BIOLOGICAL ASSESSMENT

4.1 Introduction

On June 3, 1979, an exploratory petroleum well named Ixtoc I being drilled by Petroleos Mexicanos in the Gulf of Campeche, Mexico, blew out uncontrollably. The well gushed oil until late March, 1980, when it was finally capped. The accident was the largest spill to date by far in the Gulf of Mexico, releasing approximately $5.3 \times 10^5/m^3$ of crude oil into the ocean. Oil from Ixtoc I apparently weathered rapidly near the wellhead and then moved northward on the surface and beneath it. About 4,350 m^3 of oil were deposited on south Texas beaches during the spill (Gundlach et al. 1981); however, the quantity of oil reaching the benthos is completely unknown. The south Texas shelf is nearly all unconsolidated sediment, ranging from sand nearshore to predominantly clay and sandy and silty clay offshore (Flint and Holland 1980, Gallaway 1981).

By coincidence, part of the area believed to be exposed to petroleum from the Ixtoc I spill had been subjected to an extensive environmental study during 1975, 1976, and 1977, under the sponsorship of the U.S. Bureau of Land Management (BLM). For many years, "baseline" outer continental shelf studies sponsored by the Bureau of Land Management (BLM) have had as their avowed purpose to describe biological conditions, so that in the event of an environmental catastrophe (e.g. an oil spill), the extent and nature of the impact might be understood by comparison to the previous situation. The value of such a damage assessment program would depend upon its ability to determine if damage were, in fact, detected and assigned beyond a reasonable doubt to its proper cause. The South Texas Outer Continental Shelf (STOCS) baseline study program included a wide variety of environmental measurements designed to meet BLM needs for impact assessment should the area be leased for future petroleum development. A large number of intertidal and subtidal sites were studied along the south Texas shelf, which is nearly all unconsolidated sediment ranging from sand nearshore to mud (predominantly clay) offshore (Flint and Holland 1980, Gallaway 1981). Among the subtidal biological communities surveyed, the macroinfauna (defined as soft-bottom organisms retained on a 0.5 mm screen) was characterized in the STOCS program as being relatively stable, showing a lack of pronounced seasonal fluctuations (Holland et al. 1980).

In light of this supposed stability, and in part as a result of the STOCS use of repeatable, standardized methods for benthic sampling, the BLM sponsored a study of the macroinfaunal community during the Ixtoc I spill (November 1979) and one year later (December 1980). Benthic samples were taken at 12 of the same STOCS sites using the same methods previously employed in the STOCS project. The samples were subjected to biological, chemical and sedimentological analyses to determine whether or not any effects of the Ixtoc I spill on the macroinfauna might be detected.

The circumstances under which this study was undertaken could not practically be expected to have been better. The oil spill was massive, there was a large amount of baseline biological data on the area; and the methods used in the baseline study were standardized and repeatable. In some senses, this study was the first test of the utility of the baseline concept for petroleum impact assessment, since until the Ixtoc I spill no such human-caused catastrophe had occurred in an area previously included in a comprehensive baseline program.

This report describes the results of the benthic biological study, while the chemical and geological results are presented in Sections 2, 3, and Appendices 9.1 and 9.2. The 1979 samples were taken by a multi-agency "Regional Response Team" (NOAA 1982) while the 1980 samples were collected by LGL Ecological Research Associates, Inc. and by Energy Resources Company, Inc. (ERCO). Analysis of 1979 and 1980 biological samples and data was performed by LGL, while ERCO was responsible for chemical sample and data analysis. Geomet Technologies, Inc. analyzed the sediment samples for texture.

The 1980 sample collection included benthic material from 28 additional stations not previously sampled for biological parameters. Two of these stations were very near the site of the 1979 collision of the oil tanker Burmah Agate with a freighter, which resulted in a spill of over $3.4x10^4$ m^3 and a subsequent fire near the Galveston, Texas harbor entrance (Kana and Thebeau 1980). Since the data from these 28 stations cannot be compared to equivalent biological data from any other sampling periods, the results from these stations will be discussed separately in Appendices 9.3.1 and 9.3.2.

4.2 Methods and Approaches

4.2.1 Sampling

Benthic samples were collected with a Smith-McIntyre 0.1 m^2 grab. Six grabs were taken for biological and sediment samples at each of 12 stations (three each on four transects running roughly perpendicular to the beach) selected by the BLM (Figure 4-1, Table 4-1) and an additional grab furnished chemical and sediment samples. Station numbers used in the STOCS program were retained for continuity. The biological grab samples were sieved through 0.5 mm screen on board, and biota preserved in 5-10% neutral buffered formalin and dyed with rose bengal to highlight animals during the sorting process in the laboratory.

4.2.2 Analytical

A total of 72 grab samples from 1979 and 72 from 1980 collections (12 stations x 6 replicates for each year) were analyzed in the laboratory. Analysis included identification and enumeration of all individuals to the lowest possible taxon. All species identified were independently verified by specialists outside LGL. Many species (especially those for which

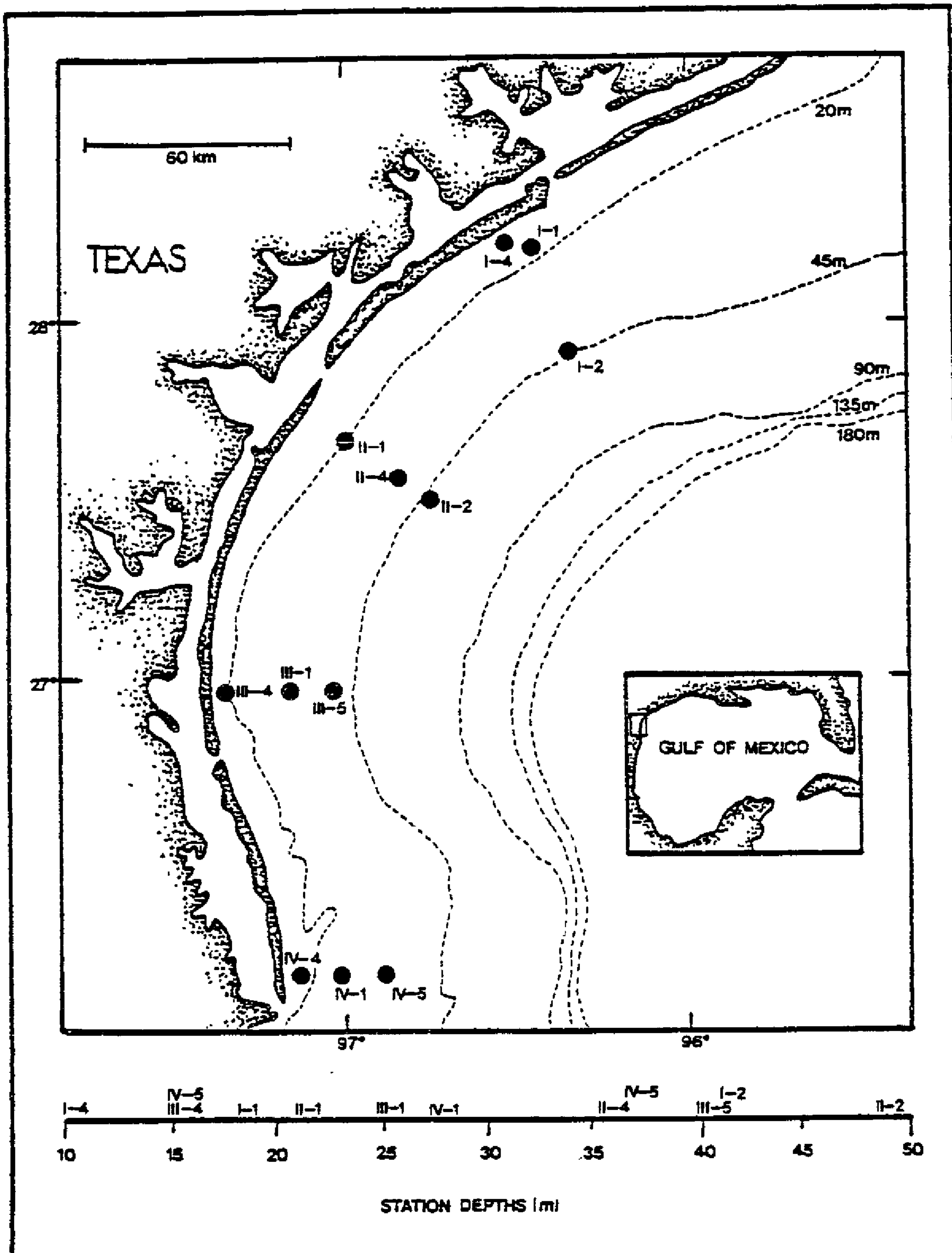

Figure 4-1. Map of 12 STOCS and LGL/ERCO stations.

Table 4-1. Station locations and depths.

BLM/STOCS STATION NUMBER	DEPTH (m)	LATITUDE (N)	LONGITUDE (W)
I-4	10	28°14'	96°29'
I-1	18	28°12'	96°27'
I-2	42	28°14'	96°29'
II-1	22	27°40'	96°59'
II-4	36	27°34'	96°50'
II-2	49	27°30'	96°45'
III-4	15	26°58'	97°20'
III-1	25	26°58'	97°11'
III-5	40	26°58'	97°02'
IV-4	15	26°10'	97°08'
IV-1	27	26°10'	97°01'
IV-5	37	26°10'	96°54'

current taxonomy is incomplete or in dispute) were verified by the same personnel responsible for identification of the STOCS samples, to ensure continuity between the LGL study and the baseline research.

It was not always possible to identify each taxon to the species level, as a number of previously undescribed species, or damaged or incomplete individuals or immature forms were collected. In several groups of organisms, taxonomic problems and limitations on resources precluded detailed identification during both the STOCS and the LGL programs. It was necessary to prevent taxa which were, e.g., previously grouped together from seeming suddenly to become common and the group to become absent, or vice versa. Whenever appropriate, therefore, taxa were grouped <u>per</u> STOCS identifications in statistical analyses comparing different sampling periods, to avoid spurious appearances or disappearances. A permanent reference collection was prepared from the 1979 and 1980 samples for deposit in the U.S. National Museum to aid in future taxonomic clarification.

Taxa that were present in the samples but known to be macroinfaunal incidentals, such as (wholly planktonic forms) and various fish (which were not collected qualitatively by the sampling methods used) were not included in the statistical analyses (Table 4-2).

While it would have been ideal to compare samples taken at each station at the same time of year, the 1976 and 1977 STOCS winter and fall samples were taken during January-February and September-October, respectively, and the 1979 and 1980 samples were collected in November and December, respectively. The chronology was, thus, winter 1976, fall 1976, winter 1977, fall 1977, November 1979, and December 1980. The month of collection is specified for 1979 and 1980 samples throughout the report (rather than "winter" to avoid confusion with the 1976 and 1977 STOCS winter samples, which did not directly overlap the 1979 and 1980 collection periods. The number of replicate grabs taken during the first year of the STOCS program was also not equivalent to later samples (four vs. six). Since the STOCS data indicated "significant temporal variation...in numbers of individuals" (Holland et al. 1980), statistical comparisons were restricted to 1980, 1979, and fall and winter 1977 and 1976 samples.

Statistical analyses included comparisons between sampling periods within stations, and comparisons between stations within sampling periods. Correlation analyses were performed on a taxon-by-taxon basis with sediment texture indices and total organic carbon (TOC) for all sampling periods in which TOC values were available in the STOCS data base. Cluster analyses were used to elucidate groupings of taxa, stations and time periods, and sediment types.

Table 4-2. Checklist of invertebrate taxa believed to have been incidentals or not macroinfauna (e.g. planktonic forms) and fish, consequently omitted from data analysis for 1979-1980 samples.

PHYLUM ARTHROPODA
- CLASS Crustacea
  - SUBCLASS Copepoda
    - Order Calanoida
      - *Acartia danae*
      - *Acartia tonsa*
      - *Acrocalanus longicornis*
      - *Aetidius armatus*
      - *Calanopia americana*
      - *Candacia curta*
      - *Centropages velificatus*
      - *Clausocalanus furcatus*
      - *Euatideus giesbrechti*
      - *Eucalanus pileatus*
      - *Heterorhabdus papilliger*
      - *Labidocera aestiva*
      - *Labidocera* cf. *scotti*
      - *Lucicutia flavicornis*
      - *Paracalanus crassirostris*
      - *Temora stylifera*
      - *Temora turbinata*
    - Order Cyclopoida
      - *Corycaeus speciosus*
      - *Sappharina nigromaculata*
    - Order Caligoida
      - *Caligus* sp.
  - SUBCLASS Malacostraca
    - Order Amphipoda
      - Hyperiidae
      - *Hyperia spinigera*
    - Order Euphausiacea
      - *Thysanopoda orientalis*
    - Order Decapoda
      - Sergestidae
        - *Lucifer faxoni*
      - Oplophoridae
        - Miscellaneous larval oplophorids (unid.)
      - Stenopodidae
        - Miscellaneous larval stenopodids (unid.)
        - Miscellaneous larval brachyurans (unid.)
        - Miscellaneous larval anomerans (unid.)
      - Albuneidae
        - Miscellaneous larval *Albunea* spp.

PHYLUM CHORDATA
- CLASS Hemichordata
  - Hemichordate (unid.)
- CLASS Cephalochordata
  - *Branchiostoma caribaeum*

Table 4-2 (cont'd)

CLASS Vertebrata
- Muraenidae
  - *Gymnothorax nigromarginatus*
- Congridae
  - *Neoconger mucronatus*
- Ophichthidae
  - *Echiophis* sp.
  - *Ophichthus gomesi*
- Bregmacerotidae
  - *Bregmaceros atlanticus*
- Ophidiidae
  - *Lepophidium graellsi*
- Sciaenidae
  - *Micropogon undulatus*
- Gobiidae
  - *Gobiosoma longipala*
- Microdesmidae
  - *Microdesmus lanceolatus*
- Cynoglossidae
  - *Symphurus* sp.

The biological data were not normally distributed, and the large amount of heterogeneity present in the data set led to significant first-, second-, and third-order interaction terms in parametric analyses of variance (ANOVA's). Consequently, comparison tests for central tendency (e.g. median abundance of taxa within stations over time) were restricted to nonparametric procedures such as the Kruskall-Wallis one-way and Friedman two-way ANOVA's (Friedman 1937, Kruskal and Wallis 1952). Kendall's Tau was used for correlation analyses (Kendall 1938). Czekanowski's Quantitative Index (= Bray-Curtis Index) was used to assess similarity in the cluster analyses, as it accurately describes overlap without regard to data distribution (Bloom 1981). Community summary statistics included the Shannon-Weaver function based on natural logs (Shannon and Weaver 1949) as a diversity index (H'), and Fager's (1972) scaled form of H', called V' by Pielou (1977) to describe evenness. Although somewhat less familiar than Pielou's (1966) evenness index J', V' is more appropriate than J' for comparison of samples with different numbers of individuals and taxa. As a practical matter, V' and J' typically respond similarly to community changes.

It was necessary to reduce the number of taxa during data analysis to statistically tractable and conceptually manageable proportions. The great majority of the 576 taxa seen during the STOCS program and in the 1979 and 1980 samples were rare, represented by single appearances or very low abundances. The entire data set included 65,166 individuals. The decision was made to focus attention on a restricted set of numerically dominant taxa. A rarefaction curve (Figure 4-2) demonstrated that 72 of these taxa (12.5% of the 576 taxa seen) included 56,584 individuals, 87% of the total, using a minimum cutoff level for inclusion of 0.2% of 65,166 (i.e., 130 individuals). Even a rather more restrictive inclusion cutoff level of 1% of 65,166 (i.e. 651 individuals) excluded all but 18 taxa (3% of the 576 taxa seen) and still included 39,999 individuals, 61% of the total. Numerically dominant taxa were arbitrarily defined by use of these two cutoff points: 0.2% of the total overall 65,166 for analyses which included all stations and sampling periods, and 1% of the total at each station for station-by-station descriptions. Figures based on either cutoff bear the notations "1% cutoff" or "0.2% cutoff" in their legends.

For simplicity and consistency, numerical abundance data were presented in terms of actual numbers of individuals collected, rather than as extrapolated values. For example, to convert density to numbers per metre square, it is necessary to multiply the count per station-period (i.e. six grabs) by 1.66. Sediment texture parameters were depicted graphically using the triangles of Buchanan and Kain (1971).

4.3 Results

LGL identified 267 taxa of macroinfaunal invertebrates in the 1979 and 1980 samples (Table 4-3). The numbers of taxa identified at all 12 stations taken together showed major changes from one sampling period to the next (Figure 4-3). Statistically significant differences ($P \leq 0.05$) in numbers of taxa identified separated the 1979 and 1980 sampling periods

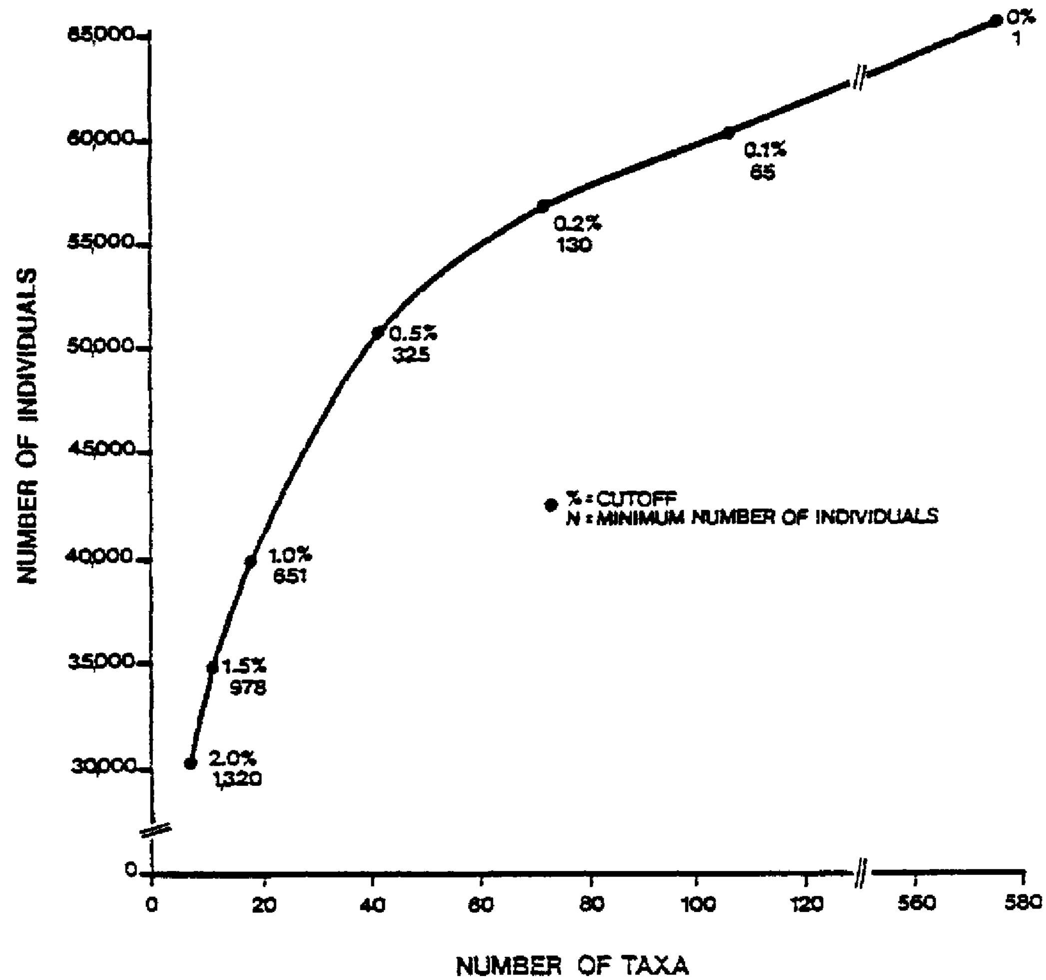

Figure 4-2. Total individuals and numbers of taxa remaining at various minimum cutoff values.

Table 4-3. Taxonomic checklist for 1979 and 1980 LGL samples. Equivalent University of Texas (STOCS) names are in parentheses.

PHYLUM CNIDARIA
  CLASS Hydrozoa
      Suborder Gymnoblastea
        Tubularidae
          Ectopleura grandis (_Tubularia_ sp.—UT)
      Suborder Calyptoblastea
        Campanulinidae
          Calycella syringa
          Lovenella grandis
  CLASS Anthozoa
          Miscellaneous octocoral polyps (unid.)
    Order Gorgonacea
          Leptogorgia setacea (gorgonian, unid.—UT)
    Order Pennatulacea
          Virgularia mirabilis (sea pen, unid.—UT)
        Renillidae
          Renilla mulleri
    Order Zoanthidea
          Palythoa texaensis
          Miscellaneous zoantharians (unid.)
    Order Actiniaria
          Actiniarian sp. A
          Miscellaneous anemones (unid.)
    Order Ceriantharia
          Ceriantharian (unid.)

PHYLUM NEMERTINEA
          Miscellaneous nemerteans (unid.)

PHYLUM NEMATODA
          Miscellaneous nematodes (unid.)

PHYLUM ECTOPROCTA
          Bugula sp. (Bryozoans, unid.—UT)

PHYLUM PHORONIDA
          Miscellaneous phoronids (unid.)

PHYLUM BRACHIOPODA
        Lingulidae
          Glottidia pyramidata

PHYLUM MOLLUSCA
  CLASS Gastropoda
        Vitrinellidae
          Cyclostremiscus pentagonus
          Vitrinella floridana
        Melanellidae
          Liostraca bilineata
        Aclididae
          Bermudaclis sp.

Table 4-3 (cont'd)

Naticidae
- *Natica pusilla*
- *Polynices duplicatus*
- *Sinum maculatum*
- *Sinum perspectivum*

Columbellidae
- *Anachis avara*
- *Anachis obesa*
- *Anachis pulchella*

Buccinidae
- *Cantharus cancellaria*

Nassariidae
- *Nassarius acutus*

Olividae
- *Oliva savana*
- *Olivella dealbata*

Turridae
- *Kurtziella cerinella*

Terebridae
- *Terebra protexta*

Pyramidellidae
- *Odostomia acutidens*
- *Pyramidella crenulata*
- *Turbonilla interrupta*

Cylichnidae
- *Cylichnella bidentata*

Retusidae
- *Volvulella persimilis*
- *Volvulella texasiana*

Aglajidae
- *Aglaja* sp. nov.

Order Nudibranchia

Corambidae
- *Doridella obscura*

CLASS Scaphopoda

Siphonodentaliidae
- *Cadulus carolinensis*

Dentaliidae
- *Dentalium eboreum*
- *Dentalium texasianum*

CLASS Pelecypoda

Nuculidae
- *Nucula aegeensis*

Nuculanidae
- *Nuculana acuta*
- *Nuculana concentrica*

Arcidae
- *Anadara ovalis*
- *Anadara transversa*
- *Arcopsis adamsi*

Lucinidae
- *Lucina amiantus*
- *Parvilucina multilineata*

Table 4-3 (cont'd)

Ungulinidae
Diplodonta cf. *punctata*
Cardiidae
Laevicardium laevigatum
Tellinidae
Macoma tenta
Macoma sp.
Tellina aequistriata
Tellina sybaritica
Tellina versicolor
Semelidae
Abra aequalis
Veneridae
Chione clenchi
Chione grus
Dosinia discus
Pitar cordatus
Petricolidae
Petricola pholadiformis
Corbulidae
Corbula caribaea
Corbula dietziana
Corbula sp.
Varicorbula disparilis
Gastrochaenidae
Gastrochaena hians
Periplomatidae
Periploma inequale

PHYLUM ANNELIDA
CLASS Polychaeta
Polynoidae
Eunoe nodulosa
Lepidasthenia maculata
Eulepethidae
Grubeulepis mexicana
Polyodontidae
Polyodontes lupina
Eupanthalis kinbergi
Sigalionidae
Sthenelais limicola
Thalanessa sp. A
Palmyridae
Bhawania goodei
Amphinomidae
Linopherus ambigua
Phyllodocidae
Eteone lactea
Phyllodoce mucosa

Table 4-3 (cont'd)

- Pilargiidae
  - Ancistrosyllis commensalis
  - Ancistrosyllis jonesi
  - Cabira incerta
  - Litocorsa stremma
  - Pilargis berkelyae
  - Sigambra bassi
  - Sigambra tentaculata
  - Sigambra wassi
- Hesionidae
  - Gyptis brevipalpa
- Syllidae
  - Exogone dispar
  - Exogone verugera
- Nereidae
  - Ceratocephale sp.
  - Ceratonereis irritabilis
  - Nereis cf. grayii
  - Nereis lamellosa
  - Nereis micromma (Nereidae [Nicon] sp. A—UT)
  - Nereis succinea
  - Nereis sp. D
- Nephtyidae
  - Aglaophamus verrilli
  - Nephtys incisa
  - Nephtys picta
- Glyceridae
  - Glycera americana
  - Glycera sp. A
- Goniadidae
  - Goniada littorea
  - Ophioglycera sp.
  - Ophioglycera sp. A
- Eunicidae
  - Marphysa sp. A
- Onuphidae
  - Diopatra cuprea
  - Onuphis cf. quadricuspis
  - Onuphis sp. A
  - Onuphis sp. B
  - Onuphis sp. C
  - Lumbrineridae
  - Lumbrineris cruzensis (L. cf. magalhaensis—UT)
  - Lumbrineris ernesti (L. tenuis—UT)
  - Lumbrineris januarii
  - Lumbrineris sp. nov. (L. parvepedata—UT)
  - Ninoe nigripes
- Arabellidae
  - Arabella iricolor
  - Drilonereis magna
- Dorvilleidae
  - Schistomeringos rudolphi

Table 4-3 (cont'd)

Spionidae
- Apoprionospio pygmaea
- Laonice cirrata
- Malacoceros sp.
- Paraprionospio pinnata
- Prionospio cirrobranchiata (Minuspio cirrifera—UT)
- Prionospio cristata
- Prionospio steenstrupi
- Scolelepis sp.
- Spiophanes bombyx

Magelonidae
- Magelona cincta
- Magelona longicornis
- Magelona pettiboneae
- Magelona phyllisae
- Magelona cf. sacculata

Chaetopteridae
- Spiochaetopterus costarum oculatus

Cirratulidae
- Chaetozone corona (C. setosa—UT)
- Tharyx marioni
- Tharyx setigera
- Tharyx sp.

Heterospionidae
- Heterospio longissima

Cossuridae
- Cossura delta

Orbiniidae
- Haploscoloplos foliosus
- Haploscoloplos fragilis
- Scoloplos rubra

Paraonidae
- Aricidea finitima
- Aricidea fragilis
- Aricidea taylori
- Aricidea sp.
- Paraonides lyra
- Paraonis gracilis

Opheliidae
- Armandia agilis
- Armandia maculata

Capitellidae
- Capitella capitata
- Mediomastus californiensis
- Notomastus hemipodus
- Notomastus cf. latericeus

Maldanidae
- Asychis carolinae
- Clymenella torquata
- Proclymene sp.

Oweniidae
- Owenia fusiformis

Table 4-3 (cont'd)

Sabellaridae
Sabellaria vulgaris vulgaris
Pectinariidae
Pectinaria gouldii
Ampharetidae
Ampharete acutifrons
Ampharete parvidentata
Isolda pulchella
Melinna maculata
Terebellidae
Loimia viridis
Pista quadrilobata
Polycirrus cf. *carolinensis*
Trichobranchidae
Terebellides stroemii
Sabellidae
Chone filicaudata

PHYLUM SIPUNCULA
Phascolion sp.
Miscellaneous sipunculids (uni

PHYLUM ARTHROPODA
CLASS Crustacea
SUBCLASS Ostracoda
Miscellaneous ostracods (unid.)
SUBCLASS Malacostraca
Order Mysidacea
Anchialina typica
Bowmaniella brasiliensis
Bowmaniella floridana
Bowmaniella cf. *portoricensis*
Metamysidopsis swifti
Mysidopsis bigelowi
Order Cumacea
Cyclaspis pustulata
Cyclaspis varians
Cyclaspis sp. B
Eudorella monodon
Oxyurostylis sp.
Order Tanaidacea
Apseudes sp. A
Kalliapseudes sp.
Typhlapseudes sp.
Order Isopoda
Anthuridae
Xenanthura brevitelson
Idoteidae
Edotea montosa
Erichsonella attenuata
Sphaeromatidae
Ancinus depressus

Table 4-3 (cont'd)

Order Stomatopoda
- *Squilla empusa*
- *Squilla neglecta*

Order Amphipoda
- Caprellidae
  - *Paracaprella pusilla*
- Ampeliscidae
  - *Ampelisca abdita*
  - *Ampelisca agassizi*
  - *Ampelisca verrilli*
  - *Ampelisca* sp. B
  - *Ampelisca* sp.
- Melitidae
  - *Eriopsia* sp. B
- Oedicerotidae
  - *Monoculodes nyei* (*Monoculodes* sp. B—UT)
  - *Synchelidium americanum*
- Corophiidae
  - *Cerapus* sp.
  - *Erichthonius brasiliensis*
  - *Grandidierella* sp.
  - *Neomegamphopus* sp.
  - *Photis melanicus* (*Photis* sp. B—UT)
  - *Unciola serrata*
- Lysianassidae
  - *Hippomedon* cf. *serratus*
- Bateidae
  - *Batea* sp.
- Synopiidae
  - *Tiron tropakis*
- Liljeborgiidae
  - *Listriella barnardi*
  - *Listriella* sp. A
- Phoxocephalidae
  - *Trichophoxus floridanus* (*Paraphoxus epistomus*—UT)
- Haustoriidae
  - *Acanthohaustorius millsi*
  - *Platyischnopus* sp.
  - *Protohaustorius bousfieldi*
- Stenothoidae
  - *Parametopella texensis*
- Amphilochidae
  - Amphilochid sp. A

Order Decapoda
- Penaeidae
  - *Penaeus* sp.
  - *Trachypenaeus constrictus*
  - *Trachypenaeus* sp.
  - *Xiphopenaeus kroyeri*
- Sicyoniidae
  - *Sicyonia dorsalis*
- Sergestidae
  - *Acetes americanus*

Table 4-3 (cont'd)

Pasiphaeidae
  Leptochela serratorbita
Palaemonidae
  Pontonia sp.
Alpheidae
  Alpheus sp. A
  Alpheus sp. B
  Automate sp.
Hippolytidae
  Latreutes parvulus
Ogyrididae
  Ogyrides limicola
Processidae
  Processa sp.
Callianassidae
  Callianassa biformis
Upogebiidae
  Upogebia affinis
Porcellanidae
  Porcellana sayana
Paguridae
  Pagurus cf. *bullisi*
Albuneidae
  Albunea gibbesi
  Albunea paretii
Calappidae
  Hepatus epheliticus
  Osachila sp.
Leucosiidae
  Persephona crinita
  Persephona mediterranea
Majidae
  Libinia emarginata
Portunidae
  Portunus gibbesii
Xanthidae
  Hexapanopeus angustifrons
Goneplacidae
  Chasmocarcinus mississippiensis
  Frevillea barbata
  Glyptoplax smithi
  Speocarcinus lobatus
  Speocarcinus sp.
Pinnotheridae
  Pinnixa cf. *retinens*
  Pinnixa sp.

PHYLUM ECHINODERMATA
  CLASS Ophiuroidea
    Amphiuridae
      Amphiura stimpsoni
      Micropholis atra

Table 4-3 (cont'd)

Ophiactidae
Hemipholis elongata

CLASS Echinoidea
Order Clypeasteroida
Melitidae
Mellita quinquiesperforata
Order Spatangoida
Schizasteridae
Moira atropos
CLASS Holothuroidea
Order Dendrochirotida
Cucumariidae
Pentamera pulcherrima
Thione mexicana
Order Apodida
Synaptidae
Protankyra cf. *benedeni*
Order Molpadiida
Holothuriidae
Holothuria cubana

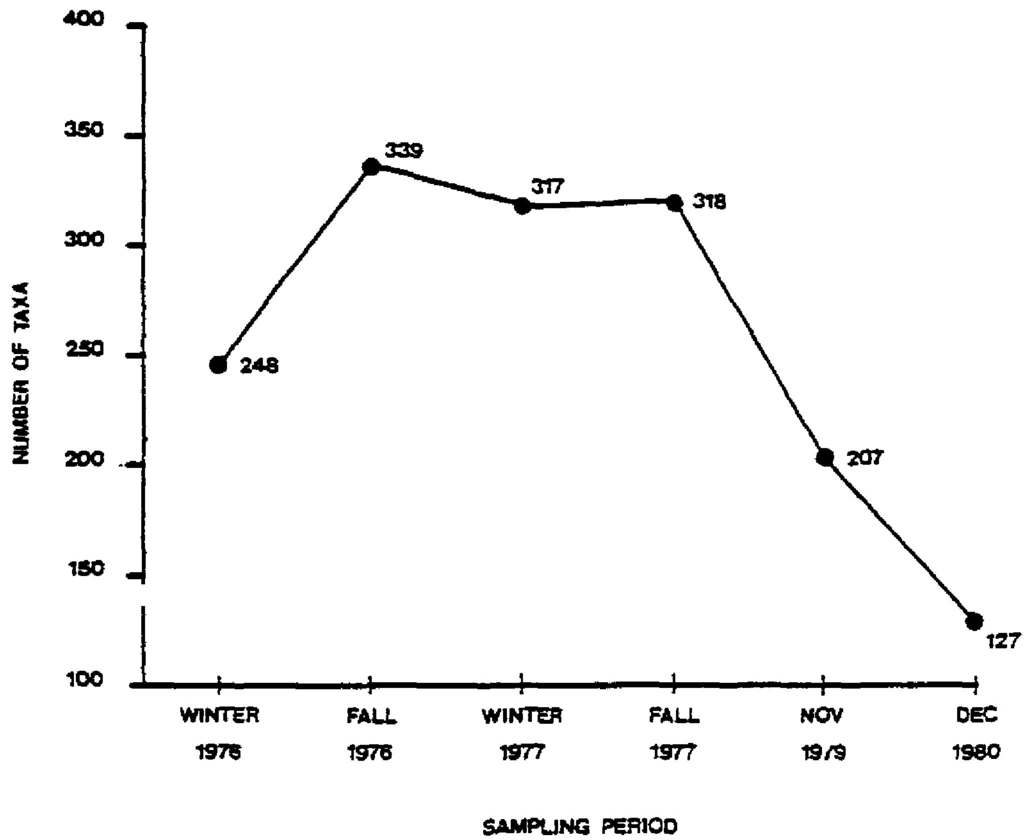

Figure 4-3. Number of taxa at all stations together, by sampling period.

from the fall 1976 and winter 1977 sampling periods, with winter 1976 and fall 1977 sampling periods falling between the two pairs (Figure 4-4A). Winter 1976, 1979 and 1980 samples included fewer taxa than did the other three sampling periods. Many taxa were present in more than 1 sampling period (Figure 4-5), although most were collected only once (201 taxa) or twice (116 taxa). There were many significant differences in numbers of macroinfaunal taxa identified from one sampling period to the next, within stations (Figure 4-4B).

The numbers of individuals of macroinfaunal taxa collected at all 12 stations taken together changed sharply from one sampling period to the next (Figure 4-6). Many of the less common taxa were extremely rare. For example, 105 taxa (18% of the total 576 taxa included in this study) were represented by only one individual; five or fewer individuals were collected for 249 taxa (43% of 576). The 1979 and 1980 samples included fewer individuals than did any of the other sampling periods. The Friedman two-way ANOVA for all stations together by sampling period (Figure 4-7A) highlighted a distinct break in abundance, with 1979 and 1980 samples having relatively low numbers of individuals, and winter and fall 1977 sampling periods having relatively high numbers of individuals. The two sets of time periods differed significantly, sharing one sampling period (winter 1976) with intermediate abundance between the two. Within stations, there were also many statistically significant differences from one time period to the next in the abundance of numerically dominant taxa (Figure 4-7B).

The strongest associations between sampling periods in terms of numbers of taxa identified (based on numbers of non-significant ($P > 0.05$) pairs in the Kruskal-Wallis ANOVA) were those between the three sampling periods having highest numbers of identified taxa: fall 1976, winter 1977, and fall 1977 (four pairs each). This may be seen in Figure 4-8, a derivative of Figures 4-4 and 4-7, in which the numbers within each shaded square equal the number of times two time periods were connected by an unbroken line (i.e. a non-significant difference) in Figure 4-4B or 4-7B (top and bottom, respectively, of Figure 4-8). Other less frequent pairings included winter 1976 with winter 1977, winter 1976 with fall 1977, and 1979 with 1980 (two pairs each). The strongest associations between sampling periods in terms of numbers of individuals were between fall 1977 and winter 1977, and fall 1976 and winter 1977 (five pairs each). Other less strong associations were between winter 1976 and winter 1977 (four pairs); fall 1976 and fall 1977, and 1979 and 1980 (three pairs each); and between winter 1976 and fall 1976, winter 1976 and fall 1977, winter 1976 and 1979, and winter 1976 and 1980 (two pairs each).

When all stations were grouped together, the relative proportions of numbers of individuals of each numerically dominant taxon (Figure 4-9) remained fairly constant. The polychaetes Magelona phyllisae (Magelonidae), Lumbrineris sp. nov. (Lumbrineridae), and Paraprionospio pinnata (Spionidae); and miscellaneous unidentified sipunculids and nemerteans were consistent components through time. The relative proportions of each major group of taxa (Figure 4-10) for all stations together also were rather stable. Deposit feeding and carnivorous or

A	ALL STATIONS TOGETHER	DEC 1980	NOV 1979	WINTER 1976	FALL 1977	WINTER 1977	FALL 1976
B	STATION I-4	DEC 1980	NOV 1979	FALL 1977	WINTER 1976	WINTER 1977	FALL 1976
	STATION I-1	NOV 1979	FALL 1977	DEC 1980	FALL 1976	WINTER 1976	WINTER 1977
	STATION I-2	DEC 1980	NOV 1979	WINTER 1976	WINTER 1977	FALL 1976	FALL 1977
	STATION II-1	DEC 1980	FALL 1977	NOV 1979	WINTER 1976	WINTER 1977	FALL 1976
	STATION II-4	DEC 1980	NOV 1979	WINTER 1976	WINTER 1977	FALL 1977	FALL 1976
	STATION II-2	DEC 1980	NOV 1979	WINTER 1976	FALL 1977	WINTER 1977	FALL 1976
	STATION III-4	DEC 1980	NOV 1979	WINTER 1976	WINTER 1977	FALL 1976	FALL 1977
	STATION III-1	DEC 1980	NOV 1979	WINTER 1976	FALL 1977	WINTER 1977	FALL 1976
	STATION III-5	DEC 1980	NOV 1979	WINTER 1976	FALL 1977	WINTER 1977	FALL 1976
	STATION IV-4	DEC 1980	NOV 1979	WINTER 1976	FALL 1977	FALL 1976	WINTER 1977
	STATION IV-1	DEC 1980	WINTER 1976	NOV 1979	WINTER 1977	FALL 1977	FALL 1976
	STATION IV-5	NOV 1979	DEC 1980	WINTER 1976	WINTER 1977	FALL 1977	FALL 1976

Figure 4-4. Non-significant differences (P>0.05)(underlined) in numbers of taxa for all stations together [a] (Friedman two-way ANOVA) and for individual stations [b] (Kruskal-Wallis ANOVAS; 1% cutoff within stations), by sampling period.

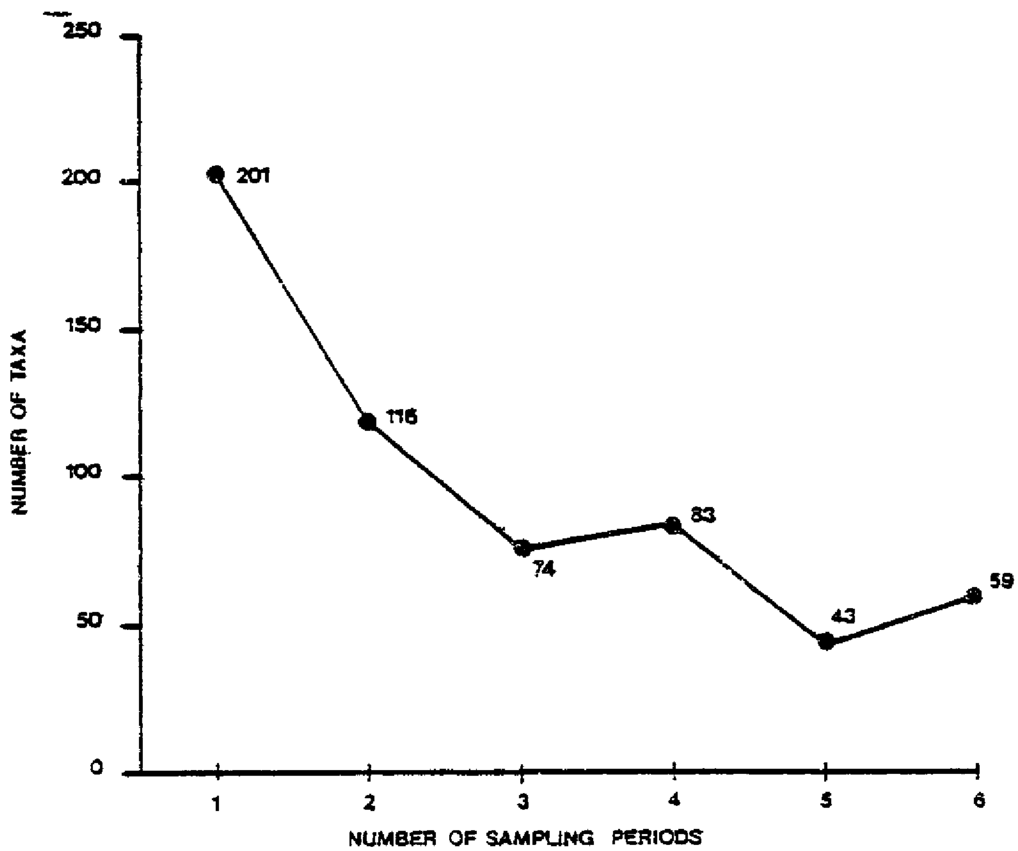

Figure 4-5. Number of taxa occurring in one or more sampling periods.

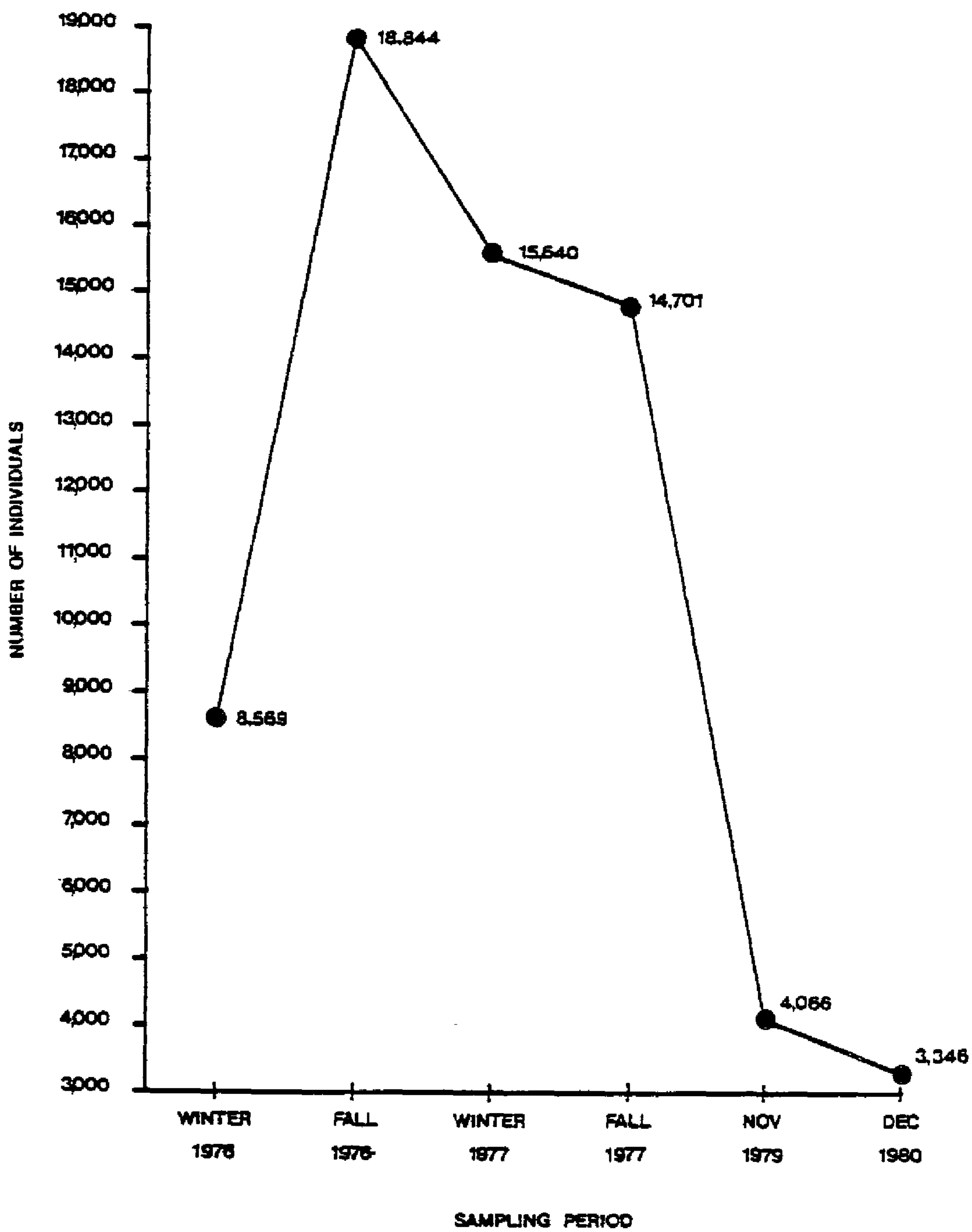

Figure 4-6. Number of individuals at all stations together (six 0.1 m^2 grabs/station x 12 stations = 7.2 m^2) by sampling period.

A.	ALL STATIONS TOGETHER	DEC 1980	NOV 1979	WINTER 1976	FALL 1977	WINTER 1977	FALL 1976
B.	STATION I-4	NOV 1979	DEC 1980	FALL 1976	WINTER 1976	FALL 1977	WINTER 1977
	STATION I-1	NOV 1979	DEC 1980	FALL 1976	FALL 1977	WINTER 1976	WINTER 1977
	STATION I-2	DEC 1980	NOV 1979	WINTER 1976	FALL 1976	WINTER 1977	FALL 1977
	STATION II-1	DEC 1980	NOV 1979	FALL 1977	WINTER 1977	WINTER 1976	FALL 1976
	STATION II-4	DEC 1980	NOV 1979	WINTER 1976	WINTER 1977	FALL 1977	FALL 1976
	STATION II-2	DEC 1980	NOV 1979	WINTER 1976	WINTER 1977	FALL 1977	FALL 1976
	STATION III-4	DEC 1980	NOV 1979	WINTER 1976	WINTER 1977	FALL 1977	FALL 1976
	STATION III-1	DEC 1980	NOV 1979	FALL 1977	WINTER 1976	FALL 1976	WINTER 1977
	STATION III-5	WINTER 1976	NOV 1979	DEC 1980	FALL 1977	WINTER 1977	FALL 1976
	STATION IV-4	DEC 1980	NOV 1979	WINTER 1976	FALL 1977	FALL 1976	WINTER 1977
	STATION IV-1	DEC 1980	NOV 1979	WINTER 1976	WINTER 1977	FALL 1977	FALL 1976
	STATION IV-5	NOV 1979	DEC 1980	WINTER 1976	FALL 1976	FALL 1977	WINTER 1977

Figure 4-7. Non-significant differences (P>0.05) (underlined) in numbers of individuals for all stations together [A] (Friedman two-way ANOVA); and for individual stations [B] (Kruskal-Wallis ANOVAS; 1% cutoff within stations), by sampling period.

	WINTER 1976	FALL 1976	WINTER 1977	FALL 1977	NOV 1979	DEC 1980
WINTER 1976		2	4	2	2	2
FALL 1976	1		5	3		
WINTER 1977	2	4		5		
FALL 1977	2	4	4			
NOV 1979	1					3
DEC 1980		1			2	

Figure 4-8. Associations between sampling periods for numbers of individuals (top) and numbers of taxa (bottom), based on total non-significant (P>0.05) pairs between time periods (numbers within shaded areas) in the Kruskal-Wallis ANOVAS (1% cutoff within stations): see text for explanation.

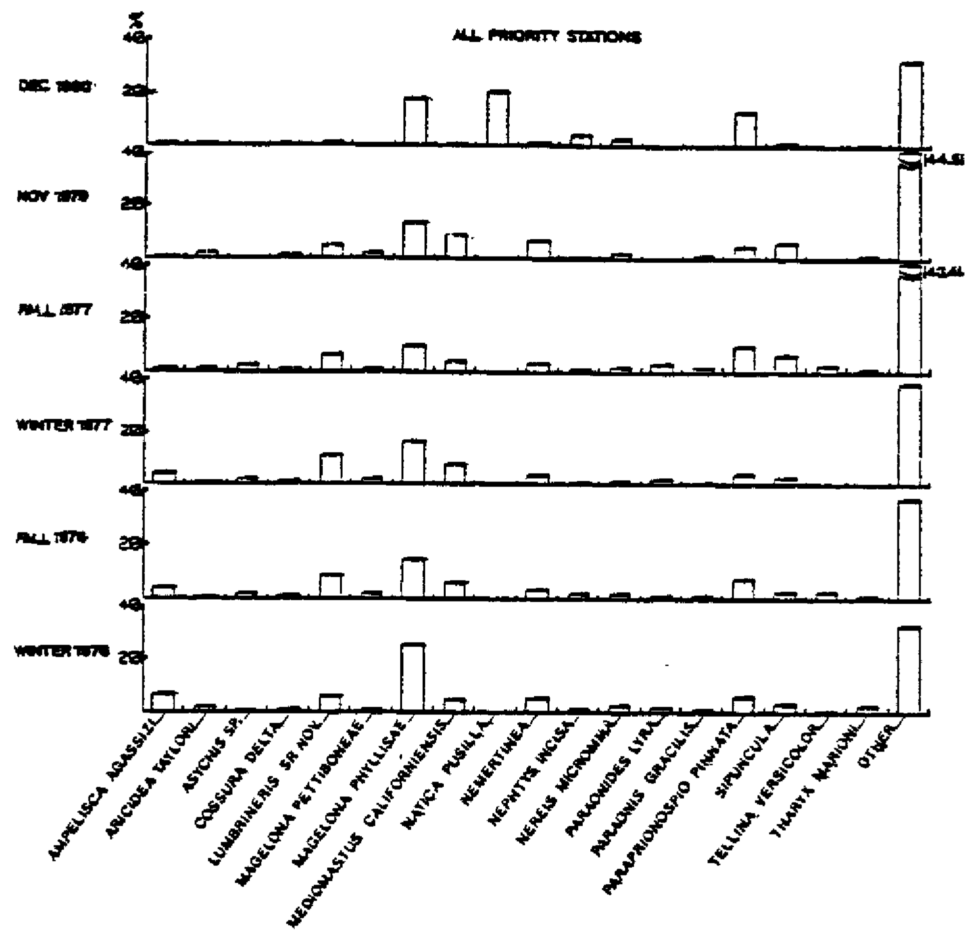

Figure 4-9. Relative proportions of numbers of individuals of numerically dominant taxa for all stations together, by sampling period (1% cutoff).

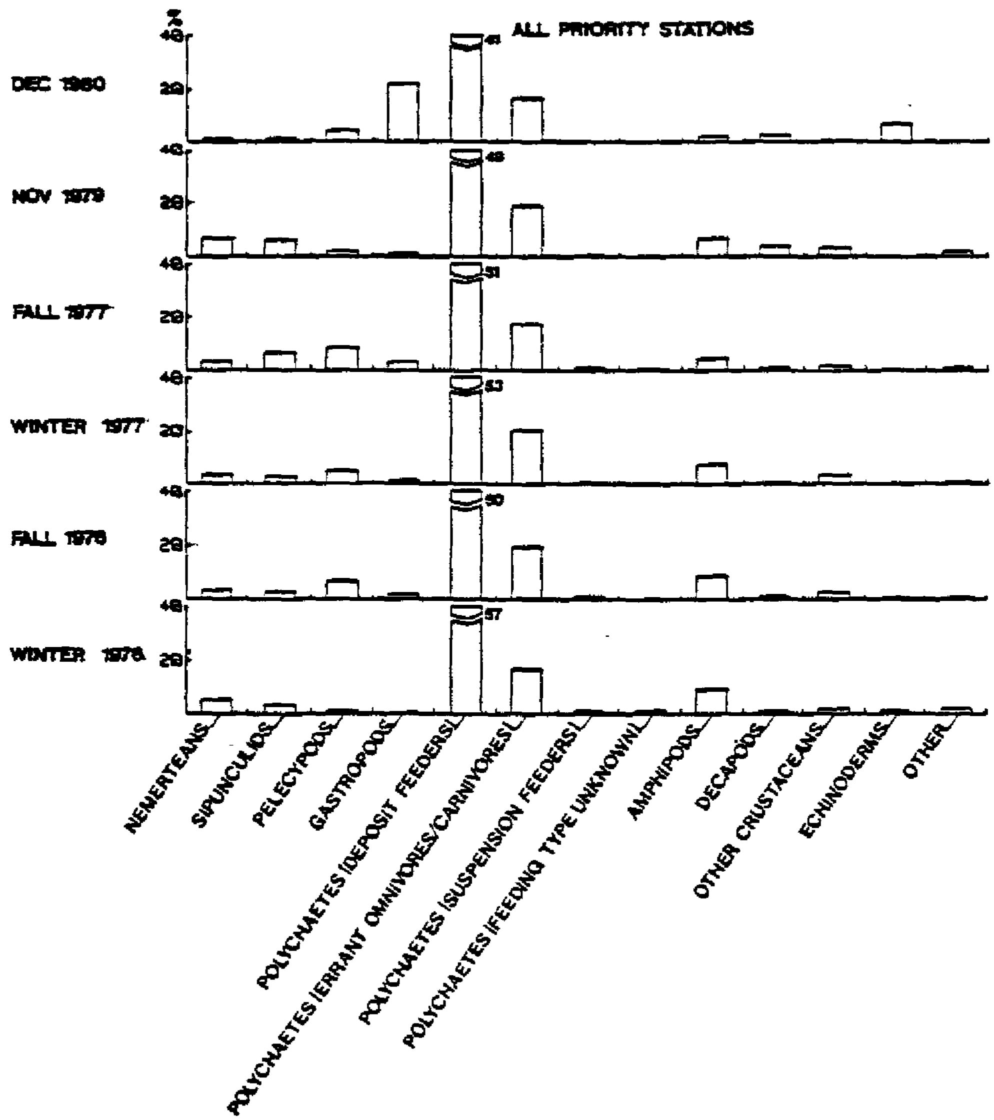

Figure 4-10. Relative proportions of numbers of individuals of major groups of taxa for all stations together, by sampling period.

omnivorous polychaetes were most important, followed by amphipods, molluscs, sipunculids, and nemerteans. However, large fluctuations in the abundance of any given taxon and even of the major groups of taxa were common at most stations from one time period to the next (Figures 4-11 through 4-34).

Diversity (H') for all taxa together showed its highest values during fall 1977 (4.13), fall 1976 (3.97), and 1979 (3.95). Winter 1977, winter 1976, and 1980 values were 3.86, 3.55, and 3.14 respectively, viewing all stations together (Figure 4-35). Evenness (V') was highest in 1979 (0.74) and fall 1977 (0.70). Fall 1976, winter 1977, winter 1976, and 1980 showed lower values (0.67, 0.66, 0.63, and 0.62 respectively). On a station-by-station basis, changes in numbers of taxa and individuals were accompanied by a variety of responses of H' and V', ranging from simultaneous increases or decreases in both indices, to increases or decreases in one or the other index without a concordant change in the other (Figures 4-36 through 4-47, Table 4-4). A test for internal consistency was performed on both indices to confirm that they were acting on the data set in the manner for which they were designed. The test results supported the use of the indices, showing that H' was positively correlated with numbers of taxa (sign test $p = 0.01$) but was independent of changes in overall numbers of individuals, and that V' was neither correlated with numbers of individuals nor with numbers of taxa.

When numerically abundant taxa were grouped into two presence/absence association diagrams, one focusing upon station groupings with depth and the other upon sampling periods (Figures 4-48 and 4-49 respectively), a number of trends were revealed. The taxa listed in both diagrams are presented in order of increasing average depth of collection (top to bottom).

Figure 4-48 is divided into six individual rectangular grids, one per sampling period. The horizontal scale within each sampling period lists stations by increasing depth (left to right). Thus, taxa present (+) primarily at shallow stations appear at the upper left of each of the six rectangular grids, while those present primarily at deeper stations appear toward the bottom right of each grid.

Figure 4-49 displays presence/absence data grouped into twelve rectangular grids, each of which represents a single station. Stations are ordered by increasing depth (left to right). The horizontal scale within each station lists sampling periods in chronological sequence, from winter 1976 ("1") through 1980 ("6"). Thus, taxa that were common at shallower stations appear toward the left side of Figure 4-49, while those common at deeper stations appear toward the right side. Taxa most frequently found in deeper water appear toward the bottom of the figure, while those restricted to shallow water appear toward the top of the figure.

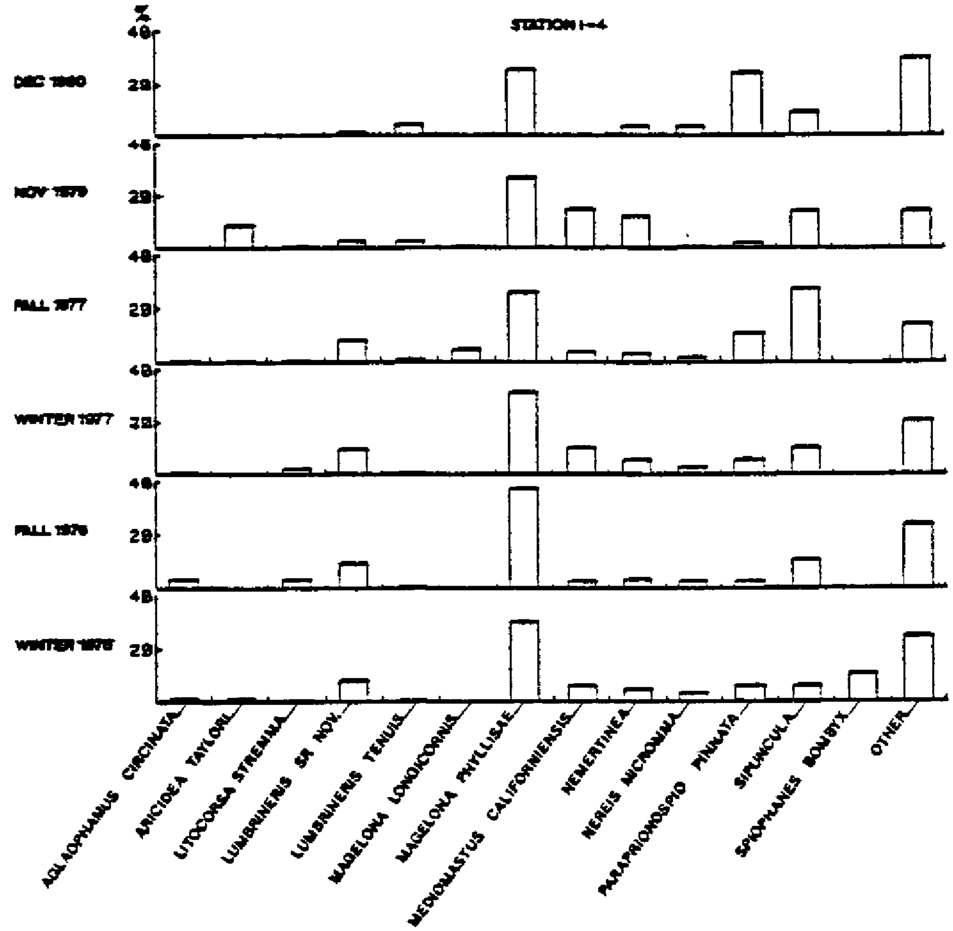

Figure 4-11. Relative proportions of numbers of individuals of numerically dominant taxa at Station I-4 (1% cutoff).

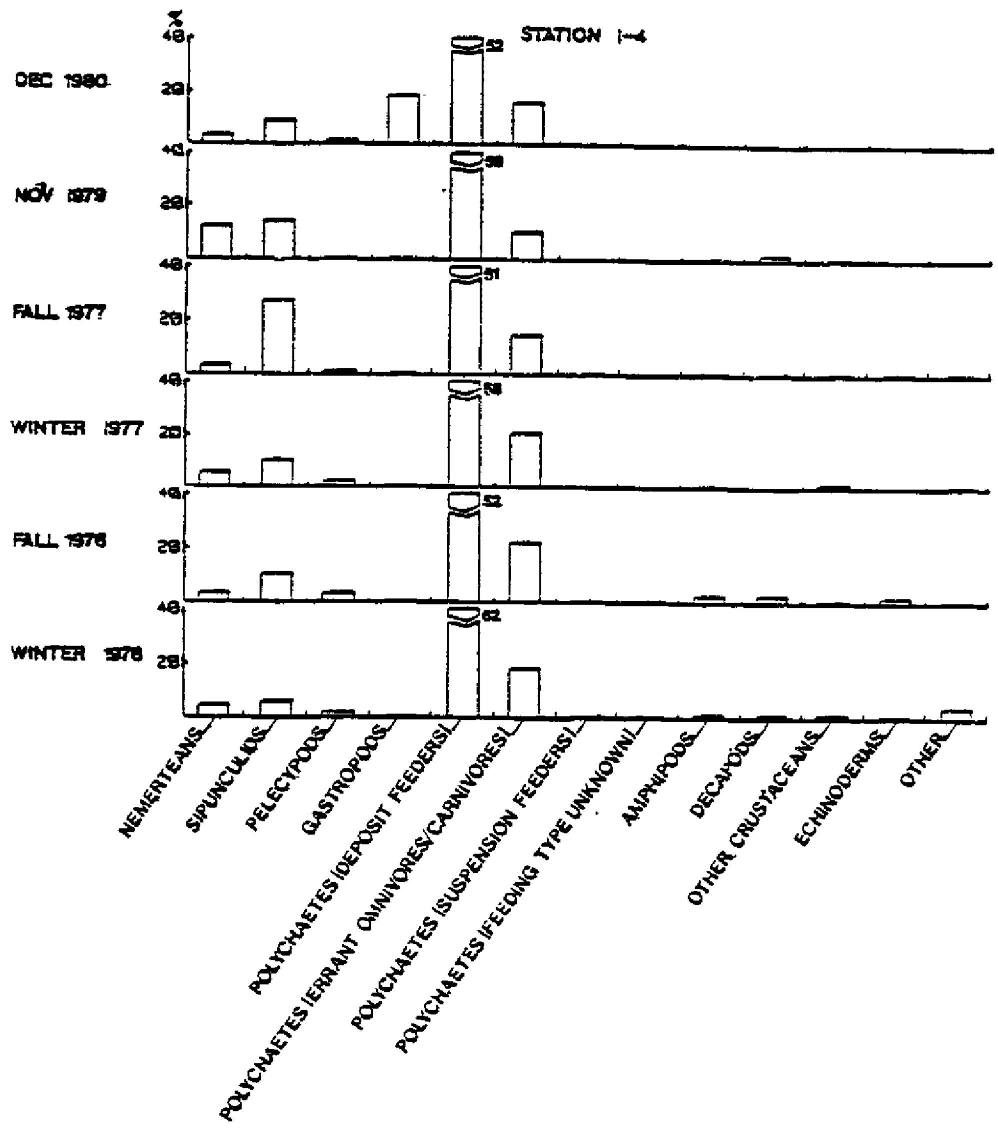

Figure 4-12. Relative proportions of numbers of major groups of numerically dominant taxa at Station I-4, by sampling period (1% cutoff).

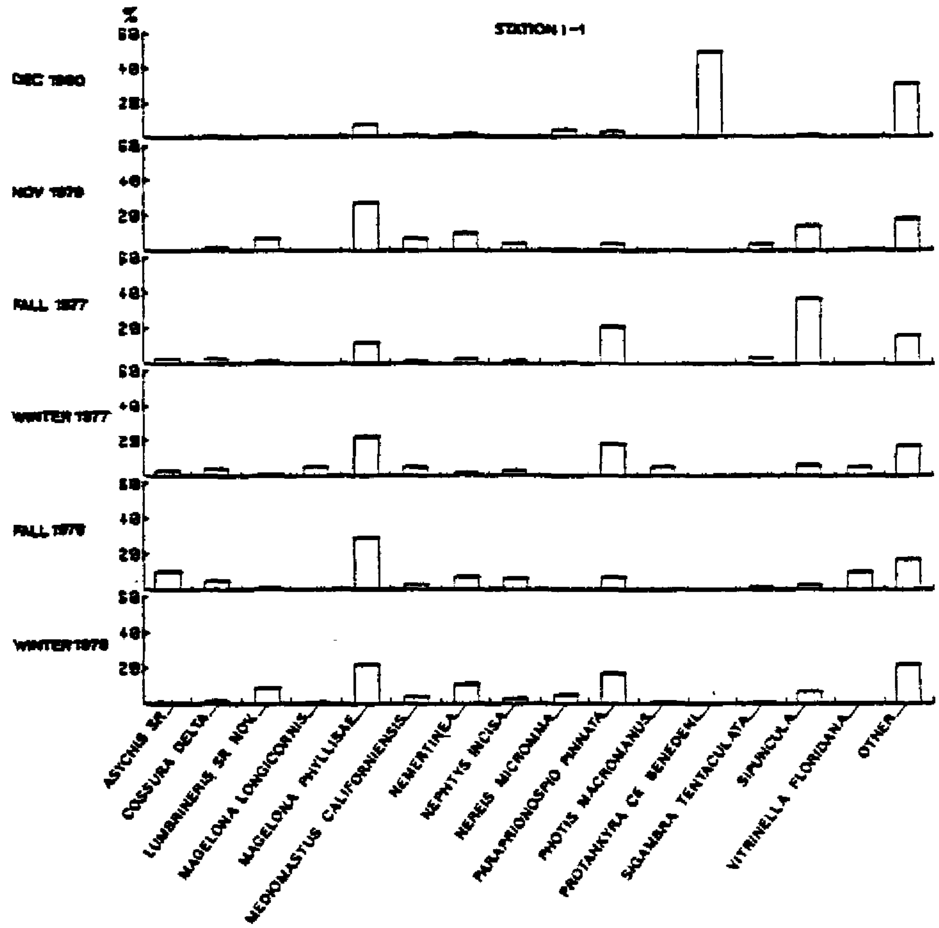

Figure 4-13. Relative proportions of numbers of individuals of numerically dominant taxa at Station I-1, by sampling period (1% cutoff).

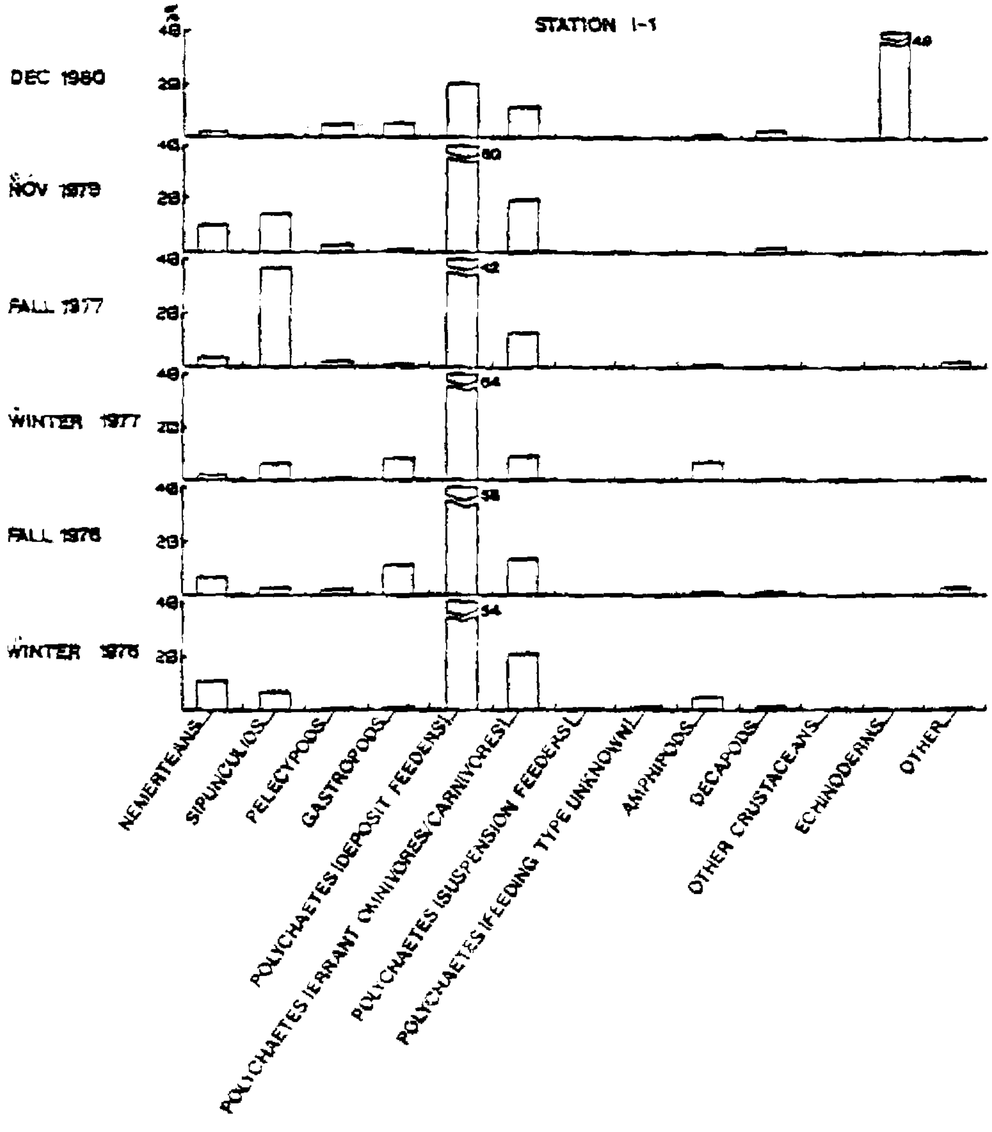

Figure 4-14. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station I-1, by sampling period (1% cutoff).

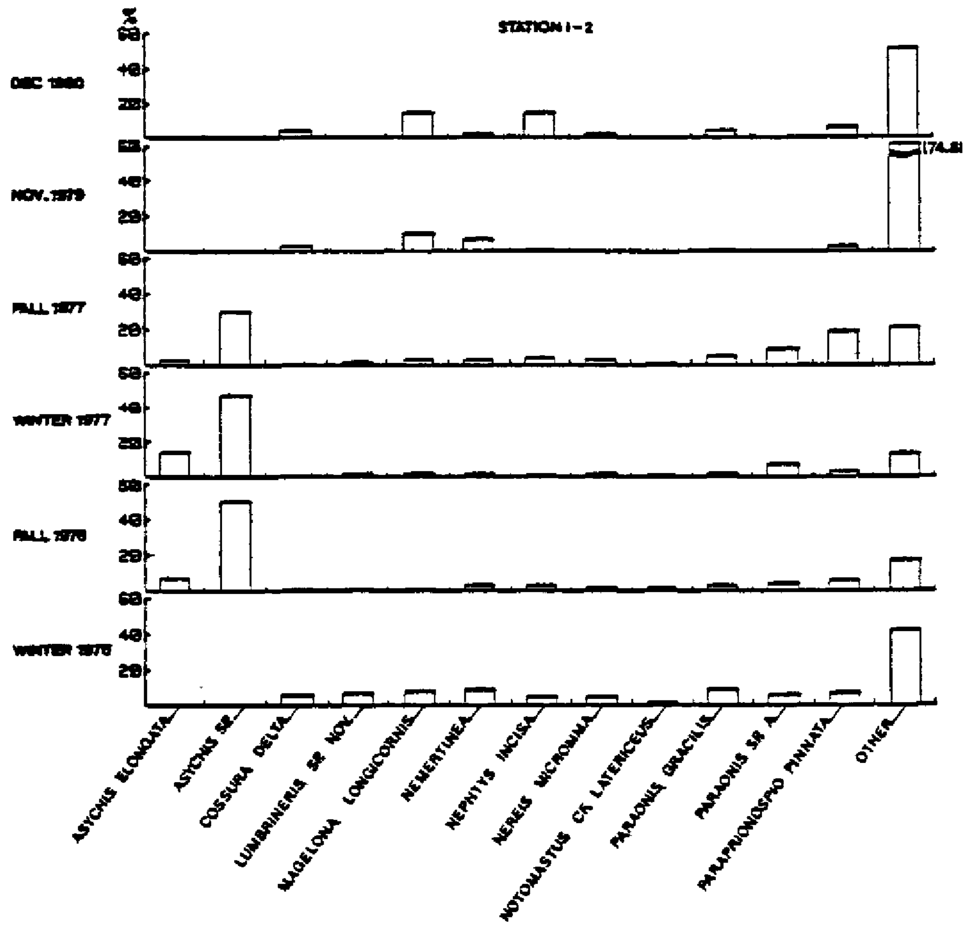

Figure 4-15. Relative proportions of numbers of individuals of numerically dominant taxa at Station I-2, by sampling period (1% cutoff).

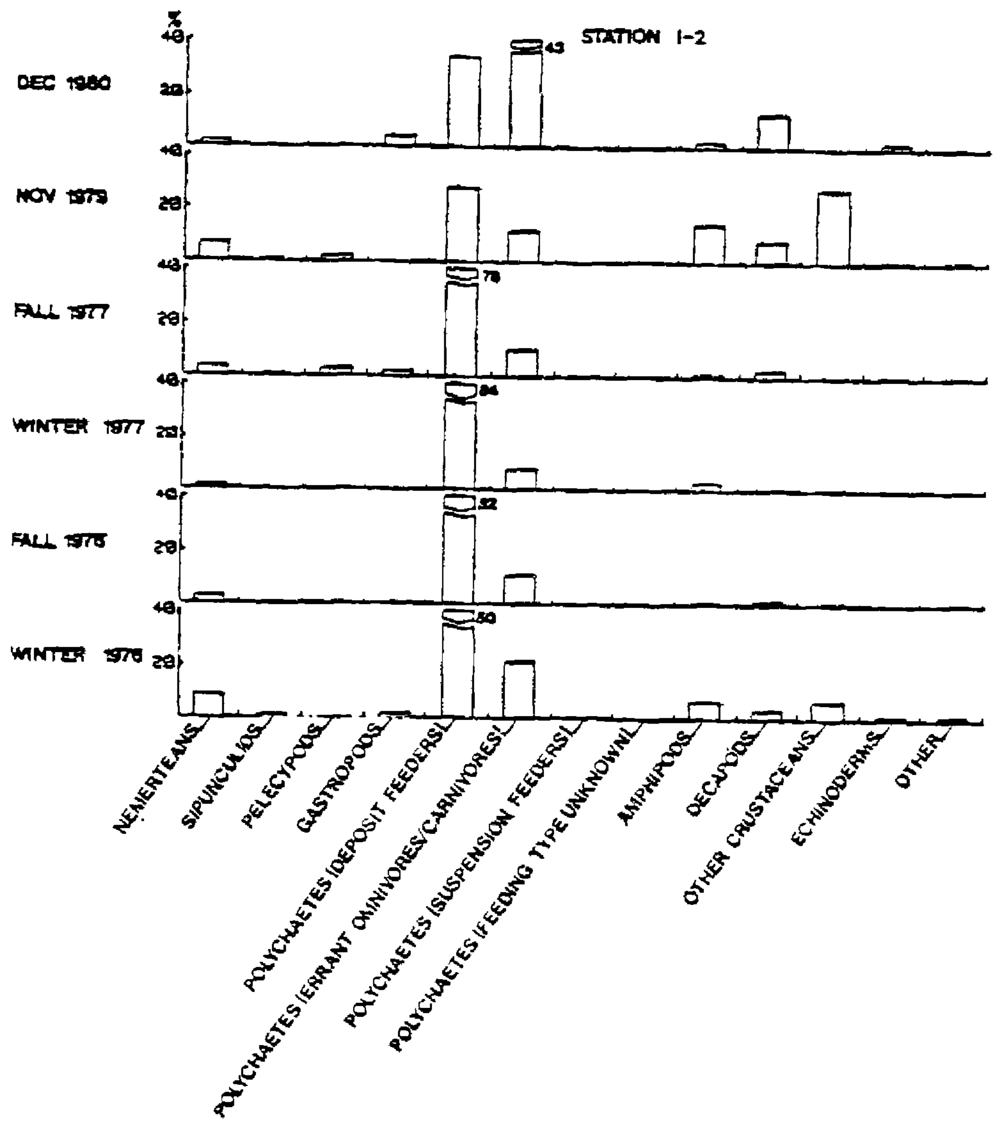

Figure 4-16. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station I-2, by sampling period (1% cutoff).

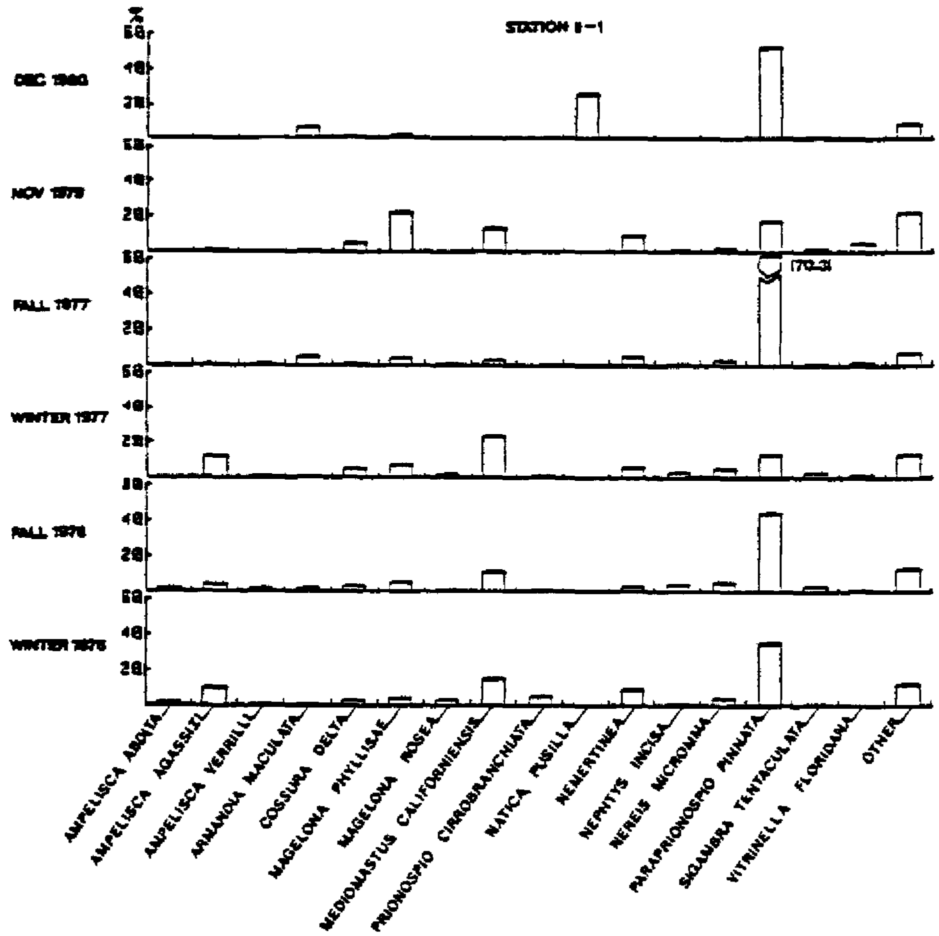

Figure 4-17. Relative proportions of numbers of individuals of numerically dominant taxa at Station II-1, by sampling period (1% cutoff).

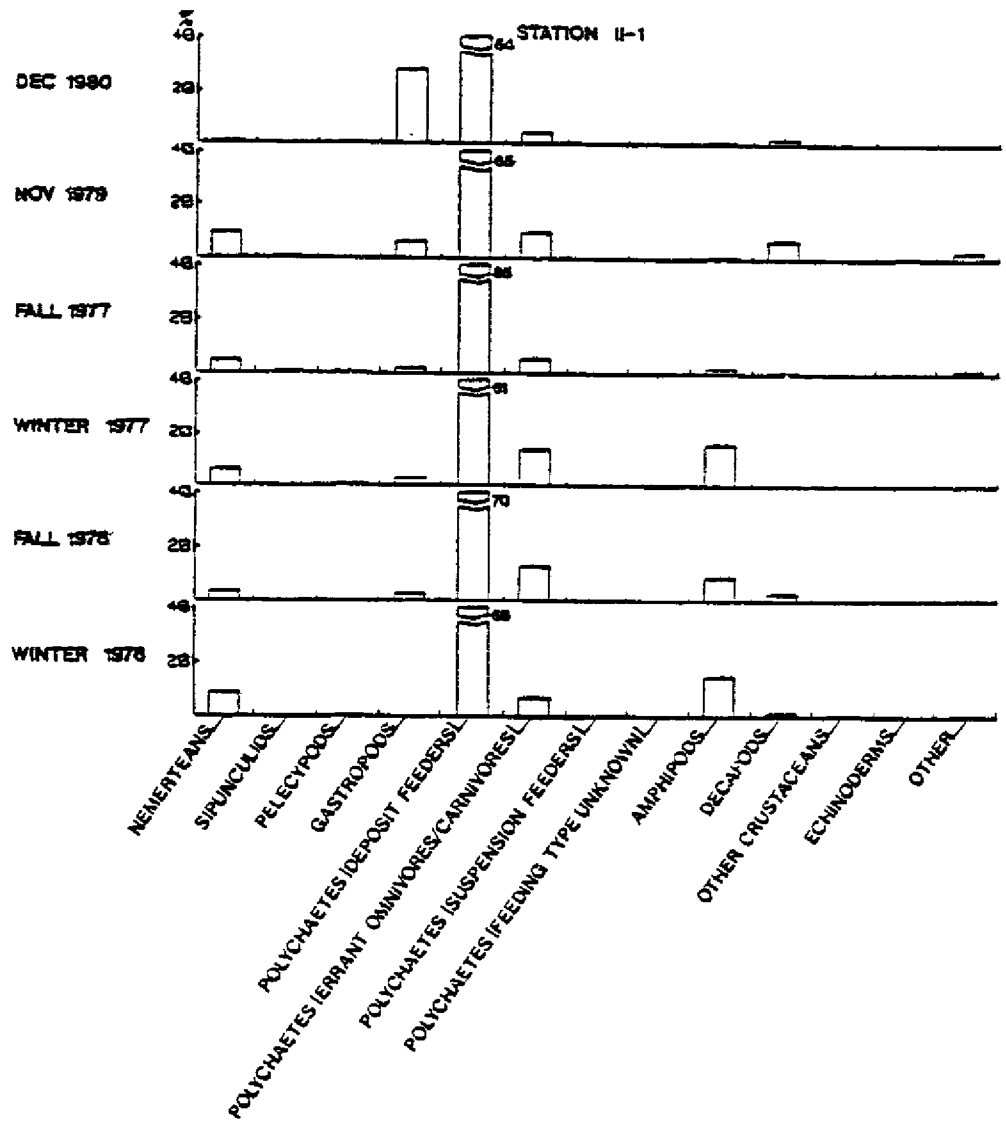

Figure 4-18. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station II-1, by sampling period (1% cutoff).

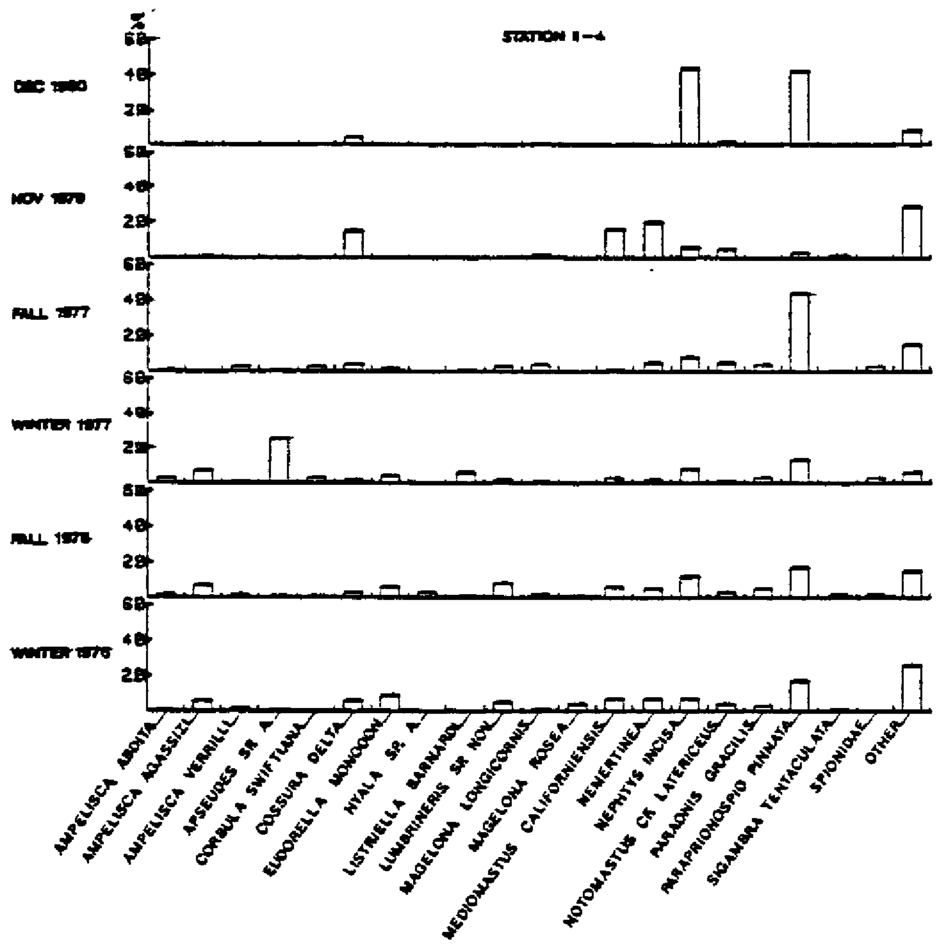

Figure 4-19. Relative proportions of numbers of individuals of numerically dominant taxa at Station II-4, by sampling period (1% cutoff).

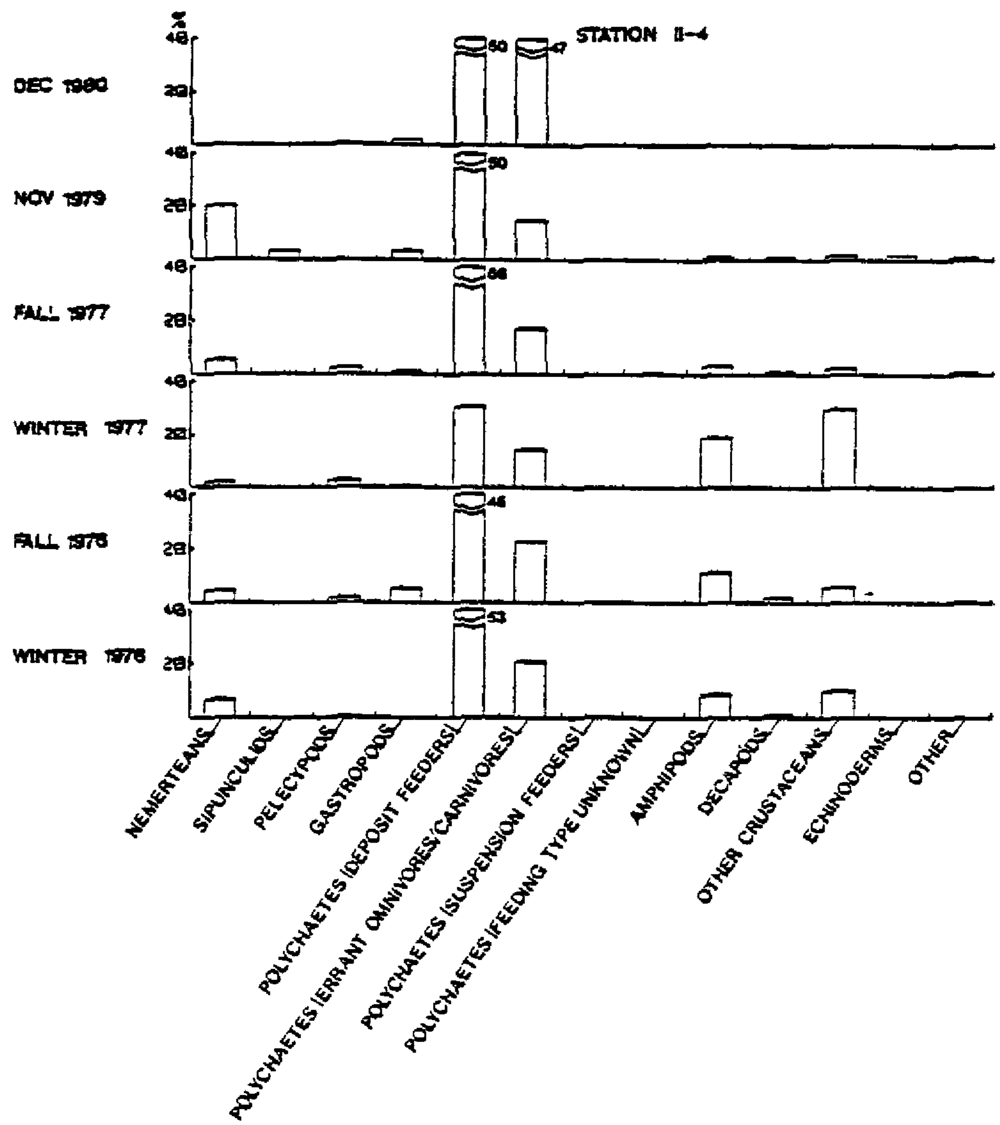

Figure 4-20. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station II-4, by sampling period (1% cutoff).

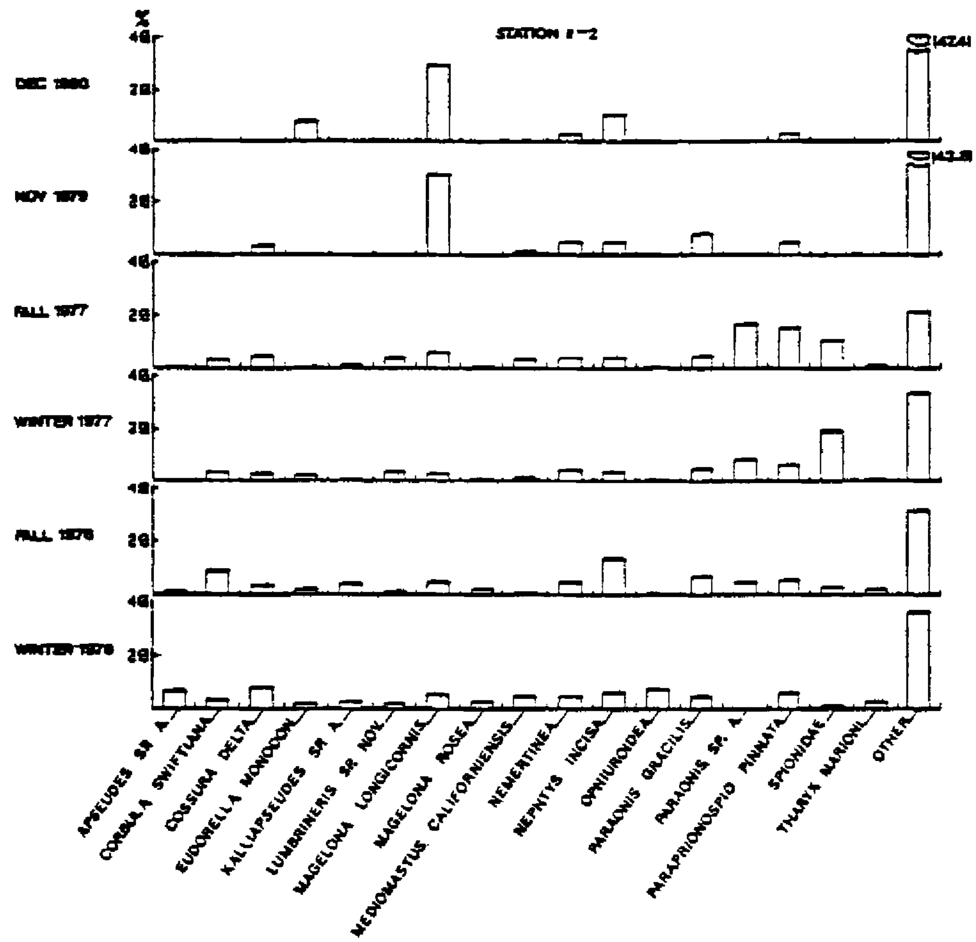

Figure 4-21. Relative proportions of numbers of individuals of numerically dominant taxa at Station II-2, by sampling period (1% cutoff).

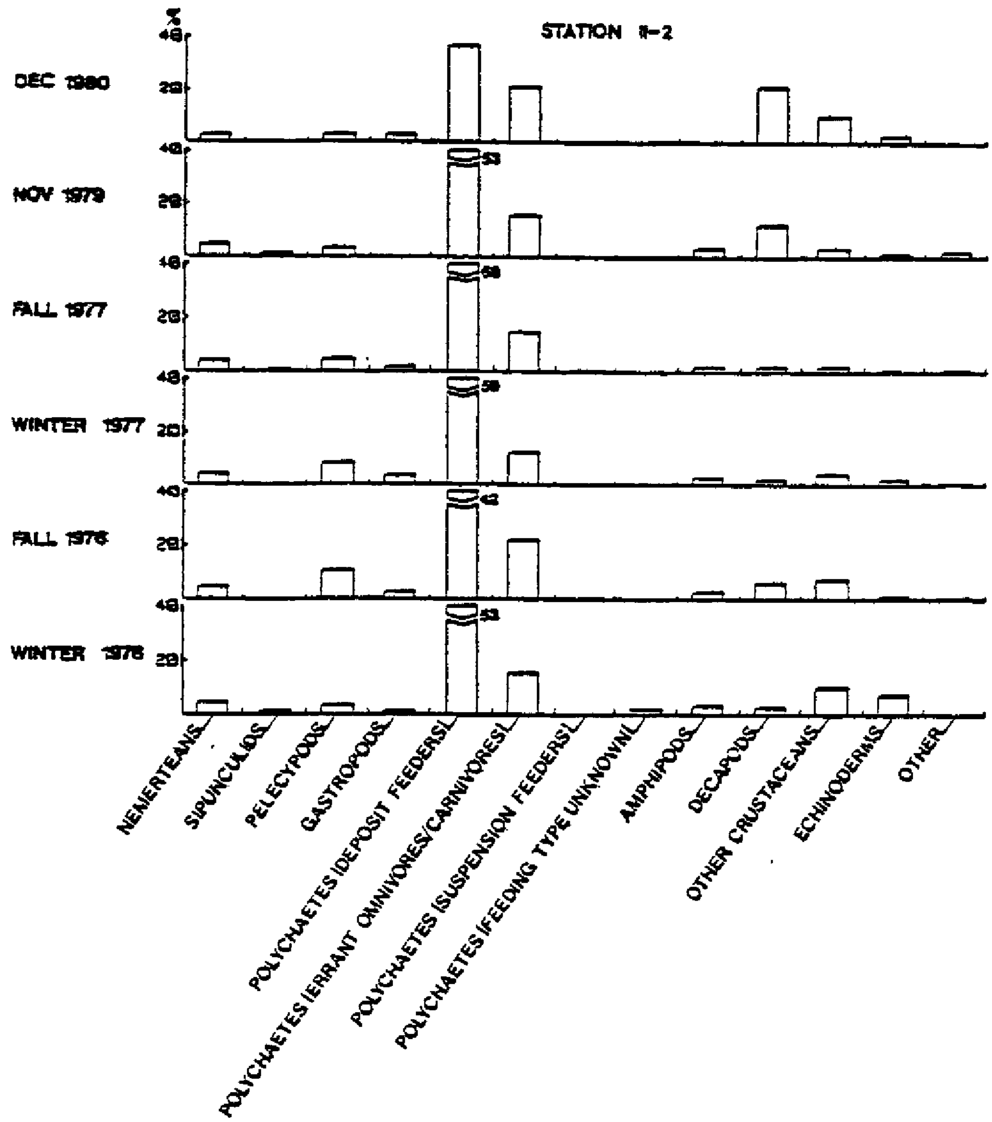

Figure 4-22. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station II-2, by sampling period (1% cutoff).

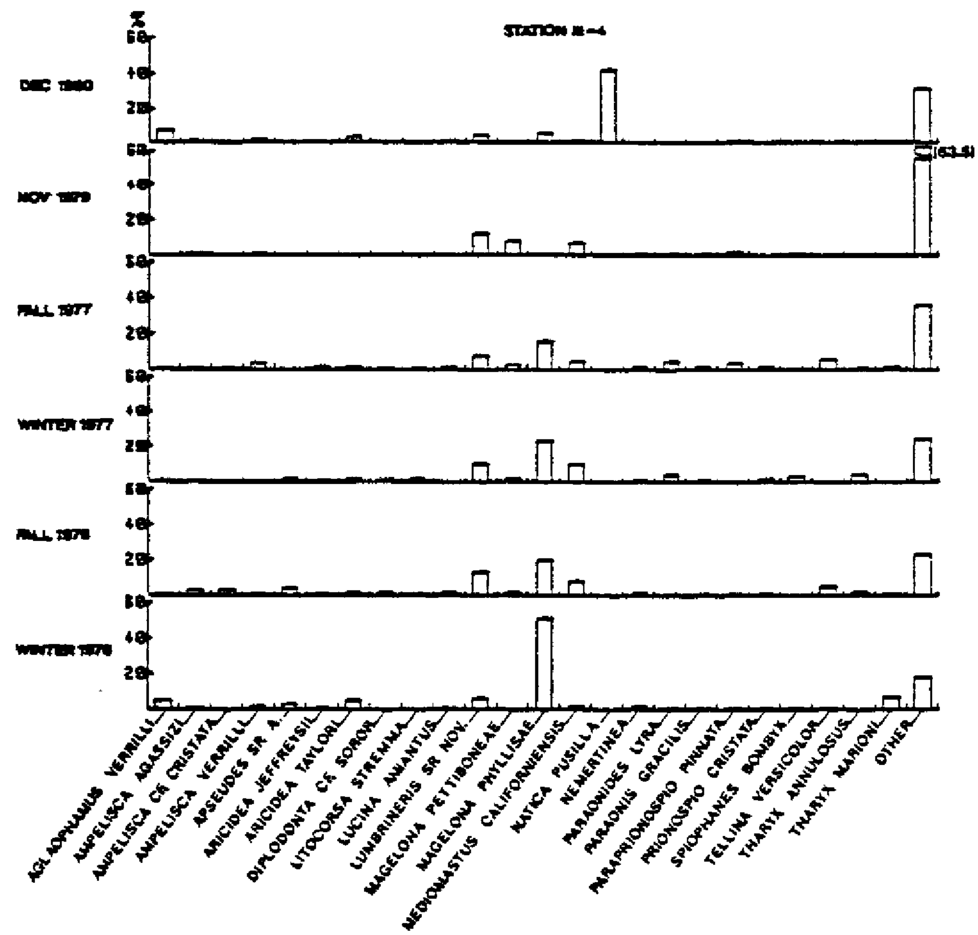

Figure 4-23. Relative proportions of numbers of individuals of numerically dominant taxa at Station III-4, by sampling period (1% cutoff).

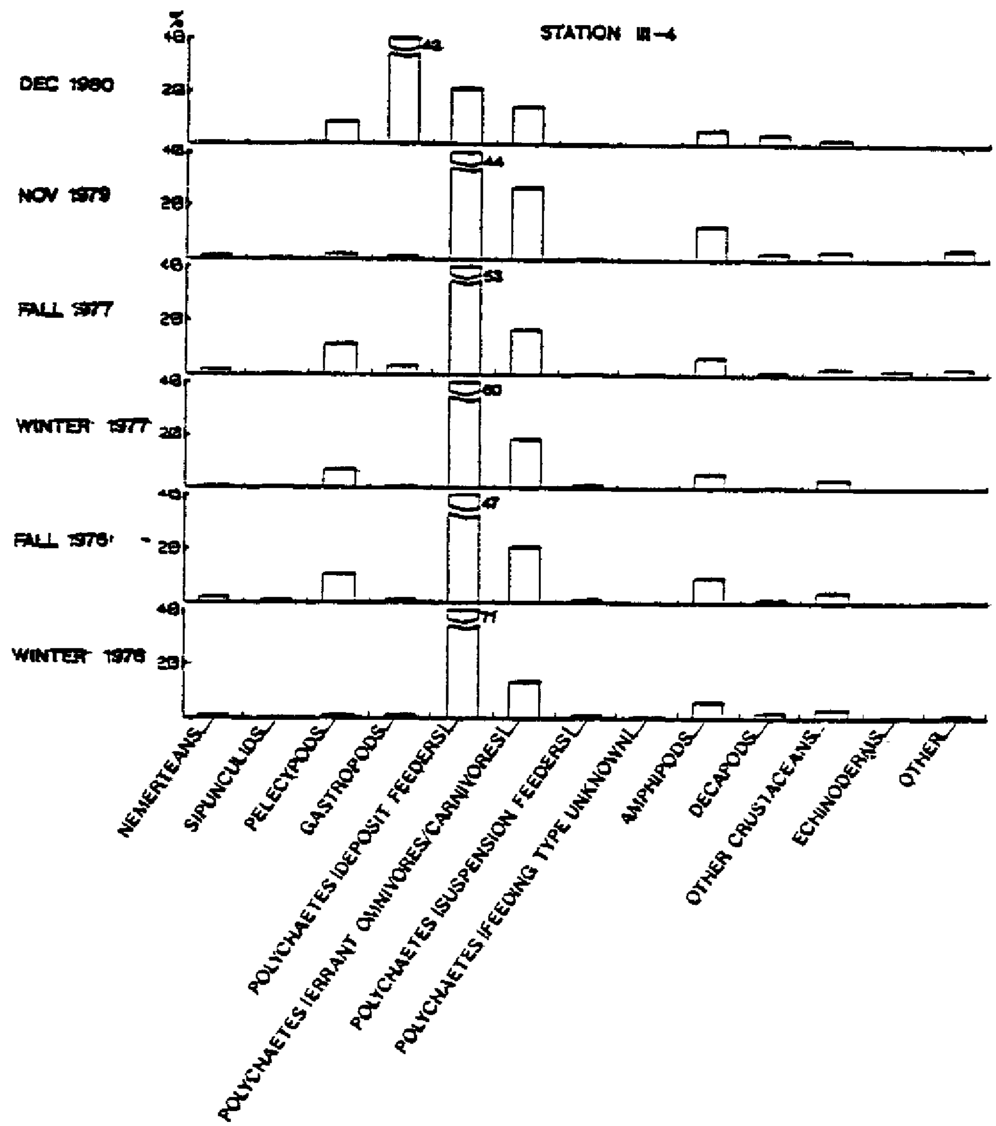

Figure 4-24. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station III-4, by sampling period (1% cutoff).

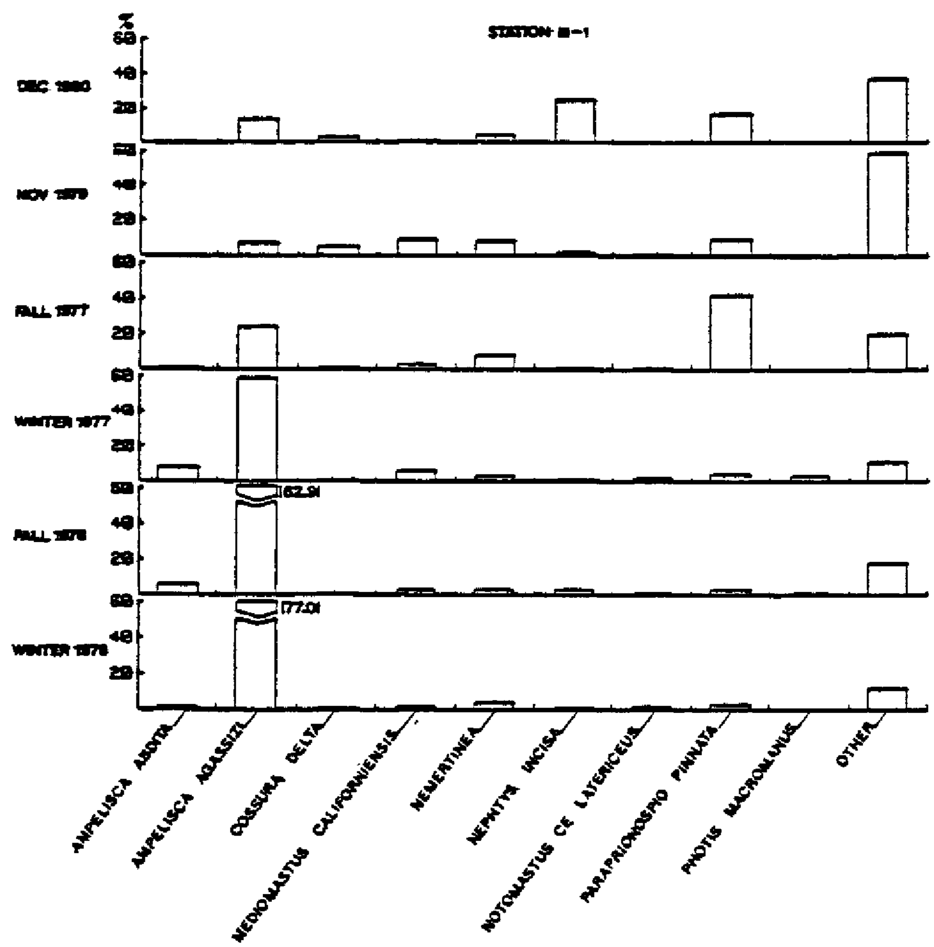

Figure 4-25. Relative proportions of numbers of individuals of numerically dominant taxa at Station III-1, by sampling period (1% cutoff).

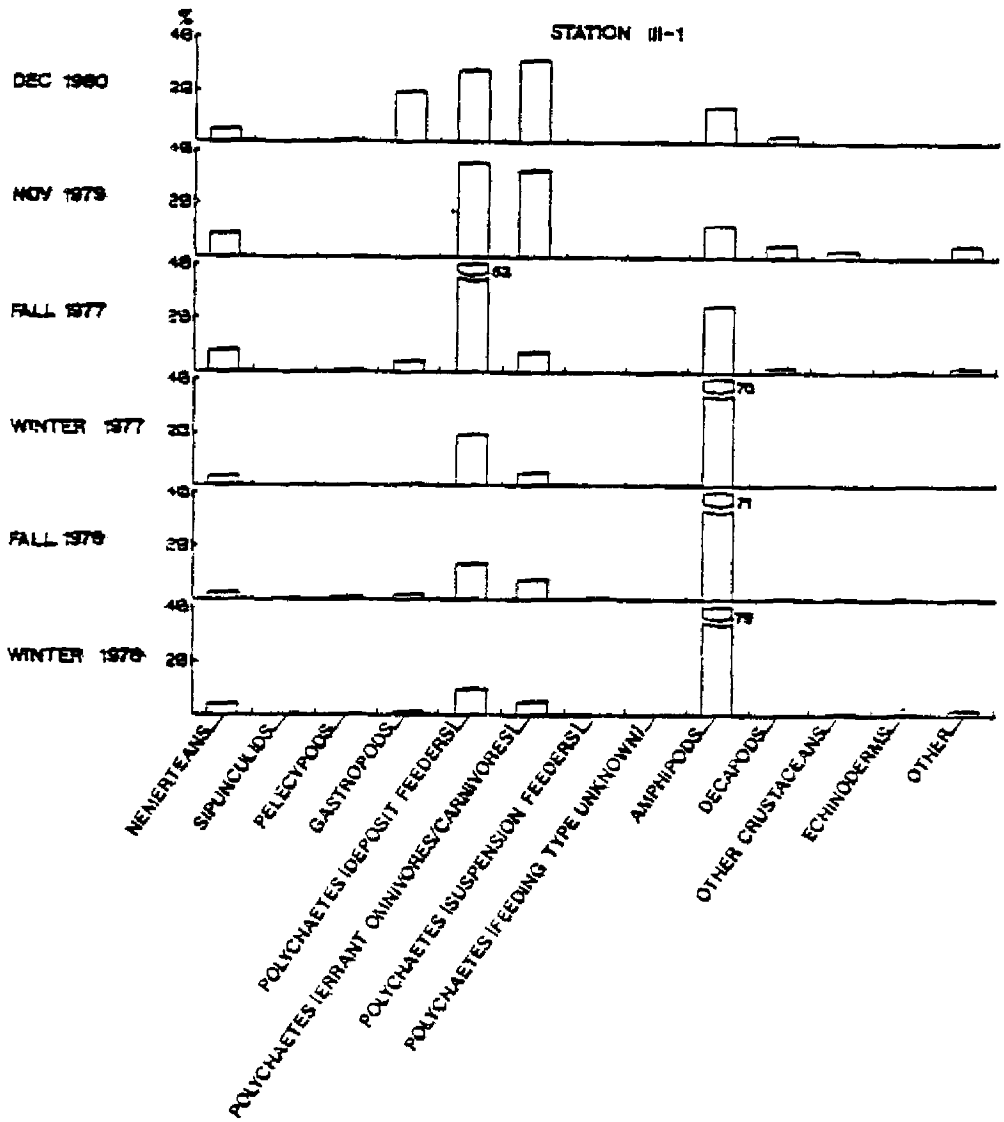

Figure 4-26. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station III-1, by sampling period (1% cutoff).

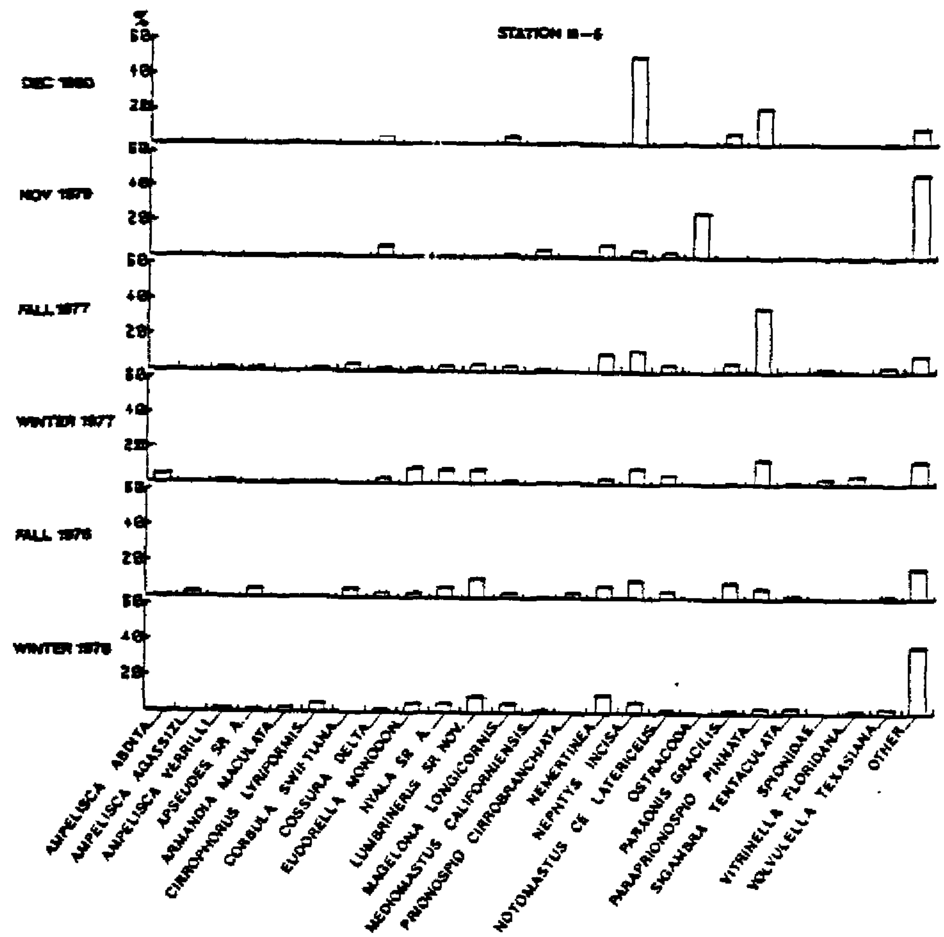

Figure 4-27. Relative proportions of numbers of individuals of numerically dominant taxa at Station III-5, by sampling period (1% cutoff).

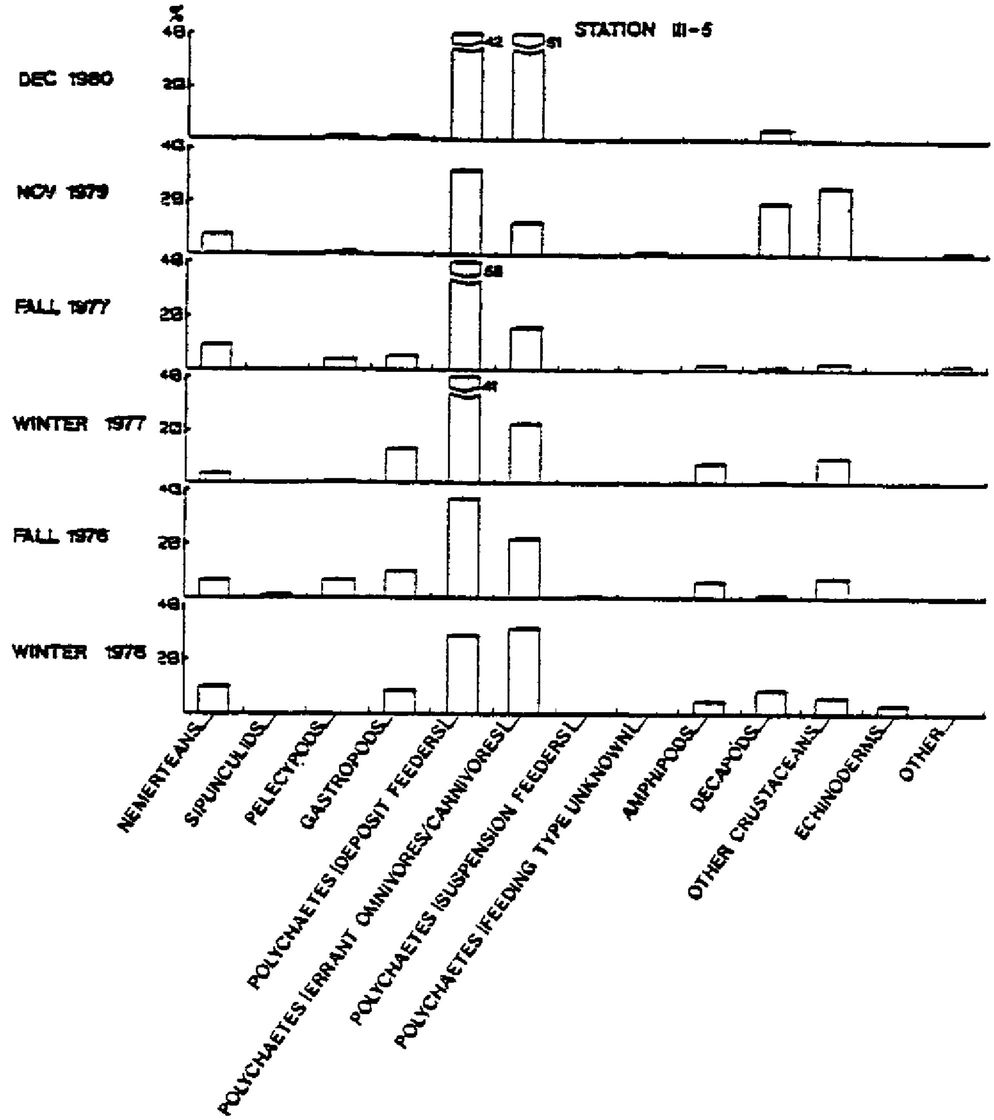

Figure 4-28. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station III-5, by sampling period (1% cutoff).

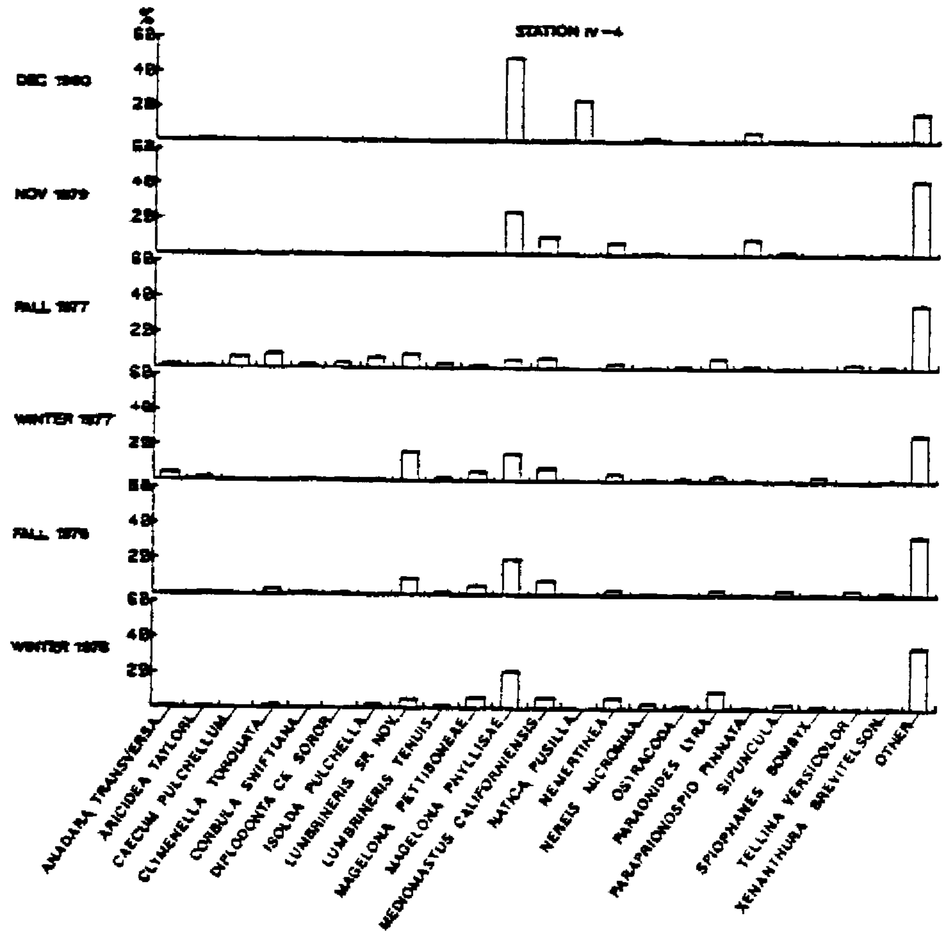

Figure 4-29. Relative proportions of numbers of individuals of numerically dominant taxa at Station IV-4, by sampling period (1% cutoff).

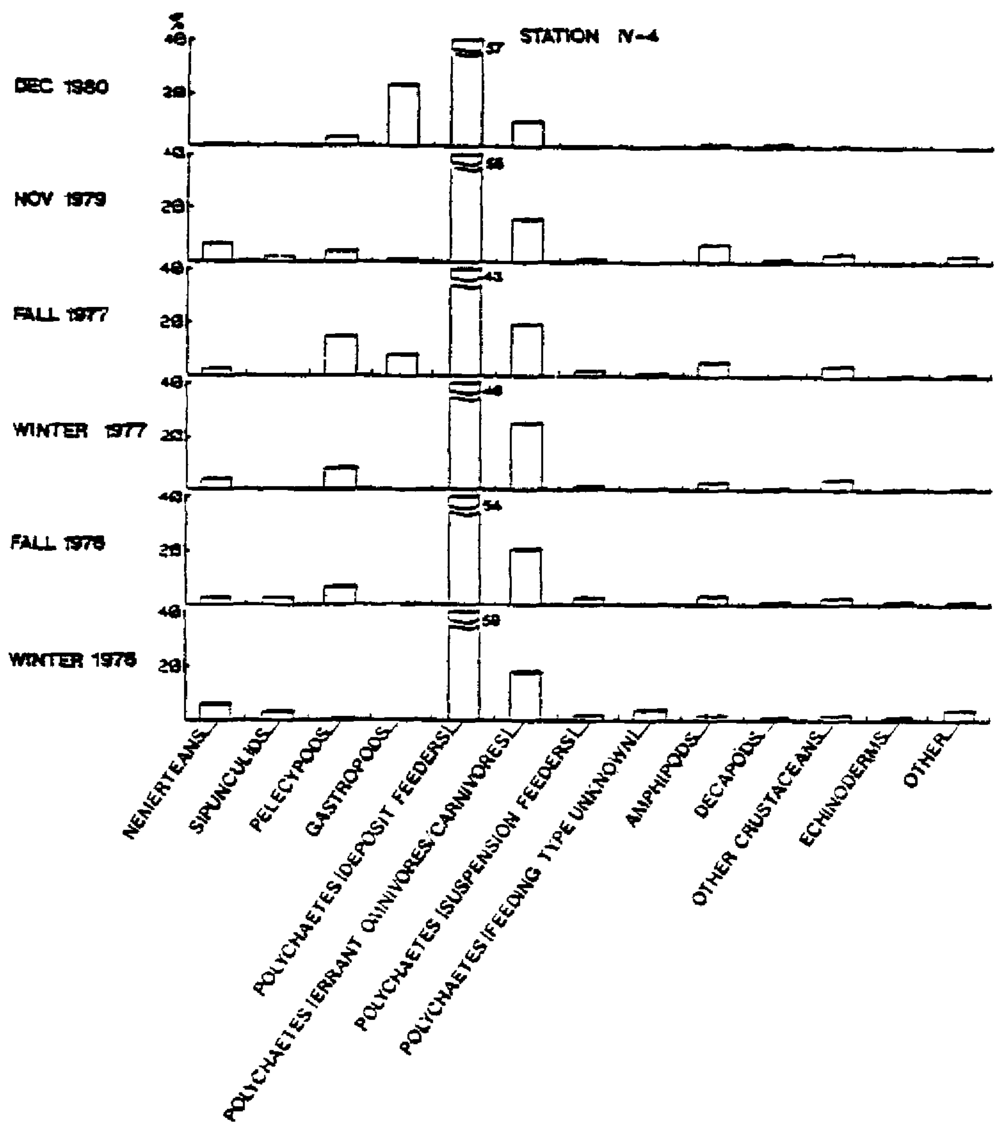

Figure 4-30. Relative proportions of numbers of individuals of major groups of numerically dominant taxa at Station IV-4, by sampling period (1% cutoff).