GEORGES BANK BENTHIC INFAUNA
HISTORICAL STUDY

Contract No. 14-12-0001-29190

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Minerals Management Service
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FINAL REPORT

by

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16. Abstract (Limit: 200 words)

Benthic infaunal samples were collected with a $0.1m^2$ Van Veen grab at eleven stations on Georges Bank and adjacent areas in 1977. Replicate samples were collected quarterly and sieved to 0.5mm. Approximately 700 taxonomic categories were identified. Polychaetes were numerically dominant in most samples and represented the greater proportion of species. The next most abundant and diverse group were the amphipods followed by the molluscs and echinoderms. Sediments were primarily medium to fine sands with low silt/clay content. Stations in the Gulf of Maine, Lydonia Canyon and mud patch had higher silt/clay content. Faunal densities and species richness increased with depth across the bank and from east to west. Most stations had densities in the range of 4,000-14,000 individuals/m^2. Numbers of species per $0.1m^2$ replicate typically range from 50-60. Shallow stations were dominated by haustoriid amphipods. All other stations were dominated by polychaetes although the amphipod, Ampelisca agassizi was the most abundant species at several stations. With increasing depth and decreasing particle size the amphipod component of the fauna diminished and the polychaete and molluscan components increased. Faunal composition was stable through the year. Inter-replicate variation was extremely low in most cases.

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The list of participants in the overall sorting program is too extensive to be included here, but we would like to express appreciation to the individuals who performed key roles in the completion of this Historical Study. They were: Mark Curran, Joan McDonald, Debra McGrath, Michael Russell and Janice White for work on taxonomic aspects; Walter Grocki and Jeanne Kelley for data summary and preparation of the final report; David Mark for graphics.

Dr. Peter Larsen, Richard Lee and Lee Dogget supervised a group at the Bigelow Laboratory for Ocean Sciences which assisted in the presorting of the samples from Cruises I and II. They also identified the molluscs and echinoderms for all Cruise I and II samples.

We are also grateful to Dr. Betsy Brown, Wayne Leathem and Peter Kinner for discussion on polychaete systematics and to the polychaete systematists who provided opinions of reference material from the collection. They are Drs. John Hartley, Thomas Perkins and Robert Zottoli. Dr. Ruth Turner checked the identification of some voucher specimens from the mollusc collection.

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INTRODUCTION

General

In 1977 the New England OCS Environmental Benchmark program was initiated under contract AA 550-CT6-51 to Energy Resources Company in Cambridge, Massachusetts. This was an extensive program in which 42 stations on Georges Bank and adjacent areas were sampled quarterly. Although there was a certain amount of information available for the area, it was not sufficient to fulfill the needs for an assessment of effects of oil and gas exploration and production. The objectives of that program as described in the Draft Final Report were:

1. Determine the ranges of high molecular weight (HMW) hydrocarbons and selected trace metal concentrations in the sediments and selected macrofaunal species preceding oil and gas development against which possible man-induced chemical change can be assessed in the future.

2. Delimit the major chemotopes, lithotopes, and biotopes for the study area, and characterize each with respect to natural seasonal variability and interrelationships.

3. Characterize the existing health of selected benthic macrofauna preceding oil and gas development, and establish a histological data base that can serve as a reference for later comparisons.

4. Describe dominant microbes in sediments and in the upper water layers and evaluate their "potential" and possible importance in the degradation of oil.

5. Describe the HMW hydrocarbon and selected trace metal concentrations in the water column.

6. Identify and describe unique or fragile/endangered areas.

7. Collect other data supportive of the above objectives.

There had been some criticism in the scientific community as to the effectiveness of benchmark programs, and, as a result of this criticism, much of which is addressed in a National Academy of Sciences Report (1976), the program was terminated in March of 1978. The program ended at short notice

and only portions of the complete data set were included in the Draft Final Report produced in May 1978. The benthic infauna was not included in the Draft Final Report because of the size and diversity of the data set and the fact that four different laboratories were involved in the analyses. Time and financial constraints were too restrictive.

In 1980 the Biological Task Force for OCS Lease Sale No. 42 on Georges Bank (BTF) was established to recommend to the U.S. Geological Survey (USGS) Supervisor of Oil and Gas Operations in the North Atlantic (now part of the Minerals Management Service) "the design of environmental studies and surveys as well as periodic sampling of environmental conditions to provide warning of adverse effects" of OCS exploration.

In order to determine and to identify the fate and effects of discharges associated with oil and gas development on Georges Bank, an understanding of the following is required:

1. the physical processes operating on Georges Bank which transport materials and nutrients;
2. areas of pollutant accumulation; and
3. the effects of the pollutants on various benthic communities of the Georges Bank ecosystem.

A field monitoring program, primarily of the benthic community and of the chemistry and geology of the sediments, was proposed to address the following specific questions:

1. What are the quantities, the physical characteristics, and the chemical composition of materials discharged during OCS drilling operations?
2. Where do discharged materials accumulate (e.g. heads of submarine canyons, the "mud patch", around rigs) and in what concentrations?
3. What are the existing background levels of contaminants in the sediments and biota and what levels above background can be detected with existing best available technology?
4. Do benthic populations change at selected regions on Georges Bank during various stages of OCS oil and gas activity compared with control sites; can these changes be related to observed changes in pollutant levels associated with discharges; and, what are the concentrations of pollutants associated with these changes?

The major emphasis of the monitoring program is to link the fate of discharges from oil and gas exploratory operations to effects on benthic components. Benthic environments are potential sinks for discharge materials. Also, because of their relative immobility, benthic organisms are susceptible to exposure, and are therefore suitable for monitoring the effects of contaminants.

Fifteen long-term regional stations were established in the monitoring program initiated in July, 1981. Eleven of these stations coincided or were very close to stations sampled in the benchmark program. At the termination of the benchmark program benthic infaunal samples from the first two cruises were sorted and identified; those from Cruises III and IV remained unsorted. In September, 1981 TAXON, Inc. was contracted to complete the taxonomic identifications of samples from Cruises III and IV and analyze the data from eleven stations for the first four seasons. This data base, called the Historical Study, including samples from 1977, was considered to be a valuable addition to the overall monitoring program. It would produce information on seasonal variation and provide a longer term base for comparison as new data were generated on the current monitoring program.

A separate aspect of contract AA851-CT1-69, a study in which the sampling efficiency of two benthic grabs was compared, was completed in December, 1981 (Michael et al., 1981). In that study, the faunal data produced from samples collected by a $0.1m^2$ Van Veen (0.5mm sieving) and a $0.04m^2$ Van Veen (0.5, and 0.3mm sieving) were compared to evaluate possible sampling precision or cost advantages associated with any one method. As a result the present monitoring program uses the small $0.04m^2$ modified Van Veen grab with the samples sieved at both 0.5 and 0.3mm.

Support for the completion of this study was related to the overall goals of the Georges Bank Monitoring Program and thus the analyses and results are presented and discussed with that perspective rather than that of general benthic ecological theory. The latter approach would require much more time and effort than was available. A significant problem in that data base has prevented any detailed discussion of species composition among those species which were not very abundant or those for which systematic problems exist. The data in this report and the publications of

Maurer and Leathem (1980, 1981) indicate that many new species were encountered in this collection and the systematics of some groups require major revisions.

In March of 1978 when the program was discontinued, perhaps as many as forty different people were involved in the sorting and identification work at four different laboratories. Funding was discontinued at short notice and there was not sufficient time to put all collections and identifications in order. Maurer and Leathem were able to find support at the University of Delaware to analyze data and publish two papers dealing with the polychaete component of the fauna. Most of the members of the original teams had dispersed in the three year period before this contract was awarded. Personnel at TAXON, Inc. assumed the responsibility of identifying all the material from Cruise IV and most of the samples from Cruise III. Because of the diversity of the fauna (more than 600 species), the state of the systematics in some groups, and in some cases, disagreement between systematists, there were significant problems in matching the data sets for all cruises. There were also isolated cases where samples had suffered some deterioration in the three year storage period making identification difficult.

The analyses in this report are therefore confined to major community parameters and dominant species. Some of the less abundant species might have been important in multivariate analyses because of their fidelity or constancy with regard to species or station groups. The community analyses reported here may therefore seem rather superficial to specialists in that field. We do not believe that corrections or more refined systematics will significantly alter the conclusions presented here. We would also like to emphasize that any comments on the systematics of various groups, or changes we made in identifications, should not be viewed as criticism of previous work on this project. We are well aware of the fact that others involved in further work on the Georges Bank benthic infauna may, in the same way, disagree with some of our identifications.

The eleven stations selected for analysis in this Historical Study are identified in Figure 1. The localities of the fifteen stations selected

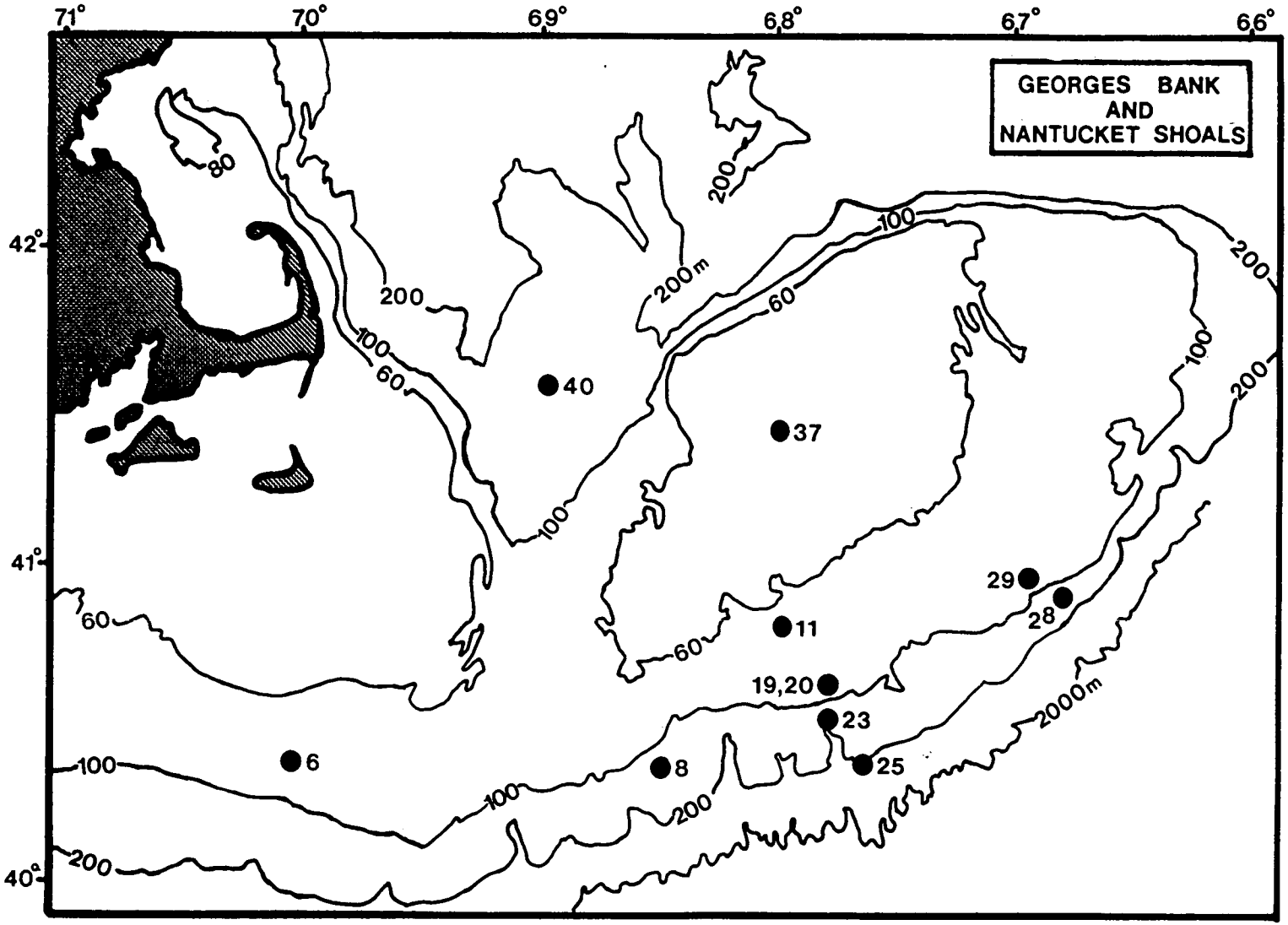


Figure 1. Location of Sampling Stations

for the Georges Bank Monitoring Program are shown in Figure 2, which also identifies the large blocks of Lease Sale No. 42. Coordinates for the Historical Study stations are listed in Table 1, together with the station number for the corresponding station in the monitoring program. In the first three cruises, six replicates were collected at each station. In the fourth cruise only four replicates were collected at nine stations. Stations 11 and 19 were not sampled.

Benthic Infaunal Studies

Although a significant number of publications dealing with the benthic infauna of the New England area exist, there are relatively few specific to the Georges Bank Region. Areas closer to shore such as Vineyard Sound, Cape Cod Bay, Nantucket Sound and Buzzards Bay are better known (e.g. Sanders, 1958; Verrill and Smith, 1874; Rhoads and Young, 1971; Young and Rhoads, 1971; Michael, 1976; Sanders et al., 1980; Sumner et al., 1913). Sanders et al. (1965) included a few stations on the continental shelf in their study of the benthic infauna on a transect from Gay Head to Bermuda. Much of the available work has been produced by Roland Wigley of the National Marine Fisheries Service (NMFS) and various co-workers (Wigley, 1956, 1961, 1965, 1968; Wigley and McIntyre, 1964; Wigley and Theroux, 1970; Wigley and Stinton, 1973). A major summary of the benthos of the Middle Atlantic Bight, including Georges Bank south of the Great South Channel, was presented by Wigley and Theroux (1981). An equivalent report dealing with the North Atlantic is almost completed (Theroux, personal communication).

The major difference in this Historical Study is that stations were sampled repeatedly (over four seasons) and with replication (four or six replicates). A further distinction is the use of a 0.5mm sieve which produces higher density estimates and more juveniles. Maurer and Leathem (1980, 1981) have published two papers dealing with the systematics and ecology of polychaetous annelids collected in the first two cruises. Larsen and Lee (1978) reported on the abundance, distribution and growth of post-larval sea scallops as determined by collections from the winter and spring cruises. This report is the first publication dealing with the entire benthic infaunal collection made in the New England OCS Environmental Benchmark program.

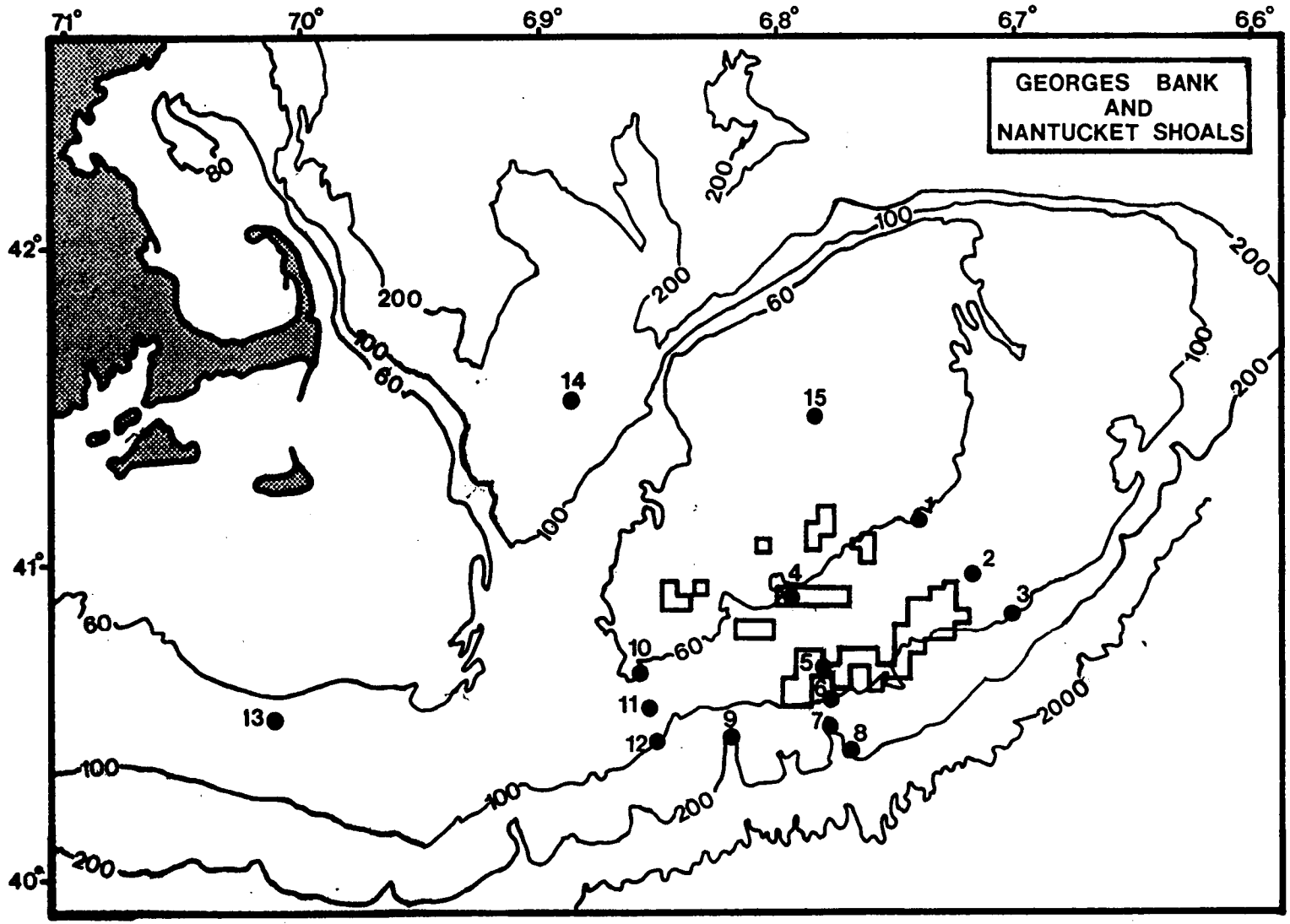


Figure 2. Location of Monitoring Stations for Lease Sale No. 42

Table 1. Historical BLM Benchmark Stations Coinciding with Georges Bank Monitoring Stations.

(ERCO)	Coordinates	Georges Bank Monitoring Station	Number of Replicates Sampling Period			
			Winter (2/77-3/77)	Spring (5/77-6/77)	Summer (8/77-9/77	Fall (11/77)
6	40°25'N, 70°03'W	13 (Near 6)	6	6	6	4
8	40°22'N, 68°30'W	12	6	6	6	4
11	40°51'N, 68°00'W	4	6	6	6	0
19	40°34'N, 67°45'W	6	6	6	6	0
20	40°36'N, 67°45'W	5 (Near 20	6	6	6	4
23	40°29'N, 67°43'W	7	6	6	6	4
25	40°27'N, 67°37'W	8	6	6	6	4
28	40°55'N, 66°48'W	3	6	6	6	4
29	40°59'N, 66°56'W	2	6	6	6	4
37	41°27'N, 68°00'W	15	6	6	6	4
40	41°34'N, 68°59'W	14	6	6	6	4

The benthos of Georges Bank is of particular interest because it supports one of the most productive fisheries in the world (Grosslein et al., 1979). The shallower regions (less than 100m) of the Bank represent a dynamic environment in which strong tidal currents and storm-generated wave activity can alter bottom sediment composition (Butman, 1980). The persistence of benthic infaunal communities in a dynamic environment and the feasibility of using the benthos to monitor the effects of oil and gas exploration and production are the focus of this report.

METHODS

Field

During 1977, quantitative sediment samples were taken quarterly (winter, February 7-March 8; spring, May 2-June 2; summer, August 15-September 4; fall, November 8-November 20) with a modified Van Veen grab ($0.1m^2$) from the Georges Bank region off New England (Figure 1). Approximately 100 kgs in weight were added to the frame of the grab to improve penetration in firm sediments.

One subsample for grain size analysis and five cores for microbial analysis were removed from the first biological replicate at each station. A grain size subsample and a subsample for total organic carbon (TOC) and total organic nitrogen (TON) analysis were removed from the remaining five biological replicates. Procedures for removal of samples of hydrocarbons and trace metals and laboratory analyses of supporting data used here are presented in Volume I of the Draft Final Report for the New England Outer Continental Shelf Environmental Benchmark 1978. The remainder of each grab was sieved through a 0.5 mm mesh Nitex screen in the field. Material retained on the sieve was then placed on 0.5 mm sieve cloth, inserted in a muslin bag and immersed in a 6% Mg Cl_2 solution for approximately 30 minutes. The muslin bag was then placed in 10% buffered seawater formalin and sealed in 30 gallon metal drums for shipment to the laboratory.

Laboratory

The 30-gallon sample drums were shipped to TAXON, Inc. (Salem, Massachusetts) and the Bigelow Laboratory (West Boothbay, Maine). Formalin in the drums was changed to 70% isopropanol. In the laboratory, samples were carefully resieved through a 0.5 mm stainless steel sieve to further reduce sample volume. Prior to sorting, samples were stained with rose bengal to increase visibility of the organisms. Samples were then presorted into several major taxa (Polychaetes, Amphipods, Molluscs, Echinoderms, other Crustacea, and Miscellaneous) under stereomicroscopes with magnification ranges of 7-40x. To increase the effectiveness of

sorting, the residue was elutriated into a fine sieve and resorted. Wet weight of biomass of major groups (Polychaetes, Amphipods, Molluscs, etc.) was determined after species material was blotted on a paper towel.

Four laboratories were involved in the taxonomic identifications for the first two cruises. Polychaeta were identified at the University of Delaware under the supervision of Dr. Don Maurer; Mollusca and Echinodermata were identified at Bigelow Laboratory under Dr. Peter Larsen's supervision; the Amphipoda were identified by Dr. Les Watling at the Darling Center of the University of Maine; and the remaining groups were identified at TAXON. All identification for samples from Cruises III and IV were completed at TAXON, Inc. The largest group, the Polychaeta, were identified under the direction of Ms. Charlene Long.

Data Analysis

Faunal data were entered into the Woods Hole Oceanographic Institution's VAX/11-780 computer and analyzed using a suite of programs maintained at WHOI specifically for benthic faunal data. These included PRARE I (diversity calculations and data listing), PERSORT (abundance rankings), and SPSTCL (classification analysis).

Diversities were calculated using the Shannon-Weiner formula:

$$H' = -\sum P_i \ \ln \ P_i,$$

where p_i is the proportion of the ith species in the sample. Classification analysis was performed on reduced data sets. The species list was reduced significantly to avoid potential systematic problems in the less common species (see Introduction and Systematics sections). Only those species which occurred in approximately 30% or more of the samples were included in the analyses. This included 40-50 species in the within-season analyses and 72 species for the overall analysis. Data was transformed (log X+1) before analysis. Normal classification was based on the Bray-Curtis similarity measure and either group average or flexible sorting (Clifford and Stephensen,1975; Boesch, 1977) used to cluster entities. The classifications are polythetic, agglomerative hierarchies based on quantitative data.

The Bray-Curtis similarity measure can be expressed as:

$$\sum_{AB} \text{MIN} \left[\frac{N_i^A}{N^A} , \frac{N_i^B}{N^B} \right]$$

which is calculated as the sum of the smaller of the two percentages at which the species occurs in the two samples, over all species in common between two samples. Group average sorting, which has space conserving properties, was used for the within-season analyses since the number of entities (stations) was small (11). In the overall analysis including four seasons, 40 entities were involved and flexible sorting was used with B set at -0.25 (Boesch 1977).

PHYSICAL ENVIRONMENT OF GEORGES BANK

Physiography and Geology

Georges Bank is a shallow submarine bank located about 150 km to the east of Cape Cod, Massachusetts forming a border to the southeast edge of the Gulf of Maine. The bank is about 300 km long and about 150 km wide and is separated from Nantucket Shoals by the shallow (approximately 70m deep) Great South Channel (Butman et al.,1982). The south side of the bank at depths greater than 70m is continuous with the continental shelf to the south but the northern edge ends abruptly at the Northeast Channel which separates the bank from the Scotian shelf. The topography and sediments of the region are determined primarily by Pleistocene glaciation and present sediment transport processes (Schlee, 1973). Notable features of the bank are the ridges and swales in the shallow areas and the canyons on the southern flank. Sands and gravels of northern Georges Bank are remnants of glacial moraine whereas fine sands and silty sands of the southern half of Georges Bank are remnants of a glacial outwash plain. Surface sediments have been smoothed and reworked by changes in sea level since the Pleistocene (Knott and Hoskins,1968).

Physical Oceanography

Colton and Stoddard (1972) described the generalized surface circulation in the Georges Bank region as a zone of convergence between a clockwise gyre around Georges Bank and a counter-clockwise gyre in the Gulf of Maine. Recent Eularian and LaGrangian current observations by Butman et al. (1982) confirm the clockwise flow pattern around Georges Bank first inferred by Bigelow in 1927. Observations suggest that the residual clockwise circulation is a permanent feature of the subsurface circulation. Some seasonal variation exists in the strength of this circulation. On the northern side of Georges Bank, strong flow to the northeast of about 25-30 cm per second exists in a band approximately 10-20 kilometers wide along the steep northern flank (Figure 3). Flow of shelf water on the southern flank was westward at about 10 cm per second toward the Middle Atlantic Bight, but some of this water flows northward through the eastern side of Great

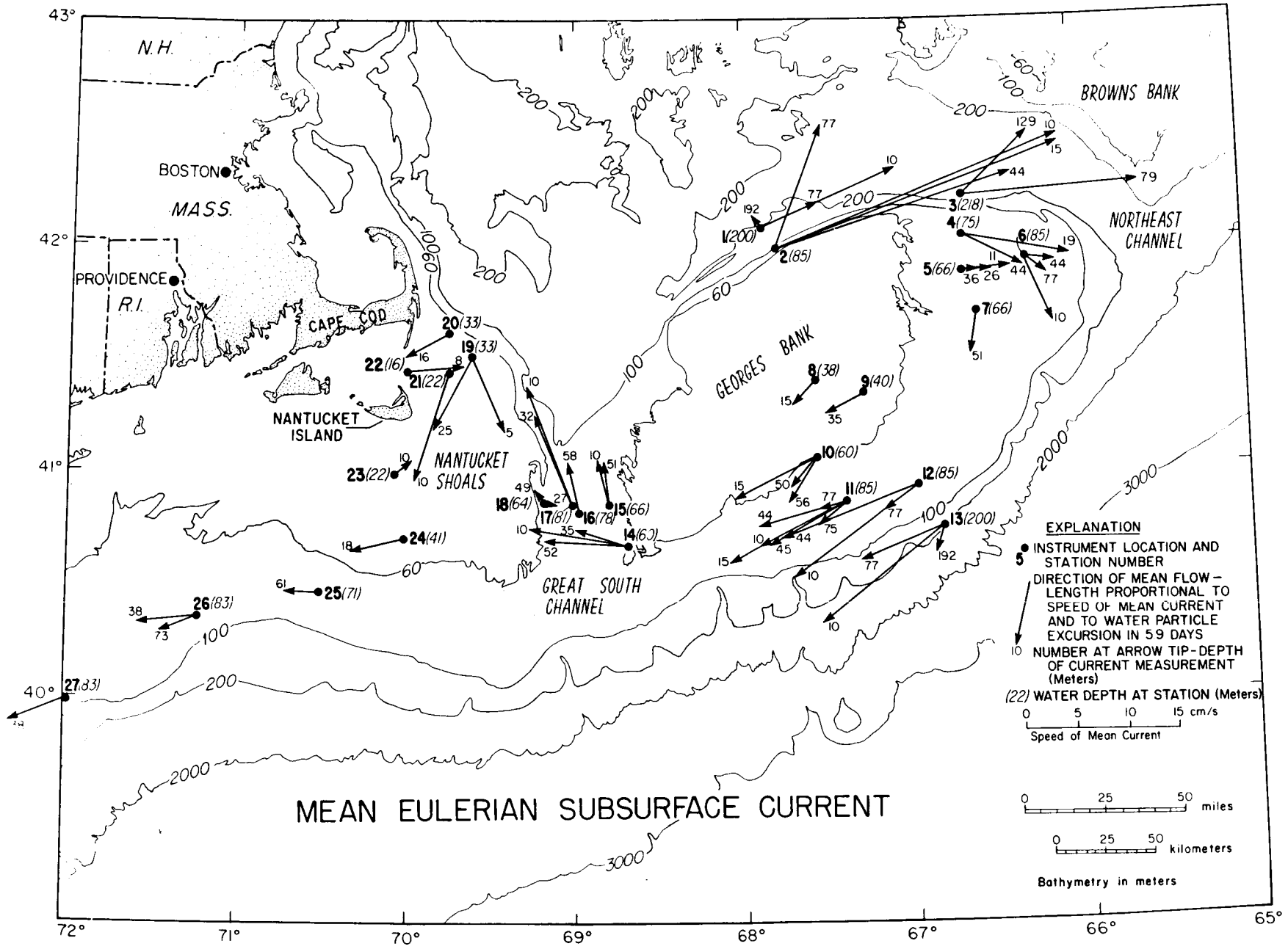


Figure 3. (Reproduced with permission from Butman et al, 1982.)

South Channel and recirculates around Georges Bank (Butman et al., 1982). Typical particle excursions caused by low frequency currents are indicated in Figure 4, reproduced from Butman et al.(1982). Major displacements occur on the northern and southern flanks of the bank and predominantly in a northeast-southwest direction. In the Great South Channel the direction of displacement in any one direction is not so clearly emphasized. Displacement near the center of the bank is small. Water on the crest of Georges Bank at depths shallower than 60 meters is vertically well mixed throughout the year by the strong semi-diurnal tidal currents (Colton et al., 1968; Bumpus, 1976; Garrett et al., 1978).

In winter, fronts separate the well mixed water on the crest of the Bank on both the northern and southern flanks (Figure 5). On the southern flank of the Bank the shelf water/slope water front intersects the bottom at approximately 80 meters, separating cooler, fresher shelf water from warmer, more saline slope water. This shelf/slope water front is similar in structure and continuous with the front at the shelf break in the Middle Atlantic Bight (e.g., Beardsley and Flagg, 1976). On the northern flank a weaker and deeper front separates Georges Bank water from Gulf of Maine water.

In summer, a seasonal thermocline develops over the Gulf of Maine, the slope water and water deeper than 60 meters on the southern flank of Georges Bank (Figure 6). A tidally mixed front forms at approximately the 60 meter isobar. A subsurface band of colder water occurs along the southern flank of Georges Bank between the 60 and 100 meter isobars, bounded by the warmer slope water to the south and warmer, well mixed water on the crest of Georges Bank and the seasonal thermocline above.

Bottom temperature ranged from 0.5 degrees to 10.6 degrees in the winter at the 42 stations sampled in the 1977 Benchmark study. Coldest temperatures were recorded on the top of the bank. There was a progressive increase in temperature from winter to summer, with an extended warm period into fall. The summer temperature range was from 5.6 degrees C. at deep stations to 15.6 degrees on the top of the bank. The annual range on the top of the bank was 10-15 degrees C., whereas stations deeper than 100m experienced a range of 4-5 degrees C. on the south side of the bank and only about 2 degrees C. on the northern flank.

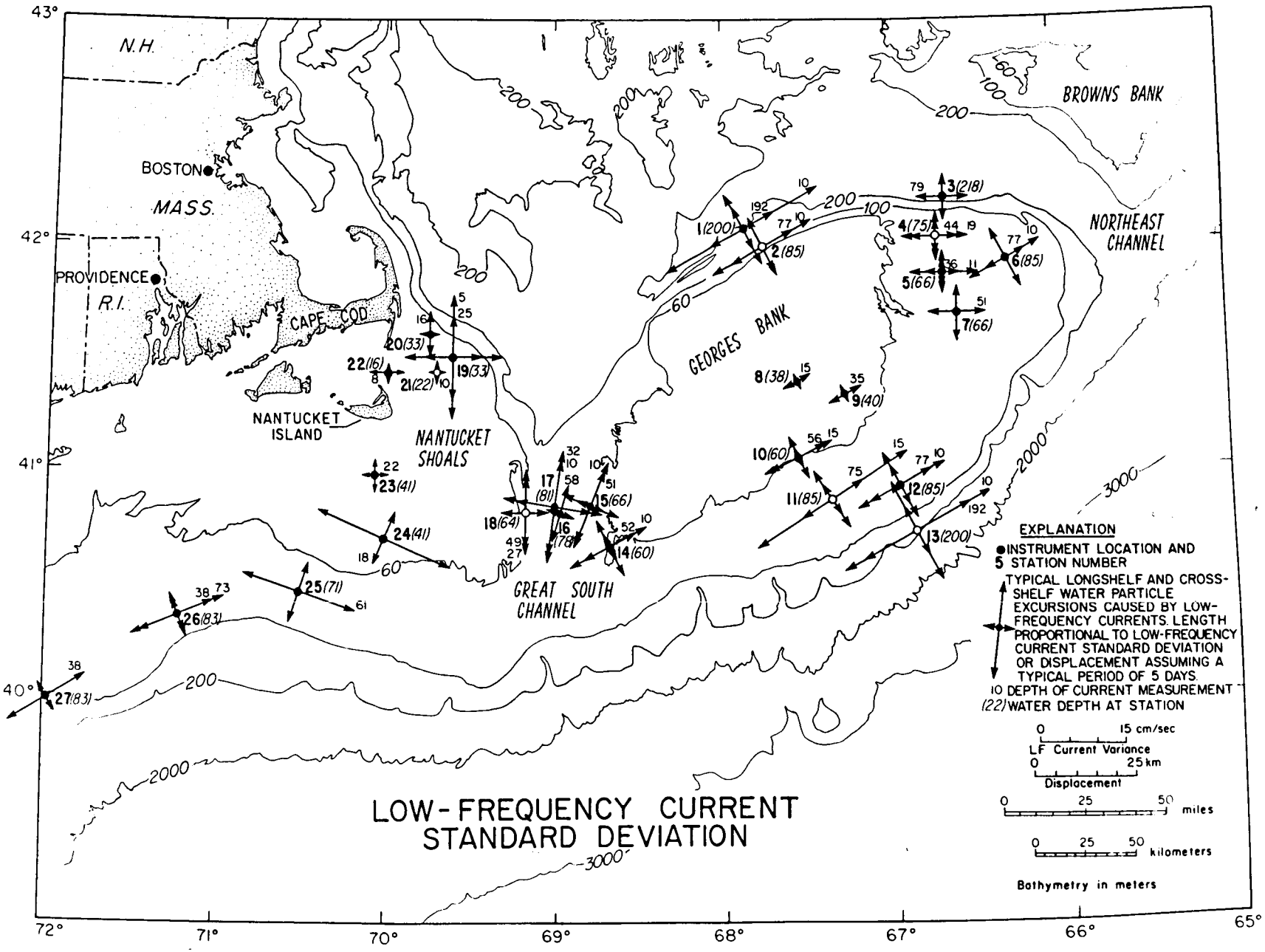


Figure 4. (Reproduced with permission from Butman et al., 1982)

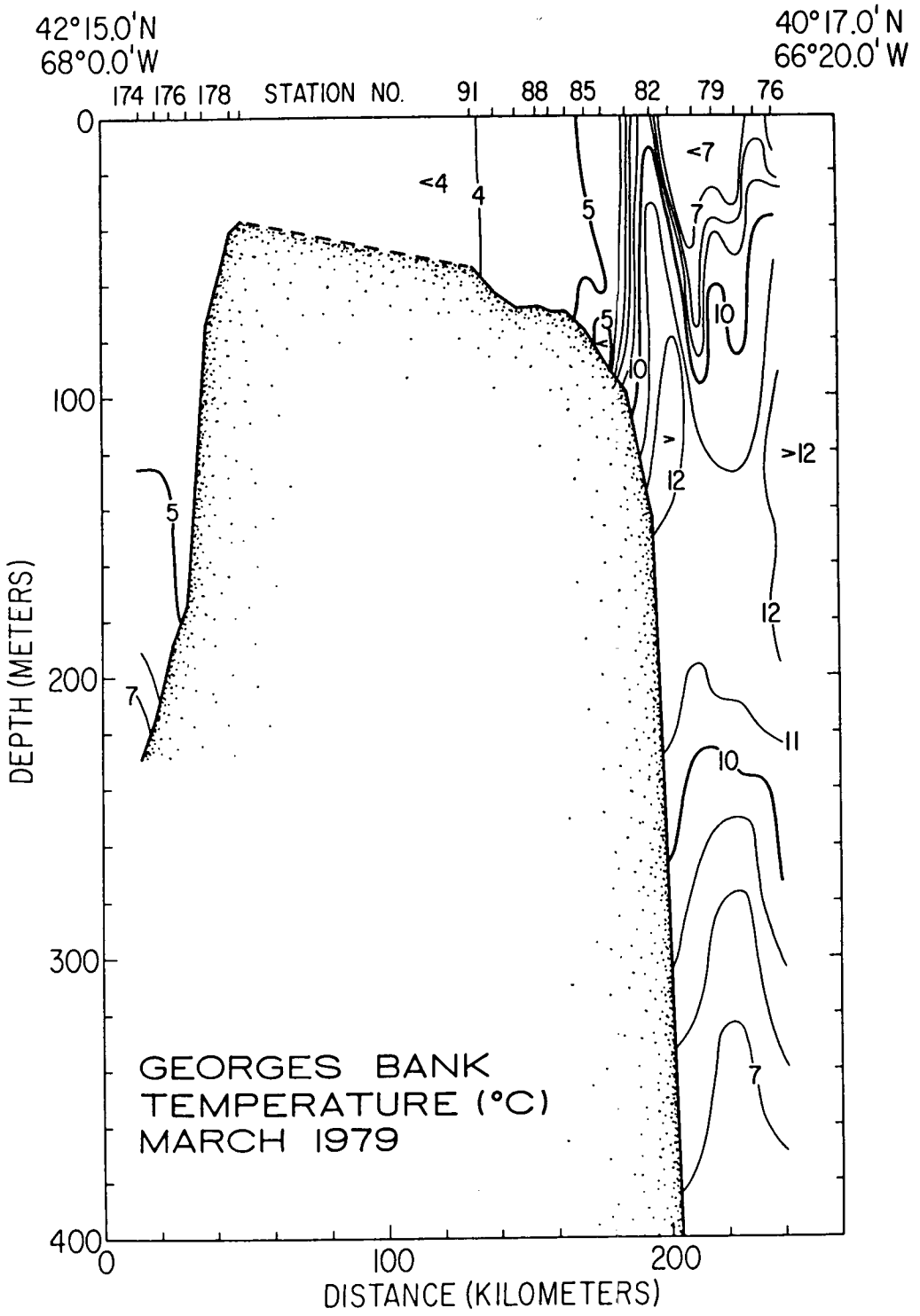


Figure 5. Reproduced from Butman et al., 1982

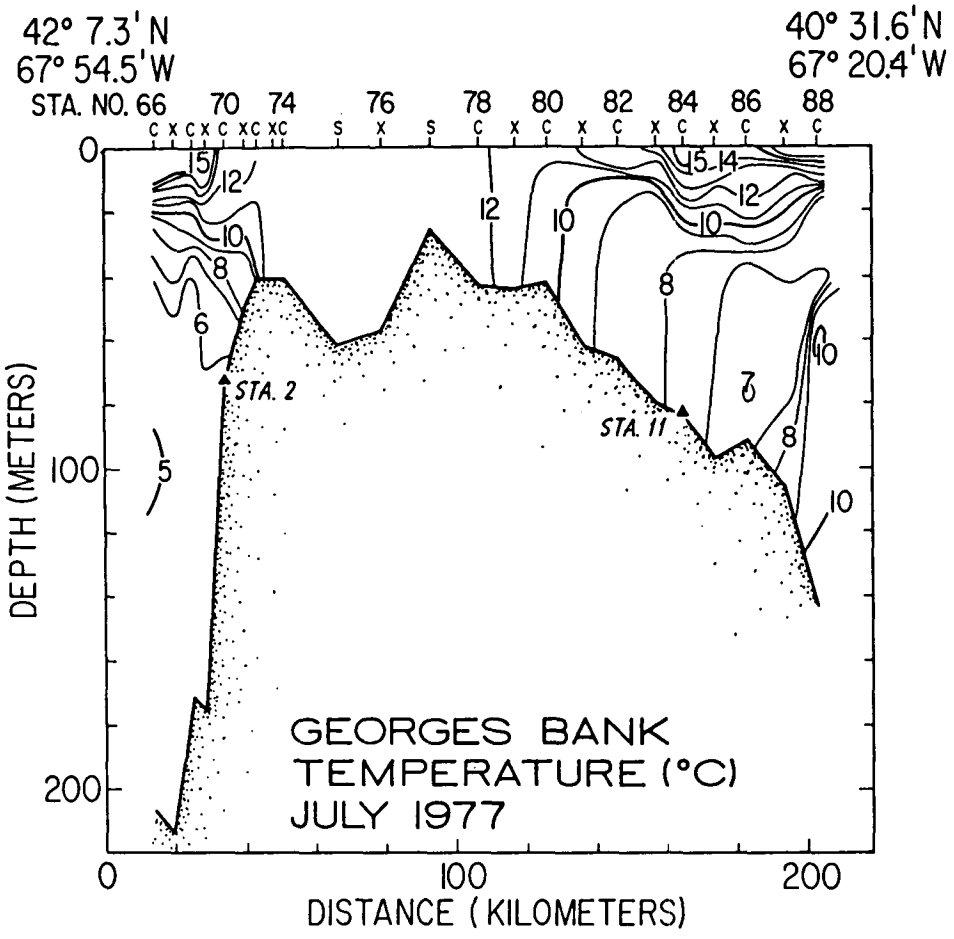


Figure 6. Reproduced with permission from Butman et al., 1982

Sediments

Continental shelf sediment, including Georges Bank, is dominated by sand (Milliman, 1973). On the crest of Georges Bank sediments are a mixture of fine to coarse sand and gravel (Schlee, 1973). Along the southern flank of the bank surface sediments become increasingly fine to the west. A depositional area which is locally known as the "Mud Patch" occurs to the south of Nantucket Island. Results of sediment analyses performed on samples from 42 stations in the 1977 Benchmark Study were summarized by Maurer and Leathem (1980).

Poorly sorted, gravelly sands from the top of the bank showed the largest variations in sediment size properties. These variations were almost entirely due to the quantity of gravel present in a sample. Samples tended to be bimodal, containing fine to medium sand mixed in varying proportions with gravel-sized material.

Samples from the south side of the bank were mostly fine to medium sand with some coarse to medium and gravelly sands found at stations near the edge of the shelf. Sediments generally had a single mode with small amounts of coarser sand or gravel. Silt/clay content was typically 1-5%. Samples from the head of Lydonia Canyon (Station 23) varied from silty fine sand to fine sand. The further down the canyon the sample came from, the more silt appeared in the sample.

Samples from the Great South Channel were moderately sorted sand with some gravel. Differences between sediment size for these stations (4 and 5) resulted from varying proportions of gravel in the samples. Both stations are located on the edge of the relict glacial terminal moraine. The sediments from the Gulf of Maine stations were reworked glacial material ranging from gravels to clays. Samples were generally poorly sorted material with rather large variations in all size classes from sample to sample at each station.

Sediment Organic Matter

In the 1977 Benchmark Study total organic carbon and organic nitrogen were determined for all sediment samples. In the predominantly sandy areas, the values of organic carbon generally remained below 2.0 mg/g and the values of organic nitrogen were less than 0.4 mg/g. In the

fine grained sediments in the Gulf of Maine and south of Nantucket, the values for organic carbon and organic nitrogen rose markedly, with the largest values being observed at Station 42 (C = 12.94 mg/g and N = 1.63 mg/g).

Levels of organic matter in the sediments in the zone where the shelf/slope front intrudes upon the bank showed higher than expected values for the type of sediment observed. In addition, there was a threefold increase in organic carbon from the winter to the summer at Stations 22, 23, 25, 26 and 27 (Maurer and Leathem, 1980). The values observed during the fall sampling period were nearly as high as the summer values. Organic nitrogen did not increase in proportion to the carbon. As a result, the C/N ratio was well over 10 at these stations during the summer and fall. The high levels of organic carbon observed in the sediments at these stations may be attributed to the high productivity in the vicinity of the front.

RESULTS

Sediments

Sediment analysis results for the four seasons are summarized in Tables 2 and 3. There were no data available for Stations 11, 19 and 40 in summer and fall. No significant changes in grain size composition were reported through the year at any station other than 23. Depth records indicate that samples from Cruise IV at Station 23 were taken in a different part of the canyon head. Although the sampling site was in close proximity to those for Cruises I-III, depth was considerably greater (274-384m vs. 150-200m for Cruises I-III) and percent silt/clay was much higher (25% vs. 14%).

Since grain size data were rather uniform for the four seasons, we have shown the geographical distribution of mean phi particle size and percent silt/clay for Cruise I samples in Figures 7 and 8, respectively. The center and the southern flank of the bank consist of medium sands with low silt/clay content (less than 3%). Station 40, in the Gulf of Maine, had slightly higher silt/clay content but, because of the gravel component, recorded the lowest mean particle size (ϕ 0.5). Station 23 in the canyon head had a higher silt/clay content (10%). Station 8 westward had a silt/clay content of 5% and the mud patch (Station 6) was 37.5% silt/clay.

Organic carbon levels were correlated with the percent silt/clay. They were lowest at Station 37 on the top of the bank (0.44 mg/g, winter) and highest (10.57 mg/g) at Station 6 in the mud patch. All other stations where silt/clay was in the 1-11% range had organic carbon values of 0.6-4 mg/g. There were significant increases ($p=$ less than 0.001 in all cases) in the organic carbon values between winter and summer for all stations except Station 6. Those changes began in spring and were still evident in the fall. This increase probably reflects the buildup of organic detritus on the sediment surface described by Butman et al. (1980). The method of sampling, although capable of detecting changes in organic carbon, was not sensitive to reflect any possible increase in silt/clay on the sediment surface during the year. Presumably the scouring action during winter storms described by Butman et al. (1980) is responsible for removing these organic-rich layers.

Table 2. Georges Bank sediment properties
Winter 1977

Station	Gravel %	Sand %	Silt %	Clay %	Silt Clay %	Mean Φ	Sorting Φ	Carbon mg/g	Nitrogen mg/g	C:N
6	0.0	62.5	28.2	9.3	37.5	4.1	1.88	10.57	1.85	5.7
8	0.0	94.6	4.0	1.4	5.4	2.1	0.64	1.88	0.26	7.3
11	0.0	99.0	1.0	0.0	1.0	2.5	0.18	0.78	0.16	5.0
19	0.2	97.1	1.8	1.0	2.8	2.0	0.46	1.67	0.38	4.4
20	1.4	97.5	1.1	0.0	1.1	0.7	0.72	0.61	0.11	5.4
23	0.5	89.1	7.3	3.1	10.5	2.4	1.15	2.20	0.61	3.6
25	1.5	96.4	2.1	0.0	2.1	1.4	0.75	0.88	0.12	7.2
28	0.0	96.9	3.1	0.0	3.1	2.1	0.37	2.05	0.29	7.1
29	1.9	97.1	1.0	0.0	1.0	0.8	0.71	0.44	0.10	4.3
37	1.2	98.1	0.7	0.0	0.7	1.5	0.52	0.44	0.14	3.1
40	17.2	76.7	2.7	3.3	6.0	0.5	1.75	3.13	0.38	8.2
					Spring 1977					
6	0.0	58.3	30.3	11.5	41.7	4.3	2.04	8.69	1.25	6.9
8	0.0	93.8	4.1	2.1	6.1	1.6	1.03	2.56	0.44	5.9
11	0.0	98.4	0.8	0.3	1.1	2.4	0.20	2.25	0.33	6.8
19	0.0	95.9	3.4	0.7	4.1	2.5	0.44	2.21	0.25	8.8
20	0.3	98.6	1.1	0.0	1.1	0.9	0.57	1.15	0.20	5.8
23	0.0	85.4	12.4	2.2	14.6	2.7	1.28	3.85	0.56	6.9
25	0.3	97.8	1.9	0.0	1.9	1.5	0.73	1.52	0.24	6.4
28	0.0	96.8	2.8	0.4	3.2	2.1	0.40	1.82	0.32	5.7
29	1.5	97.7	0.9	0.0	0.9	0.9	0.62	0.94	0.13	7.2
37	12.6	86.7	0.7	0.0	0.7	1.1	1.13	0.73	0.18	4.1
40	14.1	78.0	3.2	4.7	7.9	0.6	2.02	4.32	0.75	5.7

Table 3. Georges Bank sediment properties
Summer 1977

Station	Gravel %	Sand %	Silt %	Clay %	Silt Clay %	Mean Φ	Sorting Φ	Carbon mg/g	Nitrogen mg/g	C:N
6	-	61.6	29.3	9.4	38.6	5.1	2.07	8.50	1.01	8.4
8	-	94.9	3.1	2.0	5.1	2.3	0.57	3.09	0.37	8.4
20	-	98.8	1.2	-	1.2	1.3	0.50	1.40	0.25	5.6
23	0.1	88.9	7.5	3.6	11.0	2.7	0.70	4.13	0.46	9.0
25	-	98.2	1.8	-	1.8	1.8	0.53	3.41	0.26	13.1
28	-	97.3	2.7	-	2.6	2.3	0.42	3.31	0.38	8.7
29	-	99.0	1.0	-	0.9	1.3	0.53	0.71	0.16	4.4
37	3.8	89.1	.8	-	0.8	1.3	2.29	1.06	0.22	4.8
					Fall 1977					
6	-	59.2	30.1	10.8	40.8	5.3	2.10	8.90	1.12	7.9
8	-	95.1	2.9	1.9	4.9	1.7	0.60	3.41	0.43	7.9
20	-	97.8	2.2	-	2.2	1.5	0.51	1.34	0.21	6.4
23	-	74.7	17.1	8.2	25.3	4.3	1.39	9.21	0.91	10.1
25	-	97.1	2.9	-	2.9	1.7	0.38	3.70	0.25	14.8
28	-	97.1	2.9	-	2.9	2.4	0.35	2.32	0.31	7.5
29	-	98.3	1.7	-	1.7	1.6	0.41	1.17	0.19	6.2
37	7.0	85.9	1.0	-	1.0	1.0	0.89	1.07	0.16	6.7

No data available for stations 11 and 19.

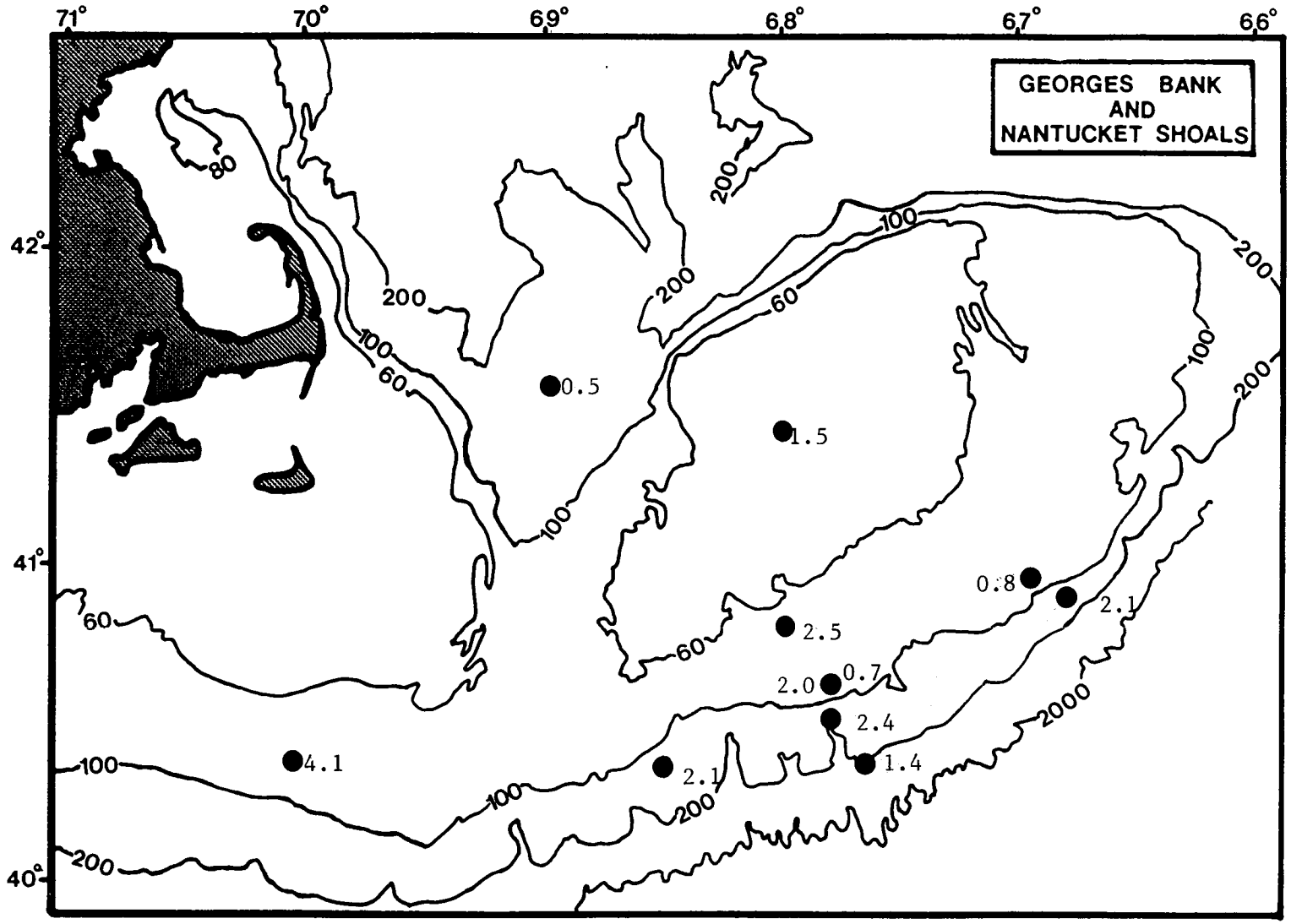


Figure 7. Mean particle size (phi units)

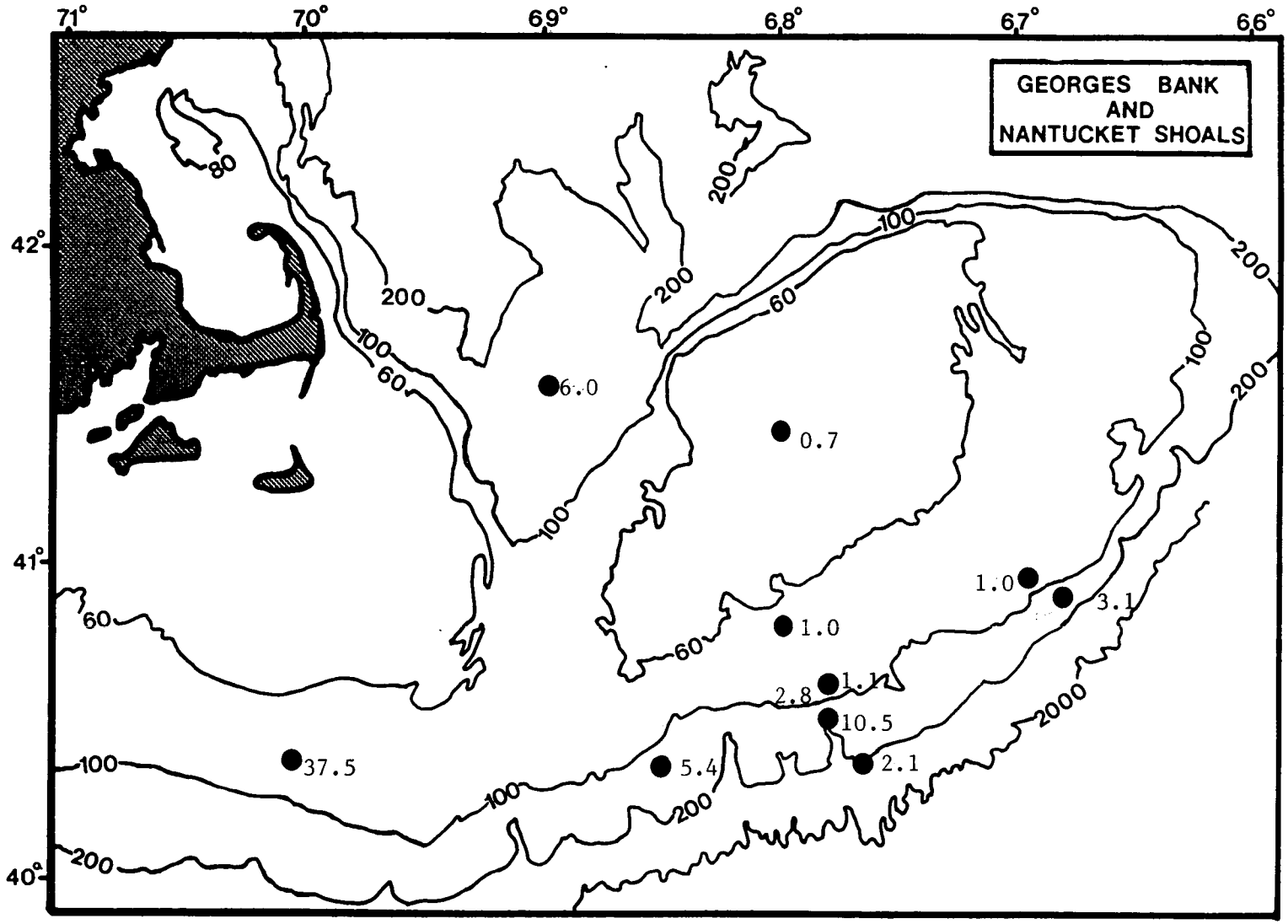


Figure 8. Percent silt/clay

The significant change in organic carbon at Station 6 was opposite to that at all other stations. Winter values were highest ($\bar{x}$ = 10.57 mg/g) where those for other seasons ranged from 8.5-8.9 mg/g. There was some increase in mean phi size (decrease in particle size) but it is not clear whether this would be sufficient to account for the change in organic carbon.

There were no significant changes in organic nitrogen through the year. These values were also correlated with silt/clay content of the sediments and were, therefore, highest in the mud patch (1.85 mg/g), Lydonia Canyon (0.91 mg/g, Cruise IV) and the Gulf of Maine (0.75 mg/g). All other values were less than 0.5 mg/g.

Because of the increase in organic carbon, the C:N ratio increased through the year at all stations except Station 6. Winter values were lowest, ranging from 3.1 to 8.2. Highest values occurred at Stations 23 and 25 in the fall (10.1, 14.8) and may be related to high productivity associated with frontal systems.

Summary information for each station, including sediment data, replicate spacing and depths, is included in the Appendix.

Systematics

In the Introduction we discussed some potential problems in the identification of the fauna. Problems arose because some four different laboratories were involved in the identification process for the first two cruises, while most remaining identifications for Cruises III and IV were completed at TAXON, Inc. A small proportion of the polychaete material from Cruise III had been identified by Dr. Maurer's group at the University of Delaware. Because of the termination schedule for the original Benchmark Study contract, not all collections were in order (i.e., identifications consistent) and, since most of the participants have relocated, it was impossible to make all identifications done by TAXON, Inc. consistent with those used previously. The faunal list (Table 4) is, therefore, a combination of the lists prepared by previous contractors and that developed by TAXON in this effort. It is obvious that there is some duplication in taxonomic categories.

We do not believe, however, that these problems have significantly affected results presented in this report. Quantitative parameters such as numbers of species, numbers of individuals and diversity were calculated on the data lists as compiled by original contractors. Analyses based on TAXON's identifications for Cruises III and IV, although in some cases based on different taxonomic categories, should not be significantly different. Most of the problems occurred with rarer species and the only real combination of the two data sets is in the faunal composition discussion,which is limited to the six to ten most abundant species,and the classification analysis,which was performed on a greatly reduced data base.

Problems in two of the three major groups were minor or insignificant. Minor taxonomic problems occurred with the molluscan data but in only one case did this involve a numerically dominant species (genus: Thyasira). There were no significant problems with the dominant amphipod species although six to ten new species were found among the less common species. Polychaetes were the most diverse and abundant group. More than 300 species were reported with a significant number of new species. Some of the problems in identifications occurred among dominant species and we have, therefore, included a discussion of polychaete systematics and explanations of our basis for combining the data sets.

The species list (Table 4) includes 700 taxonomic categories. There are 318 polychaete taxa, 136 amphipod, 63 crustacean (excluding amphipods), 76 bivalve and 62 gastropod taxa. Twenty species of echinoderms were reported. Miscellaneous groups, most of which were not identified to species, accounted for another 26 taxa.

Table 4. Species List

CNIDARIA

Anthozoa unidentified
Astrangia danae
Cerianthus americanus
Cerianthus borealis
Cerianthus sp.
Edwardsia sp.
Epizoanthus americanus
Hydroidea unidentified
Metridium senile
Sagaritia modesta
Sagaritia sp.

PLATYHELMINTHES

Platyhelminthes unidentified
Turbellaria unidentified

NEMERTEA

Amphiporus angulatus
Cerebratulus lacteus
Micrura albida
Micrura sp.
Oerstedia dorsalis
Rhyncocoela unidentified

ANNELIDA

Archiannelida unidentified
Hirudinea unidentified
Oligochaeta unidentified

Polychaeta

Ampharetidae

Amage auricula
Amage tumida
Ampharete arctica
Ampharetidae sp. A
Ampharetidae sp. B
Ampharetidae sp. C
Ampharetidae spp (T)*
Amphecteis gunneri
Anobothrus gracilis
Asabellides oculata
Melinna cristata
Melinna elisabethae

*(T) denotes TAXON, Inc. identification

A,B,C, etc. denotes Maurer & Leathem identification

Sabellides octocirrata
Samytha sexcirrata
Samythella eliasoni
Samythella elongata
Samythella sp.
Sosanella sp.

Amphinomidae
Paramphinome jeffreysii
Paramphinome pulchella
Amphinomidae sp.

Aphroditidae
Aphrodita hastata
Aphroditidae sp.
Laetmonice filicornis

Apistobranchidae
Apistobranchus sp. A

Arabellidae
Arabella sp. A
Drilonereis longa
Drilonereis magna
Drilonereis sp. A
Drilonereis sp. B
Drilonereis sp. (T)

Capitellidae
Barantolla sp. A
Capitella capitata
Capitellidae sp. A
Capitellidae sp. B
Capitellidae sp. C
Capitellidae sp. D
Capitellidae sp. E
Capitellidae sp. F
Capitellidae sp. (T)
Heteromastus filiformis
Mediomastus ambiseta
Notomastus latericeus

Chaetopteridae
Spiochaetopterus sp.

Cirratulidae

- Caulleriella sp. A
- Caulleriella sp. B
- Caulleriella sp. C
- Chaetozone spp (T)
- Chaetozone sp. A
- Chaetozone sp. B
- Cirratulidae sp.
- Dodecaceria sp. A
- Dodecaceria sp. (T)
- Non-palpate Cirratulidae
- Palpate Cirratulidae
- Tharyx acutus
- Tharyx annulosus
- Tharyx sp. B
- Tharyx sp. C

Cossuridae

- Cossura longicirrata
- Cossuridae sp.

Ctenodrilidae

- Raphidrilus sp. A

Dorvilleidae

- Dorvillea sp. A
- Dorvilleidae sp.
- Protodorvillea gaspeensis
- Protodorvillea kefersteini
- Schistomeringos caeca

Eunicidae

- Eunice pennata
- Eunice vittata
- Eunicea sp.
- Eunicidae unidentified
- Marphysa belli
- Marphysa sp. A
- Marphysa sp. B
- Marphysa sp. (T)

Euphrosinidae

- Euphrosine sp. A

Flabelligeridae
- Brada villosa
- Flabelligera affinis
- Flabelligeridae sp.
- Pherusa affinis
- Pherusa sp. A.

Glyceridae
- Glycera capitata
- Glycera dibranchiata
- Glycera robusta
- Glycera sp. A
- Glyceridae sp.

Goniadidae
- Goniada maculata
- Goniada sp. A
- Goniada sp.(T)
- Goniadella gracilis
- Goniadidae sp.
- Ophioglycera gigantea

Hesionidae
- Hesionidae sp.
- Nereimyra punctata
- Podarke obscura

Iospilidae
- Iospilus phalacroides

Lumbrineridae
- Lumbrineris acuta
- Lumbrineris impatiens
- Lumbrineris inflatum
- Lumbrineris latreilli
- Lumbrineris tenuis
- Lumbrineris sp. A
- Lumbrineris sp. C
- Lumbrineris sp. Q
- Lumbrineris sp. S
- Lumbrineris sp. Y
- Lumbrineris unidentified
- Limbrineridae unidentified
- Ninoe nigripes

Maldanidae

- Axiothella sp. A
- Clymenura borealis
- Clymenura sp. A.
- Clymenella torquata
- Euclymene collaris
- Euclymene zonalis
- Isocirrus sp. A
- Maldane sarsi
- Maldanidae sp. A
- Maldanidae sp. B
- Maldanidae sp. Z
- Nicomanche lumbricalis
- Petaloproctus tenuis borealis
- Praxillura longissima
- Proclymene sp.
- Rhodine gracilior

Nephtyidae

- Aglaophamus circinata
- Aglaophamus neotenus
- Aglaophamus sp.
- Nephtyidae sp.
- Nephtys bucera
- Nephtys caeca
- Nephtys ciliata
- Nephtys discors
- Nephtys incisa
- Nephtys picta
- Nephtys squamosa

Nereidae

- Nereis pelagica
- Nereis zonata
- Nereis sp. A
- Nereis sp. (T)

Onuphidae

- Nothria sp.
- Onuphidae sp.
- Onuphis (Nothria) conchylega
- Onuphis opalina
- Onuphis pallidula

Opheliidae

- Ophelia limacina
- Opheliidae sp.

Ophelina acuminata
Ophelina cylindricaudata
Ophelina sp.
Travisia forbesii

Orbiniidae
Orbinia michaelsoni
Orbinia swani
Orbiniidae sp. A
Orbiniidae sp. B
Orbiniidae sp. (T)
Scoloplos armiger
Scoloplos robustus

Oweniidae
Myriochele heeri
Myriochele oculata
Myriochele sp. A
Owenia fusiformis
Oweniidae sp.

Paraonidae
Aricidea catharinae
Aricidea cerruti
Aricidea neosuecica
Aricidea quadrilobata
Aricidea suecica
Aricidea wassi
Aricidea sp. C
Aricidea sp. D
Aricidea sp. E
Aricidea sp. E2
Aricidea sp. F
Aricidea sp. G
Aricidea sp. H
Aricidea spp (T)
Cirrophorus lyriformis
Paraonidae sp. (T)
Paraonides sp. A
Paraonides sp. B
Paraonides lyra
Paraonis gracilis
Paraonis sp. A
Paraonis sp. B
Paraonis sp. C
Paraonis spp (T)

Pectinariidae
Pectinariidae sp.

Pilargiidae
Ancistrosyllis groenlandica

Phyllodocidae
Eteone lactea
Eteone longa
Eteone spetsbergensis
Eteone sp.
Eumida sanguinea
Hesionura sp. A
Hesionura sp. (T)
Mystides borealis
Paranaitis speciosa
Phyllodoce arenae
Phyllodoce groenlandica
Phyllodoce mucosa
Phyllodoce sp.
Phyllodocidae sp. A
Phyllodocidae sp. (T)

Polynoidae
Gattyana amondseni
Harmothoe extenuata
Harmothoe sp. A
Harmothoe sp. (T)
Hartmania moorei
Polynoidae sp.

Protodrilidae
Protodrilidae sp.

Psammodrilidae
Psammodrilus balanoglossoides

Questidae
Novaquesta trifurcata

Sabellidae
Chone infundibuliformis
Desdemona sp. A
Euchone elegans

Euchone incolor
Euchone nr. hancocki
Euchone sp. W
Jasmineira filiformis
Megalomma bioculata
Potamilla neglecta
Potamilla reniformis
Sabellidae sp.

Scalibregmidae
Asclerocheilus beringianus
Asclerocheilus sp.
Pseudoscalibregma parvum
Scalibregma inflatum
Scalibregmidae sp.

Serpulidae
Filograma implexa
Serpula vermicularis
Serpulidae sp.

Sigalionidae
Pholoe minuta
Sigalion arenicola
Sigalionidae juvenile and unidentified
Sthenelais boa
Sthenelais limicola

Sphaerodoridae
Ephesiella minuta
Sphaerodoridae sp.

Spionidae
Laonice cirrata
Minuspio cirrata
Polydora caulleryi
Polydora concharum
Polydora socialis
Polydora sp.
Prionospio cirrifera
Prionospio cirrobranchiata
Prionospio steenstrupi
Scolelepis sp. A
Scolelepis squamata

Scolelepis tridentata
Spio filiformis
Spio multioculata
Spio pettiboneae
Spionidae sp. A
Spionidae sp. E
Spionidae sp. F
Spionidae sp. (T)
Spiophanes bombyx
Spiophanes kroyeri
Spiophanes wigleyi
Spiophanes sp.

Sternaspidae
Sternaspis scutata
Sternaspidae sp.

Syllidae
Autolytinae sp.
Autolytus prolifera
Autolytus sp. A
Braniella pupa
Eusyllinae/Syllinae
Eusyllis lamelligera
Eusyllis sp. A
Eusyllis sp. B
Exogone hebes
Exogone naidina
Exogone sp. A
Exogone sp. R
Exogone brevicornis
Exogoninae sp.
Parapionosyllis longicirrata
Proceraea cornuta
Sphaerosyllis brevifrons
Sphaerosyllis erinaceus
Streptosyllis arenae
Streptosyllis varians
Streptosyllis websteri
Syllides benedicti
Syllides convoluta
Syllides japonica
Syllidae sp.
Syllis (Langerhansia) cornuta
Syllis sp.
Syllis (Typosyllis) hyalina
Syllis (Typosyllis) sp. A
Syllis (Typosyllis) tegulum

Terebellidae

Eupolymnia nebulosa
Lysilla sp. A
Pista cristata
Polycirrinae sp.
Polycirrus haematodes
Polycirrus medusa
Polycirrus sp. A
Polycirrus sp. B
Polycirrus sp. C
Polycirrus sp. E
Polycirrus sp. (T)
Polycirrus tenuisetis
Streblosoma sp. A
Streblosoma spiralis
Terebellidae sp.
Terebellides stroemi
Terebelliforma sp. juv.
Thelepus cincinnatus
Thelepus setosus
Thelepus sp. A

Trichobranchidae

Trichobranchidae sp.
Trichobranchus glacialis

CRUSTACEA

Cephalocarida

Hutchinsoniella macracantha

Ostracoda

Cirripedia

Balanus balanoides
Balanus sp.

Malacostraca

Cumacea

Campylapsis affinis
Campylapsis rubicunda
Diastylis bispinosa
Diastylis lucifera
Diastylis polita
Diastylis quadrispinosa
Diastylis rathkei
Diastylis sculpta
Diastylis sp.

Eudorella emarginata
Eudorella hispida
Eudorella pusilla
Eudorella sp.
Eudorella truncatula
Eudorellopsis biplicata
Eudorellopsis deformis
Eudorellopsis integra
Eudorellopsis sp.
Lamprops fuscata
Lamprops quadriplicata
Lamprops sp.
Leptostylis ampullacea
Leptostylis longimana
Leptostylis sp.
Leucon nasiocoides
Oxyurostylis smithi
Petalosarsia declivis
Petalosarsia sp.

Tanaidacea

Leptochelia savignyi

Isopoda

Chiridotea caeca
Chiridotea tuftsi
Cirolana concharum
Cirolana impressa
Cirolana polita
Cirolana sp.
Cirolana spinipes
Edotea sp.
Edotea triloba
Idotea phosphorea
Janira alta
Ptilanthura tenuis

Amphipoda

Acanthohaustorius intermedius
Acanthohaustorius millsi
Acanthohaustorius shoemakeri
Acanthohaustorius spinosus
Aeginina longicornis
Ampelisca agassizi
Ampelisca declivitatus
Ampelisca macrocephala
Ampelisca vadorum

Amphilochidae
Amphilochoides odontony
Amphilochoides sp. D
Amphilochus n. sp. M
Anonyx liljeborgi
Argissa hamatipes
Bathyporeia quoddyensis
Byblis serrata
Calliopius laeviusculus
Caprella linearis
Caprella penantis
Caprella unica
Caprellidae sp.
Casco bigelowi
Corophiidae sp.
Corophium acutum
Corophium crassicorne
Dexamine thea
Dulichia monocantha
Dulichia porrecta
Dulichia sp.
Dyopedos monocanthos
Dyopedos porrectus
Dyopedos sp.
Elasmopus levis
Eophilantidae sp.
Ericthonius brasiliensis
Ericthonius rubricornis
Eriopisa elongata
Gammaridae sp.
Gammaropsis nitida
Gammaropsis n. sp.
Gammaropsis sp.
Gammarus sp.
Haliragoides sp.
Haploops setosa
Haploops tubicola
Harpinia propinqua
Harpinia sp.
Harpinia truncata
Harpinia n. sp. 2
Haustoriidae juv.
Hippomedon propinquis
Hippomedon serratus
Hippomedon sp.
Hyalella azteca
Idunella n. sp.
Idunella sp.
Ischyrocerus anguipes
Ischyrocerus megacheir
Ischyrocerus n. sp. D
Ischyrocerus n. sp. M
Ischyrocerus sp.

Jassa falcata
Jerbarnia sp.
Lepidepecreum n. sp.
Leptocheirus pinguis
Leptocheirus plumulosus
Lilljeborgia sp.
Lilljeborgiidae sp.
Lysianassidae sp.
Maera danae
Maera loveni
Maera sp.
Mayerella limicola
Melita dentata
Melita sp.
Melphidippa goesi
Metopa sp.
Microdeutopus anomalus
Monoculodes edwardsi
Monoculodes n. sp. 1
Monoculodes sp.
Monoculodes tesselatus
Oedicerotidae sp.
Orchomenella groenlandica
Orchomenella sp.
Parahaustorius attenuatus
Parahaustorius holmesi
Parahaustorius longimerus
Parametopella cypris
Parametopella sp.
Parapleustes sp.
Pardaliscidae sp.
Paroediceros lynceus
Photis dentata
Photis macrocoxa
Photis reinhardi
Photis sp.
Photis tenuicornis
Phoxocephalus holbolli
Platyischnopus sp.
Pleustidae sp.
Pleusymtes glaber
Podoceridae sp.
Podoceropsis nitida
Podoceropsis n. sp. N
Podoceropsis sp.
Pontogeneia inermis
Proboloides holmesi
Protohaustorius wigleyi
Protomedia sp.
Psammonyx nobilis
Psammonyx sp.
Pseudohaustorius borealis
Pseudohaustorius caroliniensis
Pseudunciola obliquaa

Rhachotropis n. sp. D
Rhachotropis sp.
Siphonoecetes smithianus
Siphonoecetes sp.
Stegocephalidae sp.
Stenopleustes gracilis
Stenopleustes inermis
Stenothoidae sp.
Synchelidium americanus
Tmetonyx similis
Trichophoxus epistomus
Unciola dissimilis
Unciola inermis
Unciola irrorata
Unciola serrata
Unciola sp.
Unciola sp. juv.

Mysidacea

Heteromysis formosa

Decapoda

Axius serratus
Cancer borealis
Cancer irroratus
Cancer sp.
Crangon septemspinosa
Euprognatha rastellifera
Homarus americanus
Inachinae sp.
Munida iris
Ovalipes ocellatus
Pagurus acadianus
Pagurus arcuatus
Pagurus longicarpus
Pagurus politus
Pagurus pubescens
Pagurus sp.
Pontophilus brevirostris

GASTROPODA

Aclis striata
Alvania arenaria
Alvania areolata
Alvania carinata
Alvania castanea

Alvania harpa
Alvania sp.
Amphilimna olivacea
Anachis translirata
Buccinum undatum
Cocculina beanii
Colus caelatus
Colus pubescens
Colus sp.
Colus stimpsoni
Crepidula fornicata
Crepidula plana
Crucibulum striatum
Cylichna alba
Diaphana minuta
Epitonium angulatum
Epitonium dallianum
Epitonium multistriatum
Epitonium pourtalesii
Epitonium sp.
Gastropoda unidentified
Lunatia heros
Lunatia immaculata
Lunatia triseriata
Melanella conoidea
Melanella distorta
Mitrella dissimilis
Mitrella rosacea
Mitrella sp.
Moellaria costulata
Nassarius trivittatus
Natica clausa
Natica pusilla
Neptunea decemdostata
Nudibranchia unidentified
Odostomia bartschi
Odostomia diabata
Odostomia eburnea
Odostomia gibbosa
Odostomia sp.
Odostomia sulcosa
Oenopota concinnula
Oenopota harpularia
Oenopota turricula
Philine quadrata
Philine sinuata
Pleurotemella packardi
Propebela turricula
Puncturella noachina
Sayella unifasciata
Scaphander punctostriata
Scissurella crispata
Solariella obscura

Thysita sp. 1
Turbonilla areolata
Turbonilla interrupta
Vermicularia spirata

BIVALVIA

Anomia aculeata
Anomia simplex
Anomia sp.
Anomia squamula
Arctica islandica
Astarte borealis
Astarte castanea
Astarte elliptica
Astarte quadrans
Astarte sp.
Astarte subequilatera
Astarte undata
Bathyarca pectunculoides
Bivalvia unidentified
Bivalve sp. B
Bivalve sp. C
Cerastoderma pinnulatum
Cerastoderma sp.
Corbula contracta
Crenella decussata
Crenella glandula
Crenella sp.1
Cuspidaria glacialis
Cuspidaria rostrata
Cyclocardia borealis
Cyclopecten imbrifer
Dacrydium vitreum
Ensis directus
Hiatella arctica
Lepeta caeca
Limatula subauriculata
Limea subovata
Lucinoma filosa
Lyonsia granulifera
Lyonsia hyalina
Macoma calcarea
Modiolus modiolus
Musculus discors
Musculus niger
Musculus sp.
Nucula delphinodonta
Nucula proxima
Nucula sp.
Nucula tenuis
Nuculana messanensis

Nuculana sp.
Nuculana tenuisulcata
Palliolum reticulum
Pallium imbrifer
Pandora gouldiana
Pandora inornata
Pectinidae
Periploma leanum
Periploma papyratium
Periploma sp.
Pitar morrhuana
Pitar sp.
Placopecten magellanicus
Poromya granulata
Propeamussium thalassinum
Siliqua costata
Solemya velum
Spisula solidissima
Tellina agilis
Thracia conradi
Thracia septentrionalis
Thyasira elliptica
Thyasira equalis
Thyasira flexuosa
Thyasira pygmaea
Thyasira sp.
Thyasira triseriata
Thyasira trisinuata
Yoldia sapotilla
Yoldia sp.
Yoldia thraciaeformis

ECHINODERMATA

Echinoidea
Echinarachnius parma
Strongylocentrotus droebachiensis

Asteroidea
Asterias forbesi
Asterias sp.
Asterias vulgaris
Astropecten americanus
Goniasteridae sp.
Leptasterias polaris
Leptasterias tenera

Ophiuroidea
Amphioplus abdita

Amphipholus squamata
Amphiura sp.
Ophiacantha bidentata
Ophiopholus aculeata
Ophiura robusta
Ophiura sarsi

Holothuroidea
Chirodota loevis
Chirodota wigleyi
Cucumaria frondosa

Crinoidea
Hathrometra sp.

SIPUNCULOIDEA
Phascolion strombi
Phascolion gouldii

PHORONIDA
Phoronis architecta

HEMICHORDATA
Balanoglossus sp.

UROCHORDATA
Ascidiacea
Ciona intestinalis
Molgulidae sp.

Polychaete Systematics

Introduction. A substantial number of new species were found and others, while very similar to, did not fit original descriptions of species. We believe it will be several years before publications allowing complete descriptions of the Georges Bank fauna will be available. Some polychaete families require major revision. We have established a series of assumptions and parameters within which we have analyzed the polychaete data to meet the requirements of the contract. We wish to emphasize that we in no way "take sides" with the selection of one name over another for a particular species of polychaete. Rather, we have relied upon the opinions of experts in the particular group under consideration. It should be noted that the actual name placed on specimens from the three studies in question is not as important as being sure that the same species bears the same label in all three studies. It is incumbent upon the experts in the taxon to determine whether or not that label stands or should be altered.

This section of the report is divided into two parts: (1) background for understanding polychaete systematics, and (2) a treatment, on a family by family basis, of the dominant polychaete species from Georges Bank.

Background for Understanding Polychaete Systematics

Any discussion of the names given to polychaetes from Georges Bank must be conducted in the context of: (1) the history of placing names on New England polychaetes, (2) methods available for observing the characters considered important in selecting species names, (3) condition of the specimens to be so named, (4) current trends in polychaete systematics, and (5) opinions from polychaete systematists who specialize in the taxa under consideration.

Long (1982) recently reviewed the history of trends in polychaete systematics and the implications for the selection of names for Georges Bank species (see the Appendix). In brief, the state of the art in biological thought impinges upon the selection of species names. New England has seen at least four major periods of differing biological thought. These four periods may be divided into trends 1 and 2. During trend 1 (mid 1800's and the mid 1900's) European names were affixed to specimens.

During trend 2 (late 1800's to early 1900's and currently), the names selected for specimens reflect geographic limitations. Long (1982) gave as an example of such trends the naming of a syllid frequently reported in New England reports (e.g. Battelle and WHOI, 1982) as Exogone verugera (Claparede, 1868). Experts (e.g., Perkins, personal communication), who specialize in this type of polychaete (Family Syllidae, Subfamily Exogoninae) and who have examined both specimens from the Historical Study and type specimens in museums, feel that E. verugera should be called by its New England name, E. brevicornis (Webster and Benedict, 1887). Several other examples will be detailed below in discussions under each of the dominant families from Georges Bank.

Proper observation of diagnostic characters in polychaetes usually involves the use of a dissecting microscope and a compound microscope with frequent use of the oil immersion lens. This means the minute and time-consuming examination of every single specimen. In practice, and to meet the needs of time schedules and financial constraints, a few of the more obvious characters, which can be observed with a dissecting microscope, are selected for sorting polychaetes to species. An adequate survey would also include an exhaustive check of a certain percentage of the specimens to be certain that all diagnostic characters are consistent from sample to sample. For some groups, such as the Capitellidae, it is possible that species can be sorted only by sophisticated biochemical analysis. If, in fact, there is sufficient expertise and financing to permit thorough examination of every specimen, then the quality of the resulting data would rest upon a much finer base than data derived from the standard sorting techniques. However, it must be remembered that the added effort and expense may not yield significantly different results in terms of the community parameters we are studying.

The condition of the polychaete specimens is central to any selection of a species name. Three aspects of their condition are important: (1) state of relaxation when preserved, (2) quality of preservation, e.g. how tough and elastic the preserved specimens are and (3) presence or absence of vital diagnostic characters. In large surveys, it is rare that specimens are relaxed in a fashion to maximize the quality of the

specimen for systematic observation. Therefore, the sorter is often faced with a contorted specimen that must be manipulated considerably in order to ascertain the diagnostic characters. Species of polychaetes vary greatly with regard to their response to preservation. Some, e.g., Pectinaria gouldii, are frequently flabby and diagnostic characters are obscure, regardless of how carefully they are preserved. Others, e.g., Pectinaria regalis, are nearly always in good condition. The methods used to preserve the worms can greatly affect the length of time required to select a species name. Poorly preserved specimens probably should not be identified.

The presence of diagnostic characters is probably the single greatest problem in sorting polychaetes to species, for some polychaetes have deciduous structures. Unfortunately, when these structures are critical for the selection of a species name and are absent, the sorter should not label the specimen at the species level. Realities of contracts typically dictate that the specimen be named, and the sorter resorts to "averaging out" i.e. selecting the most likely species name considering the area from which the specimen is collected. For some families, such as the Cirratulidae, this practice has led to an incomprehensive mass of data that could be quite spurious. The tail ends of cirratulids are necessary for most species identifications, and preserved specimens rarely have tail ends.

Current Trends in Polychaete Systematics

As mentioned above, with regard to polychaete systematics, we are currently in Trend 2, where regional specific names are selected. Now that specialists have had opportunities to examine hundreds, if not thousands, of specimens of a single species from one region (to some extent as a result of interest in testing population theories), a great deal more is known about variation and what can be expected of an apparently interbreeding group of individuals. Thus, differences that were, in the past, considered minor now may be used as a basis for separating species. The species Exogone brevicornis mentioned earlier

is an example of this. Previously, the presence or absence of a dorsal cirrus in the second setiger was thought to be unimportant in establishing species names (see, for example, Pettibone, 1963). However, examination of large numbers of specimens by specialists (e.g. Perkins, personal communication) indicates that the presence or absence of this structure appears to be consistent within an area. This fact is used as one of the group of facts to separate E. brevicornis from the European species, E. verugera, which is superficially similar. Additional examples of this current trend of considering regional differences are discussed below.

In order to be considered an expert on a particular polychaete taxon one must examine in minute detail both the type specimens and a large number of individuals from one region. This examination must be backed up by publications of sufficient quality to be accepted by other specialists, and the specimens on which the publications were based should be available for scrutiny by others. These qualifications necessitate great expenditures of time and energy and thus very few individuals specialize in more than one polychaete taxon. For this reason, no matter how experienced or confident the sorter is, the best assurance of the quality of identifications is to have an expert in that taxon check a representative number of specimens, specimens which ultimately should be deposited at a major museum.

Prior to preparing the section on dominant species of polychaetes from Georges Bank, descriptions and taxonomic comments were exchanged between TAXON, Inc. and Wayne Leathem and Dr. Betsy Brown. In a number of cases taxonomic differences were agreed upon and resolved. In some cases differences were not resolved. These differences are discussed in the next section.

Dominant Species of Polychaetes from Georges Bank

This section of the report is a treatment, on a family by family basis (arranged alphabetically) of the dominant species and of some others with systematic problems found on Georges Bank. For each species,

we briefly discuss the systematic problems as we understand them and the approach we used in this report to solve the problems in order to analyze the combined Maurer and Leathem and Historical Study data. Where the phrase "we found" or "we did not see" involves TAXON systematists (C.D. Long or assistants), an asterisk is used to denote TAXON, Inc.

FAMILY AMPHARETIDAE - Melinna elisabethae

Problems: The only Melinna species reported by Maurer and Leathem (1980) was M. cristata. All specimens we found in the Historical Study collections were keyed to M. elisabethae in Zottoli (MS, 1981). However, keys that were prepared by non-specialists and that did not include M. elisabethae led us to M. cristata. Conversations with Dr. Zottoli indicated that the primary difference between the species was the amount of curvature of the dorsally placed post-branchial hooks. All specimens we* checked, both from Maurer and Leathem and Historical Study materials, had strongly curved hooks, indicating that they were M. elisabethae. Battelle (1982) lists both M. cristata and M. elisabethae from Georges Bank. We* did not see the M. cristata form.

Approach used for the Historical Study: We* labelled all Melinna specimens Melinna elisabethae.

FAMILY CIRRATULIDAE - Palpate Cirratulidae

Problems: The vast majority of specimens in the Family Cirratulidae in the Historical Study belonged to a group that had two palps near the anterior end and are thus called palpate cirratulids. Those cirratulids that lack palps are called non-palpate; these were found in only nine replicates and, then, only one or two specimens in each replicate. Maurer and Leathem (1980) did not report any non-palpate forms in their list of 16 species and groups of species. Thus, any discussion of cirratulids from Georges Bank centers around palpate forms.

Some species of palpate cirratulids are easily and quickly distinguishable by color or uniquely arranged setae; these species are rare in the Historical Study. Most palpate species are distinguished by

setal differences which are sometimes limited to the posterior segments; (see Fauchald, 1977, pp. 29-30 for a key to genera and some discussion). For larger specimens, it is possible to distinguish setal differences with a dissecting microscope. With small specimens, this is risky since a broken capillary may look like a spine. In addition, the current state-of-the-art for this group, especially the genus Tharyx is, to quote Fauchald (1977, p. 30), "rather confused, and additional characters will have to be considered to clarify the relations between the several species described in this genus." Further, he writes, regarding one of his own publications (1981, p.1): "The number of cirratulid species reported is very low, more distinct taxa appear to be present, but current taxonomic practice does not allow species identification in most cirratulid genera." In that report, he attempts some identification of cirratulids and notes for his selection of the species name of Tharyx near monilaris, for some of the specimens: "More than one species may be contained in the current material, and perhaps none of these belong to T. monilaris." Again, on page 15, regarding Tharyx, near multifilis, he writes: "They differ from T. multifilis . . . More than one species may be involved."

The species list in Maurer and Leathem (1980, p. 125) for cirratulids includes more species designations than we* would choose to attempt in view of the state of the systematics. Many specimens of the Tharyx-like specimens in the Historical Study were incomplete, and thus unidentifiable anyway. Because it is not unusual to find more than one species of palpate cirratulid in one replicate, it is not safe to issue a species (or even genus) name to incomplete specimens based on the presence of complete specimens in the same replicate.

Some of the palpate cirratulids differed from one another in gross morphology in ways that appear to be distinctive. However, experience with Caribbean cirratulids (by one of the authors, C. Long) indicates that such seemingly stable characters may vary within the same species, under differing conditions. Thus, we* were reluctant to rely solely on these differences where we were unable to use the more appropriate diagnostic characters.

Approach used for Historical Study: We* did not identify the palpate

cirratulids beyond the category "Palpate Cirratulidae." The Historical and Maurer and Leathem data were combined under this label for community analysis purposes.

FAMILY LUMBRINERIDAE - Lumbrineris spp.

Problems: Fauchald (1977, p. 107) has stated that the most dependable diagnostic characters for lumbrinerids are the structure of the anterior setigers, the jaw and the hooks. The last two characters require detailed dissections and examination. The relative length of posterior parapodial lobes is also important, but lumbrinerids fragment readily and, as Fauchald writes, "no assumption should be made about the structure of posterior lobes," so identification based on gross morphology is difficult and risky when viewing incomplete specimens. He has stated more strongly that incomplete lumbrinerids should not be identified (personal communication and seminar presentations).

Unfortunately, large numbers of lumbrinerids in many replicates were incomplete. One Georges Bank species, Lumbrineris acuta, has a unique prostomium, which makes it an exception. We* compared anterior ends of specimens that we believed were correctly identified to species and found significant variation in their gross morphology. Thus, we* did not agree with the number of lumbrinerids identified in the Maurer and Leathem collection.

Approach used for the Historical Study: We combined most Lumbrineris species and called them "Lumbrineris sp."

FAMILY MALDANIDAE - Maldanidae unidentified

Problems: Many of the Historical Study maldanid specimens were unidentifiable because they were juveniles that had not yet developed adult morphology. In addition, there were incomplete adult forms (e.g. missing tail ends) which were also unidentifiable, as there are closely related species that differ in only a few characters. A check of the Maurer and Leathem data indicated that they also had large numbers of Maldanidae that they did not identify to species. For both the Maurer and Leathem and the Historical collections, well-developed adult specimens of several species were identified.

Approach used for the Historical Study: The label Maldanidae in the results of the data analysis refers to maldanids that were unidentifiable. This category may therefore include juveniles of species whose adult specimens were fully identified.

FAMILY MALDANIDAE - Euclymene collaris

Problem: The genera of Maldanidae that include specimens commonly called Euclymene collaris from the western North Atlantic have been under considerable discussion for many years. As different workers make assignments, E. collaris may take on different genus names or even be made a synonym of another species. Mangum (1962) felt that E. collaris was the European counterpart of E. zonalis and that the latter was the more appropriate name for specimens from this coast. European workers apparently agree that E. collaris is a European species. However, there has not been an adequate treatment of the Maldanidae since Arwidsson (1922) (Fauchald, personal communication) and so it is difficult to ascertain what species label the Georges Bank dominant should carry. We noted that Battelle (1982) lists only one species in this genus, Euclymene sp. A, so either they have placed collaris under another genus name as a synonym, they may have decided that the Georges Bank form is a new species, or else they may not have seen this species at all.

Approach used for the Historical Study: Although the preference of Charlene D. Long is to use the North American name zonalis over the European name collaris, the state of the art is such that it probably matters little. Therefore, we* called this species Euclymene collaris in the data analysis, rather than introduce a name that is little used and may further confuse the issue.

FAMILY NEREIDAE

Problem: While members of the Family Nereidae were found in over 49% of the stations sampled, the number of individuals per station was consistently low. Thus, this family does not represent a dominant portion of the fauna. However, the specimens examined illustrated the problems common to placing species names on polychaetes from Georges Bank.

Examination of specimens from the Maurer and Leathem work revealed that worms labelled Nereis zonata Malmgren, 1867,showed characters of both Nereis zonata and Nereis grayi Pettibone, 1956, as distinguished by Pettibone (1963). Specimens from the Historical Study showed the same duplicity of characters.

Pettibone (1963) distinguishes Nereis zonata and Nereis grayi on the basis of sharply conical parapodial ligules in grayi and evenly rounded ones in zonata. Additionally, the number of paragnaths on the proboscis differs considerably according to Pettibone (few to lacking on same areas in grayi and many in zonata). All specimens we* examined had ligules that looked more like those Pettibone illustrated for grayi than those for zonata. Careful examination of specimens with apparently identically shaped ligules, indicated that the number of paragnaths varied greatly from none (leading to another genus) to many, with all ranges in between. Morphological differences in the setae could not be detected. Since most of the specimens were very small compared to those that we had previously seen from off Massachusetts, it is possible that the morphological variation was due to lack of maturity in the specimens.

Approach used for the Historical Study: We* labelled all similar specimens as Nereis zonata in order to make our data compatible with that of Maurer and Leathem. Because this family was not one of the dominants, we* did not consult an expert in the group for a resolution.

FAMILY PARAONIDAE - Aricidea sp.

Problems: The various species of the genus Aricidea are under scrutiny by several workers, some of whom are examining western North Atlantic specimens, including Georges Bank materials from both the Maurer and Leathem collections and the Historical Study (John Hartley, personal communications).

One direct result of this scrutiny has been some questions as to the validity of previous records of species reported as dominant from Georges Bank. Consequently, we* sorted the Historical Study specimens on the basis of a series of gross morphological types and compared these to representatives from the Maurer and Leathem collections. We* found appro-

priate correspondence between what both groups (TAXON, Inc. and Maurer and Leathem) called A. catherinae, A. quadrilobata and A. wassi, so we* felt that we could safely combine the data for those three species. Unfortunately, we were unable to establish any correspondence with regard to the other species.

John Hartley is presently examining both our morphological types and the Maurer and Leathem materials.

Approach used for the Historical Study: For purposes of data analysis, we* combined all species of Aricidea (except catherinae, quadrilobata and wassi) under one label, Aricidea sp.

FAMILY PARAONIDAE - Paraonis spp.

Problems: For the stations included in this study, Maurer and Leathem (1980) reported Paraonis gracilis for nearly all specimens of this genus. Our* initial examination of the Historical Study paraonids indicated that there was considerable and perhaps significant variation in diagnostic characters between these specimens and the original description of Paraonis gracilis.

The systematics of this family are currently under intense investigation, particularly since Strelzov's radical revision, which "introduced several new taxonomic characters to the ones previously in common usage" (Fauchald, 1977, p. 18). There are European specialists currently working on North Atlantic specimens of this genus. In addition, the group at Battelle indicates that they have found three new species from Georges Bank (Battelle, 1982, p. 28).

Approach used for the Historical Study: In the data analysis, we* combined all reported species of Paraonis and called the group Paraonis spp. Note that, because Maurer and Leathem (1980) reported nearly all of their specimens from the stations under discussion under the label Paraonis gracilis, the results differ little by the change in name, which, we believe, reflects the systematic situation more correctly.

FAMILY SABELLIDAE - Euchone incolor

Problems: Specimens in the genus Euchone are remarkably easy to identify compared with other members of their subfamily, Fabricinae, because of a characteristic anal funnel. Even so, determining species names is quite another matter. Materials from Georges Bank have been examined in great detail by members of the TAXON, Inc. staff using techniques recommended by Banse (1970), who examined western North Atlantic specimens. Although Fauchald (personal communication) feels that the staining techniques recommended by Banse are valid, we* were unable to get sufficient consistency in staining for large numbers of specimens to rely solely on its use for assigning species names, as Banse suggests. We* found that those specimens that did stain appropriately appeared to be closer to Euchone hancocki than to E. incolor. However, considering the time and effort involved in staining, we did this only for a subset of the Euchone.

Apparently Maurer and Leathem (1980) labelled as Euchone incolor those specimens with a few setigers in the anal funnel, as they reported only this species among those that share this character.

Approach used for the Historical Study: We followed the Maurer and Leathem practice and labelled as Euchone incolor all specimens with a few setigers in the anal funnel.

FAMILY SABELLIDAE - Chone spp.

Problem: Most of the sabellids in this study were treated as a group because of differences between our sorting and the Maurer and Leathem collections; see the section entitled FAMILY SABELLIDAE Sabellidae unidentified. Thus the genus Chone did not appear as a dominant by itself, although at least one of its species is very common on Georges Bank. We* feel that specimens Maurer and Leathem labelled Chone infundibuliformis are, in fact, a new species of Chone that is very similar to Chone duneri (Perkins, personal communication). The discrepancy became apparent immediately when their specimens,as well as those from the Historical Study, consistently keyed out by us* to Chone duneri, bypassing Chone infundibuliformis when using publications including both species . At the present time, Perkins is working on this

genus and has recently examined several relevant type specimens. Charlene Long examined specimens of Chone infundibuliformis at the United States National Museum and found that they matched the description in Fauvel (1927) and were quite unlike those she had seen from the Georges Bank material, although that species should be found there.

FAMILY SABELLIDAE - Sabellidae unidentified

Problem: Some sabellid species have sufficiently unique diagnostic characters to be sorted quickly with a dissecting microscope, e.g. Potamilla reniformis. Unfortunately, these characters may be part of deciduous structures, such as the crown. Also, some sabellids, as well as several other polychaete groups, go through a series of morphological stages as they mature to the adult form or as they regenerate missing parts. These morphological stages may temporarily possess characters diagnostic of other species or even of other genera. The practice of assigning such specimens to the most likely species found in a given area or to the name given similar specimens already found in a lot is not appropriate, since closely related species of sabellids (and, again, several other polychaete groups) are frequently found in the same sample. Consequently, damaged, incomplete or small specimens of most sabellids should not, and sometimes cannot, be identified. This means that large numbers of sabellids from Georges Bank should bear the label "Sabellidae juvenile or unidentifiable".

A discrepancy between the Maurer and Leathem data and our* sabellid data surfaced upon examination of the two collections. For example, samples labelled Jasmineira filiformis containing a total of nearly a hundred specimens included (in our* opinion) at least three species of sabellids in at least two genera. We* do not believe they fit the description of filiformis , which has been reported as a dominant from Georges Bank.

Approach used for the Historical Study: Because of significant discrepancies in sorting between Maurer and Leathem and our* data we* left most sabellids under the label "Sabellidae unidentified", including the juveniles and damaged specimens. Not included under this label were two species of Euchone which we* sorted in a fashion similar to that of Maurer and Leathem collections.

FAMILY SYLLIDAE

Problems: The majority of the syllids that have been reported from Georges Bank belong to one subfamily, Exogoninae, which typically is represented by very small specimens (a few millimeters) that are superficially similar. Because of the importance of this group, which includes two of the dominant species from Georges Bank (reported by Maurer and Leathem (1980) as Exogone hebes and Exogone verugera), we felt an expert in this group should have an opportunity to see specimens from the area. Based on the fact that Thomas H. Perkins, Department of Natural Resources, State of Florida, had recently (1981) published a very detailed work on several species of exogonids, some of which are found on Georges Bank, we sought his opinion.

In Perkins' response he states: "There are some specimens of E. brevicornis mixed with E. hebes. Apparently, identifiers looked for the short antennae first and then for the spinigers of E. brevicornis. If they missed the spinigers they put such specimens in a vial of hebes." Since E. brevicornis is the species that Maurer and Leathem (1980) reported as E. verugera, this means that two of the dominant species were not always separated. It is also possible for specimens of E. hebes that have been damaged (e.g. missing the large, club-shaped median antenna) to have been identified as E. verugera.

A discussion of Exogone hebes and Exogone brevicornis, with a description of the problem known to exist in their identification and their current standing according to Perkins, seems appropriate because of their numerical dominance in the fauna.

Exogone hebes (Webster & Benedict, 1884):

Perkins, based on his examination of Maurer and Leathem material at USNM, stated: "Exogone hebes is for the most part identified correctly." He further noted that he regretted that he did not look at the types of E. hebes. We* found in the Historical Study collections that there were two forms of what appeared to be E. hebes: (1) those with simple setae that began on the first setiger, and (2) those with simple setae that began several segments later. In addition, all specimens we* checked had bidentate compound setae, whereas previous workers, e.g. Pettibone

(1963), illustrated only unidentate compound setae. Obviously, further systematic work needs to be done on the species that most people call Exogone hebes from Georges Bank.

Exogone brevicornis (Webster & Benedict, 1887):

Perkins (personal communication), based on his examination of Maurer and Leathem material at the USNM, stated: "I think specimens they (Maurer and Leathem) identified as E. verugera Claparede are E. brevicornis (Webster & Benedict)...". E. verugera is basically a European species, and all specimens that we* examined from the Historical Study and from the Maurer and Leathem material match the description of E. brevicornis and do not match the description of E. verugera.

Approach used for the Historical Study: We* established a sorting protocol for the exogonids that we felt would yield about the same results as that obtained by Maurer and Leathem. We* did not feel it was appropriate to use a different approach which would cause greater problems in matching the data sets. We* have however used the species name E. brevicornis.

FAMILY SYLLIDAE - Sphaerosyllis brevifrons

Problems: Perkins (1980) published a paper that included thirteen species, several of them new. This paper was unavailable to Maurer and Leathem prior to their 1980 publication. One of the results of this review is that species that had been previously synonymized were given separate stature and some western North Atlantic specimens bearing frequently-used names were redescribed as new species. As a result, the name used by Maurer and Leathem (1980), E. erinaceus, is no longer considered appropriate for species from eastern North America. Based on the information provided by Perkins, the Georges Bank specimens key to S. brevifrons. He does not describe this species so we* were unable to confirm our identification, but S. brevifrons appears to be a more appropriate name than E. erinaceus.

Approach used for the Historical Study: In the overall analysis, the Maurer and Leathem species called S. erinaceus was changed to S. brevifrons.

Species Richness

The number of species found in any one replicate sample ranged from a low of 10 at Station 37 on the top of the bank to 92 in one replicate from Station 40 in the Gulf of Maine (Figure 9). There was a tendency at all but three of the deeper stations for the number of species to increase in the spring-summer period. The following discussion deals with the average number of species found per replicate (average of either four or six).

Station 6 in the "mud-patch" at a depth of 75 meters (Figure 9) ranged from a mean of 28 species per replicate in spring through a maximum of 37 species in the summer to 36 in the fall. Variability within replicates was low throughout the year. At the station downcurrent from the lease area (Station 8, Figure 9) the average number of species was significantly higher, ranging from 49 species in the winter to a maximum of 78 in the spring. Species richness declined through the rest of the year to 63 species in the fall. There is a possibility that the lower number for the winter samples was influenced by the sediment type or locality of the first cruise samples since the physical parameters for this station in Cruise I (depth, sediments, etc.) seem somewhat different from those of Cruises II, III and IV.

In the lease sale transect area, the shallowest station (Station 11, Figure 9) had the lowest number of species. From a low of 28 species in winter there was an increase to 35 species per replicate in summer. No fall samples were taken. Station 20 at 80m depth (Figure 10) had much greater species richness with 47 species in the winter and a maximum of 63 species in the summer. The other station near the center of the lease sale area (Station 19, Figure 9) was situated in more heterogeneous sediments just to the south and appeared to have similar species richness. Winter samples produced an average of 54 species per sample and spring samples averaged 71 species per replicate. Differences from Station 20 are not statistically significant however.

At Station 23, located in the head of Lydonia Canyon, samples from the first three cruises were rather consistent at about 55 species per replicate whereas the fall samples from the deeper part of the canyon showed lower species richness with only 46 species per replicate (Figure

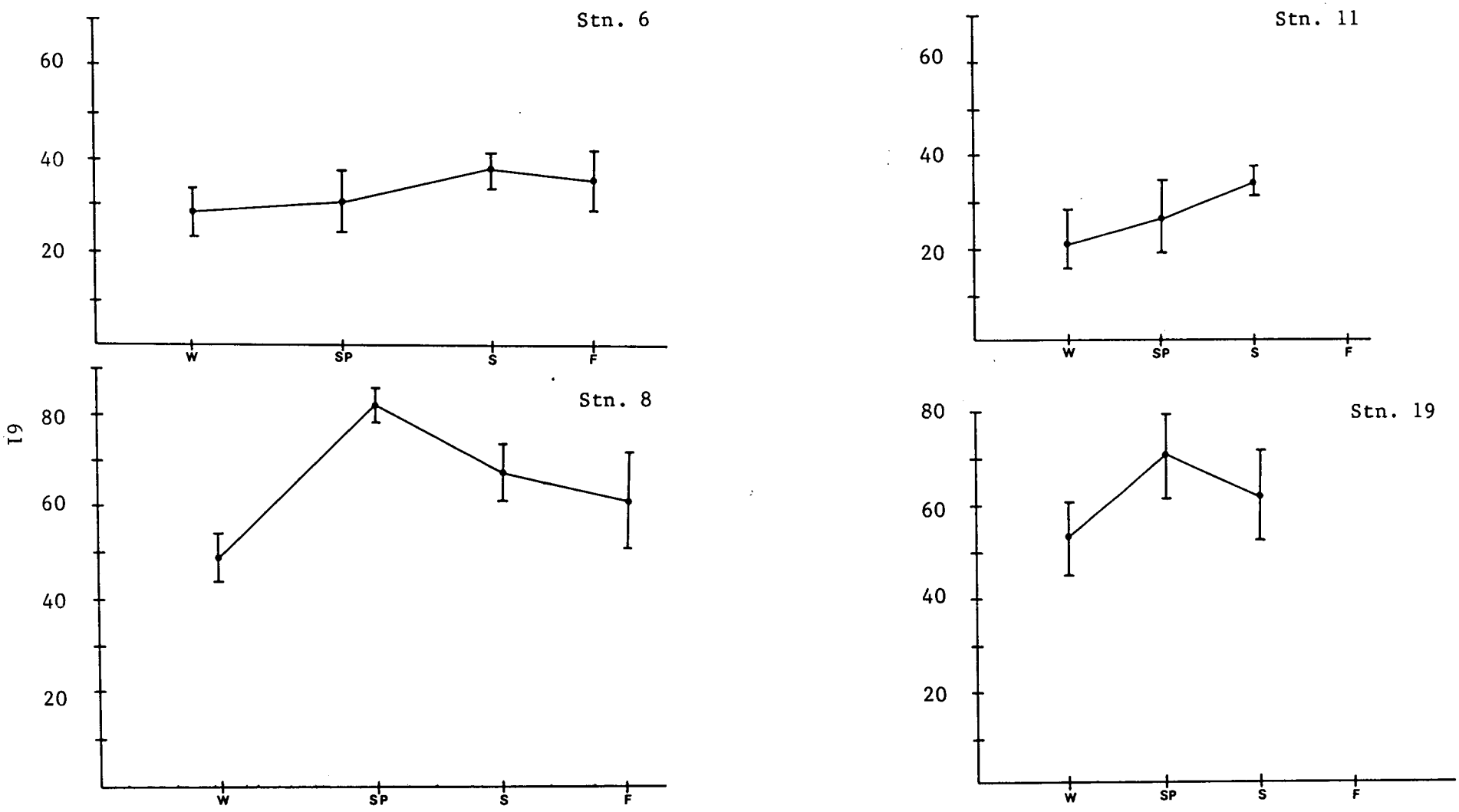


Figure 9. Number of Species at Stations 6,8,11 and 19
(Mean ± one standard deviation)

10). Sediment and depth data indicate that fall samples were taken in a different part of the canyon head. It appears that the canyon head is not subject to the same seasonality that occurs up on the bank. Station 25 on the flank of the canyon at 145m depth showed a similar lack of seasonality but with fewer species present year round. The maximum was 48 species found in the fall (Figure 10).

The stations situated upstream from the lease area (28, 29) (Figures 10, 11) both showed marked seasonal trends. Lowest species richness occurred in winter when 40-46 species were recorded. At Station 28, the maximum occurred in summer when 74 species per replicate were found whereas at Station 29 the maximum of 59 was found in the spring. The differences between these two stations are not statistically significant because of sampling variability. Station 28 which showed lower variance in sediment composition was, rather surprisingly, more variable in the number of species in individual replicates.

Station 37 on the top of the bank had the lowest number of species throughout the year. There was a significant increase from winter to spring (25-35) but three of the four seasons averaged less than 25 species per sample. In contrast, Station 40 in the Gulf of Maine had high numbers of species in all samples (Figure 11). There was however considerable variability between replicates and this was no doubt due to the variation in sediment texture. Station 40 at 117m was one of the deeper stations and the seasonal trend seen at shallow stations was absent. The apparent reduction through the spring and summer (65, 62 species respectively) from a high of 82 in the winter is not statistically significant.

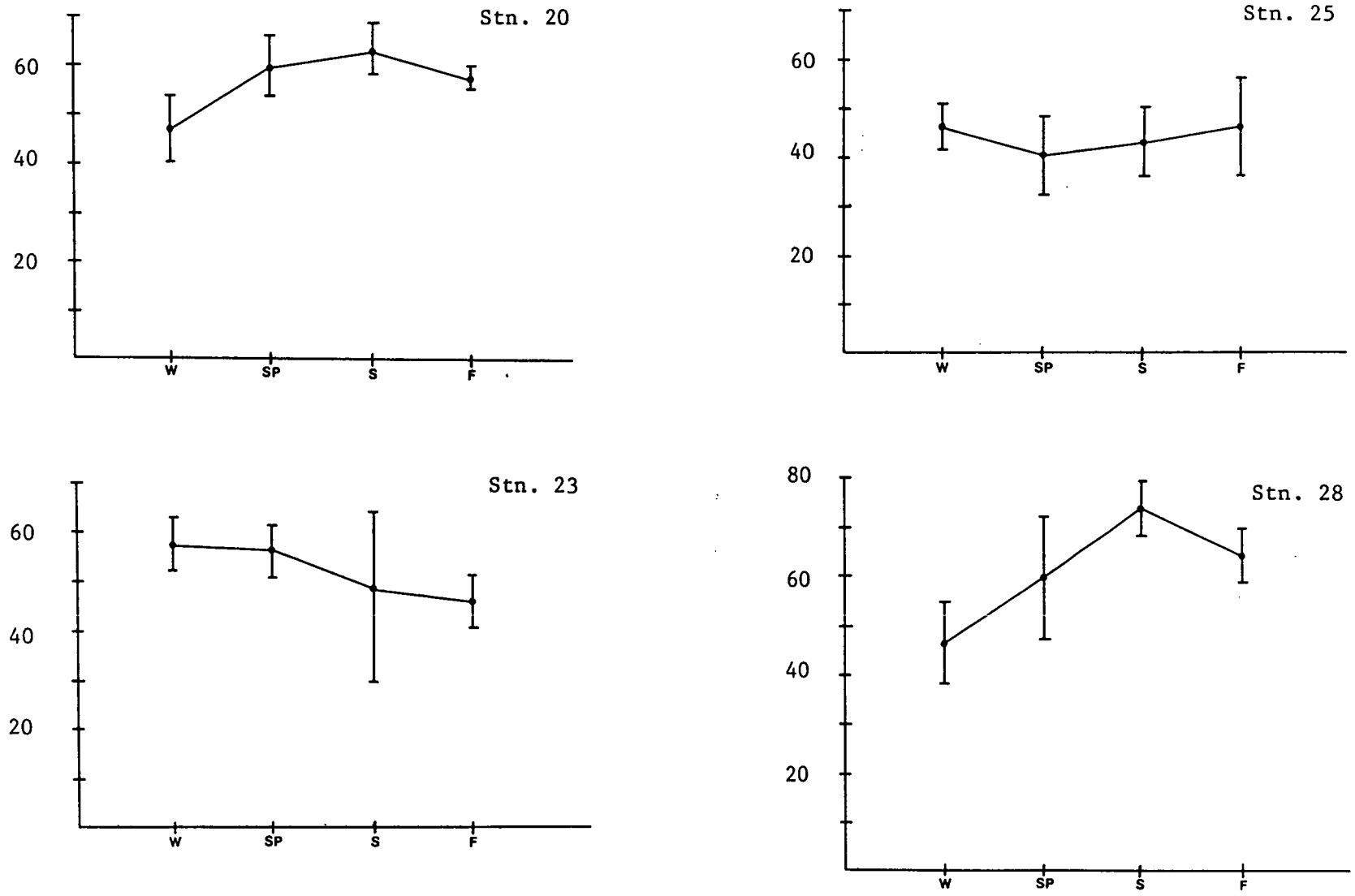
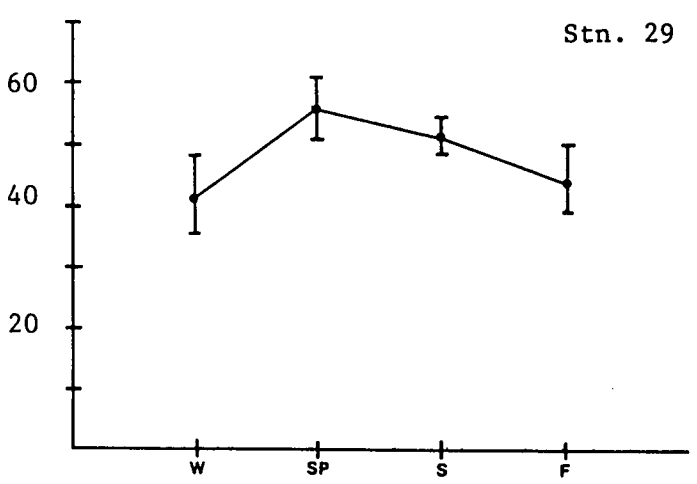
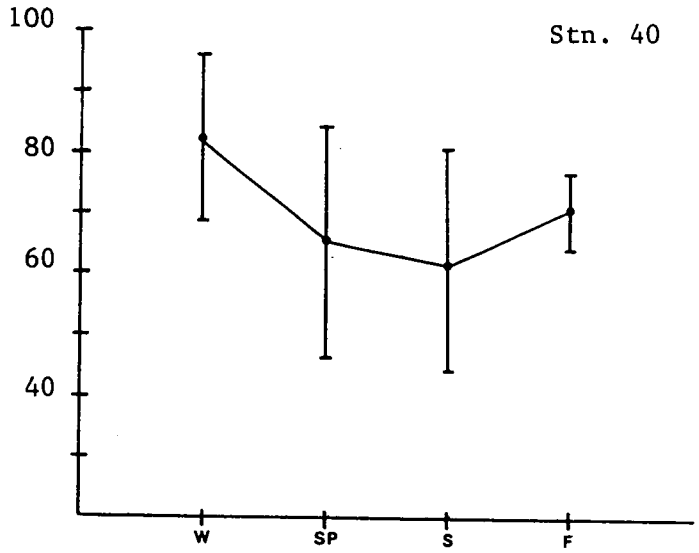


Figure 10. Number of Species at Stations 20,23,25 and 28
(Mean ± one standard deviation)





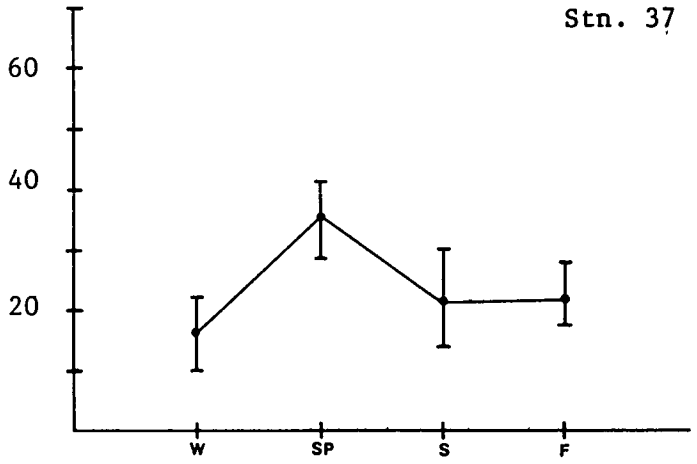


Figure 11. Number of Species at Stations 29,37 and 40

(Mean ± one standard deviation)

Faunal Density

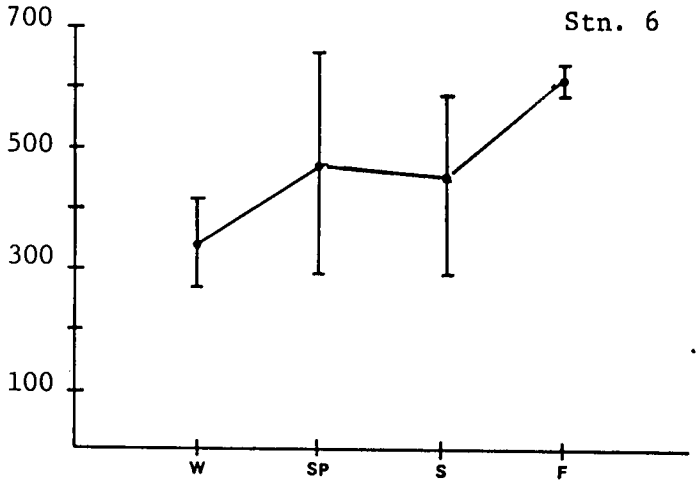
Mean density of all species ranged from 1,000 individuals/m^2 in the winter at Station 37 on the top of the bank to over 40,000/m^2 at Station 40 in the Gulf of Maine. Most of the stations on the bank had densities in the 4,000 to 14,000 range. There was an overall trend of an increasing number of individuals with depth and an increase from east to west on the bank itself. Stations 28 and 29 on the eastern transect had lower densities than stations at equivalent depths in the transect through the lease sale area (19 and 20). Station 8 had higher densities than Stations 19 and 20. As with species richness there were suggestions of seasonal trends in densities at the shallower stations.

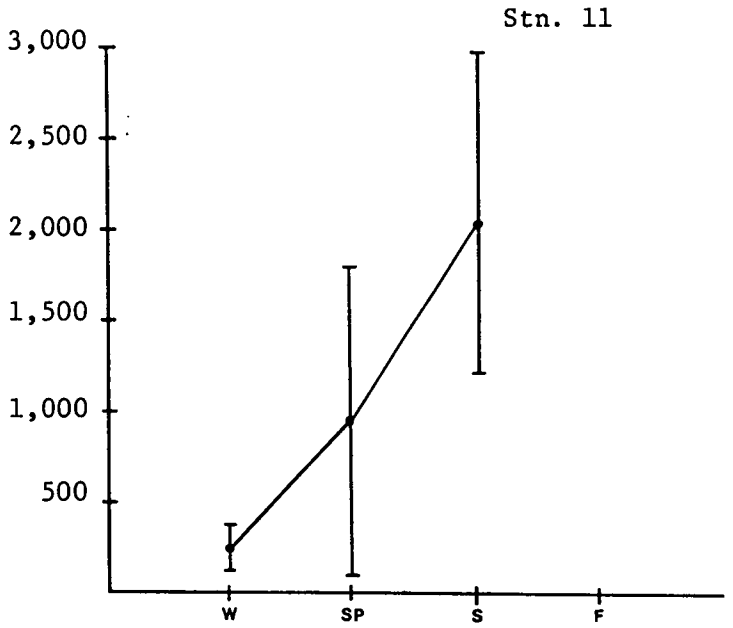
Station 6 (Figure 12) in the mud patch had the lowest density of all stations except Station 37 on the top of the bank. There was a steady progression from a low of 3,000 individuals/m^2 in the winter to a high of 6,000/m^2 in the fall. Station 8, downcurrent from the lease sale area, had the highest densities of any station on the bank itself (Figure 12). A low value of 4,000 individuals/m^2 was reported in the winter samples but, as previously indicated, this may be an anomolous result due to incorrect station location in Cruise I. The data as collected suggests a maximum of 12,000 individuals/m^2 in the spring.

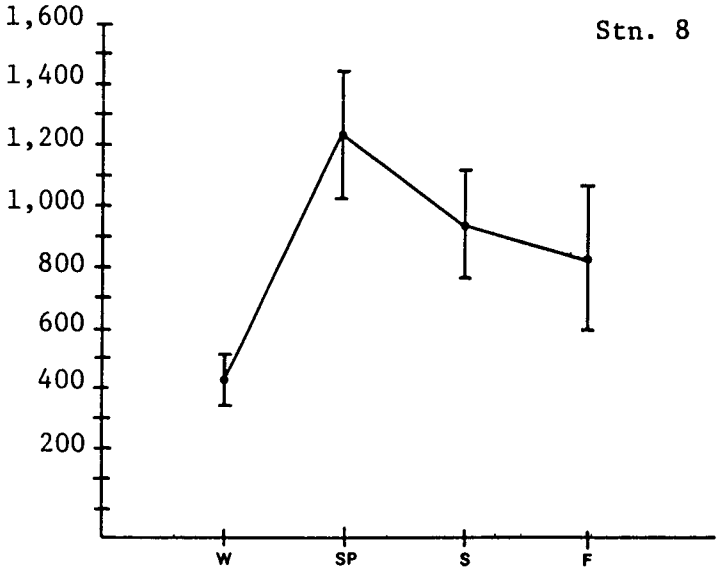
Station 11, the shallowest on the lease sale transect and dominated by haustoriid amphipods,showed a marked increase from a low of 2,000 individuals/m^2 in winter to 20,000/m^2 in the summer (Figure 12). No fall samples were taken. There was a wide variation among replicates and, since sediment results were very consistent, it appears that this represents a fairly harsh environment: i.e. spatial heterogeneity of sediments was not the causal factor.

Station 19 (Figure 12) had faunal densities of 4,000/m^2 in the winter and 6,000 to 7000/m^2 in the spring and summer. No fall samples were collected.

Station 20 was rather consistent throughout the year at 7,000 to 8,000 individuals/m^2. Standard deviations in each sampling period were, however,large and probably reflect spatial heterogeneity of sediments.







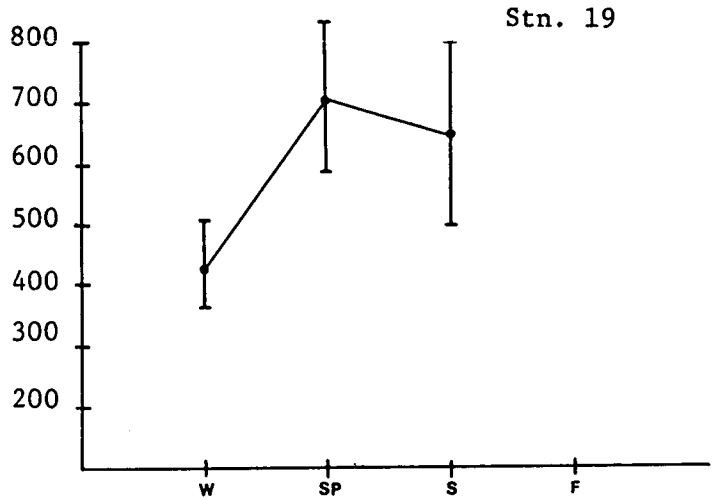


Figure 12. Faunal Density (per $0.1m^2$ replicate) at Stations 6,8,11 and 19 (Mean $\pm$ one standard deviation)

Major variation at this station in sediment composition was in the percent fine sand which ranged from 0% to 26%.

Mean density in Lydonia Canyon (Station 23) was fairly constant at 6,000 - 9,000 individuals/m^2 (Figure 13). The lowest density was in the fall and this may reflect the different locality of the sampling discussed earlier. Station 25 (Figure 13) on the flank of Lydonia Canyon had modest densities of 3,000 - 4,000 individuals/m^2.

On the eastern transect, Station 28 showed a progressive increase in mean density from 3,500 individuals/m^2 in winter to over 7,000/m^2 in fall. Variations between individual replicates were particularly high in spring and summer. Station 29 had slightly higher overall densities and ranged from a mean of 4,200 individuals/m^2 in winter to a maximum of over 10,000/m^2 in summer. There was an apparent decline in the fall.

Station 37 on the crest of Georges Bank had very low densities in the winter (1,000 individuals/m^2). Densities were considerably higher in the spring (4,000/m^2) but very variable (Figure 14). Mean density showed an apparent, though not statistically significant, decline to approximately 2,000 individuals/m^2 in the fall (Figure 14). The overall low densities and wide variation emphasize the fact that this is a harsh and unpredictable environment.

Station 40 in the Gulf of Maine had the highest densities. There was no significant change through the year until the fall sampling when mean density changed from about 15,000 individuals/m^2 to 45,000/m^2. This change was primarily due to one faunal component - sabellid polychaetes. Densities of this group increased from 7,000/m^2 to 31,000/m^2. There was no sediment or replicate locality data available for the fourth cruise so we cannot determine whether this increase reflects a different sampling locality.

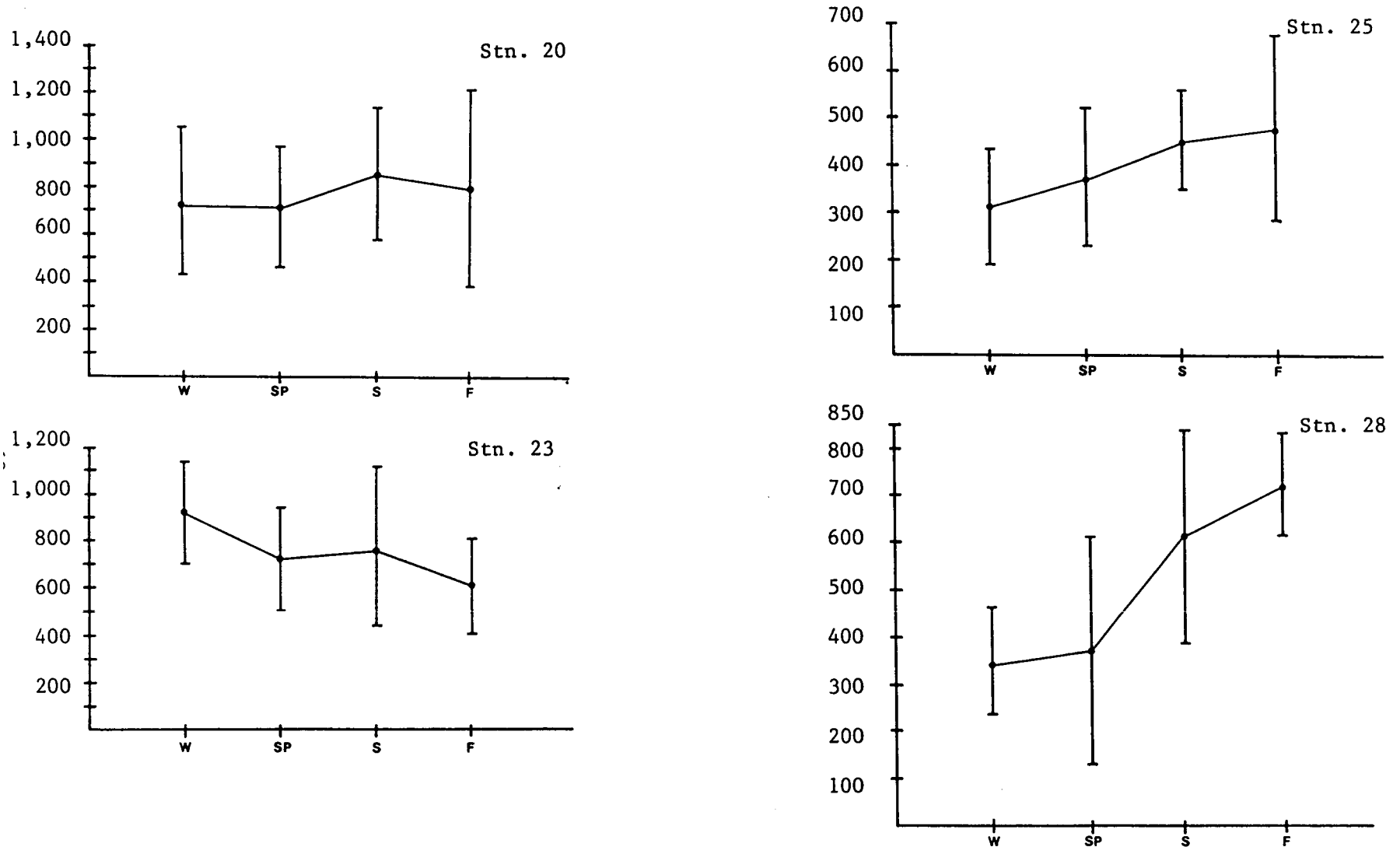
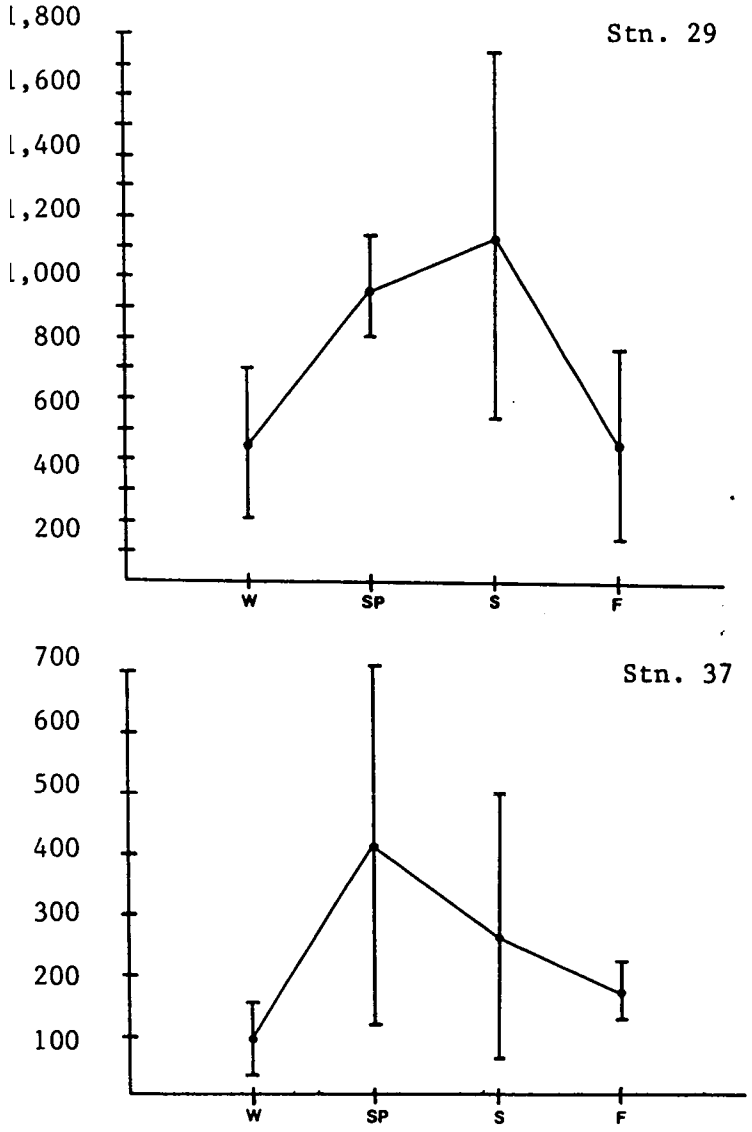


Figure 13. Faunal Densities (per $0.1m^2$ replicate) at Stations 20,23,25 and 28
(Mean $\pm$ one standard deviation)



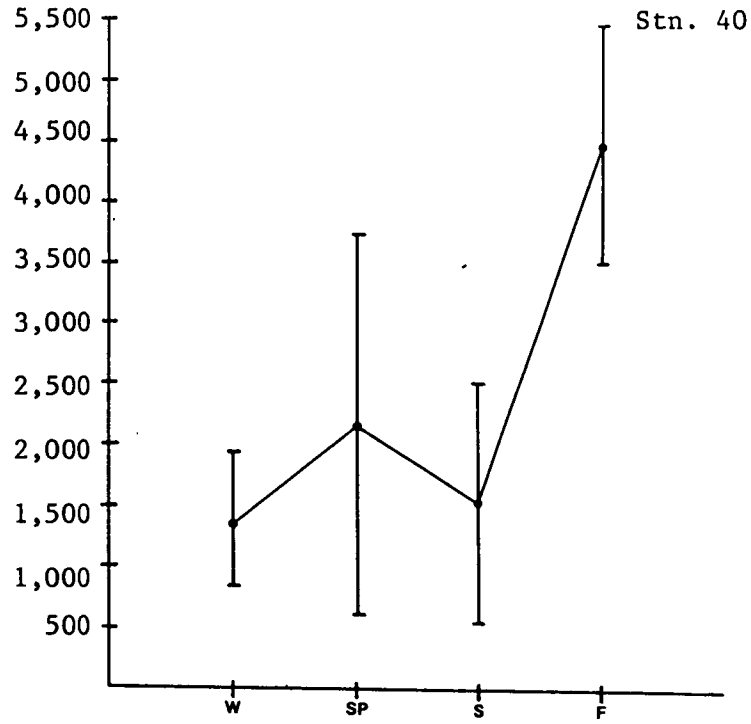


Figure 14. Faunal Densities (per $0.1m^2$ replicate) at Stations 29,37 and 40
(Mean $\pm$ one standard deviation)

Biomass

Biomass in grams/m^2 wet weight for winter and spring cruises are listed in Table 5. As a quantitative parameter, biomass shows greater variability than other faunal parameters and comparisons between the results of different workers should be viewed cautiously. Slight differences in procedures for determining wet weight can produce significantly different results. The data in Table 5 excludes large individual molluscs whose weight, because of the shell, would exceed the total value for all other specimens. Values ranged from 7.81 grams/m^2 at Station 37, the shallowest station, to 26.42 grams at Station 29. Stations 6 in the mud patch and 40 in the Gulf of Maine ranked in the top three in both seasons. Biomass values at these and most other stations were primarily due to the polychaete fraction which comprised up to 88% of the total weight. Stations 8 and 37 were the only localities where the weight of the non-polychaete fraction was similar to or exceeded that for polychaetes. This was due to both low values for polychaete biomass (in comparison to most other sites) at these stations and a higher value for non-polychaete. In both cases it is the amphipod fraction which is dominant in the non-polychaete component.

Faunal Composition

The following summaries for each station discuss the dominant species and the relative proportions of each of the major faunal groups (amphipods, molluscs, polychaetes). A single table of the six to ten numerically dominant species has been prepared which indicates the average density per 0.1m^2 replicate in each season and the overall density for the year. Standard deviations and coefficients of variation are also presented to give an indication of the consistency of each species at a station (occurrence in replicates). Typically these six to ten species represented more than 90% of the individuals at a station. The annual pattern of occurrence is also figured graphically for at least four of the dominant species.

Table 5. Biomass*

	Winter			Spring		
Station	Polychaete	Non-P.	Total	Polychaete	Non-P.	Total
6	13.00	3.83	16.83	18.70	4.05	22.75
8	6.77	7.30	14.07	8.20	5.00	13.20
11	12.81	2.01	14.82	5.83	4.06	9.89
19	8.85	5.22	14.07	11.50	3.46	14.96
20	11.45	4.98	16.43	10.40	1.82	12.22
23	12.52	2.11	14.63	8.70	1.90	10.60
28	9.06	3.63	12.69	23.20	3.22	26.42
29	8.16	1.28	9.44	9.50	1.58	11.08
37	1.21	9.84	11.05	4.25	3.56	7.81
40	15.98	4.65	20.63	15.40	3.27	18.67

* Biomass in gms/m^2 wet weight: averaged and extrapolated from six replicates. Large individual molluscs (e.g. Arctica) which greatly exceed these values are excluded.

The most frequently occurring taxa are listed in Table 6 which ranks taxa according to the number of samples (replicates) in which they occurred throughout the year. The top three groups, Rhyncocoela, Oligochaeta, and Archiannelida, were not identified to species. Individual species from these categories may not have placed as high in the rankings. Archiannelids and oligochaetes were, however, numerically important at several stations. The six species which occurred in 50% or more of all samples were the polychaetes Aricidea catherinae, Exogone hebes, Notomastus latericeus, Exogone brevicornis and the amphipods Ampelisca agassizi and Unciola irrorata. Distributions of these species around the Bank are shown in Figures 15 to 17 which report maximum density recorded for each species in any season.

Figures 18 and 19 show the seasonal densities of Ampelisca agassizi at eight of the eleven stations. This amphipod was present in densities of over 1,000 individuals/m^2 at four stations. It is perhaps the most characteristic species of the southern flank of Georges Bank.

In the systematics section we indicated that polychaetes represented the richest (most species) component of the benthic infauna; they were also numerically dominant at most stations. Amphipods were the second most abundant group followed by bivalves.

Station 6 (Table 7, Figure 20)

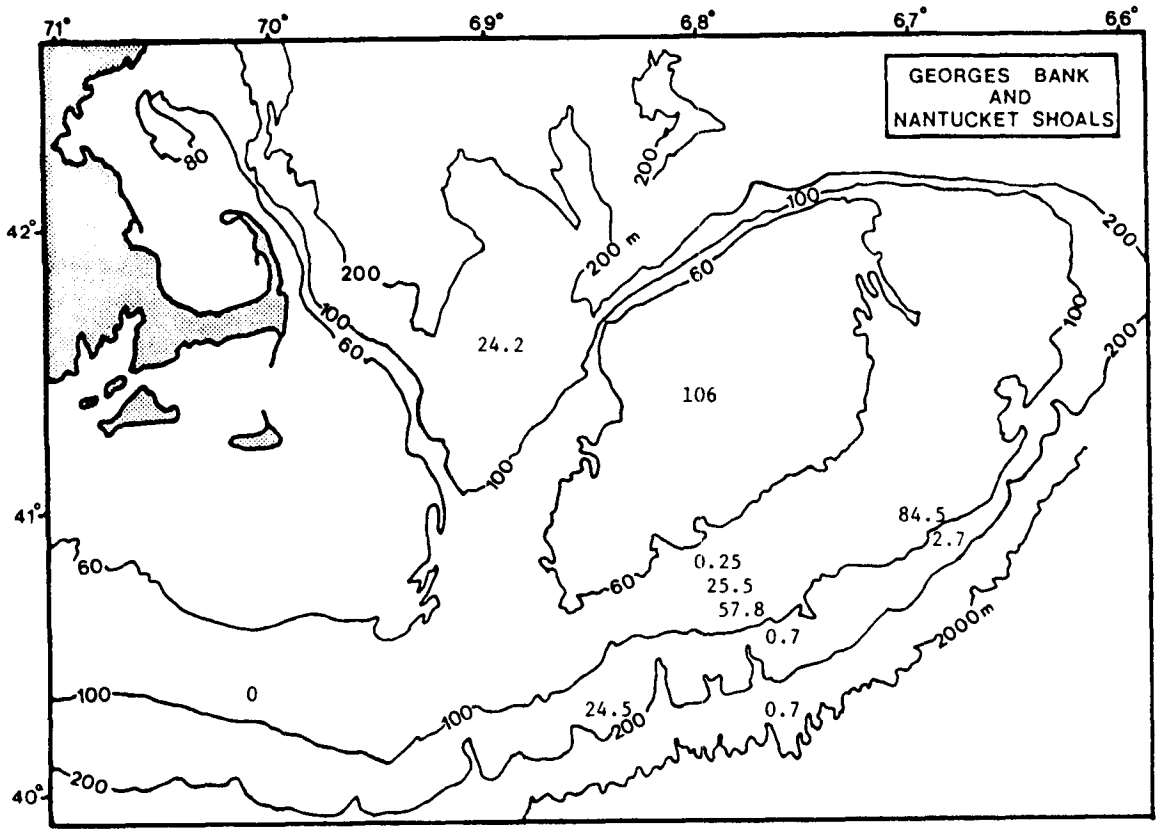
Of the 30-40 species present in each sample at Station 6, located in the mudpatch, more than 70% were polychaetes. Only one amphipod species, Ampelisca agassizi, and one mollusc, the bivalve Thyasira trisinuata, were among the dominant species. The small polychaetes Ninoe nigripes and Paraonis sp. were, overall, the most abundant and consistent in their occurrence throughout the year. Ninoe nigripes had an annual mean density of more than 1,000 individuals/m^2 and Paraonis sp. ranged from 300 to 900 individuals/m^2. The third most abundant was the amphipod Ampelisca agassizi, which is known to occur over a wide area of the southern flank of Georges Bank. This species is an important food item in the diet of several benthic fish species (e.g., cod and haddock). Densities ranged from 200 to over 700 per m^2, but this was well below the densities reached at some other

Table 6. Most Frequently Occurring Taxa

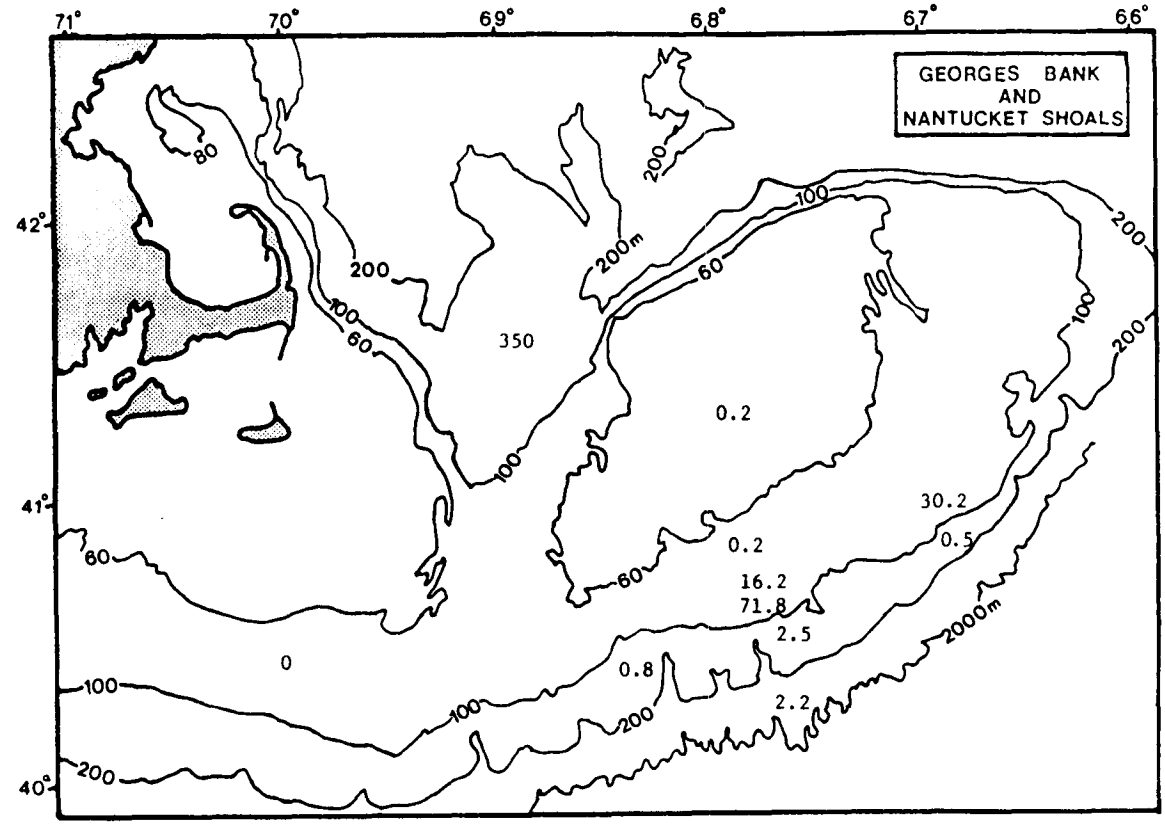
Species	% of Samples
Rhyncocoela	79
Oligochaeta	69
Archiannelida	69
Aricidea catherinae	64
Exogone hebes	63
Notomastus latericeus	62
Ampelisca agassizi	61
Uniciola irrorata	57
Exogone brevicornis	50
Ostracoda	50
Scalibregma inflatum	49
Leptochelia savignyi	49
Nereis zonata	49
Arctica islandica	47
Spiophanes bombyx	47
Phyllodoce muscosa	47
Potamilla reniformis	46
Spiophanes wigleyi	43
Aglaophamus circinata	41
Amphipholus squamata	40
Cirratulidae	39
Maldanidae	38
Palpate cirratulidae	37
Astarte undata	36
Echinarachnius parma	36
Cerastoderma pinnulatum	36
Dentalium sp.	36
Nephtyidae	35
Ophelina acuminata	34
Cyclocardia borealis	34
Crenella glandula	33
Ampharete arctica	32
Byblis serrata	32
Tharyx annulosus	32
Ampharetidae	32
Erichthonius rubricornis	30
Phoxocephalus holbolli	30
Trichophoxus epistomus	30
Sipunculoidea	30
Glycera capitata	30
Dorvilleidae	30
Schistomeringos caeca	28
Cirolana polita	25
Laonice cirrata	25
Chone infundibuliformis	25
Anobothrus gracilis	25
Parapionosyllis longicirrata	25
Unciola inermis	24
Tharyx sp. B	24
Sthenelais limicola	24

Species	% of Samples
Eusyllinae/Syllinae	24
Phascolia strombi	24
Prionospio cirrifera	23
Ninoe nigripes	23
Diastylis bispinosa	23
Paraonis sp.	23
Thyasira flexuosa	23
Polycirrinae	22
Nucula delphinodonta	22
Aricidea type H	22
Minuspio nr. cirrifera	22
Scoloplos armiger	21
Terrebellides stroemi	21
Exogone naidina	21
Myriochele oculata	21
Lumbrineris latreilli	21
Protohaustorius wigelyi	21
Harpinia n. sp. 2	21
Protodorvillea gaspeensis	20
Eudorella pusilla	20
Lumbrineris acuta	20
Spiophanes kroyeri	20
Periploma papyratium	20
Diastylis quadrispinosa	20
Nephtys incisa	20
Sphaerosyllis erinaceus	20
Exogoninae sp.	20
Euchone incolor	20
Drilonereis longa	19
Mitrella dissimilis	18
Polydora sp.	18
Paraonis gracilis	18
Yoldia sapotilla	18
Diastylis sculpta	18
Crenella decussata	17
Clymenella torquata	17
Goniadella gracilis	17
Tellina agilis	17
Amphecteis gunneri	17
Aricidea suecica	17
Sphaerosyllis brevifrons	16
Clymenura sp. A	16
Terebellidae juv.	16
Aricidea neosuecica	16
Euchone nr. hancocki	16
Thyasira sp.	15
Cirrophorus lyriformis	15
Goniada maculata	15
Caulleriella sp. A	15
Chiridotea tuftsi	15

* % occurrence in all samples; four cruises: n=213

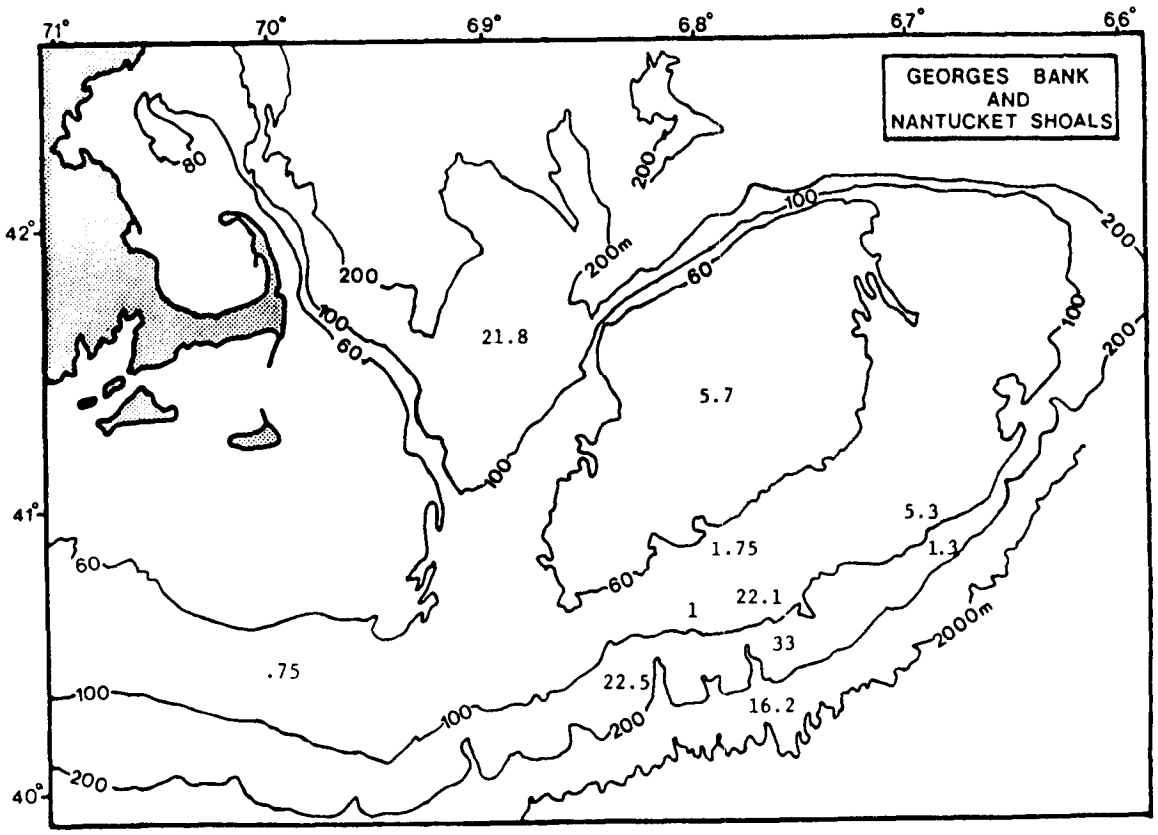


Density (per $0.1m^2$) of Exogone hebes at Sampling Stations

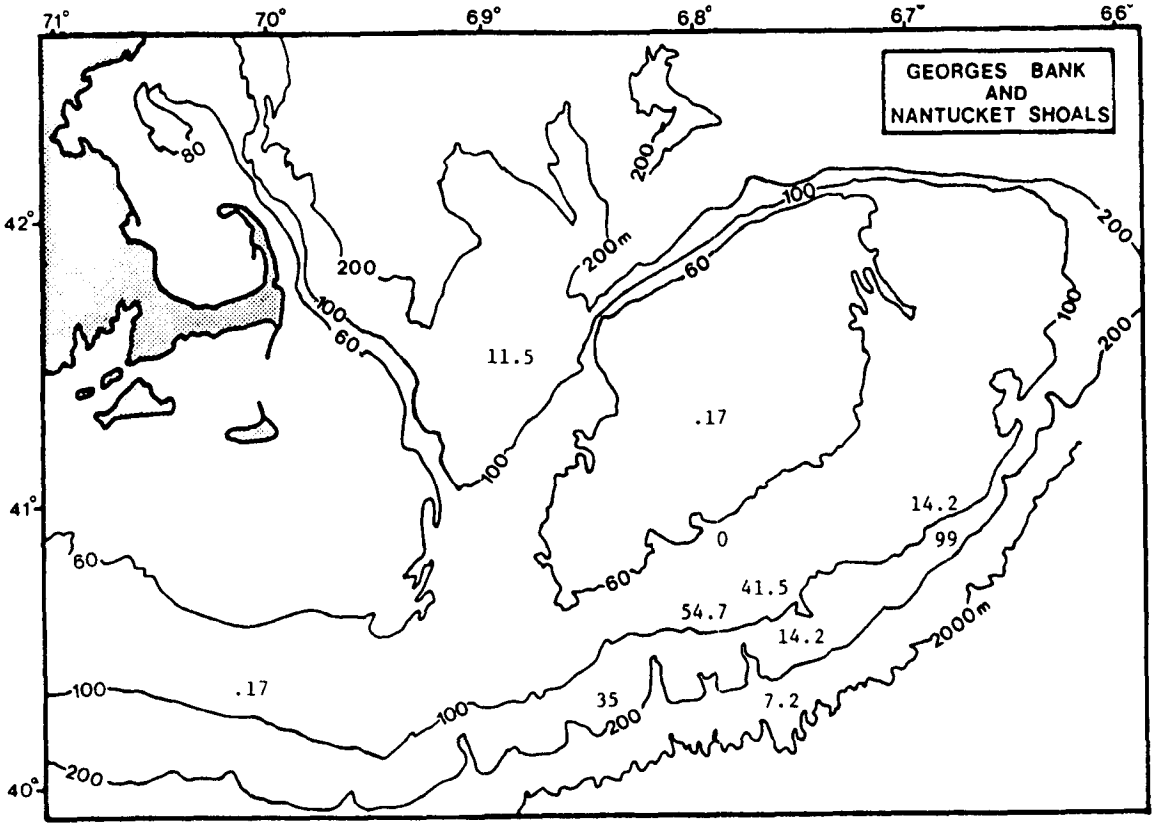


Densities (per $0.1m^2$) of Exogone brevicornis at Sampling Stations

Figure 15.

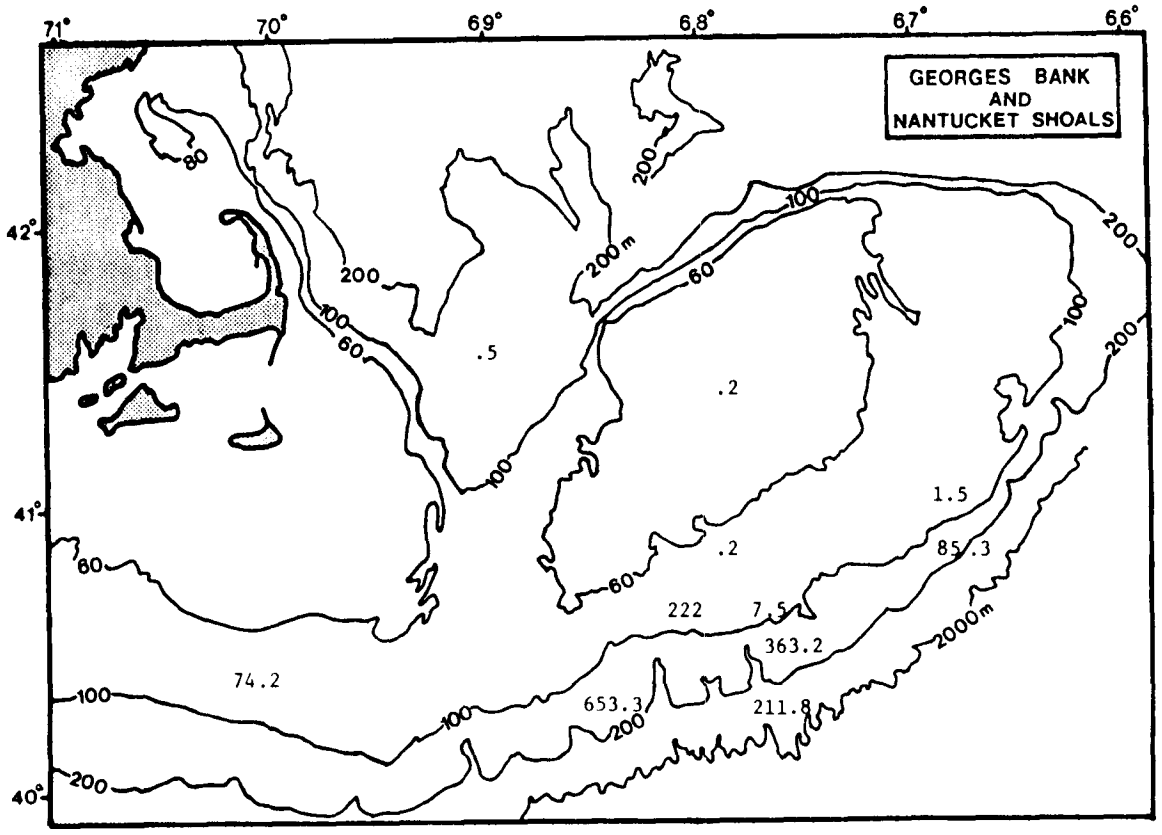


Density (per $0.1m^2$) of Aridicea catherinae at Sampling Stations

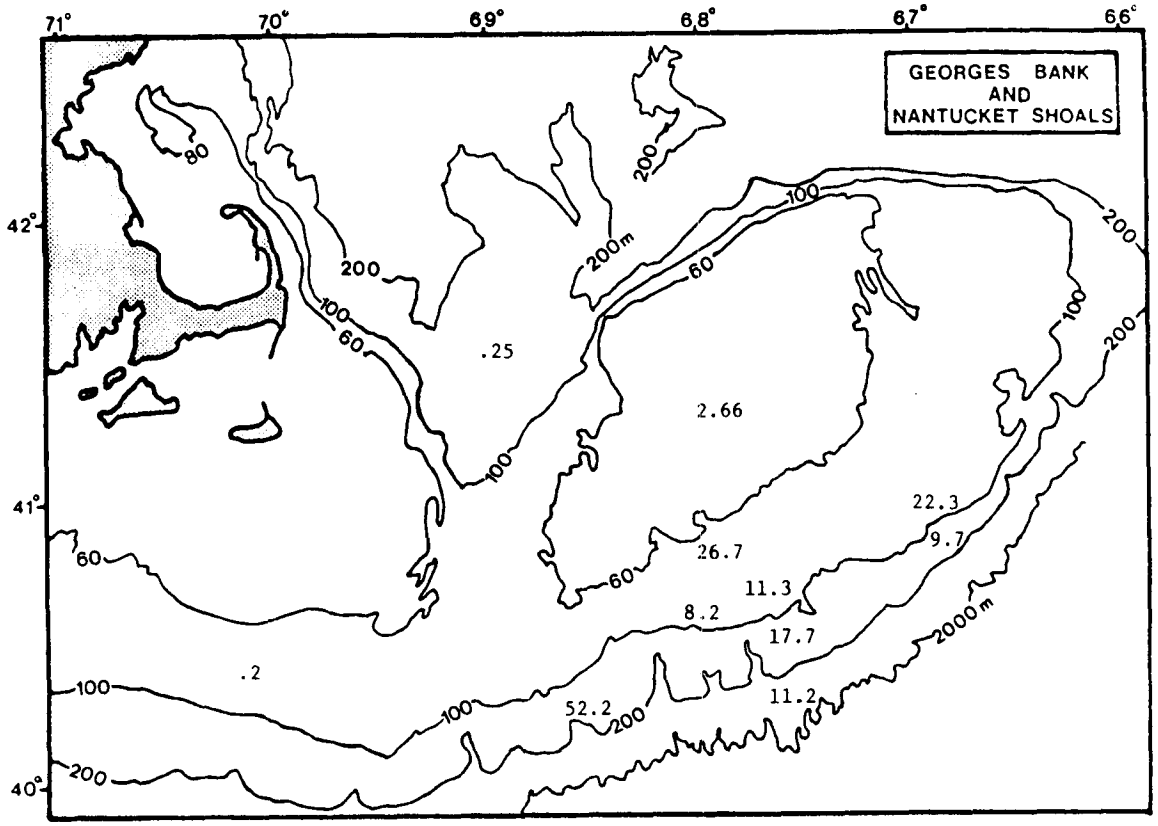


Density (per $0.1m^2$) of Notomastus latericeus at Sampling Stations

Figure 16



Density (per $0.1m^2$) of Ampelisca agassizi at sampling stations



Density (per $0.1m^2$) of Unciola irrorata at Sampling Stations

Figure 17.

Table 7. Dominant Species at Station 6.

Species	Cruise	$\bar{x}$	SD	CV
Ninoe nigripes	1	117.3	12.8	0.11
	2	78.0	28.5	0.36
	3	94.6	50.5	0.53
	4	204.3	49.6	0.48
	Annual	120.0	57.5	0.48
Paraonis sp.	1	35.3	11.6	0.33
	2	92.5	21.1	0.23
	3	54.8	29.2	0.53
	4	53.0	11.7	0.22
	Annual	56.2	27.7	0.49
Ampelisca agassizi	1	65.3	24.5	0.38
	2	20.8	10.9	0.52
	3	21.3	9.9	0.46
	4	74.3	30.4	0.41
	Annual	45.0	31.0	0.69
Cossura longocirrata	1	16.5	17.8	1.08
	2	61.5	29.7	0.48
	3	28.5	48.2	1.69
	4	89.8	53.5	0.59
	Annual	43.8	45.9	1.05
Oligochaeta	1	10.8	9.6	0.89
	2	47.2	37.1	0.79
	3	20.0	17.5	0.85
	4	50.7	35.8	0.71
	Annual	28.8	28.7	1.00
Leptocheirus pinguis	1	1.0	0.9	0.90
	2	45.7	63.5	1.34
	3	36.2	31.8	0.88
	4	6.5	4.7	0.73
	Annual	21.6	35.8	1.66
Thyasira trisinuata	1	22.5	13.7	0.61
	2	8.0	4.5	0.56
	3	11.3	4.1	0.36
	4	18.2	9.9	0.54
	Annual	15.4	10.4	0.67
Nephtys incisa	1	17.0	13.1	0.77
	2	4.0	3.7	0.92
	3	7.0	8.0	1.14
	4	32.5	17.3	0.53
	Annual	14.5	14.9	1.03

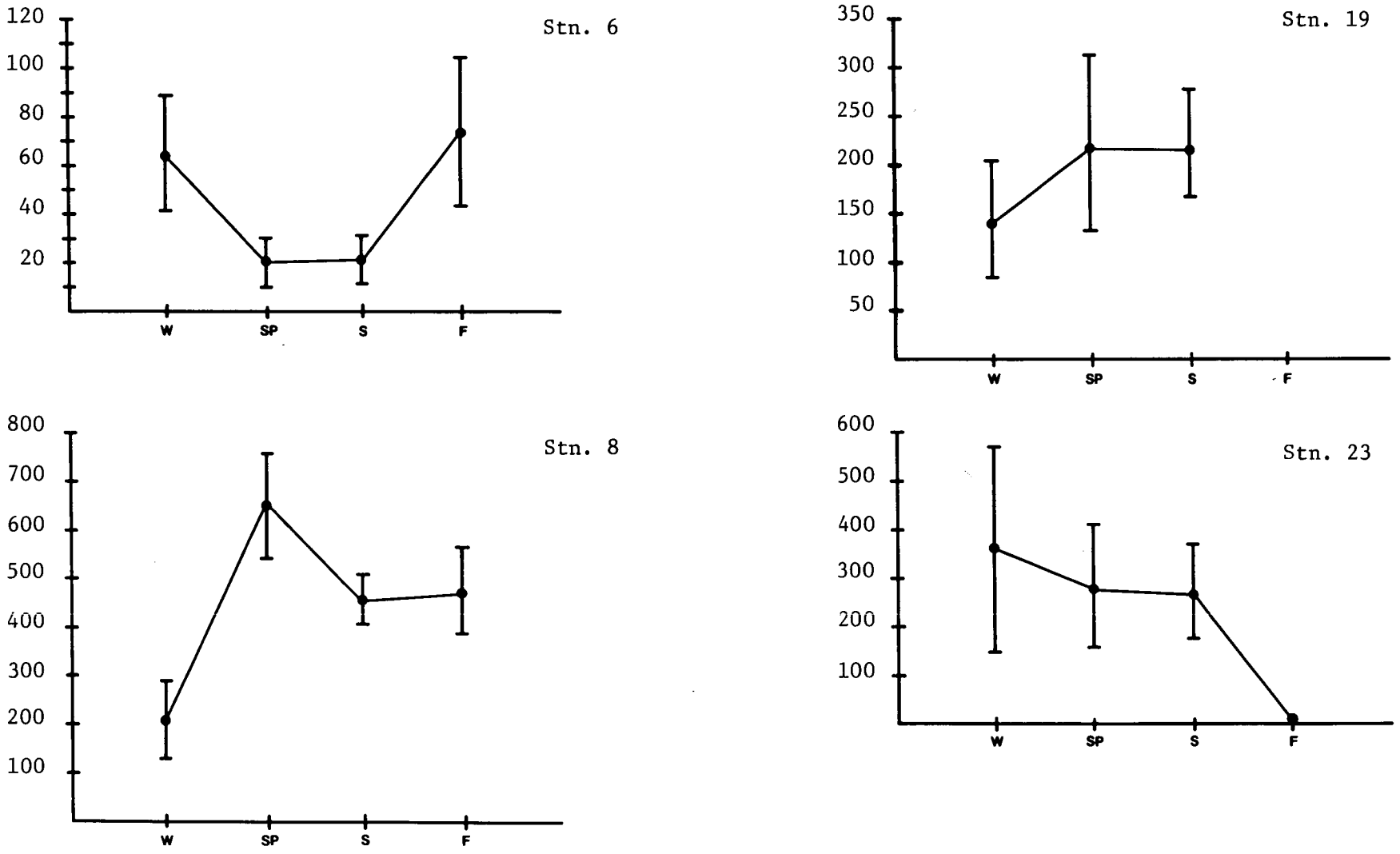


Figure 18. Densities of Ampelisca agassizi at Stations 6,8,19 and 23 (Mean ± one standard deviation)

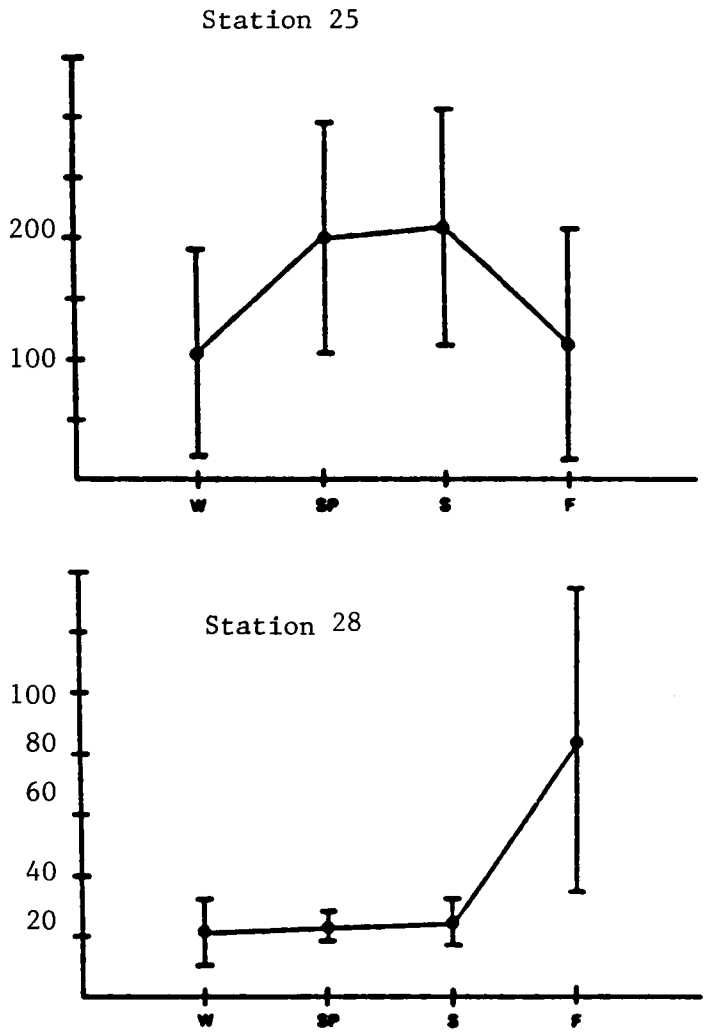
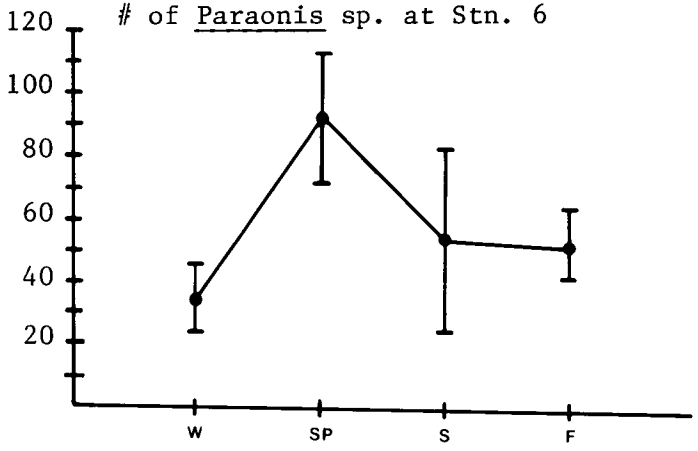
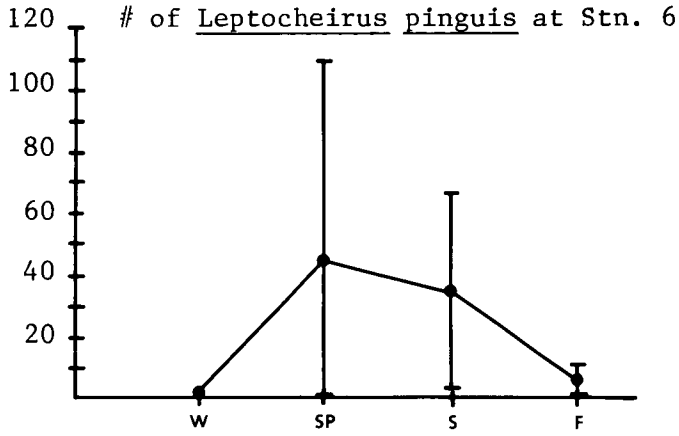
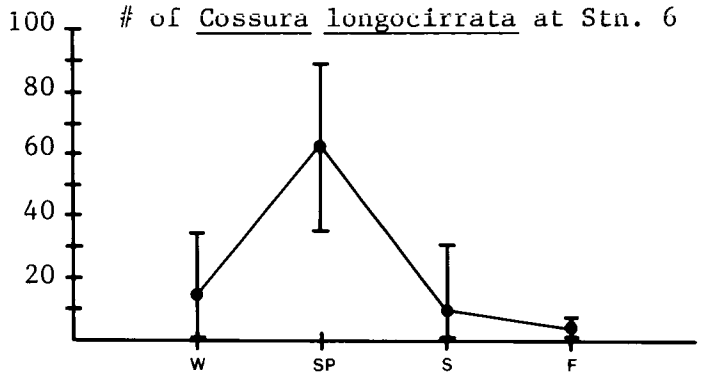


Figure 19. Densities of Ampelisca agassizi at Stations 25 and 28
(Mean ± one standard deviation)







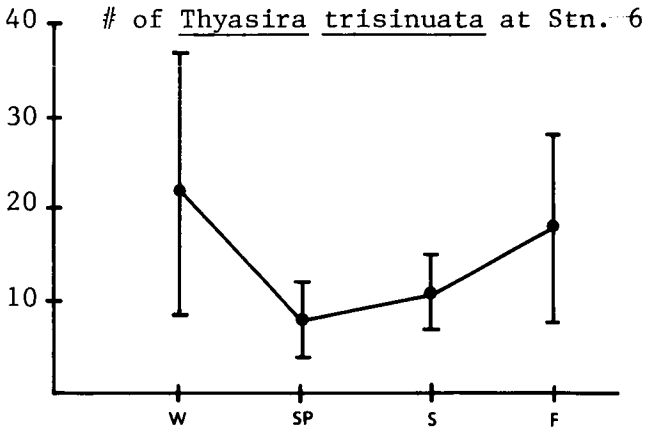


Figure 20. Densities (per $0.1m^2$) of Four Dominant Species at Station 6
(Mean $\pm$ one standard deviation)

stations (Figures 18-19). Another amphipod, Leptocheirus pinguis, which is also important in fish diets (e.g., Smith 1954), was present throughout the year but in lower and less predictable densities. Oligochaetes were also a consistent component of the fauna at Station 6. This station is notable for its stability in that the numbers of species and densities of several dominant species were rather consistent for the year. There were no apparent pulses of any opportunistic species.

Station 8 (Table 8, Figure 21)

Station 8, on the southwestern flank of Georges Bank at 105 m depth, was dominated by the amphipod Ampelisca agassizi. There is some evidence from both physical and faunal data that samples for Cruise I were taken in a slightly different locality than the remaining cruises. Station data for Cruise I indicates depths of 141-147m and bottom photographs show shell debris and numerous starfish (Asterias). Although the silt/clay percentage was similar for all cruises, the major difference was the greater percentage of fine sand (3ϕ) in samples from Cruise I.

Apart from the first cruise, when only 50 species were collected per replicate, the samples contained 60-80 species. Polychaetes accounted for approximately 70% of the numbers of species, with amphipods, molluscs and miscellaneous groups about equally represented among the remaining 30%. However, the three numerically dominant species were not polychaetes. The difference in locality and sediment texture might account for the lower density of Ampelisca agassizi (2,000/m^2) in Cruise I samples. In the remaining samples, densities were high (4,000 - 6,000/m^2) with a peak in the spring. The coefficient of variation was very low (0.11 - 0.18) for Cruises II - IV.

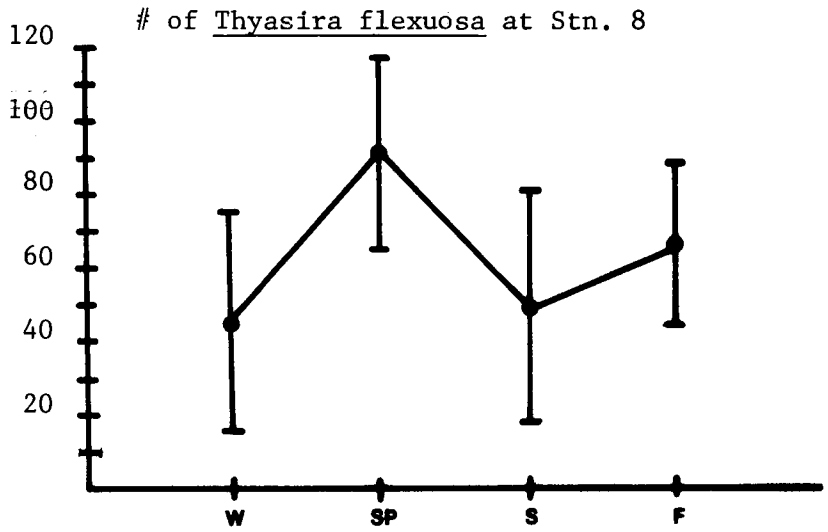
The second and third dominant species were the bivalve Thyasira flexuosa and the amphipod Unciola irrorata. Spiophanes wigleyi, with an annual mean density of 220/m^2, was, overall, the most abundant polychaete. Other species such as Notomastus latericeus, Scalibregma inflatum and Aricidea catherinae were much more abundant in samples from Cruises II - IV. They were poorly represented or absent in Cruise I samples. This suggests

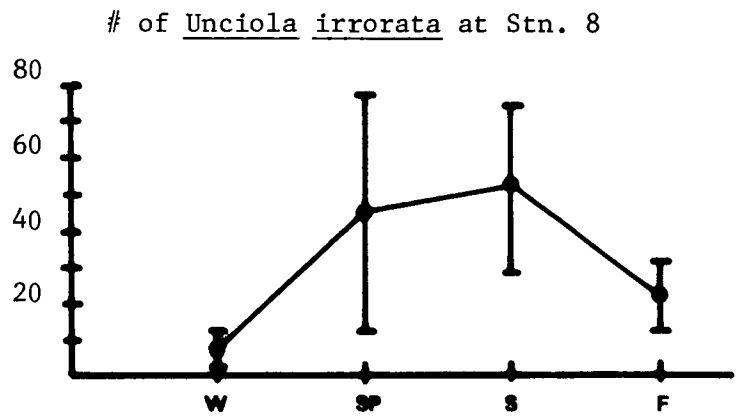
Table 8. Dominant Species Station 8.

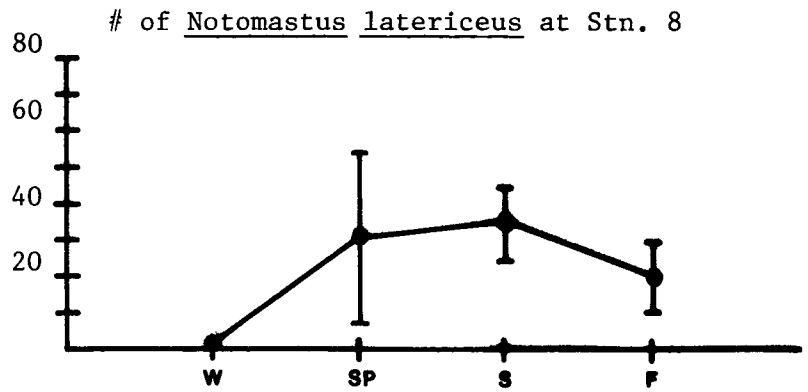
Species	Cruise	$\bar{x}$	SD	CV
Ampelisca agassizi	1	211.8	77.9	0.37
	2	653.3	111.1	0.17
	3	457.0	50.9	0.11
	4	479.0	86.5	0.18
	Annual	415.2	172.5	0.42
Thyasira flexuosa	1	40.0	30.3	0.66
	2	90.8	26.5	0.29
	3	49.3	31.3	0.63
	4	66.5	22.3	0.33
	Annual	63.2	27.6	0.48
Unciola irrorata	1	8.3	5.5	0.66
	2	44.5	32.8	0.74
	3	52.2	23.8	0.46
	4	21.2	10.3	0.49
	Annual	31.3	26.6	0.85
Spiophanes wigleyi	1	27.5	13.7	0.50
	2	21.3	8.3	0.39
	3	19.3	6.3	0.32
	4	21.5	9.9	0.46
	Annual	22.6	9.9	0.44
Notomastus latericeus	1	0.5	0.8	1.60
	2	30.7	22.7	0.74
	3	35.0	10.6	0.30
	4	20.0	9.9	0.49
	Annual	20.8	18.5	0.89
Scalibregma inflatum	1	0.0	0.0	
	2	30.2	17.2	0.57
	3	41.7	23.7	0.57
	4	0.2	0.5	2.50
	Annual	18.6	23.9	1.29
Archiannelida	1	1.2	1.6	1.33
	2	19.7	11.8	0.59
	3	11.2	14.2	1.27
	4	42.5	32.6	0.77
	Annual	16.2	21.7	1.34

Table 8 Contd.

Species	Cruise	$\bar{x}$	SD	CV
Aricidea catherinae	1	1.2	1.6	1.33
	2	19.7	11.8	0.59
	3	11.2	14.2	1.27
	4	42.5	32.6	0.77
	Annual	16.2	21.7	1.34
Dentalium sp.	1	0.2	0.4	2.00
	2	13.2	8.1	0.61
	3	11.5	12.8	1.11
	4	21.5	10.1	0.47
	Annual	10.5	11.4	1.09







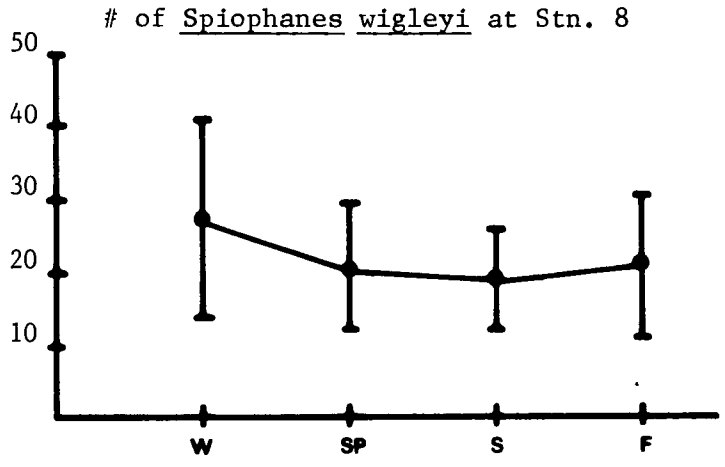


Figure 21. Densities (per $0.1m^2$) of Four Dominant Species at Station 8

that the locality of Cruise I sampling activity may not have been a suitable environment for these species. An equivalent data pattern existed for Archiannelida and the bivalve Dentalium.

Opposing patterns of occurrence were seen in the case of the polychaete Samythella sp., the cumacean Diastylis quadrispinosa and the brittle star Onuphis pallidula. Each of these species was well represented in Cruise I samples (160 - 330/m^2) but poorly represented in the other cruise data.

It is apparent that the environment sampled in Cruise II, III and IV is somewhat different from that of Cruise I. Nevertheless, the amphipod Ampelisca agassizi was consistently dominant. In both areas two crustacean and two molluscan species were numerically dominant but polychaetes were well represented and accounted for the greatest number of species.

Station 11 (Table 9, Figure 22)

Station 11 was situated in a well-sorted fine sand with low silt/clay content. Samples were characterized by low numbers of species (20 - 40 per sample), with amphipods and molluscs representing at least 50% of the species. The most consistent faunal components were the haustoriid amphipods Protohaustorius wigleyi and Pseudohaustorius caroliniensis and the phoxocephalid amphipod Trichophoxus epistomus. Typical density for each of these species was in the range of 200 - 700 individuals per m^2, although in Cruise II Protohaustorius wigleyi was present at densities approaching 2,000 individuals/m^2. In Cruises II and III the polychaete Spiophanes bombyx was overwhelmingly dominant. Physical data for the station does not suggest any difference from Cruise I and the occurrence of this species is probably an opportunistic event. Another consistent faunal species was the bivalve Tellina agilis. Archiannelids and the sand dollar Echinarachnius parma were sometimes very abundant, but not as consistent as the other dominant species.

Table 9. Dominant Species Station 11.

Species	Cruise	$\bar{x}$	SD	CV
Spiophanes bombyx	1	1.3	1.0	0.77
	2	496.8	822.8	1.66
	3	1191.5	712.5	0.60
	Seasonal	508.3	757.9	1.49
Protohaustorius wigleyi	1	77.3	29.4	0.38
	2	192.6	97.4	0.51
	3	79.2	53.0	0.67
	Seasonal	111.9	80.0	0.72
Archiannelida	1	17.3	25.0	1.45
	2	3.0	5.0	1.67
	3	185.3	265.1	1.43
	Seasonal	72.4	172.0	2.38
Tellina agilis	1	14.7	23.1	1.57
	2	45.6	50.4	1.11
	3	119.7	99.6	0.83
	Seasonal	60.8	77.9	1.28
Echinarachnius parma	1	0.3	0.5	1.67
	2	70.4	44.7	0.63
	3	109.2	80.6	0.73
	Seasonal	59.4	69.3	1.17
Trichophoxus epistomus	1	53.2	24.4	0.46
	2	39.0	17.7	0.45
	3	47.2	15.9	0.34
	Seasonal	46.9	19.4	0.41
Pseudohaustorius caroliniensis	1	27.8	24.3	0.87
	2	21.0	6.2	0.30
	3	50.3	25.1	0.50
	Seasonal	33.8	23.6	0.70

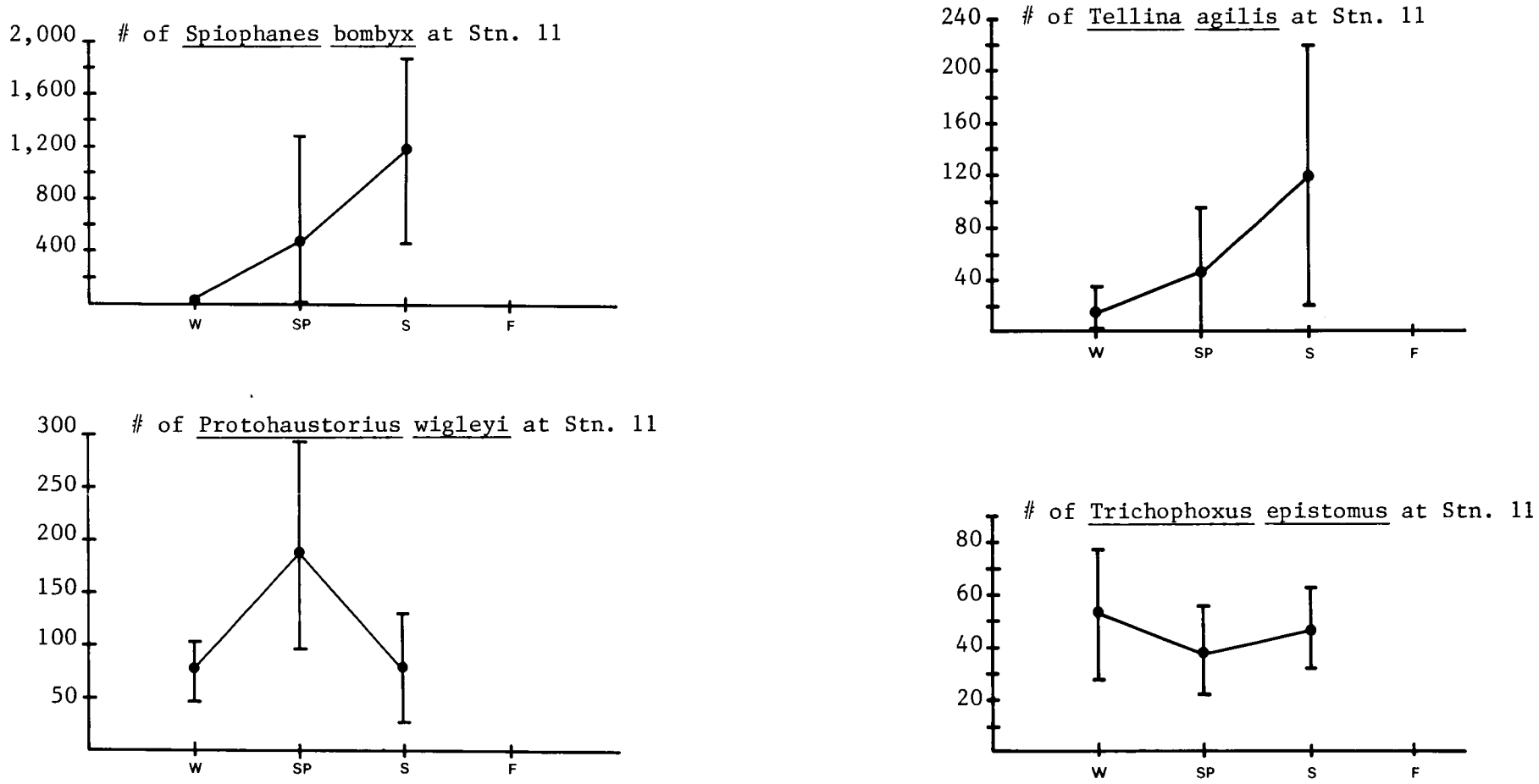


Figure 22. Densities (per $0.1m^2$) of Four Dominant Species at Station 11
(Mean $\pm$ one standard deviation)

Station 19 (Table 10, Figure 23)

Station 19,near the center of the lease blocks, had high species richness (50 - 70 species/sample) with polychaetes representing 50% or more of the types of species. The individual dominant species was, however, the amphipod Ampelisca agassizi, with an average annual density of almost 2,000 individuals/m^2. The coefficient of variation was very low, emphasizing that this species is a very predictable faunal component. Another amphipod which was abundant in the first two cruises but not in Cruise III was Ericthonius rubricornis. Sediment data show some difference between Cruises I and II in that Cruise II samples had higher percentages of fine sand, but there is no clear evidence for faunal change among the dominant species. Apart from the two amphipod species and the bivalve Astarte undata, the remaining dominant species were polychaetes such as Notomastus latericeus, Exogone hebes, Exogone brevicornis and Euchone incolor. Notomastus latericeus was the most abundant and predictable of this group. Two species which were abundant in only one of the three samplings were the ocean quahog Arctica islandica (280/m^2, Cruise III) and the cumacean Diastylis quadrispinosa (460/m^2, Cruise II).

Station 20 (Table 11, Figure 24)

The relatively short distance between Stations 19 and 20 resulted in a modest change in sediment type and a noticeable change in the fauna. Silt/clay content and the percentage of fine sand was lower at Station 20. Sediments were medium sands in the 1 - 20 range. The amphipod Ampelisca agassizi, dominant at Station 19, was absent. Faunal composition was heavily dominated by polychaetes. Polychaetes and Archiannelida accounted for more than 60 percent of the types of species and all but two of the numerically dominant species. The amphipods Unciola inermis and Ericthonius rubricornis were the only non-polychaetes among the dominants. Considering both abundance and constancy, the polychaetes Exogone brevicornis, Exogone hebes, Euclymene collaris, Parapionosyllis longicirrata and the amphipod Unciola inermis were the most characteristic species at this station. All had annual mean densities of 350 individuals/m^2 or greater, with coefficients of variation less than 1.0. This station is

Table 10. Dominant Species Station 19

Species	Cruise	$\bar{x}$	SD	CV
Ampelisca agassizi	1	143.2	60.5	0.43
	2	222.0	90.4	0.41
	3	220.7	56.1	0.25
	Seasonal	191.6	73.9	0.39
Notomastus latericeus				
	1	33.7	9.6	0.28
	2	42.5	12.8	0.30
	3	54.7	14.1	0.26
	Seasonal	43.7	14.8	0.34
Ericthonius rubricornis				
	1	80.8	85.3	1.06
	2	48.3	22.2	0.46
	3	1.7	1.2	0.71
	Seasonal	43.0	61.7	1.43
Exogone hebes	1	12.3	19.8	1.61
	2	25.5	31.8	1.25
	3	18.7	12.9	0.69
	Seasonal	18.0	20.4	1.13
Astarte undata	1	4.2	2.6	0.62
	2	17.5	12.6	0.72
	3	23.3	9.5	0.41
	Seasonal	14.7	11.8	0.81
Exogone brevicornis	1	16.2	14.0	0.86
	2	10.5	1.7	0.16
	3	10.3	8.3	0.81
	Seasonal	12.6	9.8	0.78
Euchone incolor	1	9.2	8.7	0.95
	2	16.8	5.1	0.31
	3	28.8	13.9	0.48
	Seasonal	18.4	13.2	0.71

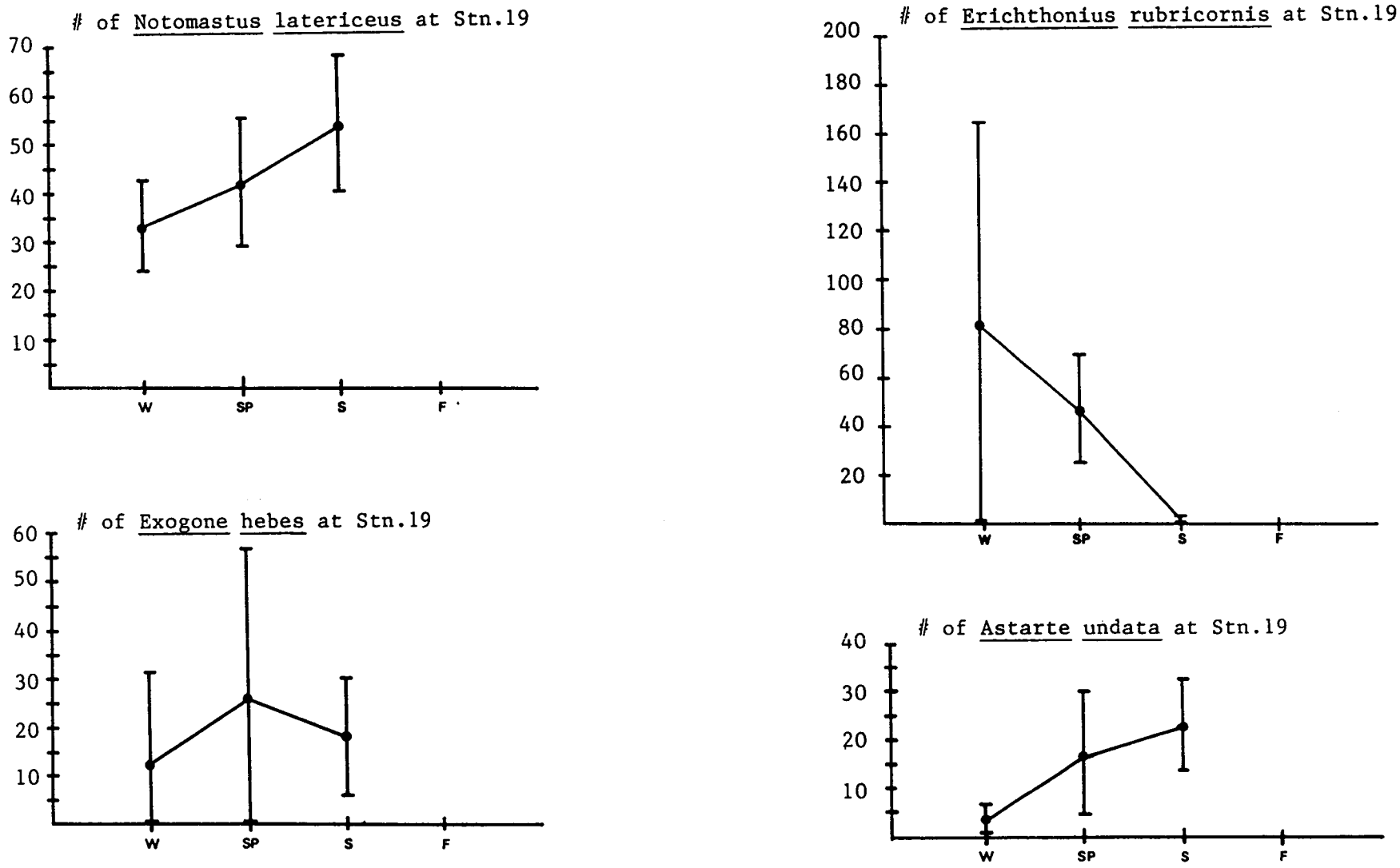


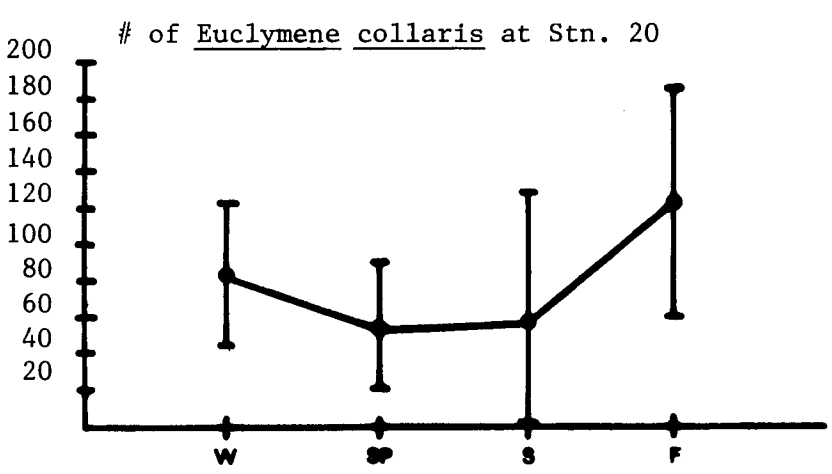
Figure 23. Densities (per $0.1m^2$) of Four Dominant Species at Station 19
(Mean $\pm$ one standard deviation)

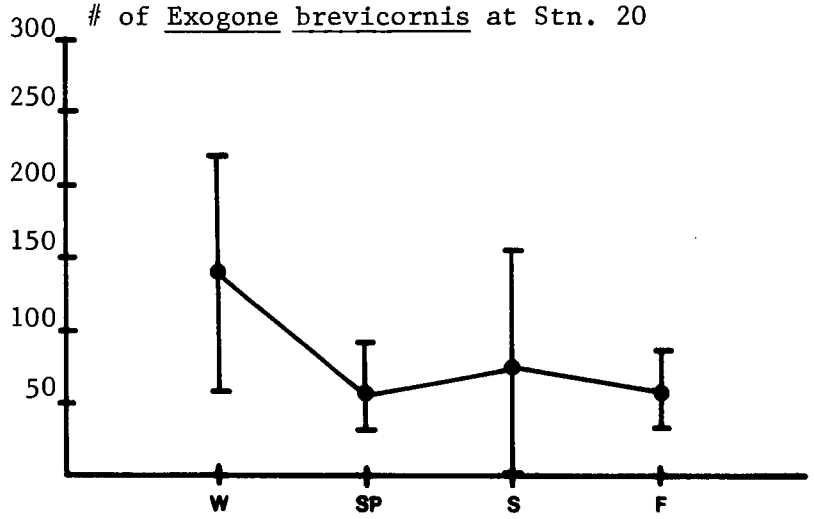
Table 11. Dominant Species Station 20

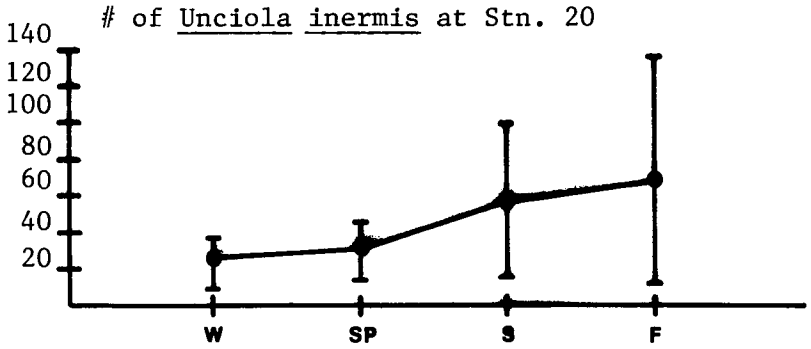
Species	Cruise	$\bar{x}$	SD	CV
Exogone brevicornis	1	141.0	81.8	0.58
	2	61.0	31.6	0.52
	3	74.8	79.8	1.07
	4	60.3	26.0	0.43
	Annual	89.0	70.4	0.79
Euclymene collaris	1	83.3	39.2	0.47
	2	55.8	35.8	0.64
	3	58.0	70.2	1.21
	4	121.0	63.5	0.52
	Annual	77.8	56.3	0.72
Maldanidae	1	3.2	4.7	1.47
	2	96.0	36.0	0.37
	3	110.0	71.7	0.65
	4	36.0	54.4	1.51
	Annual	60.3	65.1	1.08
Archiannelida	1	26.8	19.9	0.74
	2	43.5	19.7	0.45
	3	63.2	66.4	1.05
	4	54.7	55.7	1.02
	Annual	46.6	45.2	0.97
Exogone hebes	1	57.8	30.6	0.53
	2	31.5	10.3	0.33
	3	39.2	35.3	0.90
	4	46.8	20.1	0.43
	Annual	44.7	27.5	0.62
Unciola inermis	1	23.5	13.9	0.59
	2	29.3	16.0	0.55
	3	58.3	41.8	0.72
	4	70.3	58.3	0.83
	Annual	44.4	38.4	0.87
Parapionosyllis longicirrata				
	1	61.8	22.3	0.36
	2	17.2	23.3	1.38
	3	22.0	31.1	1.41
	4	34.5	33.2	0.96
	Annual	35.5	31.5	0.89

Station 20

Species	Cruise	$\bar{x}$	SD	CV
Sphaerosyllis brevifrons				
	1	33.5	43.8	1.31
	2	3.0	4.2	1.40
	3	25.3	43.2	1.71
	4	42.8	59.4	1.39
	Annual	26.8	41.8	1.55
Ericthonius rubricornis				
	1	0.7	1.2	1.71
	2	36.3	16.1	0.44
	3	34.3	38.9	1.13
	4	0.5	0.6	1.20
	Annual	17.8	27.4	1.54







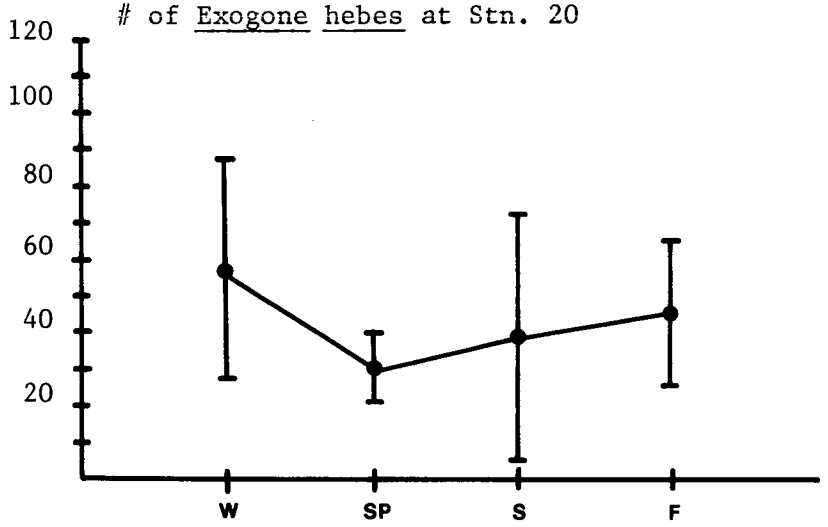


Figure 24. Densities (per $0.1m^2$) of Four Dominant Species at Station 20

notable for the absence of a single very dominant species. Faunal dominance was spread over a fairly large group of species, most of which showed a high degree of constancy. The single exception is the Maldanidae, which were present in very low numbers in Cruise I.

A site close to Station 20, identified as Station 5 in the current monitoring program, was sampled in 1981 and the data analyzed for the benthic grab comparability study (Michael et al., 1981). Dominant species in the 1981 study were the amphipods Ericthonius rubricornis and Unciola inermis and the polychaetes Exogone brevicornis, E. hebes and Euclymene collaris. The major difference was the numerical dominance by Ericthonius rubricornis in the 1981 samples. With the change in the fauna between Stations 19 and 20, the discrepancies here could be attributed to the difference in locality. Nevertheless there was a fair degree of overlap and this is also evidence of the persistence of certain dominant species over a four year period. Station 5 was also characterized by the lack of a single very dominant species.

Station 23 (Table 12, Figure 25)

Although the sediments at this station were somewhat variable in the first three cruises (4 - 20% silt/clay), the fauna was consistently dominated by the amphipod Ampelisca agassizi. Densities were typically 2,000 - 3,000 individuals/m^2. The fourth cruise samples, although taken in fairly close proximity, represented a totally different faunal community. Depths were 274-374m rather than the 148-200 m of the first three cruises and the silt/clay percentage in sediments was 32-51%. This change virtually eliminated species dominant in the first three cruises. In addition to Ampelisca agassizi, the bivalve Thyasira flexuosa and the polychaetes Spiophanes wigleyi, Anobothrus gracilis and Aricidea suecica were numerically dominant in this community.

The number of species per replicate was moderately high throughout the year (50-60) and more than 60% were polychaetes. Molluscs were the second most diverse group with about 20% of the species and the amphipods ranked third. The increasing silt/clay percentage in the sediment is correlated with a reduction in the number of amphipod species and an increase in the number of molluscs.

Taxa which were more abundant in the different community sampled in the fourth cruise were Oligochaeta, the polychaete taxa Anobothrus gracilis (density: 1000/m^2), Cossuridae and palpate Cirratulidae. The variability of the physical environment in the canyon head was shown in different depths and sediments among replicates for one cruise. Certain other species were recorded in large numbers for some replicates and some cruises, e.g., the ophiuroid Ophelina cylindricaudata (340/m^2, Cruise II; 240/m^2, Cruise III), the cumacean Diastylis bispinosa (390/m^2, Cruise III; 60/m^2, Cruise IV) and the polychaete Minuspio (210/m^2, Cruise III; 460/m^2, Cruise IV).

Station 25 (Table 13, Figure 26)

Located on the flank of Lydonia Canyon, Station 25 had only moderate species richness (40 - 50 species/replicate) and was dominated by the amphipod Ampelisca agassizi. Sediments were medium sands with low silt/clay content (1 - 5%). Apart from Ampelisca all the other dominant species were polychaetes. Species richness was primarily due to the polychaete component which accounted for more than 70% of the species in any sample.

Densities of Ampelisca were consistent and moderately high (1,000 - 2,000m^2). The dominant polychaete taxa such as palpate Cirratulidae, Aricidea sp., Nothria conchylega, Lumbrineris sp. and Aricidea catherinae were present in lower densities (100 - 400/m^2) but constancy was very high. Coefficients of variation were all 0.75 or lower.

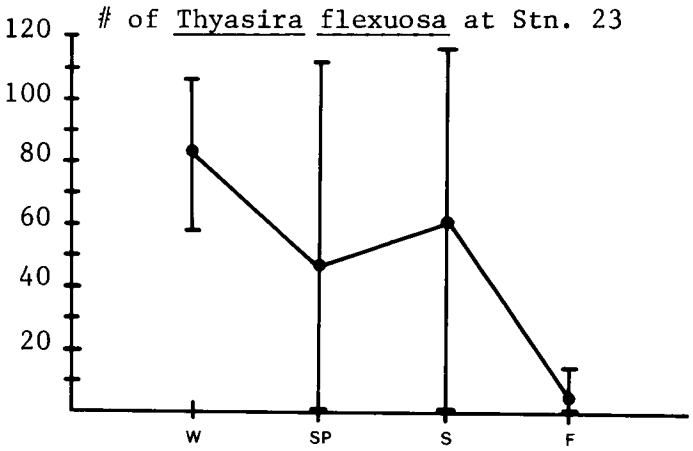
The most abundant mollusc was the bivalve Thyasira which was present in densities of 100/m^2 in Cruise I but was rare or absent in the remaining samples. Other species which, although present in lower densities, were consistent members of the fauna were the polychaetes Spiophanes wigleyi (75/m^2) and Notomastus latericeus(42/m^2). The mollusc and amphipod component of the fauna (apart from Ampelisca) was rather poorly represented.

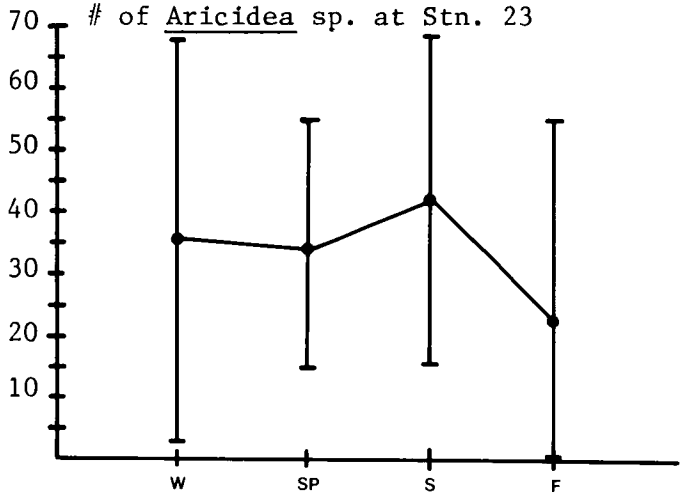
Station 28 (Table 14, Figure 27)

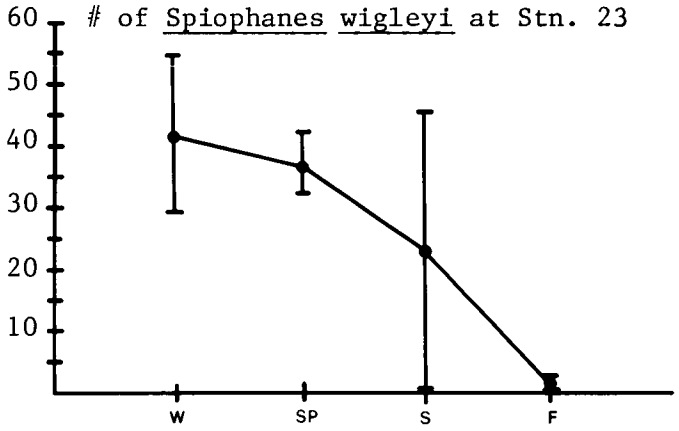
This station,situated on the upcurrent transect,showed a fairly high species richness with from 40 to nearly 80 species per replicate.

Table 12. Dominant Species Station 23

Species	Cruise	$\bar{x}$	SD	CV
Ampelisca agassizi				
	1	363.2	214.0	0.59
	2	286.3	133.7	0.47
	3	270.6	98.6	0.36
	4	0.5	0.6	1.20
	Annual	246.3	190.7	0.77
Thyasira flexuosa	1	83.2	25.9	0.31
	2	48.7	62.9	1.29
	3	60.5	57.1	0.94
	4	5.5	9.7	1.76
	Annual	49.5	38.9	1.08
Oligochaeta	1	16.7	9.4	0.56
	2	2.7	4.9	1.81
	3	4.8	6.9	1.44
	4	190.0	181.3	0.95
	Annual	45.0	103.9	2.31
Spiophanes wigleyi				
	1	42.0	12.9	0.31
	2	37.7	4.7	0.12
	3	23.2	22.9	0.99
	4	0.7	1.5	2.14
	Annual	27.2	20.8	0.76
Anobothrus gracilis				
	1	0.0	0.0	
	2	1.7	2.2	1.29
	3	0.0	0.0	
	4	100.2	93.1	0.93
	Annual	20.8	57.0	2.74
Aricidea suecica	1	28.7	34.0	1.18
	2	26.7	22.3	0.84
	3	12.2	29.8	2.44
	4	0.0	0.0	
	Annual	17.6	27.4	1.55







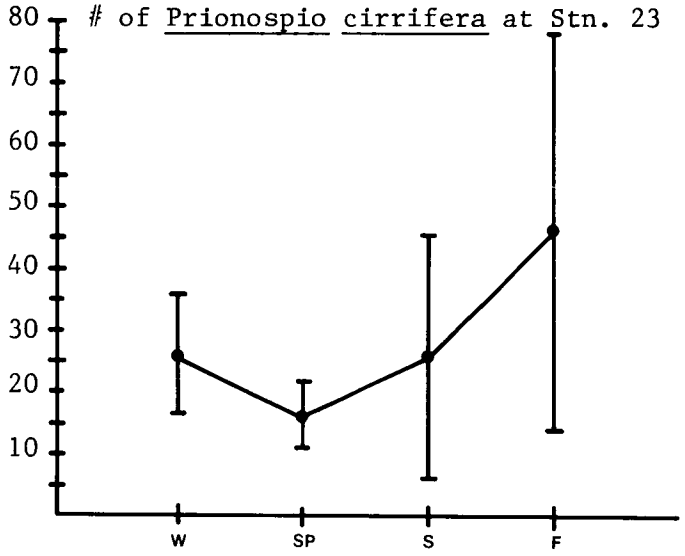
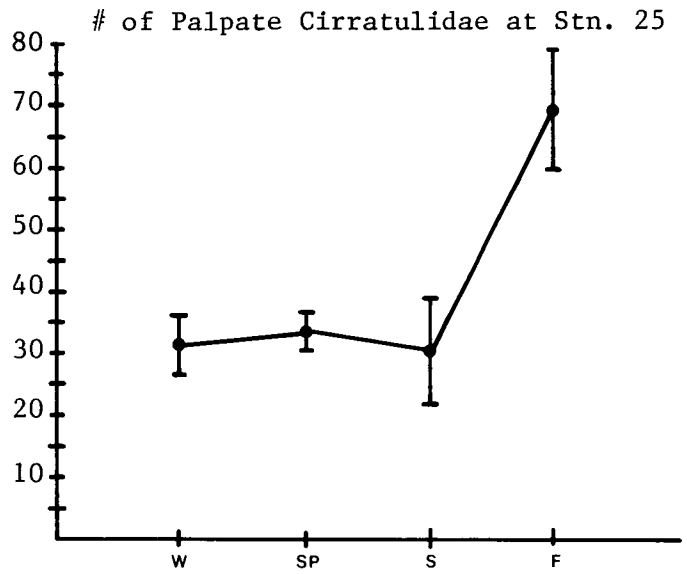
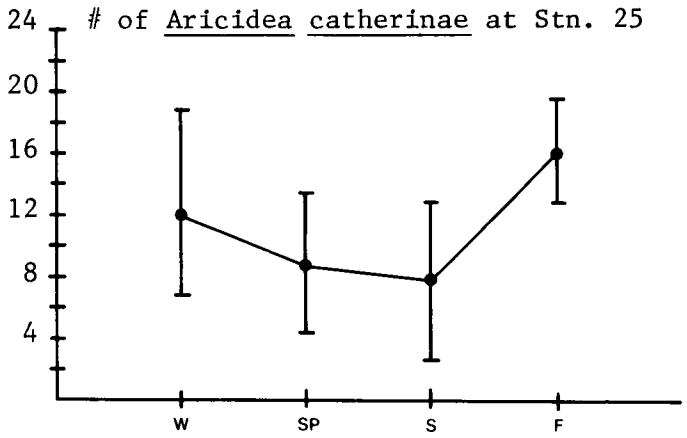


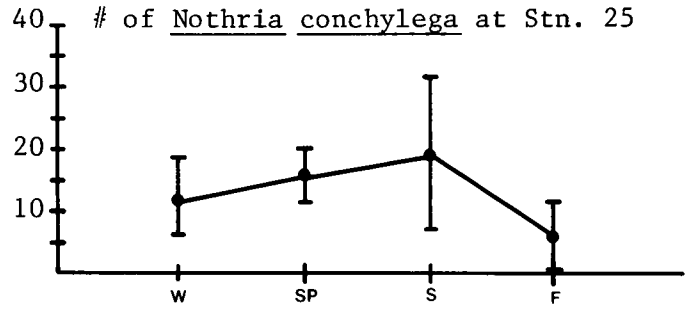
Figure 25. Densities (per $0.1m^2$) of Four Dominant Species at Station 23
(Mean $\pm$ one standard deviation)

Table 13. Dominant Species Station 25

Species	Cruise	$\bar{x}$	SD	CV
Ampelisca agassizi	1	106.7	84.3	0.79
	2	201.5	94.7	0.47
	3	211.8	98.4	0.47
	4	115.3	94.8	0.82
	Annual	158.9	98.9	0.62
Palpate Cirratulidae	1	31.8	5.4	0.17
	2	33.8	3.3	0.10
	3	30.2	8.2	0.27
	4	69.5	9.7	0.14
	Annual	39.3	16.9	0.43
Aricidea sp.	1	23.0	8.4	0.36
	2	13.0	4.2	0.33
	3	7.7	1.4	0.18
	4	24.3	6.2	0.25
	Annual	16.7	9.0	0.54
Nothria conchylega	1	12.2	6.2	0.51
	2	15.8	4.2	0.27
	3	19.5	12.8	0.66
	4	6.5	5.3	0.81
	Annual	13.9	9.2	0.66
Lumbrineris sp.	1	9.0	4.0	0.45
	2	8.8	7.2	0.82
	3	11.2	7.6	0.68
	4	30.3	6.4	0.21
	Annual	13.8	10.3	0.75
Aricidea catherinae	1	12.0	7.2	0.60
	2	9.0	4.7	0.52
	3	8.0	5.0	0.62
	4	16.2	3.6	0.22
	Annual	11.0	6.0	0.55







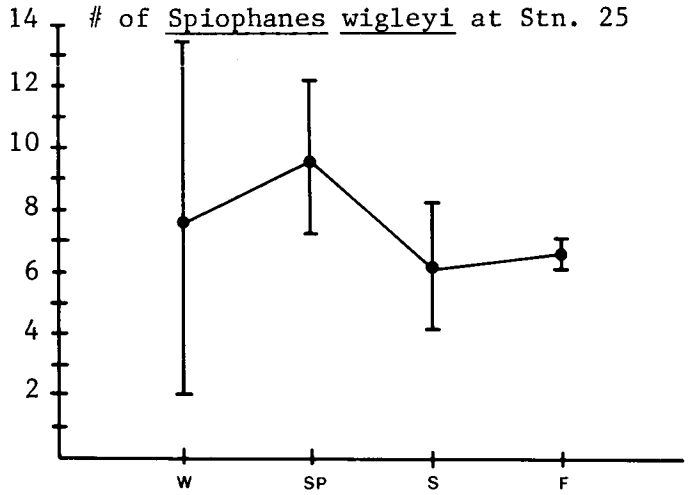


Figure 26. Densities (per $0.1m^2$) of Four Dominant Species at Station 25

Table 14. Dominant Species Station 28

Species	Cruise	$\bar{x}$	SD	CV
Archiannelida	1	152.8	105.9	0.69
	2	34.0	68.0	2.00
	3	75.0	101.8	1.36
	4	125.5	31.8	0.25
	Annual	100.2	93.3	0.93
Scalibregma inflatum	1	17.3	8.5	0.49
	2	13.7	12.6	0.92
	3	74.0	49.8	0.67
	4	33.0	7.6	0.23
	Annual	41.2	37.9	0.92
Ampelisca agassizi	1	21.3	11.9	0.56
	2	22.8	3.9	0.17
	3	24.7	6.9	0.28
	4	85.3	49.9	0.58
	Annual	35.4	33.2	0.94
Notomastus latericeus	1	6.2	5.3	0.85
	2	11.5	3.8	0.33
	3	25.3	15.8	0.62
	4	99.0	18.4	0.19
	Annual	30.8	37.1	1.20
Trichophoxus epistomus	1	21.2	2.3	0.11
	2	16.7	7.0	0.42
	3	14.3	7.4	0.52
	4	19.2	5.9	0.31
	Annual	17.8	6.1	0.34
Ericthonius rubricornis	1	9.8	7.3	0.74
	2	14.8	11.1	0.75
	3	30.2	24.4	0.81
	4	1.0	1.4	1.40
	Annual	15.1	17.7	1.17
Arctica islandica	1	3.0	1.7	0.57
	2	7.7	12.8	1.67
	3	31.3	14.9	0.48
	4	11.2	7.7	0.69
	Annual	14.1	15.4	1.09

Station 28

Species	Cruise	$\bar{x}$	SD	CV
Spiophanes bombyx	1	5.3	3.1	0.58
	2	19.5	7.7	0.39
	3	15.7	6.9	0.44
	4	8.0	1.4	0.17
	Annual	11.8	7.6	0.65
Echinarachnius parma	1	0.0	0.0	
	2	18.7	12.7	0.68
	3	17.0	11.6	0.68
	4	0.0	0.0	
	Annual	8.8	12.0	1.36

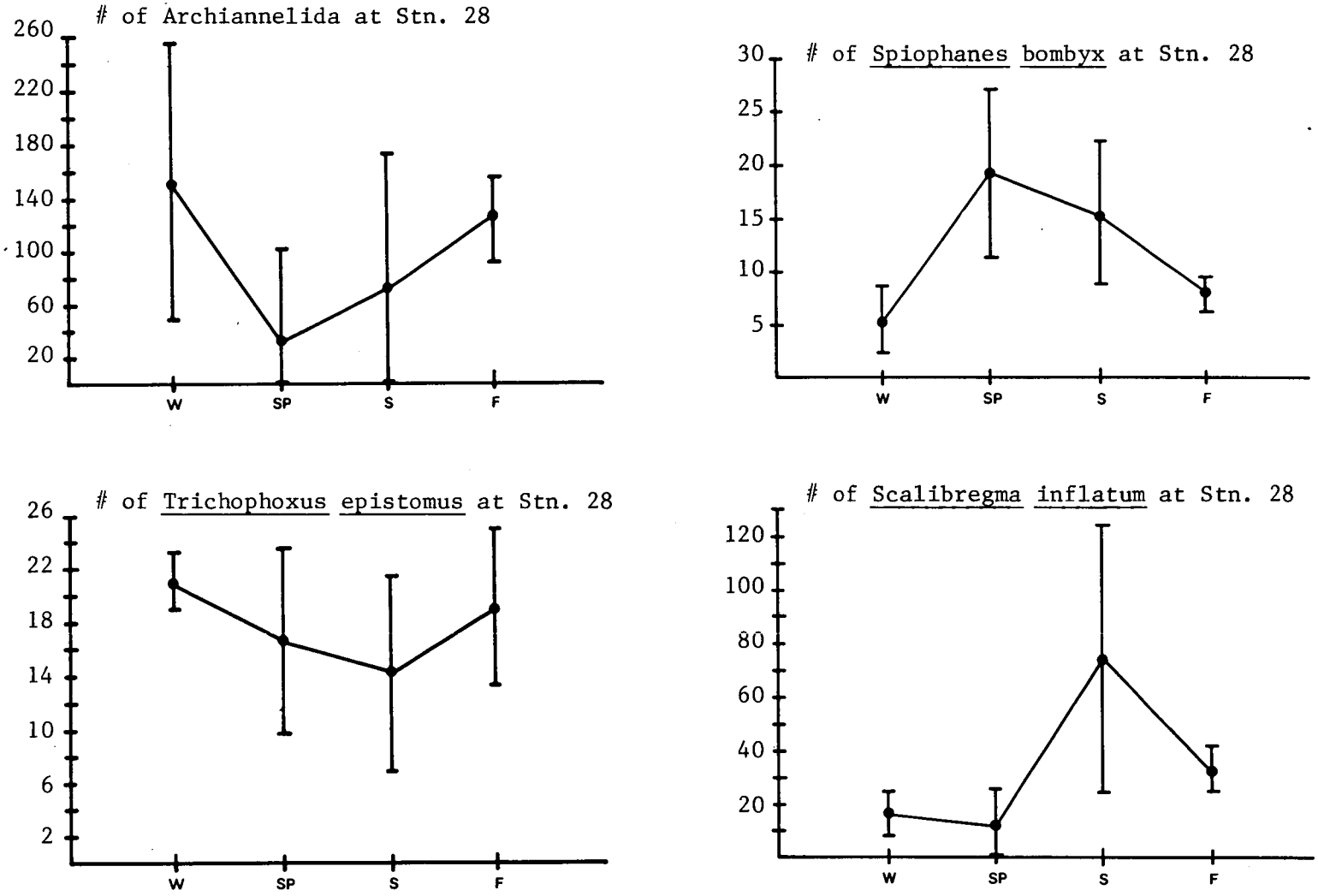


Figure 27. Densities (per $0.1m^2$) of Four Dominant Species at Station 28
(Mean $\pm$ one standard deviation)

Although polychaetes represented approximately 50% of the species found, the amphipod and molluscan components were well represented. Archiannelids were the most abundant because of high densities (greater than 1,000/m^2) in the winter and fall samples, but overall, dominance was shared among several phyla.

The polychaete Scalibregma inflatum (410/m^2)ranked just ahead of the amphipod Ampelisca agassizi (350/m^2) and another polychaete Notomastus latericeus (308/m^2). The amphipod Trichophoxus epistomus, although present in lower densities (178/m^2),was much more consistent than any of the above species and must be considered a characteristic species for this environment. The bivalve Arctica islandica was present in high densities in Cruises III and IV (100 - 300/m^2) probably as a result of larval settlement earlier in the year. The polychaete Spiophanes bombyx was consistently present but in modest densities (118/m^2). The patchy distribution of the sand dollar Echinarachnius parma is seen in the high densities recorded in spring and summer and the total absence in winter and fall samples.

Station 29 (Table 15, Figure 28)

This station in the upcurrent transect located in about 70m water depth was dominated by the small polychaetes Parapionosyllis longicirrata and Exogone hebes. The sand dollar Echinarachnius parma was very abundant in the spring and summer samples (3,000 - 4,000/m^2) but was found in much reduced densities in the fall and was very rare in winter samples. This pattern probably reflects both the large-scale patchy distribution of this species and the settlement of many small juveniles in the spring and summer.

The remaining species in Table 15 are all polychaetes including Aricidea sp., Exogone brevicornis, Scalibregma inflatum, Lumbrineris acuta and Clymenura. These species were present in lower densities--typically less than 200 individuals/m^2. The mollusc and amphipod component was a small fraction of the fauna but two crustacea, the tanaid Leptochelia savignyi, and the amphipod Unciola inermis, were consistently present in fairly low densities (less than 100/m^2).

Table 15. Dominant Species Station 29

Species	Cruise	$\bar{x}$	SD	CV
Echinarachnius parma	1	1.2	1.2	1.00
	2	422.0	207.4	0.49
	3	381.7	337.1	0.88
	4	25.3	22.1	0.87
	Annual	204.3	276.5	1.35
Parapionosyllis longicirrata	1	45.5	31.7	0.70
	2	72.0	42.0	0.58
	3	157.7	76.4	0.48
	4	35.5	64.3	1.81
	Annual	85.4	71.6	0.84
Exogone hebes	1	60.3	23.4	0.39
	2	70.5	32.0	0.45
	3	84.5	38.4	0.45
	4	31.5	14.4	0.46
	Annual	63.8	33.1	0.52
Aricidea sp.	1	14.2	15.9	1.12
	2	26.0	22.4	0.86
	3	26.7	11.5	0.43
	4	10.0	13.7	1.37
	Annual	19.5	16.2	0.83
Exogone brevicornis	1	14.5	13.0	0.90
	2	17.8	7.8	0.44
	3	30.2	8.2	0.27
	4	10.0	3.3	0.33
	Annual	18.9	11.7	0.62
Scalibregma inflatum	1	5.0	6.8	1.36
	2	2.0	1.2	0.60
	3	12.2	8.0	0.66
	4	37.3	23.9	0.64
	Annual	13.0	17.0	1.31

Station 29

Species	Cruise	$\bar{x}$	SD	CV
Lumbrineris acuta	1	9.7	7.7	0.79
	2	12.8	6.3	0.49
	3	15.0	7.3	0.49
	4	3.0	4.8	1.60
	Annual	10.9	7.4	0.68
Clymenura sp. A	1	5.3	5.6	1.06
	2	3.0	2.9	0.97
	3	13.0	8.3	0.64
	4	19.0	17.2	0.91
	Annual	10.6	10.4	0.98

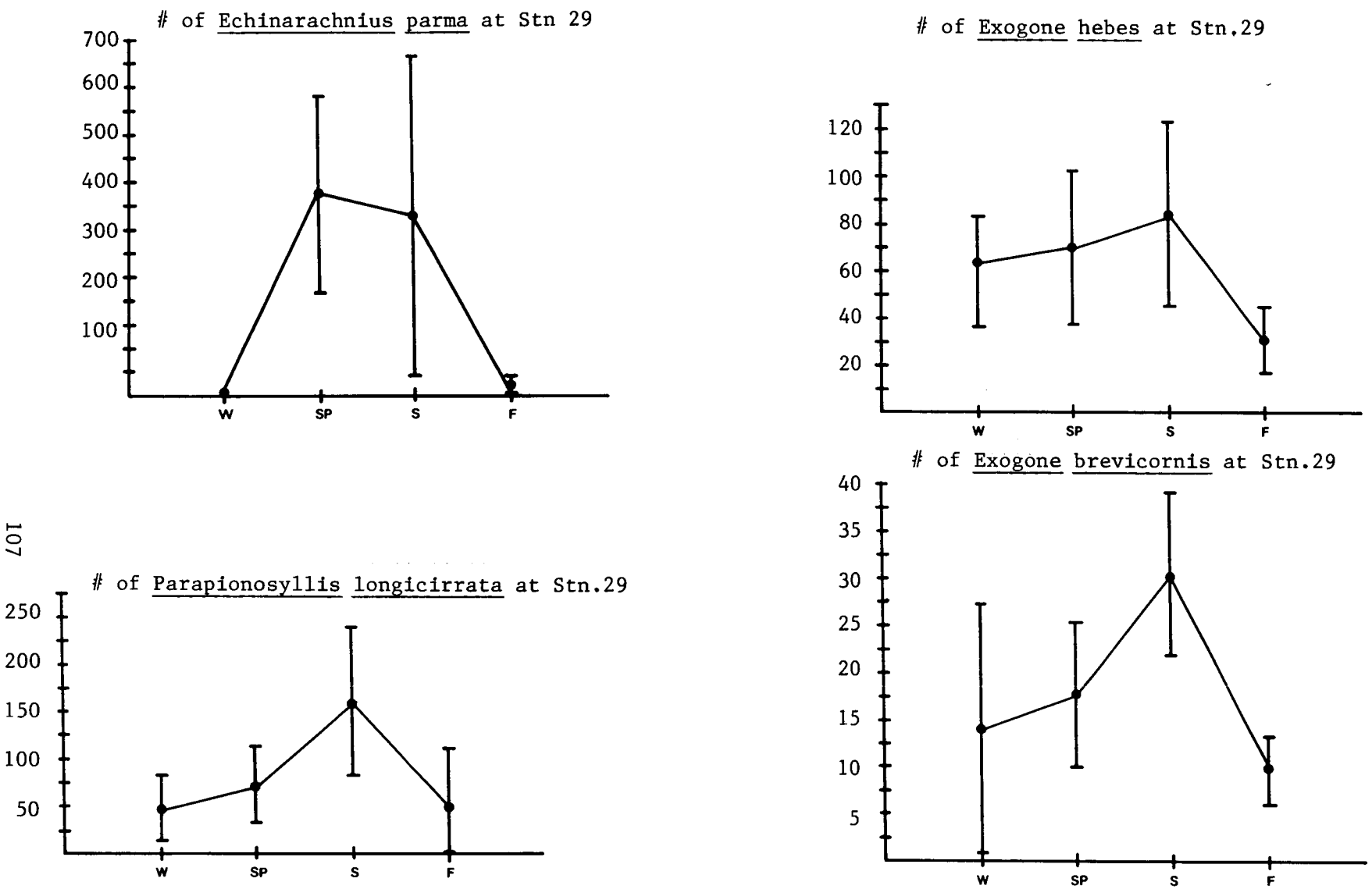


Figure 28. Densities (per $0.1m^2$) of Four Dominant Species at Station 29
(Mean $\pm$ one standard deviation)

Station 37 (Table 16, Figure 29)

The harsh physical environment on the top of the Bank was reflected in low species richness, low densities and poor predictability in the fauna. Coefficients of variation for all but one of the dominant species were above 1.5. The polychaete Exogone hebes and the tanaid Leptochelia savignyi were the most characteristic species. The polychaete Spiophanes bombyx was common in spring samples (226/m^2) and abundant in summer (1,000/m^2) but virtually absent from samples in the fall and winter. The sand dollar, Echinarachnius parma was present in high densities in the first three cruises but very rare in samples taken in the fall. The two remaining polychaete species listed as dominants, Parapionosyllis longicirrata and Scolelepis squamata also showed patchy distribution within replicates for one season and throughout the year.

The species list for this station also includes a number of haustoriid amphipods such as Protohaustorius wigleyi, Acanthohaustorius intermedius, A. millsi, Parahaustorius longimerus and P. attenuatus. Densities of all these were, however, very low. The most abundant and consistent was Protohaustorius wigleyi with an annual mean density of 38/m^2.

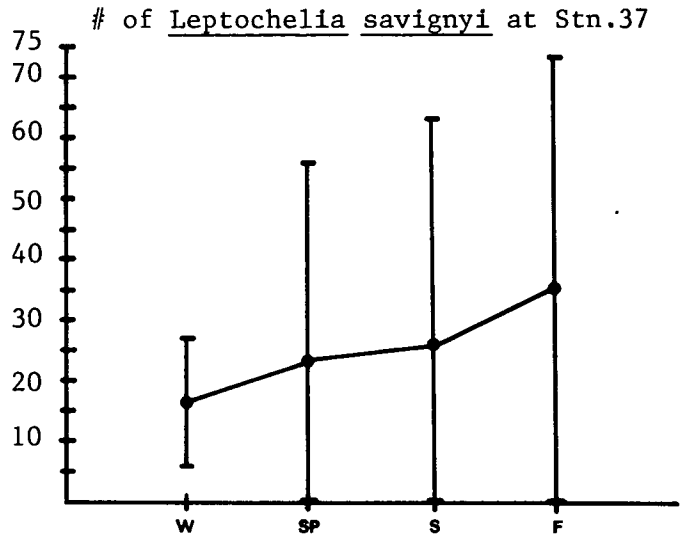
Station 40 (Table 17, Figure 30)

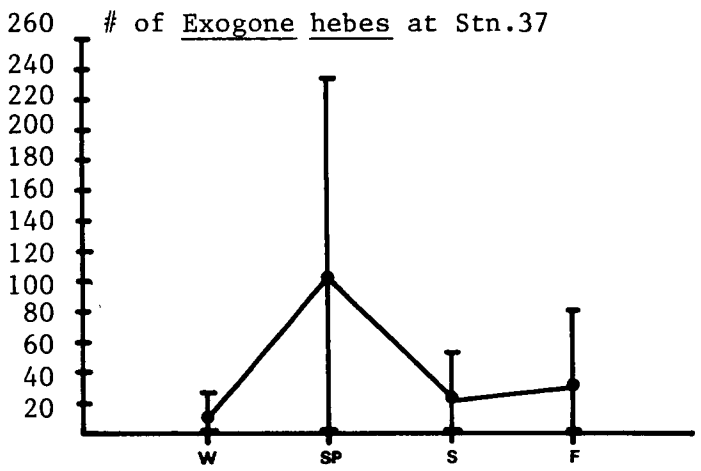
Station 40 in the Gulf of Maine had the highest densities and greatest species richness of all the stations. The three major groups, polychaetes, molluscs and amphipods, were all well represented in the fauna. The most characteristic feature, however, was the extraordinary abundance of a variety of polychaetes. The Sabellidae, which probably includes several species, were present in densities ranging from 2,000 - 30,000 individuals/m^2. Two other polychaetes, Spiophanes kroyeri and Exogone brevicornis, were present throughout the year in densities from 1,000 to 3,500 individuals/m^2. The remaining polychaete species among the dominant species were Melinna elisabethae, Glycera capitata and Notomastus latericeus.

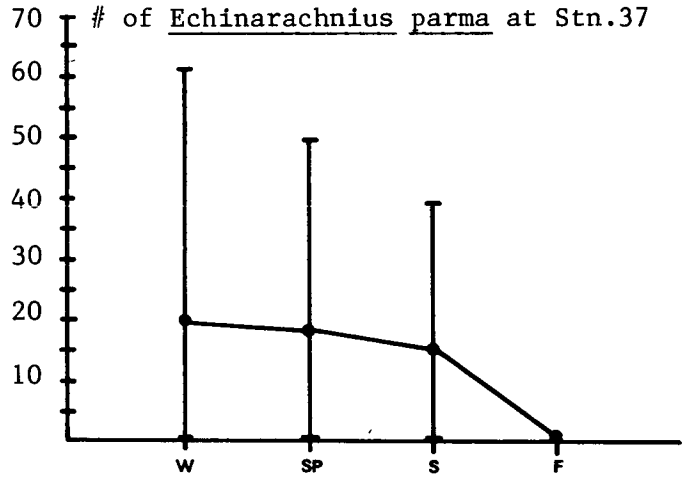
Molluscs were abundant and many different species were found in samples from Station 40. Three bivalves, Bathyarca pectunculoides, Yoldia sapotilla and Crenella glandula were among the numerically dominant species. Amphipods were never abundant but those taxa which were most characteristic of this site were photids, and ampeliscids of the genus Haploops.

Table 16. Dominant Species Station 37

Species	Cruise	$\bar{x}$	SD	CV
Exogone hebes	1	10.2	17.2	1.69
	2	106.0	127.9	1.21
	3	23.0	32.8	1.43
	4	33.0	47.6	1.44
	Annual	41.7	67.0	1.61
Spiophanes bombyx	1	.5	.8	1.60
	2	28.3	22.6	0.80
	3	69.3	168.4	2.43
	4	0.0	0.0	0.00
	Annual	26.6	92.1	3.46
Leptochelia savignyi	1	16.2	10.8	0.67
	2	23.5	31.8	1.35
	3	25.8	37.4	1.45
	4	35.5	37.9	1.07
	Annual	24.4	28.8	1.18
Echinarachnius parma	1	20.0	41.4	2.07
	2	19.0	31.0	1.63
	3	15.5	24.1	1.55
	4	.3	.5	1.67
	Annual	15.4	28.3	1.84
Parapionosyllis longicirrata				
	1	2.8	5.5	1.96
	2	26.8	20.9	0.78
	3	14.3	22.8	1.59
	4	13.3	13.1	0.98
	Annual	13.1	17.7	1.35
Scolelepis squamata	1	1.5	2.3	1.56
	2	25.0	12.7	0.51
	3	7.3	17.9	2.46
	4	3.8	4.2	1.12
	Annual	8.4	13.9	1.65







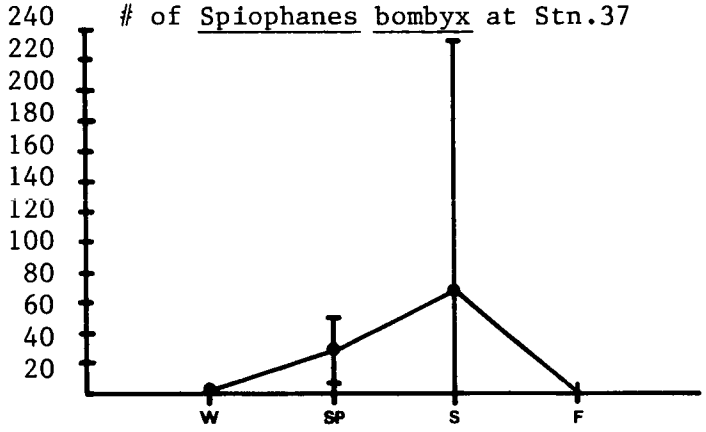


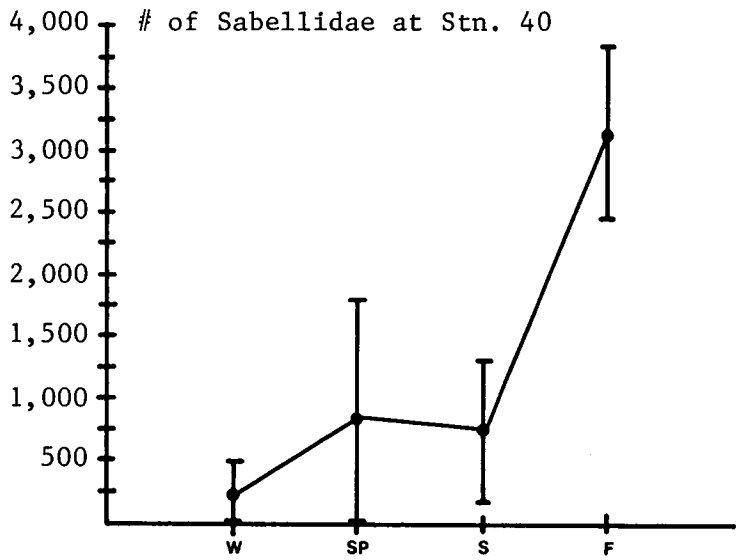
Figure 29. Densities (per $0.1m^2$) of Four Dominant Species at Station 37
(Mean $\pm$ one standard deviation)

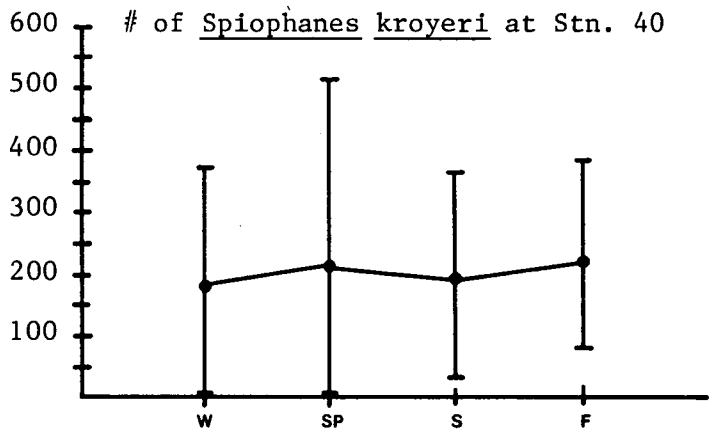
Table 17. Dominant Species Station 40

Species	Cruise	$\bar{x}$	SD	CV
Sabellidae	1	245.8	257.4	1.05
	2	855.3	913.7	1.07
	3	753.8	564.2	0.75
	4	3117.8	681.1	0.22
Annual		1094.5	1201.7	1.10
Spiophanes kroyeri				
	1	187.6	186.6	0.99
	2	213.8	302.3	1.41
	3	194.8	168.3	0.86
	4	226.0	148.3	0.66
Annual		202.7	186.4	0.92
Exogone brevicornis				
	1	114.0	113.9	1.00
	2	148.5	55.7	0.38
	3	204.3	127.5	0.62
	4	350.8	139.0	0.40
Annual		195.3	137.5	0.70
Melinna elisabethae				
	1	102.8	66.2	0.64
	2	87.8	120.7	1.37
	3	43.7	36.9	0.84
	4	64.5	27.5	0.43
Annual		74.4	67.4	0.91
Bathyarca pectunculoides				
	1	26.3	22.8	0.87
	2	22.0	33.8	1.54
	3	14.8	15.6	1.05
	4	32.0	5.7	0.18
Annual		23.1	20.7	0.90
Yoldia sapotilla				
	1	22.8	21.5	0.94
	2	10.0	17.4	1.74
	3	6.8	7.1	1.04
	4	13.8	12.3	0.89
Annual		13.6	15.8	1.16

Station 40

Species	Cruise	$\bar{x}$	SD	CV
Crenella glandula				
	1	13.3	22.3	1.68
	2	35.5	43.2	1.22
	3	.2	.4	2.00
	4	9.8	12.3	1.26
Annual		13.1	24.7	1.89
Glycera capitata				
	1	9.5	5.5	0.58
	2	13.0	2.2	0.17
	3	12.0	12.1	1.01
	4	5.5	2.1	0.38
Annual		10.1	7.4	0.74
Notomastus latericeus				
	1	6.2	7.1	1.15
	2	3.0	3.5	1.15
	3	2.0	1.8	0.90
	4	11.5	7.5	0.65
Annual		5.4	6.1	1.15





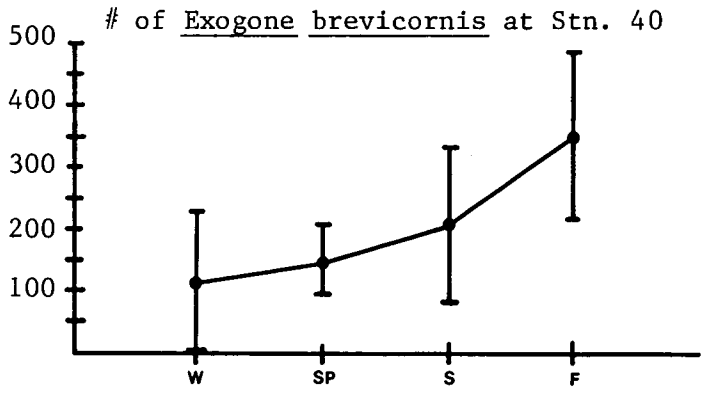


Figure 30. Densities (per $0.1m^2$) of Four Dominant Species at Station 40

Diversity

Figures 31 - 33 indicate Shannon-Weiner diversity values for each station throughout the sampling period. These values and other components of diversity such as evenness, H max and H min are listed in Tables 18 and 19. Most of the values were in the range of from 3 to 4. The two shallow stations on the bank (11 and 37) had the lowest diversity overall. Highest values were found at Stations 20, 28 and the winter samples from Station 40. The Shannon index was typically over 4.0 and reached 4.9 at Station 28. There were no significant trends except at Station 40. The greatly reduced Shannon value (2.1) in the fall is partly due to the extremely high densities of one group - the sabellid polychaetes. The overall decline through the year could also be affected by the different sorting between Cruises I, II and III and IV. TAXON's identification for Cruises III and IV involved more lumping of species groups. There was, however, a significant downward trend from 4.4 to 3.4 between Cruises I and II which were both sorted by Dr. Maurer's group.

Stations showing the least variation through the year and among replicates were 6, 8 and 20. Stations 11 and 37 with the lowest diversity also had low evenness values compared to other sites. Station 40 had very low evenness (.35) in the fall due to the large numbers (35,000/m^2) of one polychaete taxon.

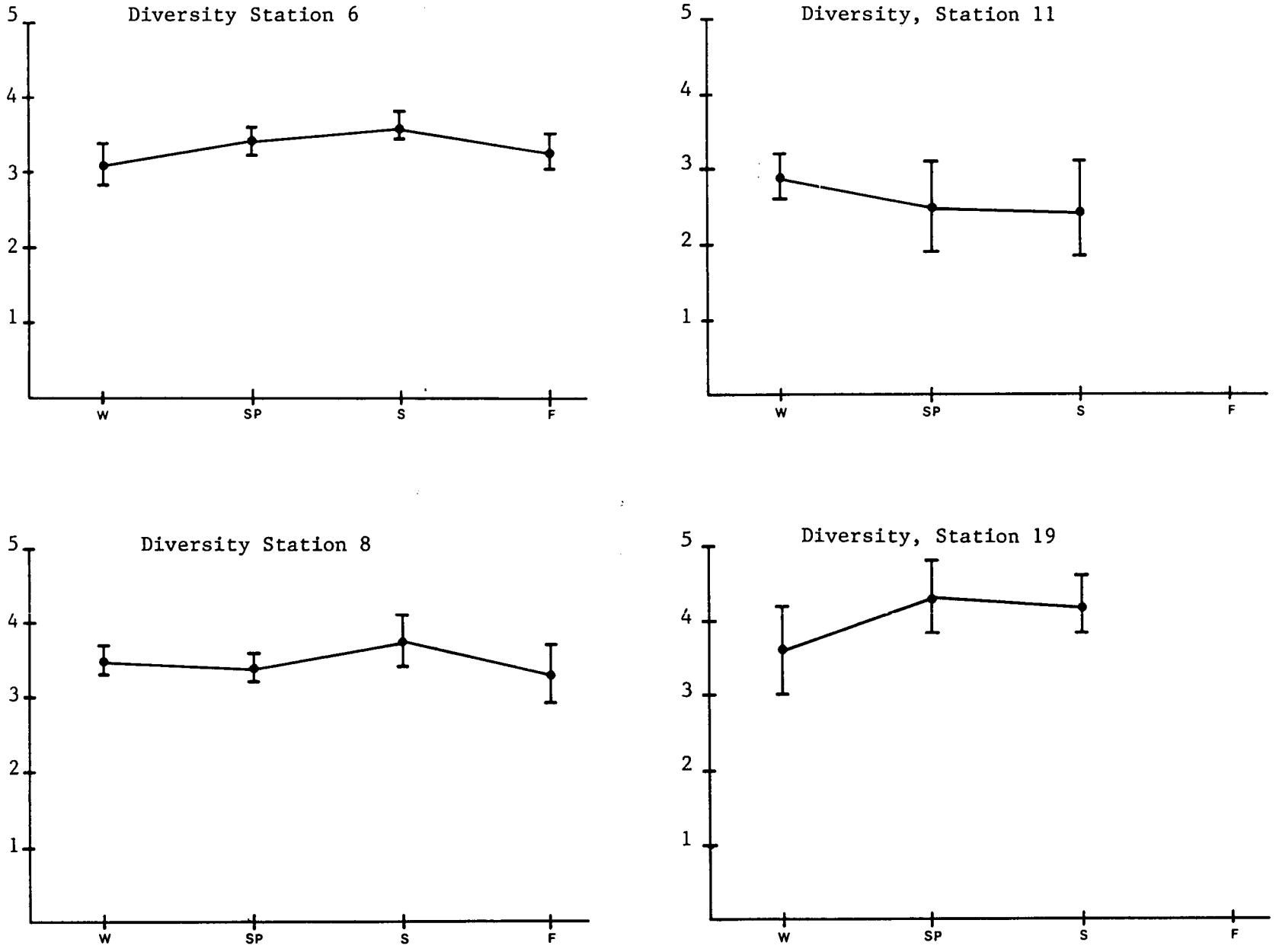
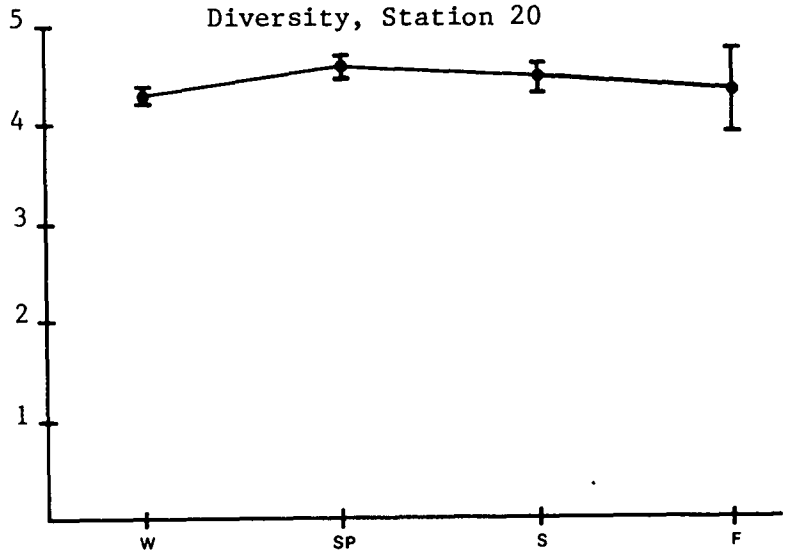
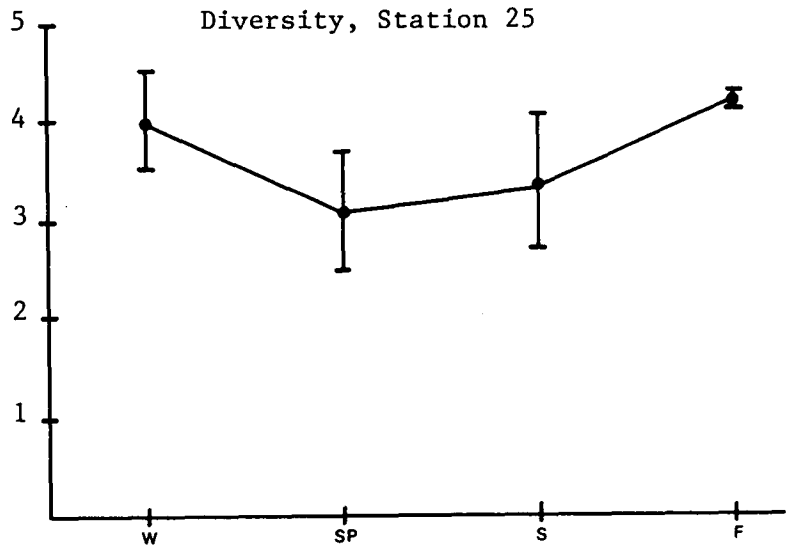
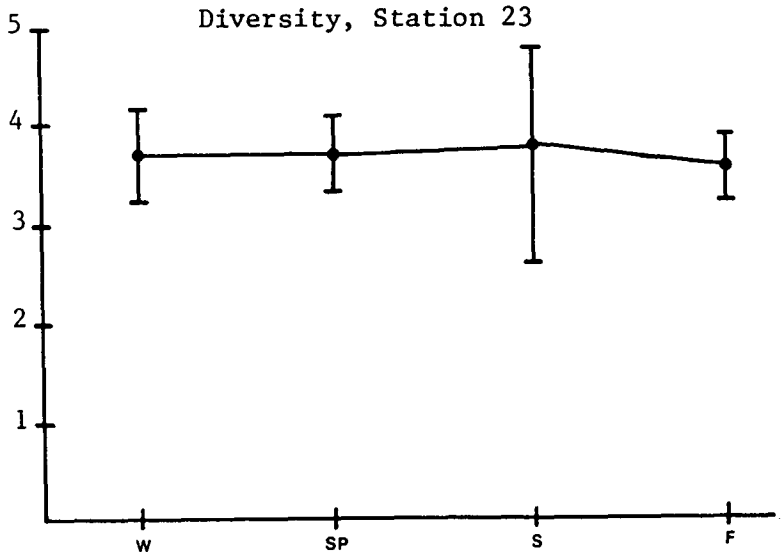


Figure 31. Diversity at Stations 6, 8, 11 and 19 (Mean ± One standard deviation)







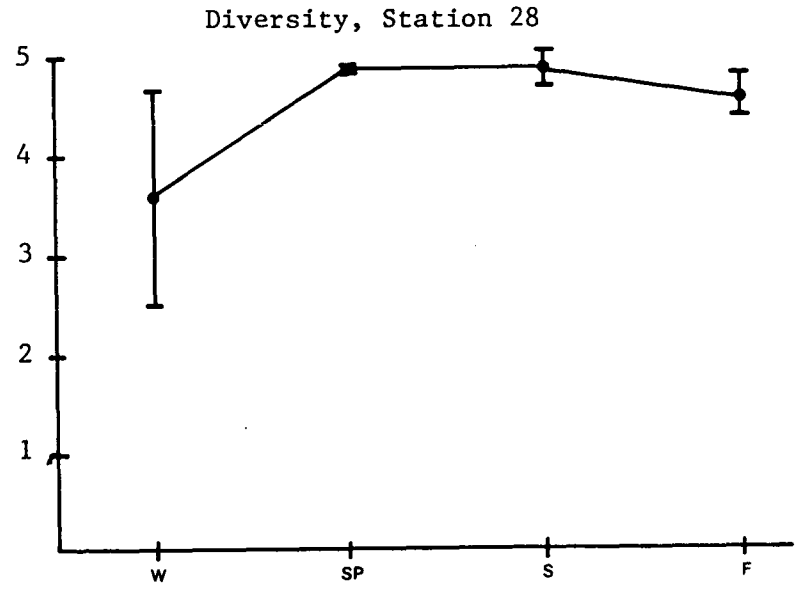
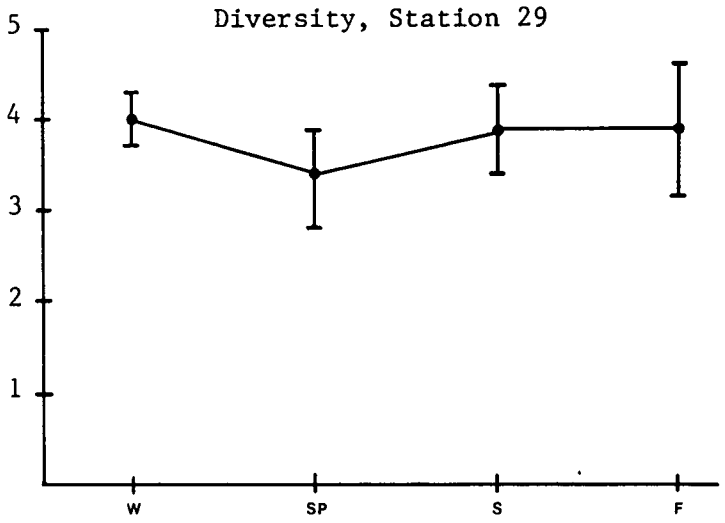
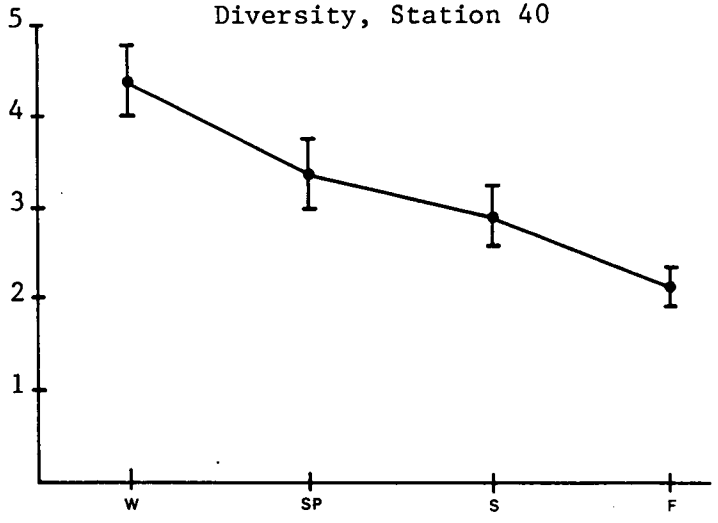


Figure 32. Diversity at Stations 20, 23, 25 and 28





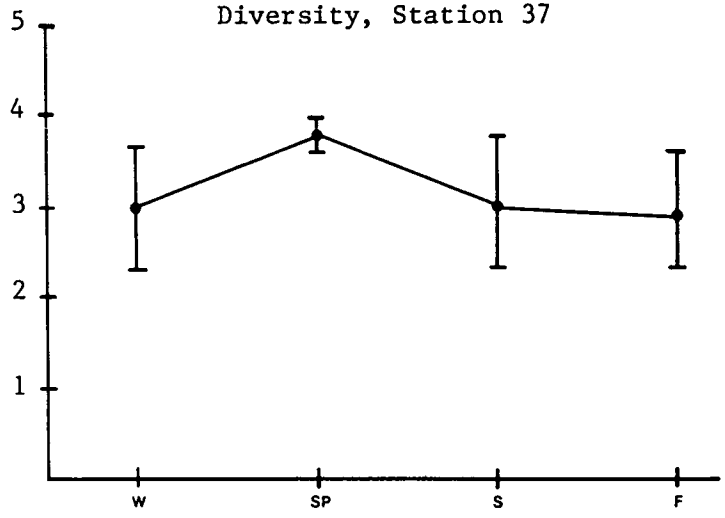


Figure 33. Diversity at Stations 29, 37 and 40

Table 18 Diversity Cruise I (Winter)

Station	H'	SD	J	H max	H min
6	3.1	.33	.65	4.7	.77
8	3.5	.22	.62	5.6	.95
11	2.9	.25	.67	4.4	.82
19	3.6	.59	.63	5.7	1.22
20	4.3	.08	.77	5.5	.79
23	3.7	.53	.65	5.8	.72
25	4.0	.48	.72	5.5	1.53
28	3.6	1.05	.66	5.5	1.39
29	4.0	.34	.76	5.4	1.04
37	3.0	.69	.76	3.9	1.54
40	4.4	.36	.69	6.3	.77
			Cruise II(Spring)		
6	3.4	.20	.71	4.9	.68
8	3.4	.17	.54	6.3	.71
11	2.5	.64	.54	4.7	.38
19	4.3	.49	.70	6.1	1.07
20	4.6	.15	.78	5.9	.95
23	3.7	.38	.65	5.8	.87
25	3.1	.56	.58	5.3	1.13
28	4.9	.00	.84	5.8	1.75
29	3.4	.55	.60	5.8	.65
37	3.8	.24	.74	5.1	.96
40	3.4	.43	.58	5.9	.72

H' Shannon Diversity

SD Standard Deviation

J Evenness

Table 19 Diversity Cruise III(Summer)

Station	H'	SD	J	H max	H min
6	3.5	.19	.68	5.3	.93
8	3.7	.35	.62	6.1	.74
11	2.4	.62	.48	5.1	.25
19	4.1	.38	.69	5.9	1.04
20	4.4	.16	.75	5.9	.85
23	3.7	1.09	.67	5.5	.72
25	3.3	.70	.62	5.4	.99
28	4.9	.22	.79	6.2	1.35
29	3.8	.47	.68	5.7	.63
37	3.0	.75	.69	4.4	1.07
40	2.9	.34	.51	5.8	.68
			Cruise IV(Fall)		
6	3.2	.23	.62	5.1	.6
8	3.3	.41	.56	5.9	.74
20	4.3	.43	.75	5.8	.91
23	3.5	.34	.65	5.5	.82
25	4.1	.09	.75	5.5	1.06
28	4.6	.22	.76	6.0	.96
29	3.9	.72	.72	5.4	.74
37	2.9	.63	.61	5.0	.92
40	2.1	.26	.35	6.1	.21

H' Shannon Diversity

SD Standard Deviation

J Evenness

Classification

Analyses were performed on reduced data sets to avoid systematic problems among the less common species. Dendrograms resulting from classification are shown in Figures 34-37. Figures 34 and 35 are the result of within-season analyses. Figure 36 is an analysis based on replicate samples from Cruise IV. All replicates within any station were clustered together. A similar analysis for each cruise produced the same result. Thus, although some stations clustered with different entities in different seasons, individual replicates remained faithful to the station group.

The most discrete stations overall were 37 on top of the bank, Station 11, the haustoriid dominated community, and Station 6 in the mud patch. Station 6 is separated out because of its faunal dissimilarity from any other stations. Stations 37 and 11 share some overlap in their fauna. Station 40 in the Gulf of Maine is the next most discrete but it is included in a major cluster including all other stations. Samples from station 40 contained some widely distributed species such as Exogone brevicornis and Exogone hebes. There is some separation of Stations 19, 20, 28 and 29 from Stations 8, 23 and 25, particularly in the first two cruises. Station 23 which produced a completely different community in the fourth cruise because of sampling locality shows appropriate change in affinities in the dendrograms for Cruise IV. Because of the difference in some of the dominant species, it is possible that the less common species are responsible for the changes in affinities shown by Stations 8, 19, 20, 28 and 29 in the summer and fall results.

The dendrogram for all cruises (Figure 37) shows a clear separation of Stations 37, 11 and 6. Another major group (IV) includes Stations 19, 20, 28 and 39 (3 seasons for each) and the fall sample for Station 23. At approximately the same level of similarity a fourth major grouping includes all remaining samples. This is further divided into one group consisting of Stations 40, three seasons from Station 25

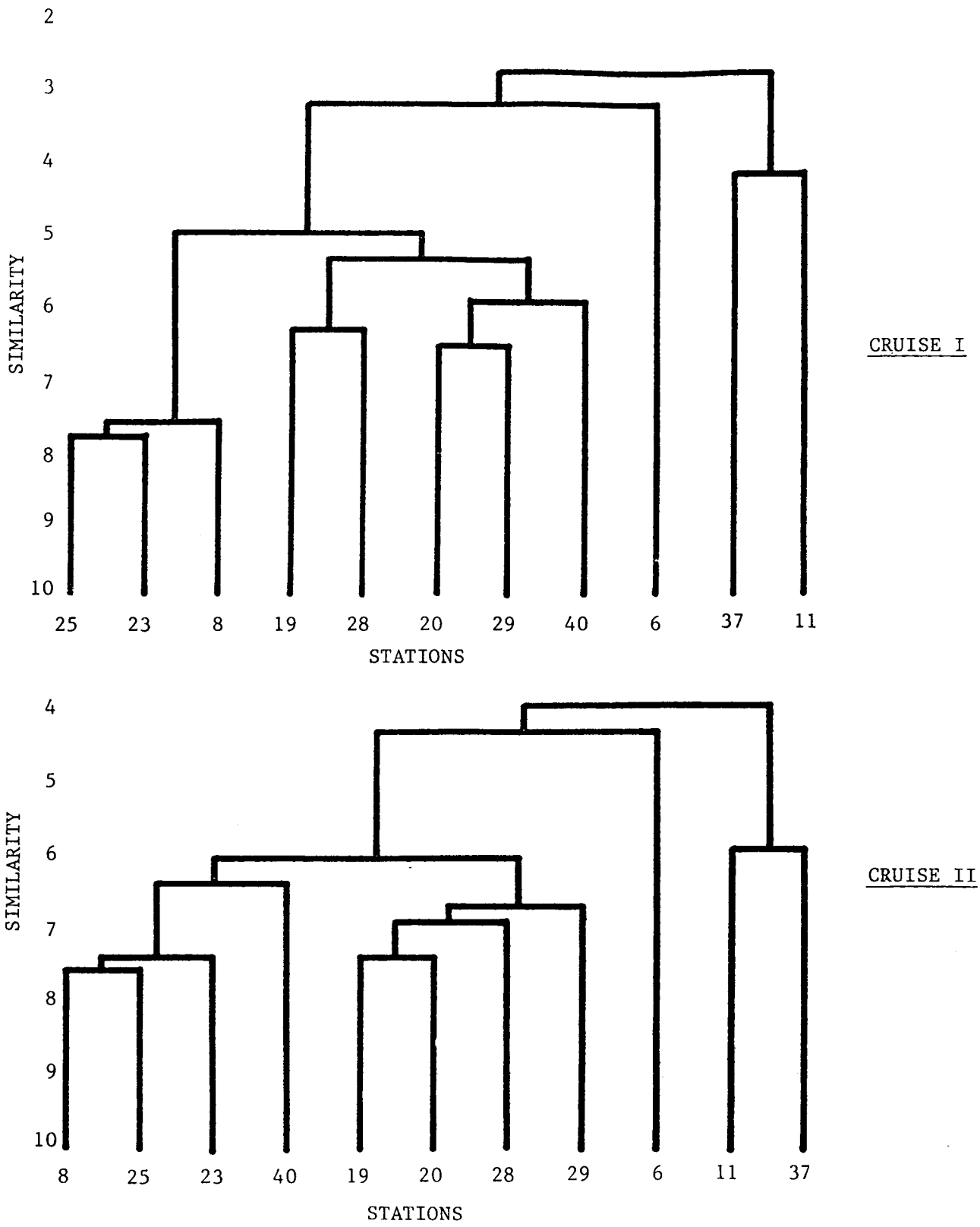


Figure 34. Classification Dendrograms for Cruises I and II

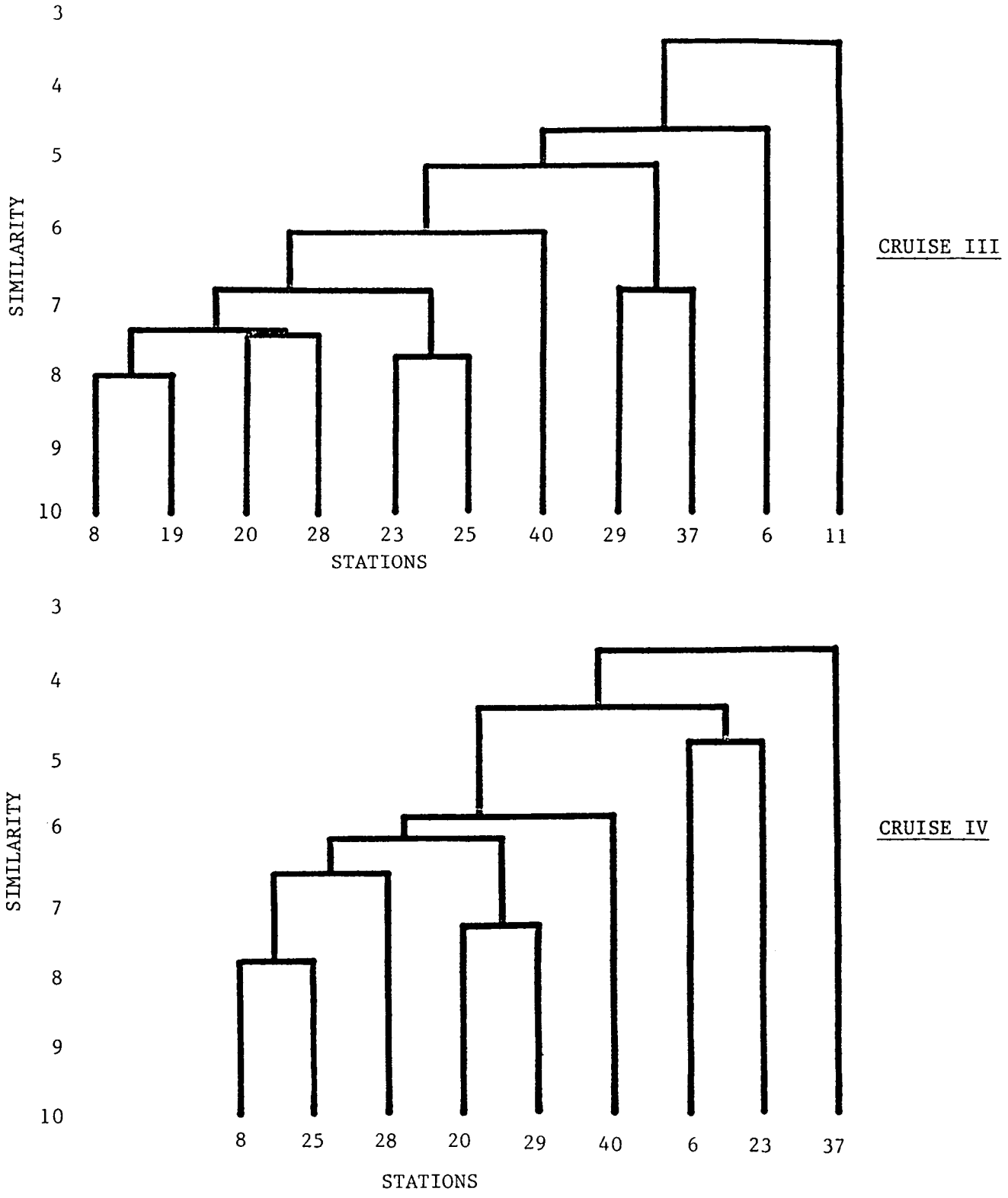
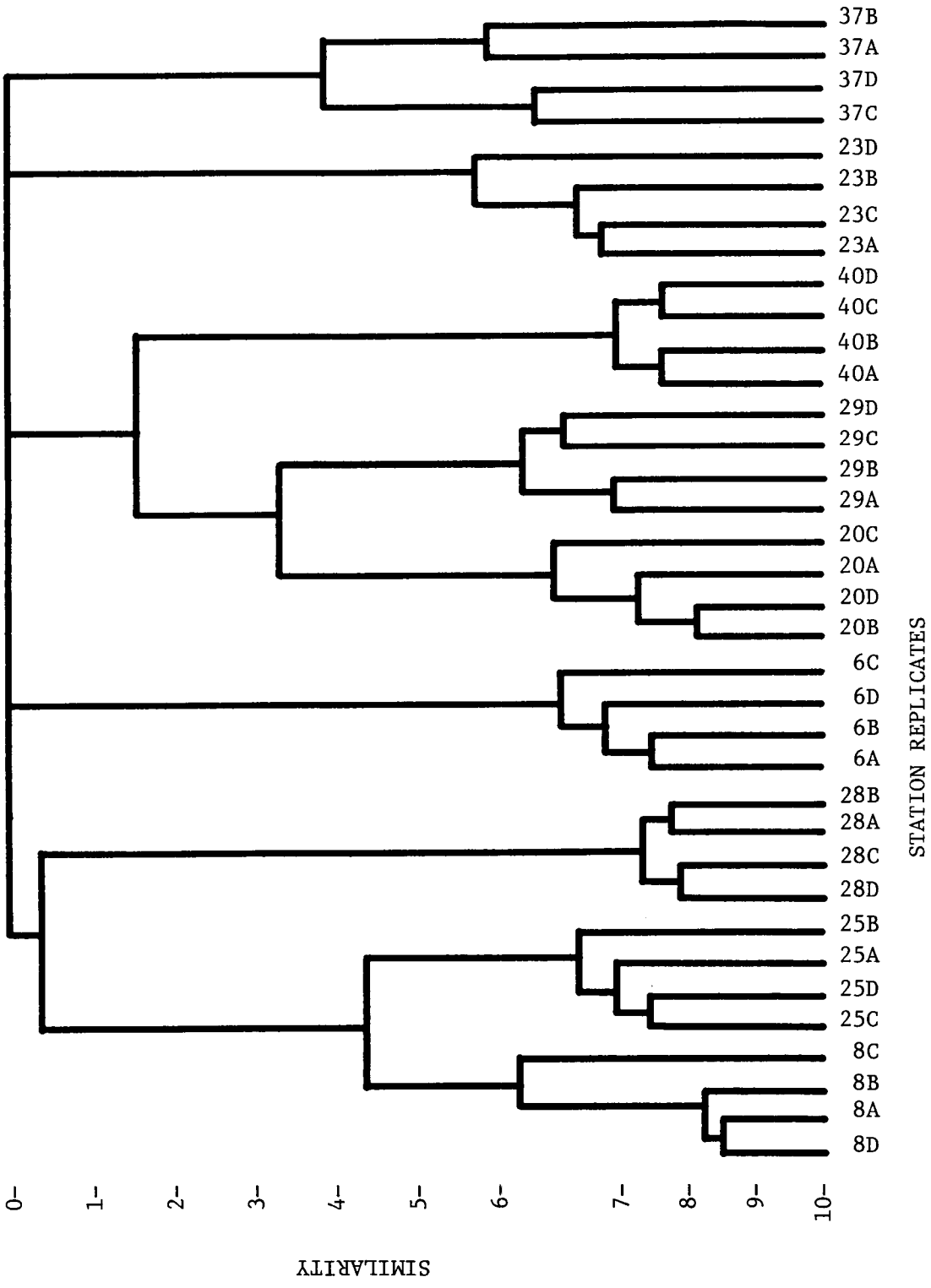


Figure 35. Classification Dendrograms from Cruises III and IV

Figure 36. Classification Dendrogram for Cruise IV based on replicate samples



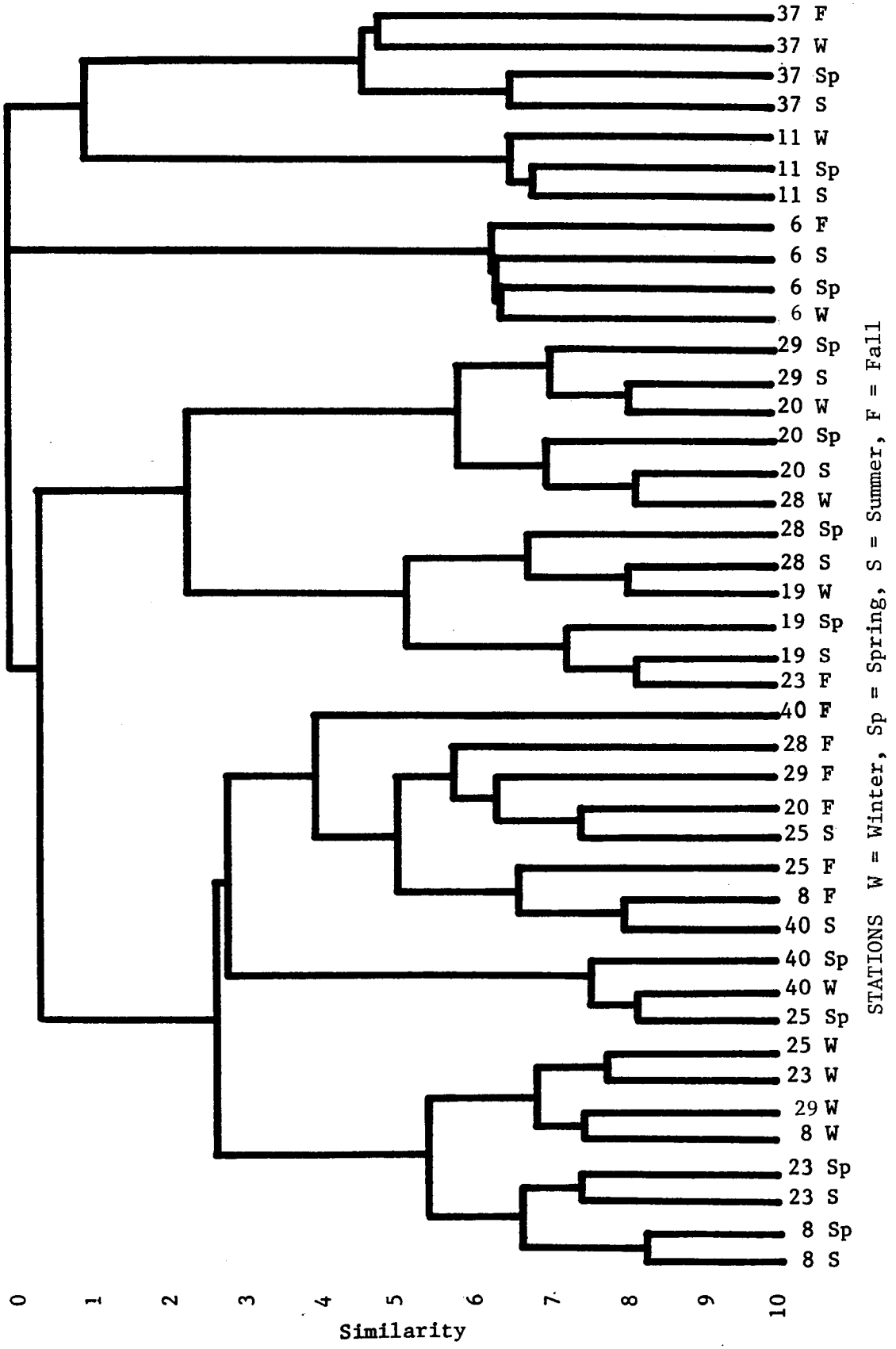


Figure 37. Classification Dendrogram for all cruises

and the fall samples from Stations 8, 20, 28 and 29. The remaining subdivision of group IV includes three seasons from Stations 8 and 23 and one season from 25 and 29.

The dendrogram suggests that seasonality is a factor in faunal affinities at all stations except 6, 11 and 37. Stations 19, 20 and 28 appear to be next in their separation from other sites throughout the year. It is interesting that it is the fall samples from each of these stations that clusters into the other group (IV). The fall sample from Station 40 is quite distinct in Group IV possibly because of the very high abundance of sabellid polychaetes.

Because of the greatly reduced data base and possible identification problems it is not appropriate to overemphasize the results of this combined seasonal analysis. The classification does however show clear separation of certain stations and similarity among those which will be used for comparisons in the monitoring program. There is some evidence of seasonality and since some of these stations are quite discrete in terms of the 6 - 10 dominant species (see Faunal Composition sections) it appears that changes are due to the remaining, less abundant component of the fauna.

DISCUSSION

Abundance and Diversity

For discussion purposes annual mean values for four quantitative parameters (number of species, faunal density, biomass and diversity) have been presented graphically on a transect across Georges Bank (Figures 38-41). We have (rather liberally) assumed that Stations 40, 37, 11, 20, 19, 23 and 25 represent a transect across the bank from the Gulf of Maine to the outer shelf on the flank of Lydonia Canyon. This transect runs through the lease sale area. Stations 28 and 29 represent upstream (net flow) controls for Stations 19 and 20 respectively and Station 8 is a potential downstream control. While the depths and sediment types do not match exactly, a comparison of this type allows us to discuss the feasibility of finding control stations for monitoring.

Figure 38 for species richness illustrates the overall trend for greater species richness with depths. Paired t tests for the annual data set were conducted between adjacent pairs of stations from Station 37 on the crest of the bank to Station 25. Resultant t values are listed in Table 20. Highly significant differences occurred in the pairing of Stations 11 vs 20 and 23 vs 25.

If we consider Stations 28 and 29 potential upstream controls and Station 8 a potential downstream control, the appropriate matches (i.e. similar depth) would be 20 vs 29, 19 vs 28, 19 vs 8 and 28 vs 8. The upstream stations did not differ significantly from lease sale transect stations in the number of species. The only potential downstream site (Station 8) had significantly more species than either 19 or 28. This illustrates the overall trend of increasing species richness in a westward direction across the southern flank of the bank.

Faunal densities show some evidence for an increase in density with depth. The only significant difference in station pairings across the bank was between Stations 11 and 37. The between-transect pairings

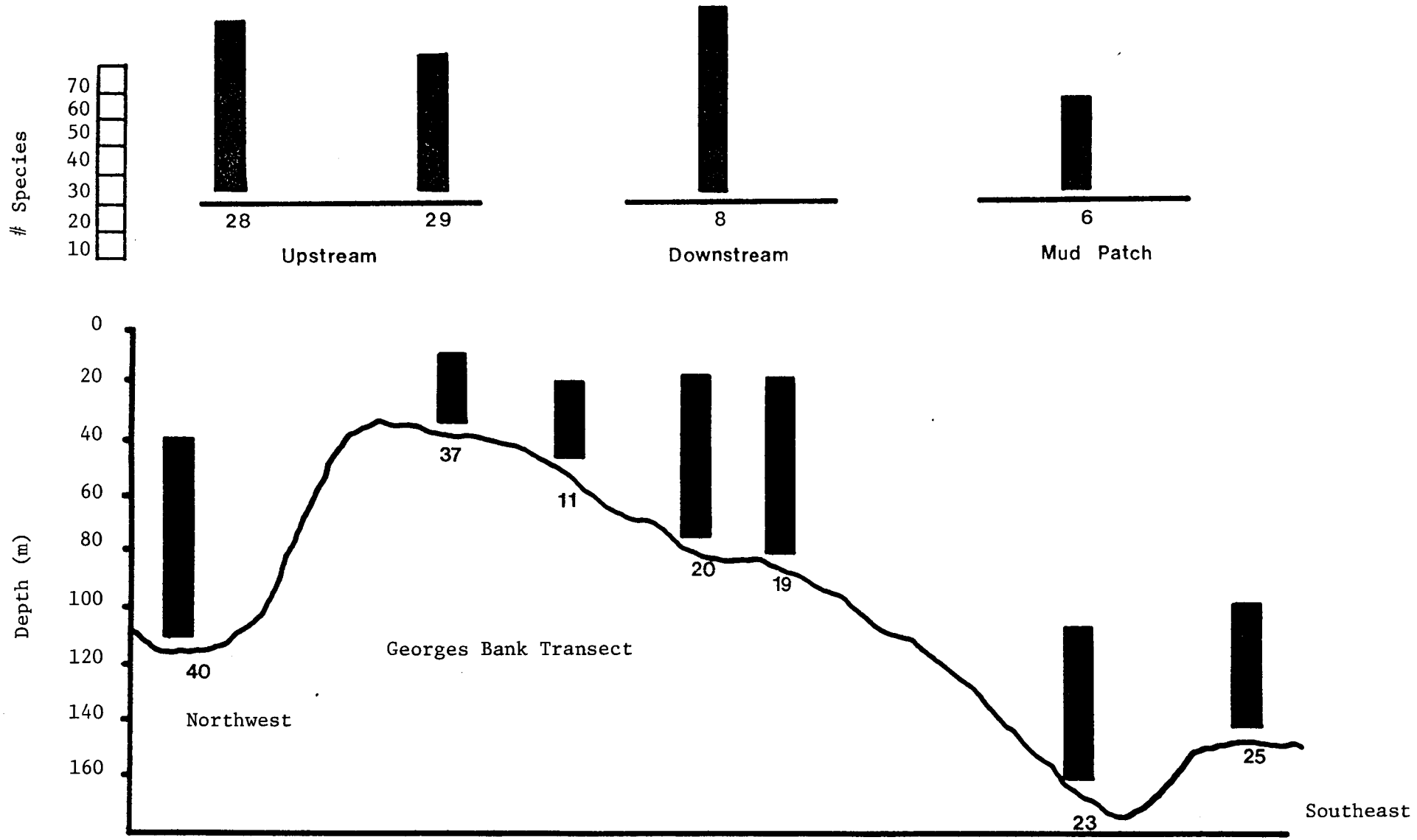


Figure 38. Mean annual species richness : Georges Bank Transect

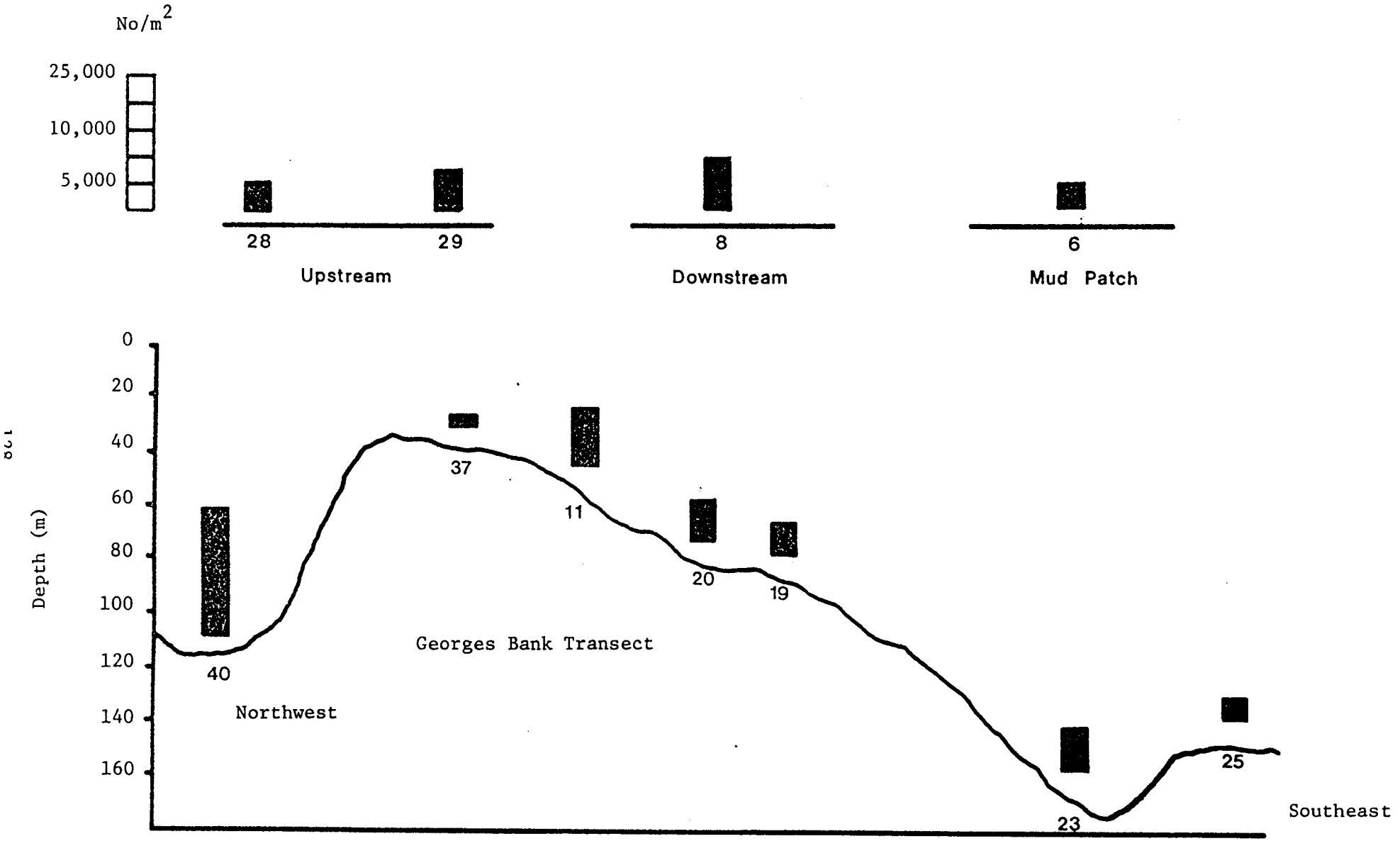


Figure 39. Mean annual densities : Georges Bank Transect

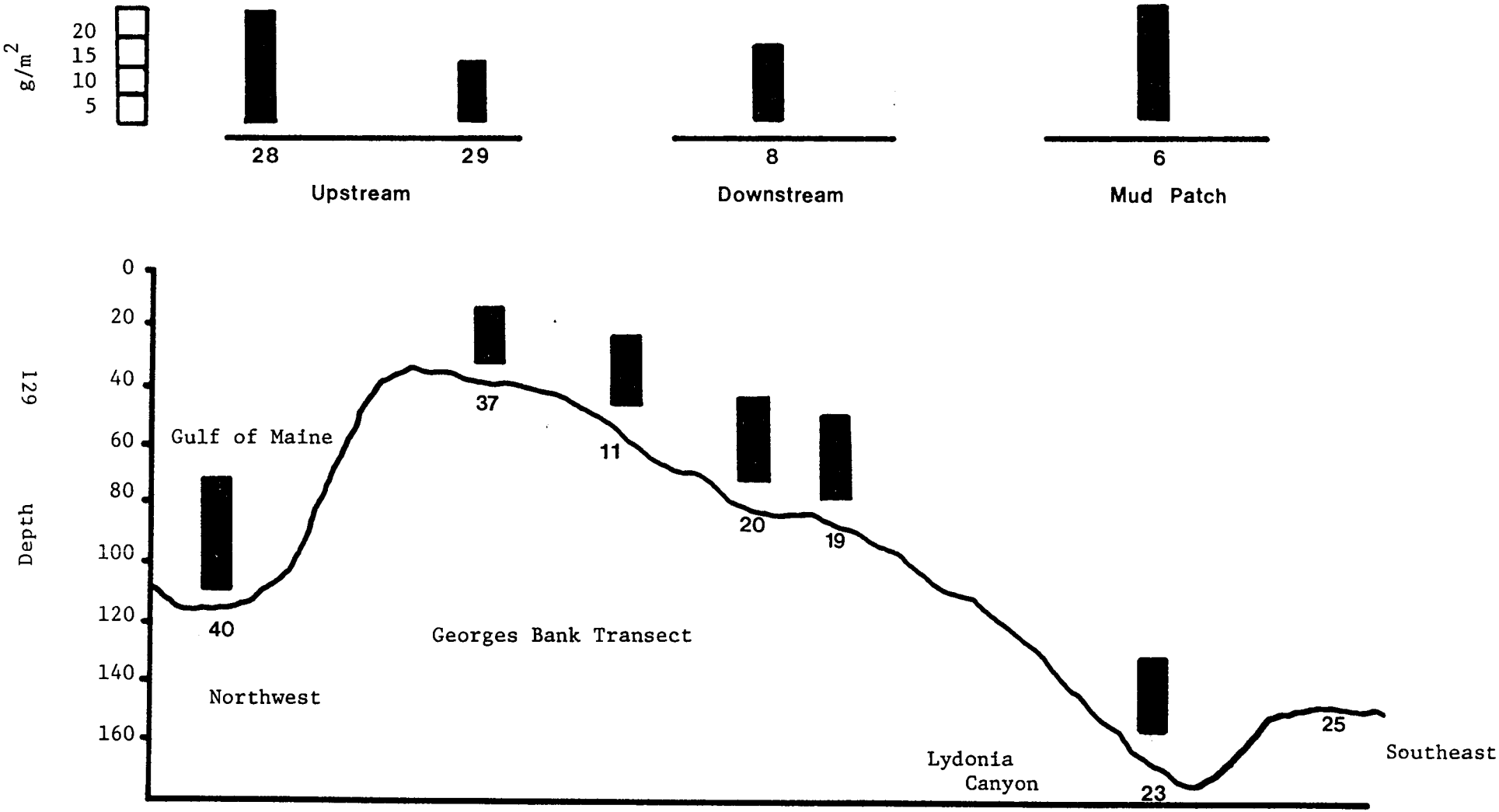


Figure 40. Mean annual biomass: Georges Bank Transect

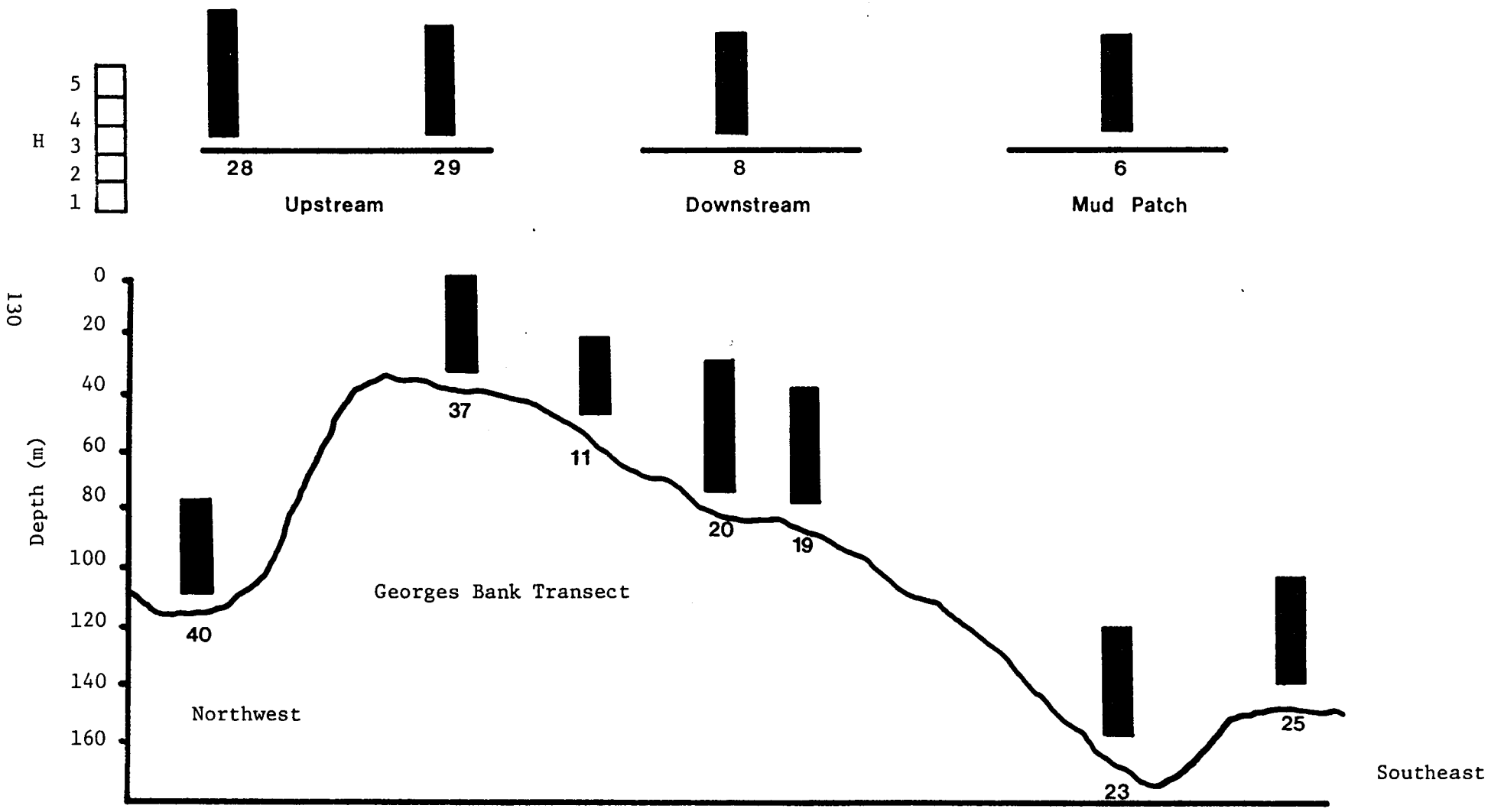


Figure 41. Mean annual diversity: Georges Bank Transect

duplicated results for species richness. There was no significant difference between lease sale transect stations (19 and 20) and upstream stations (28,29) but the downstream station (8) had significantly higher densities than Stations 19 or 28 along the same depth contour.

Table 20. Paired difference tests between stations

Within-Transect Pairs	# Species	#Individuals
11 vs 37	1.73	-3.38**
11 vs 20	-17.13***	1.31
20 vs 19	-1.62	2.22
19 vs 23	1.29	-2.55
23 vs 25	3.94***	6.12
Between Transect Pairs		
20 vs 29	1.74	-0.13
19 vs 28	0.44	1.85
19 vs 8	-0.44	-4.32***
28 vs 8	0.57	4.51***

** p =<0.01

*** p =<0.001

Densities at the six stations on the bank were higher than those reported by Boesch (1979) for similar depths in the Middle Atlantic Shelf. Mean density for Stations 8, 11, 19, 20, 28, 29 in the 50-99m depth range was over 8,000 individuals/m^2. Boesch reported a median density of 4,320/m^2 for the outer shelf area. A difference such as this must however be considered in the correct perspective. Timing of sampling with respect to larval sets can produce even greater discrepancies. Michael (1976) reported a difference of over 26,000 individuals/m^2 between samplings in two different years at one station in Cape Cod Bay. The very large change in density at Station 40 in this data set is another example.

The number of species per 0.1m^2 replicate appears to be similar to that reported by Boesch (1979) for the Middle Atlantic Shelf. Outer Shelf habitats in that study had from 37 to 62 (mean per each habitat type) species per replicate. Stations in the equivalent depth range on Georges Bank (50-100m) were typically in the range of from 40 to 60 species per 0.1m^2 replicate.

Biomass values in Figure 40 are for the first two cruises only. Replicate information for polychaetes was not available. Statistical tests were not performed because of the low number of observations. Stations 6, 28 and 40 had the highest biomass but these values were far less than other stations sampled during the Benchmark Study. Maurer and Leathem (1980) reported 5 stations with polychaete biomass alone of over 30 grams/m^2 and one instance where this component was 74.4 grams/m^2.

Mean diversity values for the year are shown in Figure 41. The only significant difference ($p < .001$) between station pairs was between Stations 11 and 20. There were no significant differences between lease sale transect stations and upstream or downstream comparison stations.

Faunal Persistence

In spite of the fact that Georges Bank is a physically dynamic environment there is a suprisingly high degree of persistence in the fauna. Station 37 on the top of the bank was the only one which showed a high level of variability in composition of both the fauna and sediments. Other than the obvious error in station locations (e.g. Station 23, Cruise IV) return visits to the same locality produced the same fauna - at least in terms of dominant species. There were some occurrences of different species among dominants at the same station but these were due to a sudden increase in opportunists e.g. Spiophanes or heavy sets of juveniles which did not persist. Some stations were more variable in faunal composition than others because of local heterogeneity in sediments. The small distance between Stations 19 and 20 resulted in a complete change in the fauna from a community dominated by the amphipod Ampelisca agassizi to one dominated by the polychaete Exogone brevicornis. There was however a high level of consistency within each station. There are large areas on Georges Bank where the fauna is similar. Ampelisca agassizi is widely distributed along the southern flank of Georges Bank where sediments are fine sands (mode 2 or 3 ϕ) and the silt/clay content from about 3 to 20%.

Further evidence of faunal persistence is found in a comparison of these data with that in the benthic grab comparability study (Michael et al., 1981). In 1981, samples were collected at Station 5 of the current monitoring program, which is near Station 20 for this study. Although there were some faunal differences which could easily be attri-

buted to the slightly different location, five species were among the ten dominant species for both data sets (the polychaetes Exogone brevicornis, Exogone hebes and Euclymene collaris and the amphipods Unciola inermis and Ericthonius rubricornis).

There is an obvious overlap between the fauna on Georges Bank and that of the Middle Atlantic Bight. Table 21 shows the dominant species for three habitat types sampled by Boesch (1979) for which we have equivalent data. All but two of the species listed were found in this study and most figure prominently in our lists of dominant species for Georges Bank. The only obvious exception is the greater densities of the small syllid polychaetes Exogone brevicornis and Exogone hebes on Georges Bank.

We cannot assess long term persistence since this study involves only one year's sampling. The classification analysis suggested some seasonality among less common species. The many similarities between this data set and that of the Middle Atlantic Bight suggest that Boesch's (1979) conclusions might apply here. "The assemblages of the outer shelf and upper slope of the Middle Atlantic Bight have a high proportion of apparently 'conservative' species and relatively few opportunists or 'volatile' forms".

Statistical Sensitivity of the Data

An examination of the replicate spacing between cruises is seen in Figures 42 - 47. These identify the locality where each individual replicate was taken. Shipboard practice was to identify the moment when the grab hit the sea floor so the LORAN coordinates could be recorded. Stations 6 and 8 (Figure 42) represent the range of spacing. In some cases all replicates were taken within a radius of about 200m. In other cases the spread of replicates was over a radius of 500 - 800m. Time of sampling with respect to the tidal cycle had a considerable impact on the spread of replicates, particularly at shallow stations where tidal currents can reach several knots. An example of this is seen at Station 11 (Figure 43) where Cruise II samples form a straight line - presumably due to the drift of the ship with the tide.

In spite of the relatively large area over which replicates were collected inter-sample variance was often very low. Table 22 lists the coefficient of variation for several parameters (species richness, mean particle size and density of a dominant species). In the case of species

Table 21. Numerically Dominant Species from Three Habitats in the Middle Atlantic Bight*

CENTRAL SHELF	SPECIES	MEAN DENSITY (m^{-2})
	Pseudunciola obliquua	200.0
	Tanaissus liljeborgi	78.9
	Trichophoxus epistomus	92.3
	Spiophanes bombyx	219.1
	Echinarachnius parma	63.3
	Goniadella gracilis	113.7
	Protohaustorius wigleyi	53.9
	Spisula solidissima	88.6
	Byblis serrata	54.2
	Lumbrinerides acuta	25.3
OUTER SHELF	SPECIES	MEAN DENSITY (m^{-2})
	Unciola irrorata	260.0
	Spiophanes bombyx	329.0
	Ampelisca vadorum	460.4
	Goniadella gracilis	188.0
	Lumbrinerides acuta	91.0
	Byblis serrata	148.9
	Trichophoxus epistomus	63.7
	Erichthonius rubricornis	302.2
	Euchone sp. A	111.1
	Ampelisca agassizi	215.2
SHELF BREAK	SPECIES	MEAN DENSITY (m^{-2})
	Ampelisca agassizi	566.2
	Lumbrineris latreilli	165.6
	Thyasira flexuosa	152.5
	Onuphis pallidula	157.8
	Aricidea neosuecica	405.9
	Harbansus bowenae	101.5
	Spiophanes wigleyi	86.0
	Amphioplus macilentus	232.1
	Onuphis atlantica	63.5
	Unciola irrorata	70.0

* Compiled from Boesch (1979).

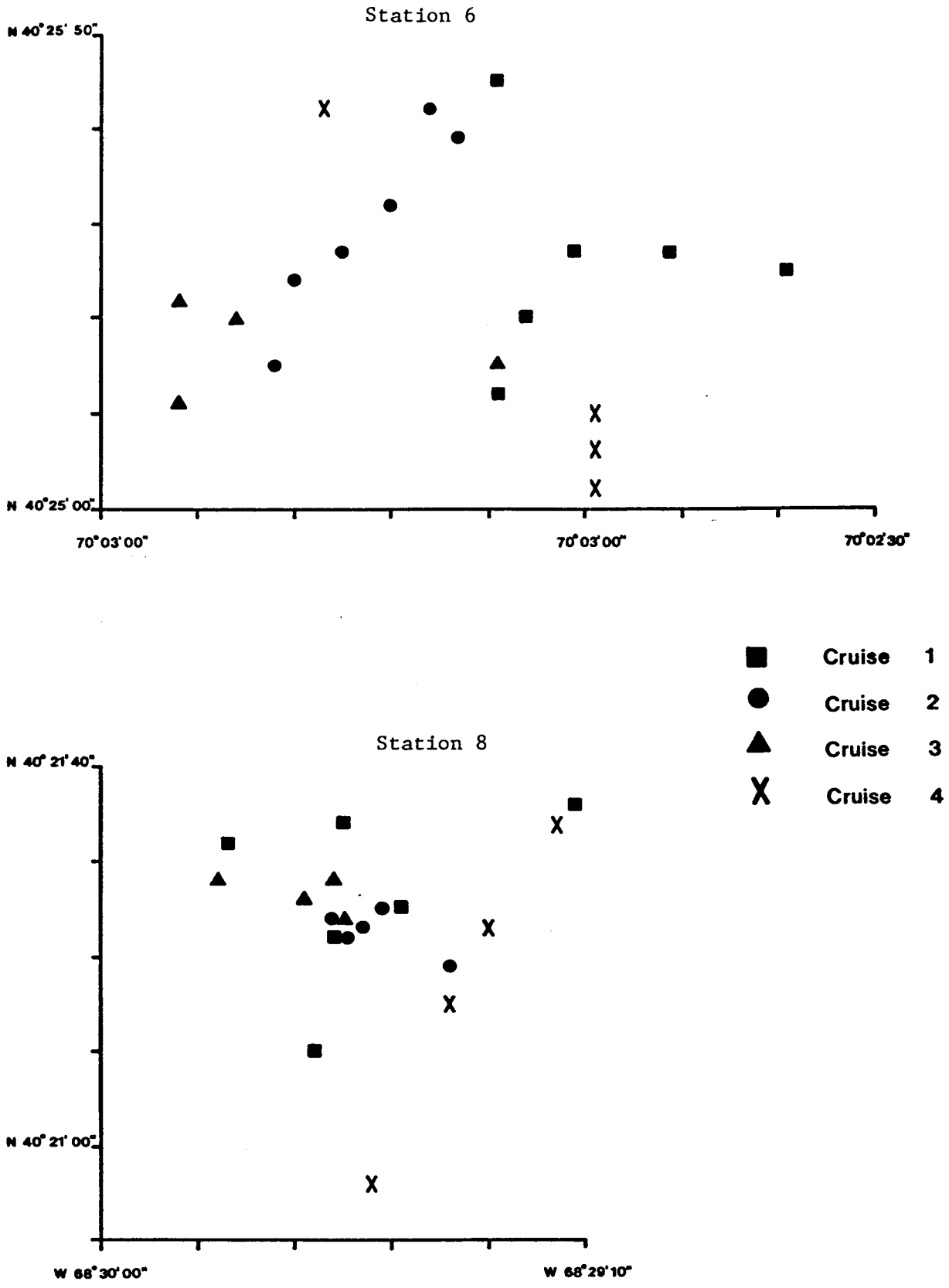


Figure 42 Replicate spacing at stations 6 and 8

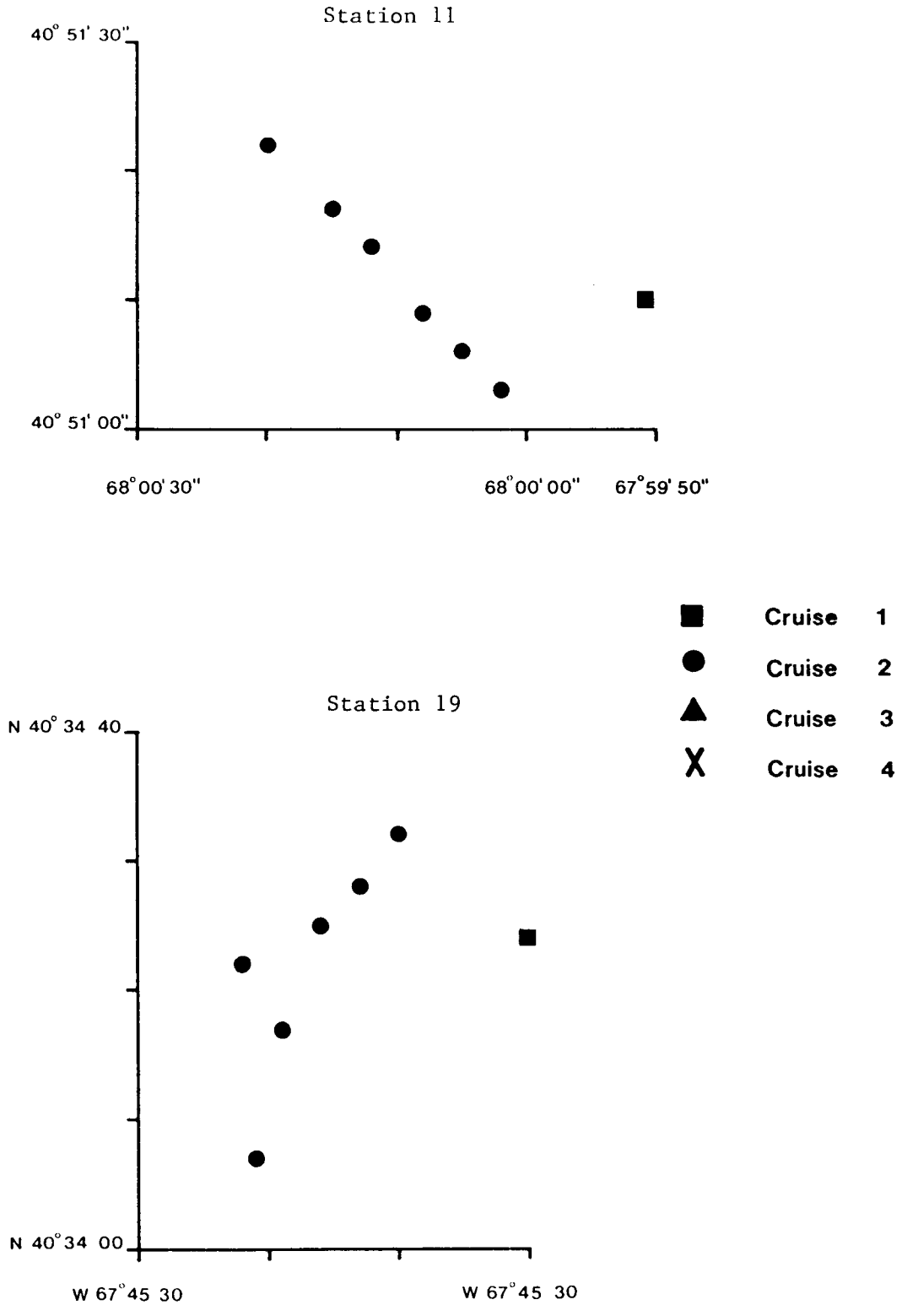


Figure 43 Replicate Spacing Maps for Stations 11 and 19

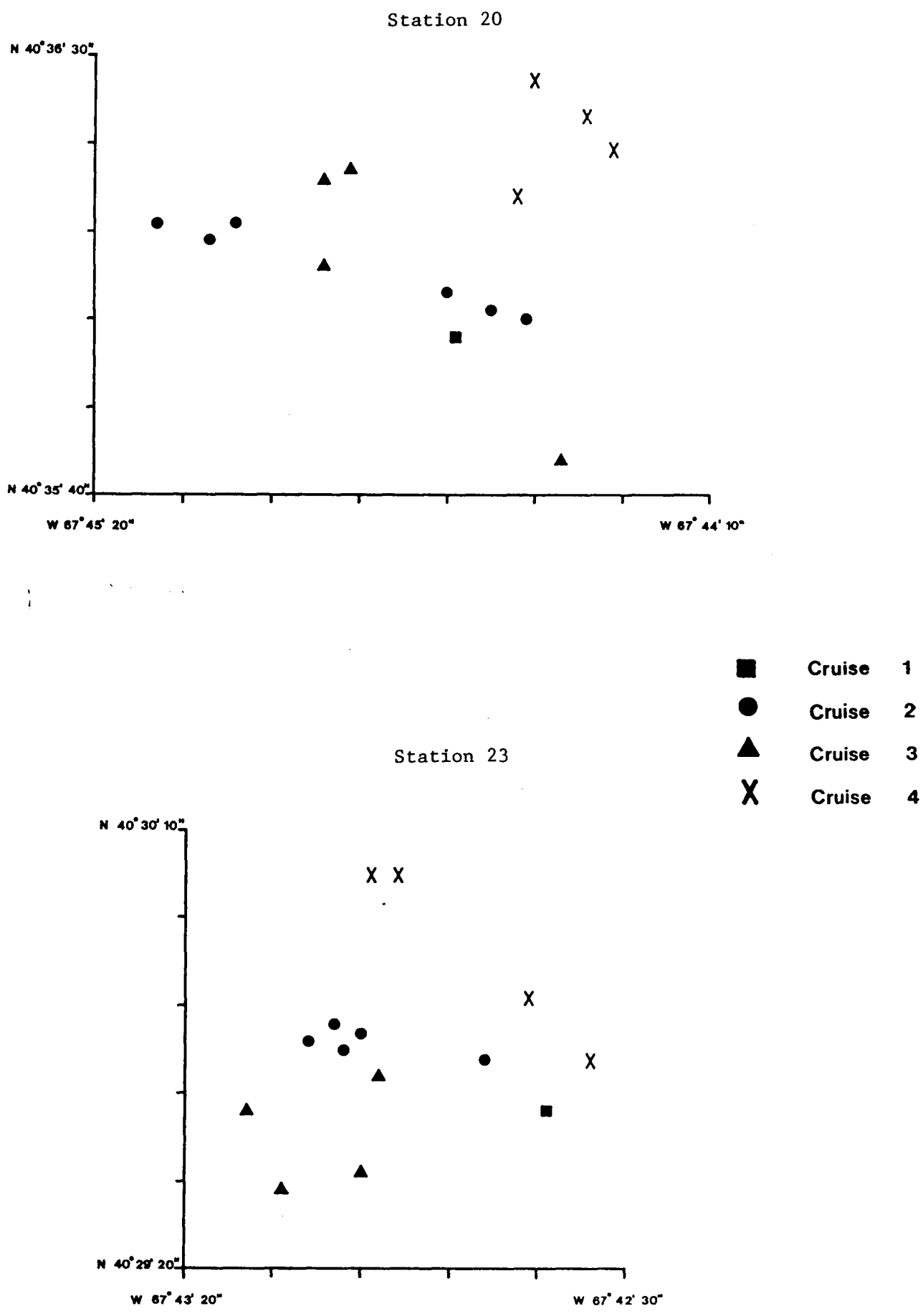
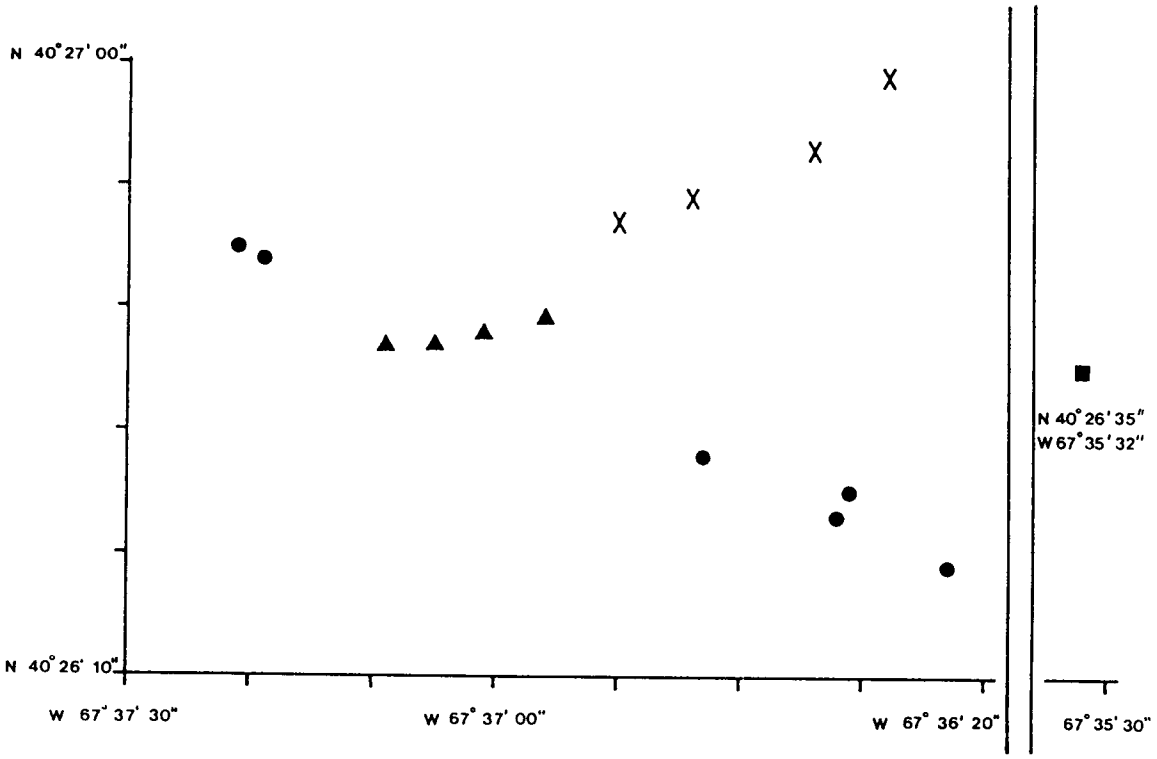
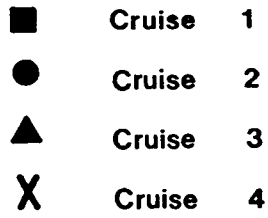


Figure 44 Replicate Spacing Maps for Stations 20 and 23

Station 25





Station 28

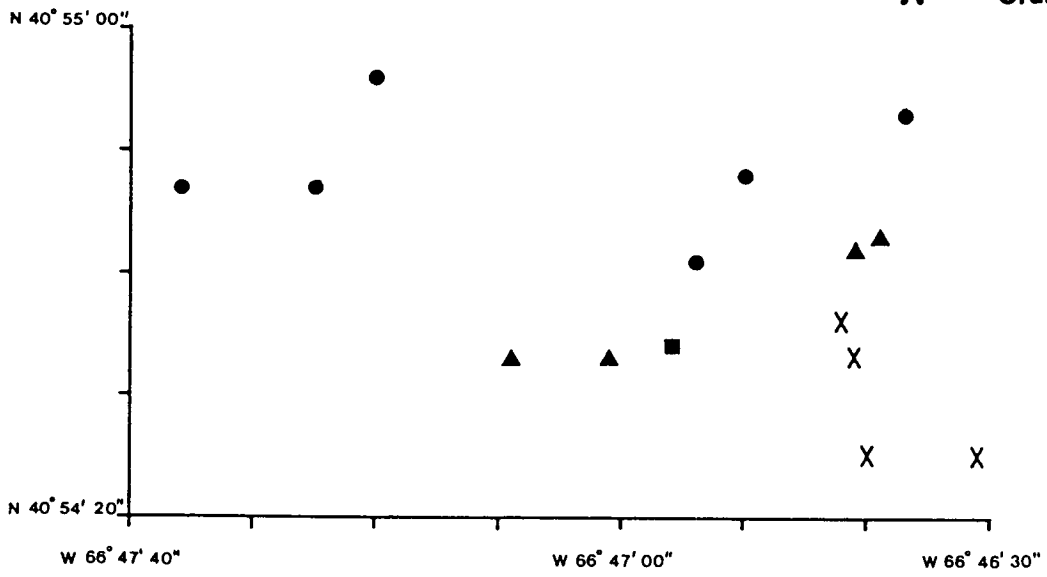
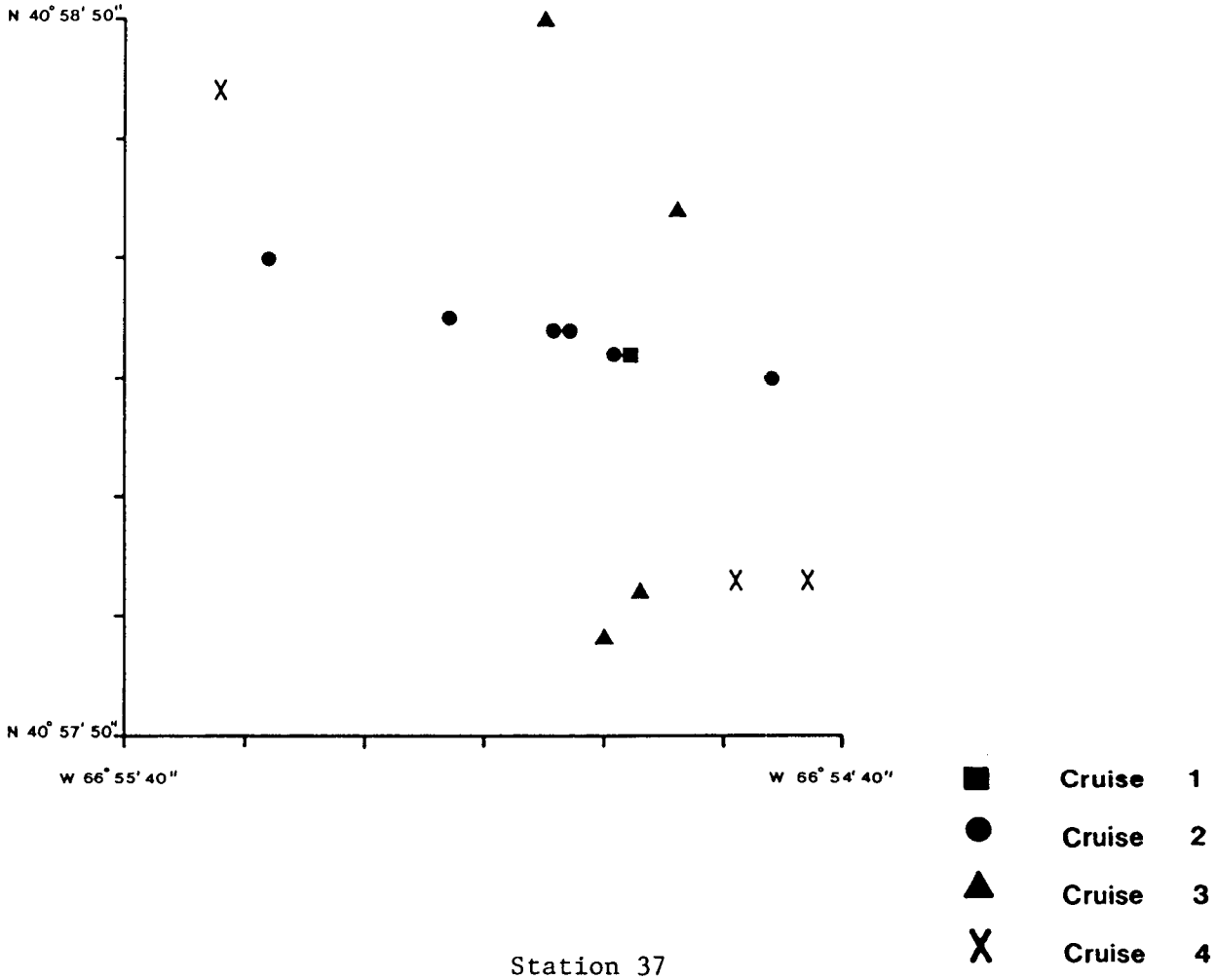


Figure 45 Replicate Spacing Maps for Stations 25 and 28

Station 29



Station 37

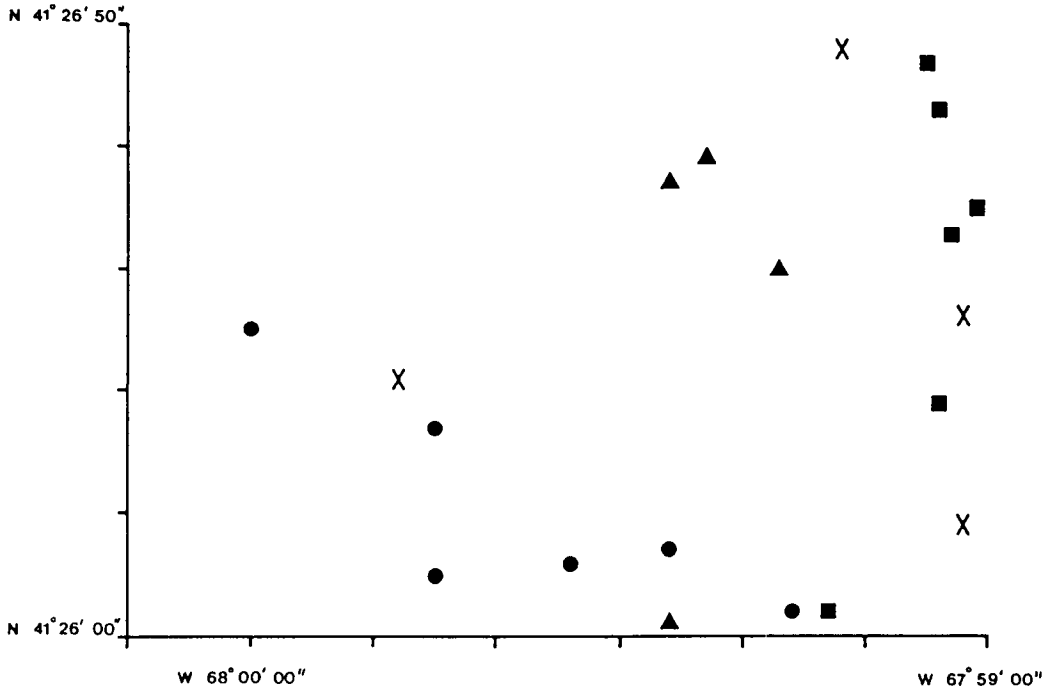


Figure 46 Replicate Spacing Maps for Stations 29 and 37

Station 40

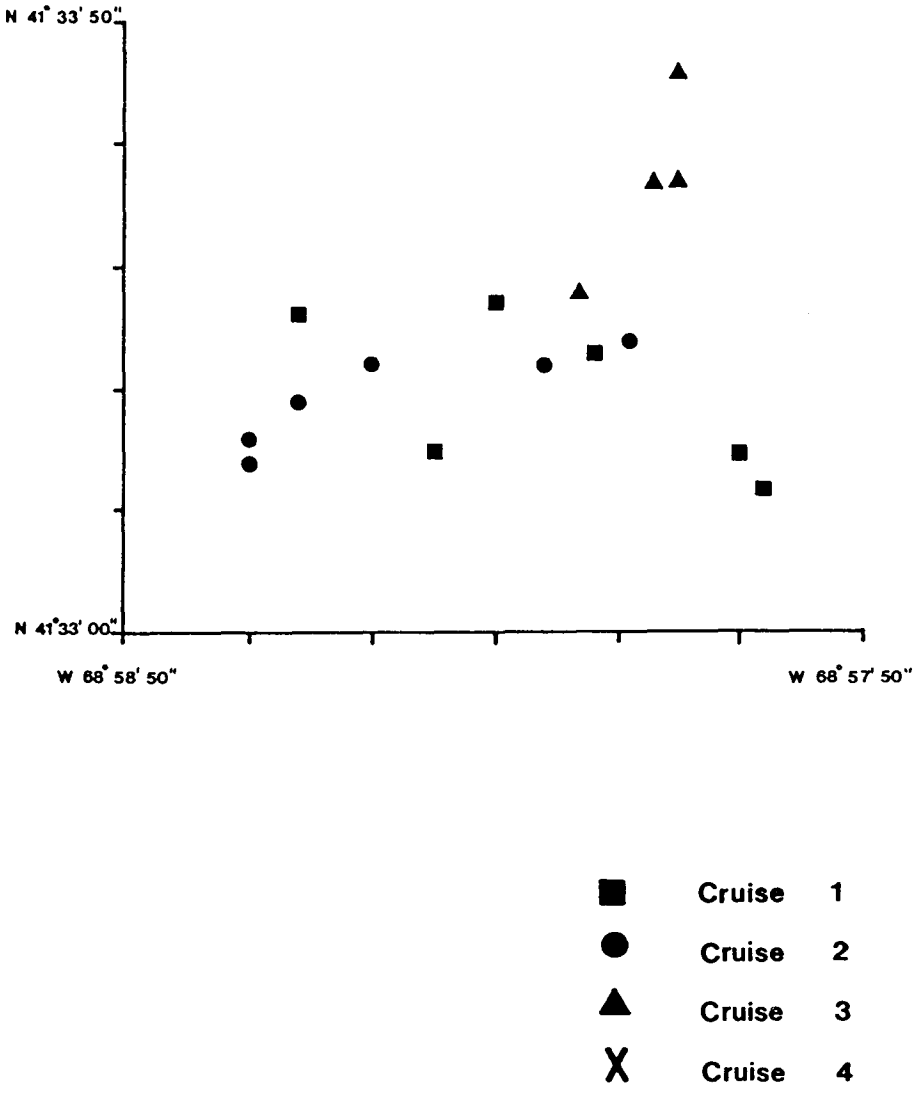


Figure 47 Replicate spacing st station 40

Table 22. Coefficients of Variation for Three Biological Parameters and Mean Sediment Grain Size

Station	Species	Individuals	Dominant Species*	Sediment
6	.17	.23	0.11	.06
	.22	.38	0.36	.03
	.10	.26	0.53	.04
	.20	.04	0.48	.03
8	.11	.15	0.37	.09
	.05	.16	0.17	.10
	.09	.18	0.11	.19
	.16	.26	0.18	.06
11	.30	.44	0.38	.01
	.29	.90	0.51	.01
	.08	.47	0.67	ND*
19	.15	.16	0.28	.19
	.12	.18	0.30	.17
	.16	.24	0.26	ND
20	.15	.43	0.58	.29
	.10	.36	0.52	.15
	.08	.32	1.07	.16
	.04	.51	0.43	.17
23	.10	.24	0.59	.23
	.10	.31	0.47	.13
	.26	.43	0.36	.36
	.12	.35	1.20	.11
25	.10	.40	0.17	.15
	.18	.39	0.10	.09
	.16	.24	0.27	.13
	.21	.43	0.14	.04

* Dominant species chosen was the least variable of the six most abundant species. Actual species involved are listed in Table 46

Table 22 continued

Station	Species	Individuals	Dominant Species	Sediment
28	.18	.34	0.49	.08
	.22	.64	0.92	.03
	.08	.37	0.67	.03
	.08	.16	0.23	.03
29	.16	.56	0.39	.50
	.09	.18	0.45	.18
	.06	.55	0.45	.22
	.14	.71	1.35	.53
37	.39	.65	0.67	.12
	.19	.71	1.35	.53
	.37	.96	1.45	.60
	.24	.24	1.07	ND
40	.17	.42	1.00	ND
	.29	.71	0.38	ND
	.29	.64	0.62	ND
	.09	.22	0.40	ND

* ND = No Data

richness e.g. most values are less than 0.2; i.e. the standard deviation was less than 20% of the mean value. There are in fact many values in the 0.1 - 0.15 range and two of 0.05 or less. These are equal to, or lower than, those produced by replicate sampling over a very small area (5 meter radius) when divers were used to collect samples in coastal waters (A. Michael, R. McGrath, unpublished data).

The variance inherent in the data is the primary determinant of statistical sensitivity, and can be used to examine the minimum amount of change which must occur in order to be shown statistically via the expression:

$$n \geq 2\left(\frac{s}{\delta}\right)^2 \left(t_{\alpha\,(v)} + t_{2(1-P)\,(v)}\right)^2 ,$$

where:

n = number of replicates

s = population standard deviation

δ = smallest detectable true difference

v = degrees of freedom for a group with n replicates per group ($v = a(n-1)$)

$t_{(v)}^{\alpha}, t_{2(1-P)(v)}$ = values from a two-tailed t table with v degrees of freedom and probabilities of α and $2(1-P)$, respectively

p = desired probability that the difference will be detected.

α = desired level of statistical significance

The expression may be rearranged to:

$$\delta = \left[\frac{2s^2\left(t_{\alpha\,(v)} + t_{2(1-P)\,(v)}\right)^2}{n}\right]^{\frac{1}{2}}$$

Finally, substituting the coefficient of variation (CV) for the standard deviation (s) provides δ in units of $\pm$ percent of the mean, which is more useful for our purposes than the actual numerical value.

The use of this formula requires certain a priori determinations, some of which are dictated by the data set and others of which are set at the discretion of the investigator. The value of the standard deviation (or coefficient of variation) is fixed once the samples have been taken and analyzed and has a profound effect on the sensitivity of the data. The analysis assumes that the variability will remain fairly constant over succeeding collections.

In determining appropriate degrees of freedom, the comparison could be made between two collections only. This is representative of the situation encountered when comparing one station with another, or with itself at another time. It is conservative in the sense that additional information is gained through repeated sampling and this can be used to increase the degrees of freedom and thereby increase sensitivity. However, the variability of the collection will almost certainly increase as the future collections are considered, offsetting these gains somewhat.

The choice of values for α and P is arbitrary. It seems reasonable to adopt the "accepted" value of .05 but values of .1 and .01 may also be defensible. Similarly, the choice of P may be defended at different values and there is no generally accepted level to use. A P of .8 was somewhat arbitrarily selected for computational purposes; the formula is not overly sensitive to changes in P, the values for s and α being of considerably greater importance.

If we use six replicates for n in the above formula (this really applies to Cruises I - III; only four replicates were collected in Cruise IV), the detection levels associated with the corresponding coefficients of variation shown in Table 22 are:

Coefficient of Variation	Percent Change in the Mean Detectable at P = 0.05
0.05	8.9
0.1	17.9
0.15	26.9
0.20	35.8
0.25	44.8
0.50	89.6
1.00	179.3

The detection limits for number of species range from better than 8% to approximately 50%. More than a third of the coefficients of variation were .10 or less allowing for a detection limit of 18% or lower for the mean number of species.

Detection limits were poorer in the case of densities (total number of individuals) and densities of a dominant species for each

station. We have deliberately selected the dominant species showing the lowest inter-sample variation for each station in Table 23. These two parameters are much more variable than species numbers in virtually any benthic data set. Many of the coefficients of variation fall between 0.1 and 0.3 which allows for a detection limit of approximately 18 - 50% change in the mean. Nevertheless this is an acceptable range for use in monitoring. It should be pointed out that these samples were collected in a broad scale benchmark program. It is quite possible that a sampling program specifically designed for monitoring with improved navigation etc. might result in lower inter-sample variability.

Coefficients were very low for the mean particle size (phi units). This is in part due to the fact that mean particle size is expressed in terms of phi units which involves a log transformation.

Collecting samples through the year should increase variance of data due to seasonal effects but this is offset by an increase in n in the sensitivity formula. Table 23 shows the change in the mean density detectable over the entire year for one dominant species at each station. The number of replicates used in the formula was 20 although the actual range was from 18-22. The error introduced by this generalization is insignificant. In most cases the detection level is better than a 50% change in the mean value. A notable exception is Station 37 on the east of the Bank which showed low faunal predictability. These results are very encouraging since the sampling was not specifically designed for this purpose.

The Feasibility of Monitoring

The stations sampled in this study were part of a suite of 42 stations in the original Benchmark Study. Design of the current Georges Bank monitoring program is based on three transects; one through the lease sale area, one upcurrent (in terms of net flow) and another down-current. Stations selected for analysis here were either close to, or in the same locality as, those proposed for the monitoring program. One major issue in the feasibility of monitoring is the predictability of the fauna. If natural variation is high, our ability to detect change is greatly reduced and can be negligible in extreme cases. The results in

Table 23. Minimum Change (± % of mean) Detectable at $p < .05$ for Selected Dominant Species

Station	Species	C.V.	Detection Level
6	Ninoe nigripes	0.48	43.5
8	Ampelisca agassizi	0.42	38.1
11	Trichophoxus epistomus	0.41	37.2
19	Ampelisca agassizi	0.39	35.4
20	Exogone brevicornis	0.79	71.7
23	Ampelisca agassizi	0.51	46.3
25	Ampelisca agassizi	0.62	56.3
28	Trichophoxus epistomus	0.34	30.8
29	Exogone hebes	0.52	47.2
37	Exogone hebes	1.61	146.2
40	Exogone brevicornis	0.70	63.5

this report clearly show that there was (at least in 1977) a strong element of predictability in the benthic infauna. We cannot, however, comment on annual variation but similar studies by Boesch (1979) in the Mid-Atlantic Bight have established that there is an element of continuity in the shelf infauna over more than one year.

A second issue is that of finding control stations for those in the lease sale area. There are some overall trends on Georges Bank which affect the selection of control sites. There is a decrease in mean particle size of the sediments from east to west along the southern flank and a corresponding increase in species richness and faunal density. These changes parallel the change across the bank from the crest south to the slope.

Because of the overall trends, Station 29 upstream differed somewhat in the fauna from Station 20 in the lease sale transect. Only two species were among the numerical dominants at both stations. The less abundant species may overlap more since these stations did cluster together in some of the classifications analyses. Quantitative parameters such as species richness and density did not differ significantly. Stations 19 and 28 showed a better overlap among the dominant species. Ampelisca agassizi, Notomastus latericeus and Ericthonius rubricornis were well represented at both sites. Species richness and density did not differ significantly.

Station 8, to the west of the lease sale transect had two species which were numerical dominants at Station 19. Faunal densities were, however, higher and this station showed more affinity to Stations 23 and 25 in the classification analysis.

It should be emphasized that the above stations were not matched exactly according to depth and there is good evidence that small depth differences can result in markedly different fauna. The few meters difference between Stations 19 and 20 (90 vs 82m) resulted in a complete change in the dominants. The respective depths in the above pairings were:

Station 20 (78m)	vs	Station 29 (68m)
Station 19 (90m)	vs	Station 28 (93m)
Station 19 (90m)	vs	Station 8 (105m)

It is reasonable to assume that better depth matches could produce a closer overlap in the fauna and thus it may well be possible to find better control sites.

Benthic data generated on the 1977 Benchmark sampling program has shown that the prospects for using the benthos as a monitoring tool on Georges Bank are good for the following reasons:

1) There are large areas on Georges Bank inhabited by the same or similar benthic communities.
2) Replicate sampling within these areas shows low variability thus enhancing the possibility of detecting statistically significant changes.
3) The persistence of these communities is high. Repeated visits to the same general locality through 1977 produced a similar fauna.
4) The possibility of finding suitable control sites for experimental stations on the southern flank is good. There are some faunal changes across the bank from the crest to the southern flank and from east to west along the flank. These trends parallel overall sediment distribution patterns. There are, however, species which are distributed over wide areas (e.g. Ampelisca agassizi, Exogone hebes). Faunal composition is sufficiently similar to provide adequate control sites.

CONCLUSIONS

1) The macrobenthos (collected by a $0.1m^2$ Van Veen grab and sieved through a 0.5mm mesh) of eleven stations in the Georges Bank area and adjacent areas was dominated by small polychaetous annelids and peracarid crustaceans and, to a lesser extent, by molluscs and echinoderms. Approximately 700 taxa were identified including several new species. Haustoriid amphipods were dominant on the crest of the bank. With increasing depth the polychaete and molluscan components increased and the amphipod component decreased.

2) Sediments on the bank were predominantly medium or fine sands with low silt/clay content. Silt/clay content was significantly higher in the Gulf of Maine, Lydonia Canyon and the mud patch. There was an increase in the percent of fine material with increasing depth southward from the crest of the bank and from east to west along the flank.

3) The average number of species per replicate ranged from 17 at Station 37 on the crest of the bank to 82 in the Gulf of Maine. The stations in the lease sale area had 50-60 species per replicate. Faunal densities were typically in the range of 4,000 - 14,000 individuals/m^2. There was some evidence for seasonality in species richness and faunal density at shallow ($<$ 100 m) stations. An increase in faunal density and species richness was correlated with percent fine material in sediments. The pattern was similar to that for sediments: increases with depth southward from Station 37 on the crest of the bank and from east to west along the flank.

4) Biomass ranged from 7.81 to 26.42 gms/m^2 (wet weight). Polychaetes were the dominant component at all but two of the shallowest stations.

5) There was a high degree of faunal persistence through the year at most stations. Many species were widely distributed and six occurred in 50% or more of all samples. They were: the polychaetes Aricidea catherinae, Exogone hebes, Exogone brevicornis and Notomastus latericeus and the amphipods Ampelisca agassizi

and Unciola irrorata. Ampelisca agassizi was a dominant species at six of the eleven stations sampled. This species is distributed over a wide area of the southern flank of Georges Bank where sediments are fine sands (2 or 3ϕ) with silt/clay content of 3-20%

6) With the possible exception of Station 40, there were no significant trends in Shannon-Weiner diversity values. Most values were between 3 and 4 with a maximum of 4.9 at Station 28.

7) Although replicate samples in any one cruise were collected over a radius of 250 - 500 m, inter-sample variation was typically very low except at the shallowest area, Station 37. Coefficients of variation for species richness, densities of all species and densities of selected dominant species were lower than those seen in shallower benthic environments nearer the coast.

8) Prospects for using the benthos to monitor the effects of drilling muds discharges are good. There are large areas of Georges Bank inhabited by the same or similar benthic communities which show low sampling variability and high degrees of persistence.

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APPENDIX

1. Station Summaries

2. Trends in Polychaete Systematics: C.D. Long

Summary: Station 6

Cruise I	Spacing	Fair (475m)1
	Depths	72-75m
	Sediments	Similar; silt/clay, 25-44% Mode: 4 ϕ, 38-61%
Cruise II	Spacing	Fair (450m)
	Depths	70-80m
	Sediments	Very similar; silt/clay, 36-45% Mode: 4 ϕ, 41-56%
Cruise III	Spacing	Fair (425m)
	Depths	73-75m
	Sediments	Similar; silt/clay, 36-39% Mode: 4 ϕ, 50-58%
Cruise IV	Spacing	Good* (625m with R1-100m without)
	Depths	70-78m
	Sediments	Similar; silt/clay, 38-43% Mode: 4 ϕ, 50-59%

Overall:

Generally very similar sediments
Mode 40-60% in 4 ϕ. Silt/clay 25-44%.
Seasonal spacing over about 2.6 km.
Depths 70-80m.

1. Radius of a circle encompassing all replicates
* except for replicate 1.

Summary: Station 8

Cruise I	Spacing	Fair (475m)
	Depths	141-147m
	Sediments	Similar; silt/clay, 4-5.5% Mode: 3 ϕ, 45%
Cruise II	Spacing	Very good (163m)
	Depths	106-108m
	Sediments	Similar; silt/clay, 5.5-6.7% Mode: 2 ϕ, 50%
Cruise III	Spacing	Very good (175m)
	Depths	101-103m
	Sediments	Similar; silt/clay, 4.5-5.9% Mode: 2 ϕ, 50%
Cruise IV	Spacing	Poor (550m)
	Depths	101-108m
	Sediments	Very similar; silt/clay, 4.5-5.9% Mode: 2 ϕ, 50%

Overall: Spacing fair. Probable error in Cruise I data since depths are approximately 140m but coordinates are similar to other cruises when depths were 101-108m. Sediments very consistent at 5% silt/clay with the mode (50%) in 2 ϕ size range. Cruise I had different mode,further indicating the station was taken in a slightly different place. Bottom photographs for Cruises I and II only. There is an obvious difference between the two. Cruise I shows fairly flat,featureless sand with silt, occasional crabs (Cancer) and fish. Cruise II shows shell debris and numerous starfish (Asterias) although the sediments appear similar.

Summary: Station 11

Cruise I	Spacing	No data
	Depths	58m
	Sediments	Very similar; silt/clay, 1%
		Mode: 3 ϕ, 95%
Cruise II	Spacing	Fair (338m)
	Depths	59-61m
	Sediments	Very similar; silt/clay, 1%
		Mode: 3 ϕ, 95%

No data for Cruises III and IV

Summary: Station 19

Cruise I	Spacing	No data
	Depths	84-92m
	Sediments	Variable; silt/clay, 1.3-3.9% Fine sand, variable 15-82%
		Mode: 3 ϕ or 2 ϕ
Cruise II	Spacing	Fair (350m)
	Depths	94 - 97m
	Sediments	Very similar; silt/clay, 2.7-5.3%
		Mode: 3 ϕ, 77-84%

No data for Cruise III and Cruise IV

Summary: Station 20

Cruise I	Spacing	No data
	Depths	75-78m
	Sediments	Fairly uniform; silt/clay, 0.5-1.5%
		Mode: 1 or 2 ϕ, 53-66%
Cruise II	Spacing	Poor (550m)
	Depths	82-84m
	Sediments	Fairly uniform; silt/clay, 0.8-1.5%
		Mode: 1 or 2 ϕ, 37-54%
Cruise III	Spacing	Poor (525m) (2,3,4, close)
	Depths	81-83m
	Sediments	Fairly uniform; silt/clay, 1-2.2%
		Mode: 1 or 2 ϕ, 47-64%
Cruise IV	Spacing	Good (175m)
	Depths	84-86m
	Sediments	Fairly uniform; silt/clay, 1.5-2.9%
		Mode: 2 ϕ, 44-60%

Overall: Sediments rather uniform with low silt/clay content (0.5-2.9%). Mode in either 1 or 2 ϕ range at 37-64%.

Summary: Station 23

Cruise I	Spacing	No data
	Depths	148-178m
	Sediments	Somewhat variable; silt/clay, 6-15%
		Mode: 3 or 4 ϕ, 34-46%
Cruise II	Spacing	Good (250m)
	Depths	162-182m
	Sediments	Variable; silt/clay, 10-20%
		Mode: 3 or 4 ϕ 38-47%
Cruise III	Spacing	Good (225m)
	Depths	154-200m
	Sediments	Variable; silt/clay, 4-18%
Cruise IV	Spacing	Fair (412m)
	Depths	274-374m
	Sediments	Variable; silt/clay, 18-35%
		Mode: 1 or 2 ϕ, 32-51%

Overall: Overall spacing reasonable (1 km^2) -- quite a bit of variability in sediments 6-35% silt/clay. 1 ϕ category varied from 0-29%. Mode generally in 3-4 ϕ range Problem with wide range in depths because station was located in a canyon head.

Summary: Station 25

Cruise I	Spacing	No data
	Depths	154-159m
	Sediments	Fairly uniform; silt/clay, 1.8-3.1% 12-30% very fine sand
		Mode: 2 ϕ, 45-66%
Cruise II	Spacing	Poor (800m)
	Depths	145-148m
	Sediments	Uniform; silt/clay, 0.8-2.4% 13-22% very fine sand
		Mode: 2 ϕ, 51-64%
Cruise III	Spacing	Good (175m)
	Depths	142-143m
	Sediments	Uniform; silt/clay, 0.9-2.9% 14-25% very fine sand
		Mode: 2 ϕ, 48-64%
Cruise IV	Spacing	Fair (325m)
	Depths	145-146m
	Sediments	Fairly uniform; silt/clay, 1.7-5.5%
		Mode: 2 ϕ, 61-67%

Summary: Station 28

Cruise I	Spacing	No data
	Depths	90-93m
	Sediments	Similar; silt/clay, 2-5%
		Mode: 3 ϕ, 27-68%
Cruise II	Spacing	Poor (750m)
	Depths	93-96m
	Sediments	Very similar; silt/clay, 1.5-5%
		Mode: 3 ϕ, 58-69%
Cruise III	Spacing	Fair (450m)
	Depths	89-92m
	Sediments	Very similar; silt/clay, 2-3%
		Mode: 3 ϕ, 59-66%
Cruise IV	Spacing	Good (200m)
	Depths	92-94m
	Sediments	Similar; silt/clay, 2-3%
		Mode: 3 ϕ, 64-76%

Overall: Very similar sediments except for one replicate in Cruise I. Mode: 3 ϕ, 58-76%. Silt/clay, 1.5-5%. Depths 89-96m. Seasonal spacing over about 2.6 km^2.

Summary: Station 29

Cruise I	Spacing	No data
	Depths	68m
	Sediments	Variable in sand fraction Silt/clay, 0.6-1.6% Mode: 1 or 2 ϕ, 40-60%
Cruise II	Spacing	Poor (550m)
	Depths	71-78m
	Sediments	Similar; silt/clay, 0.6-1.9% Mode: 2 ϕ, 45-65%
Cruise III	Spacing	Poor (675m)
	Depths	71-75m
	Sediments	Variable in find sand, 2-12% Silt/clay, 0.75-1.9% Mode: 2 ϕ, 49-55%
Cruise IV	Spacing	Very poor (800m)
	Depths	76-81m
	Sediments	Similar; silt/clay, 0.8-2% Mode: 2 ϕ, 41-73%

Overall: Sediments varied in % fine sand, 1.3-20%. Mode in either 2 or 3 ϕ, 37-73%. Silt/clay consistent at less than 2%. Depths 68-81m. Seasonal spacing over about 2.6 km.

Summary: Station 37

Cruise I	Spacing	Poor (575m)
	Depths	43m
	Sediments	Variable in 1-3 ϕ range Silt/clay, 71% Mode: 2 ϕ, 61-84% Percent fine sand varied, 6-28%
Cruise II	Spacing	Poor (625m)
	Depths	19-40m (sand wave?)
	Sediments	Variable in 1-3 ϕ range Silt/clay, 0.3-1.7% Mode: generally 2 ϕ, 45-65% (except replicate 4: 40% gravel)
Cruise III	Spacing	Fair (475m)
	Depths	37-40m
	Sediments	Variable; silt/clay, 0.5-1.62% Mode: 2 ϕ, 42-77% Replicate 2 with 28% gravel
Cruise IV	Spacing	Poor (600m)
	Depths	39-40m
	Sediments	Similar except for replicate 3 (44% gravel) Silt/clay, 0.6-1.3% Mode: 2 or 3 ϕ, 31-52%

Overall: Sediments of low silt/clay content but variable in percent fine sand and gravel. Mode generally in 2 or 3 ϕ range, 31-84%. Depths mostly around 40m except for one sample at 19m in Cruise I. Seasonal spacing over 2.6 km^2.

Summary: Station 40

Cruise I	Spacing	Poor (512m)
	Depths	117m
	Sediments	Variable; silt/clay, 0.2-13%
		Mode: 0 or 1 ϕ, 16-54%
		2 replicates with high gravel content
Cruise II	Spacing	Fair (412m)
	Depths	119-126m
	Sediments	Variable; silt/clay, 3-13%
		Mode: 0 or 1 ϕ, 20-52%
		2 replicates with high gravel content
Cruise III	Spacing	Good (250m)
	Depths	120m
	Sediments	Variable; silt/clay, 0.6-9%
		Mode: 0 or 1 ϕ, 39-47%
Cruise IV	No data	

Overall: Sediments variable with silt/clay content from 0.2-13% but most typically 4-8%. Poorly sorted and several replicates had high levels (up to 50%) gravel. Mode: 0 or 1 ϕ, 16-54%. Depths 117-126m. Seasonal spacing over about 1.4 km^2.

TRENDS IN POLYCHAETE SYSTEMATICS AND IMPLICATIONS FOR THE SELECTION OF NAMES FOR GEORGES BANK SPECIES

Charlene D. Long

Introduction

This presentation is divided into two sections. The first is a brief historical review of trends in the selection of species names for polychaetes from the northwestern North Atlantic. To illustrate the impact of these trends on the selection of species names, the second section traces the history of the various names used for one species of polychaete that is dominant on Georges Bank.

Historical Review

In an ecological survey, the name that a polychaete specialist or a sorter selects for a particular specimen depends on several factors. One of the most obvious factors is the individual's level of experience. The word experience here refers both to knowledge of polychaete systematics and to knowledge of the species from the region being studied.

There are, however, more subtle factors that impinge upon the selection of names. For instance, sorters who are inexperienced about the intricacies of polychaete terminology can often develop considerable skill in sorting to species based on an eye for polychaete "Gestalt." Such an individual can be remarkably accurate in sorting large numbers of polychaetes to species without knowing a single species name.

Another subtle factor can be the state of the art of biological science at the time the species name is selected. The application of state-of-the-art thought about biology, whether deliberate or not, has resulted in what I call taxonomic trends, and the selection of names for polychaetes from Georges Bank forms the basis for an excellent example of such trends in polychaete taxonomy.

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A review of polychaete names from our coast shows that the first surveys, in the mid 1800's, utilized European names for the specimens that were found. Before the 1900's, many of these names were replaced by new species names, thus making the names for the specimens specific to the region from which they were collected. By the mid 1900's, many of these regional specific names were made synonyms of European names, sometimes the same ones that had been used previously, other times different ones. Recently, the regional specific names are being reinstituted or else new regional specific names are being formulated for some of these species.

This switching around from one name to another for the same species does not indicate capriciousness on the part of polychaete systematists. Rather, it is a reflection of two repetitive trends in the attitudes about what constitutes a species. I will label these Trend 1 and Trend 2.

Both of these trends are exemplified in Verrill's (1882) review of North American publications on New England polychaetes from 1842 to 1880. It is obvious in his review that polychaetes that had previously been given European names (Trend 1) were later described under new species names (Trend 2). In fact, from the mid to the late 1800's, nearly 160 new species names were given to New England polychaetes, some of which had been previously identified as European species.

By 1963, we were back to Trend 1, when Pettibone published her volume on 180 or so species of errant polychaetes from New England. In this, she reported about 65 of the regional names used in the 1800's as synonyms of European names. In some cases, the synonymization was because the original descriptions had been sketchy; in other cases, because the names had been based on seemingly minor differences in morphology, and Pettibone felt they were not clearly distinguishable from European forms. You may note that at about this same time, workers began to understand the great variation in morphology even in a single species, and this was reflected in names that were used in terms of populations rather than just individuals. Thus minor differences in morphology were discounted, and considerable synonymization took place.

We are currently back in Trend 2, for biologists have a slightly better understanding of the subtleties of environmental effects on repro-

duction and development and on the resulting morphology of polychaetes, and we have at our disposal thousands of specimens of a single species from one region, if not from one station. In addition, travel and world-wide cooperation among institutions permit a specialist to more readily view type specimens and collections from other regions. As a result, what used to be widely distributed species are now being carved down to regional groupings, and we are now using the words "species pairs" and "species complexes" to label the similarities and differences.

What does this have to do with the average student, researcher, or contractor who is faced with the identification of a mass of worms, perhaps missing diagnostic parts and, all too often, undersized? The implication for you is that many of the old, trusted polychaete names that have been around for so long are on their way out. Just from the 100 or so species that I have documented in the last few months, I am sure that at least 20 are, in fact, sufficiently different from the original descriptions of the names that were used for them to indicate that new descriptions, or at least altered old descriptions, are necessary.

For those who are not polychaete specialists I would emphasize that this does not mean that previous workers had done a sloppy job or that those who are currently describing species are any better at what they are doing. Rather, we are again in the trend of using new names for regional polychaetes.

No telling what the future, as we currently see it in SEM and complex physiochemistry, will bring us. After all, the describer of most invertebrate new species violates the very definition of the word "species" nearly every time a new species name is created, for we rarely know anything about the sex life and habits of the creatures we study. Perhaps if we did, the whole business would be a little less esoteric.

Implications

Throughout this talk on trends in polychaete systematics, I have touched on a few points that directly impact on the individual who attempts to identify polychaetes or who attempts to interpret the data that results from such identifications. The most important of these points is the selection of characters that are important in the choice of a species name. The type and number of such characters have shown a history parallel to that of

the selection of European names vs. regional specific names, because, as I mentioned, thinking about individuals vs. populations and about environmental effects on biology vs. the evolving genetic structure of populations has also been changing.

In line with that, the abstract that I turned in for this presentation indicated that I intended to conclude with an outline of the types of morphological characters that are currently of importance in the selection of names for some of the dominant species from Geroges Bank. However, while I was preparing that section, I decided that it was too obtuse for other than someone currently wrestling with polychaetes. I will, instead, give a brief history of one of the species involved in these trends, one that is dominant on Georges Bank.

Exogone verugera is listed by Maurer and Leathem (1980) as a Georges Bank dominant. It had been described by Claparede in 1868, from Western Europe. Apparently, there was no report of verugera, under any name, from eastern North America in the mid 1800's (Verrill, 1882; Pettibone, 1963), so this species was missed during Trend 1, when European names were being used for North American species. However, during Trend 2 near the end of the 1800's when regional specific names were instituted, Webster and Benedict (1887) described brevicornis from Maine. By 1963, we were back to Trend 1, when Pettibone made brevicornis a synonym of verugera. And, today, at least some of the specimens that traditionally have been called verugera are now called brevicornis by someone who is currently publishing detailed descriptions of several Exogone species (Perkins, personal communication). Thus we are back at Trend 2.

Based on this, I would suggest that the name verugera probably will not be used in the future for the eastern North Atlantic representatives of this particular species complex. Most likely, specimens we have called verugera in the past will, in some cases, be called brevicornis, and, in other cases, will be given other names.

A number of species in several families from the eastern North Atlantic show similar patterns of name changing, and I think you can expect to find more of the situation illustrated by Exogone verugera.