species, and species more typical of southern latitudes.

Station 14, in the Gulf of Maine, was dropped after only three samples each from July (M1) and November (M2) had been analysed. These samples were dominated by high numbers of sabellid polychaetes, including a possible undescribed species of Euchone resembling E. elegans and an undescribed species of Chone.

5.1.4 Density

The average number of individuals per 0.04 m^2, plus or minus one standard deviation, is graphed for each regional station except Station 14 and for Site-Specific Station 5-29 for each of the four seasonal sampling periods in Figures 5-7. Densities were highest at Stations 5, 12 and 13, averaging approximately 1020, 870, and 1200 individuals per 0.04 m^2, respectively. Station 2, although similar in species composition to Station 5, had slightly less than half the average densities found at Station 5.

The pattern of change in density with season was clearly different at Station 13 than at most other regional stations. At Station 13, the average density increased from July (M1) (ave. = 1076/0.04 m^2) to February (M3) (ave. = 1686/ 0.04 m^2), and then declined drastically to a low (ave. = 552/0.04 m^2) in May (M4). Other stations showing a decline in M4 included Stations 1, 4, and 10, Stations 6 and 8, and the Block 410 stations 16, 17, and 18. None of these stations, however, showed as dramatic a decline from M3 to M4 as that seen at Station 13.

Other stations, such as Regional Stations 7, 11, and 15, and Site-Specific Station 5-29, showed a decline in densities from November (M2) to February (M3), and an increase or recovery in May (M4). A third pattern, seen at Stations 5-1, 9 and 12, was a decline in average densities from July (M1) to November (M2), followed by a steady rise through February (M3) and May (M4).

Patterns of change in densities at site-specific stations are discussed below (see section 5.2.2.2).

5.1.5 Diversity

Species diversity at regional stations, averaged over all four sampling periods, is mapped for the Shannon-Wiener (H') index (Figure 8) and Hurlburt's rarefaction or

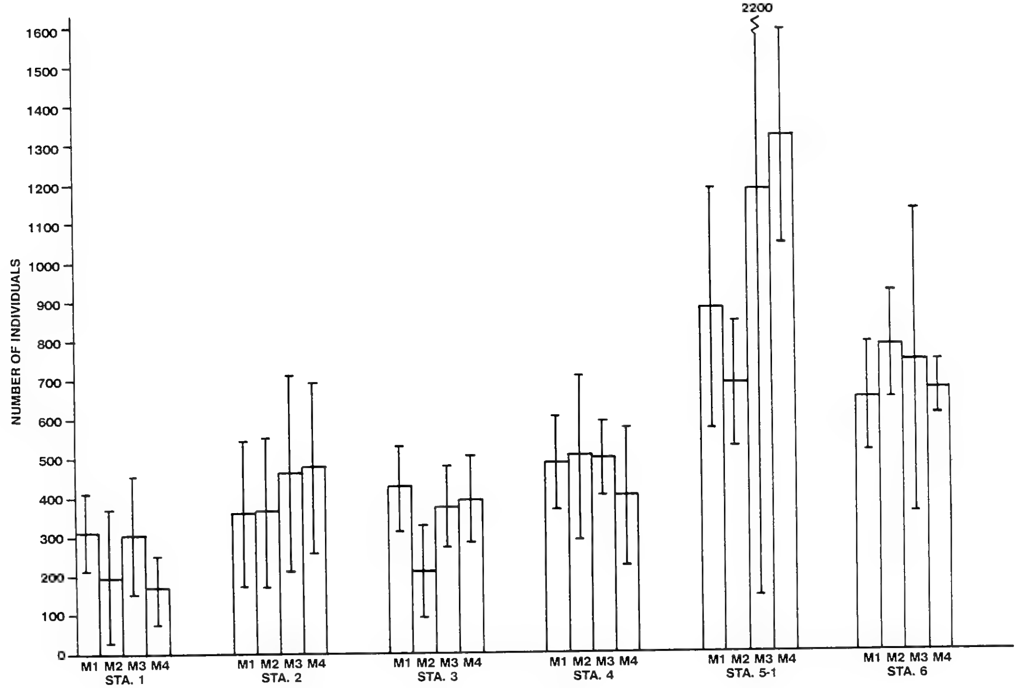


FIGURE 5. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION AT REGIONAL STATIONS 1-6 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND (M-4).

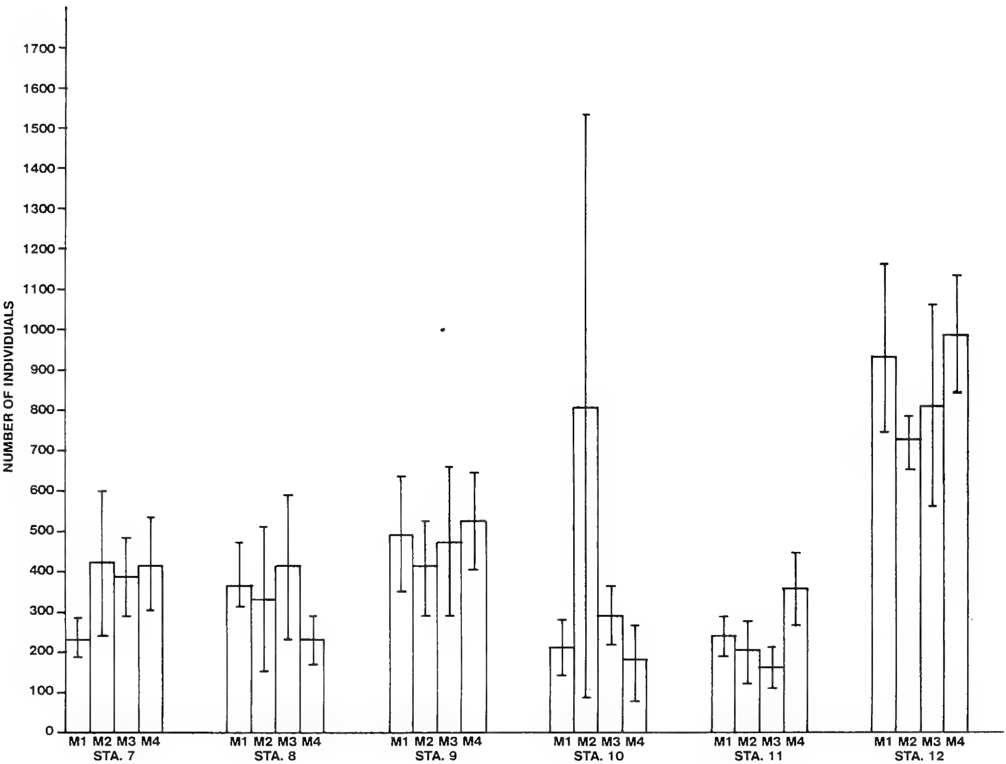


FIGURE 6. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 $\pm$ ONE STANDARD DEVIATION AT REGIONAL STATIONS 7-12 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

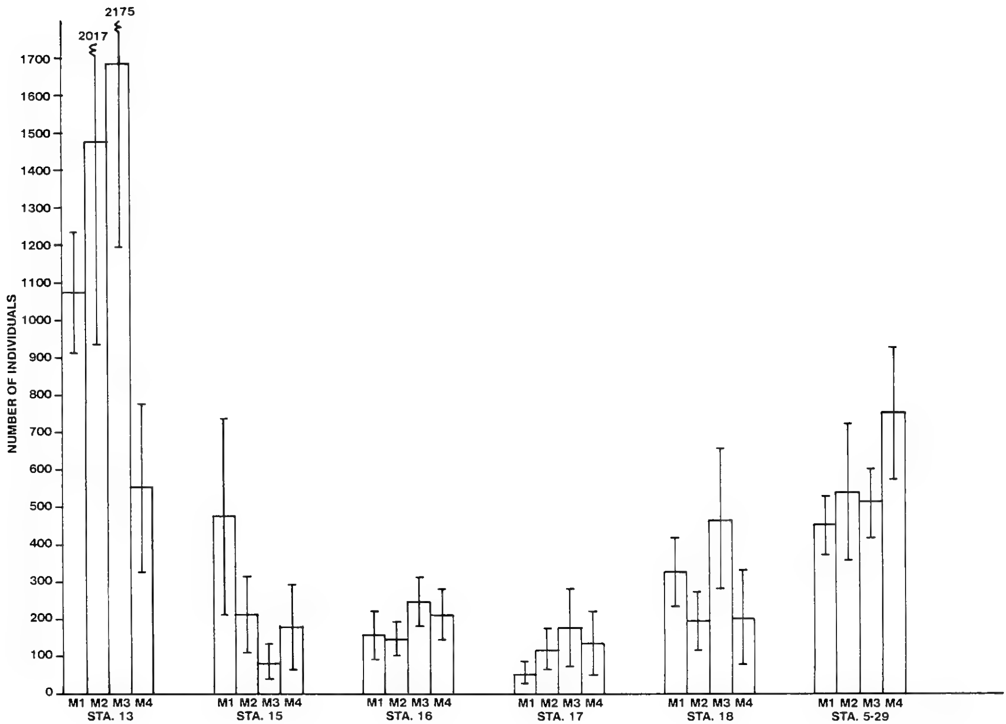


FIGURE 7. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 $M^2 \pm$ ONE STANDARD DEVIATION AT REGIONAL STATIONS 13, 15-18, AND SITE-SPECIFIC STATION 5-29 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

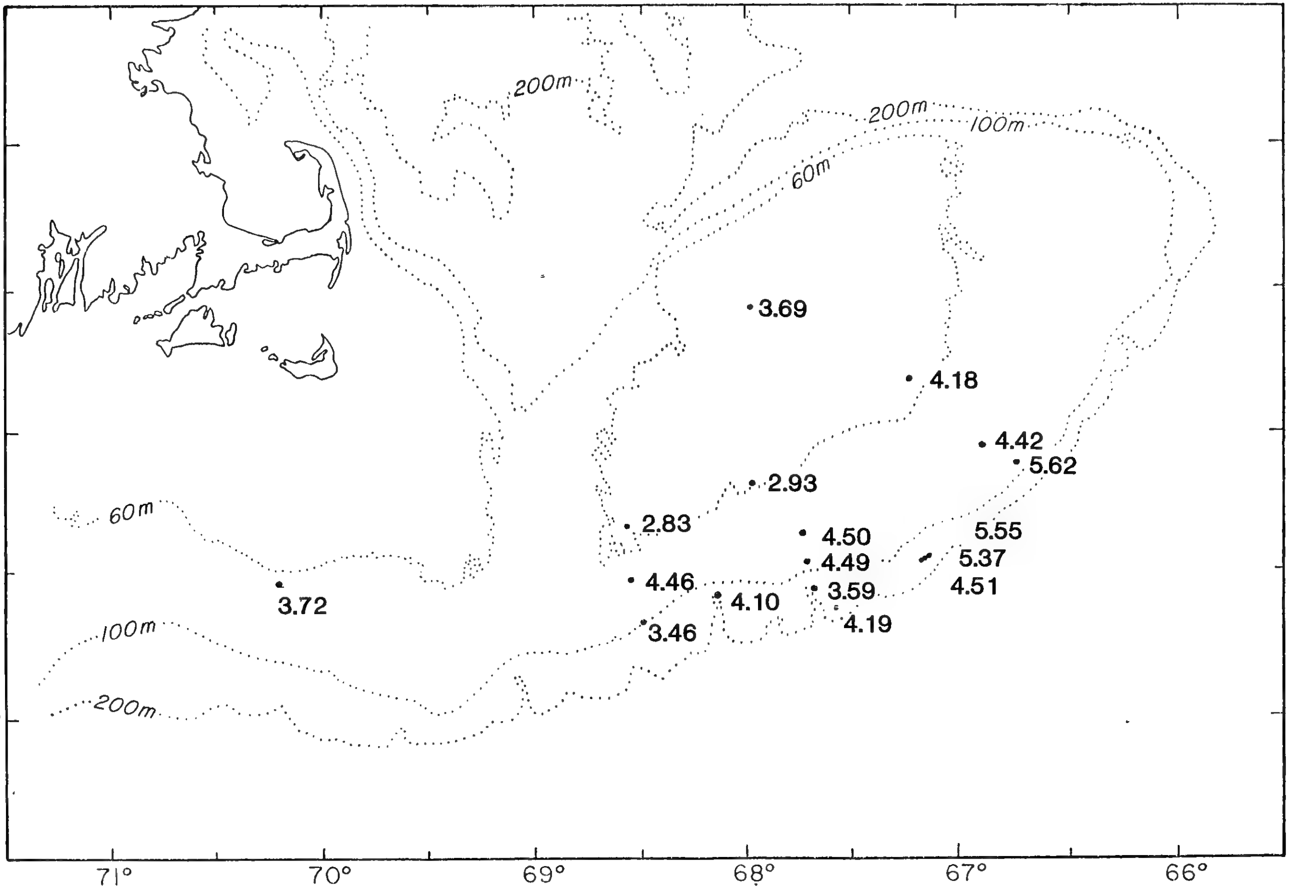


FIGURE 8. SHANNON-WIENER (H') DIVERSITY FOR REGIONAL STATION DATA SUMMED OVER ALL CRUISES.

number of species expected per 100 individuals (Figure 9) and number of species expected per 1000 individuals (Figure 10). The pattern shown in all three indices is the same: shallow Stations 4 and 10 have the lowest diversity, and Stations 3, 16 and 17, all 100 m or deeper, have the highest diversity.

Community parameters including total number of species, total number of individuals, H', evenness, and species per 100 or 1000 individuals at site-specific stations are presented in Appendix C, Tables C-1 and C-2. The average and 95 percent confidence limits of the number of individuals, number of species and number of species per 100 individuals at Regional Station 2 and Site-Specific Stations 5-1, 5-9, 5-25, and 5-29 are given in Appendix C, Table C-3. There does not appear to be any significant change over time in these parameters at these stations.

5.1.6 Biomass

Wet-weight biomass was measured to the nearest 0.001 g for each species collected. Average biomass of polychaetes, amphipods, bivalves, echinoids and all echinoderms except echinoids found at regional stations at all four sampling dates is mapped in Figures 11-15. Molluscs and echiniods clearly dominate the biomass, because non-living material (the shells of molluscs and the calcareous endoskeletons of echinoderms) were included.

5.2 Cluster Analysis and Population Patterns of Selected Species

5.2.1 Regional Stations

5.2.1.1 Cluster Analysis by Replicate. The most remarkable feature of the cluster analysis of the regional stations is that all of the replicate samples of one station cluster with each other before joining with those of another station (Figures 16-25). This occurs at each of the four sampling dates. The only exception is that a single February sample from Station 8 (located next to Block 410) clusters with the Block 410 stations instead of with the other five Station 8 replicates (Figure 20), and replicates from the closely spaced Stations 16 and 17 often cluster together (Figures 18, 20, 22 and 24).

The 60 m contour Stations 1, 4, and 10 cluster as a unit at each season except May (M4) when Station 10 shows affinities with the top-of-the- Bank Station 15. Stations 2 and 5 are always together but have some similarity to Station 15 as may be seen using group average sorting. Stations 11 and 3 are usually distinct from each other and all other

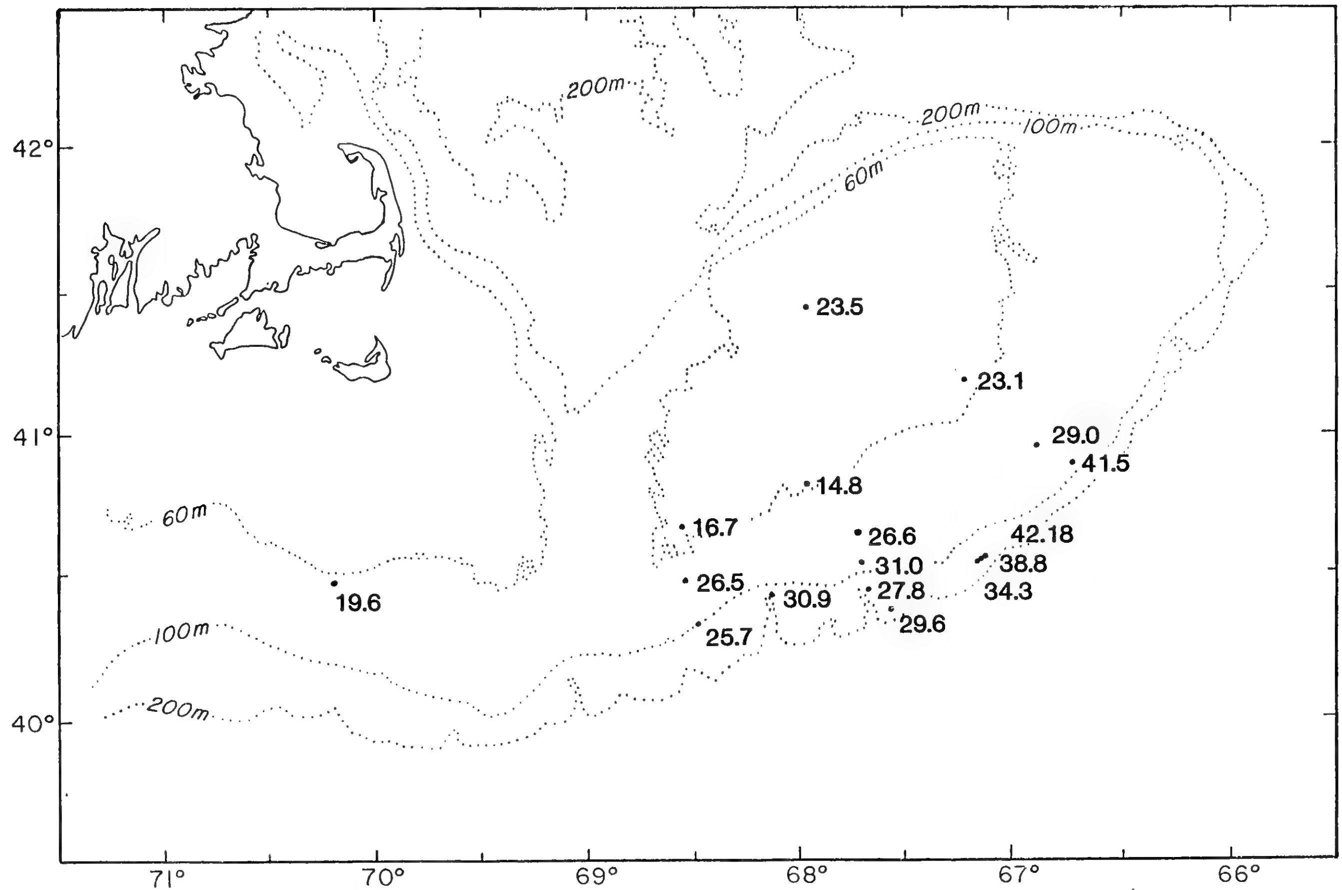


FIGURE 9. NUMBER OF SPECIES PER 100 INDIVIDUALS BASED ON REGIONAL STATION DATA SUMMED OVER ALL CRUISES.

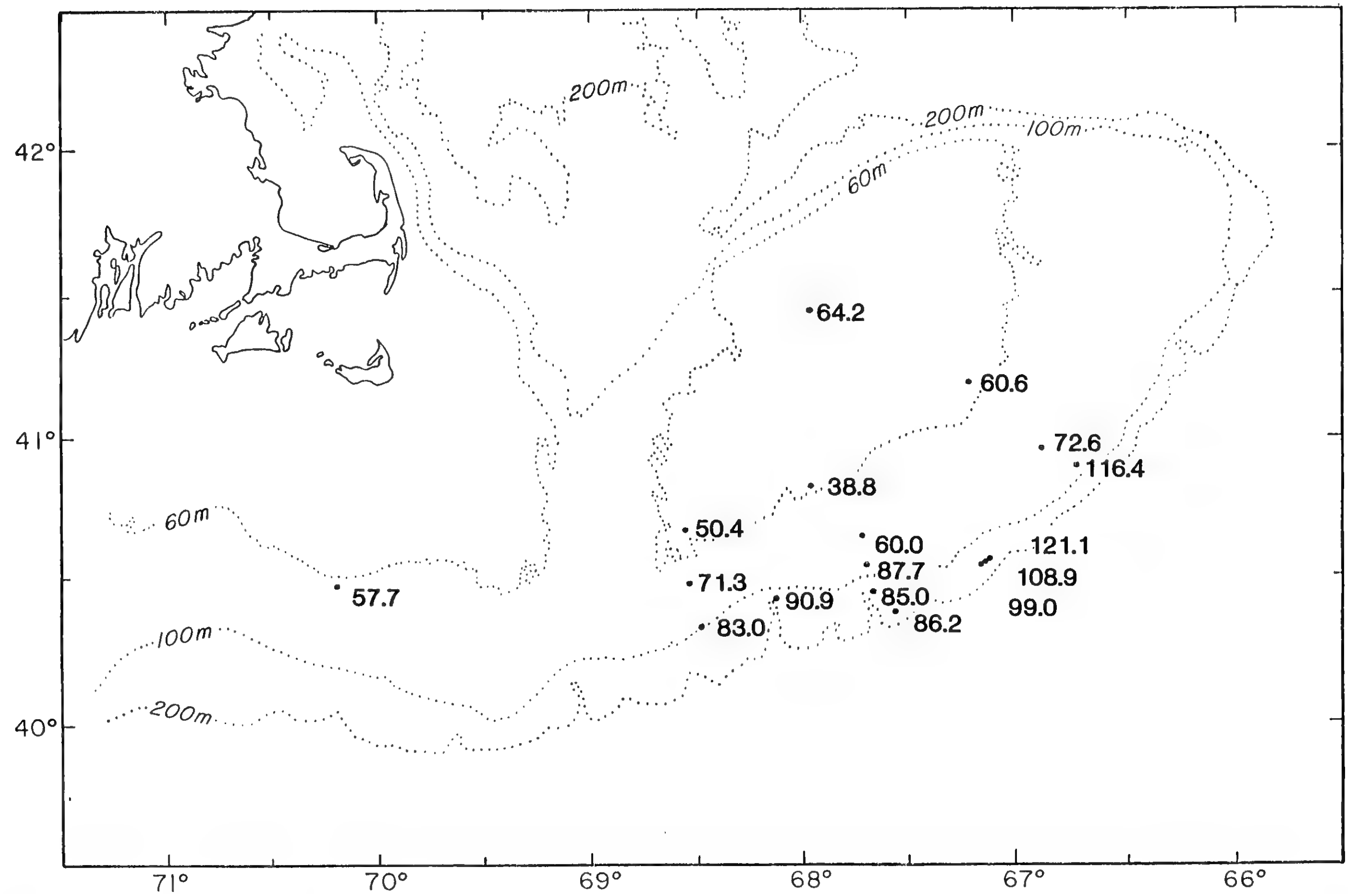


FIGURE 10. NUMBER OF SPECIES PER 1000 INDIVIDUALS BASED ON REGIONAL STATION DATA SUMMED OVER ALL CRUISES.

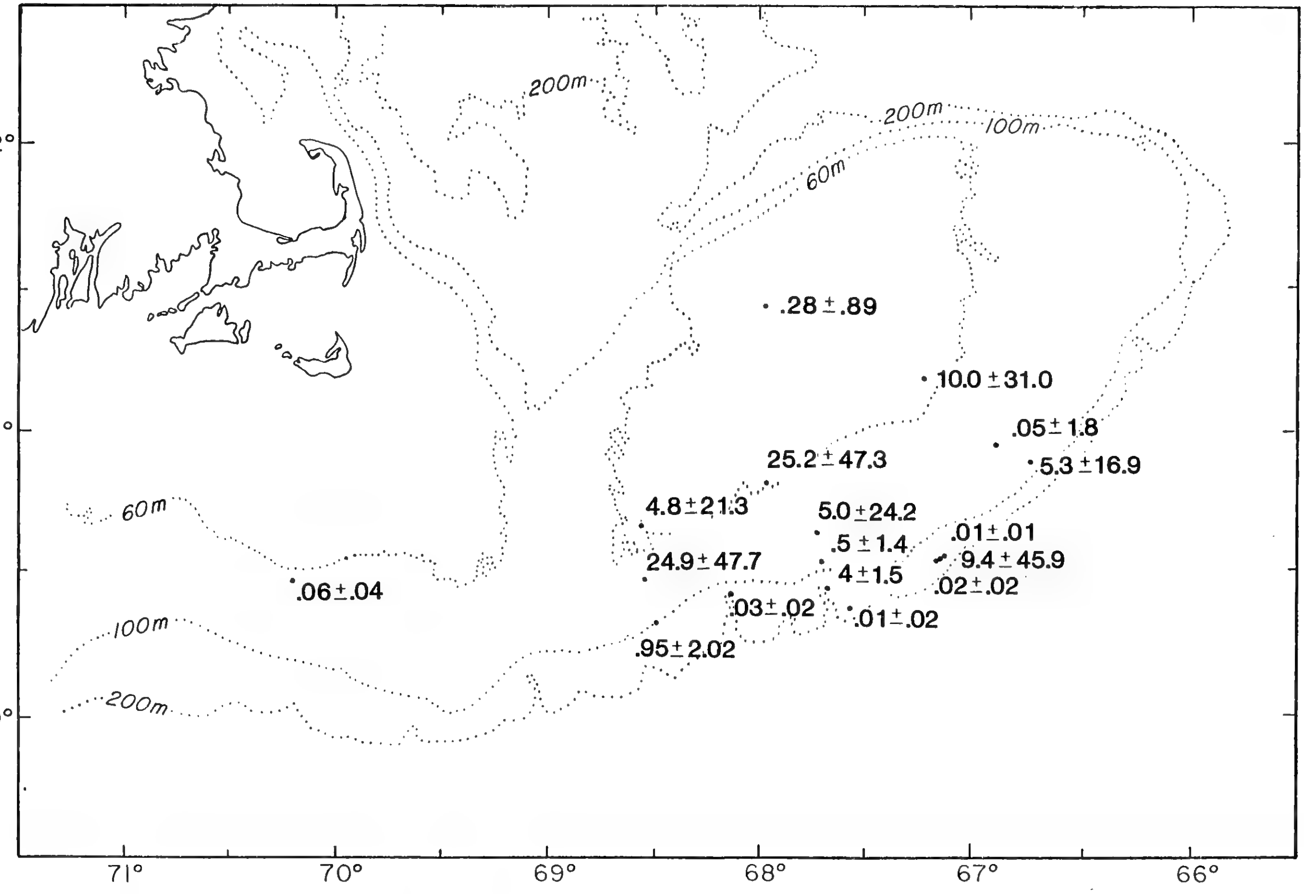


FIGURE 11. AVERAGE BIOMASS IN GRAMS ± ONE STANDARD DEVIATION OF BIVALVES FOUND AT REGIONAL STATIONS FOR CRUISES M-1 THROUGH M-4.

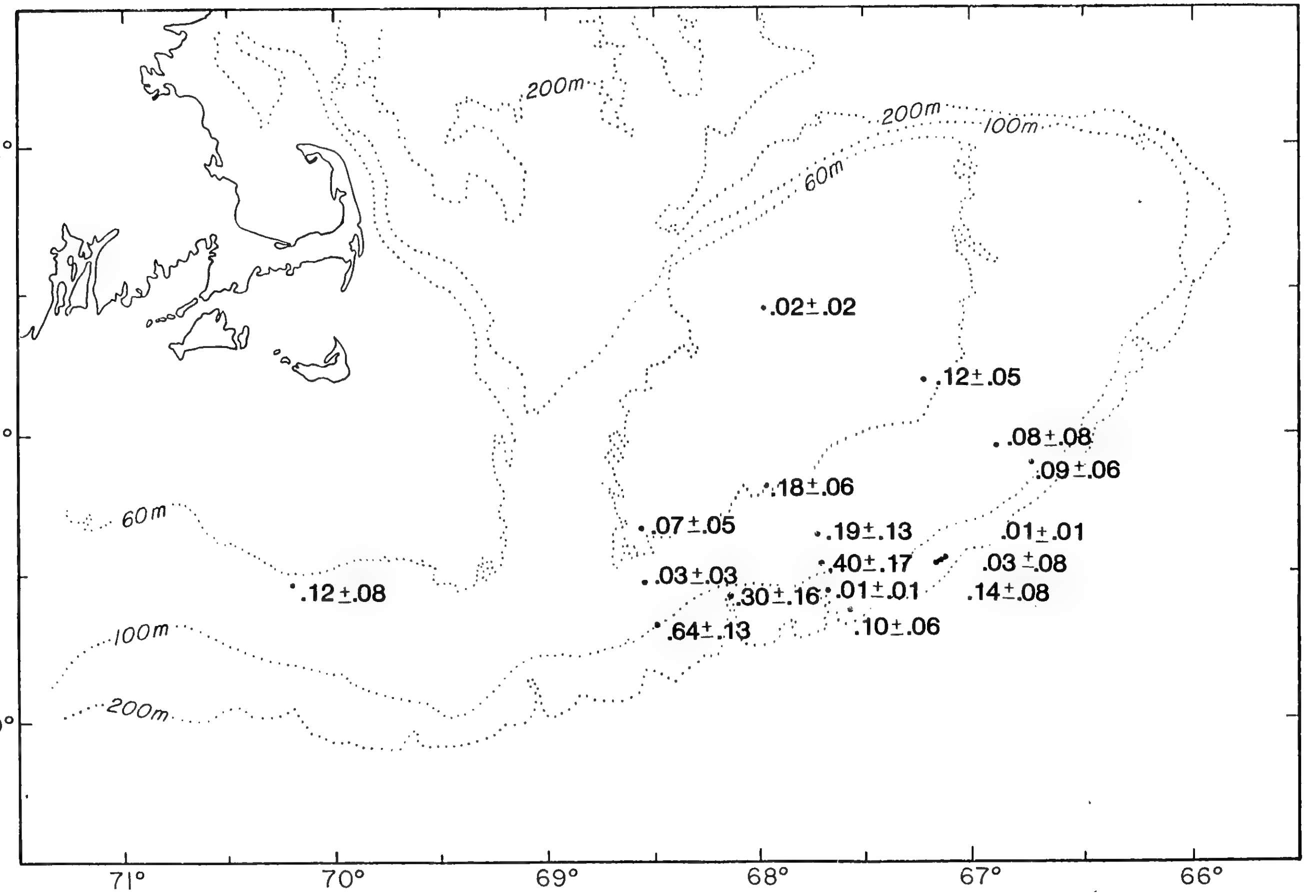


FIGURE 12. AVERAGE BIOMASS IN GRAMS ± ONE STANDARD DEVIATION OF AMPHIPODS FOUND AT REGIONAL STATIONS FOR CRUISES M-1 THROUGH M-4.

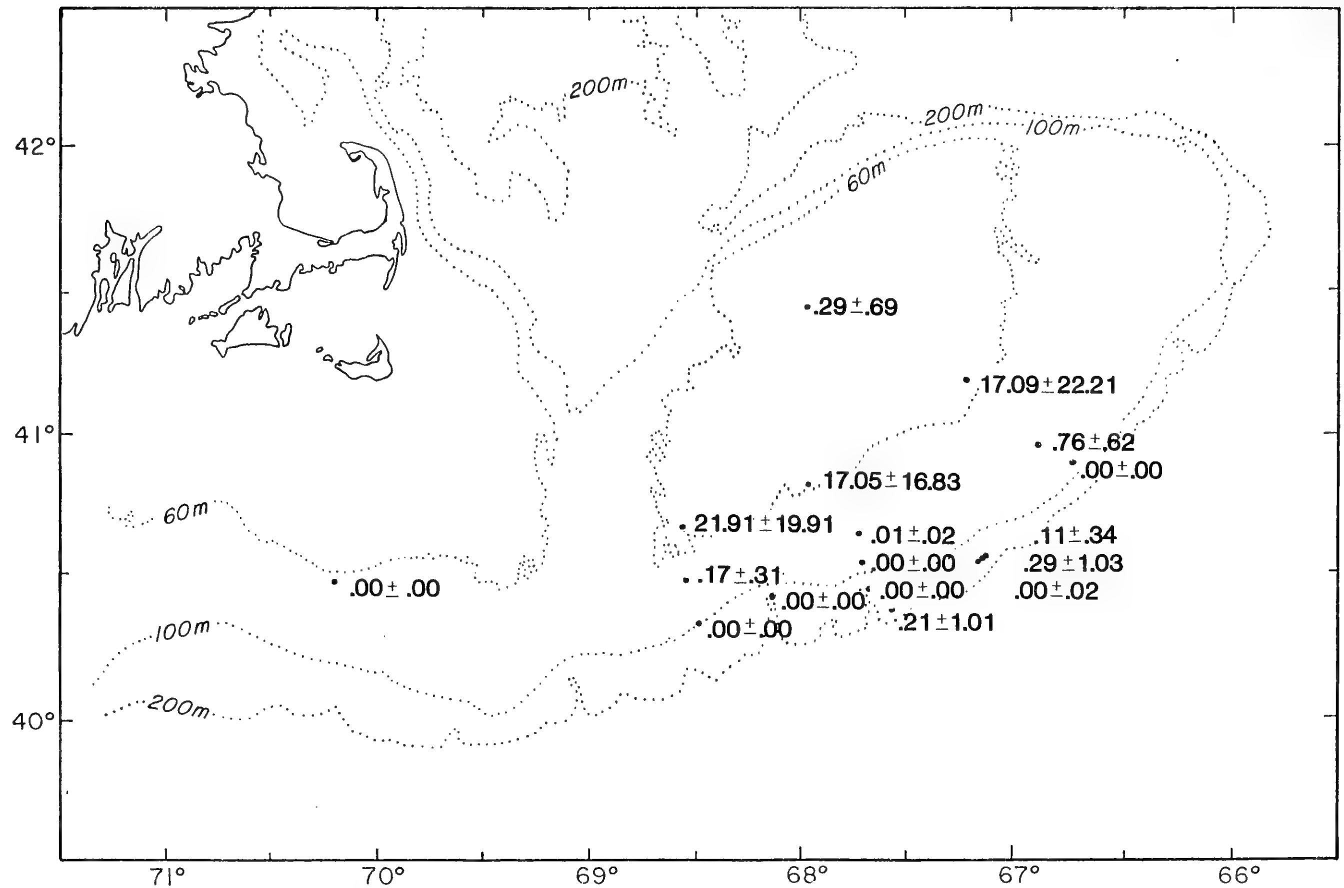


FIGURE 13. AVERAGE BIOMASS IN GRAMS ± ONE STANDARD DEVIATION OF ECHINOIDS FOUND AT REGIONAL STATIONS FOR CRUISES M-1 THROUGH M-4.

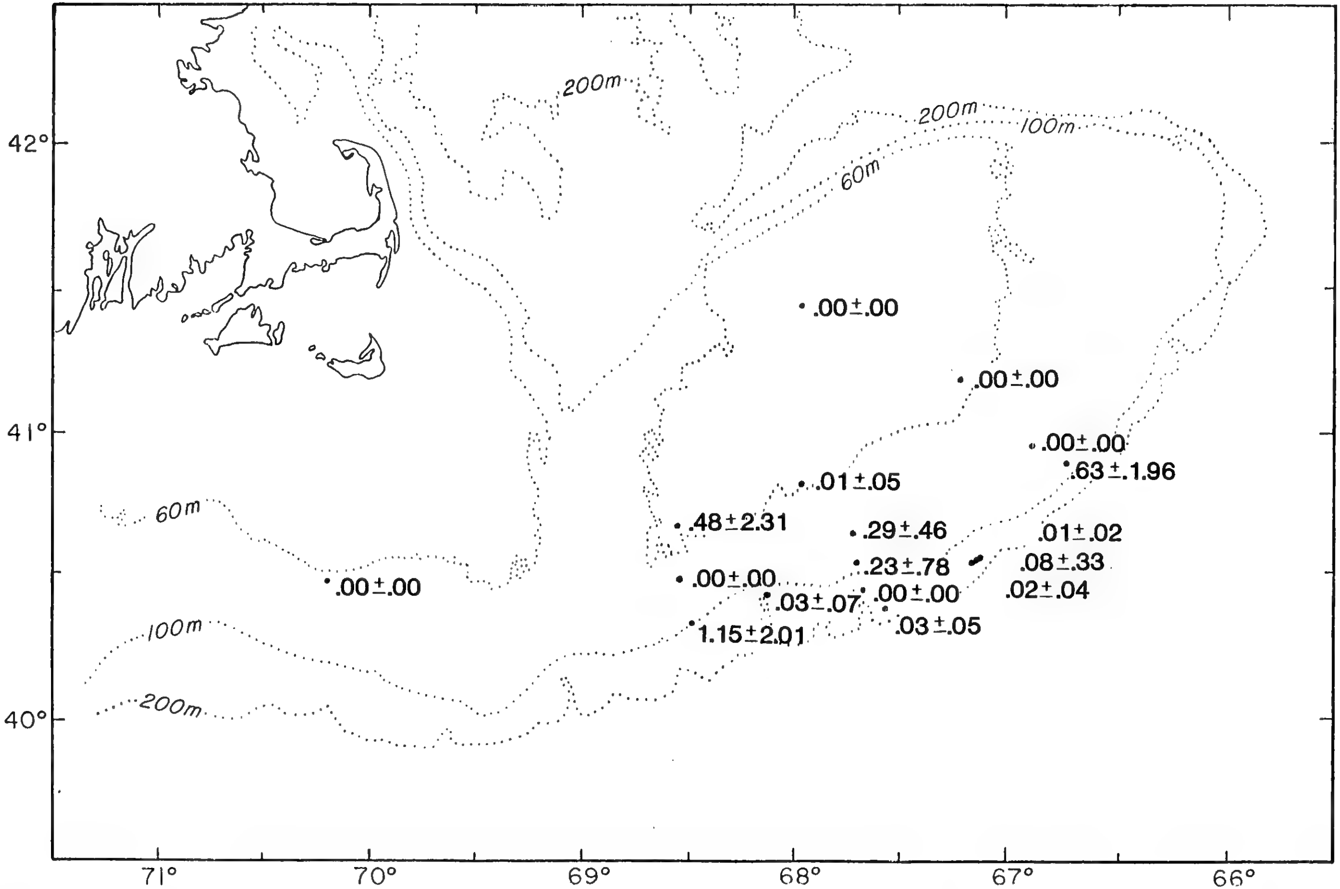


FIGURE 14. AVERAGE BIOMASS IN GRAMS ± ONE STANDARD DEVIATION OF ALL ECHINODERMS EXCEPT ECHINOIDS FOUND AT REGIONAL STATIONS FOR CRUISES M-1 THROUGH M-4.

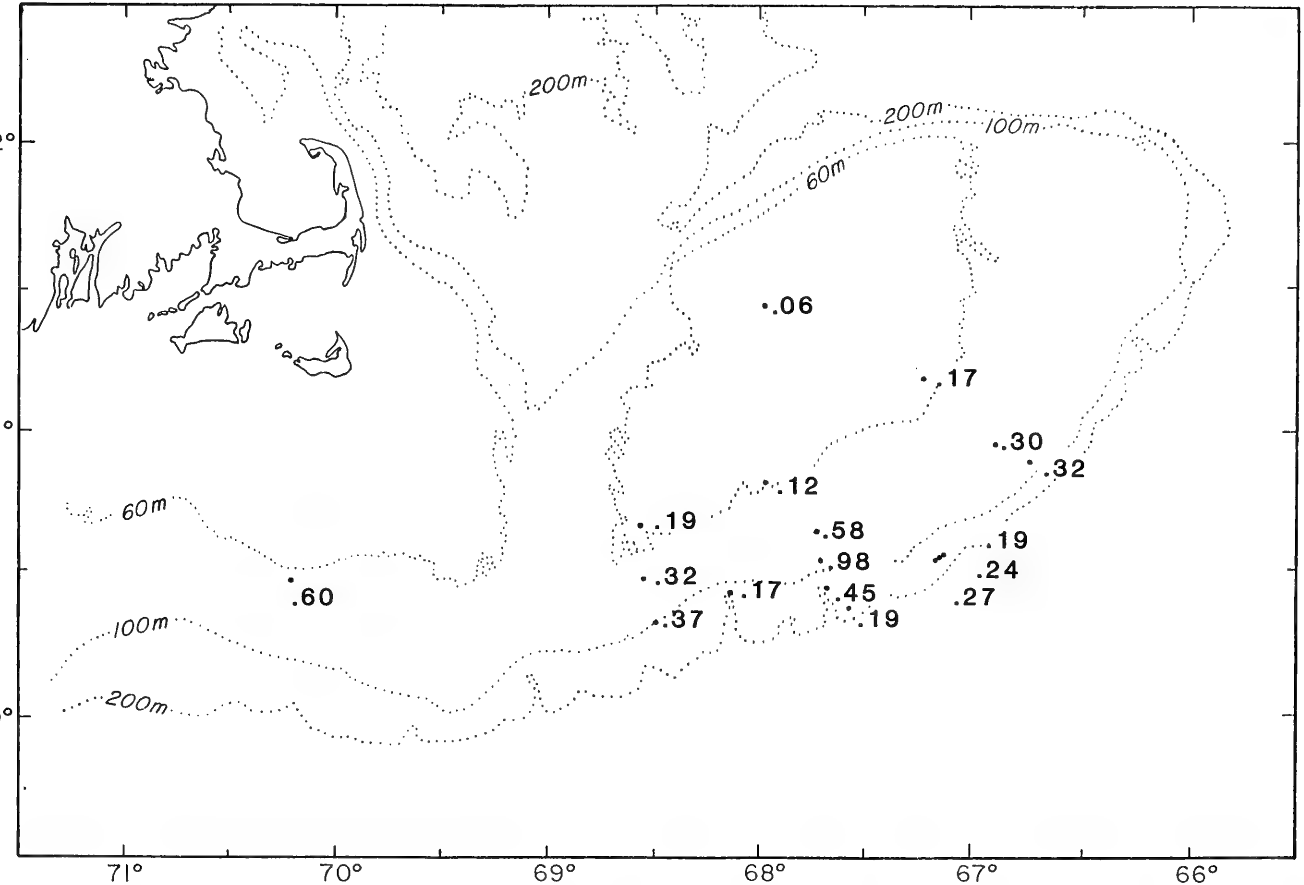


FIGURE 15. AVERAGE BIOMASS IN GRAMS OF ALL POLYCHAETES FOUND AT REGIONAL STATIONS FOR CRUISES M-1 THROUGH M-4.

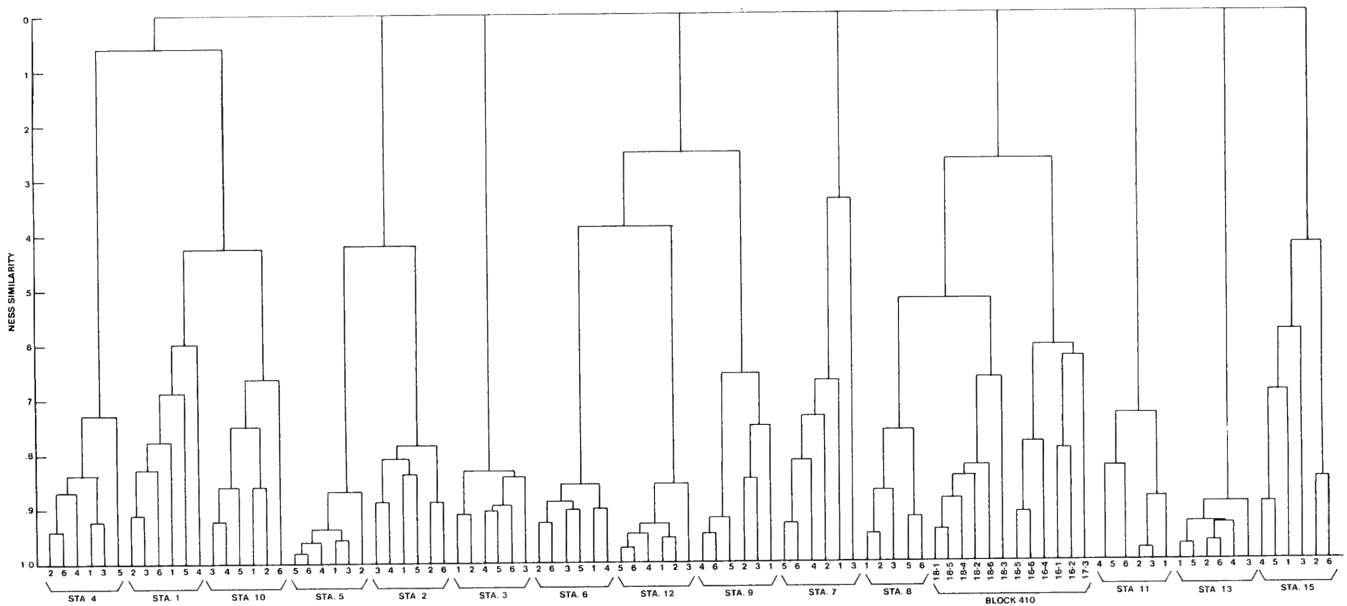


FIGURE 16. REPLICATES OF JULY (M-1) REGIONAL STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

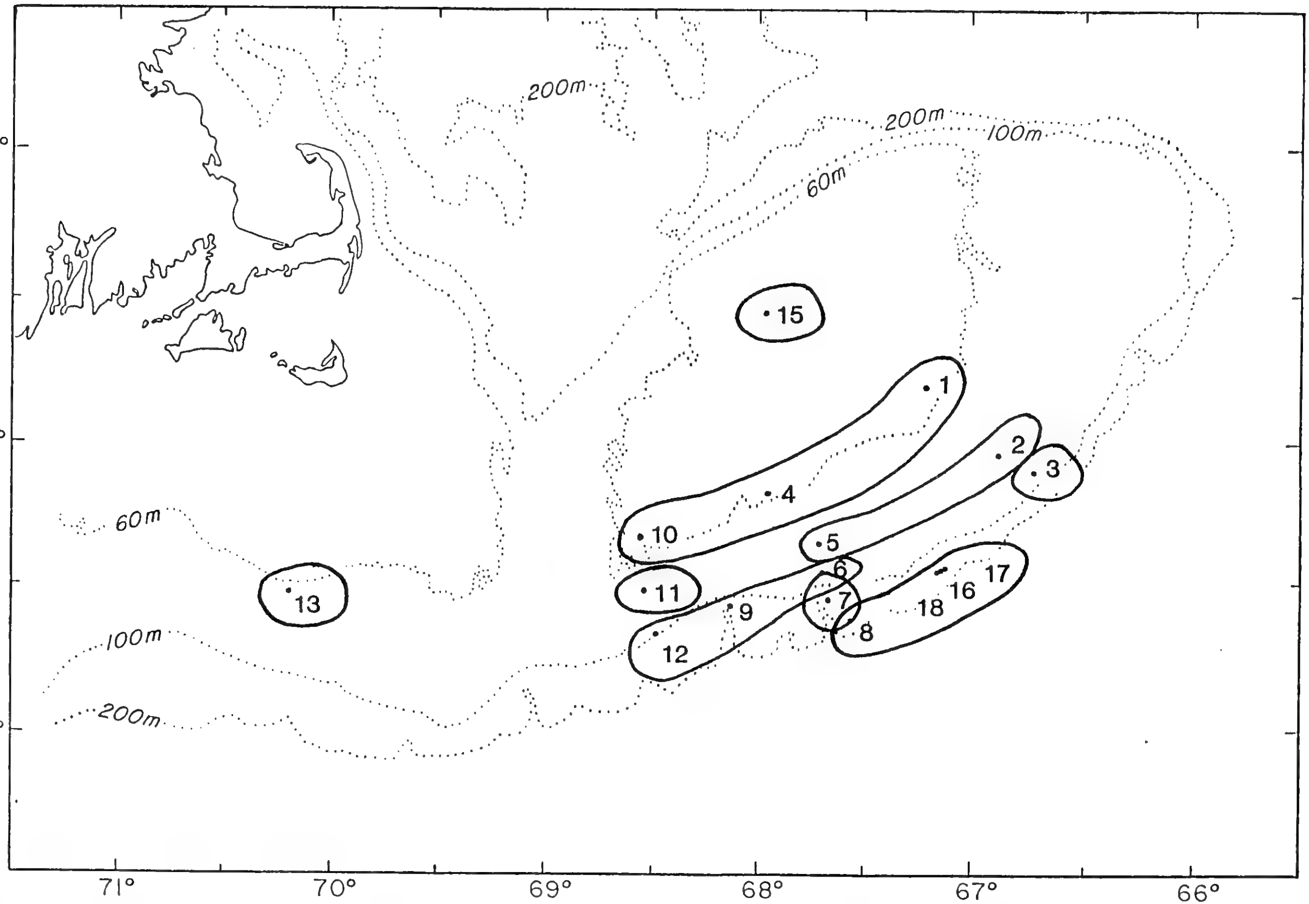


FIGURE 17. MAJOR CLUSTERS OF M-1 REGIONAL STATIONS AS DELIMITED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

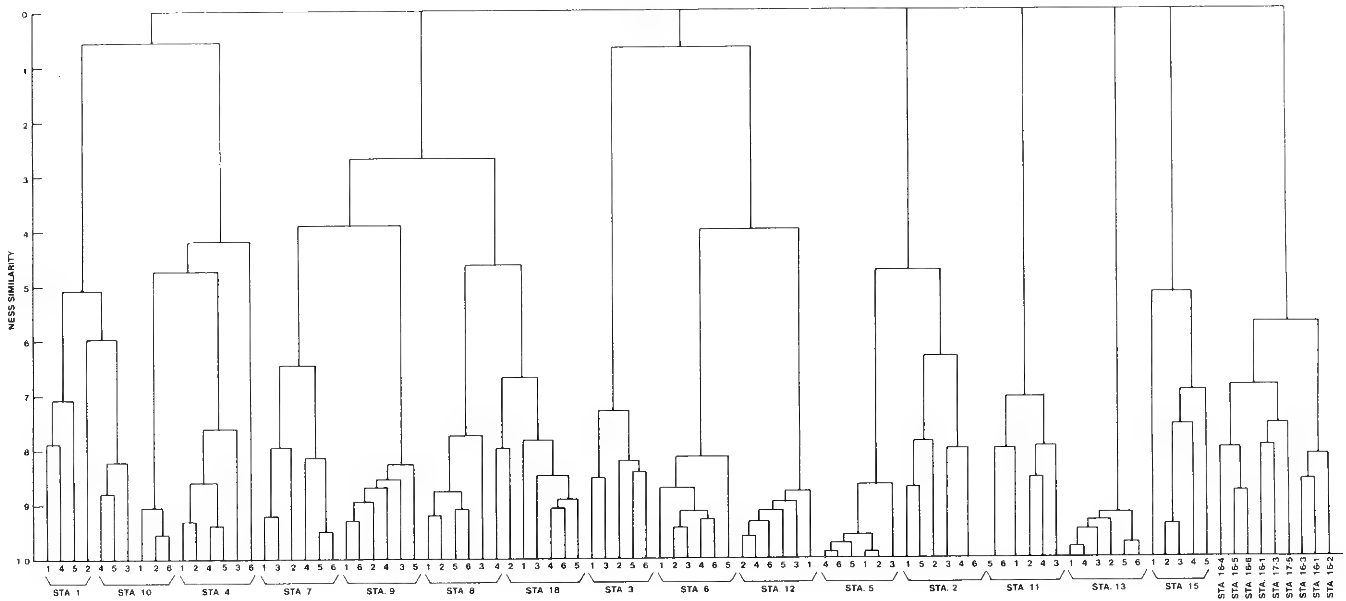


FIGURE 18. REPLICATES OF NOVEMBER (M-2) REGIONAL STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

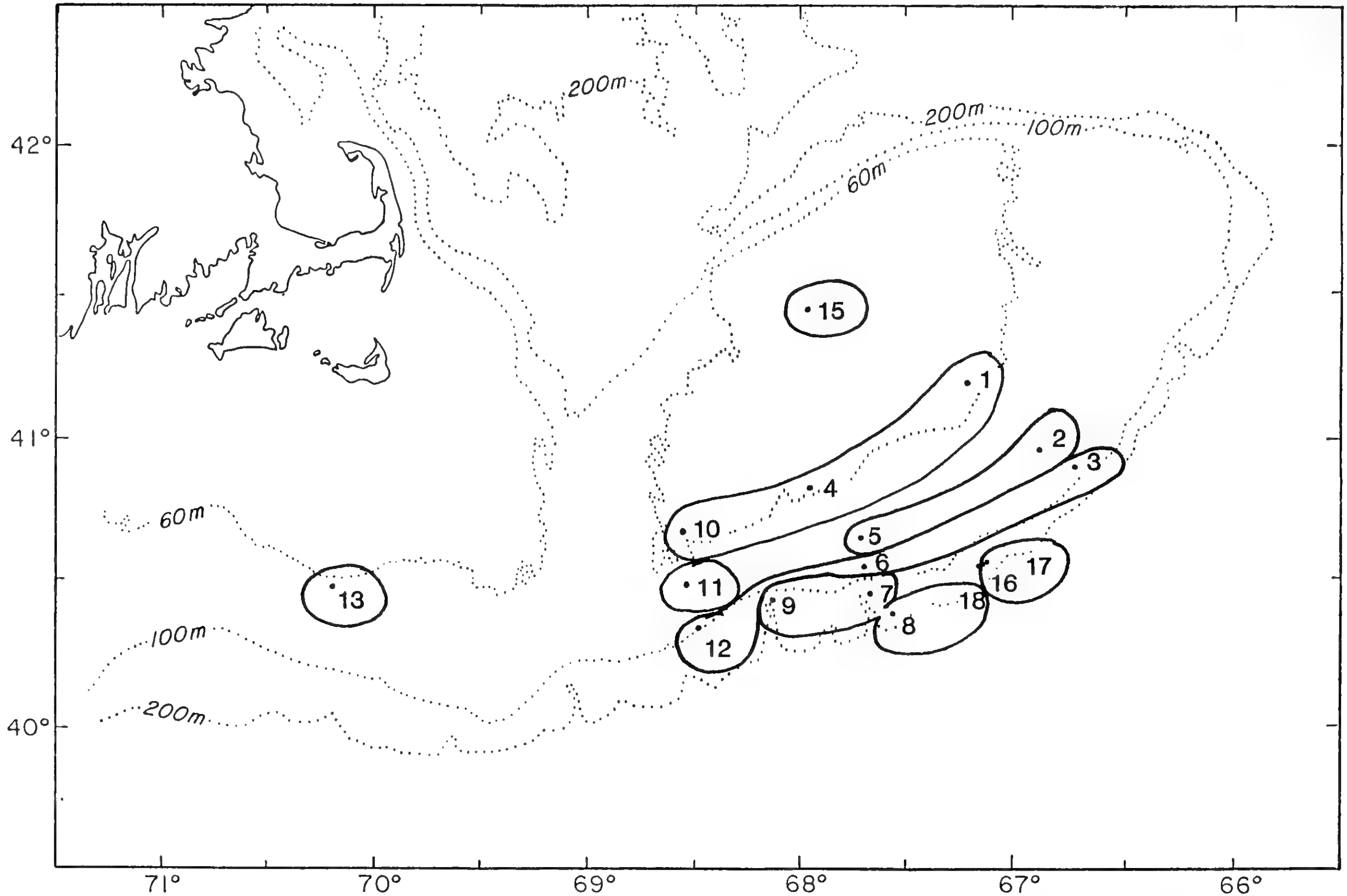


FIGURE 19. MAJOR CLUSTERS OF M-2 REGIONAL STATIONS AS DELIMITED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

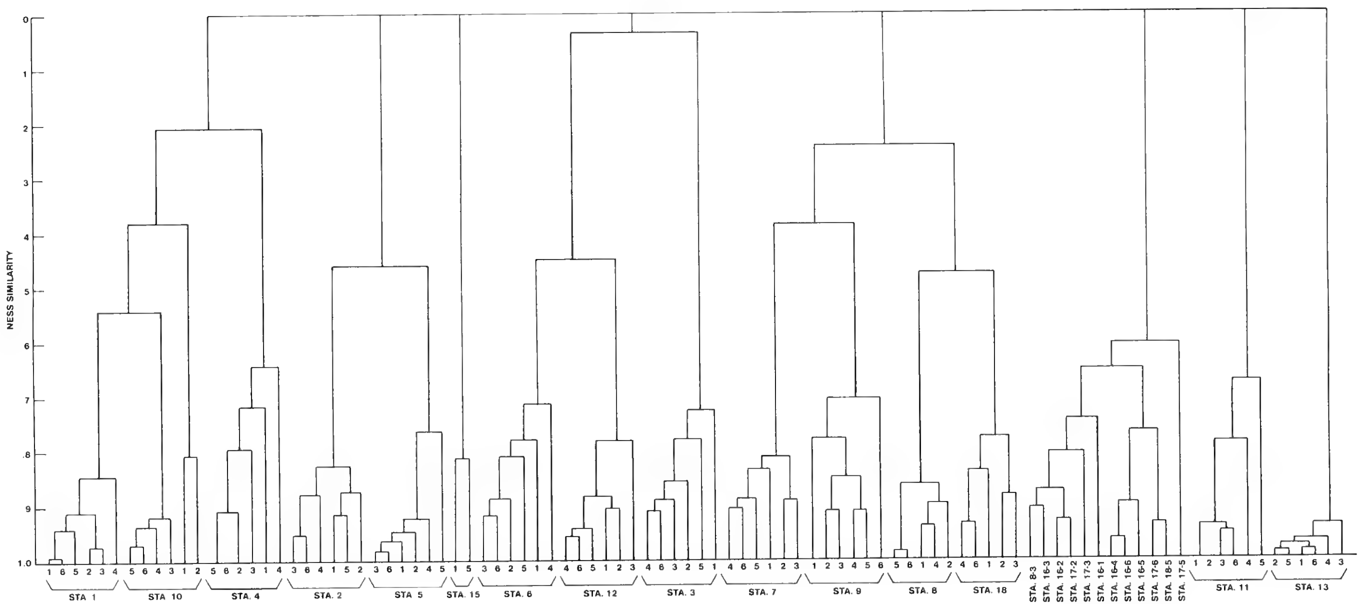


FIGURE 20. REPLICATES OF FEBRUARY (M-3) REGIONAL STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

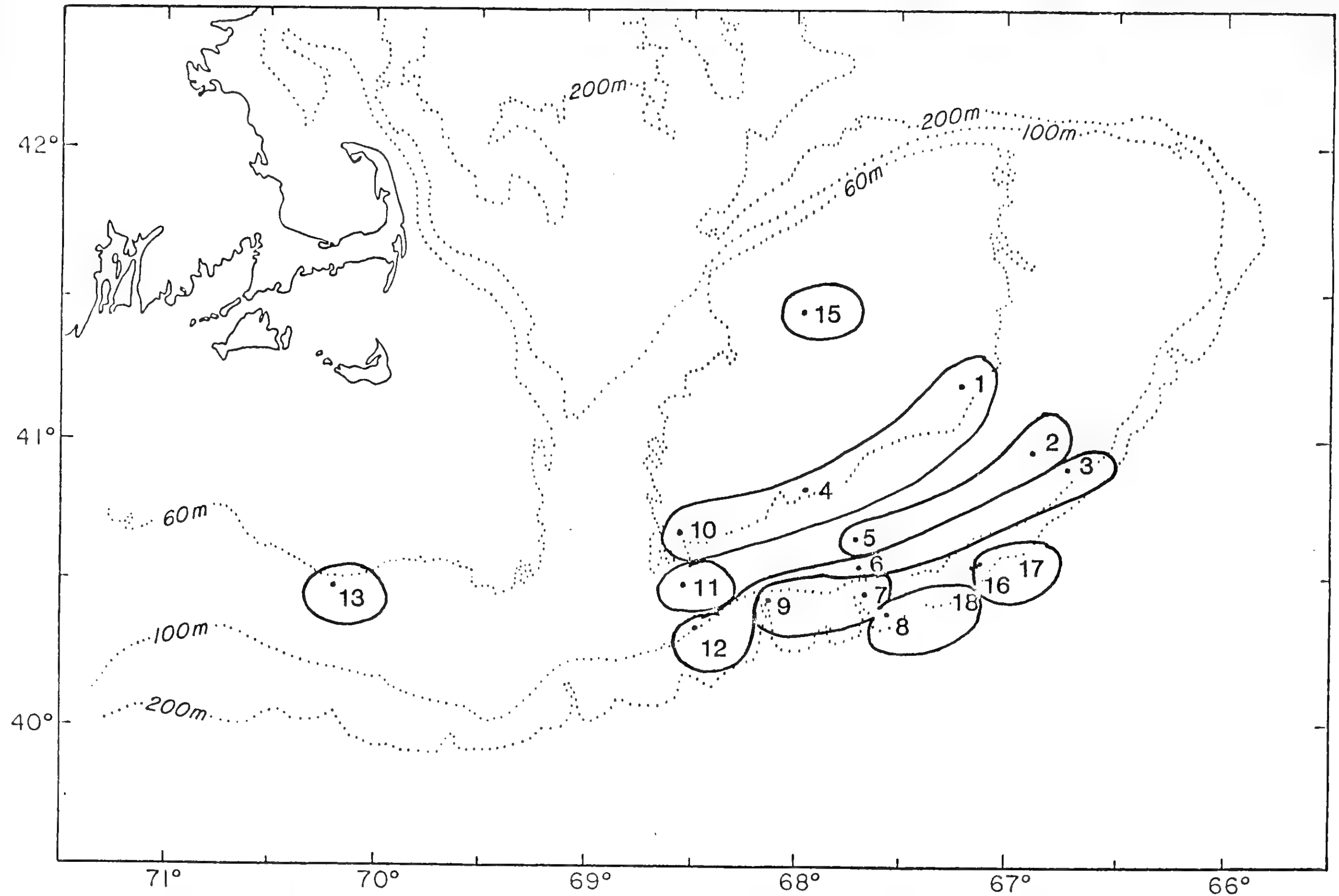


FIGURE 21. MAJOR CLUSTERS OF M-3 REGIONAL STATIONS AS DELIMITED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

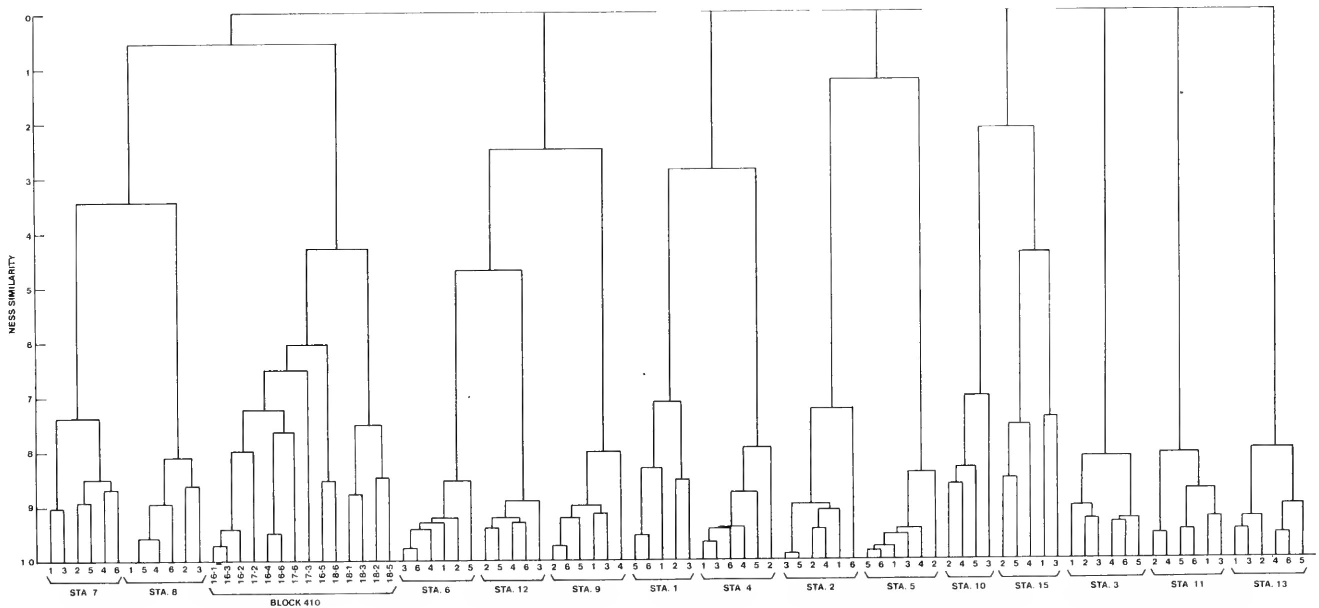


FIGURE 22. REPLICATES OF MAY (M-4) REGIONAL STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

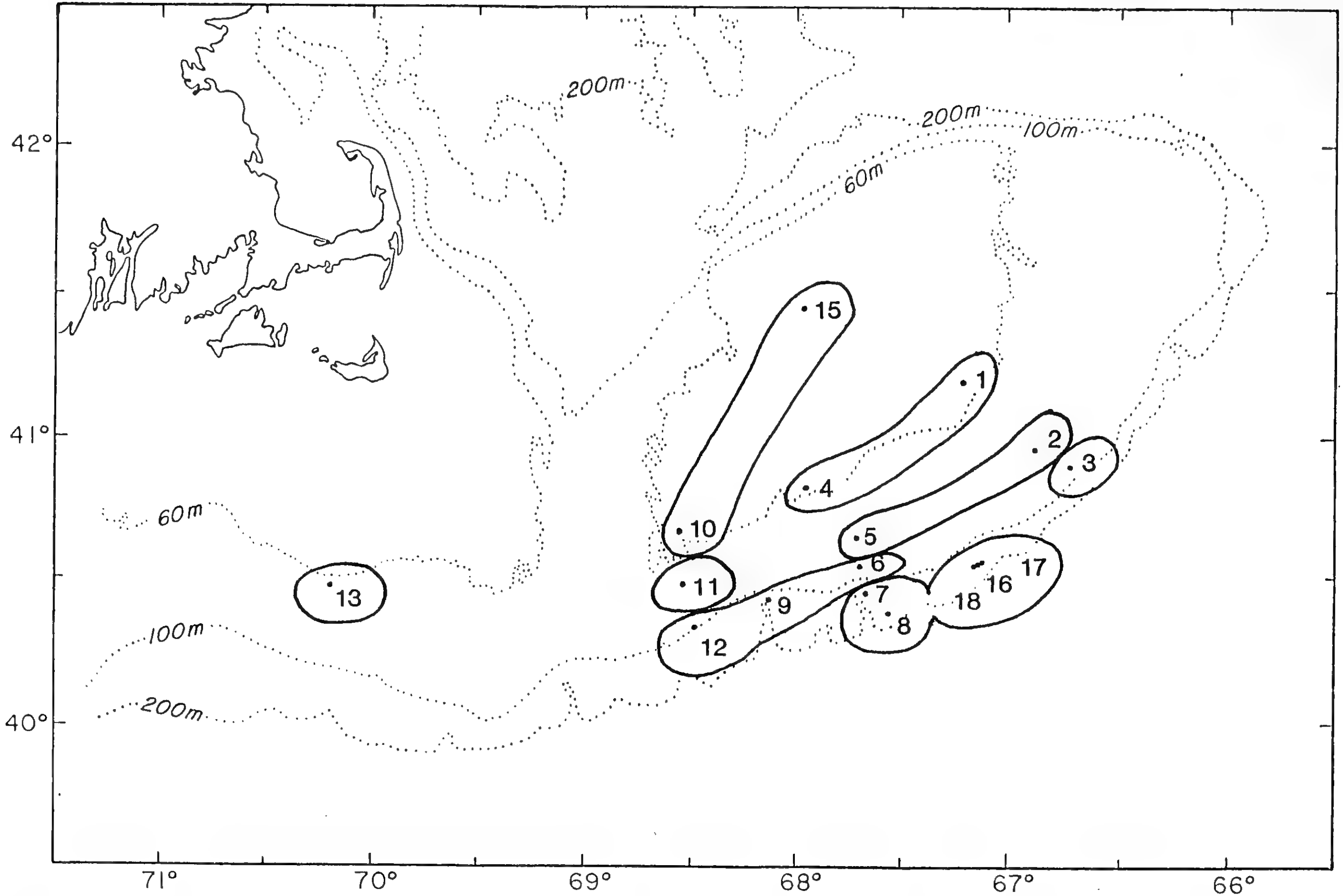


FIGURE 23. MAJOR CLUSTERS OF M-4 REGIONAL STATIONS AS DELIMITED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

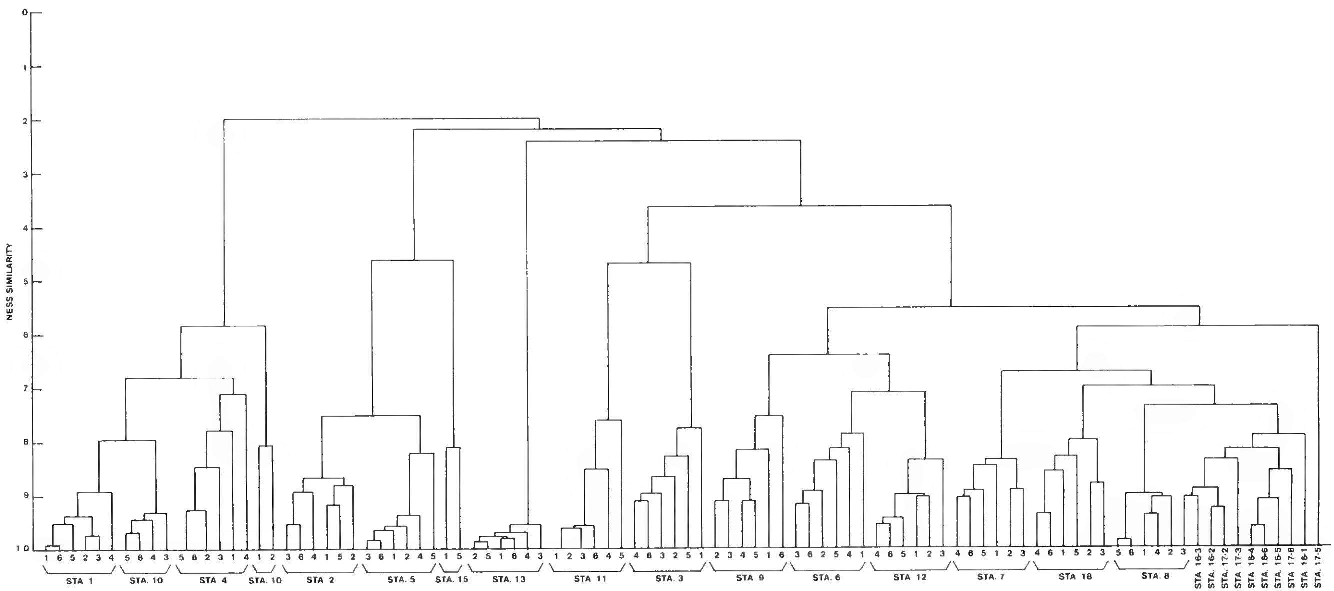


FIGURE 24. REPLICATES OF FEBRUARY (M-3) REGIONAL STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND GROUP AVERAGE SORTING.

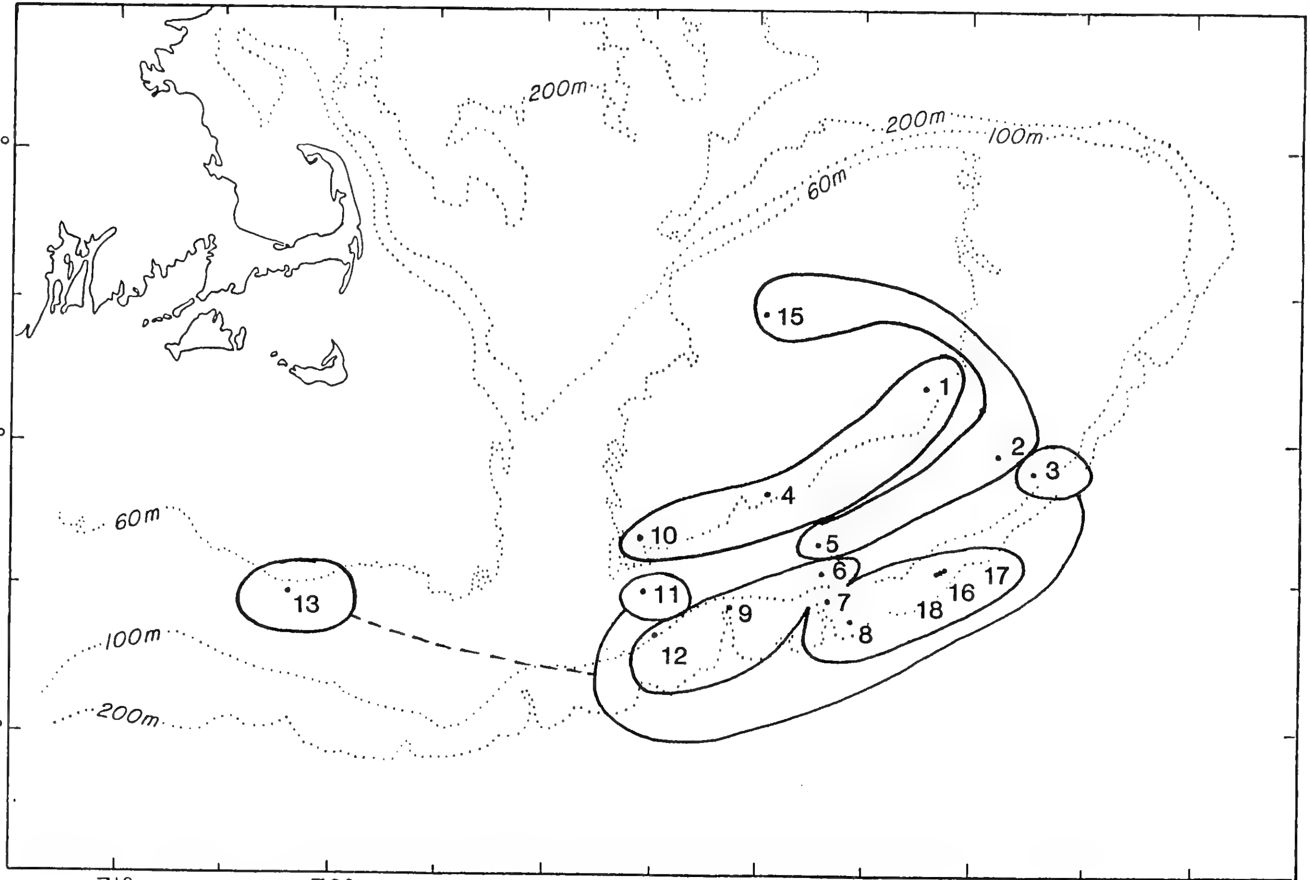


FIGURE 25. MAJOR CLUSTERS OF M-3 REGIONAL STATIONS AS DELIMITED BY NESS AT 50 INDIVIDUALS AND GROUP AVERAGE SORTING.

stations, but are somewhat similar in February (M3) using group average sorting. With flexible sorting at $\beta = -0.25$, the large group fusions place more emphasis on the least similar samples and Station 3 joins the other stations (6 and 12) on the 100 m contour. Stations 6 and 12 group more often with the deepest Stations 7, 8, 9, 16, 17, and 18. Stations 6, 9, and 12 usually form an eastern subgroup. Station 18 differs from Stations 16 and 17 in having Ampelisca agassizi as one of the most abundant species. Station 18 sometimes groups with its neighbors Stations 16 and 17 and sometimes with Stations 7 and 8. Station 13 usually clusters by itself but shares species with Station 11 more often than with other stations.

5.2.1.2 Cluster Analysis by Station (Replicates Summed). By using a summation of the six replicates at each sampling date as the set of samples to be clustered, it is possible to include all of the regional data in a single cluster analysis. Using NESS (Flexible Sorting for m = 50 and m = 200 and Group Average Sorting for m = 50), the samples from each of the four seasons fuse before any separation occurs between stations (Figures 26-31). The only exceptions are the samples from the closely spaced Stations 16 and 17 which are particularly similar. The species composition of the Georges Bank fauna changes very little over the year and differences between sampling dates are always less than differences between stations. Another similarity measure, the commonly used percent similarity index, results in a grouping of the Station 6 summer samples (M1) with Station 12 and a heterogeneous mix of sampling periods from Stations 1 and 10 (Figures 32-33). Percent similarity is much more sensitive to the abundance of a few common species than is NESS.

The groups of stations are not very different from those resulting from the clusters of replicates within each sampling period. Using NESS at m = 200 (Figures 26-27) there are two distinct stations (the Mud Patch Station 13 and top-of-the-bank Station 15) and five groups: the eastern deep (140-150 m depth) Stations 8, 16, 17, and 18, a western deep (100-250 m) grouping of Stations 6, 7, 9, and 12, a low similarity fusion of the 80 m Station 11 with a 100 m Station 3, a 70-80 m grouping of Stations 2 and 5, and a 60 m contour group of Stations 1, 4 and 10. Within these groups the easternmost deep Stations 16 and 17 group separately from Stations 8 and 18 and the 100 m contour Stations 6 and 12 cluster away from the deeper Stations 7 and 9. NESS at 50 individuals gives a similar result except in this diagram the stations around 140-150 m depth (Stations 7, 8, 9, 16, 17, and 18) are all together (Figures 28-29). This leaves Station 11 distinct from the other stations.

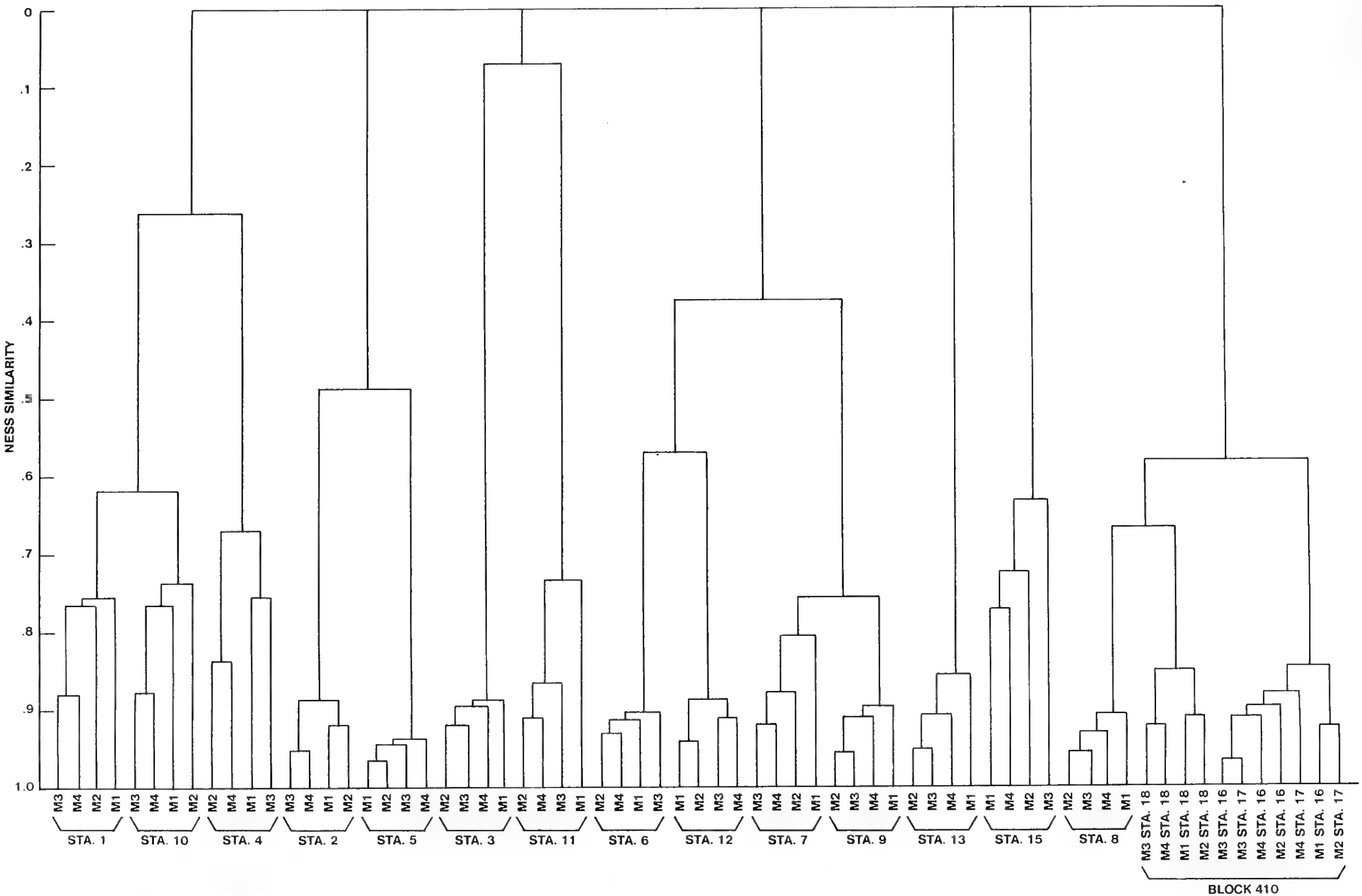


FIGURE 26. SUMMED REPLICATES OF M-1, M-2, M-3 AND M-4 REGIONAL STATIONS CLUSTERED BY NESS AT 200 INDIVIDUALS AND FLEXIBLE SORTING.

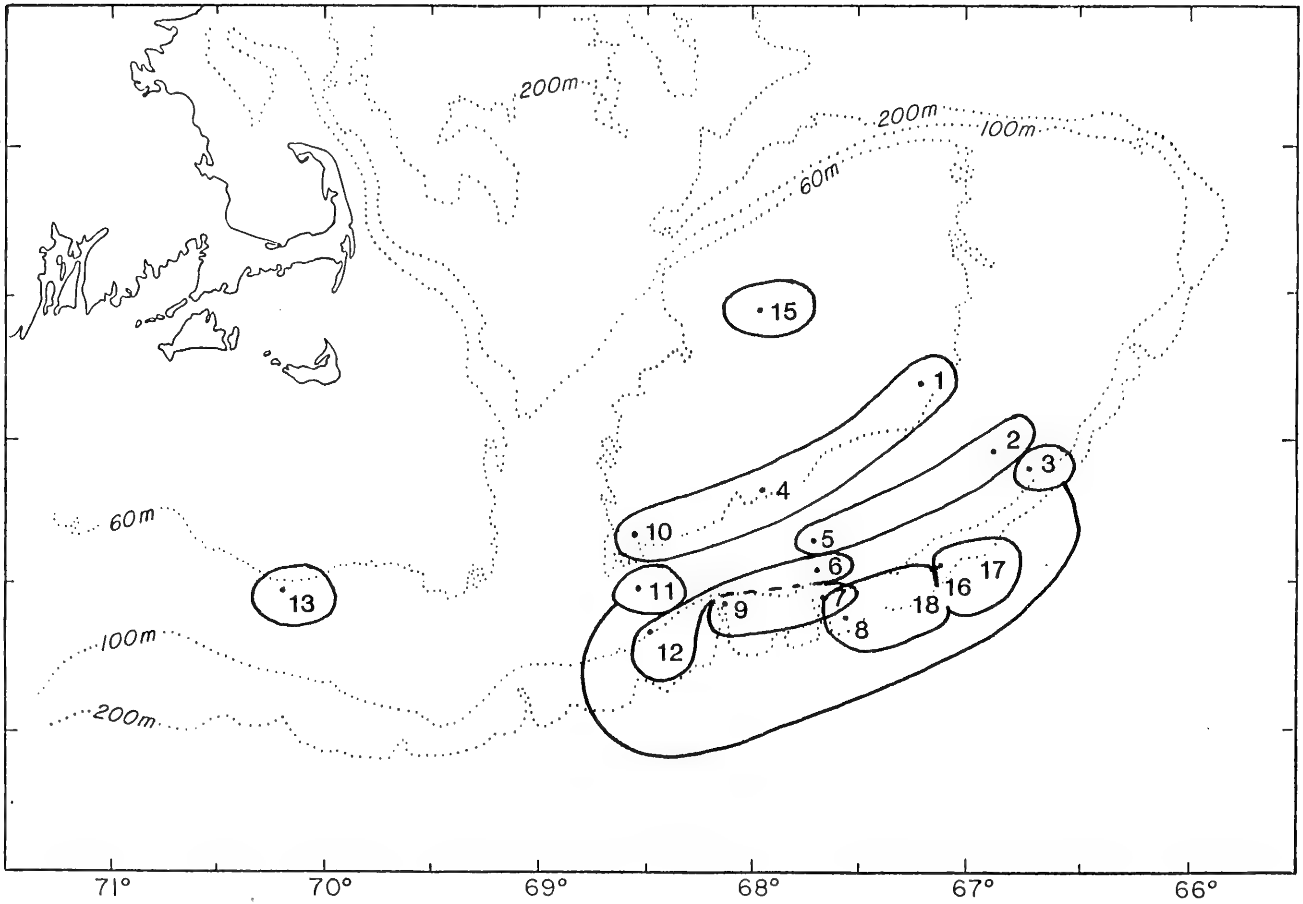


FIGURE 27. MAJOR CLUSTERS OF SUMMED REGIONAL STATIONS AS DELIMITED BY NESS AT 200 INDIVIDUALS AND FLEXIBLE SORTING.

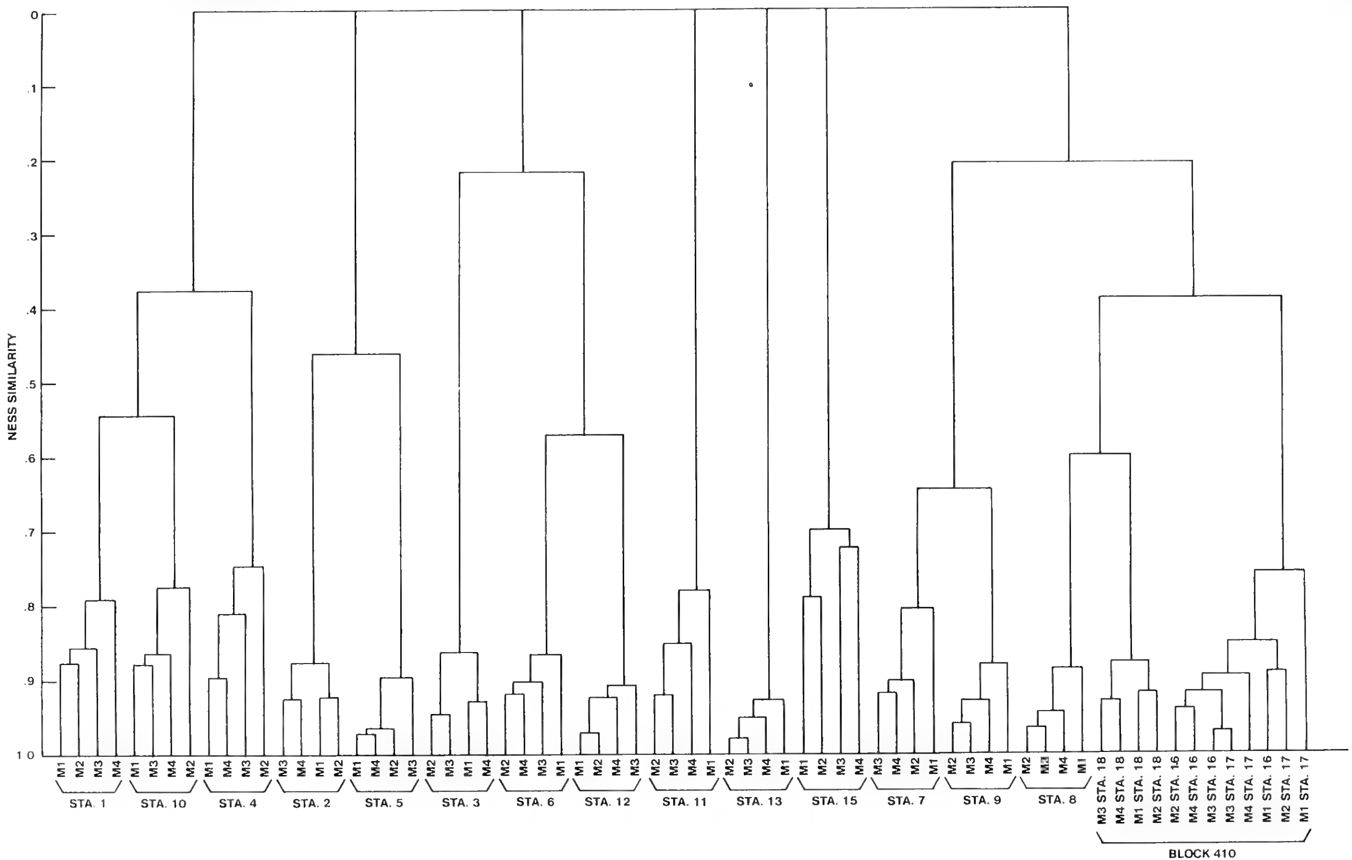


FIGURE 28. SUMMED REPLICATES OF M-1, M-2, M-3 AND M-4 REGIONAL STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

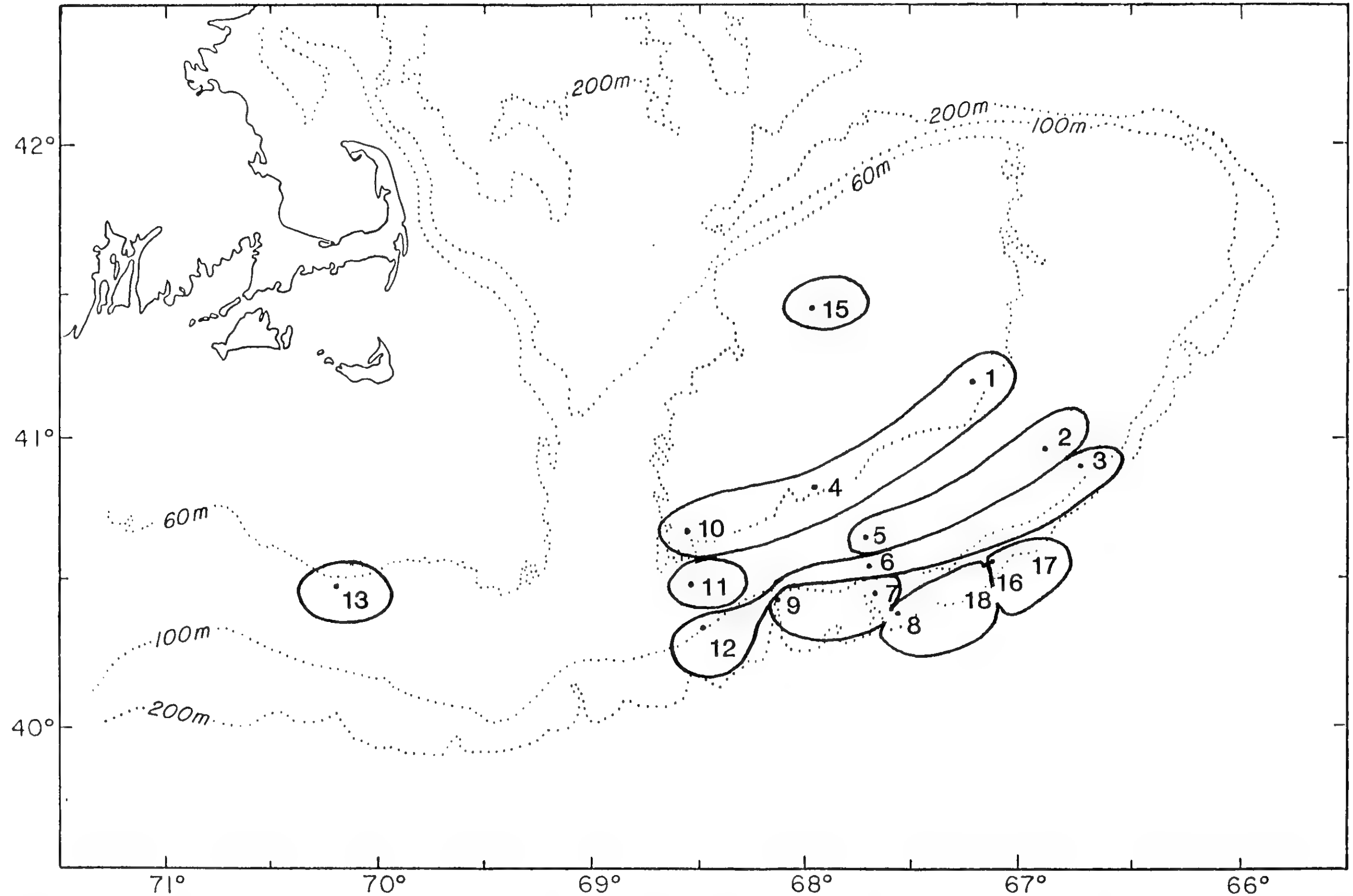


FIGURE 29. MAJOR CLUSTERS OF SUMMED REGIONAL STATIONS AS DELIMITED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

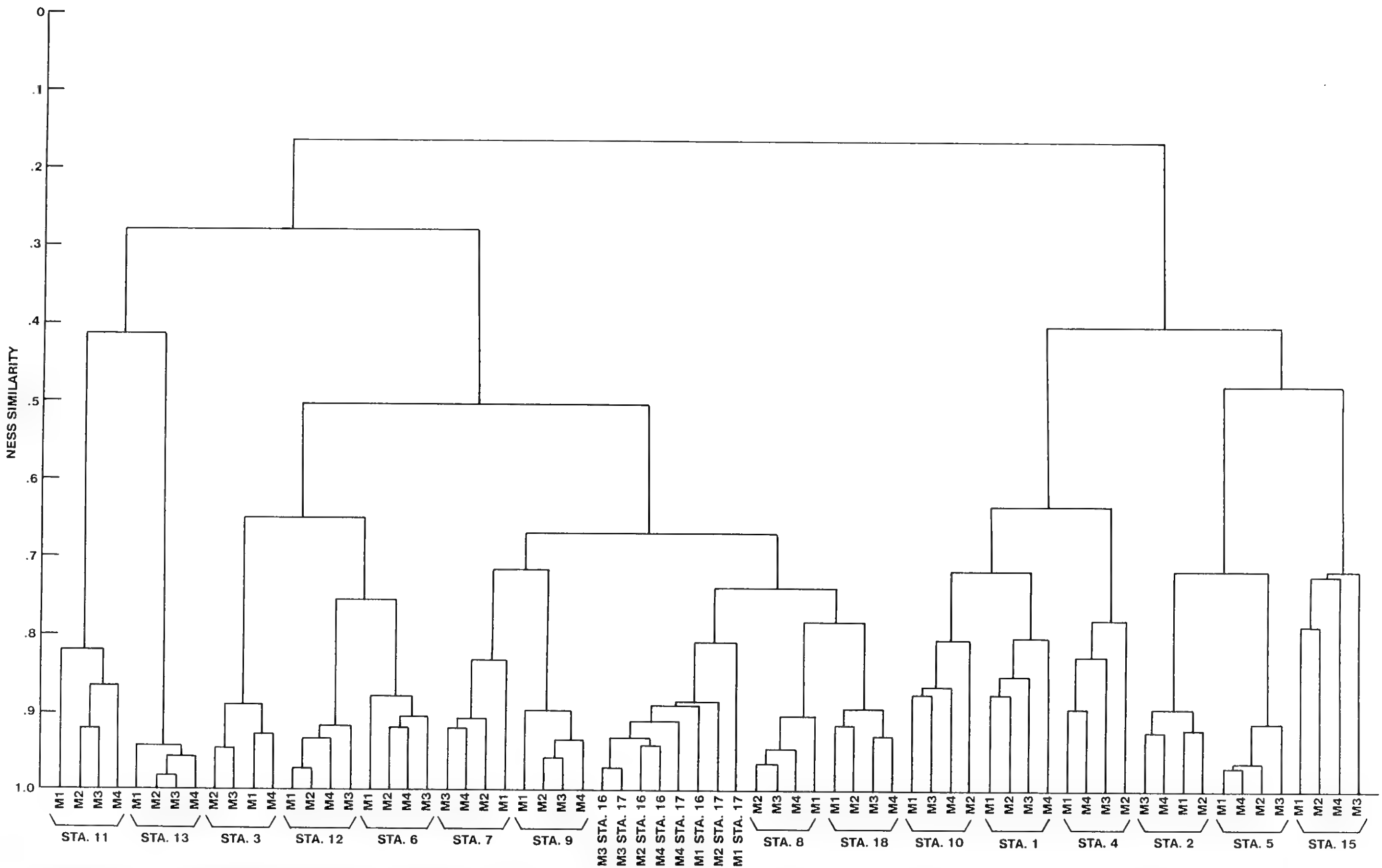


FIGURE 30. SUMMED REPLICATES OF M–1, M–2, M–3 AND M–4 REGIONAL STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND GROUP AVERAGE SORTING.

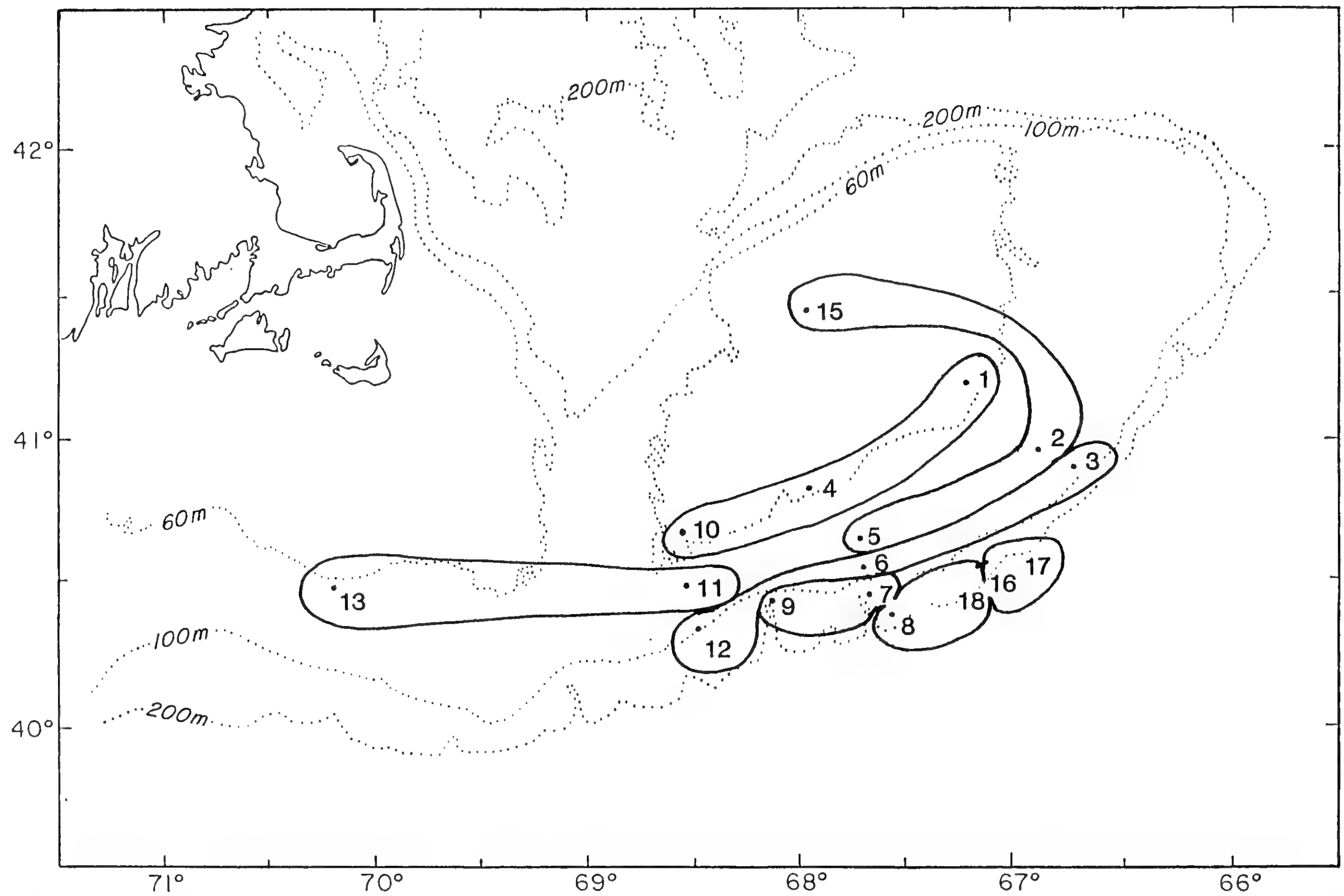


FIGURE 31. MAJOR CLUSTERS OF SUMMED REGIONAL STATIONS AS DELIMITED BY NESS AT 50 INDIVIDUALS AND GROUP AVERAGE SORTING.

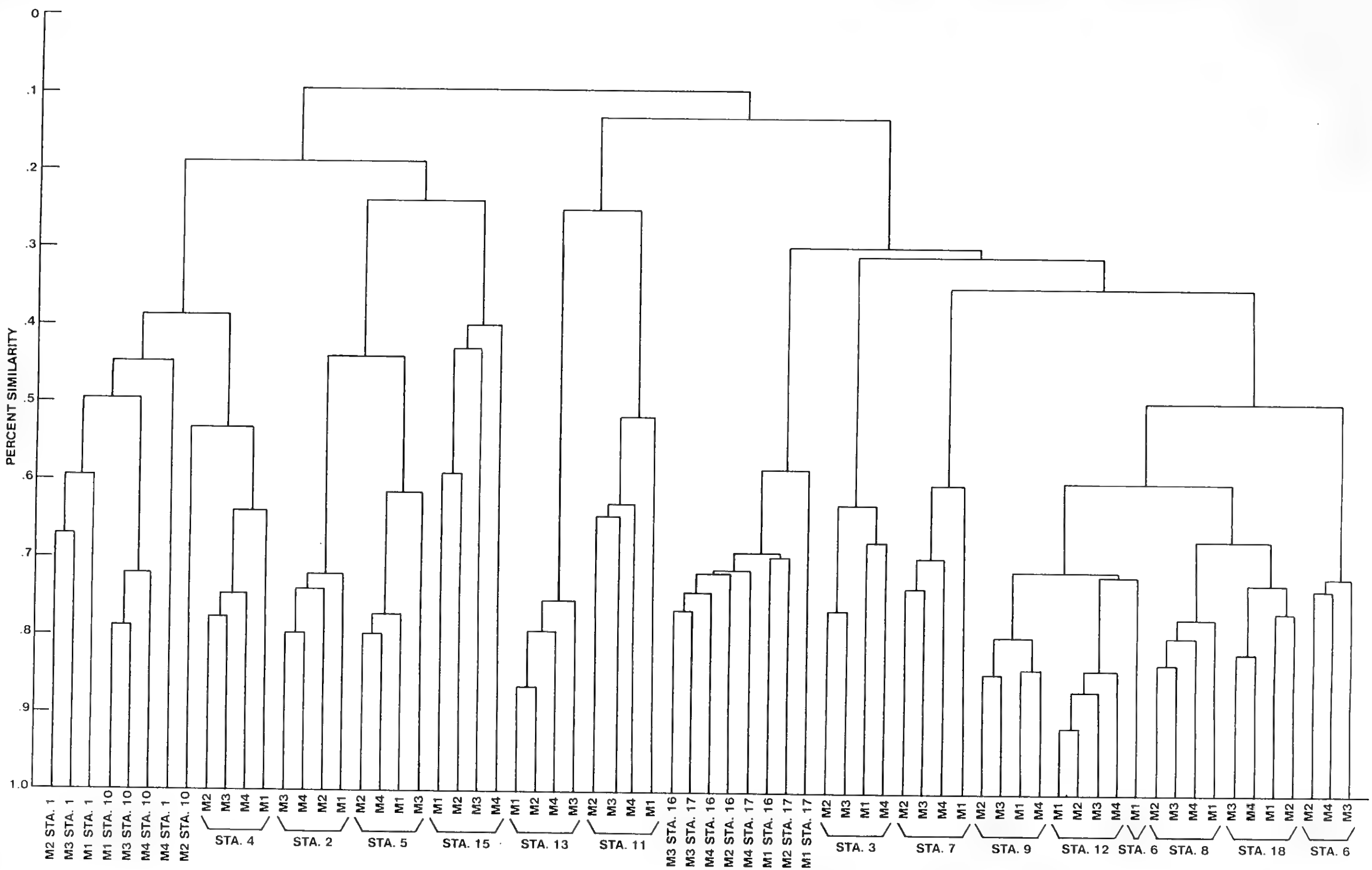


FIGURE 32. SUMMED REPLICATES OF M-1, M-2, M-3 AND M-4 REGIONAL STATIONS CLUSTERED BY PERCENT SIMILARITY AND GROUP AVERAGE SORTING.

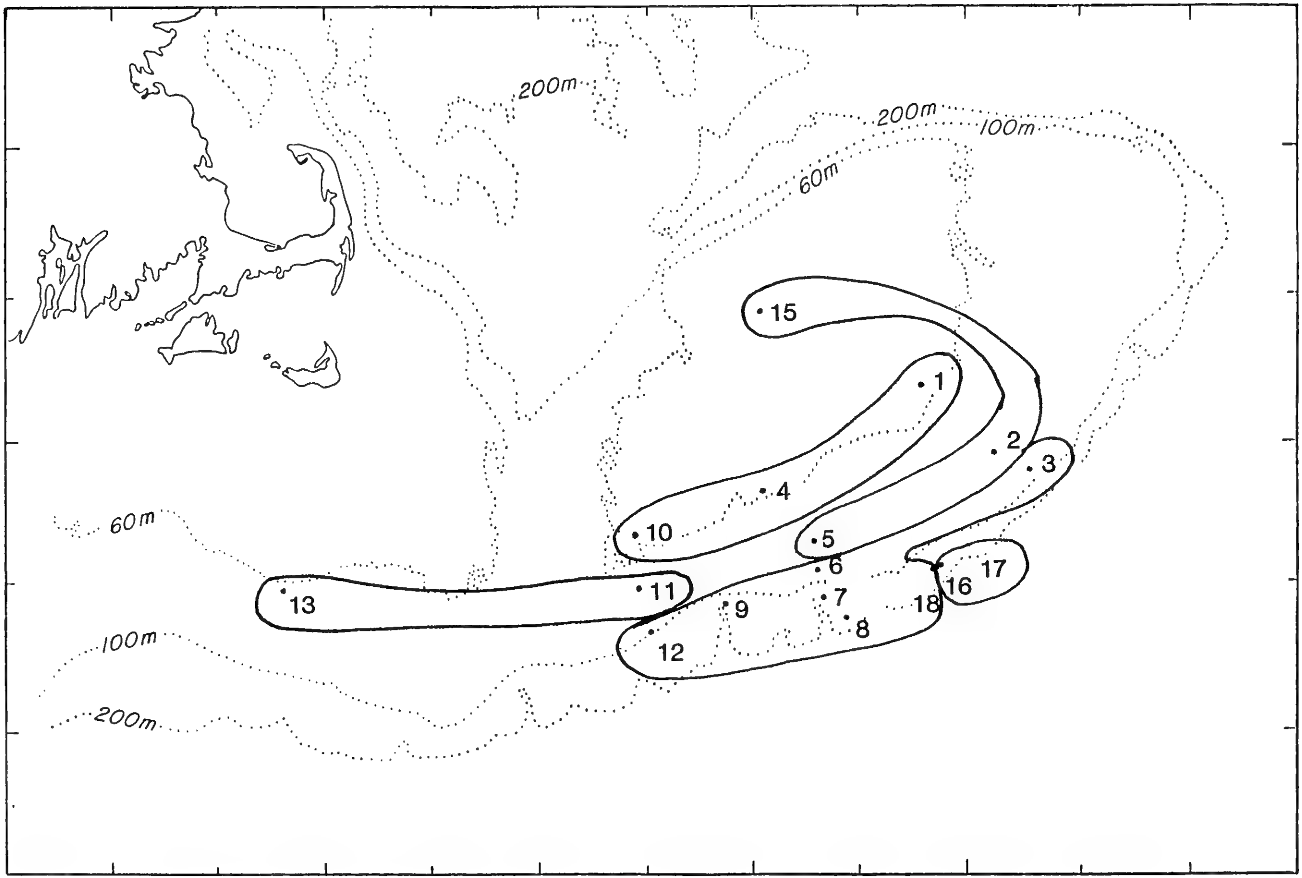


FIGURE 33. MAJOR CLUSTERS OF SUMMED REGIONAL STATIONS AS DELIMITED BY PERCENT SIMILARITY AND GROUP AVERAGE SORTING.

If group average sorting is used with NESS at 50 individuals, the first major division separates the 40-80 m depth eastern stations from the rest and the next division separates the remaining two shallow stations from the stations at 100 m depth or greater (Figures 30-31). The deeper stations divide into 100 m and 140-150 m groups.

With the percent similarity, the most dissimilar large groups are the same as with NESS: Stations 1, 10, and 4; Stations 2, 5, and 15; Stations 11 and 13 and the remaining stations (Figures 32-33).

5.2.1.3 Cluster Analysis of Block 410. At Block 410, Station 18 to the west of the rig Station 16 is clearly different from the samples taken at Stations 16 and 17, regardless of sampling date (Figure 34). Samples from the several sampling periods are scattered throughout the cluster diagram and any temporal trend is less obvious than differences between stations. For example, Ampelisca agassizi is dominant at Station 18 and rare at Stations 16 and 17, whereas Paradoneis n. sp. A is the most abundant species at Stations 16 and 17, but rare at 18.

5.2.1.4 Population Patterns of Selected Species. In an effort to determine if drilling activities were affecting benthic populations at Block 410 stations and also at the Mud Patch Station 13, the average densities of several species for each of the four seasonal samples were plotted. Drilling began at Station 16 shortly after the completion of Cruise (M1), and continued until March, 1982.

For Block 410, the densities of 10 important polychaetes, one oligochaete and the amphipod Ampelisca agassizi were plotted (Figures 35-36). There was a general tendency in at least two of the three stations for populations of Tharyx nr. monilaris, Notomastus latericeus, Polycirrus sp. A and Paradoneis n. sp. A to increase from July (M1) to February (M3) and to decline in May (M4). With the possible exception of Paradoneis n. sp. A, there is no apparent influence of drilling activities on abundances of the species examined. For Paradoneis n. sp. A, there is a decline in November (M2) at Station 16, followed by a large increase in February (M3) and a subsequent decline in May (M4). However, the large standard deviations for all three stations at all four sampling periods suggest that the decline of this species in November (M2) is not significant.

Ampelisca agassizi is far more abundant at Station 18 than at either Station 16 or 17. Gravid females and recently hatched young were most abundant in February (M3), which was the sampling period with the highest densities. The general population

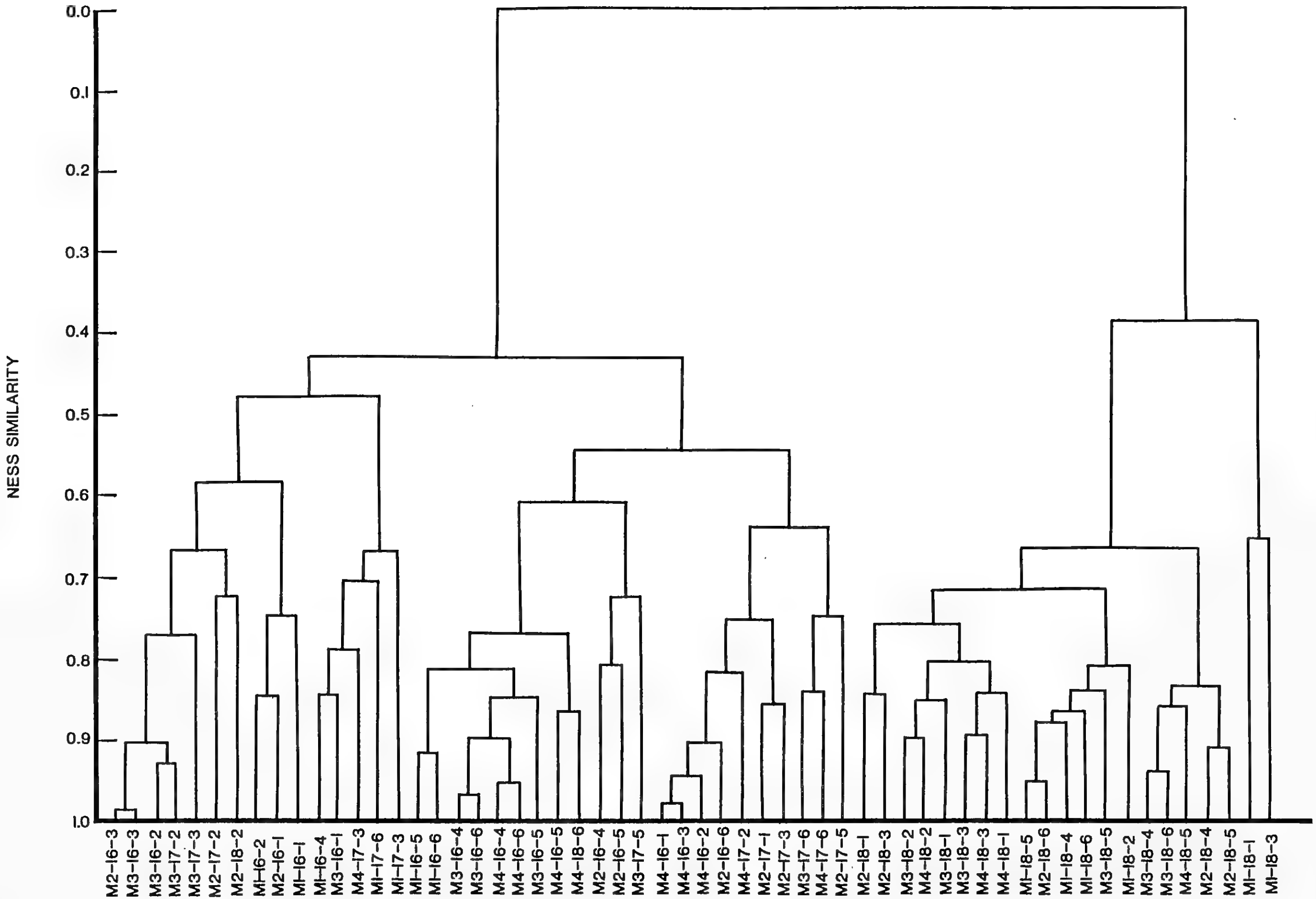


FIGURE 34. REPLICATES OF BLOCK 410 (STATIONS 16, 17 AND 18) CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

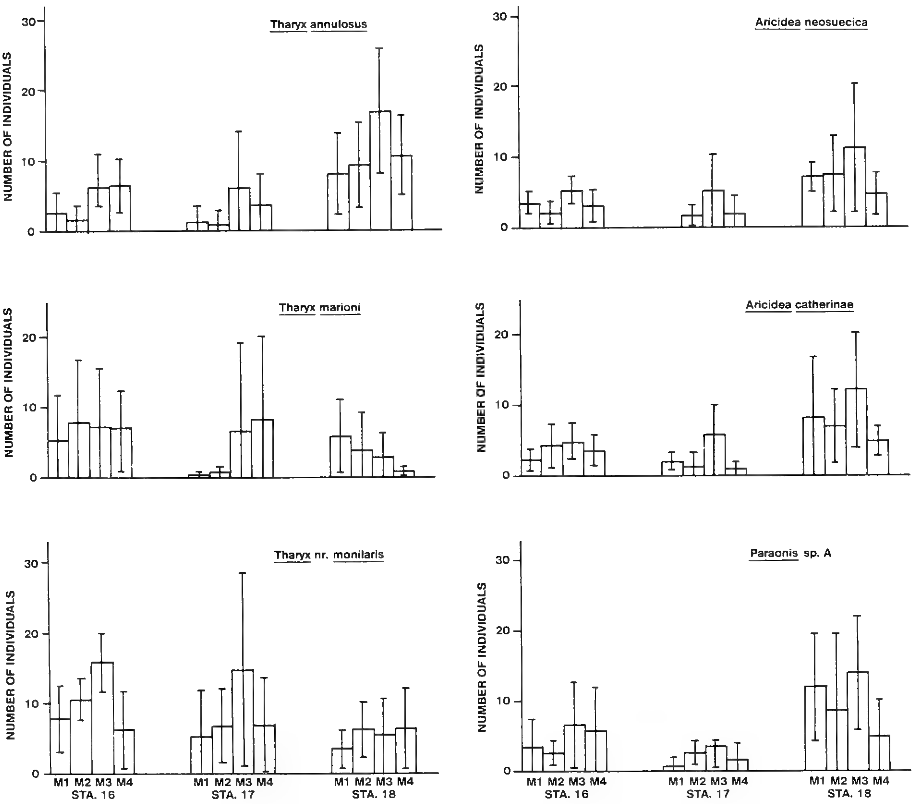


FIGURE 35. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF THREE CIRRATULIDS AND THREE PARAONIDS AT BLOCK 410 STATIONS 16, 17 AND 18 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

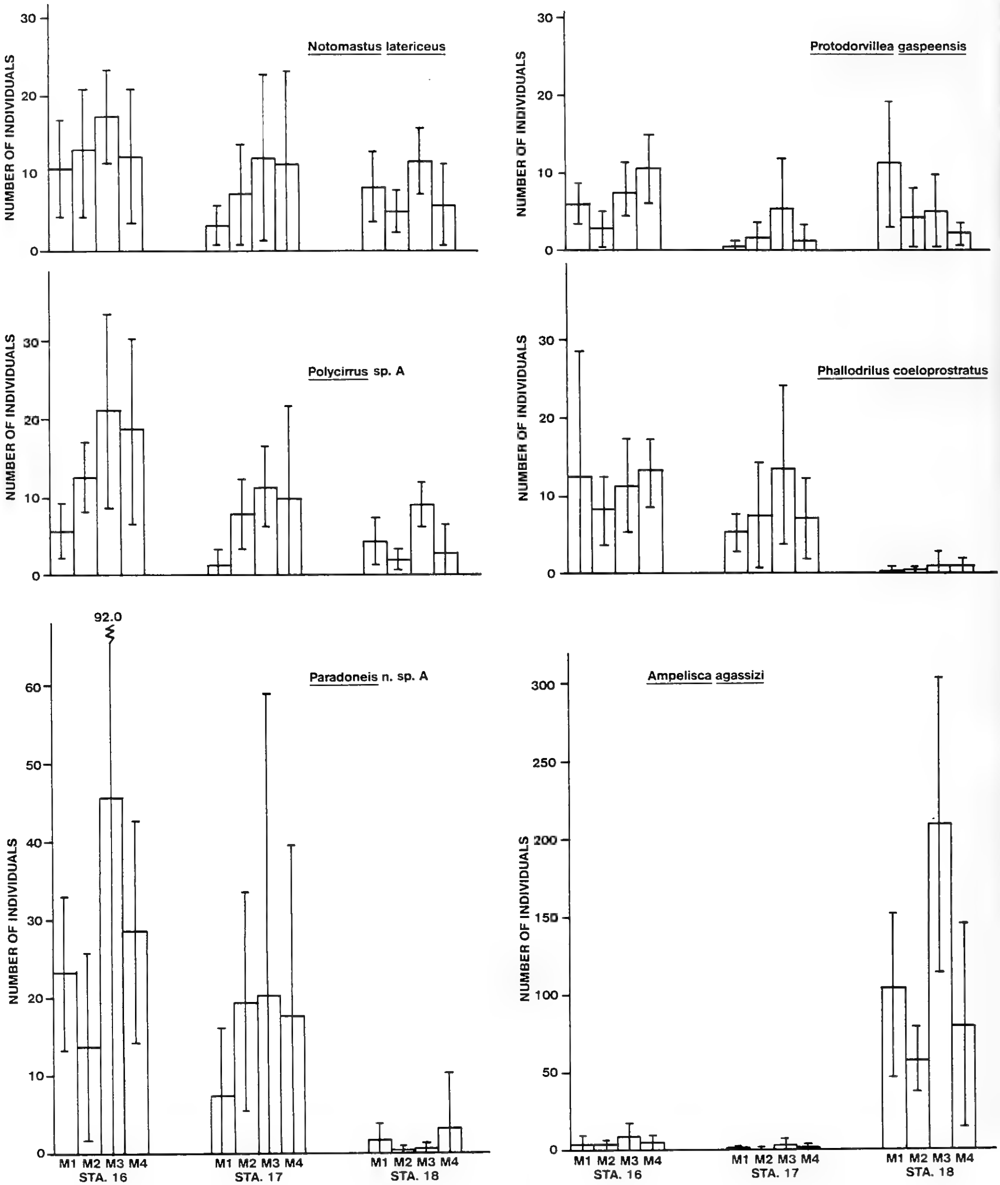


FIGURE 36. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF SIX IMPORTANT SPECIES AT BLOCK 410 STATIONS 16, 17 AND 18 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

fluctuations observed at Station 18 were similar to those seen at Stations 6, 8 and 13, but differed considerably from the pattern seen at Station 12. At that station, densities were always greater than 420 per 0.04 m^2 and steadily increased over all four sampling periods, with no decline in May (M4).

Seasonal densities at Station 13 have been plotted for 12 polychaete and one oligochaete species (Figures 37-38). All 13 species show an abrupt density drop in May (M4), corresponding to the overall population decline (Figure 7). This decline is most dramatic in Levensenia gracilis and Cossura longicirrata. An amphipod, Ampelisca agassizi (not figured), also shows an abrupt decline [avg.=142/0.04m^2 in February (M3) to avg.=25/0.04m^2 in May (M4)]. Sharp declines from February (M3) to May (M4) are also documented for Ninoe nigripes, Aricidea cathernae, Mediomastus fragilis, Lumbrineris impatiens, Aricidea suecica, Nephtys incisa, Tharyx acutus, T. annulosus and T. dorsobranchialis. Densities of Euchone incolor also decreased in May (M4), but had also declined in February (M3) from a peak in November (M4). The oligochaete, Limnodriloides medioporus also dropped in density from a peak in November, but most of the decline occurred in February (M3). Other invertebrates, such as the amphipod, Metopella angusta and the protobranch bivalve, Nucula proxima also showed population declines in May M4) (See Fig. 36 of Second Summary Report, BNMRL, 1982).

The population fluctuations observed at Station 13 probably represent a sequence of normal seasonal settlement and mortality patterns. The suite of species which dominate at Station 13 are for the most part not dominants at other stations on the Bank. Exceptions include Ampelisca agassizi which also dominates at Station 18. This species exhibits the same population decline in May (M4) at Stations 13 and 18, suggesting that this is a typical seasonal pattern for this species. Preliminary results from Station 13 for the M5 (July, 1982) cruise indicate that both Cossura longicirrata and Levensenia graclis have returned to high density levels.

5.2.2 Site-Specific Stations

5.2.2.1 Cluster Analysis. All the site-specific stations and the sampling dates can be clustered at once using NESS at 200 individuals (m = 200) drawn from samples consisting of all six replicates at any given sampling date pooled (Figure 39). The clearest separation occurs between Station 5-29 and the rest of the site-specific stations. This

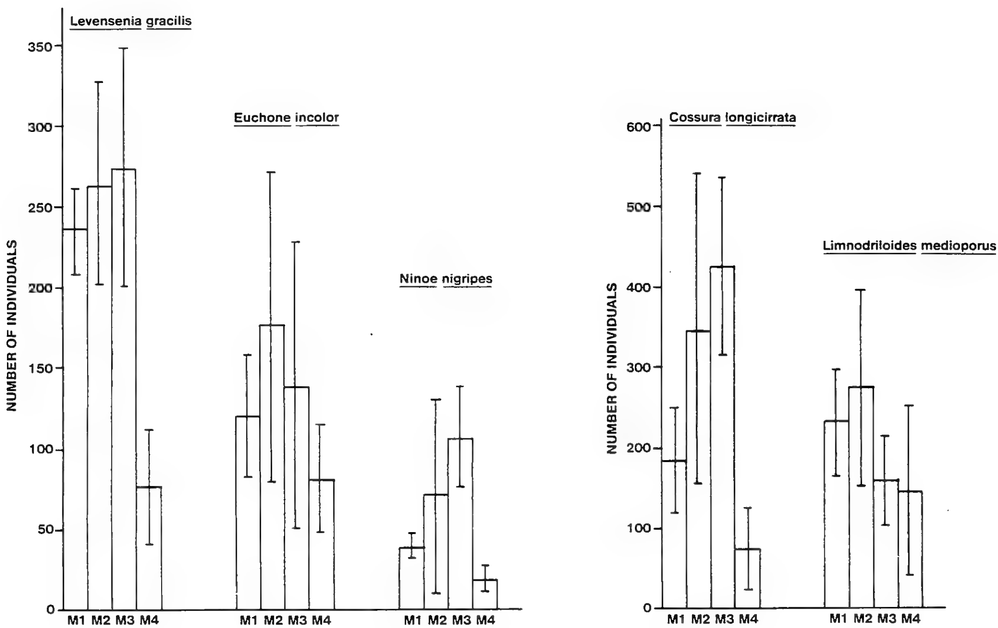


FIGURE 37. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF FIVE DOMINANT SPECIES AT REGIONAL STATION 13 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

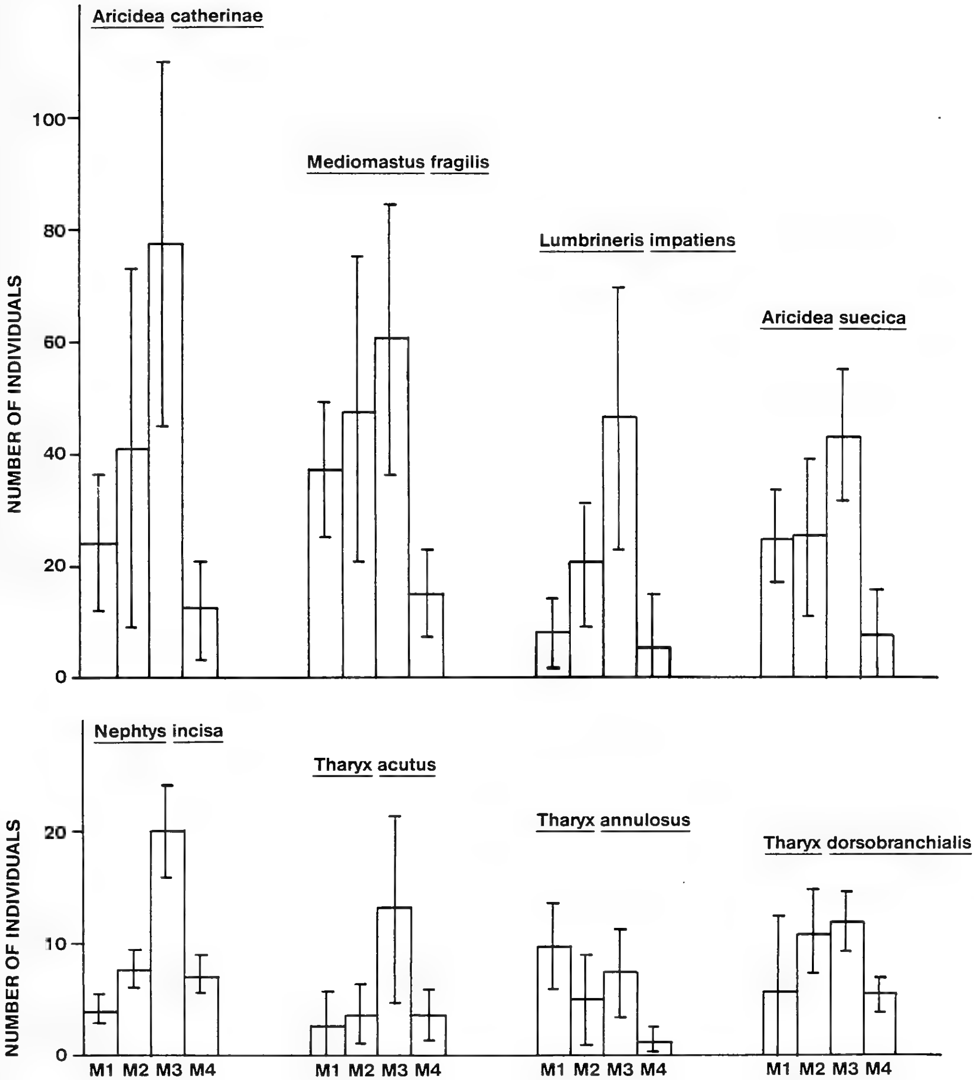


FIGURE 38. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF EIGHT IMPORTANT SPECIES AT REGIONAL STATION 13 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

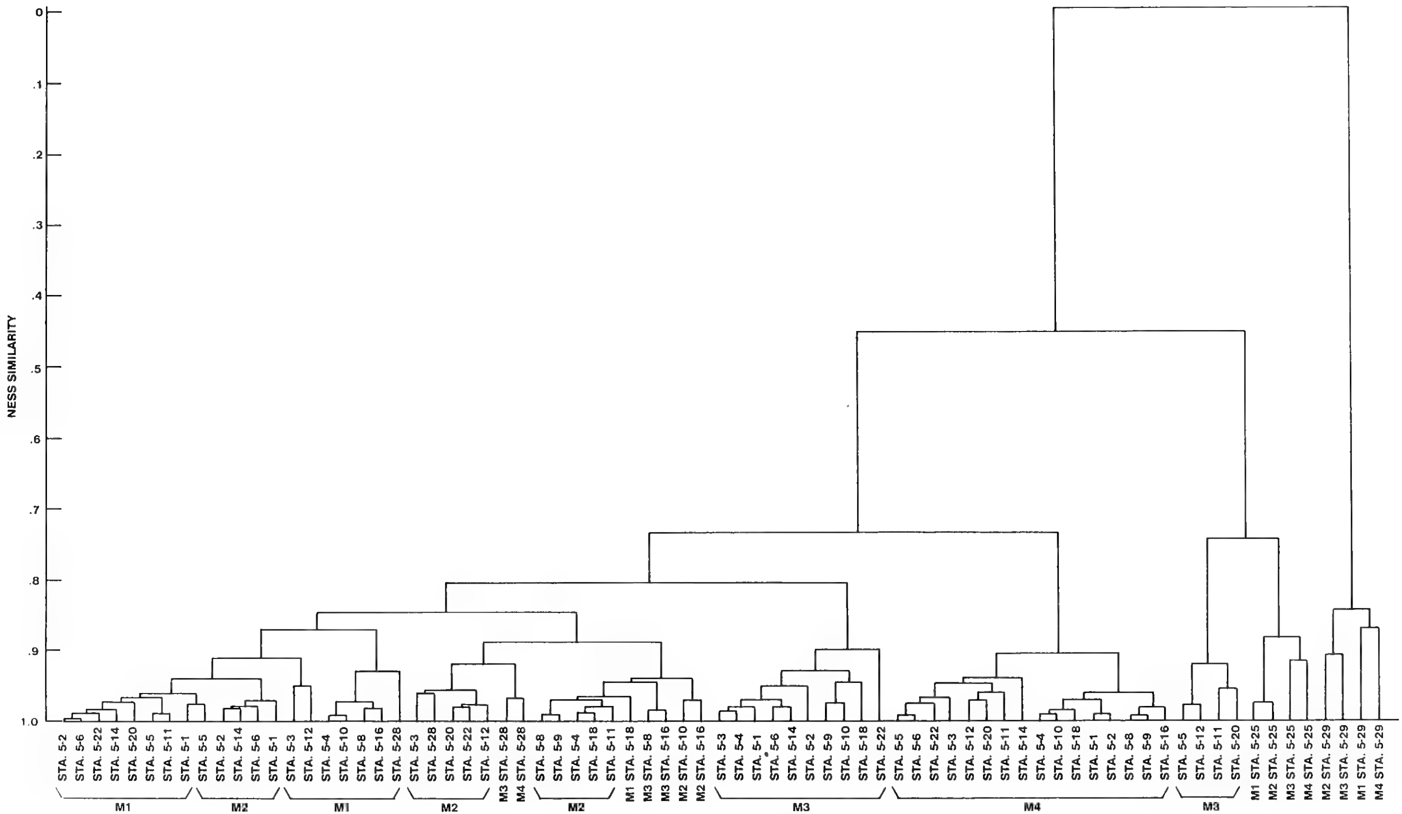


FIGURE 39. SUMMED REPLICATES OF M-1, M-2, M-3 AND M-4 SITE-SPECIFIC STATIONS CLUSTERED BY NESS AT 200 INDIVIDUALS AND FLEXIBLE SORTING.

partly results from a change in the amphipod fauna: at Station 5-29 there are higher numbers of Ampelisca agassizi and fewer Erichthonius rubricornis and Unciola inermis regardless of season. We attribute this change in fauna to an east-west change in sediment composition. At Station 5-29, 6 km west of the drill site, the sediments are 50.0 ± 6.6% fine sand while at Station 5-25 4 km west of the drill site, the sediments are 14.9 ± 5.0% fine sand (Figure 40). The remaining site specific stations have a lower fine sand component.

Station 5-25 shows a tendency to cluster by itself and also has some affinities with the February (M3) samples located south of the drill site (Stations 5-5, 5-11, 5-12, 5-20). These stations also have a high fine sand component and cluster together in February concurrent with the peak proportion of fine sand (Figure 41).

Excluding Stations 5-25, 5-28 and the four stations in February, the remaining samples separate over time starting with a tight cluster of July (M1) and November (M2) samples. February (M3) is the next most dissimilar sampling period and May (M4) is least similar to July (M1) and November (M2). The second year of sampling will determine if this is a seasonal pattern.

An interesting feature of this diagram is that unlike any other station, the February (M3) and May (M4) samples at the easternmost upstream station (5-28) cluster with the July (M1) and November (M2) samples. In other words, Station 5-28 is the only station that does not show the temporal changes that occur at the rest of the site-specific stations. Because Station 5-28 changes less than the other site-specific stations during February, it can be considered as a reference station to which the other stations can be compared. For the comparison of each of the other site-specific stations with Station 5-28, we calculated NESS similarity at 200 individuals. From inspection of the sediment data, it appears that the distribution of fine sand changes during the winter months, with the percentage of fine sand being higher in February at many of the site-specific stations. To test whether the community changes at most of the site-specific stations in February are related to changes in sediment composition, we have used the Spearman rank correlation to test whether NESS similarity to Station 5-28 is correlated with percent fine sand. There is a significant inverse correlation between NESS similarity to Station 5-28 and percent fine sand during both February (M3) and May (M4). An alternative hypothesis is that the changes in community similarity in February may be correlated with increases in levels of barium (used as an indicator of the distribution of drilling fluids). To rank the stations on the basis of the potential effects of drilling fluids, we have used the data in

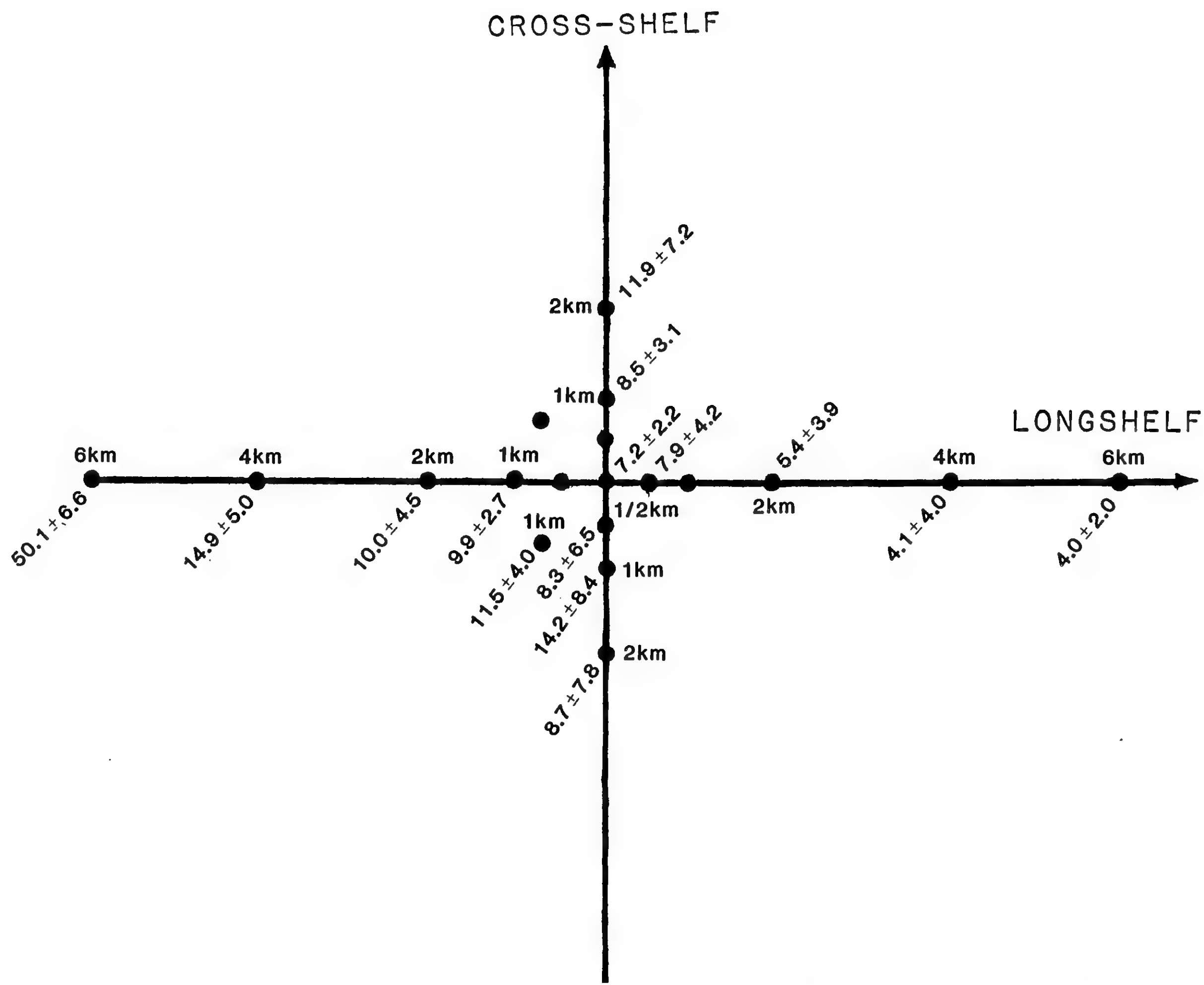


FIGURE 40. PERCENTAGE OF FINE SAND (Ø5) AT PRIMARY SITE-SPECIFIC STATIONS AVERAGED OVER THE ENTIRE YEAR (M-1-M-4).

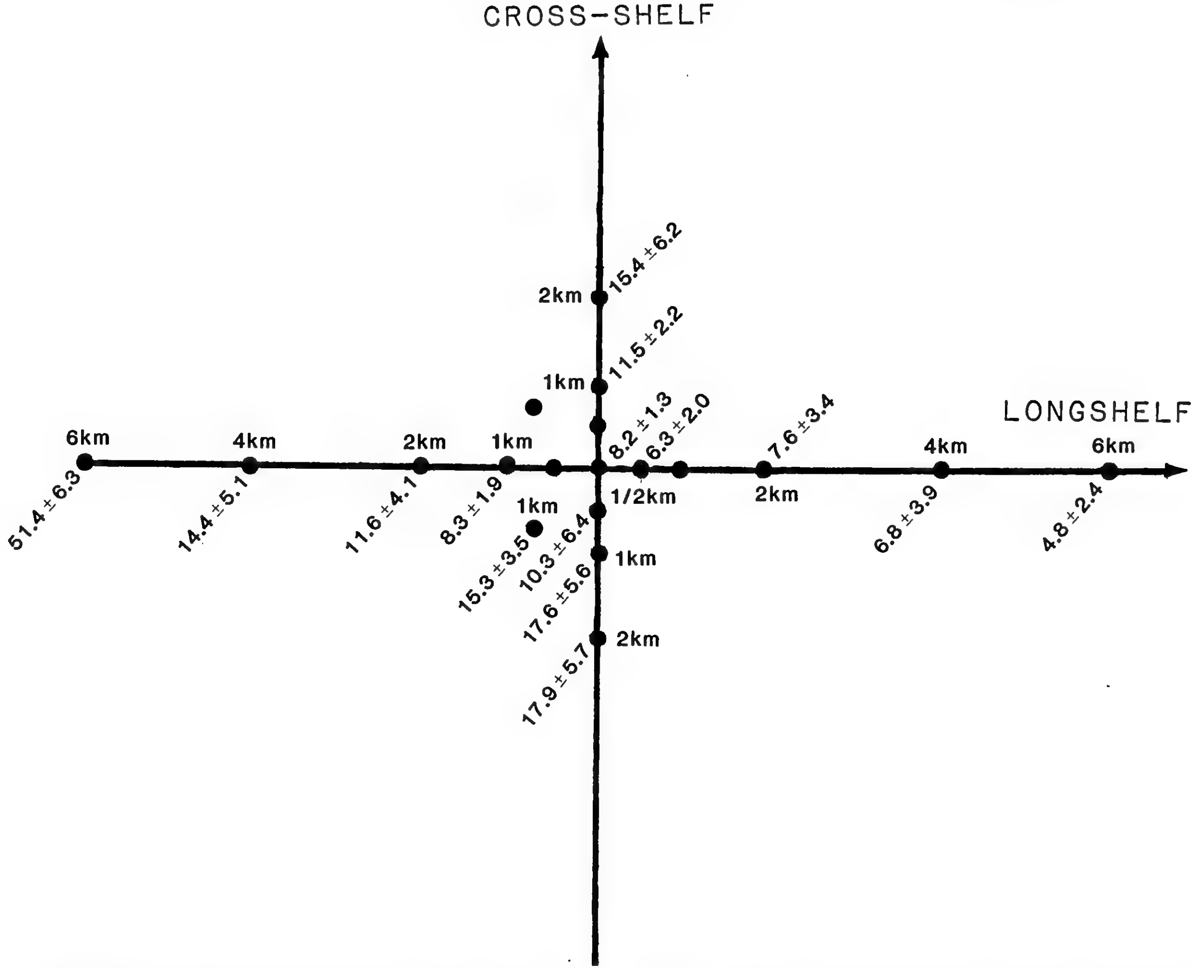


FIGURE 41. PERCENTAGE OF FINE SAND (ϕ5) AT PRIMARY SITE-SPECIFIC STATIONS IN FEBRUARY (M-3).

Bothner et al. (1982, figs. 8 and 11). There is no significant rank correlation (Spearman rank correlation, $p < .01$) between the increase of barium from July (M1) to May (M4) and the NESS ($m = 200$ individuals) similarities to Station 5-28 for data from either February (M3) or May (M4).

When comparing NESS at 50 individuals, the pattern is similar but less obvious as would be expected if the differences seen depend heavily on some of the less common species (Figure 42).

When all of the replicates are used separately as illustrated by the figures for November (M2) and May (M4) (Figures 43 and 44), the only completely consistent separation is the westernmost Station 5-29. Other stations where the replicates tend to group with each other are Station 5-25 in November (M2) and Stations 5-20, 5-22, 5-25 and 5-28 in May (M4). There is some affinity between most of the replicates of Stations 5-20, 5-22 and 5-25 and a few replicates of Stations 5-12 and 5-14 in May (M4).

Based on cluster analysis, none of the samples from the site-specific stations are very dissimilar with the exception of Station 5-29.

5.2.2.2 Population Analysis of Species Along a Barium Gradient. The results of trace metal analysis presented by Bothner et al. (1982) show increased levels of bulk sediment barium at several site-specific stations. Those stations showing the highest magnitude of change (M4 levels compared to M1 levels) were Stations 5-8, 5-2 and 5-1, with 2.5, 2.4 and 2.3 times as much barium in May (M4) as in July (M1) (Bothner et al., 1982:32, fig. 8). Stations 5-10 and 5-25 are downcurrent of the rig site, and had 1.6 and 1.5 times as much barium in May (M4) as in July (M1). Station 5-28, at the furthest point upcurrent from the rig, had only 1.1 times as much barium. No clear increase in barium occurred at Station 2, the upcurrent control station on Transect 1. Because barium is a major constituent of the drilling muds used on the Bank, the increased levels at certain stations can be regarded as an indication of the dispersal of the drilling muds around the rig. Using these barium levels as a basis for a gradient, the total number of individuals and the densities of 24 species abundant at these seven stations were plotted. The semi-submersible rig ROWAN MIDLAND arrived in Block 312 on November 21, immediately after completion of Cruise M2 and drilling started on December 8, 1981.

Figure 45 shows the average number of individuals of all infaunal species at these stations. Although the standard deviations of all samples are large, different trends can be detected. At Stations 5-8, 5-2 and 5-1, the stations closest to the rig, there was a

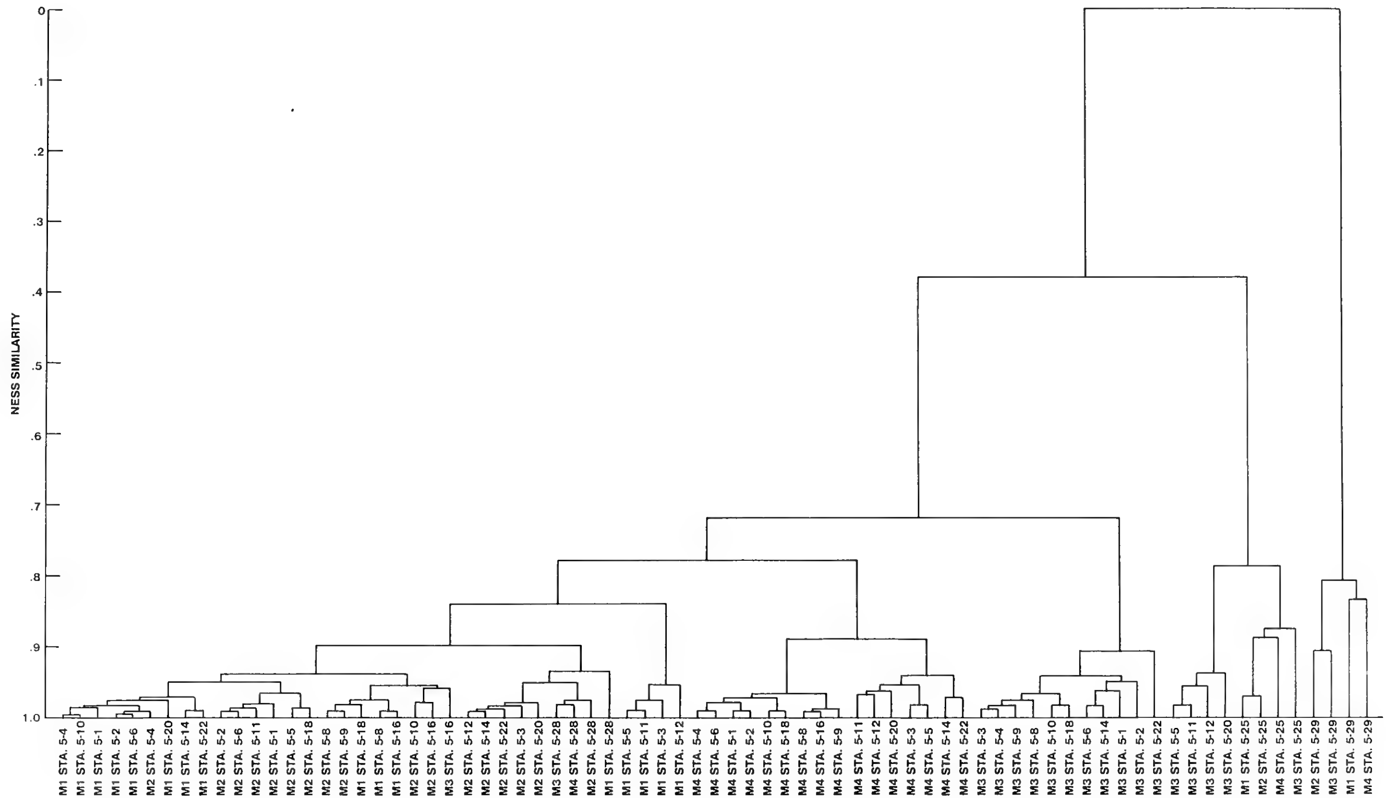


FIGURE 42. SUMMED REPLICATES OF M–1, M–2, M–3 AND M–4 SITE–SPECIFIC STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

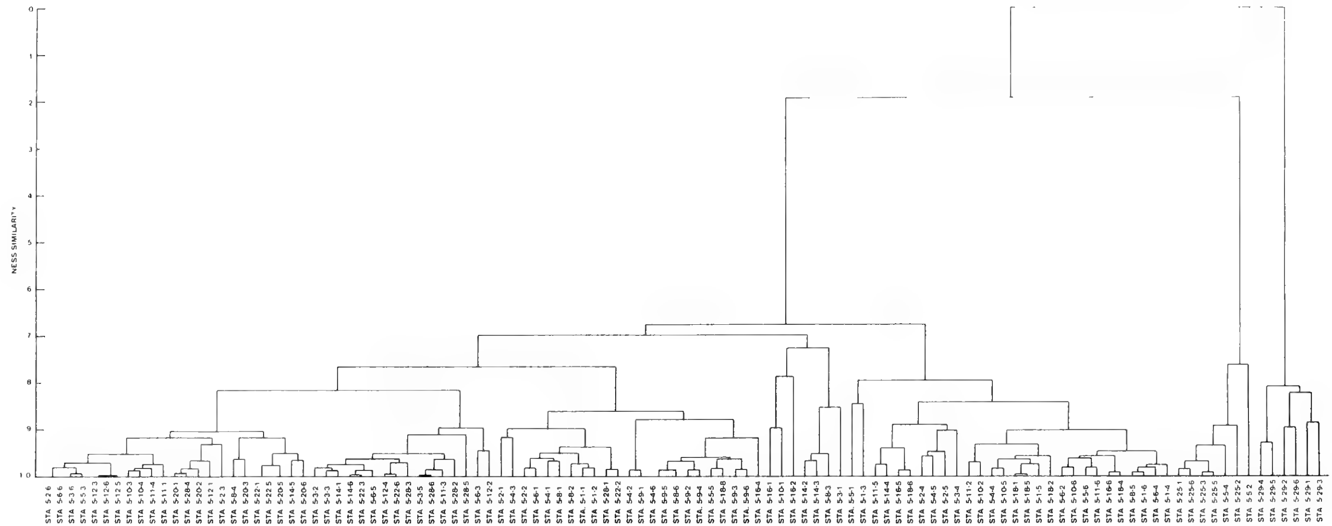


FIGURE 43. REPLICATES OF M-2 SITE-SPECIFIC STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

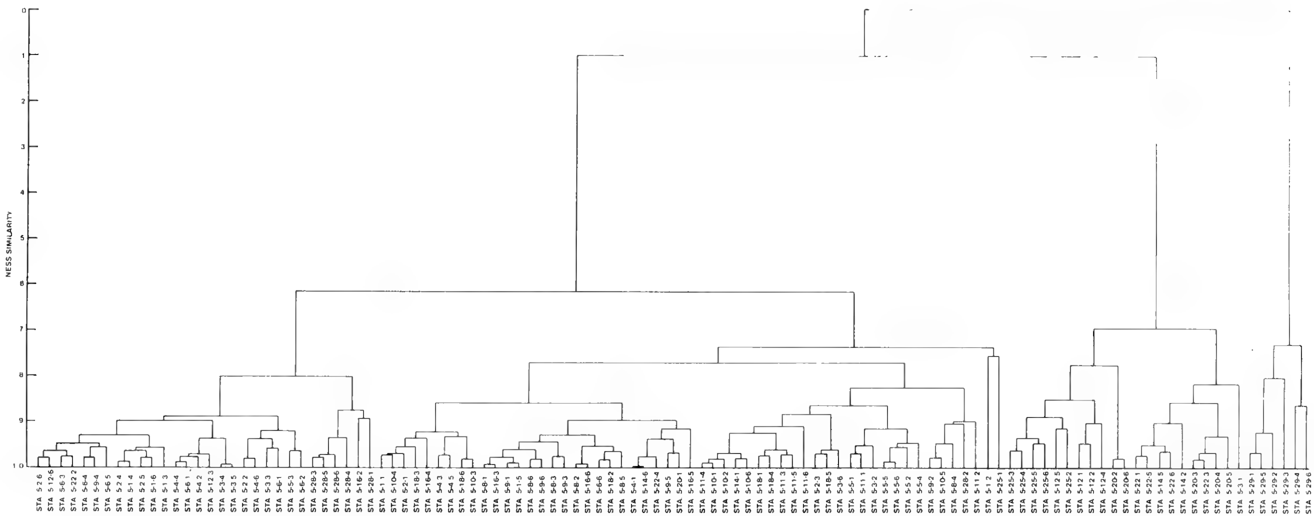


FIGURE 44. REPLICATES OF M-4 SITE-SPECIFIC STATIONS CLUSTERED BY NESS AT 50 INDIVIDUALS AND FLEXIBLE SORTING.

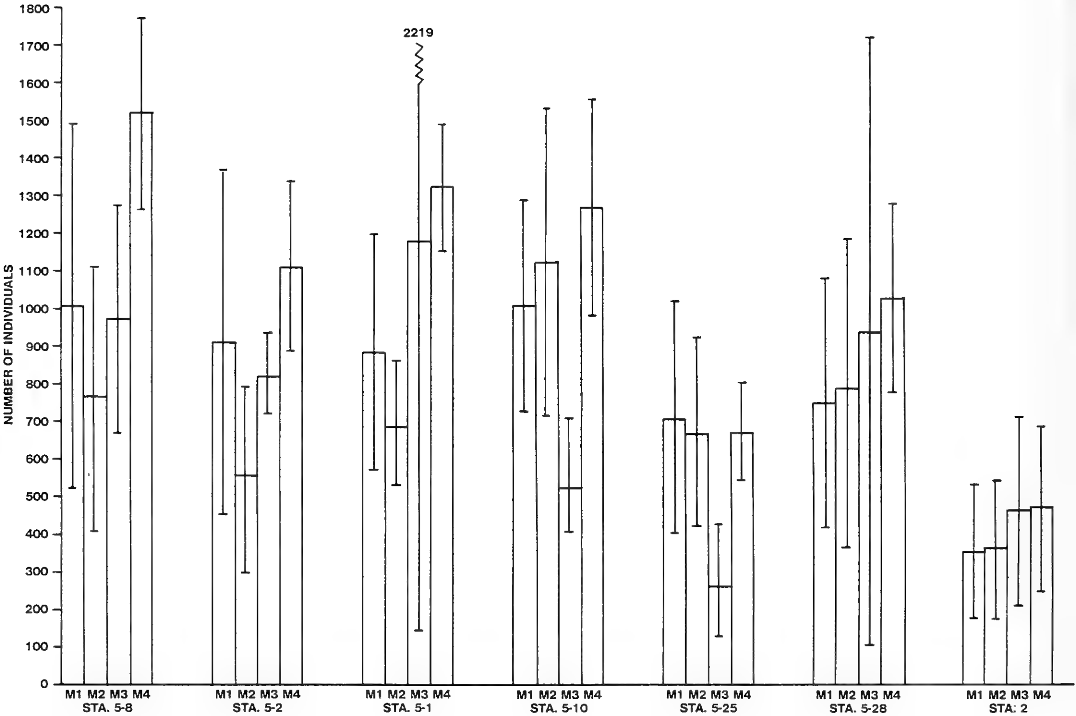


FIGURE 45. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 $\pm$ ONE STANDARD DEVIATION AT SELECTED SITE-SPECIFIC STATIONS AND REGIONAL STATION 2 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

decrease in faunal densities from July (M1) to November (M2), with a good recovery in February (M3) continuing through May (M4). Stations 5-10 and 5-25, downcurrent of the rig, did not exhibit a decline in total numbers until February (M3); these stations also showed a strong recovery in May (M4). Stations 5-28 and 2, the farthest upcurrent of the rig, did not demonstrate decreases in either November (M2) or February (M3), but exhibited gradual increases in total density throughout all four seasonal sampling periods. Station 5-28 can be considered to function as an upcurrent control station for the site-specific array. Station 2 also is an upcurrent control, but to a lesser extent, since some species which are abundant at site-specific stations are rare at Station 2.

Because of the relatively large standard deviations associated with each mean, it is not possible at this time to attach a high level of statistical significance to these observed patterns. In order to determine if the observed pattern of the overall fauna is repeated for individual species, we have plotted the densities of 24 species of amphipods, polychaetes and oligochaetes at these stations. Some preliminary data on reproduction of 6 syllid polychaete species and size class data on one maldanid polychaete are also presented in an effort to determine if reproduction or recruitment can explain the observed patterns.

Unciola inermis (Figure 46) follows the overall pattern in a general manner except that there is poor recovery in February (M3) at Stations 5-8 and 5-2, and it continues to decline in February (M3) at Station 5-1. At Stations 5-10 and 5-25, densities of U. inermis decrease in both November (M2) and February (M3). These declines are also seen at the control Station 5-28 in November (M2) and February (M3), but they are not as strong. Densities recover well at all stations in May (M4). Unciola inermis was rare at Station 2 and is therefore not included in Figure 46. The distribution of U. inermis is related to sediment grain size characteristics: densities of this species are low at stations with a high percentage of fine sand. For example, there is a significant inverse correlation (Spearman rank correlation coefficient, $p < .05$) between the density of U. inermis and percent fine sand in February (M3).

Erichthonius rubricornis (Figure 46) shows the most dramatic population decline in the vicinity of the rig site. Average density of this species declines in November (M2) at Stations 5-8, 5-2 and 5-1 followed by continuing severe declines in February (M3), with poor recovery in May (M4). Stations 5-10 and 5-25 show virtual elimination of the species in February (M3) with poor recovery in May (M4). A totally different pattern is seen at the control Station 5-28, with populations steadily increasing

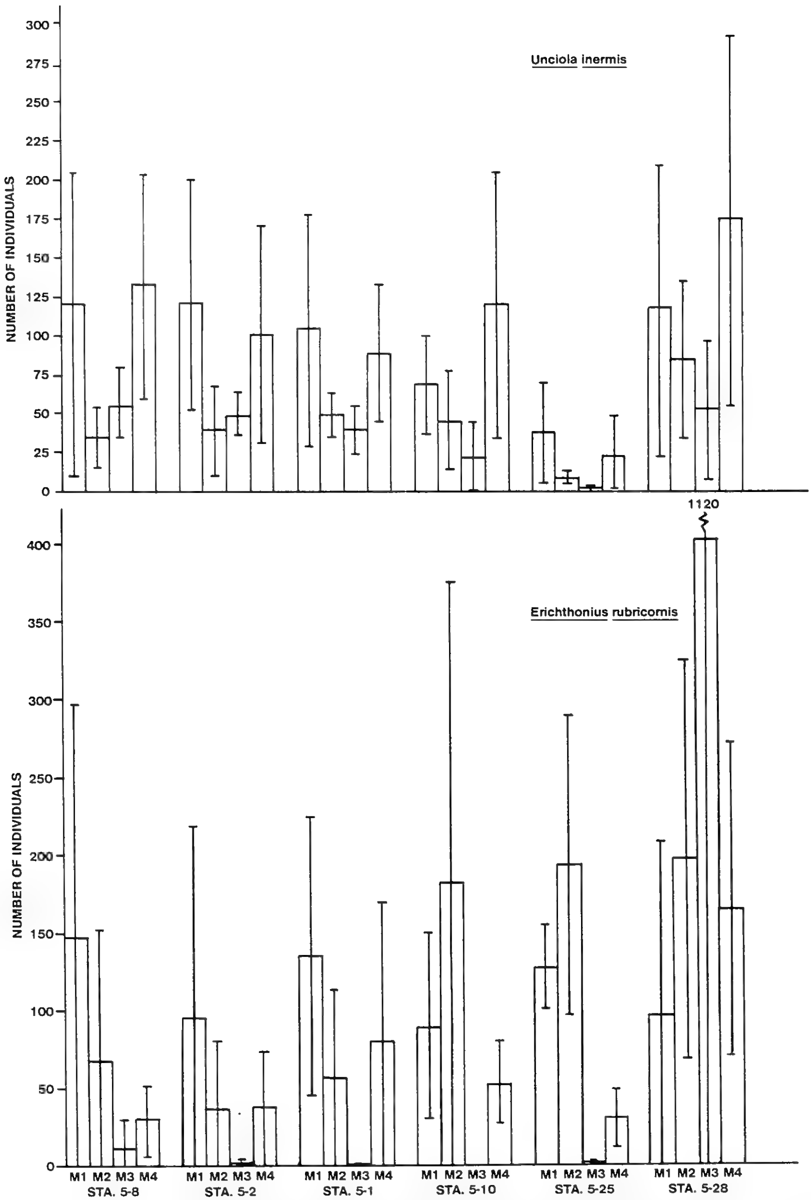


FIGURE 46. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF UNCIOLA INERMIS AND ERICHTHONIUS RUBRICORNIS AT SELECTED SITE-SPECIFIC STATIONS IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

from July (M1) through February (M3) when there are extremely high numbers, followed by a decline in May (M4). However, the high average density at Station 5-28 for February (M3) is due to only two of the six replicates. Four replicates contained from 5 to 20 E. rubricornis, but two others contained densities of 576 and 1717 individuals each. Only one individual of this species was collected at Station 2, on Cruise M2. The distribution of E. rubricornis is also clearly related to sediment characteristics. It is similar to U. inermis in preferring coarser sediments, for instance, there is a significant correlation (Spearman rank correlation coefficient, $p < .05$) between high densities of E. rubricornis and high percentages of gravel in February (M3).

The oligochaete species Phallodrilus coeloprostratus (Figure 47) generally declines at the site-specific stations, including Station 5-28. At Station 5-2 and Regional Station 2 there is a decline in November (M2) and an increase in May (M4).

Protodorvillea kefersteini, a dorvilleid polychaete, follows the general pattern very closely (Figure 47). This species is rare at Station 5-25 and at Station 2.

The six species of syllid polychaetes analyzed generally follow the basic pattern described above for total individuals (Figures 48-50). Exogone verugera, Parapionosyllis longicirrata, Syllides benedicti and Streptosyllis arenae all repeat the pattern, but densities of E. hebes did not decline at all at Station 5-8 and densities of Sphaerosyllis sp. A did not decline at Station 5-1. These six species differ in the timing of reproductive events (Tables 6 and 7), suggesting that recruitment of juveniles to the benthos may not be important in explaining differences between stations.

Fourteen species of polychaetes exhibit varying degrees of adherence to the general pattern (Figures 50-54). Aricidea catherinae, A. cerruti, and Euclymene sp. A follow this pattern closely, while 11 others depart from it in various ways at Stations 5-8 and 5-1. Some preliminary size class data is available for Euclymene sp. A (Table 8). Percentages of juveniles (< 5 mm) at five of the six site-specific stations gradually increased from July (M1) through November (M2) and February (M3) and declined in May (M4). Values at Station 5-10 were slightly lower in November (M2) than in July (M1), but increased in February (M3). These values indicate recruitment to the benthos through reproduction in summer and fall. However, the pattern is essentially the same at all stations, regardless of distance from the drilling site, which implies that, as for the syllids, reproductive events cannot be used to explain differences in patterns of changes in densities.

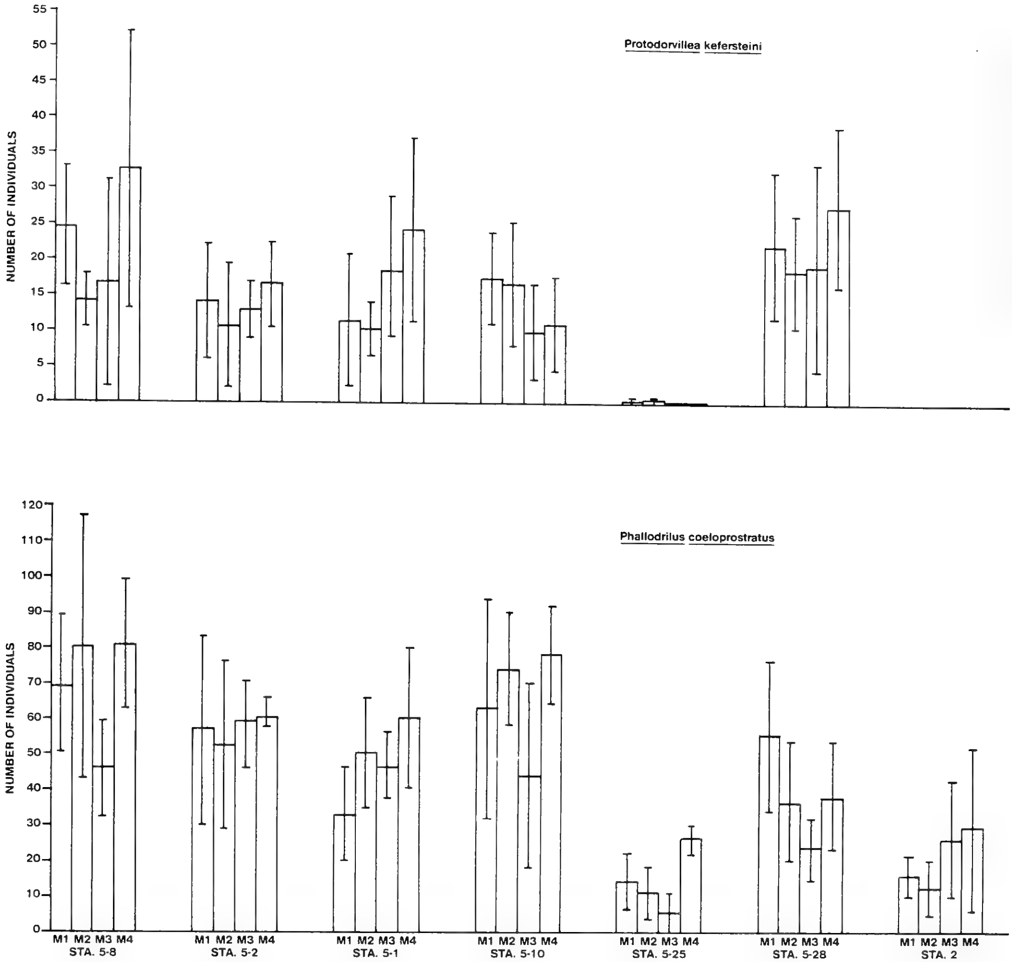


FIGURE 47. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF PROTODORVILLEA KEFERSTEINI AND PHALLODRILUS COELOPROSTRATUS AT SELECTED SITE-SPECIFIC STATIONS AND REGIONAL STATION 2 IN JULY (M-1), NOVEMBER (M-2). FEBRUARY (M-3) AND MAY (M-4).

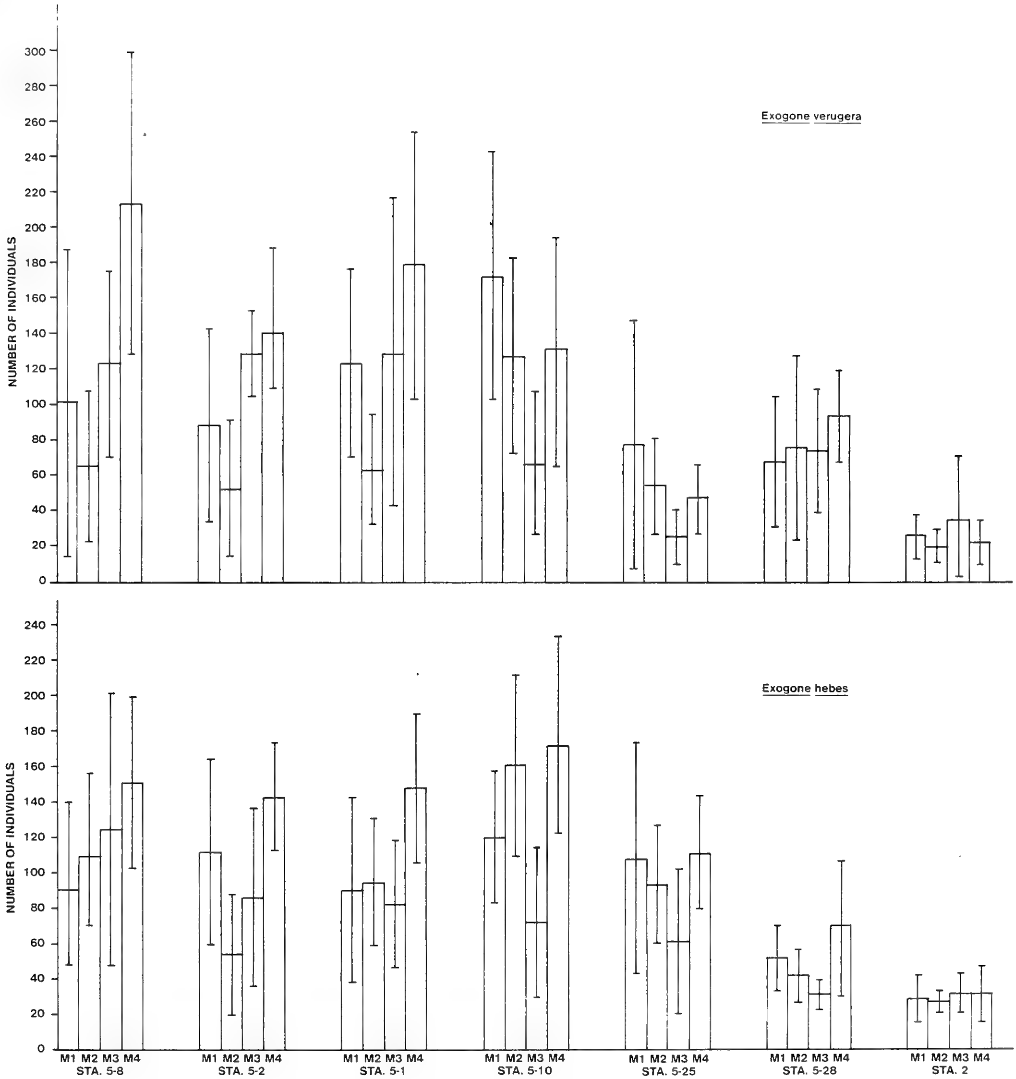


FIGURE 48. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF EXOGONE VERUGERA AND E. HEBES AT SELECTED SITE-SPECIFIC STATIONS AND REGIONAL STATION 2 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

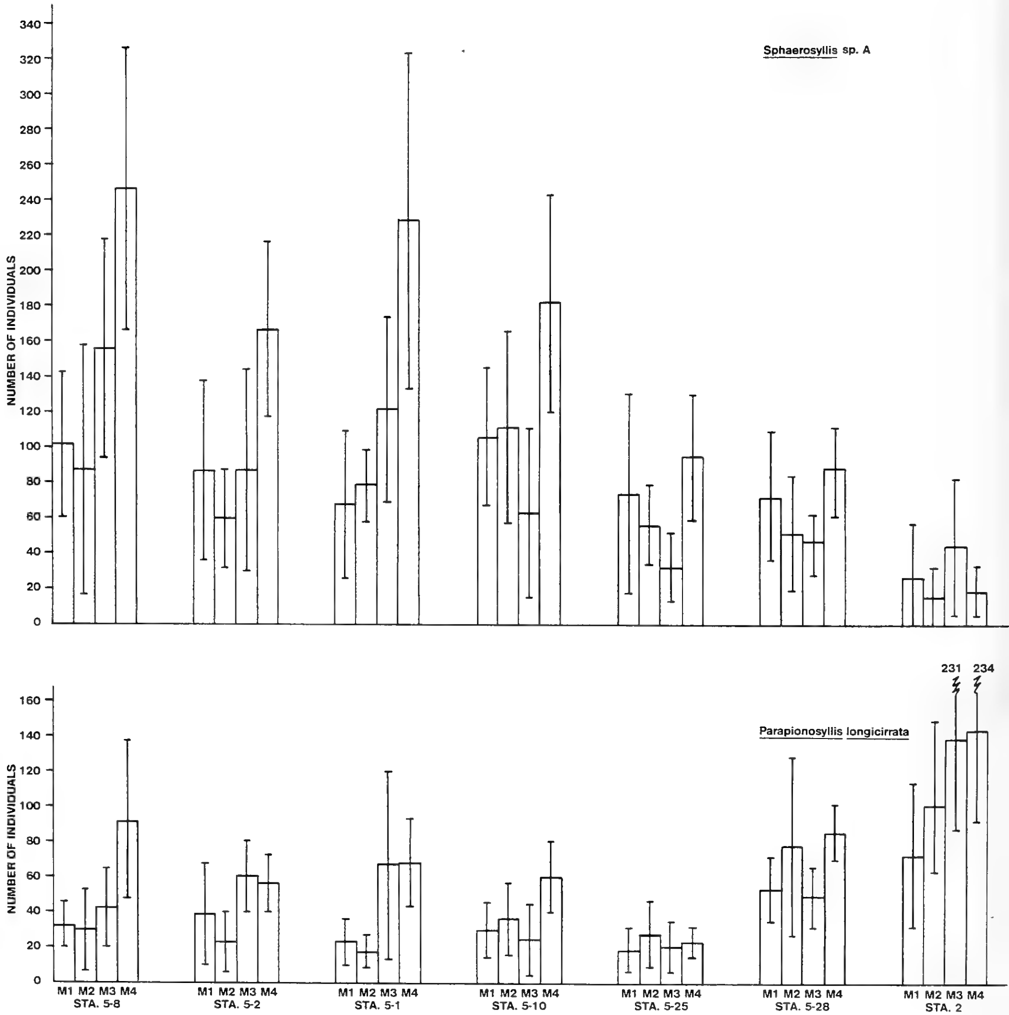


FIGURE 49. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF SPHAEROSYLLIS SP. A AND PARAPIONOSYLLIS LONGICIRRATA AT SELECTED SITE-SPECIFIC STATIONS AND REGIONAL STATION 2 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

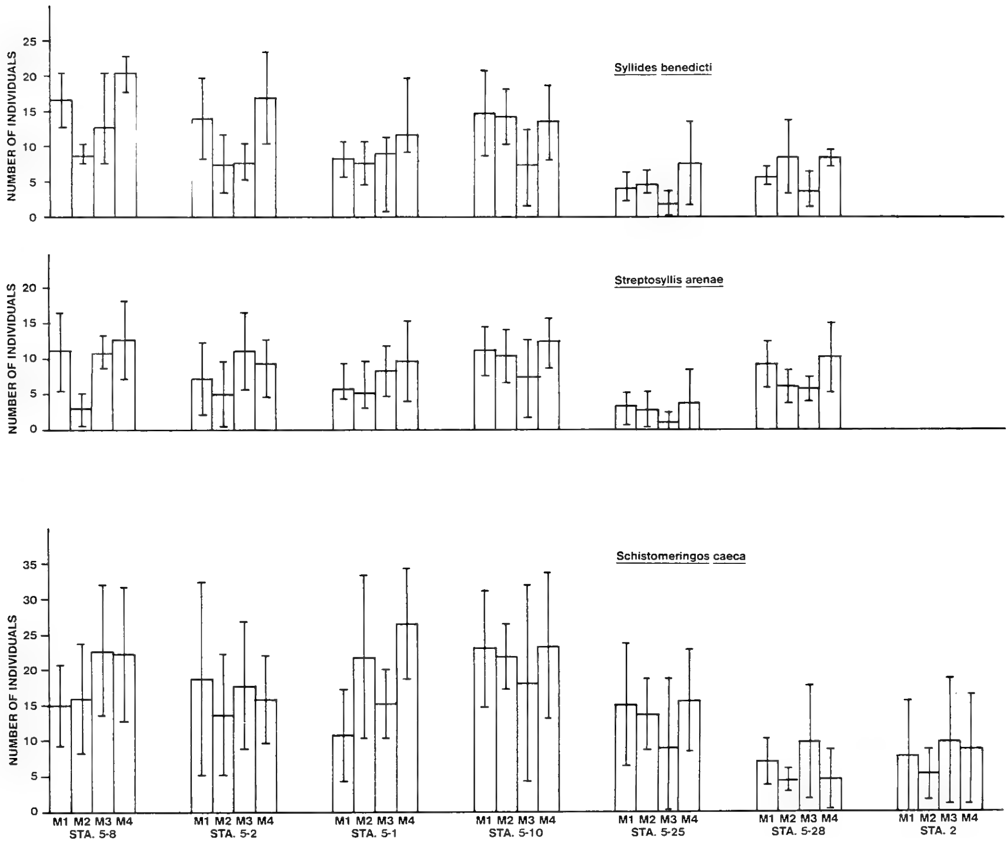


FIGURE 50. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 $\pm$ ONE STANDARD DEVIATION OF THREE COMMON SPECIES AT SELECTED SITE-SPECIFIC STATIONS AND REGIONAL STATION 2 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

TABLE 6. OBSERVATIONS ON THE REPRODUCTION OF SIX SPECIES OF SYLLIDAE.

Species	Cruise	Percent Juveniles	Percent Reproductive
Exogone verugera	M-1	0	0
	M-2	19	2.5 (gametes)
	M-3	18.6	2.8 gametes & larvae
	M-4	9.6	0
Exogone hebes	M-1	39.6	1.0 (eggs & young)
	M-2	43.4	6.6 (gametes)
	M-3	35.6	0.4 (eggs & larvae)
	M-4	48.6	0.1 (eggs & larvae)
Sphaerosyllis sp. A	M-1	26.0	10.0
	M-2	75.0	0
	M-3	81.0	0
	M-4	71.8	0
Parapionosyllis longicirrata	M-1	2.1	5.6 (eggs)
	M-2	60.0	0
	M-3	46.0	0
	M-4	49.4	10.8 (eggs)
Syllides benedicti	M-1	26.0	0
	M-2	43.0	0
	M-3	42.0	14 (eggs & larvae)
	M-4	60.0	17 (eggs & larvae)
Streptosyllis arenae	M-1	20.8	0
	M-2	0.8	1.0 (gametes)
	M-3	39.0	0.01
	M-4	14.0	0.001

TABLE 7. SUMMARY OF TIMING OF REPRODUCTIVE EVENTS IN SIX SPECIES OF SYLLIDAE ON GEORGES BANK.

SPECIES	M-1	M-2	M-3	M-4
Exogone verugera		———	———	
Exogone hebes		———	– –	– –
Sphaerosyllis sp. A	———			
Parapionosyllis longicirrata	———			
Syllides benedicti		———	———	
Streptosyllis arenae		———	– –	–

——— major reproductive events
– – rare occurrence of reproductive individuals

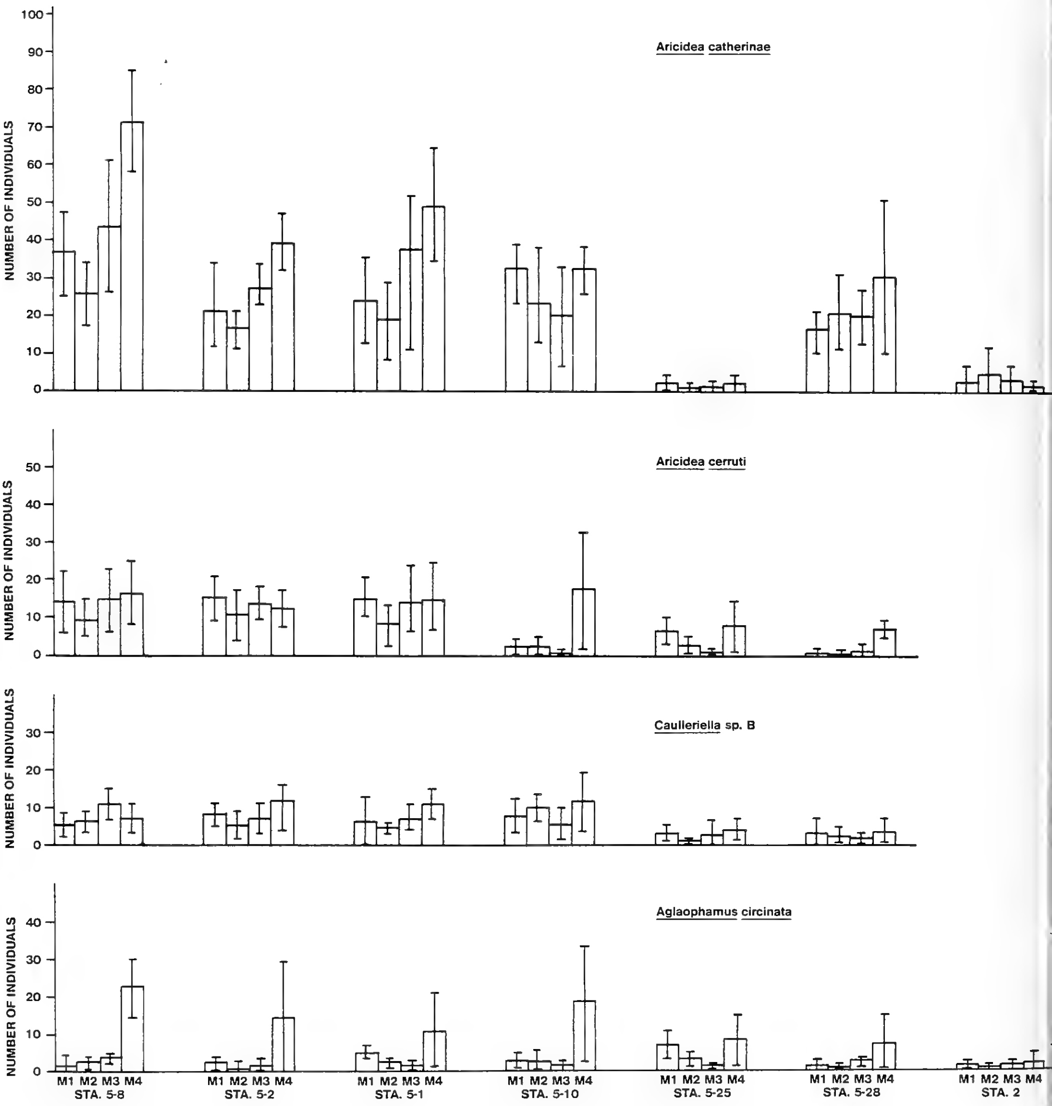


FIGURE 51. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF FOUR SPECIES AT SELECTED SITE-SPECIFIC STATIONS AND REGIONAL STATION 2 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

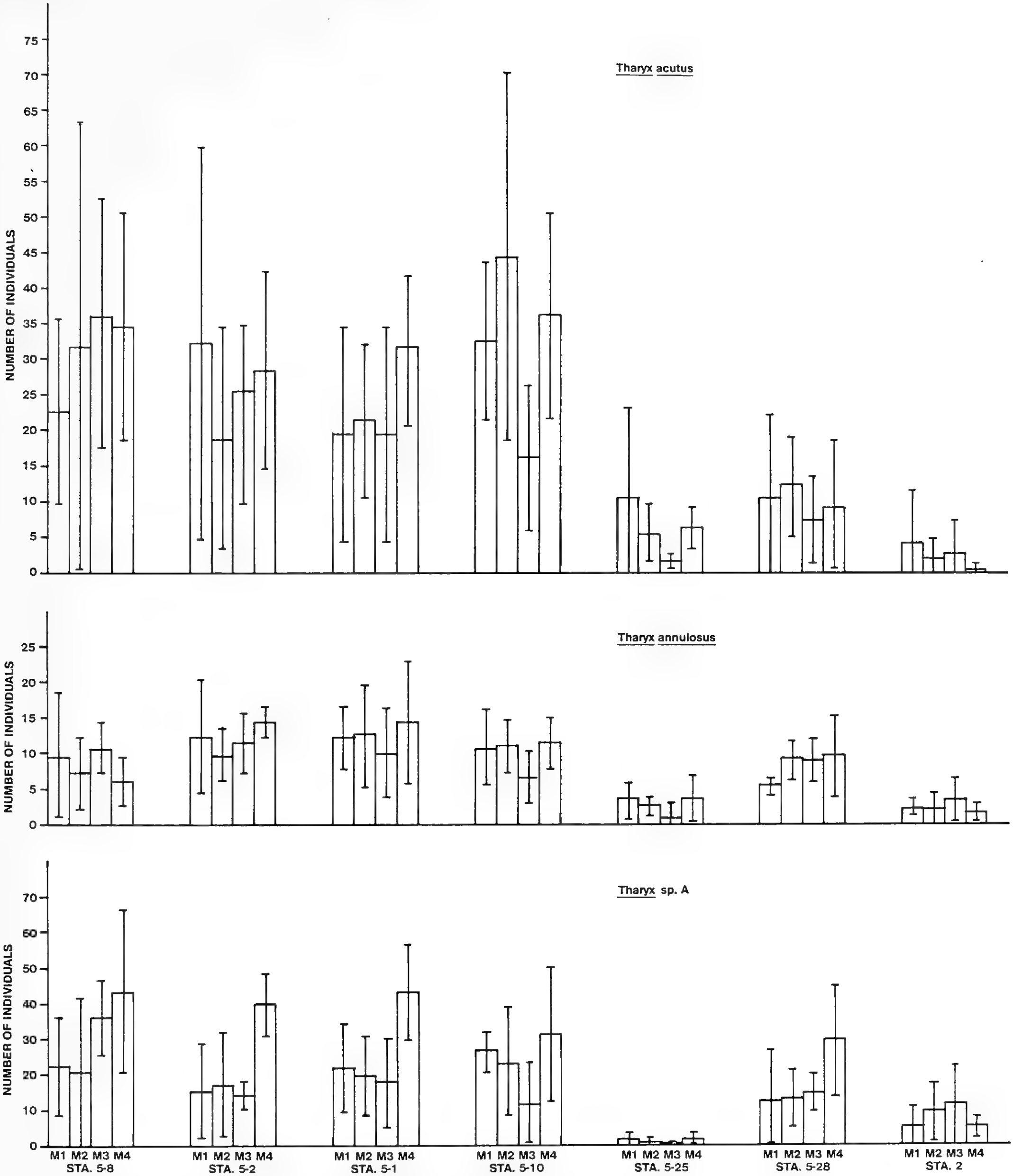


FIGURE 52. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF THREE CIRRATULIDS AT SELECTED SITE-SPECIFIC STATIONS AND REGIONAL STATION 2 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

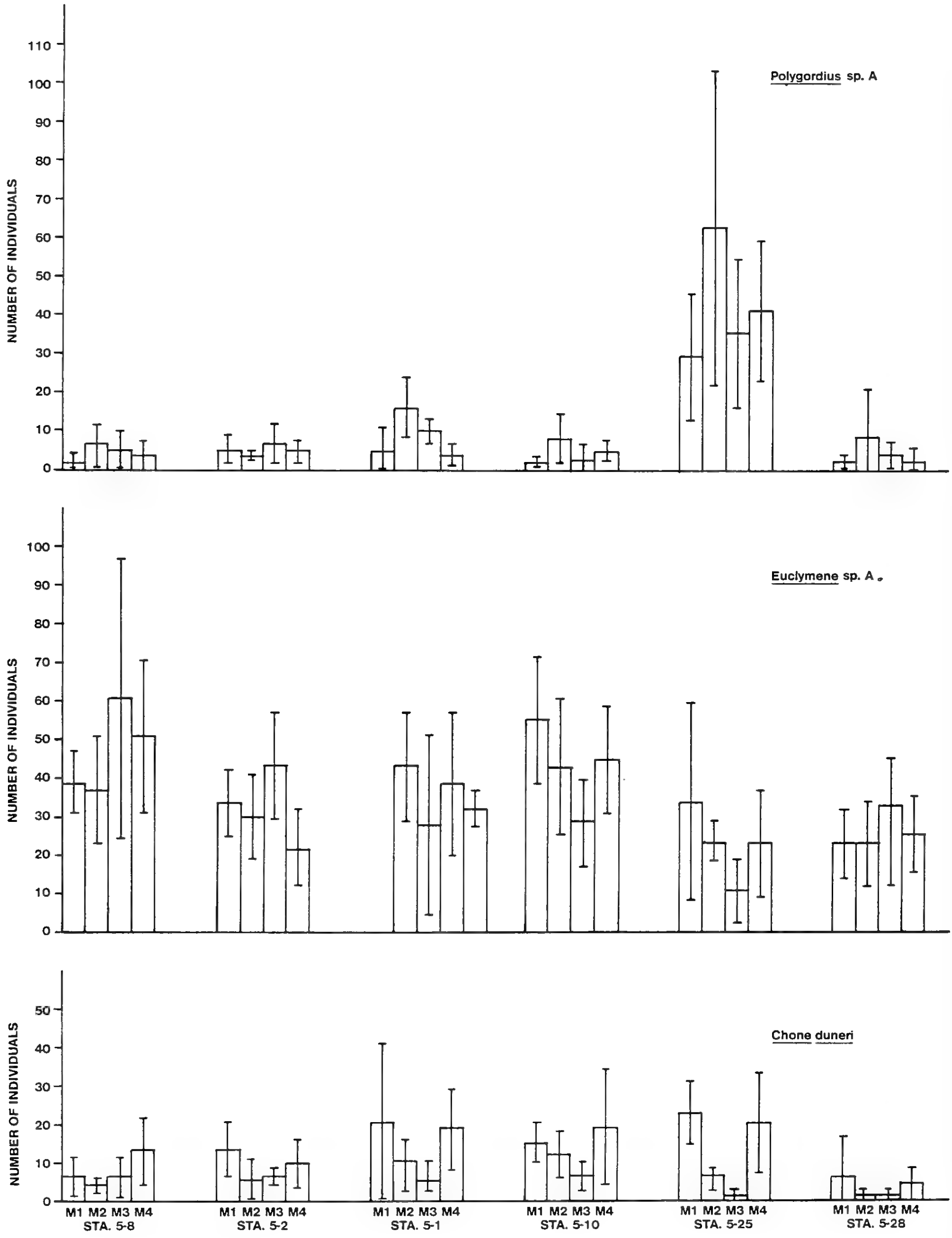


FIGURE 53. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 ± ONE STANDARD DEVIATION OF THREE SPECIES AT SELECTED SITE-SPECIFIC STATIONS IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

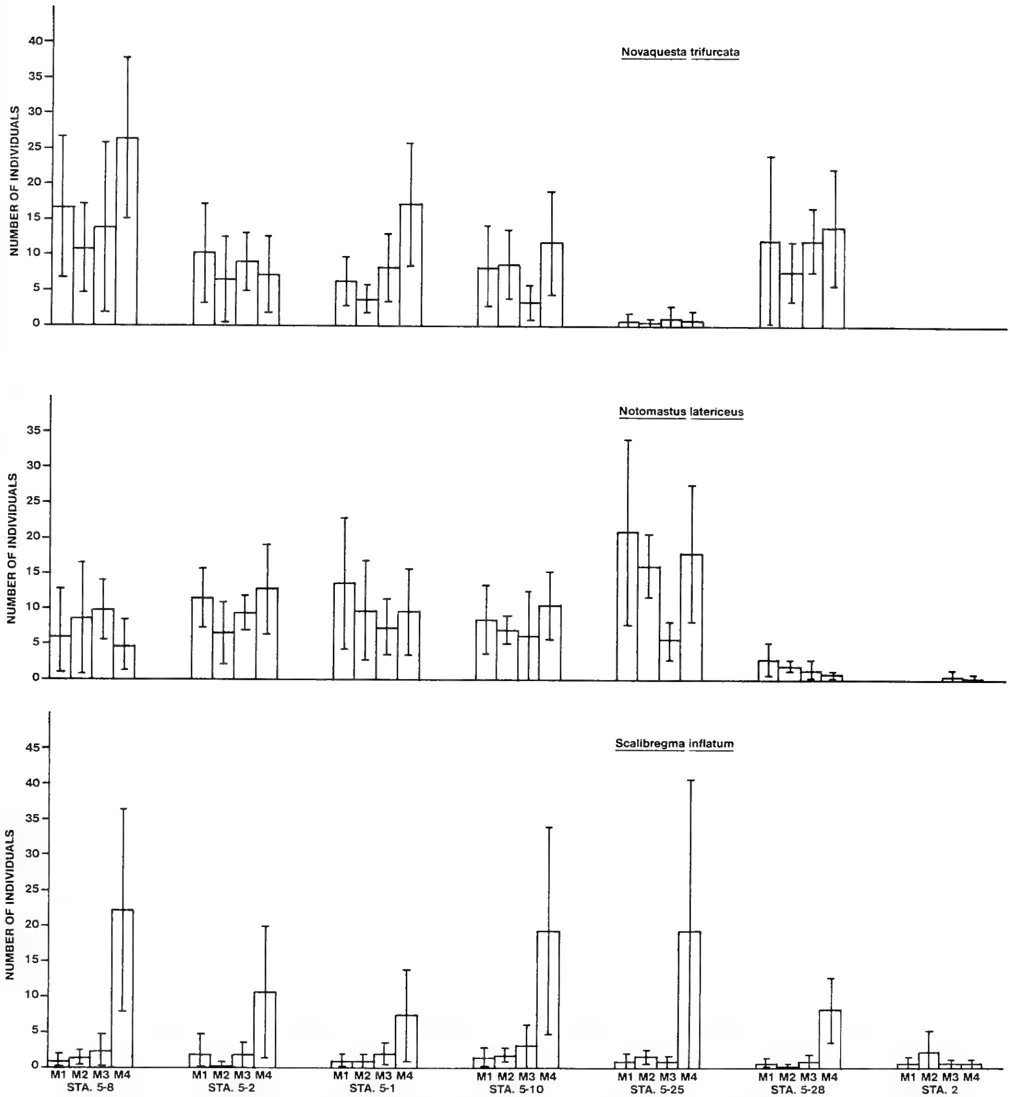


FIGURE 54. AVERAGE NUMBER OF INDIVIDUALS PER 0.04 M^2 $\pm$ ONE STANDARD DEVIATION OF THREE SPECIES AT SELECTED SITE-SPECIFIC STATIONS AND REGIONAL STATION 2 IN JULY (M-1), NOVEMBER (M-2), FEBRUARY (M-3) AND MAY (M-4).

TABLE 8. PERCENTAGE OF JUVENILES (<5 mm) OF EUCLYMENE sp. A AT SIX SITE-SPECIFIC STATIONS FOR FOUR SEASONAL SAMPLING PERIODS

Station	July M-1	Nov. M-2	Feb. M-3	May M-4
5-8	19.1	32.2	27.6	21.0
5-2	22.2	34.0	46.0	7.1
5-1	29.2	32.5	37.3	13.0
5-10	17.0	16.5	26.5	10.5
5-25	17.4	30.0	51.0	12.6
5-28	22.2	21.8	26.3	12.0

Scalibregma inflatum (Figure 54) departs completely from the general pattern by showing only a slight variation in population density from July (M1) to February (M3), and a substantial increase in May (M4). This increase is not as great at the control Stations 5-28 and 2.

Two bivalve molluscs, Cyclocardia borealis and Cerastoderma pinnulatum (not figured), exhibit density patterns related to those described for total individuals. C. pinnulatum decreased in total density from July (M1) through May (M4) at all six site-specific stations, but the numbers of individuals retained on the 0.3 mm screen were highest during July (M1) and February (M3). This suggests recruitment at those times, yet total numbers declined throughout. The density of C. borealis declined in November (M2) at Stations 5-2, 5-10 and 5-25, but not at Stations 5-8 or 5-1. Since the patterns at Stations 5-8 and 5-1 were similar to the control Station 5-28, results are inconclusive for these two species.

5.3 Sediments

Sediment grain size analyses from regional stations indicated that, with the exception of Station 13, the sediments consisted of greater than 95% sand. Station 13, as sampled in July (M1), consisted of 50% very fine sand and 50% silt/clay. Station 13A, established in May (M4), consisted of 82% silt/clay. The higher percentage of silt/clay at Station 13A supports the contention that this is even more of a depositional area than Station 13. Figures 55 and 56 are cumulative curves for the average of six replicate samples from each regional station collected in May (M4). Similar curves, plotted but not presented here for the primary site-specific stations centered around Regional Station 5, indicated that 18 of the 19 stations were nearly similar in sediment composition. The exception is Station 5-29, which had higher percentages of finer sediments. This station also appeared dissimilar to the others in terms of faunal composition and diversity (see above). The percentage of fine sand at site-specific stations was generally higher in February (M3) than in November (M2) or May (M4). Tables D-1 and D-2 in Appendix D give the average percent composition of gravel, very coarse sand, coarse sand, medium sand, fine sand, very fine sand, silt and clay for each collecting period for site-specific stations and Block 410 Stations 16, 17, and 18, respectively.

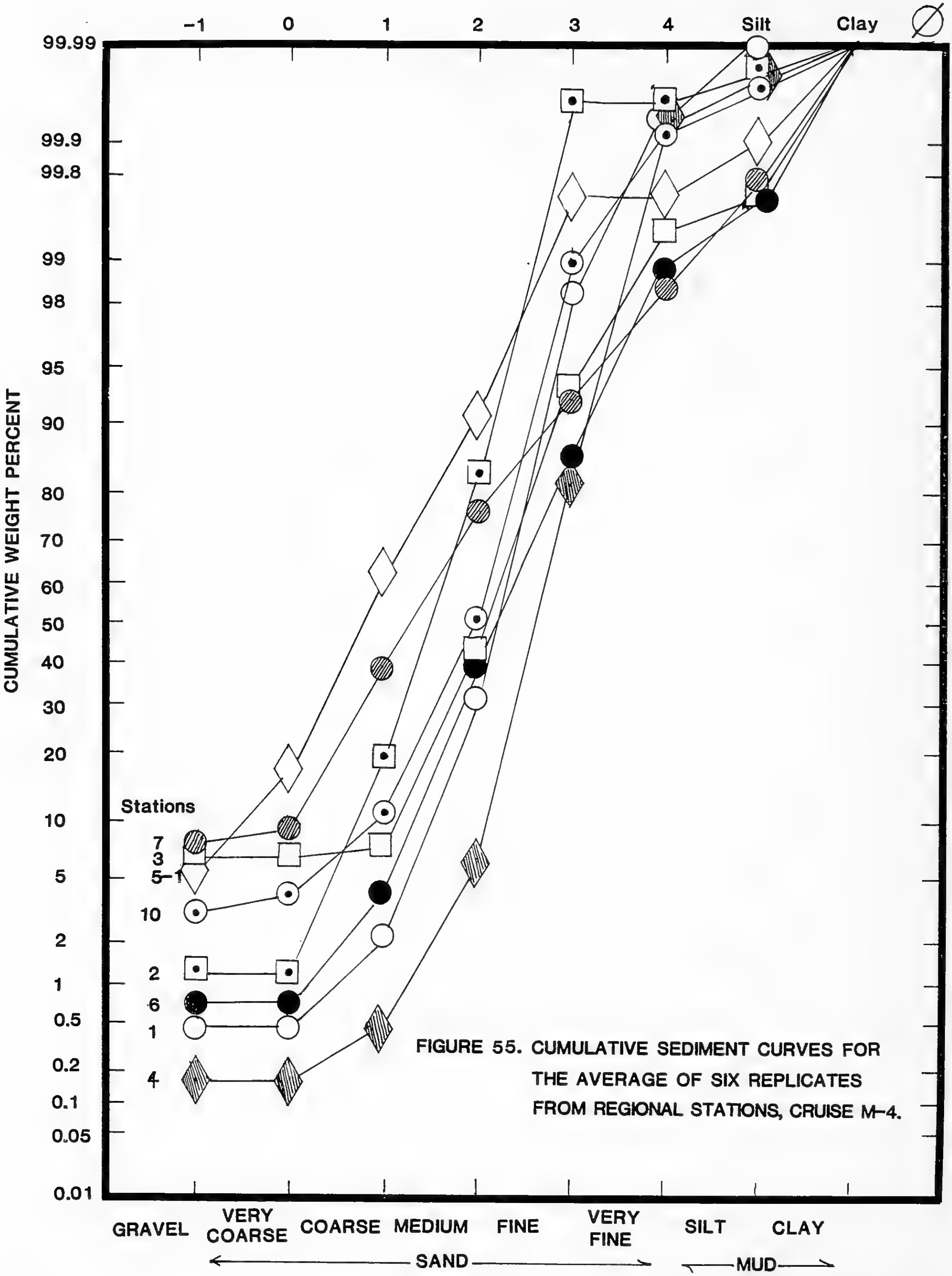


FIGURE 55. CUMULATIVE SEDIMENT CURVES FOR THE AVERAGE OF SIX REPLICATES FROM REGIONAL STATIONS, CRUISE M-4.

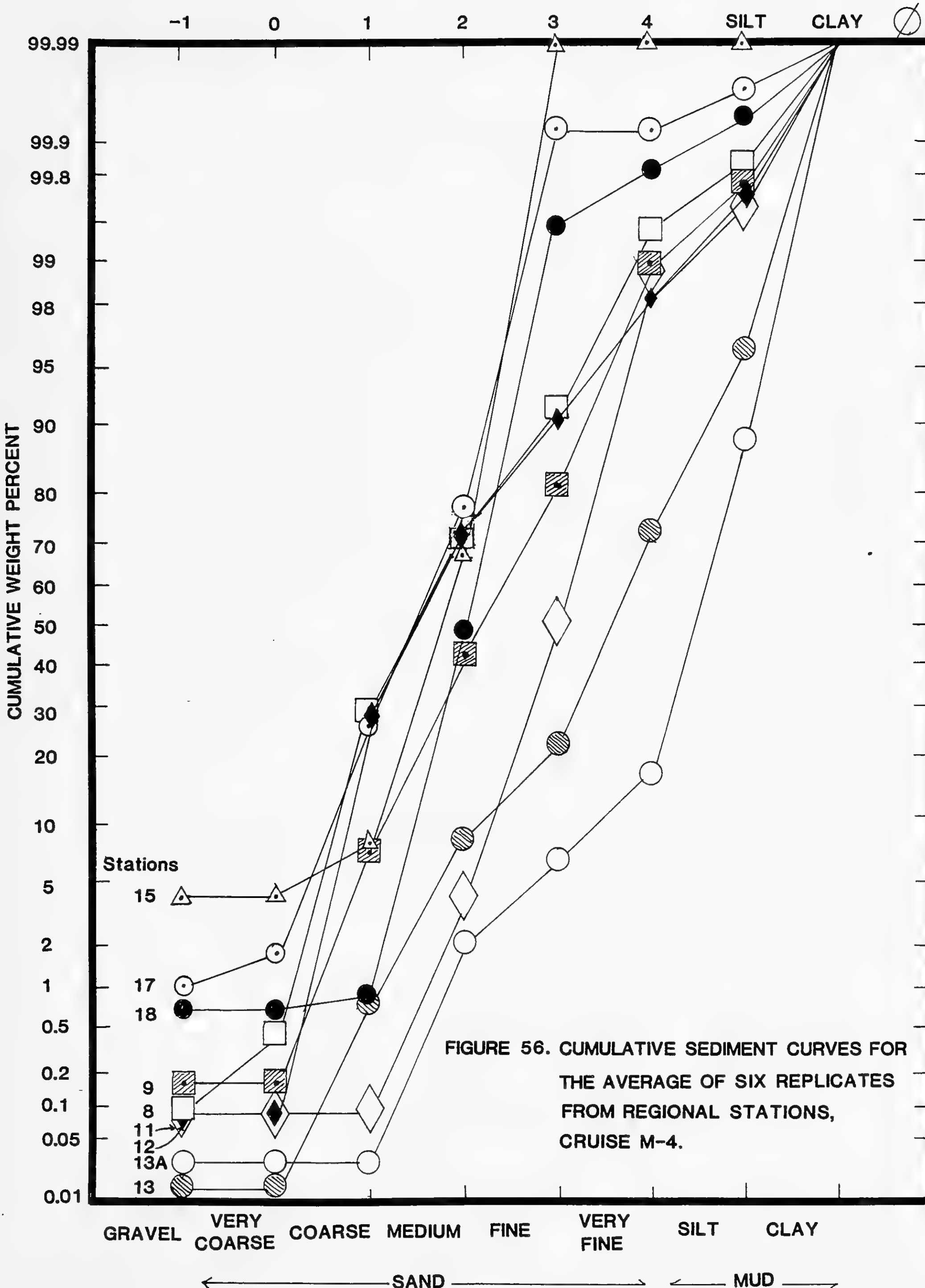


FIGURE 56. CUMULATIVE SEDIMENT CURVES FOR THE AVERAGE OF SIX REPLICATES FROM REGIONAL STATIONS, CRUISE M-4.

5.4 Bottom Photographs

The stations for which useful film footage was obtained and analyzed for cruises M1 through M4 are shown in Table 9. The stations photographed, number of frames exposed, and quality of the film were all affected by several factors.

The bottom contact switch failed to operate at several regional stations on Cruise M2. The camera was lost on that cruise when a large swell caused the hydrowinch wire to snap. The camera was later recovered, but most of the site-specific stations were not photographed.

Mechanical problems during Cruise M3 reduced the number and quality of photographs obtained. A strobe malfunction caused the areas photographed to be poorly illuminated, if at all. Rapid advancement of the film resulted in only alternate frames being exposed, and no film was exposed at several regional stations.

Rough seas prevented camera use for much of Cruise M4. Although many stations were reoccupied for camera work, the focal point of the strobe was misaligned when the bottom contact switch wire was shortened, resulting in very dark and therefore unusable photographs for many M4 stations. This dark film was stepped-up during development in an effort to overcome the problem; however, this was only partially successful.

If available, at least 6 frames from each station/cruise were analyzed for microtopographical features and densities of visible epifauna. A descriptive summary of the results of this analysis is presented in Table 10. The qualitative information developed through inspection of the photographs complimented the quantitative results of the infaunal grab analysis in several ways. It confirmed the patchy distribution of certain species, particularly the sand dollar, Echinarachnius parma, whose numbers varied widely in replicate grab samples at Stations 1, 4 and 10. Seasonal changes in topographical features such as ripple marks became apparent. Of particular interest was the potential accumulation of drilling muds or cuttings around the 2 drilling rigs. No such accumulations were noted in any of the photographs examined.

5.4.1 Microtopography of Regional Stations

Several regional stations, generally those at the same depth interval, showed similarities in surface topography, amount of detritus or biological cover, and sediment

TABLE 9. STATIONS FROM WHICH USEFUL FILM FOOTAGE WAS OBTAINED ON GEORGES BANK MONITORING CRUISES

SITE-SPECIFIC STATIONS

	5-1	5-2	5-3	5-4	5-5	5-6	5-7*	5-8	5-9	5-10	5-11	5-12	5-14	5-16	5-18	5-19*	5-20	5-22	5-25	5-28	5-29
M-1	x	x					x	x	x	x	x			x	x	x	x	x	x	x	x
M-2														x	x				x		x
M-3	x	x		x	x	x		x	x	x	x	x	x	x	x		x	x	x	x	x
M-4																					

REGIONAL STATIONS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
M-1	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
M-2	x	x	x	x			x	x	x	x	x	x			x	x	x	x
M-3	x				x	x	x	x				x				x	x	x
M-4	x	x	x	x						x	x	x				x	x	x

* = Secondary Site-Specific Stations

TABLE 10. SUMMARY OF RESULTS OF BOTTOM PHOTO ANALYSIS

Regional Stations	Biota	Sediments & Surface Topography	M-1 vs. M-2 vs. M-3 vs. M-4
1	Dominated by sand dollar, Echinarachnius parma; empty Arctica islandica shells; Raja sp. and Urophycis chuss in some frames.	Sandy, with fine shell hash in troughs of ripples; ripples asymmetrical, discontinuous, low, frequent.	Fewer E. parma in M-3; M-1 ripples more symmetrical than those in M-2 or M-3. M-4 with few small ripples.
2	Few organisms visible; 1 Placopecten magellanicus, 1 Raja sp., 1 Asterias vulgaris, & Arctica islandica shells seen.	Sandy, sorted with coarser sediment in troughs of ripples; ripples asymmetrical, discontinuous, low, frequent.	M-1 ripples much less distinct than those in M-2; M-4 bottom flat, without ripples.
3	Asterias vulgaris, Leptasterias tenera & Ctenodiscus sp. common; Urophycis chuss & Placopecten magellanicus also noted. Many empty Arctica shells.	Silt and sand with some detritus; no ripples; biogenic features evident.	M-1, M-2, and M-4 similar.
4	Dominated by sand dollar, E. parma; empty Arctica islandica shells; a few U. chuss, Cancer borealis.	Sandy; ripples asymmetrical, discontinuous, low, and frequent.	M-1 and M-4 ripples less distinct, less common than in M-2.
5 (and SS* (Stations)	Leptasterias tenera & Asterias common; empty Arctica shells.	Coarse sand, large amount of detritus; bottom flat (M-1) or with irregular, asymmetrical ripples (M-2, M-3).	Evidence of ripples in M-2 and M-3, not present in M-1.
6	Asterias sp. common, also U. chuss and Limanda ferruginea; many empty Arctica shells.	Sand and silt with some detritus; biogenic features evident.	M-1 and M-3 similar, but more shell fragments and other debris in M-3.
7	Few organisms visible, many conical, elevated burrow entrances visible; many surface depressions with burrow entrances centrally located also present.	Sand and silt with fine shell hash and detritus; bottom is flat and smooth except for biogenic features.	M-1 shows least amount of surface relief; M-2 has more shell hash, most contoured bottom; M-3 shows many times more shell hash and debris, possibly some evidence of bottom current.
8	Few organisms visible, some starfish & 1 large ophiuroid; burrow entrances in almost every frame.	Sandy, with small amount of fine shell hash; bottom is mostly flat and smooth except for biogenic features	M-3 shows some very low ripples.

TABLE 10.(continued)

Regional Statons	Biota	Sediments & Surface Topography	M-1 vs. M-2 vs. M-3 vs. M-4
9	Cancer borealis present.	Sandy, with some detritus, fine shell hash; ripples asymmetrical, low, discontinuous.	M-1 bottom mostly smooth, M-2 with ripples.
10	Dominated by sand dollar, E. parma; empty Arctica islandica shells; Raja sp. and Cancer borealis present.	Sandy, with some shell hash; ripples irregular, asymmetrical, discontinuous; orientation and development of ripples varies between frames.	M-1, M-2 and M-4 similar.
11	E. parma, Asterias sp. common, empty Arctica shells.	Sandy, little or no detritus; ripples both symmetrical and asymmetrical; irregular, discontinuous.	M-1 ripples more symmetrical and linear; M-2 ripples very irregular and convoluted. M-4 without ripples.
12	Ctenodiscus sp. and Asterias sp. numerous, E. parma, Limanda ferruginea, hermit crabs and empty Arctica shells also present.	Sand and silt with some fine, light detritus; bottom flat and featureless except for small shallow depressions.	M-1, M-2, M-3, and M-4 all similar.
14	Starfish present.	Sandy, with some detritus and a few shell fragments, topography varies from flat to large, well-formed asymmetrical ripples.	M-1 film dark, poor resolution; no M-2, M-3, or M-4 film available.
15	Raja sp., empty Arctica shells present.	Sandy with small patches of debris or detritus in depressions; ripples very irregular, vary in orientation, size, and symmetry.	M-1 ripples more pronounced than M-2; M-2 frames often show large ridge and trough across frame.
16	Leptasterias tenera common; Raja sp., Limanda ferruginea, Urophycis chuss and snake eels present; empty Arctica and Placopecten shells and fragments common.	Coarse sand with covering of detritus and shell hash; some evidence of fish-feeding activity; bottom flat, except in M-3 when low ripples are evident.	M-1, M-2, M-4 similar; M-1 has more detritus and less visible shell hash; M-3 with ripples.
17	Few organisms visible, Leptasterias tenera, Asterias sp. and Oreaster present; empty Arctica shells.	Sandy with fine shell hash and detritus; bottom flat, but some rounded, symmetrical ripples in M-3.	M-1, M-2, and M-4 bottom flat; M-3 with ripples.
18	Urophycis chuss, Asterias sp., and Leptasterias tenera common.	Sand and silt with a cover of coarse detritus; fish-feeding depressions present.	M-1 lacks U. chuss and feeding depressions. M-2 and M-4 similar; M-3 with ripples.

*SS = Site-Specific

type. Although differences were often noted between frames taken at a single station on a particular cruise, and also between cruises, the following general groupings of stations can be delineated.

I. Stations 1, 4, and 10, approximate depth 60 m

Sediment sandy, well-sorted, without detritus. Small amount of fine shell hash in troughs of ripples. Small, discontinuous, frequent, asymmetrical ripples present.

II. Stations 2 and 11 - depth between 70 and 80 m

These two stations are similar to Stations 1, 4, and 10. Sediment is coarser, with some detritus and larger shell fragments present. The ripples are symmetrical, and more linear.

III. Stations 3, 6, and 12 - approximate depth 100 m

These stations are characterized by silty sediment covered with detritus and shell fragments. The shell fragments are of all sizes and most are partially covered with detritus. The bottom is flat except for some biogenic features. Station 7 is similar but has less detritus and shell fragments.

IV. Stations 8 and 9 - depth 145 m

Sediment is sand and silt, with a small amount of fine detritus and fine shell hash. There is some contour to the bottom. Ripples are not very distinct but some low, rounded, symmetrical ripples are present. Biogenic features are evident, most are faint trails across the sediment.

V. Stations 16, 17, and 18 - depth 140-145 m

The Block 410 stations are situated very close together and are very similar. Sediment consists of sand and silt with some fine and medium textured detritus. The bottom is flat but not smooth. There are many biogenic features and disturbed areas.

Photographs from Stations 14 and 15 are of poor quality, partially due to water turbidity. It can be seen that the bottom is very irregular. Ripples and bottom contour vary. There appears to be very little detritus or shell fragments.

The differences in these groups seem to be a function of the presence and strength of water currents. The shallower stations of group I have obvious ripples and well-sorted sediment without detritus indicating a higher energy environment. In contrast, the deeper stations of groups II and III have relatively featureless surfaces with fine sediment and are littered with more shell fragments and a more uniform cover of detritus or biological material.

The degree of water movement varies not only between different areas but also between seasons. The photographs show similar seasonal changes for nearly all stations. This is illustrated by photographs from Block 410, Stations 16, 17, and 18 (Figures 57-62). There are concurrent changes in surface topography and detritus cover. As the bottom becomes more contoured and ripples begin to form, the amount of detritus is reduced. Photographs from M1 and M4 are most similar, reflecting more stable conditions during July and May. The bottom has less contour and the fine detritus is uniformly distributed. M2 and M3 photographs, taken during November and February, show irregular surface topography and patchy, coarser detritus. M3 (February) photographs in particular show rippled sediment at most stations.

5.4.2 Microtopography of Site-Specific Stations

The site-specific stations, located at Regional Station 5, at an average depth of 80 m are all very similar. Most are characterized by poorly sorted, sandy sediment with some silt; a fairly uniform cover of medium-to-coarse detritus; shell fragments of all sizes and flat surface topography with many biogenic features.

As in the regional stations, consistent seasonal changes can be seen (Figures 63-65). The above description of site-specific stations is most accurate for Cruise M1

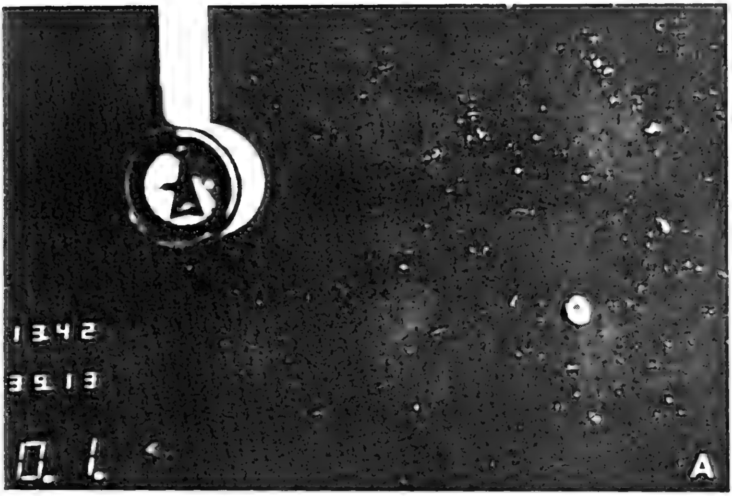


FIGURE 57. REGIONAL STATION 16

A. July, 1981 (M-1). Note scattered shell debris and large mounds indicative of a burrowing animal.

B. November, 1981 (M-2). Greater amount of shell hash and coarse sediment present.

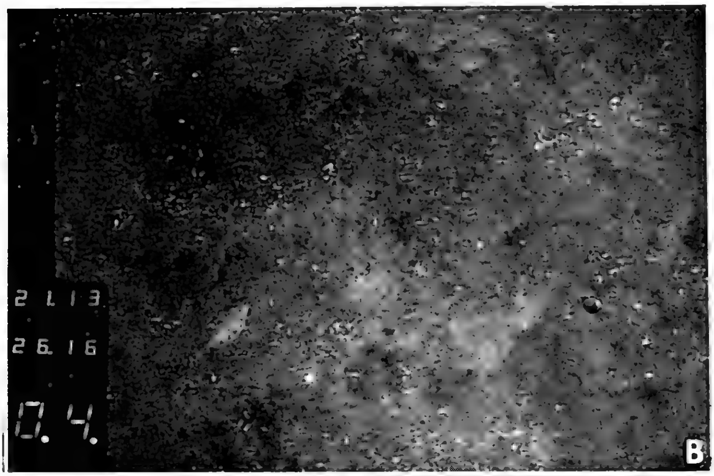


FIGURE 58. REGIONAL STATION 16.

A. February, 1982 (M-3). Bottom appears slightly rippled.

B. May, 1982 (M-4). Irregular rows of animal burrows and fine shell hash are evident. Less coarse sand present and more silt seen than in February, 1982 (M-3). Note flounder, Paralichthys dentatus, in lower left quadrant.

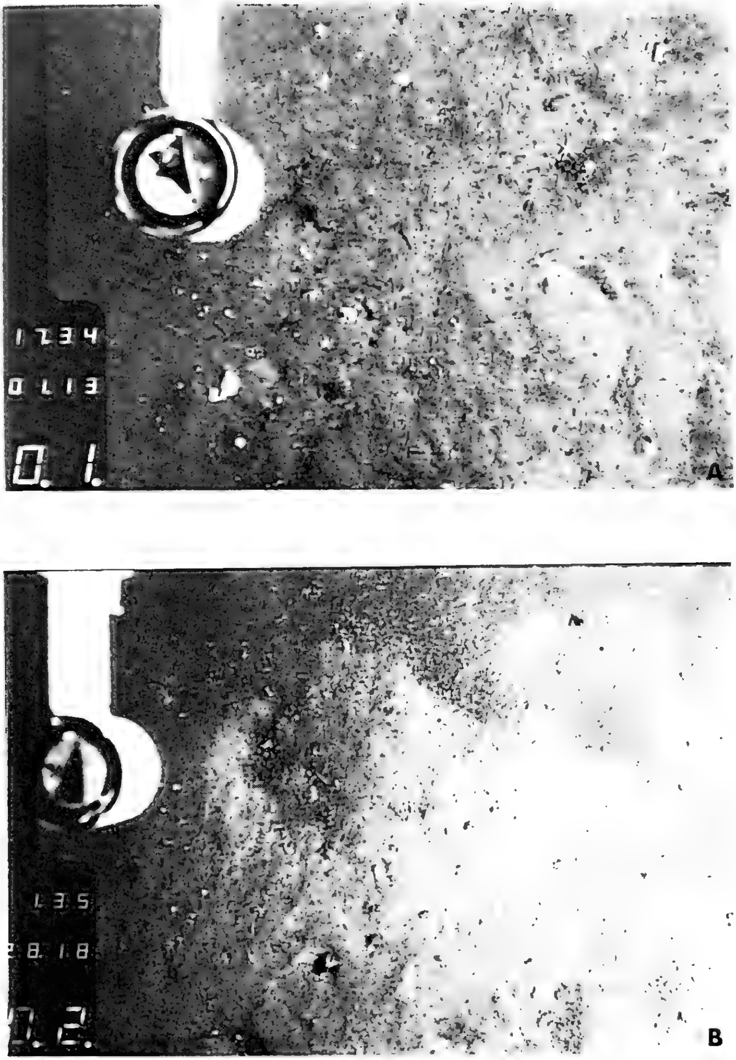


FIGURE 59. REGIONAL STATION 17

A. July, 1981 (M-1). One small asteroid, <u>Leptasterias</u> <u>tenera</u> is present in the right half of this frame. Burrow entrances and animal traces are present in the center.

B. November, 1981 (M-2). Several large feeding depressions, probably formed by demersal fish, are evident. Shell hash is present in moderate amounts and sediment is coarser than that seen in February, 1982 (M-3) and May, 1982 (M-4) photographs.

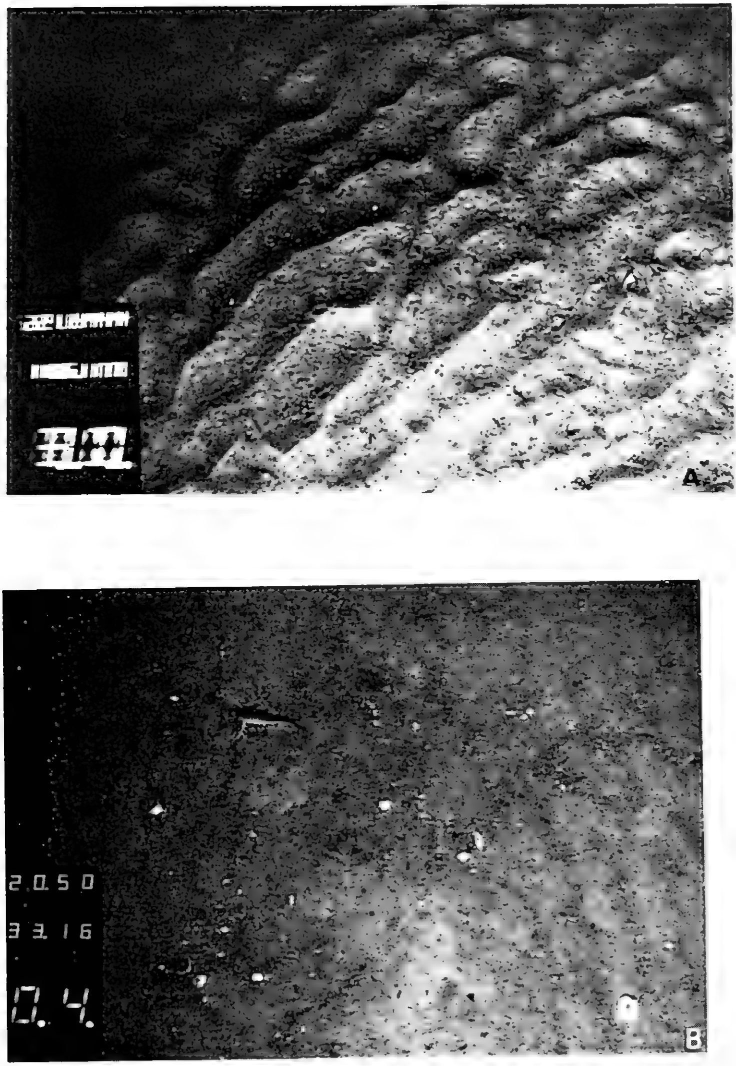


FIGURE 60. REGIONAL STATION 17

A. February, 1982 (M-3). Symmetrical, discontinuous ripples were characteristic of this station in February. A few biogenic features and small amounts of shell hash are evident.

B. May, 1982 (M-4). Bottom is only slightly rippled, with some fine shell debris present in troughs. Sediment is finer than that seen in February, 1982 (M-3) photographs. Urophycis sp. present in upper left quadrant.

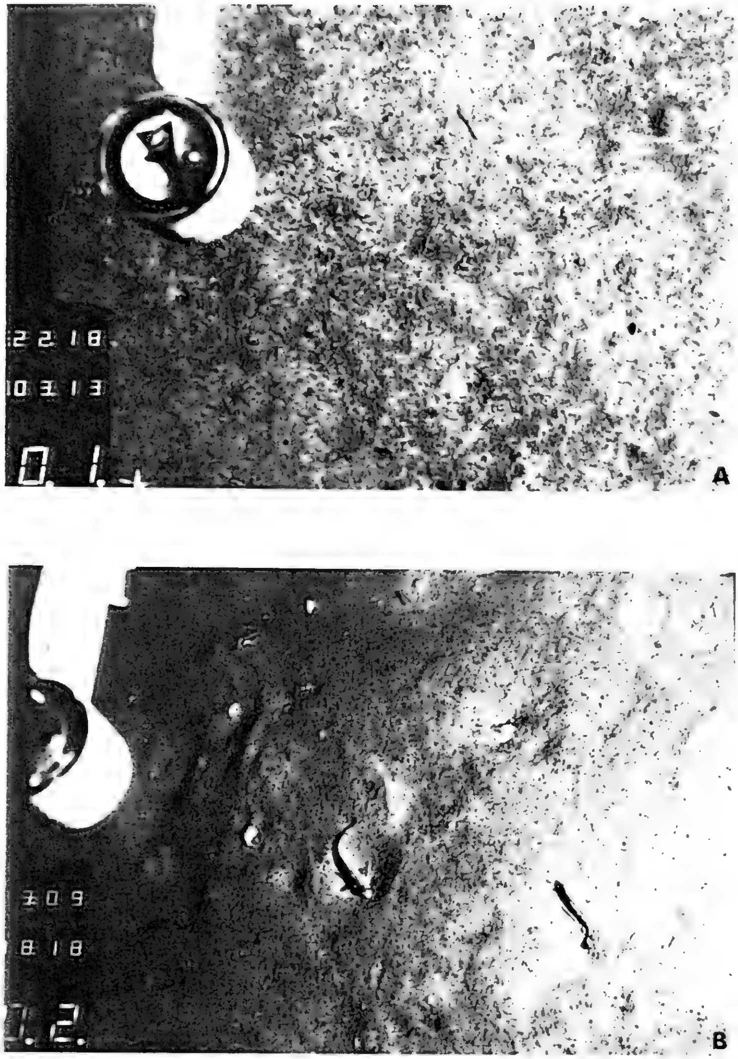
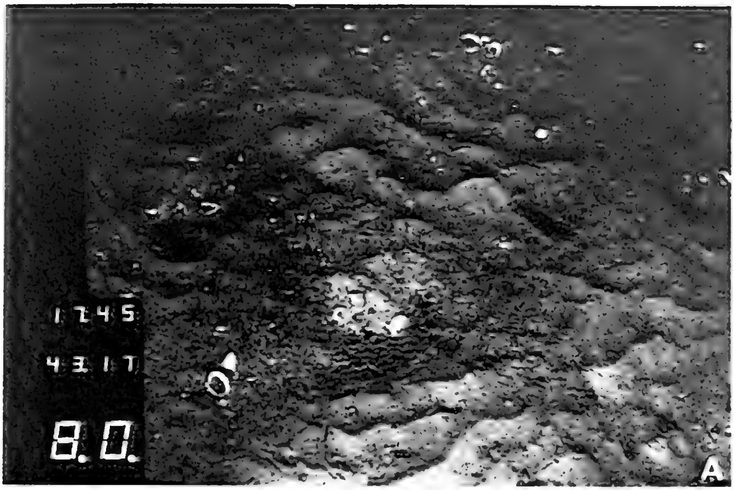


FIGURE 61. REGIONAL STATION 18

A. July, 1981 (M-1). Sediment appears to be sand overlain by biological mat, mostly Ampelisca tubes.

B. November, 1981 (M-2). Biological mat is less evident, but several small depressions are noticeable. A Urophycis sp. sits in the center of one such feature.



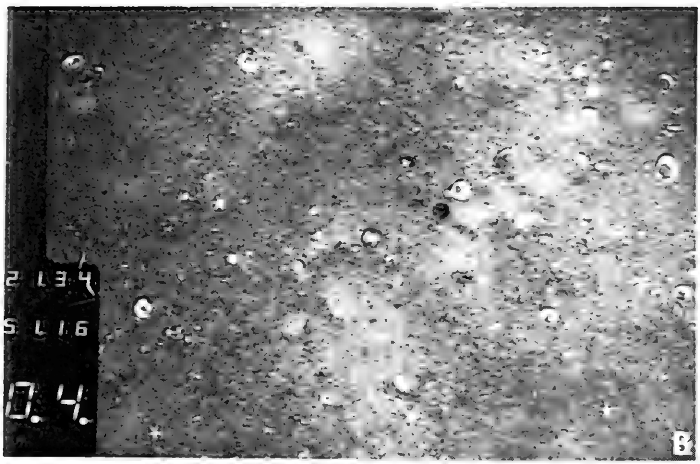
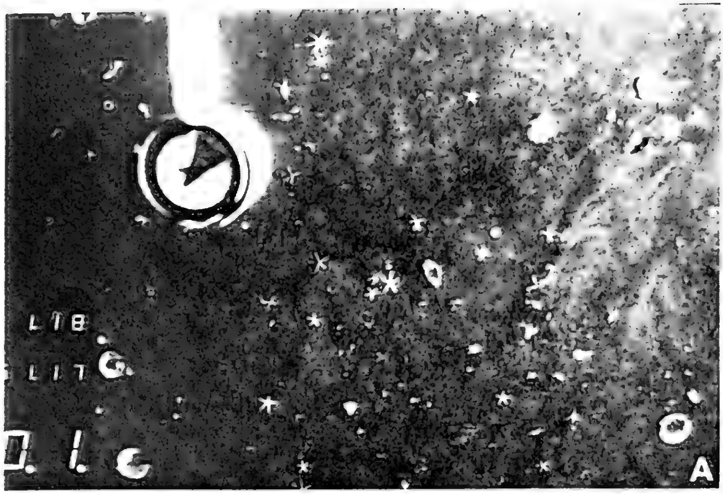


FIGURE 62. REGIONAL STATION 18

A. February, 1982 (M-3). Bottom shows high relief, with irregular discontinuous ripples and depressions. Shell hash has been deposited in depressions and sediment is slightly coarser than that in November, 1982 (M-2) and May, 1982 (M-4) photographs.

B. May, 1982 (M-4). Bottom appears flat, with Arctica valves in irregular rows. Several small Asterias vulgaris are present.



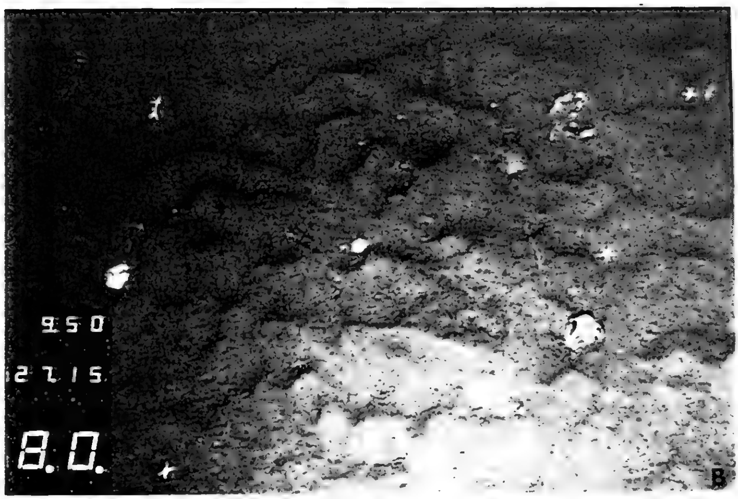
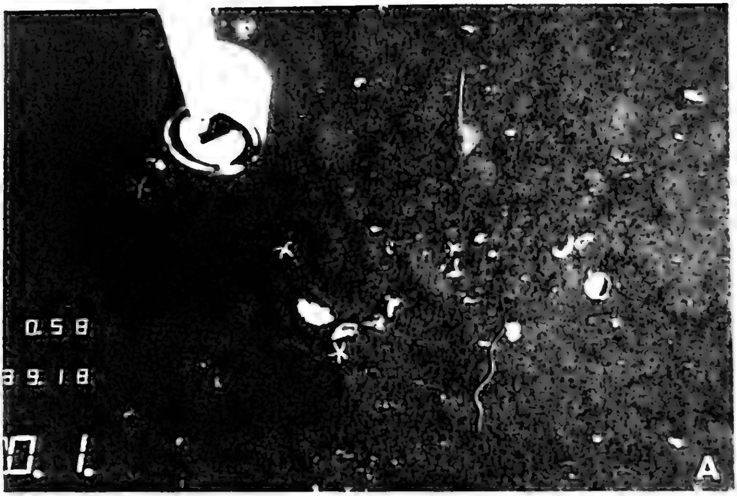


FIGURE 63. SITE-SPECIFIC STATION 5-1

A. July, 1981 (M-1). Sandy sediments covered by a dense biological mat, and many small asteroids (Leptasterias tenera and Asterias vulgaris are typical of this station.

B. February, 1982 (M-3). Starfish are fewer in number, and bottom is characterized by irregular, discontinuous ripples.



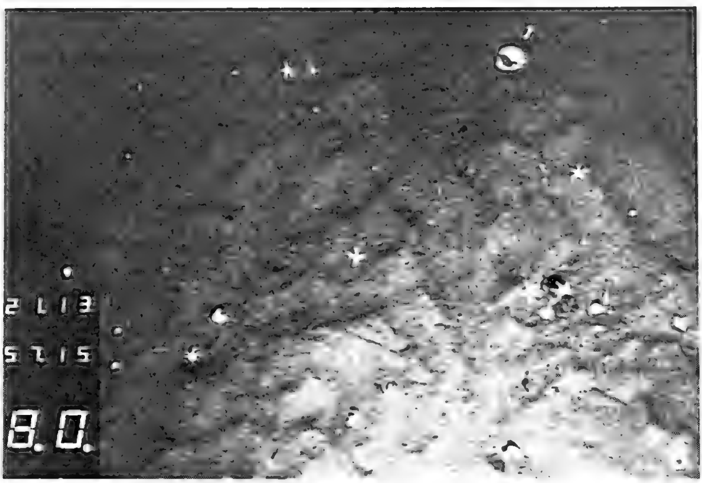
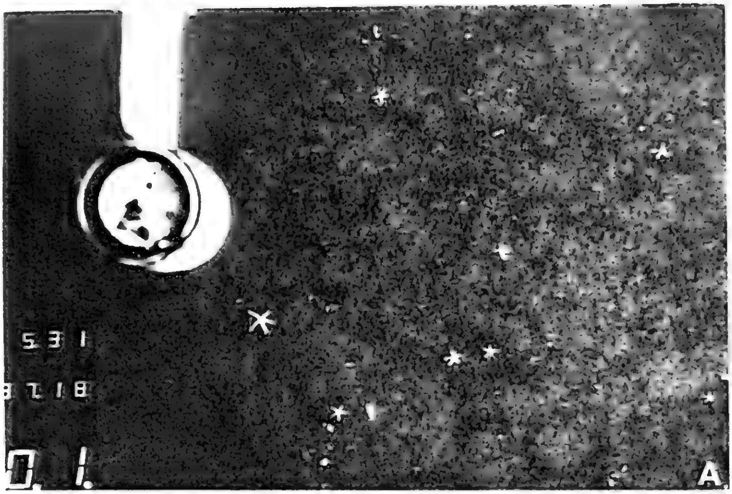


FIGURE 64. SITE-SPECIFIC STATION 5-10

A July, 1981 (M-1). A dense biological mat covers the bottom. Several starfish, a sand eel, Omochelys cruentifer, and a skate, Raja sp., are present near the center of the frame.

B. February, 1982 (M-3). Biological cover is reduced, although several starfish are present. Bottom is characterized by very irregular, discontinuous ripples.



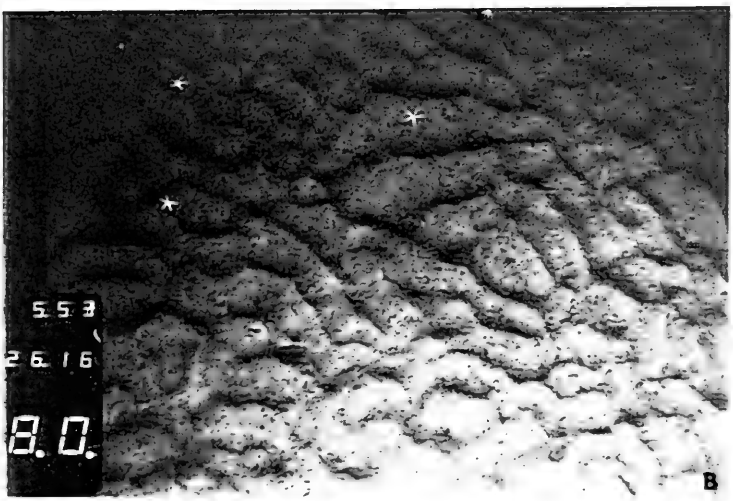


FIGURE 65. SITE-SPECIFIC STATION 5-11.

A. July, 1981 (M-1). A dense biological mat is present, and several Leptasterias tenera.

B. February, 1982 (M-3). The biological cover is reduced, and the bottom is characterized by discontinuous, irregular ripples.

(July). Contrary to the results of the sediment grain size analysis, the bottom photographs at many of these same stations during Cruise M3 (February) appear to show coarser sediment with very little detritus present, less fine shell hash and more large fragments. The bottom is not smooth but irregular and sculptured, sometimes with ripples and large troughs present.

There are, however, several site-specific stations with unique characteristics. Site-Specific Station 5-29 is distinct in the larger amounts of Arctica shells and fragments covering its surface. The fragments vary in size and most are partially covered by sediment. Photographs from this station did not show any seasonal changes.

Photographs from M3 Site-Specific Stations 5-12, 5-16, 5-22, and 5-28 show a great change in sediment and detritus compared to M1 and M2. The M3 photographs show dark, coarse, sometimes clumped sediment or detritus, usually accumulated in depressions or troughs.

Another unusual feature, present only in the M3 photographs, is the appearance of small, bluish areas of sediment. These as yet unexplained patches are seen at Site-Specific Stations 5-2 and 5-9.

5.4.3 Densities

Visible organisms of 17 taxa were identified and counted from the photographs. The presence of empty Arctica shells was also noted. Densities per square meter were calculated for each taxon in each frame and averaged for each station (Tables 11 and 12. Echinarachnius parma sometimes occurred in dense patches and were impossible to count accurately; in those cases percent cover was used as an indication of abundance.

At regional stations, Echinarachnius parma and asteroid echinoderms are the most numerous organisms. Asterias spp. and Leptasterias tenera were the most common starfish. Ctenodiscus sp. was seen less often. The most common fish were sculpin, Urophycis, Raja and flounder. Lophius americanus and Macrozoarces americanus were rare. Gastropods were seldom seen and Placopecten magellanicus occurred at only two stations. Sponges, hydroid or bryozoan colonies and Cancer irroratus and C. borealis occurred infrequently. Onuphid polychaetes were identified at Station 17 from Cruise M2 photographs and Station 8 from Cruise M3 photographs.

The site-specific stations are characterized by a high number of starfish. Arctica shells are common at almost every station and there are no Echinarachnius parma. Cancer spp., Raja sp., Urophycis sp., and Macrozoarces americanus are less

TABLE 11. AVERAGE DENSITY PER SQUARE METER OF EPIBENTHIC MACROFAUNA IDENTIFIED IN BOTTOM PHOTOGRAPHS TAKEN AT GEORGES BANK BENTHIC MONITORING PROGRAM REGIONAL STATIONS.

		M-1	M-2	M-3	M-4
Sta. 1	Gastropod			3.8	
	Arctica islandica (empty shells)	83	0.2		
	Cancer sp.			0.2	0.4
	Hermit crab	0.2			
	Echinarachnius parma	95	210	95	139
	Myoxocephalus sp.				0.6
	Urophycis sp.	0.1			
Sta. 2	Hydroid colonies	0.3	0.7		1.2
	Arctica islandica (empty shells)	0.4	2.5		
	Placopecten magellanicus	0.1			1.0
	Cancer sp.		0.2		
	Echinarachnius parma		0.2		
	Asteroidea		0.2		
	Asterias sp.	0.1			
	Lophius americanus				0.2
	Raja sp.	0.1			
Sta. 3	Porifera		0.4		
	Anthozoa		0.1		
	Placopecten magellanicus	0.4	0.7		0.2
	Cancer sp.	0.1	0.3		0.2
	Hermit crab	0.1	0.1		
	Asteroidea	0.7	0.2		
	Asterias sp.	0.8	1.1		6.2
	Leptasterias tenera	0.3	0.2		
	Ctenodiscus sp.	2.8	0.4		
	Urophycis sp.	0.2			
	Raja sp.	0.1			
Sta. 4	Porifera				0.2
	Hydroid colonies	0.8	2.5		3.0
	Gastropod	0.1			
	Arctica islandica (empty shells)	12.1	0.5		1.8
	Cancer sp.	0.2	0.2		
	Echinarachnius parma	31.2	+		
	Asteroidea	0.2	0.3		0.8
	Asterias sp.	0.5			
	Urophycis sp.	0.1	0.2		

TABLE 11. (continued)

		M-1	M-2	M-3	M-4
Sta. 5-1	Hydroid colonies			0.3	
	Cancer sp.	0.1			
	Arctica islandica (empty shells)	4.2		1.7	
	Placopecten magellanicus	0.1			
	Asteroidea	5.5		2.0	
	Asterias sp.	2.8		0.2	
	Leptasterias tenera	6.5		9.2	
	Macrozoarces americanus			0.2	
	Urophycis sp.	0.1			
Sta. 6	Arctica islandica (empty shells)	+		+	
	Asterias sp.	1.5		1.6	
	Leptasterias tenera	0.5			
	Flounder	0.1			
	Urophycis sp.	0.4			
	Raja sp.			0.2	
Sta. 7	Porifera	0.7		0.5	
	Gastropod			0.3	
	Asteroidea		0.3		
	Flounder			0.3	
	Omochelys cruentifer		0.3	0.3	
	Urophycis sp.		0.4	0.3	
Sta. 8	Anthozoa			0.2	
	Onuphid polychaetes			+	
	Arctica islandica (empty shells)	+	+	0.8	
	Asteroidea		0.3	0.2	
	Flounder		0.2		
Sta. 9	Cancer sp.		0.6		
	Arctica islandica (empty shells)	1.0	1.2		
Sta. 10	Hydroid colonies		0.3		0.6
	Gastropod				0.2
	Arctica islandica (empty shells)		1.2		1.4
	Cancer sp.	0.2			
	Hermit crab				0.2
	Echinarachnius parma	85% cover	30%		30%
	Asterias sp.	1.4			1.0
	Urophycis sp.	0.1			
	Raja sp.	0.2			

TABLE 11. (continued)

		M-1	M-2	M-3	M-4
Sta. 11	Hydroid colonies	0.2			
	Gastropod		0.1		
	Arctica islandica (empty shells)	2.8	3.7		2.5
	Echinarachnius parma	2.8			
	Asteroidea	0.8			
	Asterias sp.	0.4			
	Leptasterias tenera				5.5
	Flounder	0.1			
Sta. 12	Porifera		0.2	0.2	0.4
	Arctica islandica (empty shells)	1.9	3.0	4.6	2.0
	Hermit crab		0.3		
	Echinarachnius parma	1.4			
	Asteroidea		5.3	6.6	14.4
	Asterias sp.	12.6	0.2	1	2.8
	Ctenodiscus sp.		2.8		
	Flounder		0.3		0.2
	Urophycis sp.				0.2
Sta. 14	Asteroidea	0.3			
Sta. 15	Asteroidea		0.3		
	Arctica islandica (empty shells)	1.8	0.3		
	Raja sp.	0.4			
Sta. 16	Arctica islandica (empty shells)	0.4	0.6	2.2	11.0
	Hydroid colonies			0.2	
	Asteroidea	0.2		0.5	0.5
	Asterias sp.			1.0	
	Leptasterias tenera	0.4	0.6		
	Oreaster sp.		0.4		
	Flounder	0.2			0.2
	Urophycis sp.	0.2			
Sta. 17	Arctica islandica (empty shells)	0.4	0.7		0.8
	Onuphid polychaetes		+		
	Asteroidea	0.1		0.4	0.8
	Asterias sp.		0.5		
	Leptasterias tenera	0.8	0.3		
	Oreaster sp.	0.2	0.2		
	Omochelys cruentifier		0.2	0.2	
	Urophycis sp.				0.2
	Raja sp.			0.4	

TABLE 11. (Continued)

		M-1	M-2	M-3	M-4
Sta. 18	Arctica islandica (empty shells)	0.5	0.2	3.3	6.4
	Cancer sp.			0.2	0.2
	Asteroidea	0.4		0.2	
	Asterias sp.	1.1	0.2		15.8
	Flounder		0.2	0.2	0.2
	Omochelys cruentifier		0.2	0.2	0.4
	Urophycis sp.			0.2	0.2

+ indicates a thick cover, density impossible to estimate accurately.

TABLE 12. AVERAGE DENSITY PER SQUARE METER OF EPIBENTHIC MACROFAUNA IDENTIFIED IN BOTTOM PHOTOGRAPHS TAKEN AT GEORGES BANK BENTHIC MONITORING PROGRAM SITE-SPECIFIC STATIONS.

		M-1	M-2	M-3
Sta. 5-1	Hydroid colonies			0.3
	Arctica islandica (empty shells)	4.2		1.7
	Placopecten magellanicus	0.1		
	Cancer sp.	0.1		
	Asteroidea	5.5		2.0
	Asterias sp.	2.8		0.2
	Leptasterias tenera	6.5		9.2
	Macrozoarces americanus			0.2
	Urophycis sp.	0.1		
Sta. 5-2	Hydroid colonies			1.2
	Arctica islandica (empty shells)	2.3		1.8
	Asteroidea	5.4		
	Asterias sp.	0.1		1.0
	Leptasterias tenera	5.6		12.8
	Urophycis sp.	0.2		
Sta. 5-4	Hydroid colonies			0.2
	Arctica islandica (empty shells)			2.0
	Asterias sp.			0.2
	Leptasterias tenera			7.6
Sta. 5-5	*Arctica islandica* (empty shells)			.6
	Asterias sp.			1.2
	Leptasterias tenera			9.4
Sta. 5-6	*Arctica islandica* (empty shells)			1.6
	Asteroidea			0.6
	Leptasterias tenera			9.2
	Raja sp.			0.2
Sta. 5-7	*Arctica islandica* (empty shells)	0.2		
	Placopecten magellanicus	0.2		
	Cancer sp.	0.1		
	Asteroidea	1.6		
	Leptasterias tenera	11.0		
Sta. 5-8	Porifera	1.2		
	Hydroid colonies			1.0
	Arctica islandica (empty shells)	2.0		0.8
	Asteroidea	4.5		
	Leptasterias tenera	4.8		9.6

TABLE 12. (continued)

		M-1	M-2	M-3
Sta. 5-9	Hydroid colonies			0.4
	Anthozoa	0.1		
	Porifera	0.5		
	Gastropod			0.2
	Arctica islandica (empty shells)	3.5		1.2
	Cancer sp.	0.1		
	Asteroidea	5.5		0.2
	Leptasterias tenera	4.6		6.2
	Sculpin	.1		
Sta. 5-10	Porifera	0.2		
	Arctica islandica (empty shells)	2.6		1.8
	Cancer sp.	0.1		
	Asteroidea	6.3		
	Asterias sp.			0.4
	Leptasterias tenera	2.9		10.8
	Macrozoarces americanus	0.1		
	Omochelys cruentifier	0.1		
	Raja sp.	0.1		
Sta. 5-11	Hydroid colonies			0.6
	Anthozoa	0.1		
	Arctica islandica (empty shells)	2.6		3.0
	Placopecten magellanicus	0.1		
	Asteroidea	9.2		3.4
	Leptasterias tenera	1.9		7.2
	Macrozoarces americanus	0.1		
	Urophycis sp.	0.1		
Sta. 5-12	Hydroid colonies	0.4		
	Arctica islandica (empty shells)	1.8		
	Leptasterias tenera	12.6		
	Raja sp.	0.2		
Sta. 5-14	Hydroid colonies	0.2		
	Arctica islandica (empty shells)	0.8		
	Placopecten magellanicus	0.2		
	Leptasterias tenera	8.4		
	Raja sp.	2		

TABLE 12. (continued)

		M-1	M-2	M-3
Sta. 5-16	Porifera	0.3	0.6	
	Hydroid colonies		1.2	1.2
	Arctica islandica (empty shells)	1.4	+	1.8
	Placopecten magellanicus	0.1	0.3	
	Cancer sp.	0.2		
	Asteroidea	5.2		
	Asterias sp.	0.1		
	Leptasterias tenera	5.2	10.6	10.2
	Flounder		0.1	
	Macrozoarces americanus		0.1	
	Omochelys cruentifier		0.3	
	Urophycis sp.	0.2		
	Raja sp.		0.1	
Sta. 5-18	Porifera	0.5		
	Hydroid colonies		1.0	0.7
	Arctica islandica (empty shells)	3.1	+	2.5
	Cancer sp.	0.1		
	Placopecten magellanicus	0.2	0.3	
	Asteroidea	6.5	0.2	1.3
	Asterias sp.		0.8	0.2
	Leptasterias tenera	1.8	3.3	8.8
	Sculpin		0.2	
Sta. 5-19	*Arctica islandica* (empty shells)	2.0		
	Asteroidea	9.3		
	Urophycis sp.	0.2		
	Raja sp.	0.1		
Sta. 5-20	Anthozoa	0.1		
	Arctica islandica (empty shells)	0.7		
	Placopecten magellanicus	0.3		
	Asteroidea	7.9		19.7
	Leptasterias tenera	1.3		
Sta. 5-22	Porifera	0.1		
	Arctica islandica (empty shells)	0.2		
	Placopecten magellanicus	0.4		
	Hermit crab	0.6		
	Asteroidea	5.4		2.0
	Asterias sp.	1.4		0.2
	Leptasterias tenera			2.2
	Urophycis sp.	0.3		

TABLE 12. (continued)

		M-1	M-2	M-3
Sta. 5-25	Porifera	0.6		
	Hydroid colonies		1.8	1
	Arctica islandica (empty shells)	5.9	+	4.8
	Placopecten magellanicus	0.2	.4	
	Asteroidea	5.6	0.6	
	Leptasterias tenera	1.0	5.9	8.8
Sta. 5-28	*Arctica islandica* (empty shells)	0.9		1.8
	Asteroidea	3.5		5.8
	Asterias sp.	2.4		0.5
Sta. 5-29	Porifera	0.4	0.1	
	Hydroid colonies	0.1	0.9	0.2
	Gastropod		0.1	
	Arctica islandica (empty shells)	+	+	+
	Placopecten magellanicus	0.3	0.1	
	Cancer sp.	0.1		
	Asteroidea	1.4		
	Asterias sp.			0.2
	Leptasterias tenera	0.7	0.2	1.4
	Raja sp.	0.1		

+ Indicates a thick cover, densities impossible to estimate accurately.

common. Sculpin are seen at only two stations. There are more hydroid colonies and Placopecten than at the regional stations.

5.5 Dredge and Trawl Samples

Epifaunal samples were collected from Regional Stations 2, 7, and 13 and Site-Specific Stations 5-1, 5-18, and 5-28. The primary purpose of these collections was to provide tissue for analysis of trace metal and hydrocarbon levels. Voucher specimens of all species collected were preserved, identified and archived by Battelle. Species for which voucher specimens had been collected on early cruises were not retained on later cruises. No voucher specimens were retained on Cruise M1. A tabulation by station and cruise of species for which voucher specimens were retained is given in Appendix D.

In general, results of dredging and trawling were poor. Various types of gear were used on successive cruises in an attempt to increase the amount of tissue available for chemical analyses. An epibenthic sled was used at 5 stations on Cruise M1; however, no voucher specimens were retained. On Cruise M2, a Day dredge with a 1/2-inch mesh net was used at all stations except Regional Station 13, where collections were made with an epibenthic sled. Three types of gear were used on Cruise M3, including a Blake trawl (Station 13), the Day dredge (Stations 7, 5-18, and 5-28), and the epibenthic sled (Station 2). The net of the Blake trawl was ripped out on the first attempt to use it, and no specimens were collected at this station. Only Stations 2 and 5-18 yielded diverse samples. Anchor lines and subsurface current meters associated with drilling activities at Station 5-1 prevented sampling at that station.

As a result of the poor collections from previous cruises, it was decided to employ a 40-foot otter trawl on Cruise M4. The trawl was used at Regional Stations 10 and 13 and Site-Specific Stations 5-1, 5-18, and 5-28. The epibenthic sled was used at Regional Station 7, at the head of Lydonia Canyon, because of the possibility of snagging and tearing the otter trawl net.

The species collected by the various dredges mentioned above included, for the most part, large numbers of echinoderms such as the sand dollar (Echinarachnius parma), starfish (Asterias vulgaris and Leptasterias tenera), attached hydrozoans and bryozoans, or single specimens of large crabs (Cancer borealis, Bathynectus superbus) or gastropod molluscs (Colus stimpsoni, Buccinum undatum). These species were either inappropriate for chemical analysis, or were not collected in sufficient numbers from enough stations to justify analysis.

The ocean quahog, Arctica islandica, was determined to be a species of particular interest. Although it was occasionally taken in dredge samples, it was sampled more routinely by the 0.1m^2 Van Veen grab sampler. Specimens of A. islandica for chemical analysis were therefore saved from the large chemistry grabs in which they occurred. On recent cruises (M-5, M-6, and M-7), a Rocking Chair Dredge has been used to collect this species. Similarly, the otter trawl was found to be more efficient than other sampling gear in collecting demersal fish, and has been used on recent cruises.

5.6 CHN Analysis

The raw data developed as a result of CHN analyses at regional and primary site-specific stations for all sampling cruises are given in Appendix F. Values for these parameters were fairly consistent across all stations over all cruises. Values of percent carbon were highest at Regional Station 13.

5.7 Hydrography

Appendix G contains data on dissolved oxygen (Table G-1), surface and bottom temperature (Table G-2), and surface and bottom salinity (Table G-3). The temperature values are those recorded on the XBT charts during each cruise.

6. DISCUSSION

6.1 General Comments

The Regional Stations analyzed as part of the Georges Bank Monitoring Program clearly show that faunal composition is very closely related to depth and sediment type. Analysis of both grab samples and bottom photographs provide evidence for this conclusion. Stations along similar depth intervals appear similar in the photographs, and group with each other in the cluster analysis of infaunal samples. Replicate samples at each station showed an exceptionally high degree of homogeneity. Cluster analysis demonstrated that all of the replicates of any one regional station are more similar to each other than to replicates from any other station. When replicates at each station are summed, the samples from each of the four sampling periods fuse before any separation occurs between stations. This homogeneity should enable us to detect biological changes should they occur at these stations.

The array of site-specific stations centered around Regional Station 5 are all very similar in terms of species composition, with the exception of Station 5-29. That station, located 6 km to the west of the rig site, has a higher number of species present and fewer individuals of those species which are dominant at the other site-specific stations. Faunal densities at Station 5 and the primary site-specific stations averaged about 25,000 per m^2, and were second only to densities at Station 13, which averaged close to 30,000 per m^2.

Station 13 at the Mud Patch is characterized by sediments that are somewhat finer than those at most of the other stations. Sample residues from this station in July (M1) appeared "oily"; that is, after several rinsings in water and 70 percent alcohol, a surface sheen reminiscent of oil contamination persisted. Several specimens of amphipods from this station also appeared to be fouled by a dark, oily substance. Since this was observed in samples collected before drilling had started on the Bank, this contamination must be from a source other than drilling activities. However, if this station has already been stressed by various forms of pollution, it may be difficult to distinguish changes caused by deposition of drilling muds from those caused by other sources of stress. The fauna at Station 13 is somewhat different than that found at other regional stations. This is almost certainly due to the presence of finer sediments at Station 13.

In general, the species recorded in our analyses correspond to those reported by Maurer and Leathem (1980a; 1981) for polychaetes, and Michael (1977) for amphipods and other groups. However, our stations are located in a limited region of the Bank compared to the broad area covered by the earlier Benchmark Study. Because of this, and also due to the use of fine mesh (0.3 mm) screens which retain small species and sample populations of certain other species more efficiently, the dominant polychaetes in the present samples are not identical with those reported by Maurer and Leathem (1980b). For example, in that study, Spiophanes bombyx was the single most abundant polychaete on Georges Bank for both winter and spring. This species is also reported as occurring widely and abundantly throughout the Middle Atlantic Bight (Pratt, 1973; Maurer, et al., 1976) and is most abundant in sandy sediments from 30-60 m. S. bombyx was not abundant in our samples, and was not dominant at any station, although it might have been expected to be abundant at Stations 1, 4, 10 or 15.

Maurer et al. (1976) and Maurer and Leathem (1981) considered species of syllid, paraonid and cirratulid polychaetes to be characteristic of the northeastern Continental Shelf. These polychaete families are also clearly dominant in our samples, along with spionids. In terms of numbers of species reported, paraonids, syllids and spionids accounted for 26 percent of all polychaete species recorded. Unlike earlier studies in which bipalpate cirratulids have not been speciated, we have been able to separate this portion of the fauna into 13 species. Several of these species co-occur at some stations, so it is clearly important to be able to separate them. For example, at Regional Station 17, three species of Tharyx are all among the ten most abundant species. Similarly, oligochaetes have not been speciated in most other benthic studies, but have been separated in this study. At least three oligochaete species are among the dominants reported here, although the dominant species differed between stations.

Several rare species more typical of slope depths or more southern latitudes occurred at the deeper stations (generally greater than 100 m). Polychaete species such as Malacoceros indicus, Apoprionospio dayi, Prionospio aff. cirrobranchiata, and Nematonereis unicornis were previously known only from as far north as Cape Hatteras. Arthropod species in this category included larvae of Ocypode quadrata and juveniles of Anoplodactylus petiolatus. The polychaetes Cirrodoce cristata and Typosyllis tegulum and the arthropods Epimeria obtusa and Janaria alta are more typical of slope depths.

In general, the molluscs in our samples tend to be smaller in size than the size ranges given in published descriptions. As mentioned above for polychaetes, some species of molluscs reported in other studies (e.g. Michael, 1977) do not occur in high numbers in our samples. For example, turrid gastropods were represented by only three specimens of one species. Two species, Arctica islandica and Spisula solidissima, are commercially important. Arctica islandica was most numerous at Stations 3, 6 and 11, between 80 and 100 m. Specimens collected in our infaunal samples exhibited a great size dichotomy, with the largest diameter of most specimens being either 0.5 mm to 2.0 mm or over 80 mm. This species reaches sexual maturity at an average size of 39 mm (Ropes and Murawski, 1980). The high proportion of juveniles to adults in our samples implies a high juvenile mortality.

Use of the wet weight technique for biomass determinations provides results that are of limited value. Because the non-living, calcium carbonate components are included, molluscs and echinoderms dominate the total biomass recorded, accounting for close to 95% of the total in most samples. Because the values are so clearly dominated by $CaCO_3$ skeletal and shell components, the values cannot be used for analysis of energetic relationships within the Georges Bank ecosystem. Also, since the random inclusion of single large animals, such as a large specimen of Arctica islandica, can distort the total values. Comparisons between sampling periods should only be made with caution. Although no method of determining biomass is without criticism (Mills et al., 1982), determination of decalcified wet weights, ash-free dry weights or organic carbon would be more useful for estimates of secondary productivity.

6.2 Discussion of Results at Drilling Sites

Exploratory drilling started in Block 410, within 200 m of Regional Station 16, shortly after Cruise M1 in July, 1981, and continued until the end of March, 1982. In Block 312, the location of the site-specific sampling array, exploratory drilling began on December 8, 1981, shortly after completion of Cruise M2 in November, and was completed in June, 1982 shortly before Cruise M5.

Bothner et al. (1982) reported that concentrations of barium in bulk (unfractionated) sediments at Station 16 increased by a factor of 3.5 between July, 1981 (predrilling) and May, 1982 (postdrilling). There also was an increase of lesser magnitude in concentration of barium in bulk sediment between July and November, 1981 at Station 18 located 2,000 m west (downcurrent) of the rig site, and evidence of a small increase at Station 17 located 2,000 m east of the rig site. However, these increases were within the normal pre-drilling range of concentrations of barium. There was no clear evidence of an increase with time in the concentration of chromium (the other major drilling fluid metal) in bulk sediments at Station 16. With analysis of the fine sediment fraction, the average barium concentrations showed an increase of about 36 times the predrilling level at Station 16, with smaller changes at Stations 17 and 18. Increases in Al, Cu, Hg and Cr concentrations in the fine fraction were observed only at Station 16. These metals increased by a factor of about two. By May, 1982, the concentrations of these metals had decreased and were similar to the pre-drilling levels.

In Block 312, smaller increases in bulk sediment barium concentration were reported following initiation of drilling (Cruises M3 and M4). The magnitude of the increases between Cruises M1 and M4 ranged from 1.1 to 2.5-fold. Stations showing a 2-fold or greater increase in bulk sediment barium concentration included Stations 5-1 at the drill site, 5-2, 0.5 km to the east, and 5-8, 1 km to the north. Analysis of the fine sediment fractions showed an increase in barium of up to 22 times the predrilling levels. Increases of slightly greater than 16 times the predrilling levels occurred at Stations 5-8 to the north and 5-12 to the south. No increases in Al, Cr, Cu or Hg concentrations were observed at Block 312 stations.

In Block 410, for which we have analyzed one set of pre-drilling infaunal samples (July, M1), two sets of samples collected during drilling operations (November, M2 and February, M3), and one set of postdrilling samples May (M4), no biological impacts which could be attributed to drilling were detected.

In Block 312, where drilling commenced shortly after Cruise M2, we have analyzed 2 sets of pre-drilling infaunal samples (July, M1 and November, M2) and two sets of samples collected during drilling operations (February, M3 and May, M4). No biological impacts which can be attributed to drilling have been detected. However, there were changes in abundance of several species at stations near the rig where Bothner et al. (1982) showed that barium (and by inference drilling fluids) accumulated between Cruises M1 and M4. At several stations near the rig site, the average density of several species declined between Cruises M1 and M2 and then increased again by Cruise M3 shortly after (2 months) the start of drilling. At several stations further from the rig site, the decline in abundance of certain species occurred in February (M3). The average abundance of the corophiid amphipod *Erichthonius rubricornis* showed a marked decline in February, 1982 at the site-specific stations plotted, except at Station 5-28. The distributions of *E. rubricornis* and *Unciola inermis*, another amphipod common at the site-specific stations, are clearly related to sediment grain size. In February (M3), E. rubricornis showed a significant correlation with percent gravel, and U. inermis showed a significant inverse correlation with percent fine sand. It appears that there is some redistribution of sediments in February (M3) which may relate to the decline in abundance of these species at site-specific stations. It is likely that this redistribution of sediments is due to natural causes such as winter storms. Most of the macroinfaunal species that exhibited population declines in November or February experienced substantial increases in abundance in May (Cruise M4). Thus, no short-term adverse changes in the benthic infaunal community have been identified as yet which can be related to accumulation of barium (and by inference drilling fluids) in sediments near the exploratory rig sites. Long-term impacts of drilling fluid accumulation, if they occur, may be detected when samples from Cruise M5 and later are analyzed.

6.3 Comparison with the mid-Atlantic Rig Study

The field investigation most comparable to the Georges Bank Benthic Monitoring Program is that performed by EG&G Environmental Consultants for the Offshore Operators Committee around an exploratory rig in New Jersey 18-3 Block 684 on the mid-Atlantic Outer Continental Shelf approximately 156 km east of Atlantic City, New Jersey (Mariani, et al., 1980; Menzie et al., 1980; Gillmor et al., 1981, 1982; Maurer et al., 1981, 1982; EG&G Environmental Consultants, 1982). The rig was located in 120 meters of water, compared to depths of 79 and 138 meters for exploratory rigs in Blocks 312 and 410, respectively, monitored in the Georges Bank Program. Sediments at the mid-Atlantic site contained higher concentrations of silt and clay (11.24 and 8.09%, respectively) than the sediments at the Georges Bank rig monitoring sites (0.15-0.31 and 0.15-0.49% silt and clay, respectively). The velocities of bottom water currents at the mid-Atlantic site were below 10 cm/sec 62% of the time and below 25 cm/sec 95% of the time. On the southern flank of Georges Bank, the mean velocity of residual current flow to the southwest is about 3.5 cm/sec near the bottom. But superimposed on this are semi-diurnal tidal currents with speeds of 35 to 75 cm/sec (Aaron et al., 1980). Severe northeast storms, particularly during the winter, cause substantial bottom scour. Butman (1982) reported that winter storms caused substantial bottom scour and sediment resuspension at a station (U.S.G.S. Station A) a short distance east of our site-specific array (Regional Station 5). Bottom water current speeds at Station A were typically 20 to

30 cm/sec and occasionally in excess of 40 cm/sec between December, 1976 and February, 1977. Thus, the Lease Sale 42 area of Georges Bank is a higher energy environment than the Block 684 site on the mid-Atlantic Outer Continental Shelf.

In the mid-Atlantic study, a zone approximately 150 meters in diameter of visible drilling discharge accumulations (primarily natural clays from drill cuttings) was observed in the immediate vicinity of the well site, while elevated levels of clays were detected up to 800 meters southwest (downcurrent) of the drill site immediately after cessation of drilling. A side-scan sonar survey performed one year after cessation of drilling revealed scour marks left by anchor chains and depressions left by the anchors. An area of heavy drill cuttings and debris accumulation about 40-50 meters in diameter was observed immediately south of the well site. The height of the cuttings pile was estimated to be less than 1 meter. During the second post-drilling survey one year after cessation of drilling, elevated levels of clay were not detected southwest of the drill site. In both post-drilling surveys, concentrations of barium in the upper 3 cm of sediments were high (up to 3,477 ppm in the first survey and 2,144 ppm in the second post-drilling survey compared to 148-246 ppm in predrilling sediments) near the rig site and decreased with distance from the rig. Elevated concentrations of barium were detected in sediments up to 1.6 kilometers from the drill site. No elevations in concentrations of chromium or several other metals were detected in sediments near the rig following drilling.

Some samples of mixed species of brittle stars, molluscs and polychaetes collected from near the rig site during the first and second post-drilling surveys had statistically significantly elevated concentrations of barium and chromium in their tissues in comparison to animals collected in the predrilling survey. Mean barium concentrations in polychaetes and brittle stars were 23.5 and 15.2 ppm, respectively, before drilling, and 87.8 and 217.8 ppm, respectively, during the first post-drilling survey. One year later, barium concentrations in all but a few polychaete and brittle star samples had returned to the predrilling range. Small but statistically significant elevations in chromium concentration were observed in some polychaete and mollusc samples. Concentrations of barium and chromium in tissues of benthic organisms were not correlated with concentration gradients of these metals in bottom sediments.

In the Georges Bank Monitoring Program, small amounts of cuttings were detected in bottom sediments within about 200 meters of the rigs in Blocks 312 and 410 following drilling (Bothner et al., 1982). No cuttings pile was visible in any bottom photograph. Elevated barium concentrations in the clay-size fraction of sediments were detected up to 6 kilometers to the west of the drill site in Block 312, the station farthest downcurrent from this drill site. There was no evidence of an increase in barium or chromium concentrations in any biota samples analyzed to date (Payne et al., 1982).

The abundance of benthic macroinfaunal animals in the vicinity of the mid-Atlantic rig site was higher than that at the nearby BLM Benchmark Station before drilling commenced (8,011 individuals/m^2 versus 3,064 individuals/m^2). At the rig site, benthic macrofaunal abundance dropped to 1,729 individuals/m^2 immediately after drilling, and then rose to 2,638 individuals/m^2 one year later. These changes in abundance were the same for the four major taxonomic groups (polychaetes, echinoderms, crustaceans, and molluscs). With the exception of a few stations less than 100 meters southwest (downcurrent) of the drill site that had markedly reduced benthic faunas during the first postdrilling survey, there was no relationship between direction, distance from the rig site (out to 3.2 km) or sediment barium concentration, and the extent of decrease in abundance of any major taxonomic group or major species.

Species richness at the rig site dropped from 70 $\pm$ 7/0.2 m^2 in the predrilling survey to 38 $\pm$ 10/0.2 m^2 immediately after drilling and then rose again to 53 $\pm$ 8/0.2 m^2 one year later. Shannon diversity (H') and evenness (J') showed only very small changes between the predrilling and the two postdrilling surveys. Diversity decreased slightly, which probably was related in part to increased evenness in the postdrilling surveys. These changes in areal richness, species diversity and evenness were similar at stations near the well site and at the three stations considered to be beyond the influence of drilling discharges.

Unfortunately, there were no true reference (control) stations, sufficiently far from the rig site to preclude any possibility of direct impact, with which to compare results from the three benthic samplings. Stations farthest from the rig site which were considered to be beyond the influence of drilling discharges (Stations 55, 56 and 58) showed the same patterns of faunal change as did stations near the rig site. Benthic faunal composition and abundances from the two postdrilling surveys were more similar to those from the earlier BLM Benchmark program in the area (Boesch, 1979) than to those from the predrilling survey. Thus, results of the predrilling survey may not be a suitable baseline against which to compare results of the two postdrilling surveys.

The authors concluded that physical and biological effects of exploratory drilling discharges on the benthic environment of a low-energy area of the mid-Atlantic

Outer Continental Shelf persisted for at least a year after cessation of drilling activities. To the extent that the decreased abundance and species richness of benthic macrofauna around the rig site immediately after cessation of drilling were due to drilling discharges, there was evidence of some recovery during the year following cessation of drilling.

The apparent lack of a short-term biological impact of exploratory drilling on the benthos of Georges Bank compared to that seen at the mid-Atlantic Outer Continental Shelf rig site probably is due in large part to the difference in the amounts of drilling muds and cuttings accumulating on the bottom at the two sites. In the lower-energy environment of the mid-Atlantic Outer Continental Shelf, more drilling muds and cuttings accumulated on the bottom and impacts on the benthos were greater than on Georges Bank.

6.4 Responses of Benthic Organisms to Sediment Deposition

Our results to date do not indicate any significant impact which can be attributed to drilling activities. Subtle differences in the population density patterns of individual species at site-specific stations may indicate some effects of the disposal of drill cuttings, although Bothner et al. (1982) indicated that drill cuttings were found only at each rig station and not at stations beyond the actual drill site. Although there are no direct measurements of the amount of drill cuttings which might have accumulated, Bothner (personal communications) has estimated that no more than 2 µm of material accumulated at Site-Specific Station 5-1. If greater quantities had been deposited, the discharge of drill cuttings could potentially have had an impact on the benthos.

Results of studies on the impacts of dredging and spoil disposal indicate several ways in which the benthos could be affected. Direct burial by spoils has an obvious impact on benthic organisms, many of which are killed outright (Lunz, 1938, 1942: Wilson, 1950; Brehmer, 1965; Carriker, 1967; Saila et al., 1972; Rose, 1973). Death usually results from the dumping of anoxic sediments on ambient sediments and the benthic organisms suffocate before they can migrate laterally or vertically to oxygenated areas. In addition, both suspension and deposit feeding organisms in the impacted area might ingest the resuspended and re-deposited sediment during and after the dredge-disposal operations.

There have been several recent reviews dealing with the ability of the organisms to survive burial (Maurer, et al., 1981a-b). The ability to escape burial depends on several factors. For example, Kranz (1972; 1974) found that life habits, morphology and size were extremely important in determining the ability of epifaunal and infaunal bivalves to survive burial. Epifaunal suspension feeders, boring organisms, and deep burrowing siphonate suspension feeders generally were able to survive more than one cm of overburden. Infaunal non-siphonate suspension feeders were generally able to survive 5-10 cm of overburden, while shallow-burrowing siphonate suspension feeders and juvenile deep-burrowing siphonate suspension feeders could escape 10-50 cm of their native sediment. Mucus feeders and deposit-feeders were most influenced by sediment burial. Saila et al. (1972) demonstrated that Arctica islandica reached the surface of 4-5 cm of dredged material (fine sand) and as much as 14 cm of sand. Clams buried under 8-17 cm of dredged material did not migrate upward, but established air holes to the surface. Bousfield (1970) suggested that the burrowing ability of amphipod crustaceans is generally related to morphology. Members of the subfamily Haustoriinae are most efficiently adapted to burrow through sediments since they possess a fusiform body with large modified coxal plates and pleopods adapted for rapid burrowing. Peddicord et al., (1975) noted that two species of epifaunal crustaceans could move rapidly through deposited clay in experimental tanks. Pratt et al., (1973) observed that Ampelisia agassizi burrowed through 2 cm of dumped sediment and then swam to the surface of the water.

Among polychaetes, Maurer et al. (1978) found that two burrowing species, Scoloplos fragilis and Nereis succinea, were able to successfully migrate through 30 and 80-90 cm of sediment, respectively. Saila et al., (1972) found that Nephthys incisa could burrow through 21 cm of deposited material in 24 hours. The small tube-dwelling polychaete, Streblospio benedicti, on the other hand, was able to escape only 6 cm of overburden. However, both Myers (1972) and Oliver and Slattery (1973) found that tube dwelling onuphid polychaetes were able to migrate vertically through 30 cm of deposited sediment.

The physical and chemical nature of the deposited sediments can greatly alter the ability of organisms to survive spoil disposal, thus, Kranz (1974) determined that exotic sediments, differing in grain size composition from native sediments, always reduced the burrowing activities of the bivalves. In laboratory studies, Maurer et al., (1978) tested the ability of infaunal organisms to burrow through sediments differing in particle composition, sediment pore-water chemistry (e.g., levels of oxygen, sulfides and ammonia), and temperature. Testing several species of crustaceans, molluscs, and polychaetes revealed that no relationship between sediment pore-water chemistry and burrowing ability could be found. Burrowing responses were more influenced by sediment type, burial depth, duration of burial time and temperature. However, mortality rates were species specific. All of these various studies on escape responses following burial by dredge spoils suggest that the very slight amount of drill cuttings predicted by Bothner (personal communication) were insufficient to cause mortality by direct burial.

The most sensitive benthic organisms affected by dredging operations are those which collect food materials by filtering particles suspended in the water column (primarily bivalves, cnidarians, sabellid polychaetes, some crustaceans). Disorders are most likely caused by the abrasive action of resuspended silt and clay sized particles or by exposure to toxicants absorbed to the fine particulate material. Imposition of suspended load stress on filter feeders can affect their rate of water transport, efficiency of their filtering mechanisms and energy requirements for maintenance. Specific physiological disorders observed in laboratory studies of filter feeders exposed to heavy suspended loads include: abrasion of the gill filaments, clogging of the gill, impaired respiration, impaired feeding and excretory functioning, reduced pumping rates, retarded egg development and reduced growth and survival of larvae (Yonge, 1953; Loosanoff and Tommers, 1948; Loosanoff, 1961; Davis, 1960; Cairns, 1968; Smith and Brown, 1971; Gordon et al., 1972). To date, we have little data to determine if drill cuttings affect feeding mechanisms in a similar manner. There was no evidence that filter feeders were affected at either Block 312 or Block 410 drilling sites.

There have been few studies of the impact of suspended fluid muds in natural communities. Working in a low diversity tidal freshwater area in the James River in Virginia, Diaz and Boesch (1977) found a pronounced immediate impact on the benthos caused by a hydraulic pipeline disposal operation. However, because of the opportunistic nature of the fauna, the impact lasted only about three months after the disposal operation ceased. The benthic community recovered and was similar in abundance and species composition to that of surrounding unaffected areas. It is probable that a community dominated by non-opportunistic species would show a different recovery pattern.

There have also been very few <u>in situ</u> studies on the direct effects of drilling muds on benthic communities. In a series of aquaria experiments, Tagatz and Tobia (1978), Tagatz, et al., (1978) and Tagatz, et al., (1982) found that drilling muds adversely affected colonization of sediments by estuarine planktonic larvae. Unfortunately, these authors used a 1.0 mm mesh screen to harvest their sediments at the termination of the experiments and it is doubtful that all organisms would have been recovered from the experimental tanks. While carefully controlled laboratory experiments on effects on recruitment are clearly needed, there is also a need to document the response and behavior of resident infauna to the sudden or gradual influx of drilling muds.

Several deleterious biological responses to sublethal concentrations of used drilling fluids have been described in laboratory investigations with benthic invertebrates from Georges Bank. Used drilling fluids layered on natural bottom sediments or suspended in the water column increased the duration of larval development and caused a delay in molting, altered burrowing behavior and chemosensory responses to food cues, and caused changes in tissue enzyme activities in the lobster Homarus americanus (Gerber et al., 1980, 1981; Derby and Atema, 1981; Atema et al., 1982). In Atlantic cancer crabs, Cancer irroratus and C. borealis, low concentrations of drilling muds caused a temporary inhibition of feeding and an alteration in the activity of several tissue enzymes. Similar changes in tissue enzyme activity were observed in sand shrimp Crangon septemspinosa (Gerber et al., 1980, 1981). Drilling fluids also inhibited shell growth in larvae and juveniles of the ocean scallop Placopecten magellanicus (Gerber et al., 1981; Gilbert, 1981), and caused depressed fertilization, delayed development and an increased incidence of developmental anomalies in the sand dollar Echinarachnius parma (Crawford and Gates, 1981). These responses were observed at nominal suspended drilling mud concentrations of 10 parts per million (ppm, mg/liter) or greater or following exposure to 1-7 mm layers of drilling mud on natural sediments. The maximum mean increment in barium concentration in sediments near the rig in Block 312 was about 30 ppm (Bothner et al., 1982). Typical weighted offshore chrome lignosulfonate drilling muds may contain 100,000 - 400,000 ppm barium (Neff, 1982). Thus, the nominal maximum amount of drilling muds accumulating in sediments near the rig probably was in the range of 100-150 ppm, below the concentration at which most of the sublethal responses described above were observed.

To date, very little additional information on the population biology, life history strategies, response to burial or response to impact by toxic materials has been developed for indigenous Outer Continental Shelf species. Information of this nature, considered together with field studies of community structure, would greatly enhance our ability to predict the effects of exploratory drilling activities in an ecologically sensitive and highly productive marine environment such as Georges Bank.

7. REFERENCES

Aaron, J.M., B. Butman, M.H. Bothner and N.G. Sylvester. 1980. Environmental conditions relating to potential geologic hazards on the United States Northeastern Atlantic Continental Margin, Map. MF-1193.

Atema, J., D.F. Leavitt, D.E. Barshaw and M.C. Cuomo. 1982. Effects of drilling muds on behavior of the American lobster, Homarus americanus in water column and substrate exposures. Can. J. Fish. Aquat. Sci. 39:675-690.

Ayers, R.C., Jr., T.C. Sauer, Jr., R.P. Meek and G. Bowers. 1980. An environmental study to assess the impact of drilling discharges in the mid-Atlantic. I. Quantity and fate of discharges. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 382-418.

Battelle New England Marine Research Laboratory and Woods Hole Oceanographic Institution. 1982. Second Summary Report on the Georges Bank Benthic Monitoring Program. Report to U.S. Department of the Interior, Minerals Management Service, Washington, D.C. i + 107 pp. and 1 Appendix.

Biological Task Force. 1981. Georges Bank monitoring program and related studies. Working Group of the Biological Task Force on Georges Bank for Lease Sale No. 42.

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. Department of Commerce, NTIS PB-269 604. EPA-600/3-77-033. 114 pp.

Boesch, D.F. 1979. Benthic ecological studies: macrobenthos. In: Middle Atlantic Outer Continental Shelf Environment Studies. Vol. IIB. Chemical and Biological Benchmark Studies. Special Report in Applied Marine Science and Ocean Engineering No. 194. Virginia Institute of Marine Science, Gloucester Point, VA. U.S.D.I. Bureau of Land Management, New York OCS Office, New York, NY.

Bothner, M.H. and P.P. Johnson. 1981. 210Pb in sediment cores from the Atlantic Continental Shelf: estimates of rates of sediment mixing. U.S. Geological Survey Open-File Report 81-582A and B. 30 pp.

Bothner, M.H., E.C. Spiker, W.M. Ferrebee and D.L. Peekler. 1980. Texture, clay mineralogy, trace metals and age of cored sediments from the North Atlantic Outer Continental Shelf. pp. 3-1 to 3-25 In: Environmental Geologic Studies in the Georges Bank Area, United States Northeastern Atlantic Outer Continental Shelf, 1975-1977. U.S. Geological Survey Open-File Report 80-240.

Bothner, M.H., C.M. Parmenter, R.R. Rendigs, B. Butman, L.J. Poppe and J.D. Milliman. 1981a. Studies of suspended matter along the north and middle Atlantic Outer Continental Shelf. U.S. Geological Survey Open-File Report 82-938. 34 pp.

Bothner, M.H., E.C. Spiker, P.P. Johnson, R.R. Rendigs and P.J. Aruscavage. 1981b. Geochemical evidence for modern sediment accumulation on the continental shelf off southern New England. J. Sediment. Petrol. 51:281-292.

Bothner, M.H., R.R. Rendigs, E. Campbell, M.W. Doughten, P.J. Aruscavage, A.F. Dorrzapf, Jr., R.G. Johnson, C.M. Parmenter, M.J. Pickering, D.C. Brewster, and F.W. Brown. 1982. The Georges Bank Monitoring Program. Analysis of Trace Metals in Bottom Sediments. First Year Final Report to U.S.D.I., Minerals Management Service, Washington, D.C. U.S. Department of the Interior, Geological Survey, Woods Hole, MA.

Bousfield, E.L. 1970. Adaptive radiation in sand-burrowing amphipod crustaceans. Ches. Sci. 11:143-154.

Brehmer, M.L. 1965. Turbidity and siltation as forms of pollution. J. Soil Water Conserv. 20(4):123-133.

Bumpus, D.F. 1976. Review of the physical oceanography of Georges Bank. International Commission for the Northwest Atlantic Fisheries Research Bulletin. 12:119-134.

Bureau of Land Management. 1977. Final environmental statement. OCS Sale No. 42, Offshore the North Atlantic States. U.S. Department of the Interior, Washington, D.C., Volumes 1-5.

Bureau of Land Management. 1981. A regional studies plan for the north and mid-Atlantic regions: FY-1982. BLM, New York OCS Office, New York, NY. 78 pp.

Butman, B. 1982. Currents and sediment movements on Georges Bank. Pages 31-60 In: Georges Bank. Past, Present and Future of a Marine Environment, Ed. by G.C. McLeod and J.H. Prescott. Westview Press, Boulder, CO.

Butman, B. and R.C. Beardsley. 1982. Long-term observations on the southern flank of Georges Bank: seaonal cycle of currents. In: Environmental Geologic Studies in the Georges Bank Area, United States Northeastern Atlantic Continental Margin, 1978-1979, Ed. by D.W. O'Leary. U.S. Department of the Interior, Geological Survey. Submitted to Bureau of Land Management under Memoranda of Understanding AA551-MU8-24 and AA551-MU9-4. 34 pp.

Butman, B., R.C. Beardsley, B. Magnell, D. Frye, J.A. Vermersch, R. Schlitz, R. Limeburner, W.R. Wright and M.A. Noble. 1982. Recent observations of the mean circulation on Georges Bank. J. Phys. Oceanog. 12:569-691.

Cabioch, L., J.-C. Dauvin and F. Gentil. 1978. Preliminary observations on pollution of the sea bed and disturbance of sublittoral communities in northern Brittany by oil from the Amoco Cadiz. Mar. Poll. Bull. 9:303-307.

Carriker, M.R. 1967. Ecology of estuarine benthic invertebrates: a perspective. pp. 442-487. In: G.J. Lauff (Ed.) Estuaries. AAAS Publ. No. 83.

Clark, S.H. and B.E. Brown. 1976. Changes in biomass of finfishes and squids from the Gulf of Maine to Cape Hatteras, 1963-74, as determined from research vessel survey. Fish. Bull. 75:1-21.

Colton, J.B., Jr. and R.R. Byron. 1977. Gulf of Maine-Georges Bank ichthyoplankton collected on ICNAF larval herring surveys, September 1971-February, 1975. NOAA Tech. Report SSRF-717, 34 pp.

Colton, J.B., Jr. and R.F. Stoddard. 1972. Average monthly seawater temperatures. Nova Scotia to Long Island. 1940-1959. Amer. Geogr. Soc. Serial Atlas of the Marine Environment. Folio 21.

Cooper, R.A. and J.R. Uzmann. 1971. Migrations and growth of deep-sea lobsters, Homarus americanus. Sci. 171:288-290.

Crawford, R.B. and J.D. Gates. 1981. Effects of drilling fluid on the development of a teleost and an echinoderm. Bull. Environ. Contam. Toxicol. 26:207-212.

Crippen, R.W., S.L. Hood and G. Greene. 1980. Metal levels in sediment and benthos resulting from a drilling fluid discharge into the Beaufort Sea. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 636-669.

Davis, H.C. 1960. Effects of turbidity producing materials in sea water on eggs and larvae of the clam (Venus (Mercenaria) mercenaria). Biol. Bull. 118(1):18-54.

Derby, C.D. and J. Atema. 1981. Influence of drilling muds on the primary chemosensory neurons in walking legs of the lobster, Homarus americanus. Can. J. Fish. Aquat. Sci. 38:268-274.

Diaz, R.J. and D.F. Boesch. 1977. Impact of fluid mud dredged material on benthic communities of the tidal James River, Virginia. Technical Report D-78-45, U.S. Army Engineer Waterways Experiment Station.

Dickenson, J.J. and R.L. Wigley. 1981. Distribution of gammaridean Amphipoda (Crustacea) on Georges Bank. NOAA Tech. Rep. NMFS SSRF-746. 25 pp.

Ecomar, Inc. 1978. Tanner Bank mud and cuttings study. Conducted for Shell Oil Company. January through March, 1977. Ecomar, Inc., Goleta, California. 495 pp.

EG&G Environmental Consultants. 1982. A study of environmental effects of exploratory drilling on the mid-Atlantic Outer Continental Shelf - Final Report of the Block 684 Monitoring Program. Submitted to Offshore Operators Committee under Supervision of Exxon Production Research Company, Houston, TX. EG&G Environmental Consultants, Waltham, MA.

Ekman, J.E., A.R.M. Nowell and P.A. Jumars. 1981. Sediment stabilization by animal tubes. J. Mar. Res. 39:361-374.

Gerber, R.P., E.S. Gilfillan, B.T. Page, D.S. Page and J.B. Hotham. 1980. Short and long term effects of used drilling fluids on marine organisms. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 882-911.

Gerber, R.P., E.S. Gilfillan, J.R. Hotham, L.J. Galletto, and S.A. Hanson. 1981. Further studies on the short and long-term effect of used drilling fluids on marine organisms. Final Report, Year II, to the American Petroleum Institute, Washington, D.C., Bowdoin College, Brunswick, ME. 30 pp.

Gillmor, R.B., C.A. Menzie and J. Ryther. Jr. 1981. Side-scan sonar and TV observations of the benthic environment and megabenthos in the vicinity of an OCS exploratory well in the Middle Atlantic Bight. In: Conference Record. Vol. 2 Oceans '81 Symposium. Boston, MA IEEE Publ. No. 81CH1685-7 IEEE Service Center, Piscataway, NJ. pp. 727-731.

Gillmor, R.B., C.A. Menzie, G.M. Mariani, D.R. Levin, R.C. Ayers, Jr. and T.C. Sauer, Jr. 1982 (In Press). Effects of exploratory drilling discharges on the benthic environment in the middle Atlantic OCS: biological results of a one-year postdrilling survey. In: Proc. Ocean Dumping Symposium (New York: Wiley Interscience).

Gettleson, D.A. and C.E. Laird. 1980. Benthic barium in the vicinity of six drill sites in the Gulf of Mexico. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 739-788.

Gilbert, T.R. 1981. A study of the impact of discharged drilling fluids on the Georges Bank Environment. New England Aquarium. H.E. Edgerton Research Laboratory. Progress Rept. No. 2 to U.S. EPA, Gulf Breeze, FL. 98 pp.

Gordon, R.B., D.C. Rhoads and K.K. Thurekian. 1972. The environmental consequences of dredge spoil disposal in central Long Island Sound: I. The New Haven spoil ground and New Haven Harbor. Dep. Biology and Geophysics, Yale Univ. 39 pp. (mimeo).

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.

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.

Hennemuth, R.C. 1976. Fisheries and renewable resources of the Northwest Atlantic Shelf. In: B. Manowitz, Ed., Effects of Energy Related Activities on the Atlantic Continental Shelf. Brookhaven National Laboratory, Associated Univ., Inc., pp. 146-166.

Hopkins, T.S. and N. Garfield, III. 1981. Physical origins of Georges Bank water. J. Mar. Res. 39:465-500.

Houghton, J.P., K.R. Critchlow, D.C. Lees, R.D. Czlapinski, R.C. Miller, R.P Britch and J.A. Mills. 1981. Fate and effects of drilling fluids and cuttings discharges in lower Cook Inlet, Alaska and on Georges Bank. Prepared for U.S.D.C.-N.O.A.A. and U.S.D.I.-B.L.M. Dames and Moore, Seattle, WA.

Hrudey, S.E. 1979. Sources and characteristics of liquid process wastes from Arctic offshore hydrocarbon exploration. Arctic 32:3-21.

Kranz, P.M. 1972. The catastrophic burial of bivalves and its paleoecological significance. Ph.D. Dissertation, Univ. Chicago. 177 pp.

Kranz, P.M. 1974. The catastrophic burial of bivalves and its paleoecological significance. J. Geol. 82:237-265.

Liss, R.G., F. Knox, D. Wayne, and T.R. Gilbert. 1980. Availability of trace elements in drilling fluids to the marine environment. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 691-722.

Loosanoff, V.L. 1961. Effects of turbidity on some larval and adult bivalves. Gulf Caribb. Fish. Inst. Proc. 14:80-95.

Loosanoff, V.L. and F.D. Tommers. 1948. Effect of suspended silt and other substances on rate of feeding of oysters. Science. 107:69-70.

MacKenzie, C.L., Jr., A.S. Merrill, and F.M. Serchuk. 1978. Sea scallop resources off the northeastern U.S. Coast, 1975. Mar. Fis. Rev. 40:19-23.

Magnell, B.A., J.J. Cura, C.N. Flagg and D.E. Frye. 1981. Interpretation of the physical oceanography of Georges Bank. Preliminary Results. Submitted to U.S. Department of the Interior, Bureau of Land Management, Washington, D.C. EG&G Environmental Consultants, Waltham, MA.

Mariani, G.M., L.V. Sick, and C.C. Johnson. 1980. An environmental monitoring study to assess the impact of drilling discharges in the mid-Atlantic. III. Chemical and physical alterations in the benthic environment. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 438-493.

Maurer, D., R.T. Keck, J.C. Tinsman and W.A. Leathem. 1981a. Vertical migration and mortality of benthos in dredged material. Part I: Mollusca. Mar. Environ. Res., 4:299-319.

Maurer, D., R.T. Keck, J.C. Tinsman and W.A. Leathem. 1981b. Vertical migration and mortality of benthos in dredged material: Part II. Crustacea. Mar. Environ. Res., 5:301-317.

Maurer, D.L., R.T. Keck, J.C. Tinsman, W.A. Leathem, C.A. Wethe, M. Hutzinger, C. Lord, and T.M. Church. 1978. Vertical migration of benthos in simulated dredged material overburdens. Vol. I. Marine Benthos. Dredged material research program, Technical Report D-78-35. U.S. Army Engineer Wastewater Experiment Station. 60 pp.

Maurer, D., P. Kinner, W. Leathem, and L. Watling. 1976. Benthic faunal assemblages off the Delmarva Peninsula. Estuar. and Coastal Mar. Sci. 4:163-177.

Maurer, D. and W. Leathem. 1980a. Ecological distribution of polychaetous annelids of Georges Bank. Unpublished Report, College of Marine Studies, University of Delaware. 181 pp.

Maurer, D. and W. Leathem. 1980b. Dominant species of polychaetous annelids of Georges Bank. Mar. Ecol.-Prog. Ser. 3:135-144.

Maurer, D. and W. Leathem. 1981. Ecological distribution of polychaetous annelids from the New England Outer Continental Shelf, Georges Bank. Int. Rev. ges. Hydrobiol. 66(4):505-528.

Maurer, D., W. Leathem and C. Menzie. 1981. The impact of drilling fluid and well cuttings on polychaete feeding guilds from the U.S. northeastern Continental Shelf. Mar. Pollut. Bull. 12:342-347.

McCulloch, W.L., J.M. Neff, and R.S. Carr. 1980. Bioavailability of heavy metals from used offshore drilling muds to the clam Rangia cuneata and the oyster Crassostrea gigas. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 964-983.

McGuire, W.J. 1975. Disposal of drilling fluids and drilled-up solids in offshore drilling operations. In: Environmental Aspects of Chemical Use in Well-Drilling Operations. U.S. Environmental Protection Agency. EPA-560/1-75-004. pp. 523-530.

McMordie, W.E., Jr. 1975. Handling and treatment of oil-base drilling muds. In: Environmental Aspects of Chemical Use in Well-Drilling Operations. U.S. Environmental Protection Agency. EPA-560/1-75-004. pp. 505-513.

Meek, R.P. and J.P. Ray. 1980. Induced sedimentation, accumulation, and transport resulting from exploratory drilling discharges of drilling fluids and cuttings. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 259-284.

Menzie, C.A., D. Maurer and W.A. Leathem. 1980. An environmental monitoring study to assess the impact of drilling discharges in the mid-Atlantic. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 499-540.

Michael, A. 1977. New England OCS Environmental Benchmark. Fourth Quarterly Summary Report. Section V. 40 pp.

Mills, E. 1980. The structure and dynamics of shelf and slope ecosystems off the northeast coast of North America. In: Marine Benthic Dynamics. K.R. Tenore and B.C. Coull (Eds.), Belle W. Baruch in Marine Science No. 11. University of South Carolina Press. pp. 25-48.

Mills, E.L., K. Pittman, and B. Munroe. 1982. Effect of preservation on the weight of marine benthic invertebrates. Can. J. Fish. Aquat. Sci. 39: 221-224.

Myers, A.C. 1972. Tube-worm sediment relationships of Diopatra cuprea (Polychaeta: Onuphidae). Mar. Biol. 17:350-356.

National Oceanic and Atmospheric Administration/Coastal Zone Management (NOAA/CZM). 1979. Georges Bank Marine Sanctuary issue paper. Sanctuary Program Office, NOAA/CZM. Washington, D.C. 94 pp.

Neff, J.M. 1980. Effects of used drilling muds on benthic marine animals. Publ. No. 4330. American Petroleum Institute, Washington, D.C. 31 pp.

Neff, J.M. 1982. Fate and biological effects of oil well drilling fluids in the marine environment: a literature review. EPA-600/53-82-064. U.S. EPA, Gulf Breeze, FL. 150 pp.

Neu, H.J.A. 1970-72. Extreme wave height distribution along the Canadian Atlantic Coast. Ocean Ind. July: 45-49.

Page, D.S., B.T. Page, J.R. Hotham, E.S. Gilfillan and R.P. Gerber. 1980. Bioavailability of toxic constituents of used drilling muds. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 984-996.

Payne, J.R., J.L. Lambach, R.E. Jordan, G.D. McNabb, Jr., R.R. Sims, A. Abasumara, J.G. Sutton, D. Generro, S. Gagner, and R.F. Shokes. 1982. Georges Bank Monitoring Program. Analysis of Hydrocarbons in Bottom Sediments and Analysis of Hydrocarbons and Trace Metals in Benthic Fauna. First Year Final Report to U.S.D.I., Minerals Management Service, Washington, D.C. Science Applications, Inc., LaJolla, CA.

Peddicord, R.K., V.A. McFarland, V.A. Belfiori and T.E. Byrd. 1975. Effects of suspended solids on San Francisco Bay organisms. Appendix G. Dredge disposal study San Francisco Bay and estuary. U.S. Army Corps of Engineers, San Francisco District, 100 McAllister Street, San Francisco, CA.

Petrazzuolo, G. 1981. Preliminary Report. An environmental assessment of drilling fluids and cuttings released onto the Outer Continental Shelf. Vol. 1. Technical assessment. Vol. 2. Tables, figures and Appendix A. Prepared for Industrial Permits Branch, Office of Water Enforcement and Ocean Programs Branch, Office of Water and Waste Management, U.S. Environmental Protection Agency, Washington, D.C.

Pikanowski, R.A. 1977. An analysis of data from the National Marine Fisheries Service groundfish survey for use in assessing oil-related environmental impacts. In: Fishing and Petroleum Interactions on Georges Bank. Vol. II, 10 pp.

Pratt, S.D. 1973. Benthic fauna. In: Saila, S.B. (Ed.) Coastal Offshore Environmental Inventory, Cape Hatteras to Nantucket Shoals. University of Rhode Island, Marine Publication Series No. 2, Chapter 5:1-70.

Pratt, S.D., S.B. Saila, A.G. Gaines and J.E. Krout. 1973. Biological effects of ocean disposal of solid waste. Marine Tech. Rep. Ser. No. 9. University of Rhode Island, Kingston, RI. pp. 1-53.

Ray, J.P. 1979. Offshore discharge of drill muds and cuttings. In: Proc. of the OCS Frontier Technology Symposium. December 6, 1979, Washington, D.C.

Ray, J.P. and R.P. Meek. 1980. Water column characterization of drilling fluids dispersion from an offshore exploratory well on Tanner Bank. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C.

Riley, G.A. 1941. Plankton studies. IV. Georges Bank. Bull. Bingh. Oceanogr. Coll., 7:1-73.

Ropes, J.W. and S.A. Murawski, 1980. Size and age at sexual maturity of ocean quahogs Arctica islandica from a deep oceanic site. I.C.E.S., Shellfish Comm. K26 7 pp.

Rose, C.D. 1973. Mortality of market-sized oysters (Crassostrea virginica) in the vicinity of a dredging operation. Chesapeake Sci. 14(2):135-138.

Rubinstein, N.I., R. Rigby and C.N. D'Asaro. 1980. Acute and sublethal effects of whole used drilling fluids on representative estuarine organisms. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 828-846.

Saila, S.B., S.D. Pratt and T.T. Polgar. 1972. Dredge spoil disposal in Rhode Island Sound. Univ. Rhode Island, Mar. Tech. Rep. No. 2. 48 pp.

Sanders, H.L. 1968. Marine benthic diversity: a comparative study. American Naturalist 102:243-282.

Sanders, H.L., J.F. Grassle, G.R. Hampson, L.S. Morse, S. Garner-Price, and C.C. Jones. 1980. Anatomy of an oil spill: long-term effects from the grounding of the barge Florida off West Falmouth, Massachusetts. J. Mar. Res. 38:265-380.

Siegel, S. 1956. Nonparametric Statistics for The Behavioral Sciences. McGraw Hill. New York. 312 pp.

Sherman, K., L. Sullivan and R. Byron. 1978. Pulses in the abundance of zooplankton prey of fish on the Continental Shelf off New England. Intern. Counc. Explor. Sea. Comm. C.M. 1978/L:25 Biol. Oceanog., 11 pp.

Smith, W.L. and J.F. Grassle. 1977. Sampling properties of a family of diversity measures. Biometrics 33:283-291.

Tagatz, M.E., J.M. Ivey, C.E. Dalbo and J.L. Oglesby. 1982. Responses of developing estuarine macrobenthic communities to drilling muds. Estuaries. 5(2):131-137.

Tagatz, M.E., J.M. Ivey, H.K. Lehman and J.L. Oglesby. 1978. Effects of a lignosulfonate-type drilling mud on development of experimental estuarine macrobenthic communities. Northeast Gulf Sci. 2(1):35-42.

Tagatz, M.E. and M. Tobia. 1978. Effect of barite ($BaSO_4$) on development of estuarine communities. Estuarine and Coastal Mar. Sci. 7:401-407.

Thompson, E.P. and D.L. Harris. 1972. A wave climatology for U.S. coastal waters. Coastal Eng. Res. Center Reprints.

Tillery, J.B. and R.E. Thomas. 1980. Heavy metal contamination from petroleum production platforms in the Gulf of Mexico. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 562-587.

Tornberg, L.D., E.D. Thielk, R.E. Nakatoni, R.C. Miller and S.O. Hillman. 1980. Toxicity of drilling fluids to marine organisms in the Beaufort Sea, Alaska. In: Symposium on Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Courtesy Associates, Washington, D.C. pp. 997-1016.

Twichell, D.C., C.E. McClennen and B. Butman. 1981. Morphology and processes associated with the accumulation of the fine-grained sediment deposit on the southern New England shelf. J. Sediment. Petrol. 51:269-280.

Wheeler, R.B., J.B. Anderson, R.R. Schwarzer and C.L. Hokanson. 1980. Sedimentary processes and trace metal contaminants in the Buccaneer oil/gas field, northwestern Gulf of Mexico. Environ. Geol. 3:163-175.

Wigley, R. 1961. Bottom sediments of Georges Bank. J. Sediment. Petrol. 31:165-188.

Wigley, R. 1965. Density dependent food relationships with references to New England groundfish. ICNAF Spec. Publ., 6:51-514.

Wigley, R. 1968. Benthic invertebrates of the New England fishing banks. Bull. of Amer. Littoral Soc., 5:8-13.

Williams, W.T. 1971. Principles of clustering. Ann. Rev. Ecol. Syst. 2:303-326.

Wilson, W. 1950. The effects of sedimentation due to dredging operations on oysters in Copano Bay, Texas. Annu. Rep., Mar. Lab., Texas Game, Fish and Oyster Comm. 1948-1949.

World Oil. 1977. World Oil's 1977-78 guide to drilling, workover and completion fluids. Gulf Publ. Co., Houston, TX.

APPENDIX A

APPENDIX A

SPECIES RECORDED FROM GEORGES BANK INFAUNAL SAMPLES

PORIFERA

Calcarea sp. A
Cliona vastifica Hancock, 1849
Isodictya deichmanae (de Laubenfels, 1949)
Leucosolenia cancellata Verrill, 1874
Lissondendryx isodatylis (Carter, 1882)
Microciona prolifera (Ellis & Solander, 1786)
Polymastia robusta Bowerbank, 1860
Suberites ficus (Johnson, 1842)
Subertitidae sp. A

CNIDARIA

HYDROZOA

Acaulis primarius Stimpson, 1854
Acryptolaria conferta Allman, 1877
Campanularia abyssa Fraser, 1940
Campanularia groenlandica Levinsen, 1893
Campanularia angulata (Hincks, 1861)
Campanularia hinksi Alder, 1856
Campanularia verticillata (L., 1758)
Cladocarpus flexilis Verrill, 1883
Clytia coronata Clarke, 1879
Clytia cylindrica (Agassiz, 1862)
Clytia edwardsi (Nutting, 1901)
Cuspidella costata Hincks, 1868
Diphasia robusta Fraser, 1943
Ectopleura prolifica Hargitt, 1908
Eucopella sp. A
Eudendrium ramosum L, 1758
Eudendrium tenellum Allman, 1877
Halecium articulosum Clarke, 1875
Halecium flexile Allman, 1888
Halecium sp. A
Hydractinia echinata Fleming, 1828
Hydrallmania falcata (L., 1758)
Lovenella grandis Nutting, 1901
Lovenella sp. A
Monobrachium parasitum Mereschkowsky, 1877
Obelia dichotoma (L., 1758)
Obelia flabellata (Hincks, 1866)
Obelia hyalina Clarke, 1879
Opercularella lacerata (Johnston, 1847)
Opercularella pumilla Clark, 1875
Sertularella tenella (Alder, 1856)
Sertularella tricuspidata (Alder, 1856)
Stegopoma fastigiata (Alder, 1860)
Stegopoma plicatile (Sars, 1862)
Thuiaria cupressina (L., 1758)
Tubularia couthouyi Agassiz, 1862

ANTHOZOA

Alcyonium carneum Agassiz, 1850
Ceriantheopsis americanus Verrill, 1866
Desmophyllum cristagalli Milne Edwards and Haime, 1848
Edwardsia elegans Verrill, 1869
Edwardsia leidyi Verrill, 1898
Edwardsia sp. A, sp. B, sp. C
Epizoanthus americanus Verrill, 1864
Halcampidae sp. A
Hexactiniae sp. A, sp. B, sp. C
Hexactiniae sp. B
Anthozoa sp. A, sp. B, sp. C, sp. D, sp. E, sp. F, sp. G, sp. H

NEMERTEA

Heteronemertea

Cerebratulus lacteus (Leidy, 1851)
Cerebratulus luridus Verrill, 1873
Micrura albida Verrilli, 1879
Micrura sp. A
Lineus sp. A
Nemertea sp. A,B,C,D,E,F,G,H,I,K,L,M,N,O,P

Hoplonemertea

Monostylifera sp. A

ANNELIDA

OLIGOCHAETA

Tubificidae

Adelodrilus anisosetosus Cook, 1969
Adelodrilus sp. A
Clitellio arenicolus (Pierantoni, 1902)
Limnodriloides medioporus Cook, 1969
Peloscolex apectinatus Brinkhurst, 1965
Peloscolex intermedius Cook, 1969
Phallodrilus coeloprostratus Cook, 1969
Phallodrilus obscurus Cook, 1969
Phallodrilus parviatriatus Cook, 1971
Tubifex pseudogaster (Dahl, 1960)
Tubificidae sp. A,B,D,F,G,H

Enchytraeidae

Grania postclitellochaeta (Knöllner, 1935)
Lumbricillus codensis Lasserre, 1971
Marionina welchi Lasserre, 1971
Enchytraeidae sp. A

POLYCHAETA

Ampharetidae

Amage tumida Ehlers, 1887
Ampharete acutifrons (Grube, 1860)
Ampharete arctica Malmgren, 1866
Ampharete sp. A
Ampharete sp. B
Ampharete spp., juveniles
Amphicteis gunneri (Sars, 1835)
Anobothrus gracilis (Malmgren, 1866)
Asabellides sp. A
Eclysippe sp. A
Lysippe sp. A
Melinna elisabethae McIntosh, 1922
Sabellides borealis Sars, 1851
Samythella sp. A
Sosanella apalea Hartman, 1965
Ampharetidae, new genus, new species A
Ampharetidae, new genus, new species B
Ampharetidae, new genus, new species C
Ampharetidae, new genus, new species D
Ampharetidae spp., juveniles

Amphinomidae

Paramphinome jeffreysii (McIntosh, 1868)

Aphroditidae

Aphrodita hastata Moore, 1905
Laetmonice filicornis Kinberg, 1855

Apistobranchidae

Apistobranchus tullbergi (Théel, 1879)

Arabellidae

Arabella sp. A
Drilognathus sp. A
Drilonereis longa Webster, 1879
Drilonereis magna Webster & Benedict, 1887
Drilonereis new sp. A (free-living)
Drilonereis new sp. B (parasitic with Aricidea catherinae)
Drilonereis new sp. C (parasitic with paraonid)
Drilonereis new sp. D (parasitic with cirratulid)

Capitellidae

Barantolla sp. A
Capitella spp.
Capitella jonesi (Hartman, 1959)
Heteromastus filiformis (Claparède, 1864)
Mediomastus fragilis Rasmussen, 1973
Notomastus latericeus Sars, 1850

Chaetopteridae

Spiochaetopterus oculatus Webster, 1879

Chrysopetalidae

Dysponetus gracilis Hartman, 1965

Cirratulidae

Caulleriella new sp. B
Caulleriella new sp. C
Chaetozone new sp. A
Chaetozone new sp. B
Cirratulus cirratus (Muller, 1776)
Dodecaceria new sp. A
Tharyx acutus Webster & Benedict, 1887
Tharyx annulosus Hartman, 1965
Tharyx dorsobranchialis Kirkegaard, 1959
Tharyx marioni (Saint-Joseph, 1894)
Tharyx nr. monilaris Hartman, 1960
Tharyx new sp. A
Tharyx sp. C
Tharyx sp. D
Tharyx sp. E

Cossuridae

Cossura longicirrata Webster & Benedict, 1887

Ctenodrilidae

Ctenodrilus serratus (Schmidt, 1857)

Dorvilleidae

Dorvillea sociabilis (Webster, 1879)
Dorvillea sp. A
Ophryotrocha sp. A
Protodorvillea gaspeensis Pettibone, 1961
Protodorvillea kefersteini (McIntosh, 1869)
Schistomeringos caeca (Webster & Benedict, 1884)
Schistomeringos sp. A
Schistomeringos sp. B
Schistomeringos sp. C
Schistomeringos sp. D

Eunicidae

Eunice norvegica (L., 1767)
Eunice pennata (Müller, 1776)
Eunice vittata (delle Chiaje, 1828)
Marphysa belli (Audouin & Milne-Edwards, 1833)
Marphysa sanguinea (Montagu, 1815)
Marphysa sp. A
Nematonereis unicornis (Grube, 1840)

Flabelligeridae

Brada villosa (Rathke, 1843)
Flabelligera sp. B
cf. Flabelligera affinis Sars, 1829
Pherusa nr. falcata (Støp-Bowitz, 1947)
Pherusa plumosa (Müller, 1776)
Pherusa sp. A

Glyceridae

Glycera capitata Oersted, 1843
Glycera dibranchiata
Glycera robusta Ehlers, 1868
Glycera new sp. A
Glycera spp., juv.

Goniadidae

Goniada maculata Oersted, 1843
Goniada norvegica Oersted, 1845
Goniada new sp. A
Goniada spp. juveniles
Goniadella gracilis (Verrill, 1873)
Goniadidae, new genus & species A

Hesionidae

Microphthalmus listensis Westheide, 1967
Microphthalmus sczelkowii Mecznikow, 1865
Nereimyra punctata (Müller, 1776)
Gyptis sp. A
Hesionidae, new genus & new species A

Lumbrineridae

Lumbrineris acuta (Verrill, 1875)
Lumbrineris fragilis (Müller, 1776)
Lumbrineris hebes Verrill, 1880
Lumbrineris impatiens (Claparède, 1868)
Lumbrineris latreilli (Audouin & Milne-Edwards, 1833)
Lumbrineris paradoxa Saint-Joseph, 1888
Lumbrineris sp. A
Lumbrineris sp. B
Lumbrineris sp. C
Lumbrineridae spp. juveniles
Ninoe nigripes Verrill, 1873

Maldanidae

Asychis biceps (Sars, 1861)
Axiothella cf. catenata (Malmgren, 1865)
Axiothella sp. A
Clymenella torquata (Leidy, 1855)
Clymenura borealis (Arwidsson, 1907)
Clymenura polaris (Théel, 1879)
Euclymene sp. A
Euclymene sp. B
Euclymeninae sp. B
Heteroclymene robusta Arwidsson, 1907
Isocirrus planiceps (Sars, 1872)
Maldanidae sp. B
Maldanidae sp. C
Maldanidae sp. D
Maldanidae sp. E
Notoproctus sp. A
Petaloproctus planiceps (Sars, 1872)
Praxillura longissima Arwidsson, 1907
Rhodine loveni Malmgren, 1865
Rhodine gracilior Tauber, 1879

Nephtyidae

Aglaophamus circinata (Verrill, 1874)
Nephtys bucera Ehlers, 1868
Nephtys caeca (Fabricius, 1780)
Nephtys incisa Malmgren, 1865
Nephtys paradoxa Malm, 1874
Nephtys picta Ehlers, 1868
Nephtys squamosa Ehlers, 1887

Nephtyidae (continued)

Nephtys sp. C

Nereididae

Nereis grayi Pettibone, 1956
Nereis pelagica (L., 1761)
Nereis cf. riisei Grube, 1856
Nereis zonata Malmgren, 1867
cf. Rullerinereis sp. A

Onuphidae

Nothria conchylega (Sars, 1835)
Nothria pallidula Hartman, 1965
Paronuphis sp. A
Rhamphobrachium sp. A

Opheliidae

Ophelia limacina (Rathke, 1843)
Ophelina acuminata Oersted, 1843
Ophelina cylindricaudata (Hansen, 1878)
Ophelina sp. A
Ophelina spp. juv.
Travisia forbesi Johnson, 1840

Orbiniidae

Leitoscoloplos acutus (Verrill, 1873)
Leitoscoloplos cf. fragilis (Verrill, 1873)
Leitoscoloplos robustus (Verrill, 1873)
Orbinia swani Pettibone, 1957
Scoloplos acmeceps Chamberlin, 1919
Scoloplos armiger (Müller, 1776)
Scoloplos (?Leodamas) sp. A
Phylo felix Kinberg, 1866

Oweniidae

Myriochele oculata Zaks, 1923
Myriochele sp. A
Owenia fusiformis delle Chiaje, 1844

Paraonidae

Aricidia albatrossae Pettibone, 1957
Aricidia nr. belgica (Fauvel, 1936)
Aricidea catherinae Laubier, 1967
Aricidea cerruti Laubier, 1966
Aricidea longobranchiata Day, 1961
Aricidea lopezi Berkeley and Berkeley, 1956
Aricidea neosuecica Hartman, 1965

Paraonidae (continued)

Aricidea quadrilobata Webster & Benedict, 1887
Aricidea simplex (Day, 1963)
Aricidea suecica Eliason, 1920
Aricidea wassi Pettibone, 1965
Aricidea new sp. A
Aricidea new sp. B
Aricidea sp. C
Aricidea sp. D
Cirrophorus brevicirratus Strelzov, 1973
Cirrophorus furcatus (Hartman, 1957)
Levensenia gracilis (Tauber, 1879)
Paradoneis new sp. A
Paradoneis lyra (Southern, 1914)
Paraonis fulgens (Levinsen, 1883)
Paraonis pygoenigmatica Jones, 1968
Paraonis new sp. A
Paraonis new sp. B
Paraonis new sp. C
Paraonis new sp. D

Pectinariidae

Pectinaria gouldi (Verrill, 1873)
Pectinaria granulata (L., 1767)
Pectinaria hyperborea (Malmgren, 1866)
Pectinariidae sp. (Indeterminable)

Phyllodocidae

Cirrodoce cristata Hartman & Fauchald, 1971
Eteone heteropoda Hartman, 1951
Eteone lactea Claparède, 1868
Eteone spetsbergensis Malmgren, 1865
Eteone longa (Fabricius, 1780)
Eulalia bilineata (Johnston, 1840)
Eulalia viridis (L., 1767)
Genetyllis castanea (Marenzeller, 1879)
Hesionura elongata (Southern, 1914)
Mystides borealis borealis Théel, 1979
Mystides borealis caeca Langerhans, 1880
Paranaitis speciosa (Webster, 1880)
Phyllodoce arenae Webster, 1879
Phyllodoce groenlandica Oersted, 1842
Phyllodoce maculata (L., 1767)
Phyllodoce mucosa Oersted, 1843
Phyllodoce sp. A
Phyllodoce spp. juv.
Phyllodocidae, new genus & species A

Polygordidae

Polygordius sp. A

Polynoidae

Harmothoe extenuata (Grube, 1840)
Lepidonotus squamatus (L., 1758)

Protodrilidae

Protodriloides chaetifer (Remane, 1926)
Protodrilus sp. A

Psammodrilodae

Psammodrilus balanoglossoides Swedmark, 1952

Questidae

Novaquesta trifurcata Hobson, 1970

Sabellidae

Amphiglena sp. A
Chone duneri Malmgren, 1867
Chone infundibuliformis Kröyer, 1856
Chone sp. A
Chone sp. B
Chone spp. juvenile
Euchone nr. elegans Verrill, 1873
Euchone hancocki Banse, 1970
Euchone incolor Hartman, 1965
Jasmineira cf. filiformis Hartman, 1965
Fabricinae spp. juvenile
Megalomma bioculata (Ehlers, 1887)
Myxicola infundibulum (Renier, 1804)
Potamilla neglecta (Sars, 1851)
Potamilla reniformis (Leukart, 1849)
Sabellinae spp. juvenile

Scalibregmatidae

Scalibregma inflatum Rathke, 1843

Serpulidae

Filograna implexa (Berkeley, 1851) (Salmacina - form)
Protula tubularia (Montague, 1803)

Sigalionidae

Pholoe minuta (Fabricius, 1780)
Sigalion arenicola Verrill, 1879
Sigalion sp. A
Sthenelais picta Verrill, 1881
Sthenelais limicola (Ehlers, 1864)

Sphaerodoridae

Clavodorum sp. A
Sphaerodoridium sp. A
Sphaerodoropsis corrugata Hartman & Fauchald, 1971
Sphaerodoridium claparedii (Greeff, 1866)
Sphaerodorum gracilis (Rathke, 1843)
Sphaerodorum sp. A

Spionidae

Aonides paucibranchiata Southern, 1914
Aonides sp. A
Apoprionospio dayi Foster, 1969
Laonice cirrata (Sars, 1851)
Malacoceros indicus Fauvel, 1928
Microspio pigmentata (Reish, 1959)
Polydora barbilla Blake, 1981
Polydora nr. caeca Oersted, 1843
Polydora caulleryi Mesnil, 1897
Polydora concharum Verrill, 1880
Polydora ligni Webster, 1879
Polydora socialis (Schmarda, 1861)
Polydora new sp. A
Polydora new sp. B
Polydora new sp. C
Prionospio cirrifera Wirén, 1883
Prionospio dubia Day, 1961
Prionospio steenstrupi Malmgren, 1867
Prionospio aff. cirrobranchiata Day, 1961
Prionospio new sp. A
Scolelepis squamata (Müller, 1789)
Scolelepis texana Foster, 1971
Spio cf. armata (Thulin, 1957)
Spio filicornis (Müller, 1776)
Spio limicola Verrill, 1879
Spiophanes bombyx (Claparède, 1870)
Spiophanes kroeyeri Grube, 1860
Spiophanes wigleyi Pettibone, 1962
Spiophanes sp. A
Spionidae new genus & new species A

Spintheridae

Spinther citrinus (Stimpson, 1854)

Sternaspidae

Sternaspis scutata (Renier, 1807)

Syllidae

Ambloysyllis sp. A
Autolytus prolifer (O. F. Müller, 1788)
Eusyllis blomstrandi Malmgren, 1867
Eusyllis lamelligera Marion & Bobretzky, 1875
Exogone hebes (Webster & Benedict, 1884)
Exogone naidena Oersted, 1845
Exogone verugera (Claparède, 1868)
Parapionosyllis longicirrata (Webster & Benedict, 1884)
Procerea cornuta (Agassiz, 1863)
Procerea fasciata (Bosc, 1802)
Sphaerosyllis sp. A
Sphaerosyllis sp. B
Streptosyllis arenae Webster & Benedict, 1884
Streptosyllis varians Webster & Benedict, 1887
Streptosyllis websteri Southern, 1914
Syllides cf. articulosa Ehlers, 1897
Syllides benedicti Banse, 1971
Syllides japonica Imajima, 1966
Syllides sp. A
Syllides sp. B
Syllides sp. C
Syllides sp. D
Typosyllis hyalina (Grube, 1863)
Typosyllis tegulum Hartman & Fauchald, 1971

Terebellidae

Amaena triloba (Sars, 1863)
Eupolymnia nebulosa (Montagu, 1818)
Pista palmata Verrill, 1873
Polycirrus eximius (Leidy, 1855)
Polycirrus phosphoreus Verrill, 1880
Polycirrus sp. A
Polycirrus sp. B
Polycirrus sp. C (? = Proclea sp.)
Thelepus new sp. A

Trichobranchidae

Terebellides stroemi Sars, 1835
Trichobranchus glacialis Malmgren, 1866
Trichobranchus roseus (Malmgren, 1874)

Trochochaetidae

Trochochaeta nr. carica (Birula, 1897)

Family Undetermined

Aberranta enigmatica Hartman, 1965

PHORONIDA

Phoronida sp. A

PRIAPULIDA

Priapulid sp. A

SIPUNCULA

Golfingia eremita (Sars, 1851)
Golfingia margaritacea (Sars, 1851)
Golfingia minuta (Keferstein, 1865)
Phascolion gouldi (Pourtales, 1851)
Phascolion strombi (Montague, 1804)

MOLLUSCA

GASTROPODA

Prosobranchia

Alvania castanea Möller, 1842
Alvania pelagica (Stimpson, 1851)
Alvania exarata Stimpson, 1851
Amphissa haliaeeti (Jeffreys, 1897)
Buccinum undatum L., 1758
Cocculina beanii Dall, 1882
Colus parvus (Verrill & Smith, 1882
Colus pygmaeus (Gould, 1841)
Colus sabinii (Gray, 1824)
Colus stimpsoni (Mörch, 1867)
Colus spp.
Crepidula plana Say, 1822
Crepidula fornicata (L., 1758)
Crucibulum striatum Say, 1824
Epitonium championi Clench & Turner, 1952
Epitonium dallianum (Verrill & Smith, 1880)
Epitonium multistriatum (Say, 1826)
Lunatia heros (Say, 1822)
Mitrella dissimilis (Stimpson, 1851)
Moelleria costulata (Möller, 1842)
Nassarius trivitatus (Say, 1822)
Polynices immaculatus (Totten, 1834)
Polynices nanus (Möller, 1842)
Scissurella crispata (Fleming, 1828)
Solariella obscura (Couthouy, 1838)
Turritellopsis cf. acicula (Stimpson, 1851)
Velutina velutina (Müller, 1776)
Gastropod sp. B, sp. C

Opisthobranchia

Adalaria proxima (Alder & Hancock, 1854)
Cadlina laevis (L., 1767)
Coryphella verrilli
Cylichna alba (Brown, 1827)
Cylichna gouldi (Couthouy, 1839)
Doto coronata (Gmelin, 1792)
Dendronotus frondosus (Ascanius, 1774)
Diaphana minuta (Brown, 1827)
Doridella obscura Verrill, 1870
Eubranchus sp. A
Limacina leseueurii (Orbigny, 1836)
Limacina retroversa (Fleming, 1823)
Limacina trochiformis (Orbigny, 1836)
Odostomia gibbosa Bush, 1909
Odostomia impressa (Say, 1821)
Odostomia modesta Stimpson, 1851
Odostomia sulcosa (Mighels, 1843)
Odostomia spp.
Philine lima (Brown, 1827)
Pleurobranchia tarda Verrill, 1880
Retusa obtusa (Montagu, 1807)
Nudibranchea sp. B
Aeolidiidae sp. A

BIVALVIA

Anomia squamula L., 1758
Anomia spp.
Arctica islandica (L., 1767)
Astarte borealis (Shumacher, 1817)
Astarte castanea (Say, 1822)
Astarte montagui (Dillwyn, 1817)
Astarte quadrans Gould, 1841
Astarte crenata subequilatera Sowerby, 1854
Astarte undata Gould, 1841
Astarte sp. A
Bathyarca pectunculoides Scacchi, 1833
Cardiomya perrostrata (Dall, 1881)
Cerastoderma pinnulatum (Conrad, 1831)
Corbula contracta Say, 1822
Crenella decussata (Montagu, 1808)
Crenella glandula (Totten, 1843)
Crenella fragilis Verrill, 1885
Crenella sp. juv.
Cuspidaria rostrata (Spengler, 1783)

Cuspidaria cf. parva Verrill and Bush, 1898
Cyclocardia borealis (Conrad, 1831)
Dacrydium vitreum (Holboll, 1842)
Diplodonta sp. A
Ensis directus Conrad, 1843
Hiatella arctica (L., 1767)
Lasaeidae sp. A
Leptonacea sp. A
Limatula subauriculata (Montagu, 1808)
Limopsis sulcata Verrill & Bush, 1898
Lucinoma filosa (Stimpson, 1851)
Lyonsia granulifera Verrill & Bush, 1898
Lyonsia hyalina Conrad, 1831
Modiolus modiolus (L., 1758)
Musculus niger (Gray, 1824)
Mytilus edulis Linne 1787
Nucula delphinodonta Mighels & Adams, 1842
Nucula proxima Say, 1822
Nucula sp. juv.
Nuculana messanensis (Seguenza, 1877)
Palliolum subimbrifer (Verrill & Bush, 1897)
Palliolum sp. B
Pandora gouldiana Dall, 1886
Periploma leanum (Conrad, 1831)
Periploma papyratium (Say, 1822)
Pitar morrhuanus Linsley, 1848
Placopecten magellanicus (Gmelin, 1791)
Poromya granulatum (Nyst & Westendorp, 1839)
Siliqua costata Say 1822
Solemya velum Say, 1822
Spisula solidissima (Dillwyn, 1817)
Tellina agilis Stimpson, 1857
Tellina tenella Verrill, 1874
Thracia septentrionalis Jeffreys, 1872
Thyasira sp. A, sp. B, sp. C, sp. D, sp. E
Thyasira spp.
Yoldia sapotilla (Gould, 1841)
Bivalve sp. D, sp. E, sp. F, sp. H, Sp. J, sp. K, sp. L

SCAPHOPODA

Cadulus agassizii Dall, 1881
Cadulus sp. A
Dentalium entale stimpsoni Henderson, 1920
Siphonodentalium occidentale Henderson, 1920
Siphonodentalium bushi Henderson, 1920
cf. Siphonodentalium tythum Watson, 1879

POLYPLACOPHORA

Hanleya sp. A
Leptochiton sp. A
Leptochiton sp. B
Polyplacophora sp. A

APLACOPHORA

Nierstrassia fragile Heath, 1918
Chaetoderma nitidulum Lovèn, 1884
Chaetoderma sp. A
Neomeniomorpha sp. A, sp. B, sp. C, sp. D, sp. E

ARTHROPODA

ARACHNIDA

Acarina

PYCNOGONIDA

Anoplodactylus petiolatus (Kröyer, 1844)
Nymphon grossipes Kroyer, 1780

CRUSTACEA

CEPHALOCARIDA

Hutchinsoniella macracantha Sanders, 1955

OSTRACODA

Myodocopida

CIRRIPEDIA

Balanus sp. A

MALACOSTRACA

Cumacea

Bodotriidae

Mancocuma stellifera Zimmer, 1943
Pseudoleptocuma minor (Calman, 1912)

Diastylidae

Diastylis abbreviata Sars, 1871
Diastylis goodsiri (Bell, 1855)
Diastylis lucifera (Kröyer, 1841)
Diastylis polita (S.I. Smith, 1879)
Diastylis quadrispinosa (Sars, 1871)
Diastylis sculpta Sars, 1871
Diastylis sp. A
Diastylis sp. B
Diastylis spp.
Leptostylis longimana (Sars, 1865)
Leptostylis sp. A
Diastylidae sp. A

Lampropidae

Lamprops quadriplicata S.I. Smith, 1879
Lamprops spp.

Leuconidae

Eudorella pusilla Sars, 1871
Eudorella sp. A
Eudorellopsis deformis (Kröyer, 1846)

Nannastacidae

Campylaspis affinis Sars, 1870
Campylaspis rubicunda (Lilljeborg, 1855)
Campylaspis sp. A

Pseudocumatidae

Petalosarsia declivis (Sars, 1865)

Tanaidacea

Paratanaidae

Pseudoleptochelia filum (Stimpson, 1853)
Tanaissus lilljeborgi (Stebbing, 1871)
Typhlotanais cornutus G.O. Sars, 1885

Isopoda

Anthuridae

Ptilanthura tricarina Menzies & Frankenberg, 1966
Ptilanthura sp. A

Cirolanidae

Cirolana borealis Lilljeborg, 1851
Cirolana polita (Stimpson)
Cirolana sp. A

Desmosomatidae

Desmosoma tenuimanum (G.O. Sars, 1899)
Desmosoma sp.

Idoteidae

Chiridotea arenicola Wigley, 1960
Chiridotea tuftsi (Stimpson, 1853)
Edotea acuta (Richardson)
Edotea triloba (Say, 1818)
Edotea sp. B

Janiridae

Janira alta (Stimpson, 1853)
Janira sp. A

Munnidae

Munna fabricii (Kröyer)
Munna sp. A
Pleurogonium inerme (Sars)
Pleurogonium sp. A
Munnidae sp. A

Isopoda sp. A

Amphipoda - Hyperiidea

Hyperiidae

Parathemisto gaudichaudii (Guerin, 1825)

Amphipoda - Gammaridea

Argissidae

Argissa hamatipes (Norman, 1869)

Ampeliscidae

Ampelisca agassizi (Judd, 1896)
Ampelisca macrocephala Lilljeborg, 1852
Byblis serrata (Smith, 1873)
Byblis sp. A
Haploops sp. A

Amphilochidae

Amphilochidae sp. A
Amphilochoides odontonyx (Boeck, 1871)

Aoridae

Leptocheirus pinguis (Stimpson, 1853)
Microdeutopus anomalus (Rathke, 1843)
Pseudunciola obliquua (Shoemaker, 1949)
Unciola inermis Shoemaker, 1945
Unciola irrorata Say, 1818
Unciola spicata Shoemaker, 1945
Unciola spp. juveniles
Aoridae sp. A

Corophiidae

Corophium acutum Chevreux, 1908
Corophium crassicorne Bruzelius, 1859
Corophium tuberculatum Shoemaker, 1934
Corophium sp. A
Erichthonius rubricornis (Stimpson, 1853)
Siphonoecetes colletti

Eusiridae

Rhachotropis inflata (G.O. Sars, 1882)

Haustoriidae

Acanthohaustorius intermedius Bousfield, 1965
Acanthohaustorius millsi Bousfield, 1965
Acanthohaustorius shoemakeri Bousfield, 1965

Haustoriidae (continued)

Acanthohaustorius similis Frame, 1980
Acanthohaustorius spinosus Bousfield, 1962
Bathyporeia quoddyensis Shoemaker, 1949
Parahaustorius attenuatus Bousfield, 1965
Parahaustorius longimerus Bousfield, 1965
Protohaustorius wigleyi Bousfield, 1965
Pseudohaustorius carolinensis Bousfield, 1965
Platyischnopus sp. A

Ischyroceridae

Ischyrocerus sp. A
Ischyrocerus sp. B
Liljeborgidae sp. A

Lysianassidae

Anonyx liljeborgi Kroyer, 1870
Anonyx sp. A
Hippomedon serratus Holmes, 1903
Lysianassidae sp. A
Lysianassidae sp. B

Melitidae

Casco bigelowi (Blake, 1929)
Eriopisa elongata (Bruzelius, 1859)
Jerbarnia americana Watling, 1981
Melita dentata Kroyer, 1842

Melphidippidae

Melphidippa borealis Boeck, 1870

Oedicerotidae

Monoculodes edwardsi Holmes, 1905
Monoculodes sp. A

Paramphithoidae

Epimeria obtusa Watling, 1981

Photidae

- Gammaropsis nitida (Stimpson, 1853)
- Photis dentata Shoemaker, 1945
- Photis pollex (Walker, 1895)
- Photidae sp. A

Phoxocephalidae

- Harpinia propinqua G.O. Sars, 1891
- Harpinia truncata G.O. Sars, 1891
- Phoxocephalus holbolli Kröyer, 1842
- Rhepoxynius hudsoni Barnard and Barnard, 1982
- Phoxocephalidae sp. A

Pleustidae

- Pleusymtes glaber Boeck, 1861
- Stenopleustes gracilis Holmes, 1905
- Stenopleustes inermis Shoemaker, 1949
- Pleustidae sp. A

Podoceridae

- Dyopedos monacanthus (Metzger, 1875)

Pontogeneiidae

- Pontogeneia inermis (Kröyer, 1842)

Stenothoidae

- Metopa sp. A
- Metopella angusta Shoemaker, 1949
- Metopella sp. A
- Parametopella cypris (Holmes, 1905)
- Proboloides holmesi Bousfield, 1973

Amphipoda sp. A,B,C,G, I, J

Amphipoda - Caprellidea

Caprellidae

Aeginella spinosa Boeck, 1861
Aeginina longicornis (Kröyer, 1842-43)
Caprella unica Mayer, 1903
Caprella sp. A

Mysidacea

Mysidae

Erythrops erythrophthalma (Goes, 1863)
Heteromysis formosa Smith, 1873
Mysidopsis bigelowi Tattersall, 1926
Mysidae sp. A

Euphausiacea

Meganyctiphanes norvegica (Sars, 1857)
Euphausiacea sp.

Decapoda

Caridea

Natantia

Caridea sp. A
Natantia sp. A

Crangonidae

Crangon septemspinosa Say, 1818
Pontophilus brevirostris Smith, 1881

Palaemonidae

Palaemonetes sp. A

Pandalidae

Pandalus borealis Kröyer, 1838
Pandalus montagui Leach, 1813

Reptantia

Anomura

Axiidae

Axiidae sp. A
Axiidae sp. B

Galatheidae

Munidia iris Edwards, 1880
Galatheidae sp. A

Paguridae

Pagurus acadianus Benedict, 1901
Pagurus arcuatus Squires, 1964
Pagurus pubescens Kröyer, 1838
Pagurus sp. A
Pagurus sp. B

Brachyura

Canceridae

Cancer borealis Stimpson, 1859
Cancer irroratus Say, 1817
Cancer sp. A

Majidae

Euprognatha rastellifera Rathbun, 1925
Hyas coarctatus Leach, 1815

Ocypodidae

Ocypode quadrata (Fabricius, 1787)

Brachyura sp. A

ECTOPROCTA

Tubuliporidae

Idmonea atlantica (Johnson, 1847)

Diastoporidae

Diplosolen obelia (Johnston, 1838)

Crisiidae

Crisia eburnea (L., 1758)

Lichenoporidae

Lichenopora hispida (Fleming, 1828)

Walkeriidae

Walkeria sp. A

Nolellidae

Nolella sp. A

Alcyonidae

Alcyonidium polyoum (Hassall, 1841)

Scruparidae

Scruparia chelata (L., 1758)

Eucrateidae

Eucratea loricata (L., 1758)

Calloporidae

Amphiblestrum osburni Powell, 1968
Amphiblestrum trifolium (Wood, 1844)
Callopora aurita (Hincks, 1877)
Callopora dumerilii (Audouin)
Callopora lineata (L., 1767)

Membraniporidae

Membranipora tenuis Desor, 1848
Membranipora tuberculata (Bosc, 1802)

Electridae

Electra arctica Borg, 1931
Electra pilosa (L., 1767)

Bicellariellidae

Bicellariella ciliata (L., 1758)

Bugulidae

Bugula stolonifera Ryland, 1960
Dendrobeania murrayana (Johnston, 1847)

Calpensiidae

Microporina sp. A

Cribilinidae

Cribilina punctata (Hassall, 1841)

Cryptosulidae

Cryptosula pallasiana (Moll, 1803)

Schizoporellidae

Schizoporella biaperta (Michelin, 1841)
Schizoporella unicornis (Johnston, 1847)

Smittinidae

Parasmittina nitida (Verrill, 1875)
Porella reduplicata (Osburn, 1933)

Hippothoidae

Hippothoa divaricata Lamouroux, 1821

ECHINODERMATA

ECHINOIDEA

Brisaster fragilis (Duben & Koren)
Echinarachnius parma (Lamarck, 1816)
Echinoidea juvenile sp.A (probably juv. E. parma)
Echinoidea juvenile sp.B (probably an urchin)
Echinocardium flavescens (O.Fr. Müller)
Spatangoidea juvnile spp.

OPHIUROIDEA

Amphioplus abditus (Verrill, 1871)
Amphipholis squamata (Delle Chiaje, 1828)
Amphitarsus spinifer Schoener, 1967
Ophiura robusta (Ayres, 1851)
Ophiopholis aculeata (L.)
Ophiuroidea (juvenile) sp. A
Ophiuroidea (juvenile) sp. B
Ophiuroidea sp. C
Ophiuroidea sp. D
Ophiuroidea sp. E
Ophiuroidea sp. F
Ophiuroidea (juvenile) sp. G
Ophiuroidea juvenile spp.

CRINOIDEA

Hathrometra sp.

ASTEROIDEA

Astropecten americanus Verrill, 1880
Leptasterias tenera (Stimpson, 1862)
Leptasterias tenera juvenile A
Asterias forbesi (Desor, 1848)
Asterias vulgaris Verrill, 1866
Forcipulata sp. A
Forcipulata (juvenile) sp. B
Forcipulata sp. C
Paxillosida (juvenile) sp. A
Asteroidea (juvenile) sp. B
Asteroidea (juvenile) sp. C
Asteroidea (juvenile) spp.

HOLOTHUROIDEA

Duasmodactyla commune (Forbes, 1841)
Leptosynapta tenuis (Ayres, 1851)

HEMICHORDATA

Enteropneusta sp. A
Enteropneusta sp. B
Enteropneusta sp. D
Enteropreusta sp. E
Enteropneusta juveniles

CHORDATA

UROCHORDATA

Ascidiacea sp. A
Ascidiacea sp. B
Ascidiacea sp. C
Ascidiacea sp. D
Ascidiacea sp. E

VERTEBRATA

Ammodytes americanus De Kay, 1842
Neoliparis atlanticus (Jordan & Evermann, 1898)
Omochelys cruentifer (Goode & Bean, 1896)
Scomber scombrus L. 1758
Urophycis chuss Walbaum, 1792

APPENDIX B

APPENDIX B

ANNOTATED SPECIES LIST

PORIFERA

Suberitidae sp. A

An encrusting form with large tylostyles, with the rounded end next to substratum but differing in having spirasters as microscleres. Small sponge always found encrusting sand grains. Most common sponge.

Calcarea sp. A

Resembling Sycon in being solitary tubes yet lacking long spicule fringe around osculum. Resembles Leucosolenia but differs in having a rough or tufted surface texture.

CNIDARIA: HYDROZOA

Lovenella sp. A

Resembling Lovenella grandis in shape and structure but much smaller.

Halecium sp. B

Overall structure similar to Halecium articulosum but differing in that hydrophores alternate at 90^{o} angles to one another, whereas hydrophores of H. articulosum alternate at a full 180^{o} to one another.

Halecium sp. C

Shape resembling Lafoea spp. but hydrophores commonly reduplicated one or two times, a common characteristic of Halecium.

Eucopella sp. A

Characterized by a very large gonophore. Similar to Eucopella caliculata except hydrothecal margin toothed instead of entire.

Eudendrium sp. A

Specimens incomplete but agreeing with genus Eudendrium.

Thuiaria cupressina (L., 1758)

Most common hydrozoan.

ANTHOZOA

Edwardsia sp. A,B,C

All specimens poorly preserved, with tentacles withdrawn or lost; all with multiples of eight mesentaries and tentacles.

Hexactiniae sp. A,B,C

All 3 forms with multiples of six mesentaries and tentacles.

Halcampidae sp. A

Family assignment due to very large longitudinal muscles of mesentaries and fine mucus covering, all specimens in very poor shape and could not be assigned a genus and species.

NEMERTEA

Most nemerteans very difficult if not impossible to identify unless sectioned.

Micrura sp. A

Specimens with caudal cirrus present and without thin lateral margins.

Lineus sp. A

Specimens without caudal cirrus; with longitudinal cephalic grooves.

Monostylifera sp. A

Specimens with stylet. Rare.

ANNELIDA: POLYCHAETA

AMPHARETIDAE

Asabellides sp. A

Four pairs branchiae; with long dorsal neuropodial cirrus; peristomium narrow; one pair long anal cirri and short papillae.

Eclysippe sp. A

Palea present; with 3 pairs branchiae; 12 thoracic uncinigers; with ventral glandular band on setiger 5.

Lysippe sp. A

Paleae lacking; with 4 pairs branchiae; anal cirri with 2 eyes; with enlarged notopodial lobes on setiger 10.

Samythella sp. A

With 3 pairs branchiae; 12 thoracic uncinigers; paleae absent; without notopodial rudiments.

Ampharetidae, new genus, new species A

Paleae present; with 4 pairs branchiae; 12 thoracic uncinigers; with notopodial rudiments.

Ampharetidae, new genus, new species B

Paleae absent; with 3 pairs branchiae; 11 thoracic uncinigers; with notopodial rudiments.

Ampharetidae, new genus, new species C

Paleae reduced; with 4 pairs branchiae; 2 thoracic uncinigers; enlarged notopodia with long brushtipped setae on last thoracic setiger.

Ampharetidae, new genus, new species D.

Paleae absent; with 2 pairs branchiae and 1 pair nephridia; 13 thoracic uncinigers; several dark eyes.

APHRODITIDAE

Aphrodita hastata Moore, 1905

Juveniles with neurosetae having basal spur and few marginal teeth; thus intermediate between typical A. hastata and the European A. aculeata.

ARABELLIDAE

Arabella sp. A

Prostomium without eyes; simple limbate capillaries present, lacking denticulation at base of winged plate; upper edge of mandibles smooth; anterior parapodial lobes appear receded into body wall.

cf. Drilognathus sp. A

Yellow acicular spines not projecting; setae absent, or if present, reduced, shrunken in appearance; maxillary apparatus reduced to maxillary carriers with small, vestigal, fused mass above it; mandibles well developed; anterior parapodia bilabiate; one specimen found in Lumbrineris acuta host.

Drilonereis longa Webster, 1879

Anterior parapodia: reduced to swelling; middle parapodia: presetal lobe short, postsetal lobe long; posterior parapodia: presetal lobe short to slightly subequal to the long postsetal lobe; limbate setae with long capillary tips. Number of teeth on maxillary apparatus: MI, 4-6; MII, 4-5; MIII, 1. May be confused with D. sp. A (see below).

Drilonereis n.sp. A

Anterior parapodia: presetal lobe absent, postsetal lobe short; middle parapodia: presetal lobe short, postsetal lobe long; posterior parapodia: presetal lobe slightly subequal to long postsetal lobe; limbate capillary setae with long limbations and short capillary tip. Number of teeth on maxillary aparatus: MI, 2-3, MII, 2-3, MIII, 2. (Compare with D. longa).

Drilonereis n.sp. B

Parasitic with Aricidea catherinae.

Drilonereis n.sp. C

Parasitic with paraonid.

Drilonereis n.sp. D

Parasitic with cirratulid.

CAPITELLIDAE

Barantolla sp. A

Setal formula: $\frac{6C}{0+5C} + \frac{h}{h}$; not a juvenile Capitella.

Capitella jonesi (Hartman, 1959)

Setal formula: $\frac{3C}{3C} + \frac{h}{h}$ ....; corresponds to Grassle and Grassle (1977) Type III.

Mediomastus fragilis Rasmussen, 1973

Without capillaries in abdominal notopodia; 2 eyes present (Warren, 1979).

CHRYSOPETALIDAE

Dysponetus gracillis Hartman, 1965

New to continental shelf. Previously known from slope depths (See Hartman, 1965).

CIRRATULIDAE

Caulleriella n.sp. B

Prostomium very acute, with large dark eyes; bifid hooks numbering 2-3 per ramus; body smooth; gills tending to curl in preservation; pygidium with 2 anal cirri. Common at Sta. 5.

Caulleriella n.sp. C

Prostomium not acute, darkly pigmented, with 2 pair indistinct eyes; bifid hooks numbering 3-6 per ramus; hooks in far posterior setigers worn down to unidentate appearance; 2 anal cirri present. Found only at Sta. 14.

Chaetozone n.sp. A

Spines all acicular, not forming complete cinctures; pygidium a flattened disc.

Chaetozone n.sp. B

Similar to sp. A, but with both bifid hooks and blunt spines forming partial cinctures; with anal disc.

Dodecaceria n.sp. A

With modified setae having ribs, not spoon-shaped; resembles D. diceria Hartman (1951) from Gulf of Mexico.

Tharyx acutus Webster & Benedict, 1887

Palps arising anterior to setiger 1; thoracic region not inflated; posterior end broad, with ventral depression; with short knob-tipped setae in posterior setigers directed toward ventral channel.

Tharyx annulosus Hartman, 1965

Palps arising on anterior edge of setiger 1; thoracic region slightly inflated, some segments pigmented ventrally; serrated capillary setae broad, with deep denticulations; posterior end weakly inflated.

Tharyx dorsobranchialis Kirkegaard, 1959

Prostomium very elongated, palps anterior to setiger 1; thoracic region strongly inflated, not pigmented; with lightly serrated capillaries; branchiae and parapodia dorsally elevated, forming medial channel in thorax. New to North America.

Tharyx nr. monilaris Hartman, 1960

Palps arising just anterior to setiger 1; body with an expanded thoracic region; with bead-like abdominal segments; all capillaries smooth, not serrated. A California species; new to eastern North America.

Tharyx n.sp. A

Palps arise over junction of peristomium and setiger 1; body circular in crosssection throughout; setae few posteriorly, with simple blades, very thin, no serrations but may fray when bent; prostomium short; posterior end tapered. Common at site-specific stations.

Tharyx sp. D

Body distended; palps arising just anterior to setiger 1; capillary notosetae narrow, smooth; some long natatory setae present; neurosetae shorter, thicker, curved, with serrations. Found at Sta. 17.

Tharyx sp. E

Resembles sp. A in general appearance, but is much larger; posterior segments with broad, finely serrated setae. Found at Sta. 14.

DORVILLEIDAE

Dorvillea sp. A

Specimens incomplete; parapodia as for Dorvillea or Schistomeringos, but furcate setae not evident.

Ophryotrocha sp. A

Small, rare, not characterized as yet.

Schistomeringos sp. A

Furcate setae rare, may be mistaken for Dorvillea.

Schistomeringos sp. B

Furcate setae with pointed tines, shorter tine 1/2 length of longer.

Schistomeringos sp. C

Furcate setae with brush-tipped tines, 1/2 - 2/3 length ratio.

Schistomeringos sp. D

Furcate setae as for Schistomeringos caeca; jaws with unusual smooth margin.

EUNICIDAE

Marphysa sp. A

Prostomium with 3 antennae; eyes present; single gill filament emerging on setiger 22, continuing for 22 segments to end of fragment; tentacular cirri absent, subacicular dentition dark, appearing incompletely developed; hoods of composite falcigers, rounded, hooks bifid. Fauchald (personal communication) suggests this form may be arrested in the juvenile stage.

Nematonereis unicornis (Grube, 1840)

Northern range extension.

FLABELLIGERIDAE

Flabelligera affinis Sars, 1829

Specimens are small and one from Sta. 18 is ovigerous. Cephalic cage formed by neuro- and notosetae of first segment; cage setae long and annulated; body transluscent, no mucoid sheath present; composite neurosetae from setiger 2, setae with long blades and shaft. Papillae long and pedunculate on some specimens.

Pherusa sp. A

With variable number of cephalic cage segments (1-4) depending on size; setae appearing pseudocomposite, dependent on size; may have 4 anterior segments with forwardly directed setae consisting of typical cephalic cage setae and composite hooks; possibly juvenile of Pherusa falcata or P. plumosa.

Pherusa nr. falcata (Støp-Bowitz, 1947)

Four segments with cephalic cage setae; neurosetae differ from P. falcata in form of the pseudocomposite setae.

Pherusa plumosa (Müller, 1776)

With stout simple hooks; cephalic cage with 3 setigers; setae have very slight structural inconsistency - a faint line.

GLYCERIDAE

Glycera n.sp. A

Similar to Glycera sp. A of Gardiner (1976); without branchiae.

GONIADIDAE

Goniada n.sp. A

Neuropodial presetal lobe bilobed from setiger 3; 61 uniramous parapodia, biramous from set. 62 on (no transitionals); 3-5 pair chevrons; subdermal eyes; no anal cirri; short proboscidial organs; posterior notopodium with several slender capillaries; compound serrated spinigers in neuropodium.

Goniadidae, new genus, new species A

Similar to Goniadella gracillis, but no chevrons on proboscis. Rare.

HESIONIDAE

Microphthalmus listensis Westheide, 1967

New to New England. Differs from M. sczelkowii in having dorsal and ventral cirri much longer than podial lobe instead of subequal.

Hesionidae, new genus, new species A

With 8 pairs of tentacular cirri; 2 frontal antennae; parapodia biramous with articulated dorsal cirri; with fascicle of simple notosetae, neurosetae all composite falcigers. Close to Gyptis, but lacking medial antenna.

LUMBRINERIDAE

Lumbrineris sp. B

Similar to Lumbrineris verrilli, but with shaft of hooded hook more swollen; posterior postsetal lobes of L. sp. B shorter than in L. verrilli; pygidium with 2 short and 2 long lobes.

Lumbrineris latreilli (Audouin & Milne Edwards, 1833) Variety

Blade length of composite setae variable (short and long); addition of composite setae to anterior parapodia increases as size of animal increases; Maxillae III unidentate (differs from bidentate condition in typical L. latreilli); postsetal lobe digitiform, not increasing much in posterior segments, becoming more slender, presetal lobe absent or reduced; prostomium conical; both anal cirri frequently bifid with unequal lengths; juvenile appears to have simple setae and only 2 anal cirri (probably the undeveloped bifid part appears as a single cirrus). This form differs consistently from L. latreilli in that Maxillae III have 1 instead of 2 teeth.

Lumbrinerides acuta (Verrill, 1875)

Position (setiger number) of first hooded hook directly correlated to length of animal, first appearing in setiger 1 of juveniles; in later segments in larger specimens.

MALDANIDAE

Euclymene sp. A

With eyespots; cephalic rim high, with posterior notch; 22 setigers; 2 achaetous preanal segments; many short anal cirri, one long midventral cirrus; neurosetae as for Euclymene, except in juveniles.

Euclymene sp. B

Near Euclymene sp. A, except: no eyes, no posterior notch in cephalic rim, floor of anal plaque level. Rare.

Euclymeninae sp. B

Cephalic plate well developed, rim low, shallowly incised laterally and posteriorly, nuchal organs short, discinct collar on setiger 4; anal funnel well developed, with larger mid-ventral cirrus and additional alternating long and short cirri; acicular spines on setigers 1-3.

Isocirrus planiceps (Sars, 1872)

Agrees with description by Arwidsson (1907) rather than that by Imajima and Shiraki (1982).

Maldanidae sp. B

Eyes lacking; cephalic rim high with 3 incisions; spines in first 3 neuropodia; pygidium as for Heteroclymene robusta.

Maldanidae sp. C

Posterolateral margin of cephalic collar with about 8 incisions; first 3 setigers with rostrate setae.

Maldanidae sp. D

Similar to Praxillura, but doesn't agree with any known species; pigment bands across dorsum of anterior segments more than reported; different number of spines in anterior segments; cephalic plate reduced; no anal plaque.

Maldanidae sp. E

Weak posterolateral incisions on cephalic plate; faint eye spots on ventrolateral cephalic plate; long ventral cirrus extending from anal funnel, with shorter encircling cirri on margin.

NEPHTYIDAE

Aglaophamus circinata (Verrill, 1874)

Juveniles without eyes; second antennae long. Adult characters as in Pettibone (1963).

Nephtys bucera Ehlers, 1868

Juveniles with eyes; second antennae short. Adult characters as in Pettibone (1963).

Nephtys incisa Malmgren, 1865

Juveniles without eyes; antennae crowded on anterolateral corners of prostomium. Adult characters as in Pettibone (1963).

Nephtys picta Ehlers, 1868

Juveniles with eyes; second antennae long. Adult characters as in Pettibone (1963).

NEREIDAE

Nereis grayi Pettibone, 1956

Most common nereid on Georges Bank.

Nereis cf. riisei Grube, 1856

Similar to N. riisei, but posterior notopodial homogomph falcigers with smooth instead of serrated blade.

ONUPHIDAE

Nothria conchylega (Sars, 1835)

Juveniles with branchiae developing late; first present on setiger after attaining 20 or more setigers.

Nothria pallidula (Hartman, 1965

Juveniles with 8-10 setigers with branchiae early from setiger 6.

Paronuphis sp. A

Juvenile, agrees with generic definition, need more specimens.

OPHELIIDAE

Ophelina sp. A

Similar to O. modesta Støp-Bowitz (1958). Anal funnel with terminal cirri and single ventral cirrus. Found at Regional Sta. 18.

OWENIIDAE

Myriochele oculata Zaks, 1923

With eyes, agrees with redescription by Blake and Dean (1973).

Myriochele sp. A

Thin, slender species; without eyes; tube and methyl green staining pattern similar to that of M. oculata.

PARAONIDAE

Aricidea nr. belgica (Fauvel, 1936)

With short neuropodial postsetal lobes; branchiae broad, blunt-tipped.

Aricidea catherinae Laubier, 1967

The most common paraonid species on Georges Bank.

Aricidea longobranchiata Day, 1961

New to eastern North America.

Aricidea lopezi Berkeley & Berkeley, 1956

New to eastern North America.

Aricidea n.sp. A

Branchia from setiger 5; A. suecica-like setae; long gill bearing regions, A. catherinae-like antenna.

Aricidea n.sp. B

Medial antenna short; branchiae short, rounded, setae with terminal arista as in A. suecica. Near A. claudiae or A. hartmanae.

Aricidea n.sp. C

Short clavate antennae; concave sides of modified neurosetae with heavy arista; ciliary bands on prostomium.

Aricidea n.sp. D

Long unarticulated median antennae; A. catherinae-like branchiae from setiger 4; modified setae with terminal arista.

Paradoneis n.sp. A

Small species; without branchiae.

Paraonis n.sp. A

With 3 pairs large, broad branchiae (up to 5 on largest specimens); prebranchial region smooth, non-beaded; modified setae sharply hooked with crest and hood.

Paraonis sp. B

Small, threadlike; branchiae from setiger 4; modified neurosetae with long, thick arista.

Paraonis n.sp. C

Similar to P. fulgens. With brush-tipped notosetae among typical capillaries.

Paraonis n.sp. d

Possibly juveniles of A. nr. belgicae.

PHYLLODOCIDAE

Cirrodoce cristata Hartman & Fauchald, 1971

New records; previously known only from single damaged specimen; should be referred to another genus. With 5 antennae and 4 pairs tentacular cirri.

Mystides borealis caeca Langerhans, 1880

Without eyes; otherwise like M. borealis borealis Theel, 1979.

Phyllodoce sp. A

Third tentacular segment with setae; ventral cirri four times as long as setal lobe; solid dark, transverse pigment band on each segment; diagonal rows of papillae on proboscis.

Phyllodocidae, new genus, new species A

With chitinous proboscidial organs; four pairs tentacular cirri, 4 antennae and nuchal papilla; dorsal cirri tapering.

POLYGORDIDAE

Polygordius sp. A

Small, without eyes.

PROTODRILIDAE

Protodrilus sp. A

With setae, not Protodriloides chaetifer. Rare.

PSAMMODRILIDAE

Psammodrilus balanoglossoides Swedmark, 1952

Body with 3 regions, head, thorax, abdomen; with 3 pairs long dorsal cirri in thorax.

SABELLIDAE

Chone duneri Malmgren, 1867 & C. infundibuliformis Kröyer, 1856

May be the same species; we have no large C. duneri and no small C. infundibuliformis.

Chone sp. A

Staining pattern not as for C. duneri and C. infundibuliformis; collar laterally incised. Abundant at Sta. 14.

Euchone nr. elegans Verrill, 1873

Uncini not exactly as in Banse, 1972; marked divergence within tori of abdominal setigers not observed.

Potomilla neglecta (Sars, 1851)

Without tentacular eyes; body ragged, as if poorly preserved.

SPHAERODORIDAE

Sphaerodoridium sp. A

With 10 rows of dorsal macrotubercles.

SPIONIDAE

Malacoceros indicus Fauvel, 1928

Northern range extension.

Polydora barbilla Blake, 1981

New to eastern North America.

Polydora nr. caeca Oersted, 1843

With posterior spines.

Polydora n.sp. A

Similar to P. flava, but with bundles of posterior notopodial needles occurring in more anterior setigers.

Polydora n.sp. B

In P. socialis group, major spines with apical swelling and terminal mucron.

Polydora n.sp. C

Same species identified as P. caulleryi by Hartman (1965), not Mesnil, 1897. Major spines with crest of bristles and 2 teeth; caruncle broad, triangular shaped.

Prionospio aff. cirrobranchiata Day, 1961

Same as specimens identified as P. cirrobranchiata by Day (1973) from Beaufort, N.C. This species is not identical to P. cirrobranchiata Day, 1961 from South Africa and is being described as a new species (Maciolek, in prep.).

Prionospio n.sp. A

With 8-10 pairs long, broad, apinnate branchiae; prostomium triangular, anteriorly flared. Not P. cirrifera Wirén. Two specimens recorded from Sta. 8.

Spiophanes sp. A

Prostomium bell-shaped; occipital tentacle absent; eyes absent. May be S. soederstroemi Hartman.

Spionidae n. genus and new species A

Prostomium truncate anteriorly, confined posteriorly by a yoke which extends across dorsum between parapodia of setiger 1; branchiae from setiger 3; neuropodial hooded hooks bidentate, notopodial hooks lacking.

SYLLIDAE

Sphaerosyllis sp. A

Common at site-specific stations. Possibly S. brevifrons Webster and Benedict.

Sphaerosyllis sp. B

Rare, from Sta. 14. Appears to lack antennae.

Syllides cf. articulosa Ehlers, 1897

Rare, 2 specimens found at Sta. 13. Basically agrees with description of S. articulosa, but dorsal cirri are almost entirely lost on both specimens. One specimen had a remnant of 1 dorsal cirrus, and this appeared articulated.

Syllides sp. A

Common at Stations 16, 17 and 18. With 1-2 upper simple setae with flared tip, some with serrated edge; blades of compound setae short to long.

Syllides sp. B

Rare, found only at Sta. 14. Upper simple setae long, thin, whiplike.

Syllides sp. C

Rare, found at Stations 5-8 and 17. Upper simple setae serrated, with bifid tip.

Syllides sp. D

Rare, found at Sta. 8. Upper simple setae long, pointed, present in posterior setigers; median dorsal cirri not articulated.

TEREBELLIDAE

Polycirrus sp. A

Number of thoracic setigers 8-12; uncini begin setigers 7-8; 7-8 (10) pairs ventral shields.

Polycirrus sp. B

With 19 thoracic setigers; uncini begin setiger 16.

Thelepinae n.sp. A

With first 5 setigers bearing filamentous branchiae; notosetae first present from segment 2; uncini from setiger 6. Closest to genus Streblosoma. One specimen from M-2, Sta. 6(4).

TRICHOBRANCHIDAE

Terebellides stroemi Sars, 1835

Juveniles transitional in setal arrangement; geniculate setae of setiger 6 in adults also occur in setigers 4-5 in juveniles, thus sharing characters of other genera.

TROCHOCHAETIDAE

Trochochaeta nr. carica (Birula, 1897)

One specimen from Sta. 14. Differs from T. carica in that there is no caruncle on the prostomium, and the noto- and neuropodial lamellae are digitiform, not rounded.

ANNELIDA: OLIGOCHAETA

Adelodrilus anisosetosus Cook, 1969

Checked against paratype (USNM 38252).

Adelodrilus sp. A

Similar to A. anisosetosus in having "giant" penial setae and similar somatic setae, but with three types of penial setae and up to 30 in a bundle.

Limnodriloides medioporus Cook, 1969

Checked against paratype (USNM 38254).

Phallodrilus coeloprostatus Cook, 1969

Most common oligochaete. Checked against paratype (USNM 38258).

Phallodrilus obscurus Cook, 1969

Checked against paratype (USNM 38256).

Phallodrilus parviatriatus Cook, 1971

Checked against paratype (USNM 42017).

Tubificidae sp. A

May be a member of the genus Adelodrilus because of the presence of giant penial setae but it also has spermathecal setae.

Grania postclitellochaeta (Knollner, 1935)

Checked against paratype (USNM 43482).

MOLLUSCA: GASTROPODA

Alvania exarata Stimpson, 1831

Preferred name for A. arenaria Mighels & Adams 1842, which was mentioned as being present in the Benchmark study.

Mitrella dissimilis Stimpson, 1851

Listed as a synonym for M. lunata in Abbott (1974), yet the two are different and should be separated.

Turritellopsis cf. acicula (Stimpson, 1851)

Represented by only a few badly preserved specimens. Enough of the shell sculpture is preserved in the remaining periostracum to suggest this species.

Epitonium dallianum Verrill & Smith, 1880

This uncommon gastropod has been found in several samples and is a range extension from its type locality 175 miles off Ashbury Park, N.J. and 85 miles south of Martha's Vineyard.

Gastropod sp. B

A single minute specimen with distinctive and complex shell sculpture. It may belong to the genus Molleriopsis or the genus Solariella.

Gastropod sp. C

A single, poorly preserved specimen that resembles a very small Naticid except is sinistral instead of dextral.

Doridella obscura Verrill, 1870

Several specimens were found at Station 15, constituting a slight range extension from the Vineyard Sound. Also, this species is normally found in bays and estuaries from the intertidal to 7.7 meters, this record is also a depth extension.

Eubranchus sp. A

Is used for certain juvenile nudibranchs which lack sufficient adult characters for certain identification. This may be E. pallidus (Alder & Hancock, 1842) whose range extends to Georges Bank.

Nudibranchia sp. B

A single juvenile nudibranch specimen, not readily assignable to any family.

Aeolididae sp. A

A single adult specimen, having oblique leaflets on rhinophores. General appearance suggests Cerberilla tanna Marcus & Marcus 1959, known from Texas.

MOLLUSCA: BIVALVIA

Crenella fragilis Verrill, 1885

Represented by two specimens from Station 12. This is a range extension from off the coast of Wachapreague, Virginia.

Cuspidaria cf. parva Verrill & Bush, 1898

A clam whose characters suggested several other Cuspidaria species, but appeared nearest to this one.

Diplodonta sp. A

A single broken specimen of doubtful identification; shape of shell and presence of a bifid tooth suggest this genus.

Dacrydium vitreum (Holball, 1842)

Very numerous mollusc found in this study, attached by byssus to hydroid stems in great numbers at a few stations; notably smaller in size from reference specimens found closer to shore.

Leptonacea sp. A

A minute clam not readily assignable to any family.

Palliolum sp. B

A small scallop with rounded byssal notch and differing sculpture on opposite valves, very small specimens resemble juvenile Placopecten magellanicus, as figured in Merrill (1961), yet cannot be identified as such until juvenile stages of Palliolum have been studied.

Tellina agilis Stimpson, 1857

This bivalve is the second most numerous and is the dominent mollusc at several stations. We have not collected specimens as large as those found in shallower water. All our specimens exhibit shell sculpture of slightly raised concentric lines which appear to be a juvenile character, as they can be found on the older parts of the shells of specimens from Boston Harbor. These lines are not mentioned in this species description in Boss's (1968) monograph on Western Atlantic Tellinidae.

Thyasira spp. A-E

A confused genus which would be helped by a monograph. There are many species found in our area and some of these have several forms. Thyasira sp. A resembles T. trisinuata; sp. B resembles T. flexuosa; sp. C could be T. pygmaea, although our stations are shallow for that species, or a juvenile form of a different Thyasira species. Thyasira sp. D and E do not closely resemble any described species.

MOLLUSCA: SCAPHOPODA

Siphonodentalium cf. tythum Watson, 1879

A small scaphopod with small apex and large aperture; fragile apex features required for proper identification broken on our specimens. If identification is correct, it consitutes a range extension from the Caribbean.

MOLLUSCA: POLYPLACOPHORA

Leptochiton sp. A

A small chiton whose characters suggest L. cancellatas. Dr. Robert Bullock of the University of Rhode Island (personal communication) prefers the generic name Leptochiton to Lepidopleuras as given in Abbott (1974).

Leptochiton sp. B

A small poorly preserved specimen which lacks the valve sculpture of Leptochiton sp. A.

Hanleya sp. A

Small, poorly preserved chitons whose girdle scales suggest this genus.

MOLLUSCA: APLACOPHORA

Neomeniomorpha spp. A - E

Animals which do not fit the descriptions in Heath's (1918) monograph on western Atlantic solenogasters. Neomeniomorpha sp. A is probably in the subclass Chaetodermomorpha, the first specimens we saw were damaged and small.

ARTHROPODA: CRUSTACEA

CUMACEA

Diastylis sp. A

A juvenile with telson having two apical spines and two pairs of marginal spines. Caparace smooth.

Diastylis sp. B

Similar to Diastylis goodsiri (Bell, 1855), but has no plumose setae on peduncle of antennae.

Diastylis lucifera (Kroyer, 1841)

Georges Bank specimens represent a southern range extension. The previously reported range was from Nova Scotia to the Gulf of Maine (Watling, 1979).

Leptostylis sp. A

A juvenile, probably Leptostylis longimana (Sars, 1865).

Eudorella sp. A

A juvenile, probably Eudorella pusilla Sars, 1871.

Campylaspis sp. A

A juvenile, probably Campylaspis affinis Sars, 1870.

TANAIDACEA

Pseudoleptochelia filum (Stimpson, 1853)

With distinctively pigmented eyes. Has been sent to Dr. Jurgen Sieg at Universitat Osnabruck, West Germany for confirmation.

Tanaissus lilljeborgi (Stebbing, 1871)

The most common tanaid on Georges Bank; also common in BLM samples from the middle Atlantic Bight. Has been sent to Dr. Jurgen Sief for confirmation.

Typholotanais nr. cornutus G. O. Sars, 1885

Identified by Isabelle Williams (W.H.O.I.) using Lang (1970) It has been collected from Norway and the Davis Strait. Has been sent to Dr. Jurgen Sieg for confirmation.

ISOPODA

Ptilanthura tricarina Menzies and Frankenberg, 1966

Georges Bank specimens represent a northern range extension according to Menzies and Frankenberg (1966).

Cirolana sp. A

Juvenile, probably Cirolana polita (Stimpson), which does not have developed emarginations on the exopods.

Desmosoma sp.

Juvenile, probably Desmosoma tenuimanum (G.O. Sars, 1899)

Desmosoma tenuimanum (G.O. Sars, 1899)

A southern range extension according to Shultz (1969).

Edotea triloba (Say, 1818)

It is very difficult to distinguish between Edotea triloba and E. montosa. Dr. Les Watling of the University of Maine (personal communication) has identified our specimens as E. triloba, not believing E. montosa to be a valid species.

Edotea sp. B

Juvenile, probably Edotea triloba.

Munna fabricii (Kröyer)

Georges Bank specimens represent a southern range extension. Shultz (1969) reported the range from Greenland to Maine.

Pleurogonium inerme (Sars)

Georges Bank specimens represent a southern range extension. Shultz (1969) reported it was found in relatively shallow water (4 to 27m) in the Bay of Fundy.

Pleurogonium sp. A

Juvenile, probably Pleurogonium inerme (Sars).

Munnidae sp. A

Damaged, small specimen.

Isopod sp. A

Small, approximately 1 mm in length with a body shape similar to Cirolana; two pigmented eyes; two terminal uropods.

AMPHIPODA

Byblis sp. A

Represented by one small specimen similar to Byblis gaimardi (Kröyer, 1846).

Unciola spp. juveniles

First and second instar individuals, not having adult characteristics. Most have been found with adult Unciola inermis.

Siphonoecetes colleti (Myers & McGrath, 1979)

A synonym of S. smithianus Rathbun, 1905.

Bathyporeia quoddyensis Shoemaker, 1949

These specimens lack spines on the inner margins of the telson, therefore, Watling (personal communication) believes they are Bathyporeia parkeri. However, other morphological characters as well as the ecology coincide with B. quoddyensis. Bousfield (1973) reported that B. parkeri occurs on exposed sandy beaches, from just below the breaker zone to 10 m, whereas B. quoddyensis occurs subtidally to more than 40 m. The posterior margin of peraeopod 7 is oblique (not sharply incised, as in B. parkeri) and lacks spines (not 4-5 spines as in B. parkeri). Peraeopod 7 looks like the drawing in Shoemaker (1949) and fits the key characters of Bousfield (1973). Epimeral plates 1 and 2 do not have the posterior margin proximally produced into a sharp tooth as described and illustrated in Bousfield (1973) for B. parkeri. The eye, when pigmented, has four pigmented facets, not 6 like B. parkeri.

Platyischnopus sp. A

An undescribed species, also collected in the BLM Benchmark studies on Georges Bank; will be described by E.L. Bousfield on the Canadian National Museum in Ottawa.

Ischyrocerus sp. A

Juveniles, probably the same as I. sp. B.

Ischyrocerus sp. B

Fits within very broad concept of Ischyrocerus anguipes, in which epimeral side plate 3 rounded: telson acute with 2 clumps of spines, and spines present on peduncle of uropod 3. However, outer ramus of uropod 3 bears 7-8 blunt denticles, not 4-5 as noted in Bousfield (1973). Our specimens quite similar to Ischyrocerus sp. T-1 (Just, 1980).

Liljeborgidae sp. A

One small damaged specimen.

Anonyx sp. A

Juveniles, probably Anonyx sarsi Steel and Brunel, 1968.

Lysiannasidae sp. A

Represented by a few small specimens which are most similar to Anonyx sarsi Steel and Brunel, 1968. Sent to Dr. Watling for verification.

Lysianassidae sp. B

Represented by a few specimens, are similar to Psammonyx noblis (Stimpson, 1853). Sent to Dr. Watling for verification.

Monoculodes sp. A

Similar to drawing of Monoculodes edwardsi in Bousfield (1973). Carpal lobe on gnathopod 2 is about 1/3 the length of propodus, and not touching dactyl.

Monoculodes edwardsi Holmes, 1905

Most of our specimens are M. edwardsi as described by Holmes (1905). First segment of antennae 1 as long as the next two segments; gnathopod 2 with a long, slender carpal lobe, extending slightly more than 1/2 length of propodus and meeting dactyl.

Photis pollex (Walker, 1895)

A synonym of Photis macrocoxa as noted by Myers and McGrath (1981).

Gammaropsis nitida (Stimpson, 1853)

A synonym of Podoceropsis nitida as noted by Barnard (1973).

Photidae sp. A

A few small damaged specimens.

Rhepoxynius hudsoni Barnard and Barnard, 1982

A synonym of Rhepoxynius epistomus as described by Bousfield (1973) according to Barnard and Barnard, 1982.

Dyopedos monacanthus (Metzger, 1875)

A synonym of Dulichia monacantha according to Laubitz (1977).

Stenothoidae

The species of this family have been identified primarily on the basis of body parts. Mouth parts have not been used, except occasionally when there were several large specimens of the same species in a sample. More detailed taxonomic work is necessary.

DECAPODA

Axiidae sp. A

Similar to Axis serratus Stimpson, 1852.

Axiidae sp. B

Similar to Calocaris tempelmani Squires, 1965.

ECTOPROCTA

Eucratea loricata (L., 1758)

Most common bryozoan.

ECHINODERMATA: ECHINOIDEA

Echinocardium flavescens (Muller)

Verifies occurrance on east coast of North America, questioned by Mortensen, 1927.

Echinoidea juvenile sp. A

Probably juvenile Echinarachnius parma (Lamarck, 1816); ambulacral petaloid not developed; periproct aboral or not developed.

ECHINODERMATA: OPHIUROIDEA

Amphitarsus spinifer Schoener, 1967

8 mm disc diameter; genital clefts partioned superficially by 4-5 overlapping plates as opposed to two overlapping plates in holotype (Schoener, 1967).

Ophiuroidea juvenile sp. A

Probably juvenile Amphipolis squamata (Delle Chiaje, 1828); 4-8 arm segments; mouth parts not fully developed; tentacle scales not developed; radial shields reduced.

Ophiuroidea juvenile sp. G

Probably juvenile Amphioplus abditus (Verrill, 1871); adult characteristics lacking.

ECHINODERMATA: ASTEROIDEA

Forcipulata juvenile sp. B

Probably juvenile Leptasterias tenera (Stimpson, 1862); same with remnant attachment strands; adult characteristics not developed.

Paxillosida juvenile sp. A

Probably juvenile Astropecten americanus Verrill, 1880; adult characteristics lacking.

HEMICHORDATA: ENTEROPNUESTA

Enteropnuesta sp. A,B,D,E

All small, separated into different species by shape of proboscis.

SYSTEMATIC LITERATURE CITED

Abbott, R.T. 1974. American Seashells. 2nd Edition. Van Nostrand Reinhold Co., NY 663 pp.

Arwidsson, I. 1907. Studien uber die skandinavischen und arktischen Maldaniden nebst Zusammenstellung der ubrigen bisher behannten Arten dieser Familie. Zool. Jahrb. Suppl., 9:1-308.

Barnard, J.L. 1973. Revision of Corophiidae and related families (Amphipoda). Smithsonian Contr. Zool. 151:1-27.

Barnard, J.L. and C.M. Barnard. 1982. The genus Rhepoxynius (Crustacea: Amphipoda: Phoxocephalidae) in American seas. Smithonian Contr. Zool. 357:1-49.

Blake, J.A. and D. Dean. 1973. Polychaetous annelids collected by the R/V Hero from Baffin Island, Davis Strait, and West Greenland in 1968. Bull. Sthn. Cal. Acad. Sci. 72(1):31-39.

Boss, K.J. 1968. The Subfamily Tellininae in the Western Atlantic. The genus Tellina (Part II) and Tellidora. Johnsonia 4(46):273-344.

Bousfield, E.L. 1973. Shallow-water gammaridean Amphipoda of New England. Cornell University Press, Ithaca, NY 312 pp.

Day, J.H. 1973. New polychaeta from Beaufort, with a key to all species recorded from North Carolina. NOAA Tech. Rept. NMFS Circ.-375. 140 pp.

Gardiner, S. 1976. Errant polychaete annelids from North Carolina. J. Elisha Mitchell Sci. Soc. 91(3):77-220.

Grassle, J.F. and J.P. Grassle. 1977. Temporal adaptations in sibling species of Capitella. In: B.C. Coull (Ed.) Ecology of Marine Benthos. Belle W. Baruch Library in Marine Science No. 6. Univ. South Carolina Press. pp. 177-190.

Hartman, O. 1965. Deep-water benthic polychaetous annelids off New England to Bermuda and other North Atlantic areas. Allan Hancock Fdn. Publ. Occ. Pap. 28, 378 pp.

Heath, H. 1918. Solenogasters from the east coast of North America. Mem. Mus. Comp. Zool. 45:9-179.

Holmes, S.J. 1905. The Amphipoda of southern New England. Bull. U.S. Bur. Fish. 24:457-529.

Imajima, M. and Y. Shiraki. 1982. Maldanidae (Annelida: Polychaeta) from Japan (Part 2). Bull. Nat. Sci. Mus. 8(2):47-88.

Just, J. 1980. Amphipoda (Crustacea) of the Thule area, northwest Greenland: Faunistics and taxonomy. Greenland Bioscience 2:1-64.

Lang, K. 1970. Taxonomische und phylogenetische untersuchungen uber die Tanaidaceen, 5. Die Gattung Thyplotanais G.O. Sars, 1882 nebst Beschreibung Einer Neuen Art dieser Gattung, Dazu Eine Berichtigung der Dornenzahl des Enditen der Maxillulae Bei. I. pecularis Lang, 1968. Ark. Zool., 2(23):267-291.

Laubitz, D.R. 1977. A revision of the genera Dulichia Kroyer and Paradulichia Boeck (Amphipoda, Podoceridae). Can. Jour. Zool. 55:942-982.

Menzies, R.J. and D. Frankenberg. 1966. Handbook on the Common Marine Isopod Crustacea of Georgia. U. of Georgia Press, Athens, GA. 93 pp.

Merrill, A.S. 1961. Shell morphology in the larval and postlarval stages of the sea scallop, Placopecten magellanicus. Bull. Mus. Comp. Zool. 125(1):1-19.

Mortensen, T. 1927. Handbook of the Echinoderms of the British Isles. London. Oxford University Press. 471 pp.

Myers, A.A. and D. McGrath. 1979. The British and Irish species of Siphonoecetes Kroyer (Amphipoda-Gammaridea). J. Nat. Hist. 13(2):211-220.

Pettibone, M.H. 1963. Marine polychaete worms of the New England region. 1. Families Aphroditidae through Trochochaetidae. Bull. U.S. Nat. Mus. 227:356 pp.

Schoener, A. 1967. Two new species of Amphitarsus (Ophiuroidea) from the western North Atlantic. Breviora 269: 1-9.

Shoemaker, C.R. 1949. Three new species and one new variety of amphipods from the Bay of Fundy. J. Wash. Acad. Sci. 39:389-398.

Schultz, G.A. 1969. The Marine Isopod Crustaceans. Wm. C. Brown Co. Publ., Dubuque, Iowa. 359 pp.

Steele, D.H. and P. Brunel. 1968. Amphipoda of the Atlantic and Arctic coasts of North America: Anonyx (Lysianassidae). J. Fish. Res. Board Can. 25:943-1060.

Støp-Bowitz, C. 1958. (New polychaetes from Norway). Sciencaj Studoj Kopenhago pp. 213-216 (In Norwegian, French resume).

Warren, L.M. 1979. Mediomastus fragilis Rasmussen (Polychaeta: Capitellidae), a species newly recorded from British waters. J. mar. biol. Ass. U.K. 59:757-760.

Watling, L. 1979. Zoogeographic affinities of northeastern North American Gammaridean Amphipoda. Bull. Biol. Soc. Wash. 3:256-282.

APPENDIX C

TABLE C-1. COMMUNITY PARAMETERS FOR SITE-SPECIFIC STATIONS CALCULATED FOR EACH CRUISE, ALL REPLICATES COMBINED.

Station	Cruise	Total Species	Total Individuals	H'	Evenness	Spp/100	Spp/1000
5-1	M-1	94	5292	4.331	.6607	25.679	58.917
	M-2	84	3941	4.583	.7170	28.139	59.206
	M-3	84	6821	3.822	.5979	22.922	52.950
	M-4	92	7637	4.407	.6756	26.777	55.442
5-2	M-1	94	5471	4.413	.6732	25.962	58.584
	M-2	84	3180	4.652	.7278	28.363	60.786
	M-3	89	4735	4.516	.6974	27.515	57.752
	M-4	100	6417	4.449	.6700	27.282	57.615
5-3	M-1	93	4520	4.275	.6540	25.008	58.445
	M-2	88	4153	4.445	.6881	26.291	57.009
	M-3	89	4243	4.401	.6797	26.041	58.509
	M-4	80	3644	4.557	.7208	28.102	58.305
5-4	M-1	87	5012	4.322	.6709	25.126	56.024
	M-2	83	3546	4.491	.7044	27.249	58.178
	M-3	92	4335	4.394	.6735	26.627	60.280
	M-4	95	4558	4.460	.6789	27.511	59.706
5-5	M-1	87	5705	4.024	.6250	22.704	53.700
	M-2	93	3339	4.425	.6766	27.401	64.235
	M-3	90	3028	4.346	.6694	26.525	64.307
	M-4	82	4013	4.576	.7200	28.503	55.208
5-6	M-1	99	5951	4.301	.6487	25.730	58.578
	M-2	78	3253	4.435	.7060	26.491	54.170
	M-3	83	4400	4.318	.6773	25.797	54.952
	M-4	94	5356	4.453	.6793	26.945	58.066
5-8	M-1	98	6035	4.320	.6530	24.743	55.489
	M-2	82	4357	4.411	.6940	25.915	54.614
	M-3	99	5630	4.444	.6704	26.857	59.026
	M-4	100	8781	4.445	.6700	27.057	59.603
5-9	M-1	*					
	M-2	85	5132	4.401	.6866	25.485	55.679
	M-3	85	5024	4.437	.6922	26.751	55.222
	M-4	102	7062	4.404	.6600	26.267	56.646
5-10	M-1	95	6095	4.360	.6633	25.386	56.135
	M-2	89	6409	4.350	.6741	26.222	57.410
	M-3	77	3013	4.516	.7210	27.930	57.820
	M-4	99	7337	4.510	.6800	27.720	58.620

TABLE C-1. (continued)

Station	Cruise	Total Species	Total Individuals	H'	Evenness	Spp/100	Spp/1000
5-11	M-1	92	5157	4.310	.6607	24.904	58.714
	M-2	83	3670	4.500	.7060	27.152	57.290
	M-3	89	2109	4.354	.6724	26.872	70.320
	M-4	92	5717	4.433	.6800	27.612	59.440
5-12	M-1	107	5016	4.110	.6100	23.670	63.642
	M-2	80	2664	4.490	.7102	26.718	57.859
	M-3	90	2170	4.415	.6800	27.701	69.371
	M-4	98	3302	4.733	.7200	30.746	69.557
5-14	M-1	94	6222	4.314	.6581	25.585	57.181
	M-2	78	3942	4.441	.7070	26.752	54.798
	M-3	86	3372	4.430	.6892	26.306	58.957
	M-4	83	4825	4.300	.6743	25.532	54.764
5-16	M-1	98	8990	4.143	.6263	23.059	52.862
	M-2	92	4737	4.407	.6760	27.001	59.971
	M-3	95	5530	4.280	.6511	24.957	56.054
	M-4	93	7360	4.391	.6715	26.502	57.248
5-18	M-1	101	7682	4.322	.6490	25.291	56.563
	M-2	94	4797	4.464	.6810	27.065	61.054
	M-3	96	4302	4.470	.6780	27.863	61.878
	M-4	93	5697	4.410	.6741	26.788	58.704
5-20	M-1	90	5315	4.460	.6870	26.398	56.310
	M-2	78	2900	4.514	.7180	26.410	57.063
	M-3	77	1368	4.438	.6983	27.376	70.300
	M-4	90	2918	4.628	.7128	28.919	67.218
5-22	M-1	92	6322	4.211	.6455	24.678	56.251
	M-2	75	4137	4.268	.6851	24.370	53.419
	M-3	84	2894	4.628	.7239	28.535	60.986
	M-4	86	5473	4.232	.6590	24.883	54.246
5-25	M-1	119	4272	4.337	.6291	26.009	72.177
	M-2	93	3201	3.950	.6040	23.555	64.479
	M-3	101	1579	4.325	.6500	27.729	83.363
	M-4	97	3913	4.593	.6960	28.673	66.248

TABLE C-1. (continued)

Station	Cruise	Total Species	Total Individuals	H'	Evenness	Spp/100	Spp/1000
5-28	M-1	78	4530	4.339	.6903	25.300	53.565
	M-2	79	4479	4.075	.6464	23.646	52.444
	M-3	82	5442	3.635	.5720	23.174	54.923
	M-4	82	5963	4.237	.6664	24.615	55.467
5-29	M-1	152	2684	5.484	.7570	41.460	110.582
	M-2	120	3057	4.228	.6122	29.724	83.937
	M-3	122	2925	4.422	.6380	31.404	86.757
	M-4	133	4312	4.857	.6885	31.892	81.426

* Data being recalculated. See Table C-2 for information by replicate.

TABLE C-2. COMMUNITY PARAMETERS FOR SELECTED STATIONS CALCULATED FOR EACH CRUISE, REPLICATES SEPARATE.

Station /	Rep.	Cruise	Total Species	Total Individuals	H'	Evenness	Spp/100
2	1	M-1	40	301	3.980	.7479	25.095
	2		62	694	4.562	.7661	30.288
	3		41	334	4.363	.8144	27.324
	4		44	343	4.073	.7461	25.507
	5		32	142	4.257	.8515	27.677
	6		38	345	4.147	.7902	25.291
2	1	M-2	57	512	4.391	.7528	28.846
	2		51	521	4.094	.7217	27.529
	3		26	149	3.251	.6916	21.629
	4		32	215	3.413	.6825	22.345
	5		46	481	4.068	.7365	24.768
	6		32	195	3.738	.7477	24.123
2	1	M-3	40	331	3.760	.7065	24.121
	2		38	357	3.434	.6544	23.678
	3		37	384	3.921	.7528	23.067
	4		60	942	4.147	.7020	26.028
	5		34	366	2.722	.5349	19.931
	6		41	302	4.070	.7597	25.651
2	1	M-4	49	601	3.969	.7069	24.848
	2		45	678	3.603	.6560	20.459
	3		33	303	3.695	.7324	21.774
	4		33	249	3.601	.7139	21.817
	5		44	670	3.707	.6790	22.633
	6		36	258	3.382	.6542	23.125
5-1	1	M-1	52	571	4.456	.7817	27.509
	2		53	844	4.061	.7090	23.168
	3		53	535	4.484	.7829	28.057
	4		57	1261	4.203	.7206	24.000
	5		47	875	3.734	.6723	22.439
	6		56	1206	4.082	.7029	24.458
5-1	1	M-2	51	732	4.385	.7730	26.426
	2		48	692	4.327	.7747	26.905
	3		39	377	4.137	.7828	25.347
	4		56	650	4.500	.7749	28.480
	5		55	842	4.376	.7568	26.292
	6		53	648	4.493	.7844	28.659

TABLE C-2. (continued)

Station	Rep.	Cruise	Total Species	Total Individuals	H'	Evenness	Spp/100
5-1	1	M-3	40	353	4.454	.8370	26.930
	2		44	479	4.374	.8012	27.680
	3		57	1056	4.185	.7175	25.422
	4		55	1199	4.192	.7252	25.104
	5		52	3064	2.053	.3602	14.888
	6		55	670	4.433	.7669	28.398
5-1	1	M-4	57	1698	3.968	.6803	23.670
	2		47	944	3.978	.7161	23.555
	3		49	1300	4.265	.7595	25.281
	4		58	1204	4.438	.7576	27.927
	5		56	1410	4.348	.7488	25.571
	6		54	1081	4.587	.7971	28.346
5-9	1	M-1	51	1036	4.204	.7411	23.412
	2		55	1812	3.826	.6618	20.625
	3		57	1402	3.810	.6532	22.327
	4		59	1733	4.008	.6813	22.710
	5		54	599	4.133	.7182	25.082
	6		57	1450	4.279	.7336	24.445
5-9	1	M-2	38	645	4.071	.7757	21.088
	2		46	521	4.522	.8186	27.909
	3		54	1069	4.216	.7325	24.736
	4		54	887	4.470	.7768	27.480
	5		52	502	4.494	.7884	27.551
	6		57	1508	4.110	.7046	22.995
5-9	1	M-3	61	1136	4.337	.7313	26.261
	2		49	981	4.179	.7443	24.480
	3		50	628	4.284	.7591	25.740
	4		43	663	4.286	.7900	25.318
	5		43	600	4.359	.8032	26.200
	6		57	1016	4.574	.7841	29.372
5-9	1	M-4	46	835	4.178	.7563	24.484
	2		54	973	4.393	.7632	26.614
	3		58	1548	4.049	.6912	22.914
	4		52	1042	4.277	.7504	25.935
	5		58	1173	4.342	.7412	25.759
	6		68	1491	4.360	.7162	27.296

TABLE C-2. (continued).

Station/	Rep.	Cruise	Total Species	Total Individuals	H'	Evenness	Spp/100
5-25	1	M-1	52	461	4.083	.7163	27.476
	2		53	958	4.098	.7155	23.794
	3		68	1225	4.067	.6680	23.733
	4		49	516	4.078	.7263	25.056
	5		59	619	4.188	.7119	25.803
	6		48	493	4.212	.7542	26.501
5-25	1	M-2	40	362	3.891	.7311	23.61
	2		49	861	3.598	.6409	20.577
	3		67	875	3.850	.6347	24.523
	4				NO SAMPLE		
	5		52	671	3.958	.6944	23.852
	6		45	432	3.867	.7042	23.474
5-25	1	M-3	46	261	3.992	.7226	27.207
	2		30	100	4.031	.8214	27.207
	3		51	431	3.976	.7010	25.023
	4		50	356	4.196	.7434	27.595
	5		22	76	3.825	.8577	*
	6		48	355	4.108	.7355	26.969
5-25	1	M-4	47	687	4.246	.7644	24.702
	2		48	507	4.210	.7538	25.532
	3		53	489	4.460	.7787	28.140
	4		54	711	4.324	.7514	25.645
	5		54	725	4.253	.7390	26.523
	6		56	794	4.493	.7737	28.791
5-28	1	M-1	40	644	3.941	.7410	20.981
	2		50	1323	3.728	.6606	20.253
	3		41	566	4.233	.7901	25.274
	4		40	421	4.270	.8023	25.070
	5		48	614	4.488	.8035	27.729
	6		48	962	4.165	.7458	23.453
5-28	1	M-2	34	309	4.348	.8547	25.110
	2		54	1211	3.693	.6416	21.086
	3		40	663	3.971	.7462	21.874
	4		34	348	4.118	.8093	23.597
	5		50	1179	3.833	.6792	23.348
	6		51	769	3.966	.6992	24.678

TABLE C-2. (continued).

Station/	Rep.	Cruise	Total Species	Total Individuals	H'	Evenness	Spp/100
5-28	1	M-3	45	422	4.503	.8199	27.936
	2		50	1221	3.232	.5727	20.215
	3		51	465	4.585	.8083	28.785
	4		50	515	4.562	.8083	27.385
	5		56	2411	2.162	.3722	16.302
	6		47	408	4.445	.8002	27.588
5-28	1	M-4	50	870	4.339	.7687	25.113
	2		51	743	4.029	.7103	24.767
	3		48	1000	3.904	.6989	23.323
	4		44	810	3.974	.7279	21.740
	5		58	1392	3.850	.6573	22.511
	6		57	1148	4.206	.7211	23.864
5-29	1	M-1	81	490	5.157	.8135	39.685
	2		60	390	4.780	.8093	34.383
	3		81	507	5.245	.8273	39.710
	4		69	459	5.004	.8192	36.613
	5		54	320	4.893	.8503	34.897
	6		73	519	4.924	.7955	36.185
5-29	1	M-2	55	500	3.791	.6557	27.543
	2		58	469	3.966	.6769	27.778
	3		62	824	3.298	.5539	22.198
	4		49	354	4.322	.7697	29.468
	5		44	360	4.165	.7630	26.551
	6		73	550	4.405	.7117	32.162
5-29	1	M-3	53	354	4.211	.7352	29.305
	2		48	419	3.352	.6002	23.942
	3		62	518	3.941	.6620	28.205
	4		61	489	4.206	.7091	29.593
	5		59	566	4.211	.7158	28.720
	6		62	579	4.133	.6941	28.812
5-29	1	M-4	61	536	4.404	.7426	29.162
	2		61	601	4.505	.7600	31.960
	3		66	638	4.571	.7562	29.869
	4		62	1004	3.810	.6398	24.884
	5		58	716	4.460	.7614	28.808
	6		65	817	4.513	.7494	28.554

* Spp/100 cannot be calculated for samples with fewer than 100 individuals.

TABLE C-3. AVERAGE AND 95-PERCENT CONFIDENCE LIMITS OF NUMBER OF INDIVIDUALS, NUMBER OF SPECIES AND NUMBER OF SPECIES PER 100 INDIVIDUALS AT SIX STATIONS FOR CRUISES M-1 THROUGH M-4.

Station	M-1	M-2	M-3	M-4
	Number of Individuals			
5-1	882 ± 321.0	656.8 ± 162.2	1136.8 ± 1048.5	1272.8 ± 277.7
5-9	1345.3 ± 485.0	855.3 ± 407.5	837.3 ± 245	1177 ± 301.6
5-25	712 ± 325.8	640.2 ± 294.8	263.2 ± 153.5	652.2 ± 130.9
5-28	755 ± 346.5	746.5 ± 409.4	907 ± 838.9	993.8 ± 254.7
5-29	447.5 ± 81.5	509.5 ± 181.1	487.5 ± 91.5	718.7 ± 178.6
2	359.8 ± 190	345.5 ± 185.0	447 ± 256.3	459.8 ± 221.0
	Number of Species			
5-1	53.0 ± 3.7	50.3 ± 6.6	50.5 ± 7.2	53.5 ± 4.7
5-9	55.5 ± 3.0	50.2 ± 7.4	50.5 ± 7.7	56.0 ± 7.7
5-25	54.8 ± 7.9	50.6 ± 12.7	41.2 ± 12.8	52.0 ± 3.8
5-28	44.5 ± 4.9	43.8 ± 9.4	49.8 ± 4.0	51.3 ± 5.6
5-29	69.7 ± 11.6	56.8 ± 10.7	57.5 ± 6.0	62.1 ± 3.1
2	42.8 ± 10.7	40.7 ± 13.0	41.7 ± 9.8	40 ± 7.2
	Number of Species/100 Individuals			
5-1	24.9 ± 2.4	27.0 ± 1.4	24.7 ± 5.3	25.7 ± 2.1
5-9	23.1 ± 1.7	25.3 ± 3.0	26.2 ± 1.8	25.5 ± 1.7
5-25	25.4 ± 1.6	23.2 ± 1.9	26.8 ± 1.2	26.6 ± 1.7
5-28	23.8 ± 3.0	23.3 ± 1.7	24.7 ± 5.4	23.6 ± 1.4
5-29	37.0 ± 2.4	27.6 ± 3.5	28.1 ± 2.2	28.9 ± 2.4
2	26.9 ± 2.1	24.9 ± 3.0	23.8 ± 2.3	22.4 ± 1.6

APPENDIX D

TABLE D-1. SEDIMENT GRAIN SIZE ANALYSIS OF PRIMARY SITE-SPECIFIC STATIONS, SHOWING AVERAGE PERCENT COMPOSITION AND ONE STANDARD DEVIATION FOR EACH SIZE CLASS MEASURED. N = number of replicates included in average; some data from U.S.G.S. (Bothner et al., 1982)

Stn.	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay	
5-1									
M-1	0.55 ± .34	5.3 ± 0.6	50.1 ± 0.4	37.2 ± 2.2	5.9 ± 1.0	.33 ± .57	.40 ± .11	.17 ± .03	N = 3
M-2	2.1 ± 1.1	6.9 ± 5.0	47.9 ± 6.6	36.3 ± 8.6	6.6 ± 2.5	.00 ± .00	.14 ± .08	.10 ± .09	N = 9
M-3	2.3 ± 2.0	7.2 ± 3.0	51.0 ± 8.1	30.8 ± 9.9	8.2 ± 1.3	.00 ± .00	.13 ± .12	.13 ± .13	N = 9
M-4	6.2 ± 2.8	9.9 ± 3.0	48.0 ± 3.7	27.1 ± 4.1	7.3 ± 2.8	.00 ± .00	.36 ± .23	.22 ± .20	N = 9
Average	**3.2 ± 2.8**	**7.8 ± 3.8**	**49.2 ± 6.0**	**32.0 ± 8.3**	**7.2 ± 2.2**	**.03 ± .18**	**.23 ± .19**	**.15 ± .14**	**N = 30**
5-2									
M-2	2.06 ± .50	11.08 ± 7.62	58.05 ± 5.83	22.17 ± 4.03	5.39 ± 3.16	.33 ± .80	.07 ± .04	.03 ± .01	N = 6
M-3	.85 ± .45	9.56 ± 5.77	58.89 ± 6.17	23.93 ± 5.98	6.27 ± 1.97	.00 ± .00	.10 ± .03	.04 ± .02	N = 6
M-4	2.70 ± .66	7.12 ± 4.72	37.82 ± 14.25	37.24 ± 12.34	11.98 ± 3.78	2.91 ± 3.82	.15 ± .15	.23 ± .31	N = 6
Average	**1.87 ± .94**	**9.25 ± 6.02**	**51.59 ± 13.47**	**27.78 ± 10.39**	**7.88 ± 4.16**	**1.08 ± 2.5**	**.11 ± .09**	**.10 ± .19**	**N = 18**
5-5									
M-2	.81 ± .72	13.47 ± 13.44	42.83 ± 19.26	38.08 ± 23.40	4.66 ± 6.77	.00 ± .00	.10 ± .08	.05 ± .04	N = 6
M-3	.86 ± 1.28	4.92 ± 4.43	45.47 ± 10.05	38.35 ± 7.69	10.29 ± 6.36	.00 ± .00	.13 ± .11	.08 ± .09	N = 6
M-4	.79 ± .83	3.64 ± 2.33	49.92 ± 7.87	35.66 ± 3.44	9.87 ± 5.70	.00 ± .00	.09 ± .04	.04 ± .03	N = 6
Average	**.82 ± .92**	**7.34 ± 8.98**	**46.07 ± 12.89**	**37.36 ± 13.55**	**8.27 ± 6.47**	**.00 ± .00**	**.11 ± .08**	**.06 ± .06**	**N = 18**
5-8									
M-2	9.95 ± 5.35	14.7 ± 3.07	42.41 ± 6.61	25.79 ± 3.94	6.35 ± 2.69	.61 ± 1.50	.13 ± .06	.07 ± .01	N = 6
M-3	3.91 ± 3.23	10.13 ± 6.42	42.12 ± 5.12	31.99 ± 6.16	11.48 ± 2.15	.00 ± .00	.22 ± .17	.16 ± .08	N = 6
M-4	5.02 ± 3.47	11.68 ± 3.64	49.35 ± 4.41	26.21 ± 2.44	7.56 ± 1.63	.00 ± .00	.17 ± .08	.09 ± .04	N = 6
Average	**6.29 ± 4.73**	**12.17 ± 4.76**	**44.63 ± 6.18**	**28.0 ± 5.09**	**8.46 ± 3.06**	**.20 ± .87**	**.17 ± .12**	**.11 ± .07**	**N = 18**

TABLE D-1. (continued)

Stn.	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay	
5-10									
M-2	1.02 ± .78	6.58 ± 3.15	54.0 ± 3.1	27.82 ± 1.86	10.37 ± 2.94	.00 ± .00	.15 ± .06	.07 ± .02	N = 6
M-3	.80 ± .63	9.91 ± 1.20	50.54 ± 3.25	30.40 ± 3.83	8.30 ± 1.91	.00 ± .00	.09 ± .04	.03 ± .01	N = 6
M-4	.53 ± .43	4.63 ± 2.97	50.30 ± 4.96	33.42 ± 4.60	10.93 ± 2.74	.00 ± .00	.13 ± .09	.08 ± .07	N = 6
Average	**.78 ± .63**	**7.04 ± 3.31**	**51.61 ± 4.02**	**30.55 ± 4.14**	**9.85 ± 2.69**	**.00 ± .00**	**.12 ± .07**	**.06 ± .05**	**N = 18**
5-11									
M-2	.60 ± .95	6.10 ± 3.12	49.96 ± 7.58	34.57 ± 7.49	8.61 ± 2.44	.00 ± .00	.16 ± .08	.05 ± .02	N = 6
M-3	.15 ± .11	2.16 ± 1.60	39.39 ± 6.95	41.22 ± 3.99	15.29 ± 3.5	1.33 ± 2.06	.10 ± .07	.04 ± .02	N = 6
M-4	.28 ± .17	4.31 ± 3.19	49.05 ± 7.15	35.45 ± 6.17	10.6 ± 2.98	.00 ± .00	.23 ± .09	.07 ± .04	N = 6
Average	**.34 ± .56**	**4.19 ± 3.06**	**46.13 ± 8.39**	**37.08 ± 6.45**	**11.50 ± 4.03**	**.44 ± 1.29**	**.16 ± .10**	**.05 ± .03**	**N = 18**
5-12									
M-2	1.08 ± .58	6.75 ± 3.24	55.31 ± 7.22	30.79 ± 6.62	5.93 ± 2.73	.00 ± .00	.06 ± .02	.04 ± .02	N = 6
M-3	.23 ± .13	1.33 ± 1.63	32.55 ± 19.60	48.20 ± 18.55	17.62 ± 5.56	.00 ± .00	.03 ± .03	.02 ± .02	N = 6
M-4	.20 ± .15	3.98 ± 6.28	31.55 ± 16.32	45.17 ± 13.98	18.92 ± 8.88	.00 ± .00	.13 ± .11	.05 ± .03	N = 6
Average	**.05 ± .54**	**4.02 ± 4.54**	**39.80 ± 18.28**	**41.39 ± 15.25**	**14.16 ± 8.40**	**.00 ± .00**	**.07 ± .08**	**.04 ± .03**	**N = 18**
5-14									
M-2	.55 ± .46	4.63 ± 2.57	60.73 ± 5.62	32.12 ± 5.66	1.82 ± 2.84	.00 ± .00	.08 ± .05	.07 ± .06	N = 6
M-3	.26 ± .11	3.98 ± 3.08	51.92 ± 9.82	35.01 ± 8.40	7.63 ± 3.44	.33 ± .81	.15 ± .06	.05 ± .01	N = 6
M-4	.15 ± .06	1.66 ± 2.33	55.46 ± 8.75	35.87 ± 7.25	6.64 ± 3.00	.00 ± .00	.14 ± .09	.07 ± .02	N = 6
Average	**.32 ± .31**	**3.43 ± 2.84**	**56.04 ± 8.60**	**34.33 ± 6.95**	**5.37 ± 3.91**	**.11 ± .47**	**.12 ± .07**	**.06 ± .04**	**N = 18**

TABLE D-1. (continued)

Stn.	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay	
5-16									
M-2	5.08 ± 3.45	8.14 ± 4.3	44.35 ± 10.18	28.90 ± 7.55	13.43 ± 8.64	.00 ± .00	.06 ± .03	.03 ± .01	N = 6
M-3	6.14 ± 3.28	11.11 ± 4.95	36.09 ± 5.25	31.0 ± 6.94	15.40 ± 6.22	.00 ± .00	.20 ± .16	.07 ± .04	N = 6
M-4	3.30 ± 3.01	15.46 ± 5.2	46.02 ± 6.78	27.88 ± 9.98	6.98 ± 4.3	.00 ± .00	.30 ± .18	.06 ± .02	N = 6
Average	**4.84 ± 3.29**	**11.57 ± 9.31**	**42.16 ± 8.49**	**29.26 ± 7.87**	**11.94 ± 7.24**	**.00 ± .00**	**.19 ± .16**	**.05 ± .03**	**N = 18**
5-18									
M-1	.36 ± .29	4.63 ± .58	55.81 ± 2.24	32.7 ± 1.83	5.94 ± 1.69	.00 ± .00	.35 ± .10	.21 ± .09	N = 3
M-2	.50 ± .54	5.17 ± 3.07	52.15 ± 6.86	31.23 ± 6.63	10.59 ± 3.58	.00 ± .00	.13 ± .06	.11 ± .10	N = 9
M-3	1.13 ± 1.44	7.06 ± 4.60	51.28 ± 5.59	28.02 ± 5.15	11.62 ± 4.11	.43 ± 1.31	.30 ± .18	.15 ± .16	N = 9
M-4	.41 ± .30	5.16 ± 5.20	52.95 ± 9.00	31.72 ± 7.38	9.25 ± 5.73	.00 ± .00	.32 ± .23	.19 ± .16	N = 9
Average	**.65 ± .89**	**5.68 ± 4.10**	**52.49 ± 6.78**	**30.56 ± 6.14**	**10.03 ± 4.50**	**.13 ± .72**	**.26 ± .18**	**.16 ± .14**	**N = 30**
5-20									
M-2	4.37 ± 2.7	22.04 ± 13.07	37.40 ± 12.47	27.14 ± 13.25	5.3 ± 2.36	.00 ± .00	.06 ± .02	.04 ± .02	N = 6
M-3	.30 ± .22	1.33 ± 1.03	25.90 ± 10.46	54.14 ± 9.21	17.94 ± 5.69	.33 ± .81	.04 ± .03	.02 ± 0.1	N = 6
M-4	.32 ± .41	4.30 ± 4.08	39.45 ± 11.71	53.73 ± 9.72	2.99 ± 3.94	.00 ± .00	.14 ± .14	.07 ± .05	N = 6
Average	**1.66 ± 2.46**	**8.89 ± 12.15**	**34.25 ± 12.47**	**45.0 ± 16.53**	**8.73 ± 7.84**	**.11 ± .47**	**.08 ± .09**	**.05 ± .04**	**N = 18**
5-22									
M-2	.09 ± .11	4.66 ± 4.11	61.72 ± 3.36	32.28 ± 4.42	1.17 ± 2.04	.00 ± .00	.07 ± .02	.03 ± .01	N = 6
M-3	2.0 ± 4.08	3.49 ± 3.20	56.28 ± 7.63	31.48 ± 8.75	6.76 ± 3.87	.00 ± .00	.22 ± .21	.17 ± .08	N = 5
M-4	.89 ± 1.79	3.26 ± 5.59	54.10 ± 5.86	36.69 ± 6.91	4.94 ± 4.12	.00 ± .00	.12 ± .12	.04 ± .04	N = 6
Average	**.93 ± 2.41**	**3.82 ± 4.24**	**57.43 ± 6.35**	**33.60 ± 6.77**	**4.14 ± 4.01**	**.00 ± .00**	**.13 ± .14**	**.07 ± .08**	**N = 17**

TABLE D-1. (continued)

Stn.	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay	
5-25									
M-2	1.61 ± 2.08	.66 ± 1.02	44.0 ± 8.6	36.3 ± 3.3	17.3 ± 4.8	.00 ± .00	.07 ± .02	.05 ± .02	N = 6
M-3	.48 ± .51	4.5 ± 1.9	45.7 ± 9.8	33.7 ± 4.1	14.4 ± 5.1	.99 ± 1.97	.21 ± .08	.16 ± .09	N = 4
M-4	.43 ± .74	.33 ± .81	43.4 ± 9.4	42.7 ± 6.8	12.9 ± 4.8	.00 ± .00	.12 ± .08	.05 ± .06	N = 6
Average	**.88 ± 1.42**	**1.5 ± 2.1**	**44.2 ± 8.6**	**38.1 ± 6.1**	**14.9 ± 5.0**	**.25 ± .99**	**.13 ± .08**	**.08 ± .07**	**N = 16**
5-28									
M-1	1.71 ± .86	4.57 ± .53	54.61 ± 4.45	35.94 ± 3.78	2.94 ± 1.0	.00 ± .00	.15 ± .03	.08 ± .01	N = 3
M-2	5.09 ± 3.26	13.40 ± 7.48	49.07 ± 6.39	28.72 ± 5.93	3.58 ± 1.97	.00 ± .00	.08 ± .07	.07 ± .07	N = 9
M-3	3.80 ± 1.20	11.05 ± 6.74	49.37 ± 6.03	30.52 ± 5.92	4.78 ± 2.40	.00 ± .00	.30 ± .16	.17 ± .07	N = 9
M-4	4.72 ± 4.30	5.17 ± 3.65	49.16 ± 5.10	36.56 ± 8.38	4.06 ± 1.87	.00 ± .00	.21 ± .20	.12 ± .15	N = 8
Average	**4.24 ± 3.03**	**9.49 ± 6.78**	**49.76 ± 5.72**	**32.19 ± 7.10**	**4.02 ± 2.02**	**.00 ± .00**	**.19 ± .16**	**.12 ± .10**	**N = 29**
5-29									
M-1	18.26 ± 9.76	.77 ± .82	2.59 ± .75	27.65 ± 5.90	40.27 ± 6.55	8.22 ± 1.16	1.60 ± .61	.63 ± .15	N = 3
M-2	5.17 ± 3.54	.63 ± .95	4.80 ± 2.13	26.51 ± 4.76	48.75 ± 6.14	13.03 ± 8.57	.68 ± .41	.42 ± .32	N = 9
M-3	5.13 ± 3.49	.62 ± .94	4.55 ± 2.04	25.24 ± 5.81	51.40 ± 6.30	11.29 ± 1.96	1.10 ± .73	.66 ± .63	N = 9
M-4	6.30 ± 4.31	.00 ± .00	2.89 ± 2.19	24.20 ± 5.26	53.28 ± 4.51	11.53 ± 3.0	1.14 ± .59	.66 ± .58	N = 9
Average	**6.81 ± 5.82**	**.45 ± .79**	**3.93 ± 2.15**	**25.55 ± 5.19**	**50.05 ± 6.55**	**11.58 ± 5.07**	**1.04 ± .61**	**.58 ± .49**	**N = 30**
Grand Average	2.39 ± 3.26	7.04 ± 6.81	44.80 ± 15.46	32.53 ± 9.90	11.76 ± 12.38	1.02 ± 3.44	.22 ± .32	.12 ± .21	N = 389

TABLE D-2. SEDIMENT GRAIN SIZE ANALYSIS OF BLOCK 410 STATIONS, SHOWING AVERAGE PERCENT COMPOSITION AND ONE STANDARD DEVIATION FOR EACH SIZE CLASS MEASURED. N = number of replicates included in average; some data from U.S.G.S. included (Bothner et al., 1982)

Station	Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay	
16									
M-1	0.18 ± 0.31	26.17 ± 5.53	54.04 ± 5.17	18.01 ± 2.90	00 ± 00	00 ± 00	1.01 ± 0.55	0.59 ± 0.32	N = 3
M-2	4.32 ± 1.71	14.12 ± 8.65	41.52 ± 9.43	33.68 ± 12.71	6.06 ± 3.93	00 ± 00	0.17 ± 0.10	0.13 ± 0.11	N = 9
M-3	1.03 ± 1.67	9.86 ± 6.92	42.0 ± 8.76	37.40 ± 9.54	9.97 ± 4.65	00 ± 00	0.18 ± 0.13	0.19 ± 0.11	N = 9
M-4	0.63 ± 0.38	12.47 ± 3.93	40.09 ± 3.30	36.15 ± 3.16	9.86 ± 1.96	00 ± 00	0.41 ± 0.07	0.39 ± 0.10	N = 3
Average	**2.11 ± 2.67**	**13.82 ± 8.54**	**43.09 ± 8.89**	**33.42 ± 11.3**	**7.24 ± 4.94**	**00 ± 00**	**0.31 ± 0.34**	**0.24 ± 0.21**	**N = 24**
17									
M-2	2.36 ± 1.66	14.50 ± 6.55	50.92 ± 6.68	31.11 ± 6.43	0.97 ± 1.62	00 ± 00	0.09 ± 0.02	0.07 ± 0.01	N = 6
M-3	1.60 ± 0.93	3.43 ± 2.13	42.57 ± 7.06	40.78 ± 4.61	11.44 ± 3.02	00 ± 00	0.12 ± 0.12	0.06 ± 0.05	N = 6
M-4	1.14 ± 1.18	0.64 ± 1.58	24.30 ± 13.02	51.06 ± 4.73	22.78 ± 12.67	00 ± 00	0.05 ± 0.04	0.04 ± 0.02	N = 6
Average	**1.70 ± 1.32**	**6.19 ± 7.25**	**39.26 ± 14.44**	**40.98 ± 9.76**	**11.73 ± 11.60**	**00 ± 00**	**0.09 ± 0.08**	**0.05 ± 0.03**	**N = 18**
18									
M-2	0.28 ± 0.35	00 ± 00	5.98 ± 3.50	52.81 ± 3.96	40.85 ± 2.68	00 ± 00	0.14 ± 0.05	0.09 ± 0.02	N = 6
M-3	0.83 ± 1.26	00 ± 00	0.00 ± 0.00	60.61 ± 4.09	39.02 ± 4.12	00 ± 00	0.12 ± 0.02	0.10 ± 0.02	N = 6
M-4	0.57 ± 0.87	00 ± 00	0.33 ± 0.81	47.33 ± 3.71	51.21 ± 3.55	0.33 ± 0.81	0.12 ± 0.04	0.06 ± 0.02	N = 6
Average	**0.56 ± 0.88**	**00 ± 00**	**2.10 ± 3.43**	**53.58 ± 6.71**	**43.69 ± 6.43**	**0.11 ± 0.47**	**0.13 ± 0.04**	**0.08 ± 0.03**	**N = 18**

APPENDIX E

TABLE E-1. SPECIES COLLECTED BY DREDGE OR TRAWL FROM REGIONAL STATION 2.

	M-2	M-3	M-4
PORIFERA			
Haliclona oculata (Pallas, 1766)		X	
Polymastia robusta Verrill, 1873	X	X	
CNIDARIA			
Hydrozoa			
Campanularia gigantea Hincks, 1865		X	
Sertularella minuscula Billard, 1924	X		
Sertularella tricuspidata (Alder, 1856)		X	
Thuiaria cupressina (L., 1758)	X	X	
Tubularia couthouyi Agassizi, 1862		X	
MOLLUSCA			
Gastropoda			
Buccinum undatum L., 1758		X	
Colus pubescens (Verrill, 1882)		X	
Colus stimpsoni (Morch, 1867)	X		
Bivalvia			
Arctica islandica (L., 1767)	X	X	
Cyclocardia borealis (Conrad, 1831)	X	X	
Palliolum sp. A	X		
Placopecten magellanicus (Gmelin, 1791)		X	
ARTHROPODA			
Amphipoda			
Aeginina longicornis (Kroyer, 1842-43)		X	
Caprella unica Mayer, 1903		X	
Erichthonius rubricornis (Stimpson, 1853)		X	
Decapoda			
Crangon septemspinosa Say, 1818		X	
Pagurus acadianus Benedict, 1901		X	
Pelia sp.		X	
ECTOPROCTA			
Flustrellidra hispida (Fabricius, 1780)	X		
Electra pilosa (L., 1767)	X		
Canloramphus cymbaeformis (Hincks, 1877)	X		
ECHINODERMATA			
Echinoidea			
Echinarachnius parma (Lamarck, 1816)	X	X	
Asteroidea			
Asterias vulgaris Verrill, 1866	X	X	
Leptasterias tenera (Stimpson, 1862)		X	
Forcipulata sp. C	X		
Holothuroidea			
Stereoderma unisemita (Stimpson, 1851)		X	
CHORDATA			
Vertebrata			
Raja erinacea Mitchell, 1925		X	
Urophycis chuss (Walbaum, 1792)		X	

TABLE E-2. SPECIES COLLECTED BY DREDGE OR TRAWL FROM REGIONAL STATION 7.

	M-2	M-3	M-4
MOLLUSCA			
Bivalvia			
Arctica islandica (L., 1767)	X		
ARTHROPODA			
Crustacea			
Decapoda			
Munidia iris Milne Edwards, 1880	X	X	
Pagurus politus (Smith, 1882	X		
Bathynectes superbus (Costa, 1838)		X	
ECHINODERMATA			
Asteroidea			
Asterias vulgaris Verrill, 1866	X		

TABLE E-3. SPECIES COLLECTED BY DREDGE OR TRAWL FROM REGIONAL STATION 13.

	M-2	M-3	M-4
PLATYHELMINTHES			
Nemertea			
Cerebratulus sp.	X		
ANNELIDA			
Polychaeta			
Aricidea catherinae Laubier, 1967	X		
Chone infundibuliformis Kroyer, 1856	X		
Cossura longicirrata Webster & Benedict, 1887	X		
Harmothoe extenuata (Grube, 1840)	X		
Lumbrineris fragilis (Muller, 1776)	X		
Nephtys incisa Malmgren, 1865	X		
Ninoe nigripes Verrill, 1873	X		
MOLLUSCA			
Gastropoda			
Colus stimpsoni (Morch, 1867)	X		
ARTHROPODA			
Crustacea			
Amphipoda			
Ampelisca agassizi (Judd, 1896)	X		
Anonyx liljeborgi Kroyer, 1870	X		
Unciola irroratus Say, 1818	X		
Decapoda			
Cancer borealis Stimpson, 1859	X		
ECHINODERMATA			
Asteroidea			
Asterias vulgaris Verrill, 1866	X		
Leptasterias tenera (Stimpson, 1862)	X		

TABLE E-4. SPECIES COLLECTED BY DREDGE OR TRAWL FROM GEORGES BANK SITE-SPECIFIC STATION 5-1.

	M-2	M-3	M-4
MOLLUSCA			
Bivalvia			
Cyclocardia borealis (Conrad, 1831)	X		
ECTOPROCTA			
Eucratea loricata (L., 1758)	X		
ECHINODERMATA			
Asteroidea			
Asterias vulgaris Verrill, 1866	X		
Leptasterias tenera (Stimpson, 1862)	X		

TABLE E-5. SPECIES COLLECTED BY DREDGE OR TRAWL FROM SITE-SPECIFIC STATION 5-18

	M-2	M-3	M-4
CNIDARIA			
Hydrozoa			
Thuiaria cupressina (L., 1758)		X	
Tubularia couthouyi Agassizi, 1862		X	
MOLLUSCA			
Bivalvia			
Arctica islandica (L., 1767)	X	X	
Cyclocardia borealis (Conrad, 1831)	X	X	
ARTHROPODA			
Decapoda			
Cancer borealis Stimpson, 1859		X	
Cancer irroratus Say, 1817	X		
ECTOPROCTA			
Eucratea loricata (L., 1758)		X	
Electra pilosa (L., 1767)		X	
ECHINODERMATA			
Echinoidea			
Echinarachnius parma (Lamarck, 1816)	X	X	
Asteroidea			
Asterias vulgaris Verrill, 1866	X	X	
Leptasterias tenera (Stimpson, 1862)	X	X	
Holothuroidea			
Cucumaria frondosa (Gunnerus, 1770)	X		
CHORDATA			
Vertebrata			
Urophycis chuss (Walbaum, 1792)	X		

TABLE E-6. SPECIES COLLECTED BY DREDGE OR TRAWL FROM SITE-SPECIFIC STATION 5-28

	M-2	M-3	M-4
CNIDARIA			
Hydrozoa			
Hydrallmania falcata (L., 1758)		X	
Thuiaria cuprassina (L., 1758)		X	
ANNELIDA			
Polychaeta			
Glycera dibranchiata Ehlers, 1868		X	
Lumbrineris fragilis (Muller, 1776)		X	
Ophelina acuminata Oersted, 1843		X	
MOLLUSCA			
Bivalvia			
Cyclocardia borealis (Conrad, 1831)	X	X	
ARTHROPODA			
Decapoda			
Cancer borealis Stimpson, 1859		X	
Cancer irroratus Say, 1817	X		
Pagurus acadianus Benedict, 1901		X	
ECHINODERMATA			
Echinoidea			
Echinarachnius parma (Lamarck, 1816)	X		
Asteroidea			
Asterias vulgaris Verrill, 1866	X	X	
Leptasterias tenera (Stimpson, 1862)	X	X	
Holothuroidea			
Cucumaria frondosa (Gunnerus, 1770)	X		
CHORDATA			
Vertebrata			
Paralichthys oblongus (Mitchill, 1815)			X

APPENDIX F

TABLE F-1. RESULTS OF CHN ANALYSIS FROM GEORGES BANK BENTHIC MONITORING PROGRAM REGIONAL STATIONS.

Sta.	/ Rep.	M-2 %C	M-2 %H	M-2 %N	M-3 %C	M-3 %H	M-3 %N	M-4 %C	M-4 %H	M-4 %N
1	1	0.10	0.03	0.01	0.09	0.04	0.01	0.07	0.05	0.00
	2	0.05	0.03	0.01	0.09	0.03	0.01	0.12	0.06	0.02
	3	0.04	0.02	0.00	0.05	0.03	0.00	0.06	0.04	0.01
	4	0.05	0.01	0.01	0.17	0.03	0.00	0.16	0.05	0.01
	5	0.05	0.02	0.00	0.04	0.03	0.00	0.08	0.04	0.01
	6	0.06	0.02	0.01	0.09	0.03	0.00	0.09	0.05	0.01
2	1	0.08	0.01	0.00	0.08	0.02	0.00	0.08	0.01	0.00
	2	0.07	0.01	0.00	0.09	0.01	0.00	0.07	0.01	0.00
	3	0.08	0.02	0.01	0.15	0.02	0.00	0.12	0.01	0.00
	4	0.05	0.01	0.00	0.21	0.02	0.01	0.08	0.02	0.00
	5	0.50	0.01	0.00	0.06	0.02	0.00	0.05	0.02	0.00
	6	0.05	0.01	0.00	0.06	0.02	0.00	0.05	0.01	0.00
3	1	0.44	0.04	0.02	0.28	0.04	0.01	2.37	0.07	0.03
	2	0.32	0.04	0.01	0.26	0.03	0.01	0.29	0.04	0.02
	3	0.17	0.03	0.01	0.41	0.04	0.02	0.42	0.04	0.02
	4	0.89	0.03	0.01	0.26	0.03	0.02	0.58	0.05	0.03
	5	0.45	0.04	0.02	0.34	0.04	0.01	0.39	0.07	0.03
	6	0.49	0.03	0.01	0.36	0.04	0.02	0.73	0.06	0.03
4	1	0.09	0.03	0.01	0.15	0.06	0.01	0.12	0.08	0.01
	2	0.13	0.03	0.01	0.08	0.05	0.02	0.17	0.08	0.02
	3	0.11	0.04	0.01	0.14	0.05	0.02	0.12	0.07	0.01
	4	0.12	0.04	0.01	0.11	0.06	0.02	0.56	0.08	0.02
	5	0.10	0.04	0.01	0.10	0.05	0.01	0.14	0.07	0.01
	6	0.10	0.04	0.01	0.07	0.04	0.01	0.14	0.08	0.02
6	1	0.43	0.07	0.03	0.51	0.08	0.03	0.40	0.06	0.03
	2	0.35	0.06	0.03	0.35	0.06	0.03	0.28	0.06	0.02
	3	0.32	0.06	0.03	0.54	0.07	0.03	0.36	0.07	0.02
	4	0.37	0.07	0.03	0.53	0.07	0.03	0.34	0.07	0.03
	5	0.40	0.06	0.03	0.32	0.07	0.02	0.27	0.25	0.03
	6	0.26	0.05	0.02	0.36	0.07	0.03	0.40	0.07	0.03

TABLE F-1. (Continued)

Sta.	/ Rep.	M-2 %C	M-2 %H	M-2 %N	M-3 %C	M-3 %H	M-3 %N	M-4 %C	M-4 %H	M-4 %N
7	1	0.32	0.08	0.01	0.41	0.05	0.01	1.10	0.08	0.03
	2	0.45	0.06	0.01	0.88	0.06	0.02	0.50	0.07	0.03
	3	1.02	0.12	0.02	0.36	0.05	0.02	0.51	0.05	0.02
	4	0.49	0.11	0.02	1.11	0.07	0.02	2.50	0.08	0.02
	5	0.37	0.09	0.02	0.34	0.06	0.02	0.55	0.07	0.03
	6	0.69	0.09	0.02	0.40	0.05	0.02	0.69	0.06	0.02
8	1	0.33	0.06	0.01	0.41	0.07	0.01	0.38	0.04	0.01
	2	0.45	0.06	0.01	0.44	0.07	0.02	0.38	0.04	0.01
	3	0.42	0.05	0.00	0.38	0.06	0.02	0.55	0.06	0.02
	4	0.53	0.05	0.01	0.55	0.10	0.02	0.40	0.04	0.01
	5	0.36	0.07	0.01	0.43	0.07	0.02	0.47	0.05	0.01
	6	0.40	0.04	0.00	0.44	0.07	0.02	0.35	0.04	0.01
9	1	0.22	0.04	0.00	0.33	0.06	0.00	0.26	0.08	0.01
	2	0.21	0.04	0.00	0.27	0.04	0.01	0.24	0.08	0.01
	3	0.25	0.04	0.01	0.34	0.07	0.01	0.26	0.08	0.01
	4	0.24	0.05	0.01	0.36	0.06	0.01	0.26	0.07	0.01
	5	0.18	0.04	0.00	0.22	0.05	0.00	0.28	0.08	0.01
	6	0.24	0.04	0.00	0.24	0.05	0.00	0.26	0.07	0.01
10	1	0.04	0.01	0.01	0.05	0.03	0.00	0.11	0.06	0.01
	2	0.18	0.03	0.01	0.07	0.03	0.00	0.16	0.07	0.01
	3	0.08	0.02	0.01	0.10	0.04	0.01	0.23	0.05	0.00
	4	0.12	0.01	0.01	NO SAMPLE			0.10	0.06	0.01
	5	0.04	0.02	0.01	0.12	0.05	0.01	0.32	0.08	0.00
	6	0.15	0.02	0.00	0.06	0.03	0.01	0.08	0.05	0.00
11	1	0.23	0.06	0.02	0.24	0.08	0.03	0.20	0.09	0.02
	2	0.17	0.06	0.01	0.19	0.08	0.03	0.44	0.15	0.05
	3	0.18	0.06	0.02	0.48	0.13	0.06	0.22	0.10	0.02
	4	0.23	0.07	0.02	0.59	0.10	0.04	0.35	0.13	0.04
	5	0.22	0.07	0.02	0.24	0.08	0.03	0.31	0.13	0.04
	6	0.22	0.07	0.02	0.26	0.09	0.04	0.24	0.10	0.02

TABLE F-1. (Continued)

Sta.	/ Rep.	M-2 %C	M-2 %H	M-2 %N	M-3 %C	M-3 %H	M-3 %N	M-4 %C	M-4 %H	M-4 %N
12	1	0.59	0.07	0.02	0.25	0.06	0.02	0.33	0.10	0.03
	2	0.33	0.06	0.02	0.66	0.12	0.05	0.42	0.12	0.03
	3	0.30	0.06	0.02	0.29	0.07	0.02	0.50	0.13	0.04
	4	0.58	0.06	0.02	0.17	0.04	0.01	0.26	0.09	0.02
	5	0.74	0.05	0.01	0.35	0.08	0.03	0.11	0.06	0.01
	6	0.34	0.06	0.03	0.35	0.08	0.03	0.26	0.09	0.02
13	1	1.22	0.28	0.15	1.22	0.22	0.15	1.25	0.35	0.16
	2	0.95	0.21	0.11	1.06	0.27	0.12	1.08	0.30	0.14
	3	1.27	0.31	0.15	1.02	0.27	0.11	1.32	0.42	0.17
	4	1.09	0.28	0.13	1.07	0.29	0.13	1.15	0.36	0.14
	5	1.27	0.31	0.15	1.07	0.29	0.13	0.94	0.30	0.12
	6	0.97	0.25	0.11	1.01	0.27	0.12	0.91	0.29	0.11
14	1	0.81	0.23	0.11	SAMPLES ARCHIVED			SAMPLES ARCHIVED		
	2	0.13	0.05	0.02						
	3	0.04	0.03	0.01						
	4	0.23	0.07	0.04						
	5	0.07	0.04	0.01						
	6	0.11	0.05	0.02						
15	1	0.04	0.02	0.00	0.08	0.02	0.00	NO SAMPLE		
	2	0.04	0.02	0.00	0.09	0.02	0.00	0.06	0.04	0.00
	3	0.05	0.01	0.00	0.06	0.02	0.00	0.08	0.04	0.00
	4	0.04	0.02	0.00	0.05	0.02	0.00	0.11	0.04	0.00
	5	0.04	0.01	0.00	0.03	0.02	0.00	0.13	0.04	0.00
	6	0.05	0.02	0.01	0.07	0.02	0.00	0.06	0.05	0.00
16	1	0.42	0.03	0.00	0.12	0.01	0.00	0.19	0.03	0.01
	2	0.17	0.02	0.00	0.49	0.02	0.01	0.32	0.02	0.01
	3	0.15	0.02	0.00	0.12	0.01	0.00	0.19	0.05	0.01
	4	0.13	0.02	0.00	0.16	0.02	0.00	0.16	0.03	0.00
	5	0.47	0.03	0.00	0.17	0.02	0.01	0.19	0.04	0.01
	6	0.24	0.03	0.00	0.15	0.02	0.01	0.12	0.03	0.00

TABLE F-1. (Continued)

Sta.	/ Rep.	M-2 %C	M-2 %H	M-2 %N	M-3 %C	M-3 %H	M-3 %N	M-4 %C	M-4 %H	M-4 %N
17	1	0.24	0.02	0.01	0.32	0.02	0.00	0.24	0.03	0.00
	2	0.19	0.02	0.01	0.92	0.04	0.01	0.18	0.04	0.01
	3	0.32	0.04	0.02	0.31	0.02	0.01	0.21	0.03	0.00
	4	0.20	0.02	0.01	0.22	0.03	0.00	0.09	0.02	0.00
	5	0.14	0.02	0.01	0.67	0.02	0.00	0.28	0.03	0.00
	6	0.19	0.02	0.02	0.36	0.04	0.01	0.10	0.03	0.00
18	1	0.17	0.01	0.02	0.11	0.02	0.00	0.25	0.03	0.01
	2	0.22	0.02	0.01	0.18	0.03	0.00	0.27	0.03	0.01
	3	0.19	0.02	0.02	0.22	0.03	0.00	0.24	0.03	0.00
	4	0.20	0.02	0.01	0.17	0.03	0.00	0.11	0.02	0.00
	5	0.19	0.02	0.01	0.18	0.03	0.00	0.20	0.03	0.01
	6	0.22	0.02	0.01	0.20	0.04	0.00	0.18	0.03	0.01

TABLE F-2. RESULTS OF CHN ANALYSIS FROM GEORGES BANK BENTHIC MONITORING PROGRAM SITE-SPECIFIC STATIONS.

Sta. /	Rep.	M-2			M-3			M-4		
		%C	%H	%N	%C	%H	%N	%C	%H	%N
5-1	1	0.16	0.07	0.02	0.11	0.04	0.01	0.25/0.14	0.05/0.05	0.01/0.01*
	2	0.10	0.07	0.01	0.10	0.05	0.00	0.41/0.15	0.04/0.04	0.01/0.02
	3	0.11	0.06	0.01	0.11	0.04	0.01	0.66/0.20	0.04/0.05	0.01/0.02
	4	0.07	0.06	0.01	0.09	0.04	0.01	0.20/0.16	0.04/0.04	0.02/0.01
	5	0.16	0.08	0.02	0.06	0.03	0.00	0.12/0.16	0.03/0.04	0.01/0.01
	6	0.12	0.07	0.01	0.05	0.03	0.00	0.23/0.18	0.04/0.05	0.01/0.01
5-2	1	0.11	0.04	0.01	0.08	0.02	0.00	0.15	0.06	0.01
	2	0.03	0.03	0.00	0.11	0.03	0.01	0.17	0.06	0.01
	3	0.07	0.03	0.02	0.09	0.03	0.00	0.17	0.06	0.01
	4	0.10	0.03	0.00	0.08	0.02	0.00	0.13	0.06	0.01
	5	0.20	0.05	0.02	0.12	0.03	0.01	0.10	0.05	0.01
	6	0.07	0.02	0.02	0.12	0.04	0.01	0.15	0.07	0.01
5-3	1	0.13	0.07	0.01	0.11	0.04	0.01	0.04	0.02	0.00
	2	0.12	0.07	0.01	0.09	0.04	0.01	0.08	0.02	0.00
	3	0.11	0.06	0.01	0.15	0.05	0.02	0.08	0.01	0.00
	4	0.06	0.06	0.00	0.12	0.03	0.02	0.06	0.02	0.00
	5	0.18	0.09	0.02	0.03	0.03	0.00	0.29	0.02	0.01
	6	0.07	0.05	0.00	0.13	0.05	0.02	0.10	0.02	0.00
5-4	1	0.12	0.07	0.01	0.20	0.05	0.02	0.22	0.08	0.03
	2	0.21	0.13	0.02	0.14	0.04	0.01	0.09	0.05	0.01
	3	0.11	0.08	0.01	0.16	0.04	0.01	0.15	0.07	0.01
	4	0.14	0.07	0.01	0.38	0.05	0.01	0.14	0.07	0.01
	5	0.16	0.09	0.01	0.10	0.04	0.01	0.11	0.07	0.01
	6	0.30	0.10	0.02	0.14	0.04	0.01	0.30	0.06	0.01
5-5	1	0.12	0.04	0.02	0.05	0.03	0.01	0.07	0.02	0.00
	2	0.02	0.02	0.02	0.09	0.03	0.01	0.09	0.02	0.00
	3	0.04	0.02	0.02	0.05	0.03	0.01	0.10	0.03	0.00
	4	0.05	0.02	0.01	0.06	0.03	0.01	0.04	0.01	0.00
	5	0.09	0.03	0.01	0.12	0.04	0.01	0.07	0.02	0.00
	6	0.16	0.04	0.02	0.06	0.03	0.01	0.11	0.02	0.01

* duplicate set analysed.

TABLE F-2. (continued)

Sta.	/ Rep.	M-2 %C	M-2 %H	M-2 %N	M-3 %C	M-3 %H	M-3 %N	M-4 %C	M-4 %H	M-4 %N
5-6	1	0.05	0.03	0.00	0.08	0.03	0.00	0.06	0.02	0.01
	2	0.10	0.03	0.01	0.11	0.03	0.00	0.14	0.04	0.01
	3	0.16	0.03	0.01	0.04	0.02	0.00	0.12	0.03	0.01
	4	0.09	0.03	0.01	0.05	0.02	0.00	0.26	0.05	0.02
	5	0.08	0.03	0.01	0.09	0.03	0.00	0.21	0.05	0.02
	6	0.08	0.03	0.01	0.13	0.03	0.01	0.21	0.05	0.01
5-8	1	0.30	0.12	0.03	0.08	0.03	0.01	0.18	0.06	0.02
	2	0.11	0.06	0.01	0.12	0.03	0.01	0.20	0.08	0.02
	3	0.08	0.06	0.01	0.12	0.05	0.02	0.29	0.07	0.01
	4	0.10	0.07	0.01	0.29	0.06	0.03	0.17	0.06	0.01
	5	0.10	0.07	0.01	0.07	0.03	0.00	0.20	0.07	0.01
	6	0.11	0.06	0.01	0.13	0.04	0.01	0.15	0.05	0.01
5-9	1	0.11	0.03	0.01	0.18	0.05	0.01	0.08	0.04	0.01
	2	0.16	0.04	0.01	0.15	0.05	0.00	0.15	0.04	0.01
	3	0.13	0.02	0.01	0.18	0.05	0.01	0.13	0.03	0.01
	4	0.14	0.04	0.01	0.18	0.05	0.00	0.12	0.03	0.01
	5	0.11	0.03	0.01	0.14	0.04	0.01	0.08	0.03	0.00
	6	0.12	0.03	0.01	0.11	0.04	0.00	0.13	0.02	0.01
5-10	1	0.10	0.03	0.01	0.11	0.03	0.01	0.19	0.07	0.02
	2	0.20	0.04	0.01	0.15	0.04	0.01	0.13	0.08	0.01
	3	0.13	0.04	0.01	0.12	0.04	0.01	0.13	0.06	0.01
	4	0.16	0.05	0.01	0.11	0.04	0.00	0.15	0.07	0.01
	5	0.13	0.04	0.01	0.10	0.03	0.00	0.12	0.06	0.01
	6	0.14	0.04	001	0.11	0.04	0.00	0.13	0.07	0.01
5-11	1	0.09	0.02	0.02	0.16	0.05	0.01	NO DATA AVAILABLE		
	2	0.11	0.03	0.02	0.15	0.04	0.01			
	3	0.15	0.03	0.03	0.12	0.04	0.01			
	4	0.08	0.02	0.01	0.06	0.02	0.00			
	5	0.05	0.02	0.01	0.14	0.04	0.01			
	6	0.16	0.03	0.02	0.12	0.04	0.00			

TABLE F-2. (continued)

Sta.	/ Rep.	M-2			M-3			M-4		
		%C	%H	%N	%C	%H	%N	%C	%H	%N
5-12	1	0.14	0.03	0.01	0.15	0.03	0.00	0.05	0.03	0.01
	2	0.07	0.02	0.01	0.05	0.03	0.00	0.03	0.02	0.01
	3	0.09	0.03	0.01	0.08	0.03	0.00	0.09	0.02	0.00
	4	0.10	0.03	0.01	0.05	0.03	0.00	0.05	0.03	0.00
	5	0.10	0.02	0.01	0.10	0.04	0.00	0.08	0.03	0.01
	6	0.07	0.02	0.00	0.05	0.03	0.00	0.09	0.04	0.00
5-14	1	0.09	0.03	0.00	0.12	0.04	0.01	0.10	0.05	0.01
	2	0.13	0.04	0.01	0.07	0.03	0.01	0.09	0.04	0.01
	3	0.08	0.03	0.01	0.05	0.03	0.01	0.15	0.06	0.02
	4	0.11	0.03	0.00	0.09	0.03	0.01	0.08	0.05	0.00
	5	0.09	0.03	0.01	0.28	0.07	0.03	0.11	0.05	0.01
	6	0.10	0.03	0.01	0.17	0.05	0.04	0.10	0.05	0.01
5-16	1	0.10	0.02	0.02	0.06	0.03	0.00	0.16	0.07	0.02
	2	0.13	0.02	0.02	0.10	0.03	0.01	0.11	0.05	0.02
	3	0.05	0.02	0.00	0.11	0.03	0.01	0.24	0.08	0.03
	4	0.15	0.04	0.01	0.13	0.04	0.01	0.20	0.07	0.02
	5	0.09	0.03	0.01	0.12	0.05	0.01	0.31	0.10	0.01
	6	0.09	0.02	0.01	0.21	0.05	0.02	0.22	0.10	0.02
5-18	1	0.23	0.05	0.03	0.16	0.04	0.01	0.10	0.05	0.01
	2	0.11	0.03	0.01	0.12	0.04	0.01	0.13	0.06	0.01
	3	0.14	0.04	0.01	0.27	0.06	0.03	0.07	0.04	0.00
	4	0.18	0.04	0.01	0.20	0.05	0.02	0.14	0.06	0.01
	5	0.17	0.04	0.01	0.16	0.04	0.01	0.08	0.05	0.00
	6	0.11	0.03	0.01	0.17	0.04	0.02	0.12	0.05	0.01
5-20	1	0.09	0.03	0.03	0.09	0.02	0.00	0.16	0.03	0.01
	2	0.11	0.03	0.02	0.04	0.02	0.00	0.05	0.02	0.00
	3	0.20	0.04	0.03	0.03	0.01	0.00	0.05	0.01	0.01
	4	0.03	0.02	0.01	0.06	0.03	0.01	0.06	0.01	0.00
	5	0.11	0.03	0.02	0.04	0.03	0.00	0.09	0.02	0.00
	6	0.05	0.02	0.01	0.07	0.03	0.01	0.04	0.04	0.00

TABLE F-2. (continued)

Sta. / Rep.		M-2 %C	M-2 %H	M-2 %N	M-3 %C	M-3 %H	M-3 %N	M-4 %C	M-4 %H	M-4 %N
5-22	1	0.07	0.03	0.00	0.14	0.04	0.01	0.15	0.07	0.01
	2	0.24	0.06	0.02	0.03	0.02	0.00	0.22	0.07	0.02
	3	0.12	0.03	0.02	0.10	0.03	0.01	0.04	0.04	0.00
	4	0.12	0.03	0.02	0.09	0.03	0.00	0.18	0.07	0.01
	5	0.08	0.02	0.01	0.05	0.03	0.00	0.15	0.05	0.01
	6	0.10	0.02	0.01	0.09	0.03	0.00	0.06	0.04	0.00
5-25	1	0.10	0.03	0.01	NO DATA AVAILABLE			0.15	0.07	0.01
	2	0.09	0.03	0.01				0.11	0.03	0.00
	3	0.11	0.04	0.01				0.15	0.05	0.01
	4	0.08	0.03	0.01				0.26	0.08	0.03
	5	0.09	0.03	0.01				0.09	0.05	0.01
	6	0.07	0.03	0.00				0.11	0.05	0.01
5-28	1	0.07	0.04	0.00	NO DATA AVAILABLE			0.06	0.02	0.00
	2	0.05	0.03	0.00				NO SAMPLE		
	3	0.25	0.03	0.00				0.17	0.03	0.01
	4	0.06	0.03	0.00				0.08	0.02	0.01
	5	0.15	0.03	0.00				0.07	0.04	0.00
	6	0.17	0.04	0.01				0.09	0.03	0.00
5-29	1	0.69	0.05	0.02	0.26	0.06	0.01	0.63	0.13	0.04
	2	0.32	0.06	0.02	0.62	0.06	0.02	0.45	0.12	0.03
	3	0.33	0.06	0.03	0.41	0.06	0.01	0.34	0.12	0.03
	4	0.39	0.05	0.02	0.45	0.06	0.01	0.47	0.11	0.02
	5	0.33	0.05	0.02	0.28	0.06	0.02	2.15	0.14	0.03
	6	0.36	0.06	0.03	0.42	0.05	0.02	0.44	0.10	0.02

APPENDIX G

TABLE G-1. DISSOLVED OXYGEN (mg/l) FROM GEORGES BANK BENTHIC MONITORING PROGRAM REGIONAL STATIONS.

Station	CRUISE M-1			CRUISE M-2			CRUISE M-3			CRUISE M-4		
	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3
1	6.67	6.69	6.68	6.25	6.22	6.28	10.32	10.33	10.32	10.24	10.32	*
2	6.24	*	*	6.30	6.21	6.20	10.19	10.18	10.15	10.26	10.23	10.17
3	5.62	5.62	5.53	5.40	5.44	5.50	9.41	9.28	9.40	8.28	8.52	8.62
4	6.77	*	*	6.31	6.40	6.33	10.78	10.53	10.50	9.37	9.39	9.40
5-1	*	*	*	5.01	5.09	5.10	10.18	10.05	9.94	9.33	9.33	9.35
6	5.60	5.74	5.76	5.62	5.43	5.58	9.13	9.04	9.05	9.10	9.20	9.29
7	4.23	*	*	4.42	4.33	4.16	8.88	9.15	9.03	6.57	6.63	6.52
8	*	*	*	4.12	3.99	4.00	9.14	9.00	9.04	6.65	6.72	6.63
9	6.22	6.19	6.35	5.80	5.17	5.25	7.78	7.78	7.78	7.33	7.37	7.44
10	5.24	5.79	5.23	5.94	6.42	6.10	10.54	10.38	10.40	9.40	9.27	9.20
11	5.36	*	*	5.51	5.53	5.62	10.40	10.39	10.10	9.06	9.00	9.00
12	4.84	4.53	4.82	4.64	4.92	4.77	8.96	8.96	8.89	8.39	8.37	8.45
13	4.70	*	*	4.65	4.62	4.66	10.49	10.54	10.53	9.65	9.60	9.53
14	6.55	6.23	6.25	5.44	5.47	5.42	*	*	*	9.09	9.39	9.19
15	6.19	*	*	6.34	6.29	6.32	11.51	11.25	11.10	10.87	10.82	10.80
16	4.58	*	*	4.96	4.96	4.98	6.80	6.90	7.40	6.77	6.67	6.72
17	3.86	3.73	3.73	4.41	4.40	*	7.96	8.11	8.13	6.67	6.70	6.68
18	4.66	4.60	4.65	4.12	4.29	4.19	6.83	6.57	7.30	6.68	6.83	6.83

* No Data/Sample for these replicates.

TABLE G-2. SURFACE AND BOTTOM TEMPERATURE (^{o}C) FROM XBT RECORDS.

	M-1		M-2		M-3		M-4	
Station	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1	16.7	10.4	10.2	11.0	4.1	4.3	5.1	5.0
2	16.6	7.5	*	*	4.4	4.5	5.8	5.2
3	16.6	7.2	11.1	8.4	4.0	7.2	10.7	12.5
4	13.7	9.7	11.2	10.3	3.8	3.8	6.4	6.4
5-1	*	*	11.4	15.6	4.5	5.0	6.2	5.3
6	18.7	8.7	*	*	*	*	5.6	9.7
7	*	*	11.1	10.0	4.5	12.3	5.8	11.5
8	19.3	10.8	11.7	10.0	4.5	11.6	10.0	11.2
9	18.0	11.2	11.4	9.7	*	*	9.6	10.5
10	16.5	10.2	11.5	11.6	4.0	4.2	6.6	6.5
11	16.5	7.8	13.0	11.0	4.1	4.4	6.2	5.4
12	19.2	10.8	14.1	10.6	4.6	6.7	9.3	8.7
13	*	*	12.2	11.5	2.7	3.2	8.4	5.5
14	16.6	5.5	10.4	6.0	*	*	16.8	16.8
15	16.6	14.8	16.6	11.6	3.8	3.8	7.2	7.2
16	16.6	10.4	11.0	9.2	*	*	9.7	16.8
17	18.6	10.6	10.6	8.0	6.9	11.2	9.6	12.4
18	18.2	10.6	*	*	6.8	11.6	9.8	12.5

*No Sample/Data at these stations.

TABLE G-3. SALINITY ($^{o}/oo$) FROM GEORGES BANK BENTHIC MONITORING PROGRAM REGIONAL STATIONS.

	M-1		M-3		M-4	
Station	Surface	Bottom	Surface	Bottom	Surface	Bottom
1	32.8	32.8	31.5	31.0	31.0	32.0
2	32.3	32.9	31.0	31.5	*	31.0
3	31.5	33.8	31.0	31.5	33.0	33.0
4	32.6	32.9	32.0	31.0	31.0	32.0
5-1	*	*	30.5	31.0	31.0	31.0
6	*	*	31.5	31.0	32.0	32.0
7	*	*	30.5	32.0	31.0	33.0
8	32.6	35.1	31.0	32.0	32.0	34.0
9	*	*	31.0	33.0	33.0	34.0
10	33.0	32.5	31.0	31.0	31.0	32.0
11	33.1	33.0	31.0	32.0	32.0	32.0
12	33.4	*	32.0	32.0	31.0	32.0
13	33.0	34.5	31.0	31.0	31.0	31.0
14	32.0	33.1	*	*	31.0	32.0
15	32.7	32.8	32.0	32.0	31.0	32.0
16	32.9	32.9	32.0	32.5	32.0	34.0
17	32.4	35.2	32.0	32.5	32.0	34.0
18	32.5	34.8	32.0	32.5	32.0	33.0

*No Sample/Data at this station.