Benthic Survey of the Baltimore Canyon Trough, May 1974
Final Report

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Summary

Section 1. INTRODUCTION

The continental shelf off the Atlantic Coast of the United States is believed to contain large deposits of oil and gas, perhaps this country's last major untapped source. These deposits are thought to be buried in geological troughs which lie beneath the sediments of the middle and outer shelf. One of these depressions is referred to as the Baltimore Canyon Trough (BCT). The BCT parallels the seaboard for approximately 300 miles (483 km) from northern New Jersey (40°N) to the southern end of the Delmarva Penninsula (37°N), reaching to within 50 miles of shore and extending out to the shelf-slope break. Early estimates put oil deposits in the BCT between 3 and 5 billion barrels, and natural gas between 15 and 25 trillion cubic feet (Department of Interior, 1976).

The Bureau of Land Management (BLM), U. S. Department of Interior, has divided the BCT into lease tracts. BLM has released 154 tracts (Figure 1) totalling nearly 877,000 acres (355,000 hectares) for lease sale bidding by the oil companies (Booda, 1976). In January 1978, the U. S. Environmental Protection Agency issued eleven permits (NPEDS) for exploratory drilling, which began in March, 1978.

Extensive geological studies of the BCT have been conducted over the past decade by major oil companies and by the United States Geological Survey (USGS). Seismic profiling, stratigraphic

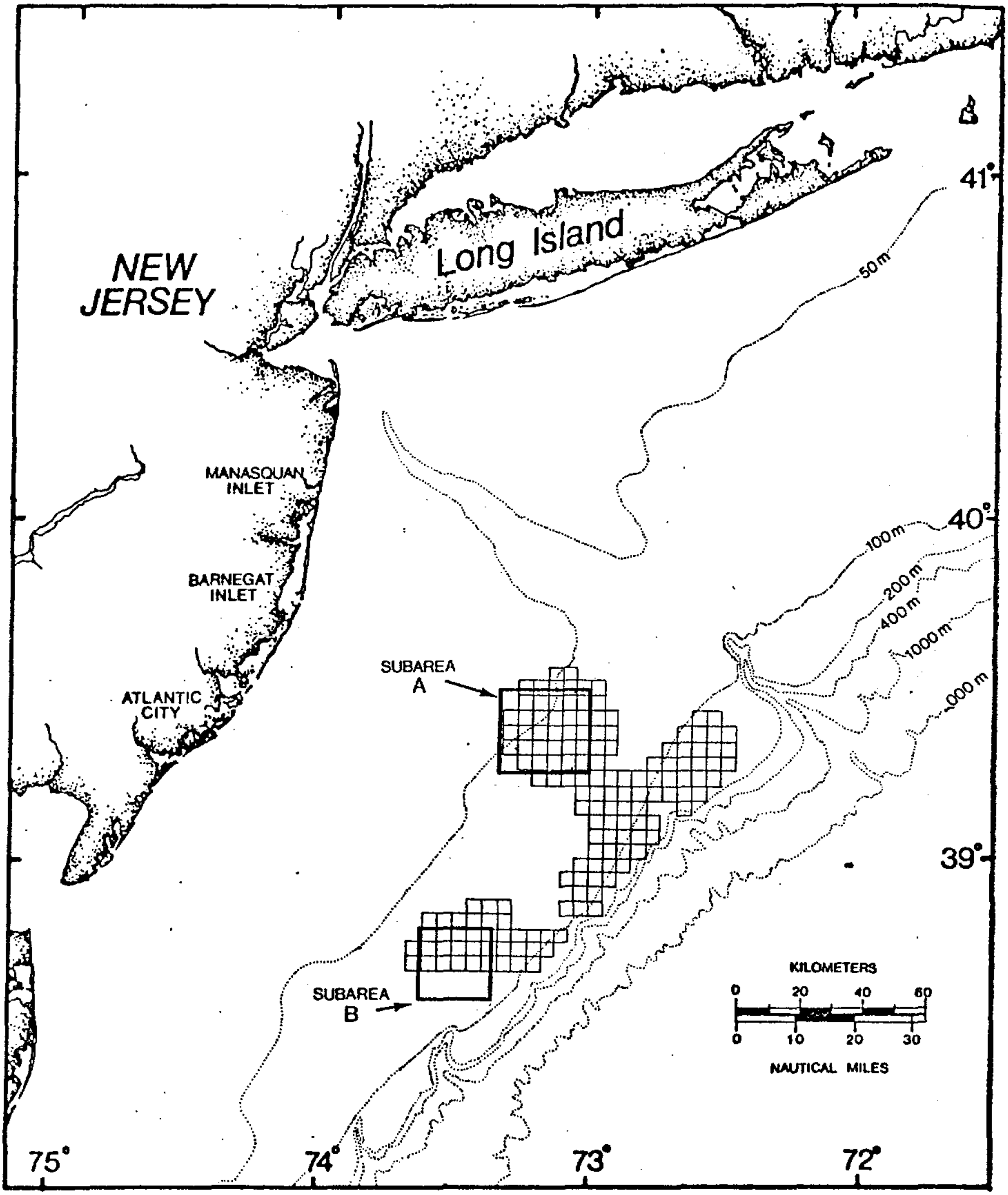


Figure 1. Sampling areas (bold outlines) and nominated tract areas in the Baltimore Canyon Trough.

and other tests have enabled scientists to establish priority areas which have the greatest potential for oil and gas. Two such areas (Figure 1) were investigated in May 1974 during a USGS-National Marine Fisheries Serivce (NMFS) cooperative cruise.

The primary objective of our investigation was to explore the benthic environments of several potential oil-bearing areas. It was hoped that such study would initiate the development of adequate physical, chemical and biological information on the middle and outer continental shelf to provide 1) baselines against which to measure impacts of oil-related activities, and 2) information for management to lessen those impacts.

Data provided here are intended to supplement information from a larger study which was begun by the Virginia Institute of Marine Science (VIMS) in 1975. VIMS has been conducting a major benchmark survey of the chemical and biological parameters of the Middle Atlantic Bight (MAB), under a contract with BLM. Our data represent some of the earliest work done in the BCT and are intended to extend the VIMS baselines temporally and add to the spatial coverage of critical areas.

The two areas covered during our cruise are designated subareas A and B (Figure 1). Figures 2-4 show the relationship of these subareas to VIMS' sampling pattern. We sampled inten-

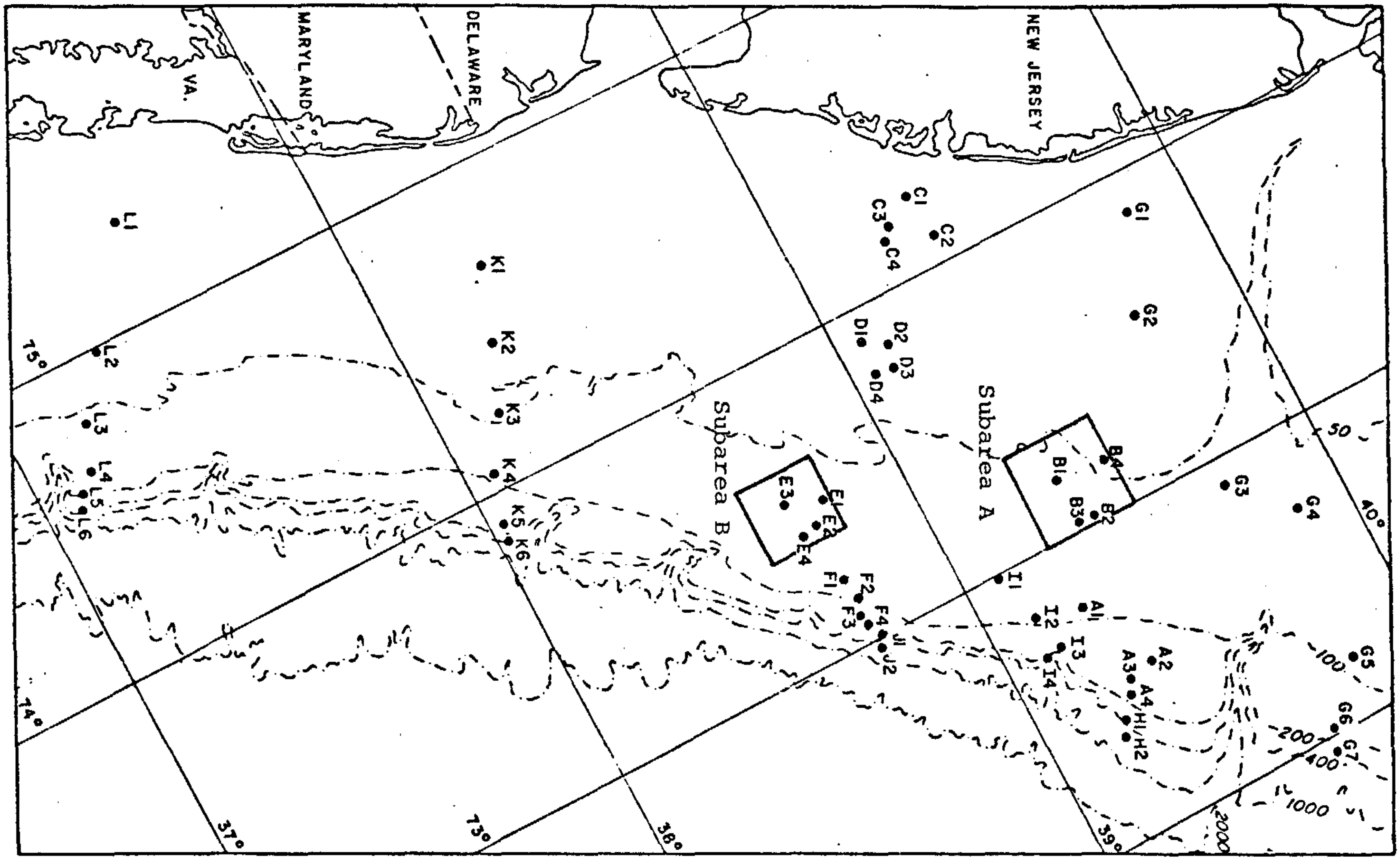


Figure 2. Middle Atlantic Outer Continental Shelf showing NMFS Subareas A and B (□) and V.I.M.S. Benchmark Study Stations (●).

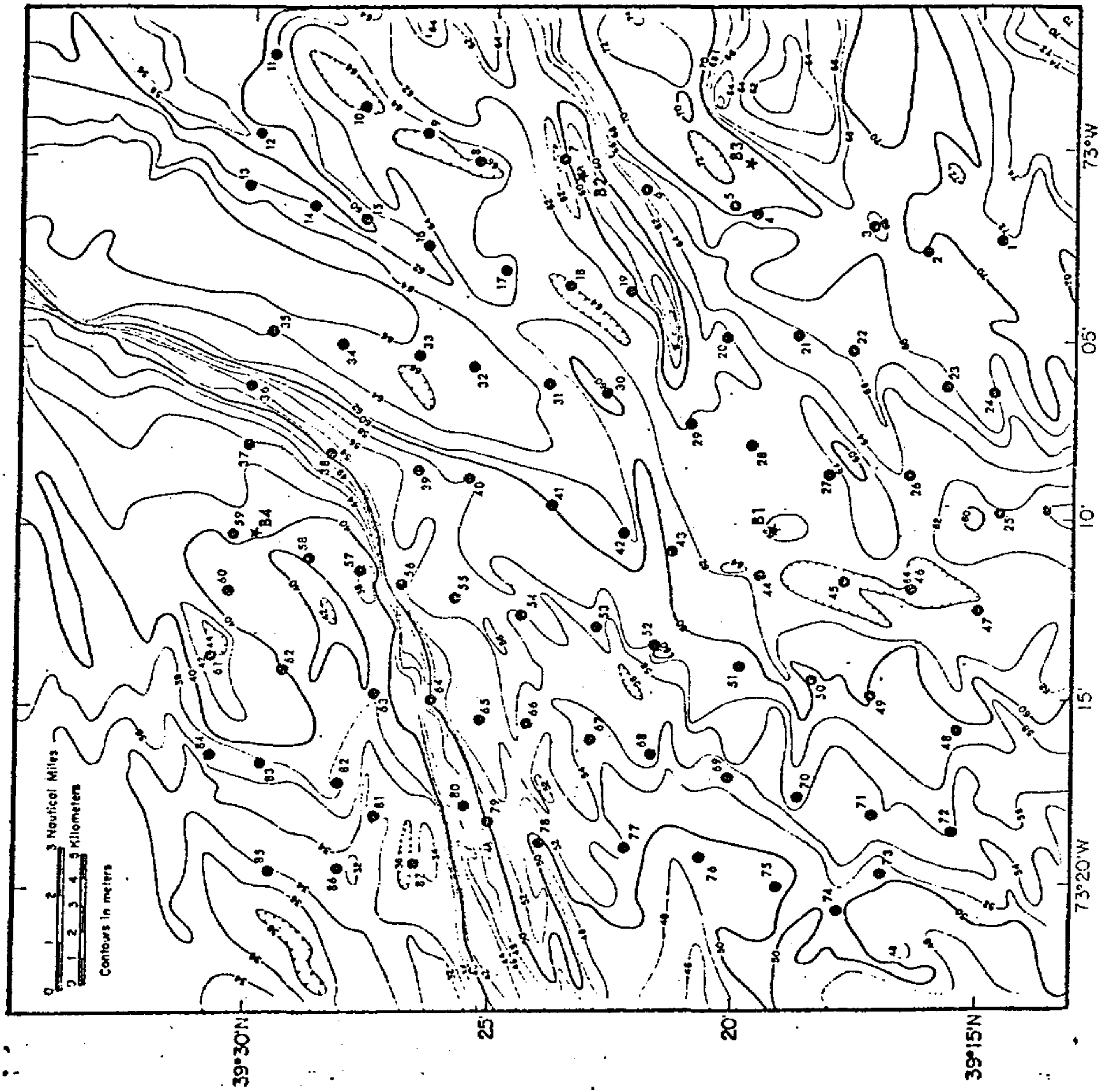


Figure 3. Bathymetries and sampling pattern in Subarea A. Approximate locations of VIMS "B" stations also shown (✱).

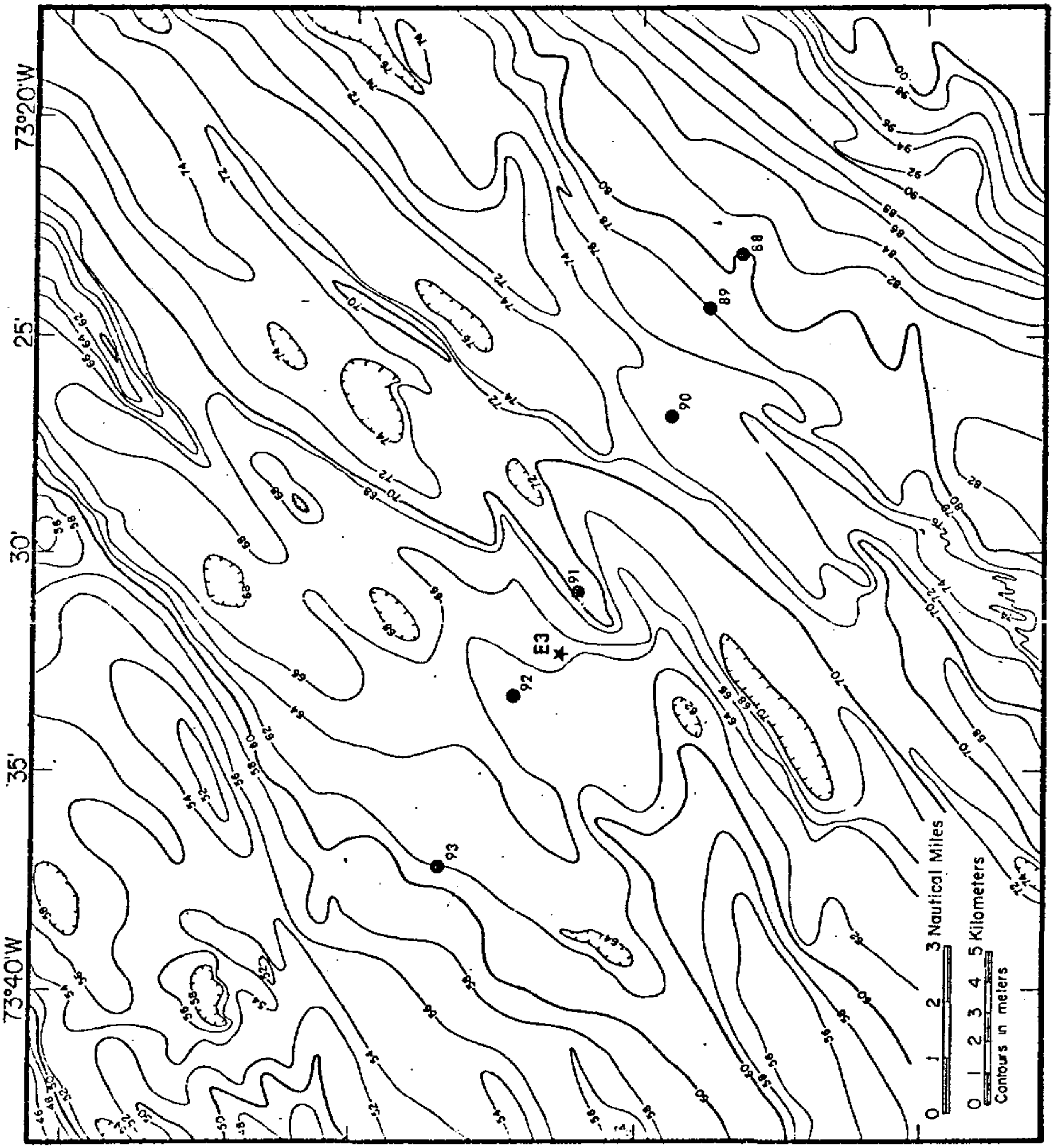


Figure 4. Bathymetries and sampling pattern in Subarea B. Approximate location of VIMS station E3 also shown(✱).

sively only in subarea A. This block, which was regarded as a potentially highly productive area for oil and gas, is located approximately 80 km east of Atlantic City, New Jersey and comprises 386 km^2. Eighty-seven stations were occupied on 8 transects (Figure 3). Water depths ranged from 33 to 72 meters. In subarea B, located 105 km east of Delaware Bay, and covering 262 km^2, we sampled 6 stations across a central transect (Figure 4). Depths ranged from 60 to 80 meters.

This report is one of a four-part historical baseline series being prepared by NMFS under contract with BLM. The other tasks, which are still ongoing, include fisheries, ichthyoplankton and pathology. NMFS has extensive historical data holdings for the MAB on these four topics. Benthic, ichthyoplankton and fisheries surveys were begun in 1957, 1965 and 1967 respectively. Our Oxford, Md., Laboratory has more recently undertaken a study of pathology in MAB biota, and has established a National Registry of Marine Pathology to catalog abnormalities in marine biota.

All data discussed in this report on Benthos are also included in a computer printout which will accompany this report. The printout gives listings of 1) location and water depth for each station; 2) numbers of each benthic macrofauna species collected; 3) total numbers of species and individuals, diversity (H') and equitability (J') values; 4) sediment grain size; 5) concentrations of six heavy metals (when taken); and 6) bottom water temperature, salinity and dissolved oxygen (when taken).

This report presents and interprets our data on sediments, sediment metals and benthic macrofauna of the BCT. A short review of the distributions of resource shellfish in the BCT area is also included. We then discuss possible impacts of oil-related activities on the BCT benthos, and make several recommendations for minimizing these impacts.

Section 2. SEDIMENTS

2.1 INTRODUCTION

The sedimentary characteristics of the outer continental shelf represent an important aspect in the development of energy resources in the MAB. If oil and gas are discovered, fixed platforms will undoubtedly be constructed. However, safe deployment of these structures as well as pipelines will require a knowledge of the supporting strength of the sediments and a determination of whether these sediments are in equilibrium with the modern current regime (Knebel, 1975). From a biological standpoint, a knowledge of the surficial sediments will help in understanding and predicting areal distributions and abundances of benthic organisms. Textural variations across the ridge-swale pattern characteristic of the Middle Atlantic shelf largely dictate distinct benthic assemblages related to specific sediment grain sizes (Boesch et al., 1977). Also, topographical depressions not only accumulate fine sediments and organic materials which support higher faunal biomasses, but also tend to concentrate contaminants. Oil and gas development could add to the contaminant loads in these important areas.

Extensive reviews of the ancestral and modern geological regimes of the Middle Atlantic Shelf, and more specifically, the BCT, are available (Freeland, et al., 1976; Knebel, 1975; Knebel and Spiker, 1977; Stubblefield, et al., 1974, 1975). The VIMS benchmark studies include a concise but comprehensive review of the sedimentary framework of the BCT (Boesch, 1977). This report, intended to supplement the VIMS studies, will not attempt to expand on the overall physiography of the shelf but will deal specifically with surface sediments of the areas investigated during the 1974 cruise (Figure 1). Methods and results discussed here are based on the work of the USGS, Office of Marine Geology, Woods Hole, Massachusetts under the direction of Dr. Harley J. Knebel.

2.2 METHODS

Sediments were collected using a Smith-McIntyre grab sampler (Smith and McIntyre, 1954). Subsamples for sediment analyses were collected at each station by skimming portions from the upper 3 cm of the grab samples. At 21 stations in subarea A, duplicate grabs were taken and two subsamples were taken from each grab. This was done to study variability within stations (using duplicate grabs) and within grabs (using subsamples) (Knebel, 1975).

A modified Woods Hole settling tube (Ziegler et al., 1960; Schlee, 1966) was used for analysis of sand-sized sediments, after removal of shell fragments. Coarser sediments were sieved at 1-phi intervals (Krumbein, 1936). Silt/clay fractions were determined by centrifugation and filtration. Size limits for sand, silt and clay follow the Wentworth (1922) scale; sizes larger than sand are considered gravel.

2.3 RESULTS

Figure 5 shows station by station histograms of sediment grain size distributions in phi units, and also lists values for mean diameter and percent silt/clay. Averaged values were used where duplicate grabs and split subsamples were taken.

Figures 6 and 4 are bathymetric maps of subareas A and B (from Knebel and Spiker, 1977), showing station locations. Soundings are in meters. Figure 6 also identifies stations in Subarea A where gravels and/or sediments containing $\geq$2% silt/clay were found.

2.4 DISCUSSION

Surficial sediments in both subareas are predominantly sands. The histograms (Figure 5) reveal the majority of these sands to be in the 1 to 3 phi classes (medium sand). Small but measureable percentages of gravel were present at 14 of the 93 stations (Figure 6), with a maximum of 15.7% at station 71. Some silts and clays were found at 88 stations, but only 16 had $\geq$2% fine sediments (Figure 6); station 33 had the most fines (5.5%).

On the single transect we sampled in Subarea B, sands were consistently finer than in subarea A. This is expected since Subarea B is in deeper waters (60-80 m) and closer to the shelf

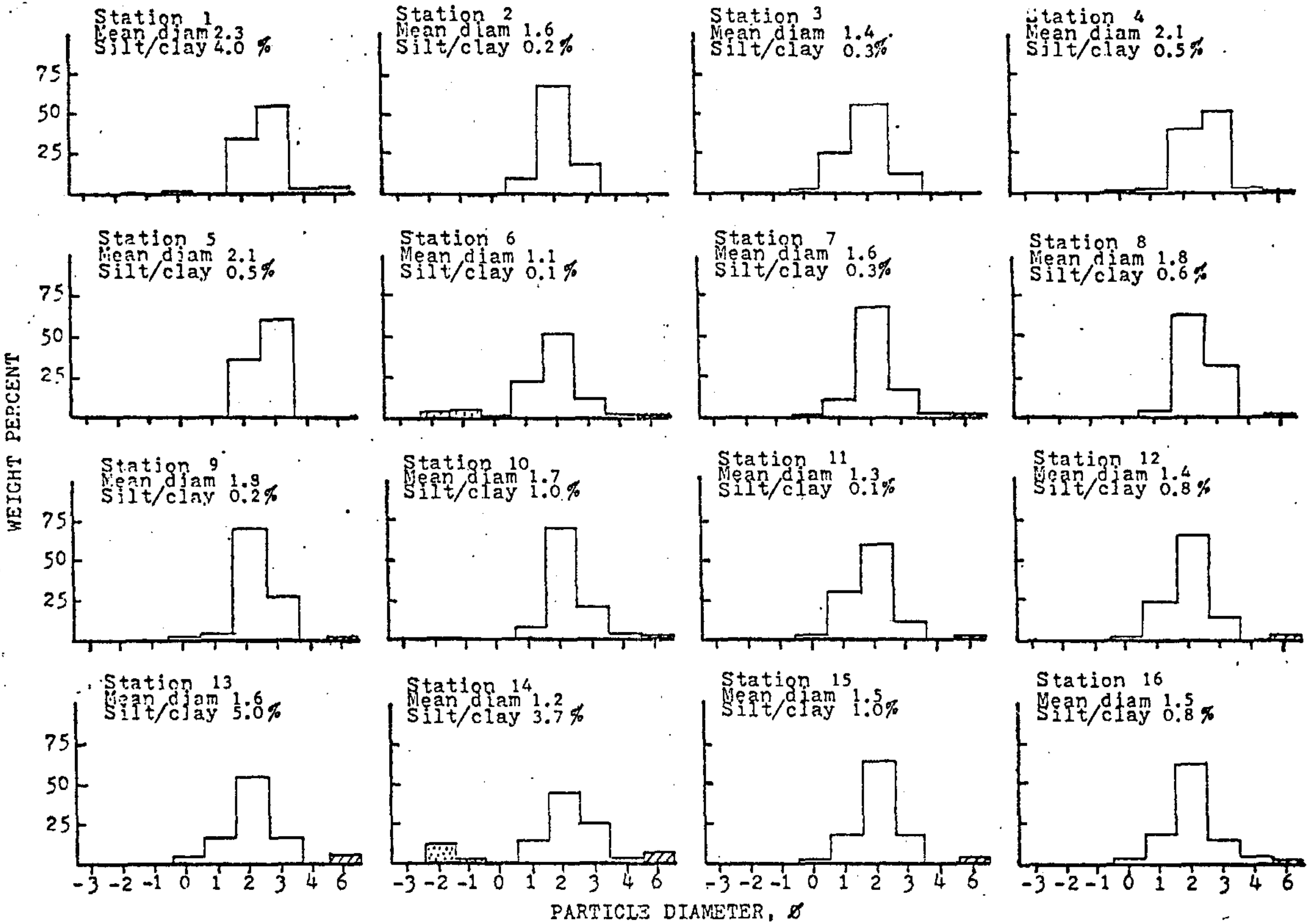
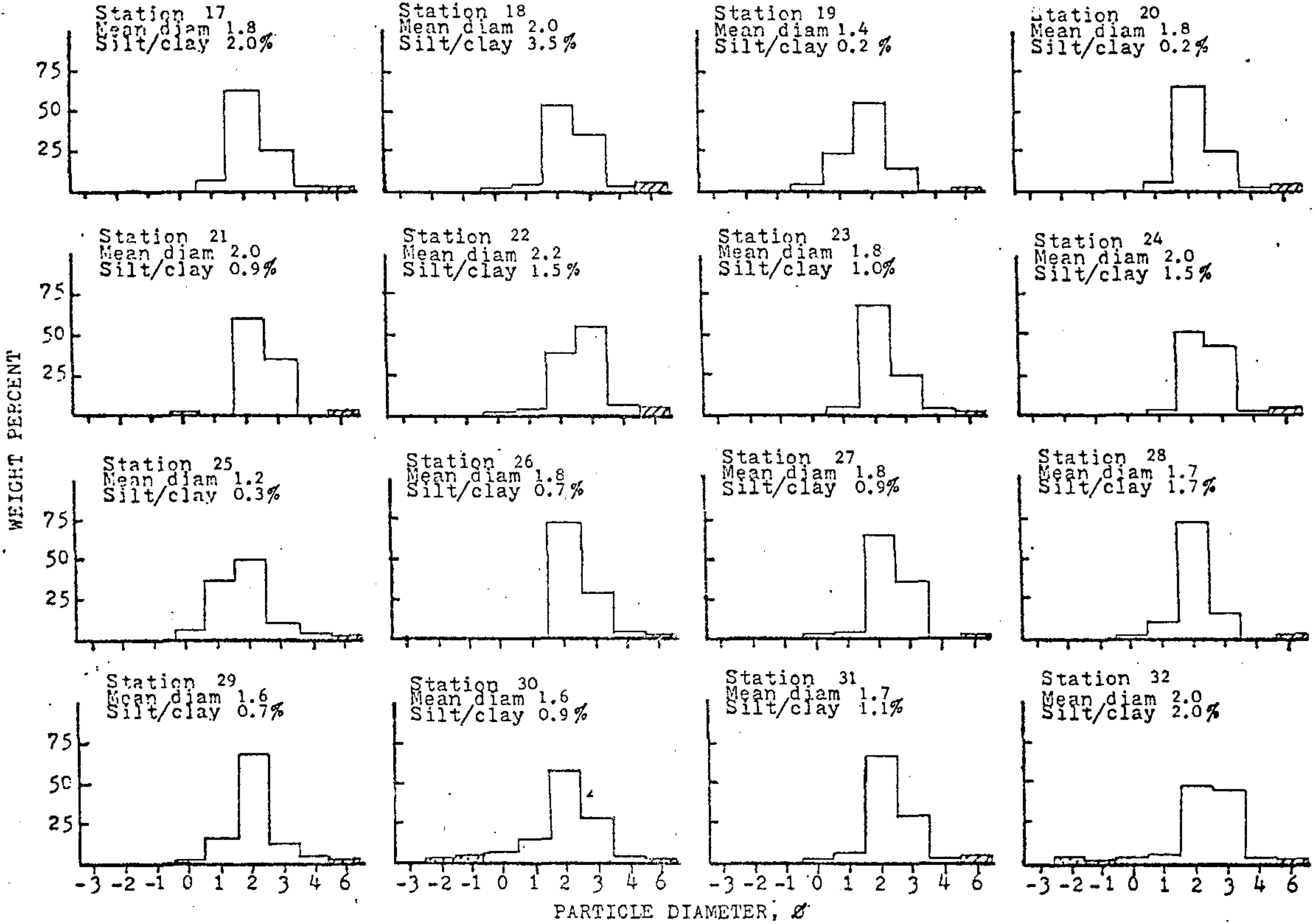


Figure 5. Sediment grain size distributions, in phi units. Crosshatched sizes are silt/clay, stippled are gravel.



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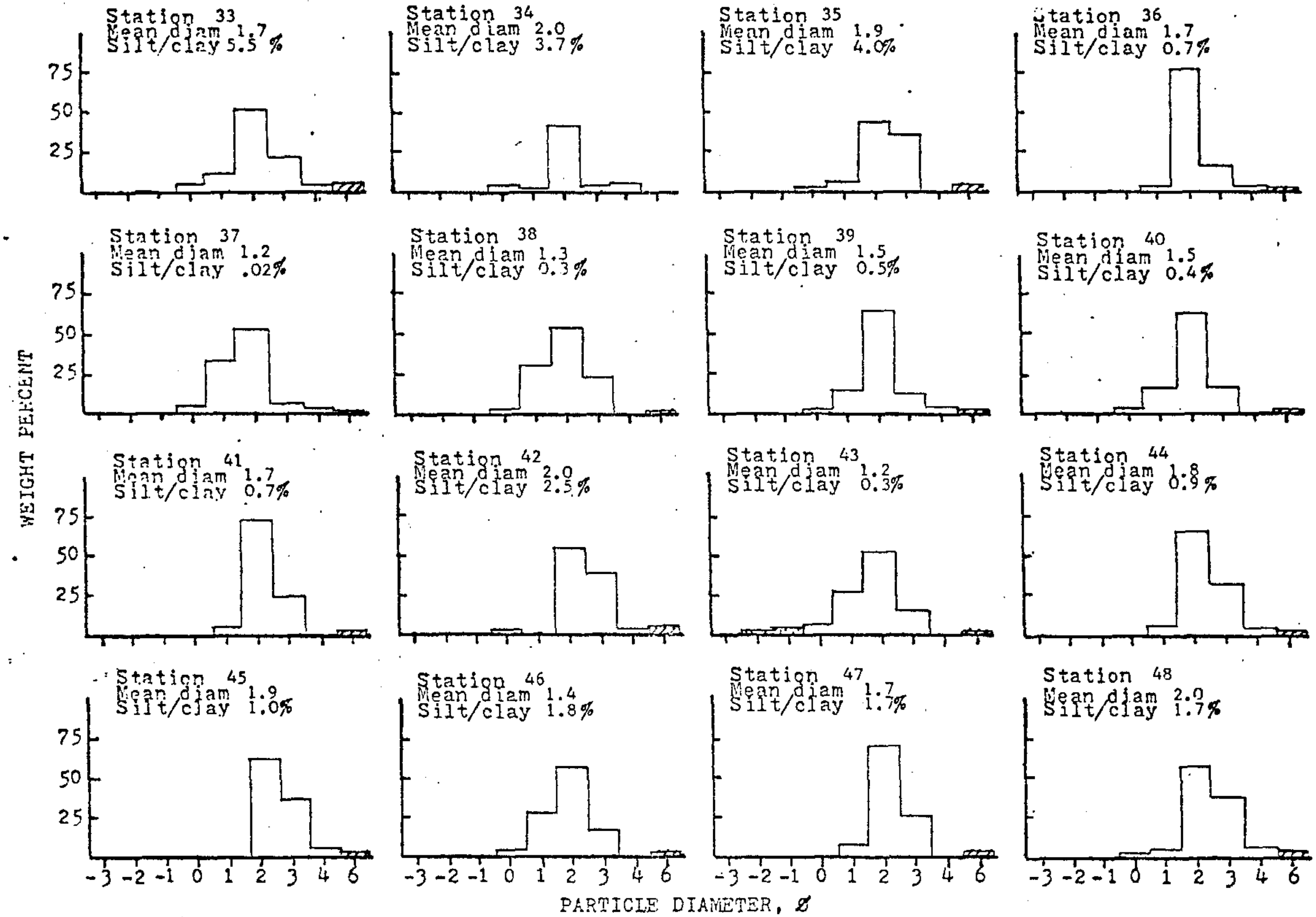

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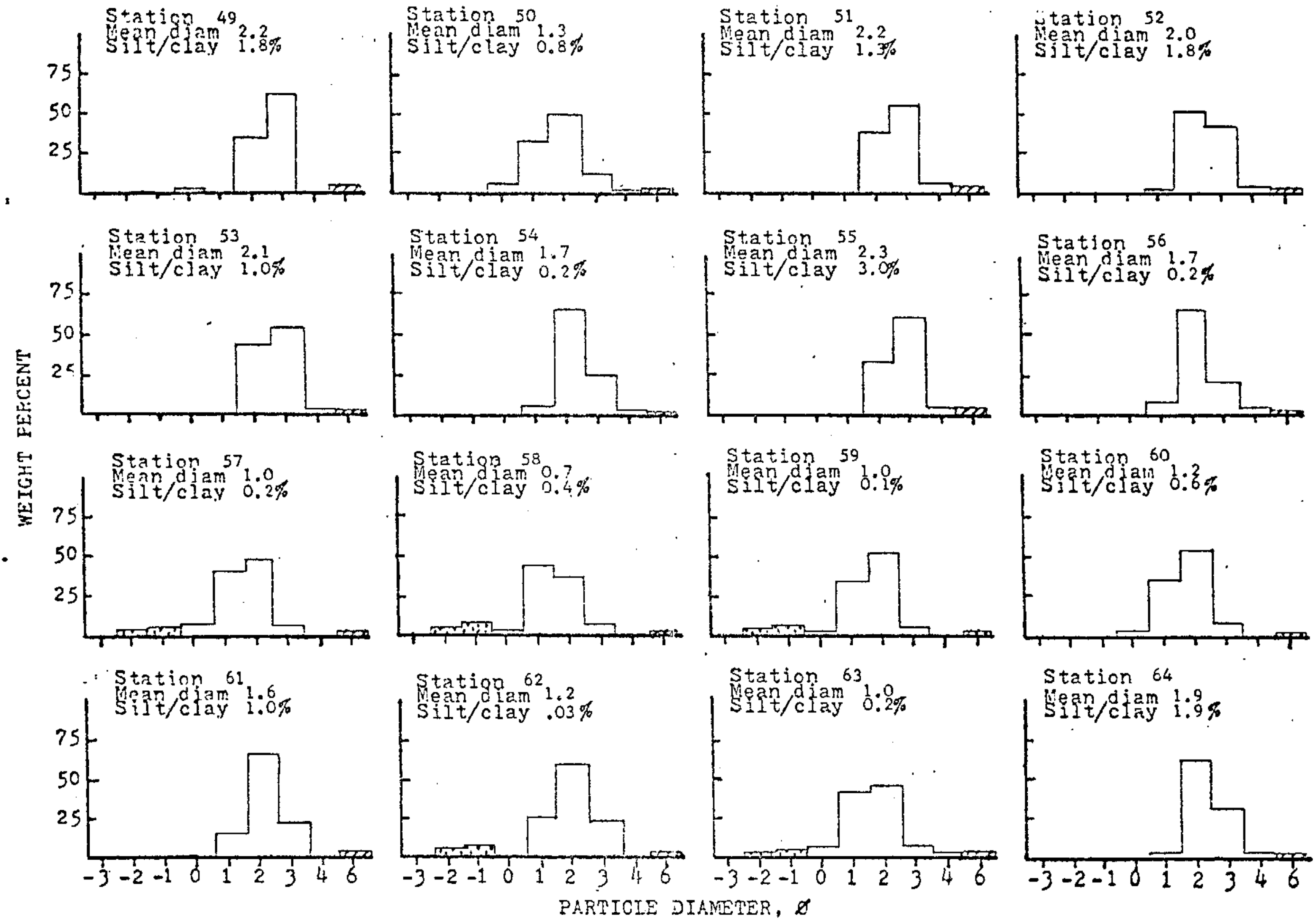

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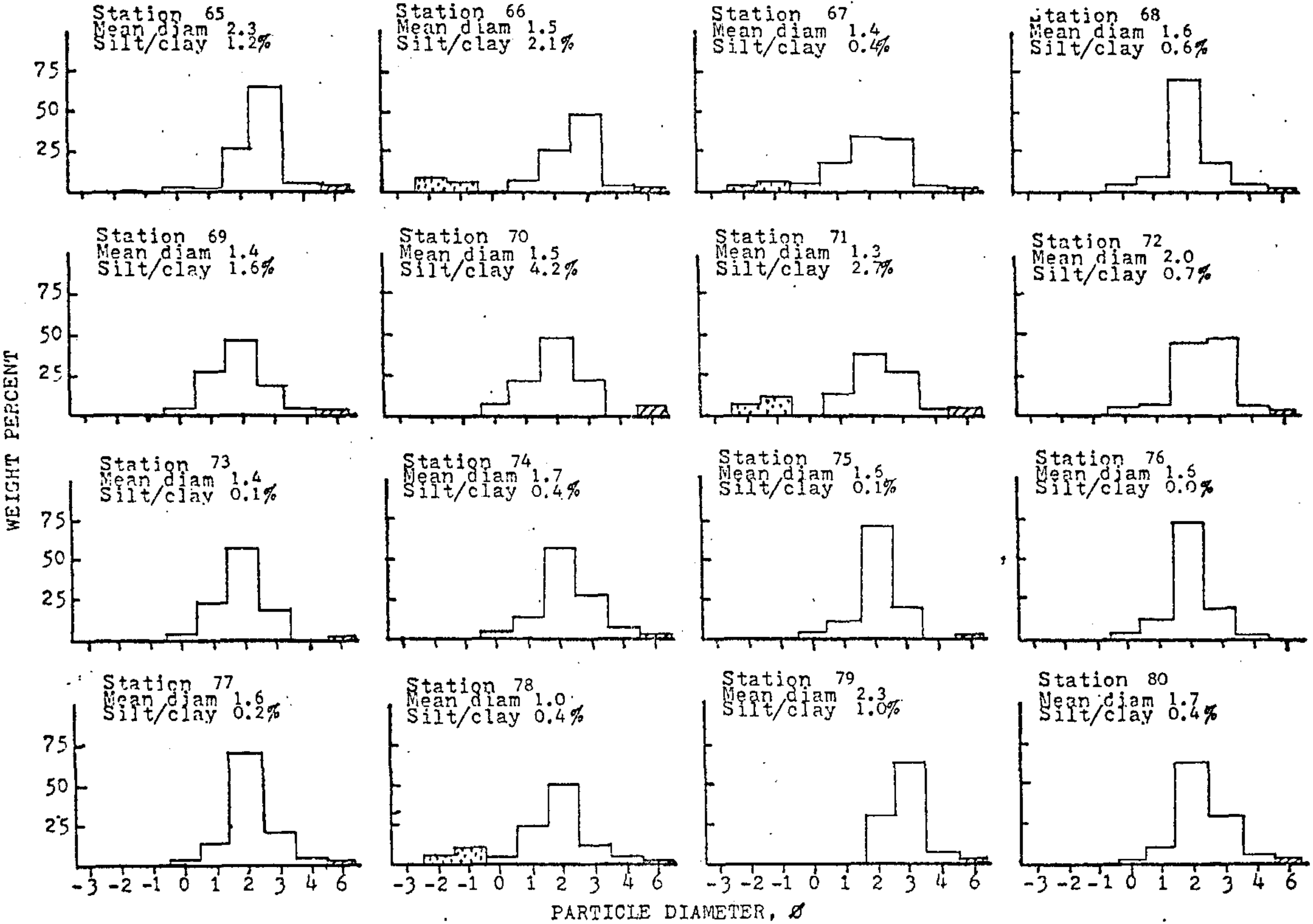

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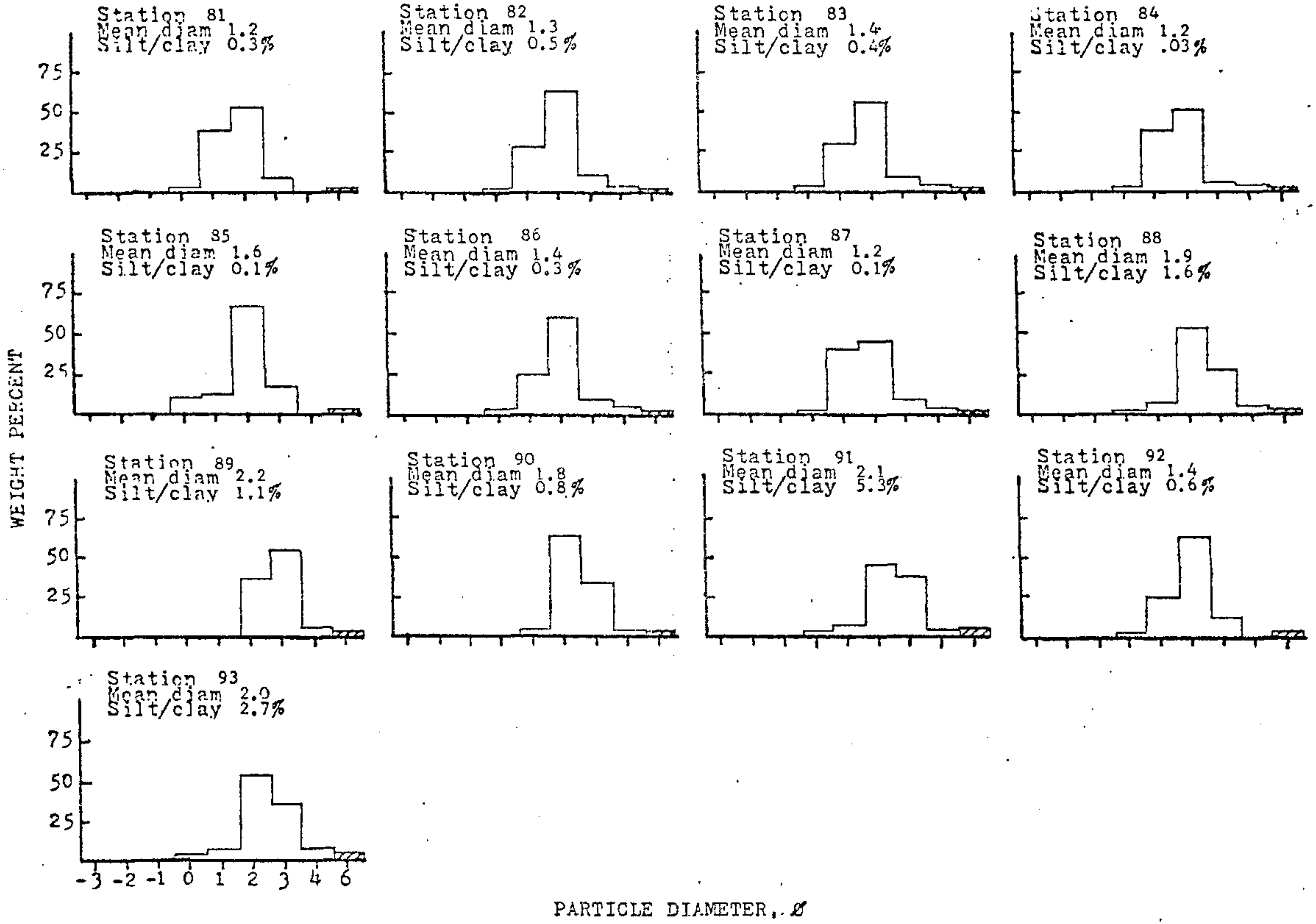

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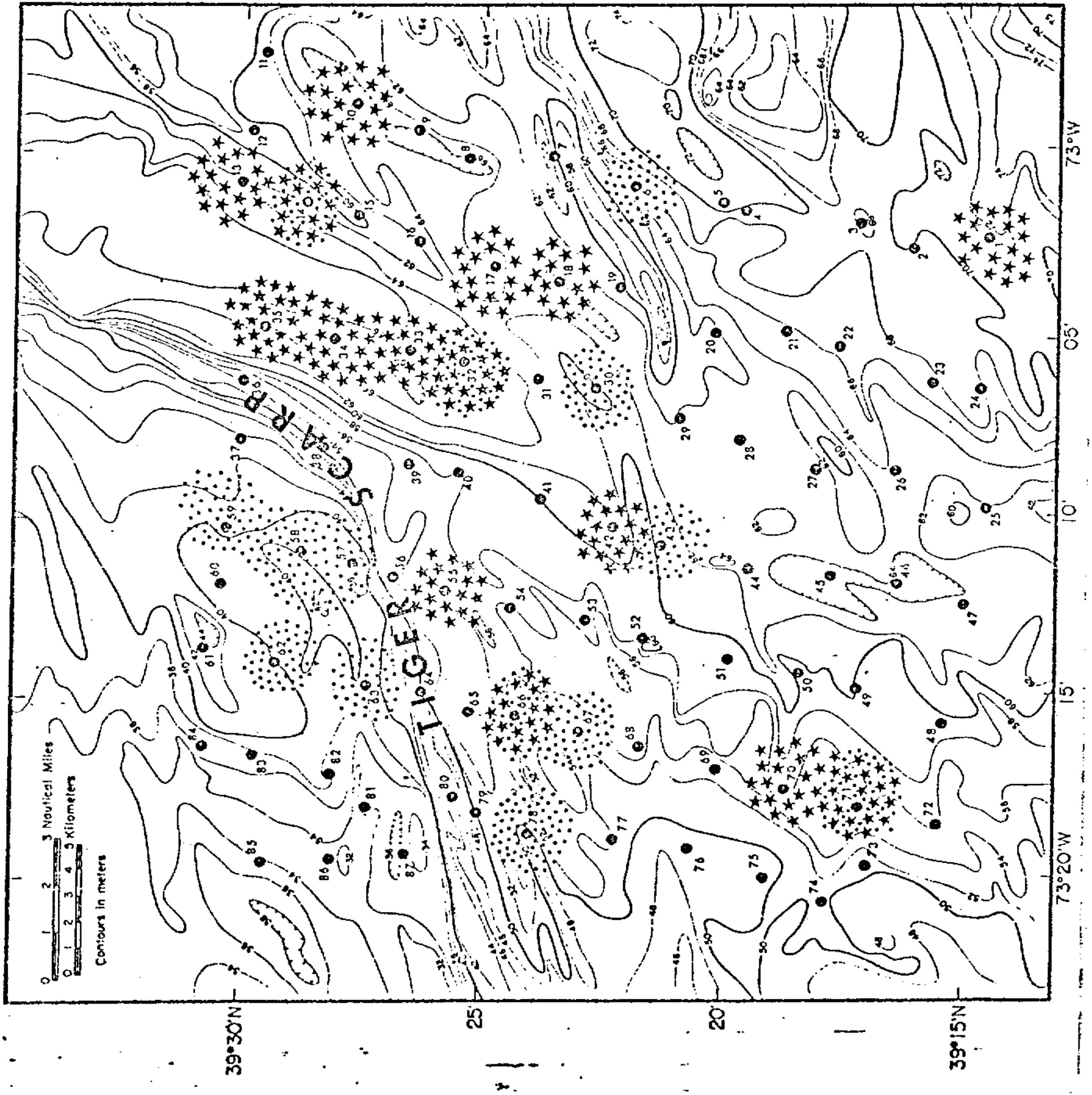

Figure 6. Bathmetries and station locations in subarea A. Stations with ≥2.0% silt clay (★★) and gravel detected (⁖) are indicated.

break. It has been shown that fine sediments tend to collect on the continental slope rather than on the shelf itself (Schubel and Okubo, 1972). Boesch (1977) also found finer sediments toward the outer margin of the shelf and on the slope, although more receint VIMS studies have found coarser sediments in the north and northeast portions of Subarea B (D. Boesch, pers.comm.).

The relationship of sediments to bathymetries is also evident within subarea A. Coarser sands with larger percentages of gravel were found in the northwestern portion of this subarea (Figure 6). The coarser sediments run across the Tiger Scarp and part of its plateau in the northwestern portion of the area. The scarp represents the easternmost edge of a gravelly fan-shaped deposit pluming off the southwestern edge of the Hudson Channel (Knebel and Spiker, 1977). Coarser sediments are also present on smaller topographic highs, e.g. at stations 14 and 30. Appreciable amounts of silt/clay are found in several depressions or troughs (stations 17, 18, 33, 34, 35). Some gently sloping or flank areas had accumulations of silts and clays (stations 1, 13, 42, 55, 66, 70, 71), and gravel was found at some (stations 6, 43, 66, 67, 71, 78) (Figure 6).

We also made visual observations of sediment texture aboard ship during macrofaunal sample processing. Although these observations were not always in agreement with sediment analyses (since subsampling can miss heterogeneous features such as clay balls), they can offer occasional insights not afforded through laboratory findings. For example, there was evidence during sampling that some stations are located in areas of erosion, where currents have exposed older, finer sediments lying beneath the surficial sand sheet (Stubblefield and Swift, 1976). Station 70 in subarea A and 91 in subarea B are apparently located in erosional areas - grabs from these stations had poorly sorted sediments which included both gravel and clay lumps.

We have compared sediment types reported for the VIMS stations in subareas A and B (Boesch, 1977) with sediments at our stations closest to the VIMS sites (within 2.7 km). The corresponding stations and approximate distances apart are: B1 (VIMS) and 44 (1.7 km apart); B2 - 7 (0.8 km); B3 - 5 (1.7 km); B4 - 59 (0.8 km); E3 - 92 (1.9 km). Parameters compared are dominant sediment type, sorting (estimated only, for our sediments) and percent silt/clay. There is good agreement between the two surveys, except that station B3 had 5-6% silt/clay, whereas station 5 had 0.5%.

The difference in silt and clay content is not surprising, since Knebel (1975), in discussing variability of BCT sediment, noted that fine sediments were highly variable even within stations. We point out the discrepancy here because the adjacent stations in the VIMS and NMFS surveys figure heavily in our later comparison of macrofauna data for determining temporal stability of the BCT fauna.

Section 3. BOTTOM WATERS, METALS IN SEDIMENTS

3.1 INTRODUCTION

Trace metals introduced into the environment will often reach the sediments. Through adsorption, ion exchange, complexing or chelation, the metals are commonly picked up by particulate or organic matter in the water column and settle to the bottom (Papakostidis et al., 1975). In the partitioning of metals among biota, water column and sediments, the latter usually receives a majority, and sometimes >99%, of total metal inputs (Renfro, 1973). Sedimenting materials and their contaminants will tend to accumulate in topographically low or hydrodynamically inactive areas.

We have a poor understanding of uptake and retention of metals by biota, and the toxicity of these metals, in nature. It is, however, realized that the affinity of metals for sediments poses a threat to the benthic macrofauna and makes the sediments valuable as indicators of metal contamination.

Surveys of heavy metals in sediments have been made in and around dumpsites in the New York Bight apex (Carmody, Pearce and Yasso, 1973) and on the continental slope (Pearce et al., 1977). Outside of the present survey and VIMS' benchmark study, however, little work had been done on concentrations of metals in outer shelf sediments of the MAB. This chapter discusses concentrations of six metals in sediments sampled at 14 stations on our May 1974 cruise. We also present data on temperature, salinity and dissolved oxygen of bottom waters for 36 of the 93 stations.

3.2 METHODS

Water samples were taken 1m above bottom with Nansen bottles. Dissolved oxygen was measured by Winkler technique, and salinity determinations were made using a Beckman RS-7C salinometer. Reversing thermometers were used to record bottom temperature.

To obtain sediment subsamples for heavy metals analysis, plastic cores 3.5 cm in diameter were inserted to the depth of the Smith-McIntyre grab. The cores were then capped, removed from the grab and frozen for later analysis. All samples were analyzed by the NMFS, Northeast Fisheries Center, Milford Laboratory, under the direction of Richard A. Greig.

In the laboratory, the top 4.0 cm of sediment were removed from the core, dried at 60° and ground into a homogeneous mass; 2.5 g of sediment were then placed in a 250 ml beaker to which were added 10 ml of concentrated nitric acid and 0.5 ml of a 30% solution of hydrogen peroxide. The solution was evaporated to dryness by gently boiling. The following were then added: 8 ml of 10% ammonium chloride, 0.4 ml of calcium nitrate (11.8 g/100 ml of $Ca(NO_3)_2 \cdot 4H_2O$) and 25 ml of a mixture of concentrated acids consisting of 80 ml of nitric acid, 20 ml of hydrochloric acid and 300 ml of distilled water. The mixture was gently boiled for five minutes or more, filtered through Whatman #2 filter paper and then diluted to 100 ml with distilled water. All samples were analyzed by an atomic absorption spectrophotometer and values were recorded in parts per million, dry weight.

3.3 RESULTS

Temperature, salinity, and dissolved oxygen of bottom water at 36 stations are presented in Table 1. Concentrations of the metals at 14 stations are given in Table 2. Concentrations are means of two measurements except where noted. Values for Ni and Zn, the only two metals which were detected at a majority of the stations, are also plotted, in Figure 7.

3.4 DISCUSSION

Temperature, salinity and dissolved oxygen were fairly uniform in bottom waters throughout the two subareas. Temperatures ranged from 8.2-12.0°C, and salinities from 33.4-35.1 ppt. All dissolved oxygen values were between 7.0 and 8.0 mg/l.

Levels of all metals were relatively low in the sediments analyzed. Values for Cd, Cr, and Cu were always below detection limits (1.0, 4.4, and 4.0 ppm, respectively), and so were close to the low concentrations found by VIMS (Harris et al., 1977) for these metals in their cluster group B (≈ subarea A) in fall 1975

Table 1. Temperature, Salinity, and Dissolved Oxygen values at representative stations sampled in subareas A and B, Baltimore Canyon Trough.

STATION #	TEMPERATURE (°C)	SALINITY (PPT)	DISSOLVED OXYGEN (mg/l)
1	10.1	34.30	8.0
4	9.4	34.00	7.3
7	8.8	33.74	7.6
10	8.4	33.66	7.7
13	8.3	33.64	7.3
16	8.3	33.65	7.6
19	8.8	33.76	7.6
22	8.9	33.42	7.3
25	9.1	33.90	7.3
28	8.7	34.11	7.3
31		33.64	7.7
34	8.2	33.60	7.5
37	9.1	33.61	7.5
39	8.3	33.58	7.5
42	8.2	33.62	7.4
46	8.4	33.72	7.3
48	8.5	33.68	7.1
51	8.9	33.64	7.3
54	8.5	33.60	7.6
56	9.1	33.61	7.3
57	9.1	33.60	7.4
60	9.0		7.5
63	9.0	33.59	7.4
65	8.7	33.66	7.7

Table 1 (continued).

STATION	TEMPERATURE (°C)	SALINITY (PPT)	DISSOLVED OXYGEN (mg/l)
67	8.4	33.61	7.4
70	8.6	33.63	7.3
73	8.6	33.64	7.4
76	8.7	33.61	7.5
78	9.1	33.59	7.6
81	9.0	33.51	7.6
84	8.6	33.50	7.6
86	9.1	33.52	7.5
88	12.0	35.06	6.8
90	11.4	34.78	6.5
91	9.2	34.09	7.0
93	9.3	33.73	7.6

Table 2 . Metal concentrations (means of two measurements) in the top 4 cm of sediment collected from the Baltimore Canyon; subarea A. See Figure 3 for station locations. Values are in ppm, dry weight.

Station	Cd	Cr	Cu	Ni	Pb	Zn
1	ND[a]	ND	ND	11.8	10.0*	16.5
4	ND	ND	ND	17.5*	10.0*	13.5
7	ND	ND	ND	7.7	ND	6.9
10	ND	ND	ND	7.7	ND	9.5
25	ND	ND	ND	ND	ND	6.3
28	ND	ND	ND	5.8	ND	9.3
31	ND	ND	ND	7.0	ND	10.3
37	ND	ND	ND	ND	ND	10.1
48	ND	ND	ND	13.5*	20.0*	11.5
51	ND	ND	ND	21.0*	10.0*	12.3
54	ND	ND	ND	9.6	ND	11.4
63	ND	ND	ND	5.2	ND	9.8
83	ND	ND	ND	11.5	ND	12.2
86	ND	ND	ND	8.3	ND	9.9

[a] ND = Not Detectable. Detection limits in ppm were: Cd, 1.0; Cr, 4.0-4.4; Cu, 4.0; Ni, 4.0; Pb, 4.0; Zn, 3.0. * - Single measurement only.

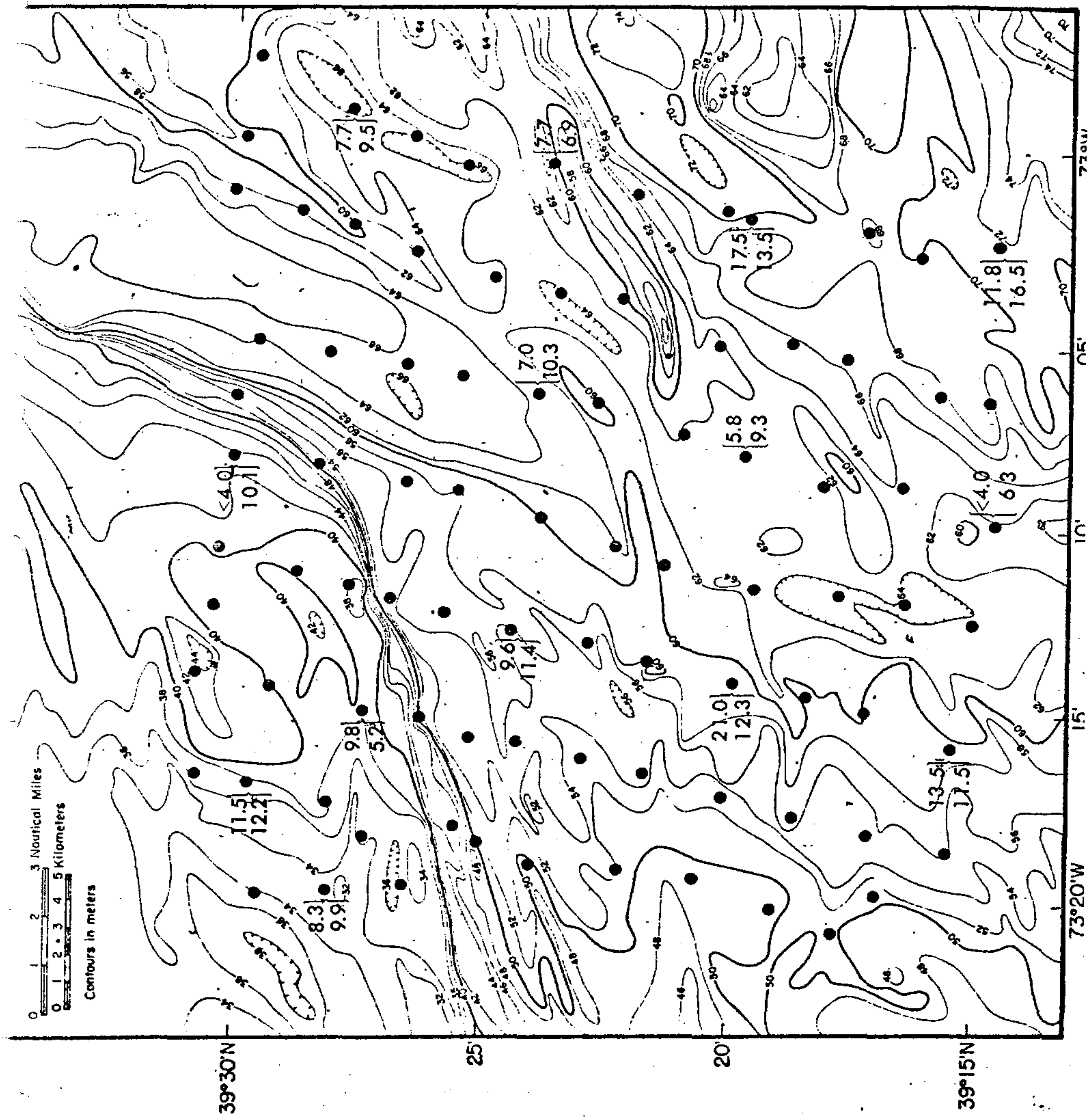

Figure 7. Concentrations of Ni (upper value) and Zn (lower) in surface sediments of Subarea A. All values are in ppm, dry weight.

and winter 1976. Mean values for Pb were also similar to levels found by VIMS, while concentrations of Ni and Zn were slightly higher in our study (minimum 21.0 vs 1.0 and 16.5 vs 7.5 ppm, respectively).

Concentrations of metals in the BCT are similar to those reported for sandy New York Bight sediments unaffected by waste disposal and, except for Ni, are more than an order of magnitude lower than concentrations in the Bight's dredge spoils and sewage sludge disposal areas (Carmody, Pearce and Yasso, 1973). Values are also much lower than those found in sediments of inshore areas such as Raritan Bay (Greig and McGrath, 1977) and Long Island Sound (Greig, Reid and Wenzloff, 1977).

The low metal concentrations in sediments of subarea A are not surprising, in view of the area's remoteness from major anthropogenic inputs. However, the metal concentrations (except perhaps for Cd) are also substantially lower than concentrations found by Pearce et al. (1977) in deep (2500 m) continental slope sediments over 170 km southeast of New York City. Another factor helping to explain the low metals levels in subarea A is the paucity of fine sediments found there. Harris et al. (1977) found strong correlations between water depth, silt/clay content and metals at stations across the MAB shelf and slope. None of the 14 stations at which we measured metals had more than 4% silt/clay, so low concentrations of metals are to be expected. Within this narrow range of silt/clays there was no clear relationship between metal concentration and percent silt/clay.

The values for Ni and Cr reported here will be of special value in determining oil-related impacts, since Ni is one of the metals most abundant in crude oils and Cr is a constituent of drilling muds. VIMS (Harris et al., 1977) is analyzing barium and vanadium, which are common in drilling muds and oils, respectively.

Section 4. MACROFAUNA

4.1 INTRODUCTION

The benthic macrofauna of the BCT are of interest from several standpoints: as 1) indicator organisms, 2) commercial resource species, 3) forage items for bottom-feeding finfish and 4) accumulators of contaminants which may be passed up food webs to man himself. Sound baselines concerning the benthic environment must be established if we are to recognize oil-related impacts.

Prior to the present survey and the benchmark program undertaken by VIMS, only scattered information was available on the benthic macrofauna of the BCT. The literature, reviewed by Boesch et al. (1977), concentrates on regions inshore and to the south of our subareas A and B. Some work has also been done on the deep-sea benthos to the east of our study area (e.g. Grassle, 1977; Pearce et al., 1977; Sanders, Hessler and Hampson, 1965).

As mentioned in the introductory section, this report should serve as a supplement to VIMS' more extensive benchmark studies, which were conducted seasonally from 1975-77. We will attempt to make data analyses and interpretations as congruous with the VIMS studies as possible. Distribution and abundance patterns for common species will be presented for subareas A and B. We will focus on distributions of certain species relative to bathymetry and sediment type. Comparisons of results from the two studies will be made whenever applicable, particularly with reference to VIMS stations which are physically close to our own sampling sites or have similar sediments and bottom topography.

4.2 METHODS

Samples were obtained using a 0.1 m^2 Smith-McIntyre grab sampler (Smith and McIntyre, 1954). We occupied 87 stations in subarea A and 6 stations in subarea B (Figures 6 and 4). Duplicate grabs were taken at 21 of the stations in subarea A. These stations are identified in the data report, which also gives latitudes and longitudes for all stations.

Grab samples were washed through a standard 1.0 mm geological screen. Materials retained on the screen were fixed in a 10% formalin solution and later transferred to a 70% ethanol solution with 5% glycerol. Dissecting microscopes were used for all sorting; identifications were made to species level whenever possible. All identifications were confirmed inhouse by one of the authors (ABF). We have also met with VIMS taxonomists and agreed on identities of most taxa which had caused identification problems between the two studies.

Species diversities were calculated using the Shannon and Weaver (1963) index, $H' = -\sum_{i}^{s} p_i \ln p_i$, where p_i is the proportion of individuals in the i^{th} species. H' has two components: number of species (S) and equitability (J', $= H'/H'_{max} = H'/\ln S$) (Pielou, 1975). Equitability represents the evenness of distribution of individuals among species at a station. We computed H', J', S and N (number of individuals) for each 0.1 m^2 sample processed. Complete listings of these parameters plus abundances of all species at all stations have been submitted to BLM in our accompanying data report.

Clustering analyses were done using a program supplied by Dr. Donald F. Boesch, VIMS. We used both Q-mode or normal analysis (clustering stations by species) and R-mode or inverse analysis (species by stations). Czekanowski's coefficient, C_z = 2w/a+b (Bray and Curtis, 1957), was used to measure faunal similarity between stations. In this formula, "a" is the sum of abundances of all species found at station A, "b" is the sum of species abundances for station B, and "w" is the sum of the lower of the abundance values for each species common to A and B. Abundances were transformed by natural logarithms and then clustered using flexible sorting with β=-0.25.

To remain consistent with the VIMS data analysis, we reduced our species list to $\leq$150 species for clustering. We could not follow the VIMS method of eliminating species, since it was partly based on data from replicate grabs, and only single grabs were taken at most of our stations. Instead, we 1) eliminated, as did VIMS, taxa not separated into species (note that some of the retained taxa have not yet been given species names); and 2) eliminated species which occurred at $\leq$ 4 stations and had a total abundance of $\leq$5 individuals in our samples.

We examined animal-sediment relationships by 1) comparing species abundant at our eight stations with coarsest sediments ($\geq$5.2% gravel) with species common in the finest sediments ($\geq$ 3% silt-clay, nine stations), and 2) attempting to relate species to the habitat types (ridge, shallow and deep flank, swale, shelf break) of Boesch et al. (1977b). This was done by categorizing our nine station groups according to these habitat types, and then ranking species based on mean density in each station group.

Specific comparisons of species abundant at several of our stations with dominant species found at nearby stations by Boesch et al. (1977) were also made, to determine temporal stability of the fauna.

4.3 RESULTS

A list of species found in our BCT collections is given in Table 3. Numbers of species and individuals, Shannon-Weaver species diversity (H'), and equitability (J') for all stations are shown in Table 4.

Table 3. Taxa found in subareas A and B of the BCT.

* - species used in cluster analysis:

CNIDARIA

Anthozoa

Cerianthidae
    *Ceriantheopsis americanus**

Edwardsiidae
    Edwardsia sipunculoides

ANNELIDA

Polychaeta

Aphroditidae

    *Aphrodita hastata**

Polynoidae
    Antinoella sarsi
    *Harmothoe extenuata**
    Hartmania moorei

Sigalionidae
    *Pholoe minuta**
    *Sthenelais limicola**
    Sigalion arenicola

Phyllodocidae
    Phyllodoce maculata
    *Phyllodoce arenae**
    Phyllodoce panamensis
    Eteone flava
    Eteone lactea
    Eteone trilineata
    Eulalia viridis
    *Eulalia bilineata**
    Notophyllum foliosum
    Phyllodocidae sp. #1*
    Phyllodocidae sp. #2

Hesionidae
    Microphthalmus aberrans

Table 3 (continued)

Syllidae
- *Typosyllis sp. #1**
- *Sphaerosyllis sp. #1*
- *Syllides sp. #1**
- *Syllides sp. #3*
- *Eusyllis lamelligera*
- *Exogone naidina**
- *Exogone hebes**
- *Sphaerosyllis erinaceus*
- *Streptosyllis arenae**
- *Parapionosyllis longicirrata**

Nereidae
- *Nereis zonata*
- *Nereis grayi**

Nephtyidae
- *Nephtys bucera**
- *Nephtys picta**
- *Micronephtys minuta*
- *Aglaophamus verrilli*
- *Aglaophamus circinata**

Glyceridae
- *Glycera capitata**
- *Glycera dibranchiata**
- *Hemipodus roseus**

Goniadidae
- *Goniada maculata**
- *Goniada brunnea**
- *Goniadella gracilis**
- *Ophioglycera gigantea*

Onuphidae
- *Nothria sp. #1*
- *Nothria sp. #2**

Eunicidae
- *Marphysa belli*

Lumbrineridae
- *Lumbrineris cruzensis*
- *Lumbrineris fragilis**
- *Lumbrineris tenuis**
- *Lumbrineris sp. #1*
- *Lumbrinerides acuta**
- *Ninoe sp. #1*
- *Ninoe nigripes*

Table 3 (continued)

Arabellidae
- *Drilonereis longa**
- *Drilonereis magna**

Dorvilleidae
- *Schistomeringos caeca**
- *Protodorvillea gaspeensis*
- *Protodorvillea kefersteini**

Orbiniidae
- *Scoloplos armiger**

Paraonidae
- *Aricidea wassi**
- *Aricidea catherinae**
- *Paraonis fulgens*
- *Paraonis sp. #5*
- *Paraonides lyra**
- *Cirrophorus lyriformis**
- Paraonidae sp. #2

Spionidae
- *Laonice cirrata**
- *Polydora socialis**
- *Polydora caulleryi*
- *Polydora concharum**
- *Polydora sp. #1*
- *Prionospio steenstrupi**
- *Spio filicornis**
- *Spiophanes bombyx**
- *Spiophanes wigleyi**
- *Scolelepis squamata*
- Spionidae sp. #2

Cirratulidae
- *Cirratulus cirratus*
- *Caulleriella cf. killariensis**
- *Tharyx acutus**
- *Tharyx annulosus**
- *Chaetozone setosa**
- *Dodecaceria coralii**
- Cirratulidae sp. #1

Flabelligeridae
- *Pherusa affinis**

Scalibregmidae
- *Scalibregma inflatum**

Opheliidae
- *Ophelina acuminata*
- *Ophelina cylindricaudata**
- *Ophelia denticulata*
- *Travisia carnea*
- *Travisia sp.* #3

Capitellidae
- *Capitella capitata*
- *Heteromastus filiformis*
- *Notomastus luridus*
- *Notomastus latericeus**
- *Mediomastus ambiseta**

Maldanidae
- *Clymenella torquata**
- *Clymenella zonalis**
- *Praxillella gracilis*
- *Rhodine loveni*
- *Clymenura dispar**

Oweniidae
- *Owenia fusiformis*
- *Myriochele heeri**

Ampharetidae
- *Ampharete arctica**
- *Ampharete acutifrons**
- *Melinna cristata**
- *Asabellides oculata**
- *Samytha sexcirrata*

Terebellidae
- *Nicolea venustula*
- *Polycirrus medusa**
- *Polycirrus eximius**
- *Polycirrus phosphoreus*
- *Amaeana trilobata*
- *Streblosoma spiralis**
- Terebellidae sp. #1*

Trichobranchidae
- *Terebellides stroemi**
- *Terebellides sp.* #2

Table 3 (continued)

Sabellidae
*Chone nr. americana**
Euchone incolor
*Euchone elegans**
Euchone sp. #2
Myxicola infundibulum
Potamilla neglecta
*Potamilla reniformis**

Serpulidae
Hydroides protulicola
*Filograna implexa**

MOLLUSCA

Gastropoda

Gastropoda sp. #1

Cocculinidae
Cocculina beanii

Trochidae
*Margarites helicinus**
*Margarites umbilicalis**
Margarites groenlandicus

Rissoidae
Alvania castanea
*Alvania pelagica**
Alvania areolata

Aclididae
Aclis striata

Calyptraeidae
*Crucibulum sp. #1**
Crucibulum striatum

Naticidae
*Polinices immaculatus**
*Lunatia triseriata**
Lunatia heros

Pyrenidae
*Astyris sp. #1**

Table 3 (continued)

Neptuneidae
- *Colus hypolispus*
- *Colus pubescens*
- *Colus pygmaeus**

Nassariidae
- *Nassarius trivittatus**

Fasciolariidae
- *Ptychatractus ligatus*

Pyramidellidae
- *Odostomia gibbosa*
- *Turbonilla interrupta*
- *Turbonilla polita*
- *Turbonilla elegantula*

Scaphandridae
- *Cylichna alba*

Philinidae
- *Philine sinuata*
- *Philine finmarchia**
- *Philine lima**
- *Philine quadrata**

Dendronotidae
- *Dendronotus sp. #1*

Polyplacophora

Lepidopleuridae
- *Lepidopleuris cancellatus*

Pelecypoda

- Bivalve sp. #2*
- Bivalve sp. #3
- Bivalve sp. #5
- Bivalve sp. #6

Nuculidae
- *Nucula proxima**
- *Nucula delphinodonta*

Nuculanidae
- *Yoldia sapotilla*

Solemyidae
- *Solemya velum*

Table 3 (continued)

Mytilidae
- *Mytilus edulis*
- *Crenella decussata**
- *Crenella glandula**
- *Musculus corrugatus**
- *Modiolus modiolus*

Pectinidae
- *Cyclopecten sp. #1* *
- *Delectopecten vitreus*

Anomiidae
- *Anomia simplex*

Montacutidae
- *Mysella planulata* *

Carditidae
- *Cyclocardia borealis**

Astartidae
- *Astarte borealis*
- *Astarte castanea**
- *Astarte undata**

Cardiidae
- *Cerastoderma pinnulatum**

Mactridae
- *Spisula solidissima**

Solenidae
- *Ensis directus**

Arcticidae
- *Arctica islandica**

Veneridae
- *Saxidomus gigantea*

Pandoridae
- *Pandora gouldiana*
- *Pandora inflata*

Lyonsiidae
- *Lyonsia hyalina**

Table 3 (continued)

Periplomatidae
    Periploma fragilis

Scaphopoda

Siphonodentaliidae
    Cadulus sp. #1
    Cadulus pandionis
    Cadulus agassizi

ARACHNIDA

Halacaridae
    Halacarus sp. #1

PYCNOGONIDA

Pycnogonida sp. #1

CRUSTACEA

Cumacea

Leuconidae
    *Eudorella emarginata**
    *Eudorella pusilla**
    Eudorellopsis deformis

Diastylidae
    *Diastylis quadrispinosa**
    *Diastylis sculpta**

Pseudocumidae
    *Petalosarsia declivis**

Bodotriidae
    Pseudoleptocuma minor

Tanaidacea

*Tanaissus liljeborgi**
*Pseudoleptochelia filum**

Isopoda

Anthuridae
    *Ptilanthura tricarina**

Cirolanidae
    *Cirolana polita**

Table 3 (continued)

Idoteidae
- *Chiridotea tuftsi*
- *Chiridotea arenicola**
- *Edotea triloba**
- *Edotea acuta**

Amphipoda

Ampeliscidae
- *Ampelisca macrocephala**
- *Ampelisca vadorum**
- *Ampelisca verrilli*
- *Ampelisca agassizi**
- *Byblis serrata**

Aoridae
- *Microdeutopus gryllotalpa*
- *Leptocheirus pinguis**

Argissidae
- *Argissa hamatipes**

Corophiidae
- *Corophium bonelli*
- *Corophium crassicorne**
- *Erichthonius brasiliensis*
- *Erichthonius rubricornis**
- *Siphonoecetes smithianus**
- *Unciola inermis**
- *Unciola irrorata**
- *Pseudunciola obliquua**

Eusiridae
- *Pontogeneia inermis*

Melitidae
- *Eriopisa elongata*
- *Maera danae**
- *Melita dentata**
- *Melita sp. #1*
- *Casco bigelowi*
- *Gerbarnia sp. #1*

Photidae
- *Protomedia fasciata*

Table 3 (continued)

Haustoriidae
- *Acanthohaustorius spinosus*
- *Protohaustorius wigleyi**

Isaeidae
- *Photis dentata**
- *Photis macrocoxa*
- *Gammaropsis nitida*

Lysianassidae
- *Anonyx sarsi*
- *Hippomedon propinquus**
- *Hippomedon serratus*
- *Orchomenella pinguis*

Oedicerotidae
- *Synchelidium americanum*

Phoxocephalidae
- *Harpinia truncata*
- *Harpinia propinqua**
- *Phoxocephalus holbolli**
- *Phoxocephalus sp. #1*
- *Paraphoxus epistomus**

Pleustidae
- *Stenopleustes gracilis**
- *Stenopleustes inermis**

Synopiidae
- *Syrrhoe crenulata*

Caprellidae
- *Caprella unica*
- *Aeginina longicornis**

Decapoda

Pandalidae
- *Dichelopandalus leptocerus*

Crangonidae
- *Crangon septemspinosa**

Axiidae
- *Axius sp. #1*

Paguridae
- *Pagurus acadianus*
- *Pagurus annulipes*

Table 3 (continued)

Cancridae
- *Cancer borealis*
- *Cancer irroratus*

SIPUNCULA

- *Golfingia pellucida*
- *Phascolion strombi**
- Sipuncula sp. #1*
- Sipuncula sp. #2*
- Sipuncula sp. #3
- Sipuncula sp. #4
- Sipuncula sp. #5*

PHORONIDA

- *Phoronis psammophila**

ECHINODERMATA

Asteroidea

- Asteroidea sp. #1*
- Asteroidea sp. #2
- Asteroidea sp. #3*
- Asteroidea sp. #4

Asteriidae
- *Asterias forbesi* *
- *Asterias vulgaris**
- *Asterias rathbuni*
- *Sclerasterias tanneri*

Echinoidea

Arbaciidae
- Arbaciidae sp. #1

Echinidae
- *Echinus gracilis*

Echinarachniidae
- *Echinarachnius parma**

Ophiuroidea

Amphiuridae
- *Axiognathus squamata**

Holothuroidea

- Holothuroidea spp.

Table 3 (continued)

Cucumariidae
    Stereoderma unisemita

HEMICHORDATA

Harrimaniidae
    *Stereobalanus canadensis**

UROCHORDATA

Ascidiacea

Ascidiacea sp. #1*

Table 4. Numbers of species and individuals, Shannon Weaver diversity and equitability per 0.1 m^2 grab sample. Replicate samples are designated A and B.

Station	Species	Individuals	Diversity	Equitability
1	54	1987	1.02	.255
2	39	449	1.96	.535
3	50	400	3.12	.797
4A	44	337	2.97	.784
4B	52	359	2.39	.605
5	49	2409	2.04	.468
6A	34	191	2.73	.775
6B	42	372	3.02	.809
7A	27	160	2.17	.660
7B	34	166	2.86	.811
8	46	392	2.98	.777
9	39	262	2.64	.720
10	34	270	2.61	.741
11	28	69	2.90	.869
12	19	53	2.70	.916
13	36	260	2.81	.783
14	31	352	2.44	.712
15	33	228	2.77	.793
16	27	75	2.95	.894
17	37	161	3.04	.842
18	18	78	2.41	.833
19A	53	387	3.13	.788
19B	30	127	2.73	.802
20A	46	323	2.76	.720
20B	40	222	2.58	.698
21	42	339	2.64	.707
22A	59	502	2.60	.638
22B	63	452	3.17	.764
23	29	240	2.03	.602
24	30	227	1.82	.536
25	43	285	3.02	.802
26	29	132	2.56	.761
27	48	214	2.93	.757
28	30	204	2.60	.766
29	37	205	2.80	.775
30A	13	30	2.13	.830
30B	25	100	2.82	.876
31A	50	326	3.05	.780
31B	21	84	2.67	.877
32A	51	383	3.25	.828
32B	46	406	3.17	.829
33	69	1373	2.54	.600
34	54	552	1.92	.481
35	56	622	3.04	.756
36	38	288	2.56	.703
37	25	164	2.15	.667
38	41	350	2.35	.632
39	46	343	3.00	.784
40	25	166	2.41	.748
41	44	239	2.91	.780
42	46	245	3.20	.836
43A	49	302	2.76	.709
43B	34	181	2.66	.755
44A	42	215	3.11	.833
44B	38	235	2.82	.775
45A	47	348	2.81	.730
45B	52	557	2.44	.619
46	41	308	2.91	.783
47	28	155	2.13	.639
48	62	591	3.21	.778
49	62	468	3.21	.777
50	42	385	2.77	.741
51	50	495	2.75	.702
52	47	414	3.05	.791
53	47	574	1.72	.446
54A	32	113	3.03	.874
54B	34	119	2.89	.819
55	51	608	2.67	.679
56A	46	335	2.75	.719
56B	37	288	2.99	.829

Table 4. (continued)

Station	Species	Individuals	Diversity	Equitability
57A	21	177	2.15	.705
57B	15	58	2.32	.859
58	19	135	2.41	.818
59	30	253	2.30	.677
60	25	222	2.60	.806
61	40	297	2.79	.757
62	26	277	2.33	.715
63A	15	168	1.72	.636
63B	28	187	2.51	.752
64	31	288	2.26	.657
65A	39	415	2.31	.630
65B	46	782	2.63	.687
66	63	603	3.12	.753
67A	55	787	2.66	.665
67B	35	310	2.30	.646
68	39	252	2.87	.784
69	57	408	3.12	.771
70	18	88	1.78	.617
71	65	1716	2.02	.485
72	49	364	2.89	.741
73	39	271	2.83	.773
74	43	283	2.85	.757
75	34	361	2.25	.638
76A	34	195	2.77	.785
76B	34	118	3.01	.853
77A	42	254	3.02	.807
77B	31	187	2.88	.839
78A	48	275	3.16	.816
78B	40	229	2.83	.767
79	41	198	3.09	.831
80	35	224	2.53	.713
81	12	51	1.82	.733
82	18	158	1.99	.688
83	17	87	2.12	.749
84	23	120	2.68	.856
85	19	86	2.32	.787
86	14	30	2.31	.875
87	17	134	2.31	.815
88	34	197	2.89	.818
89	35	172	3.06	.862
90	39	258	2.23	.608
91	78	351	3.69	.848
92	50	378	2.79	.714
93	46	151	3.24	.845

We used 147 species in performing cluster analyses of the data. Species used are identified by asterisks in the overall species list (Table 3). In the normal analysis, we used a cutoff level of 0.3 similarity to form nine groups of stations (Figure 8). Distribution of station groups in the two subareas is shown in Figures 9 and 10.

For the inverse analysis -0.2 similarity was used to form 13 groups (Figure 11). One of these groups was so large (group 13, 44 species) that we redivided it at the -0.1 level. Groups of species are listed in Table 5.

Rankings and mean densities of species most abundant in our coarsest and finest sediments are given in Table 6. Table 7 shows rankings of species for our nine station groups, and relationship of these station groups to five habitat types described by Boesch et al. (1977b). The comparisons of fauna found at proximate stations in the two surveys are shown in Tables 8-12.

4.4 DISCUSSION

4.4.1. Species Collected

We collected a total of 284 species in subareas A and B (Table 3). Of these, fifty-eight percent were also reported in the VIMS study (Boesch et al., 1977). The actual faunal similarity is no doubt higher because 1) we are comparing an intensive survey of two relatively small areas with VIMS' much more extensive survey; 2) the 58% represents only organisms

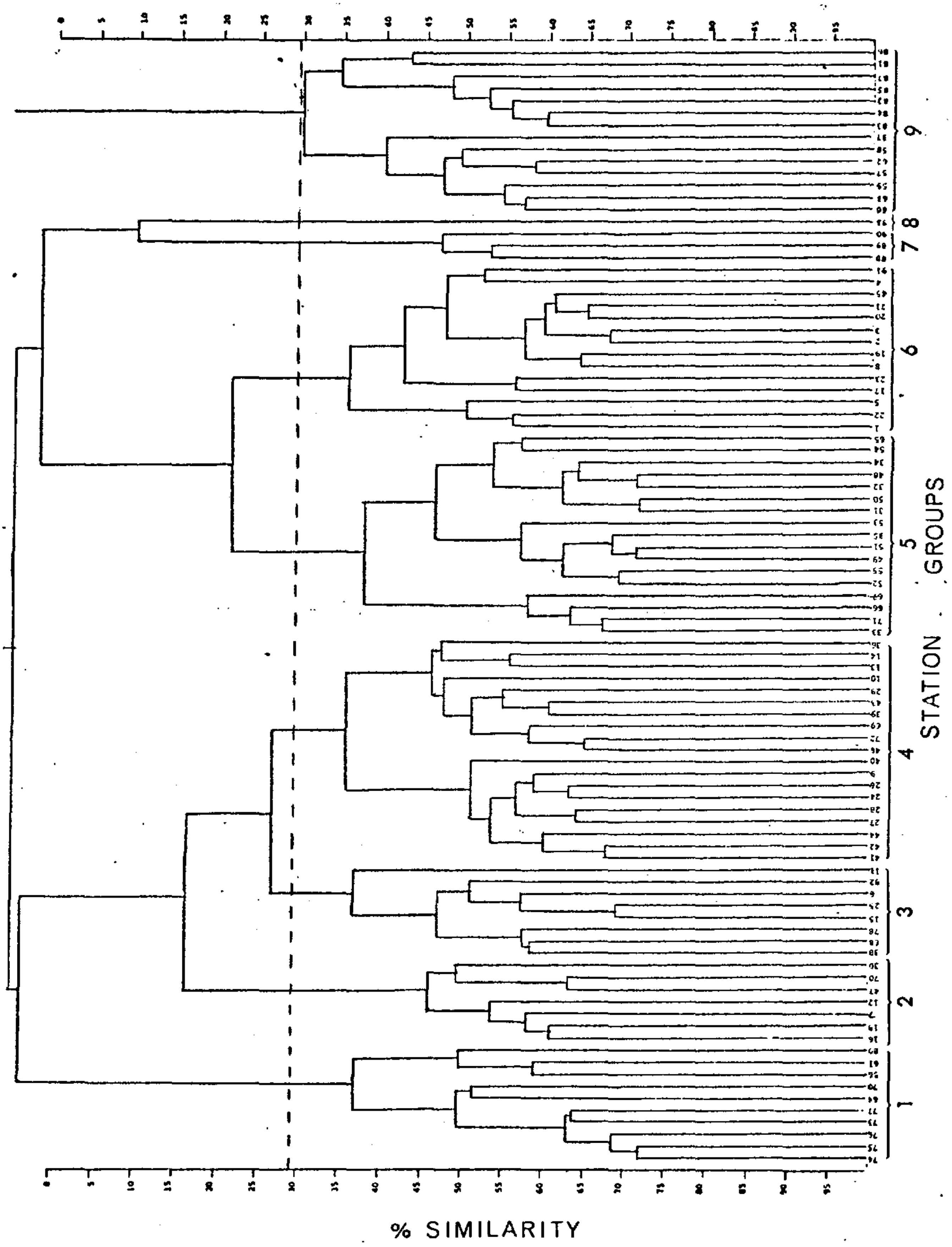

Figure 8. Dendrogram from normal cluster analysis showing similarity between stations, based on Czekanowski coefficient and flexible sorting (β= -0.25). Nine groups were formed at the 0.3 similarity level (see figures 10 and 11).

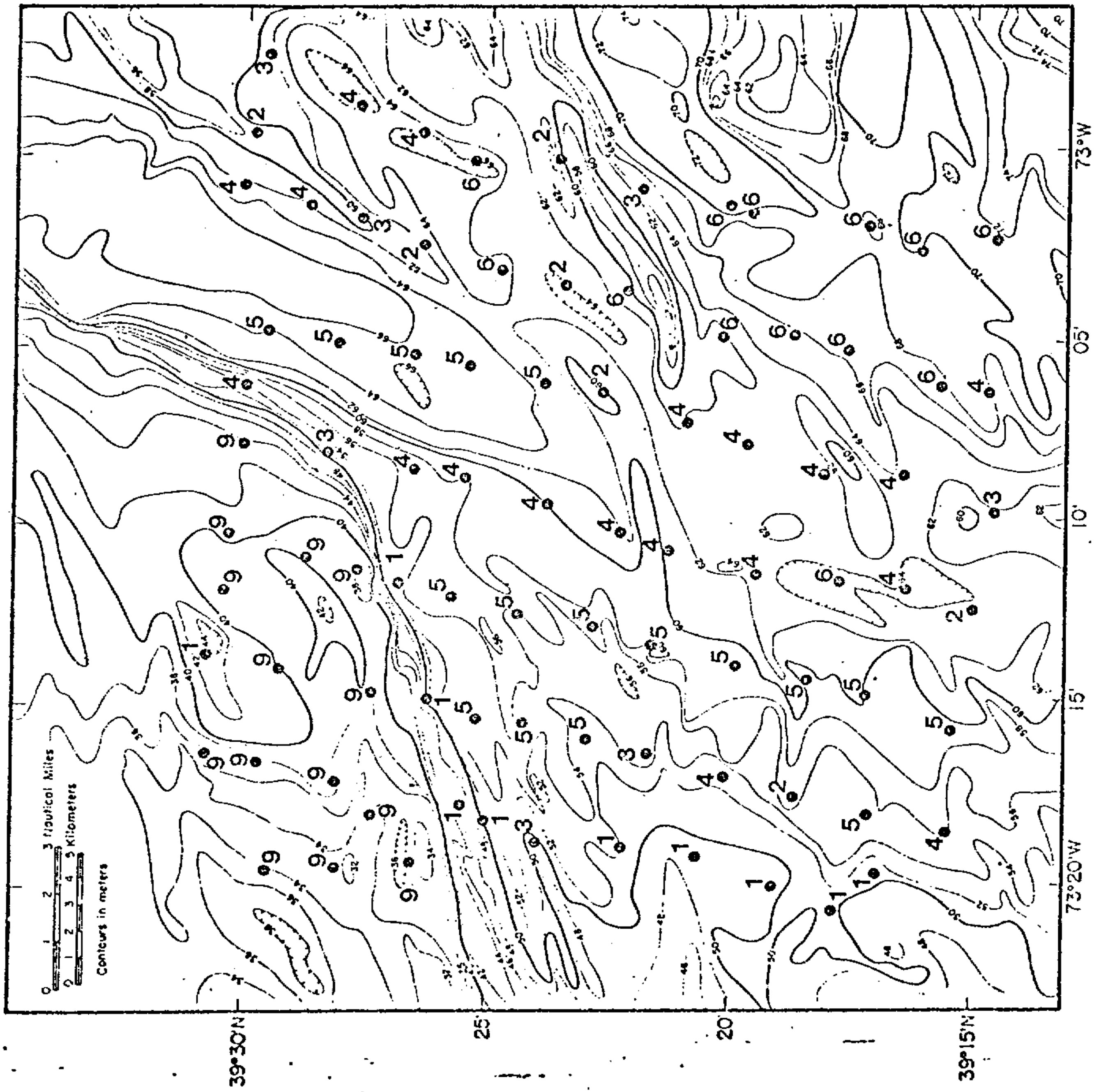

Figure 9. Distribution in Subarea A of the nine station groups formed by normal cluster analysis (0.3 similarity level).

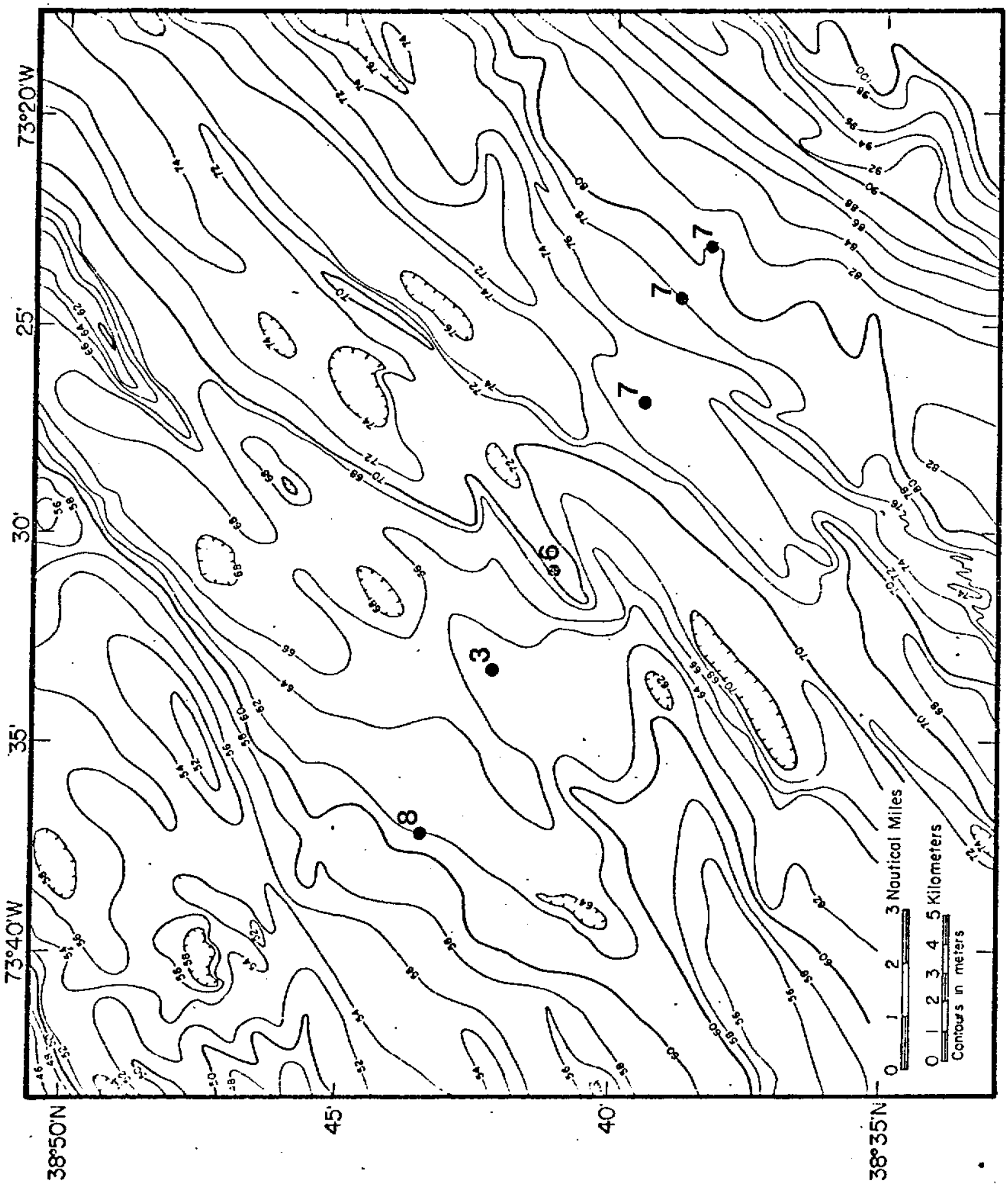

Figure 10. Distribution in subarea B of the nine station groups formed by normal cluster analysis (0.3 similarity level).

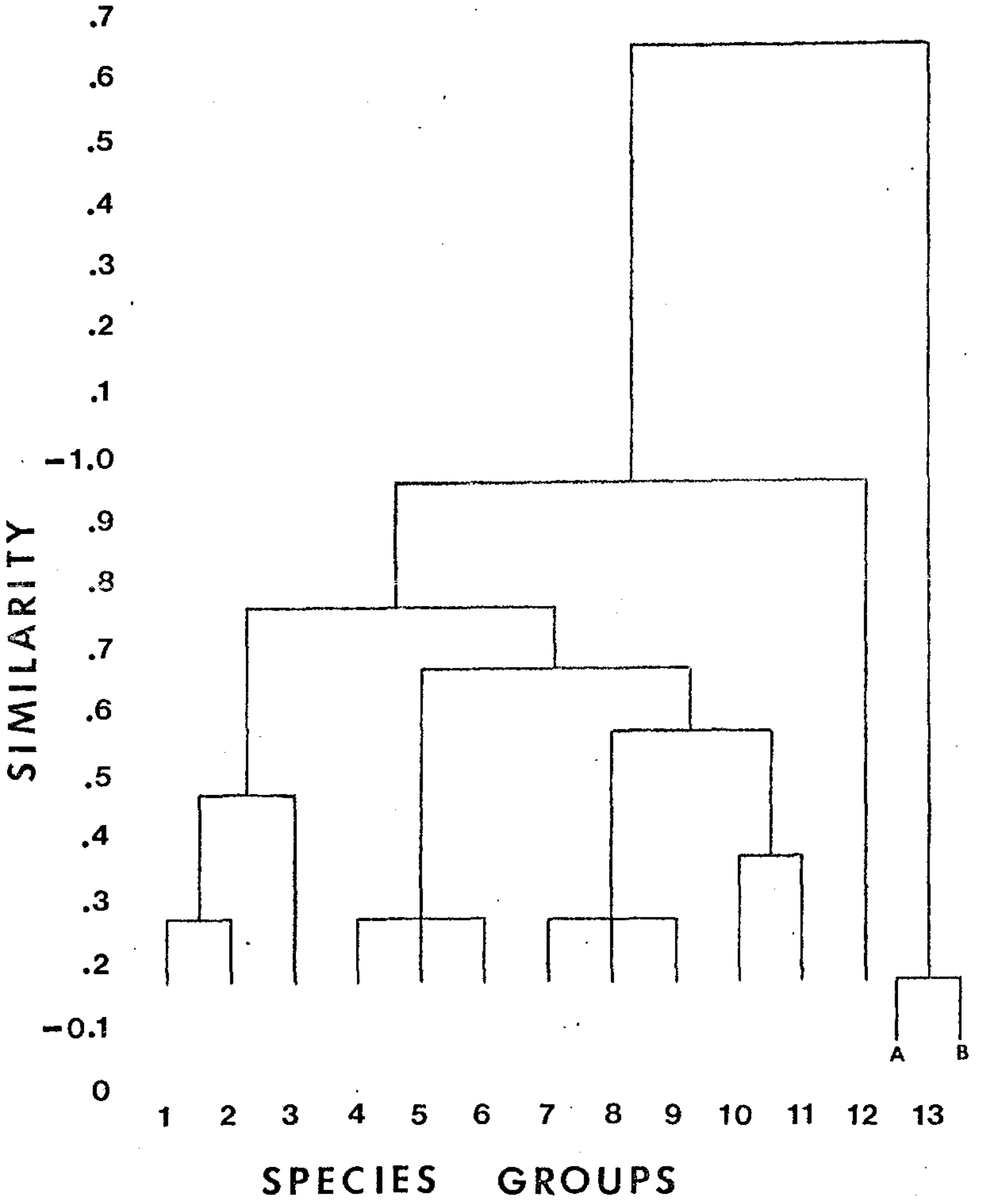

Figure 11. Species groups formed by inverse cluster analysis (-0.2 similarity), based on Czekanowski coefficient and flexible sorting(β=0.25).

Table 5. Species groups clustered by stations at -0.2 similarity. Group 13 was subdivided at -0.1 similarity.

Species Group 1

Dodecaceria coralii
Tanaissus liljeborgi
Filograna implexa

Species Group 2

Goniada brunnea
Stenopleustes gracilis
Asterias forbesii
Phyllodocidae sp. #1
Aphrodita hastata
Laonice cirrata
Prionospio steenstrupi
Lumbrineris fragilis
Mediomastus ambiseta

Species Group 3

Aeginina longicornis
Sipuncula sp. #1
Harpinia propinqua
Mysella planulata
Photis dentata
Streblosoma spiralis
Asabellides oculata
Philine lima

Species Group 4

Chone nr. americana
Scoloplos armiger
Cyclocardia borealis
Astarte undata
Spiophanes wigleyi
Nothria sp. #2
Ophelina cylindricaudata
Crenella decussata
Spio filicornis
Polydora concharum
Drilonereis longa

Species Group 5

Melita dentata
Stereobalanus canadensis
Polycirrus medusa
Astarte castanea

Species Group 6

Philine finmarchia
Edotea triloba
Bivalve sp. #2
Cyclopecten sp. #1
Notomastus latericeus
Terebellidae sp. #1
Terebellides stroemi
Goniada maculata
Melinna cristata
Sipuncula sp. #2

Species Group 7

Drilonereis magna
Caulleriella cf. killariensis
Margarites helicinus
Philine quadrata
Edotea acuta

Species Group 8

Asteroidea sp. #3
Stenopleustes inermis
Lunatia triseriata
Colus pygmaeus
Margarites umbilicalis
Myriochele heeri
Argissa hamatipes
Asterias vulgaris

Table 5 (continued)

Species Group 9

Aricidea wassi
Polinices immaculatus
Corophium crassicorne
Pseudoleptochelia filum
Nassarius trivittatus
Pseudunciola obliquua
Petalosarsia declivis
Nephtys bucera
Hemipodus roseus
Crangon septemspinosa
Asteroidea sp. #1
Crenella glandula
Spisula solidissima
Ascidiacea sp. #1
Sipuncula sp. #5
Nucula proxima
Arctica islandica
Ampelisca macrocephala
Phoronis psammophila
Syllides sp. #1
Hippomedon propinquus
Cirrophorus lyriformis

Species Group 10

Glycera capitata
Maera danae

Species Group 11

Ceriantheopsis americanus
Musculus corrugatus
Eulalia bilineata
Alvania pelagica
Ampharete acutifrons
Crucibulum sp. #1
Typosyllis sp. #1
Potamilla reniformis
Pherusa affinis
Eudorella emarginata

Species Group 12

Goniadella gracilis
Aricidea catherinae
Protohaustorius wigleyi
Chiridotea arenicola
Parapionosyllis longicirrata
Nephtys picta
Streptosyllis arenae
Protodorvillea kefersteini
Lumbrinerides acuta
Cirolana polita
Paraonides lyra

Species Group 13A

Aglaophamus circinata
Glycera dibranchiata
Phoxocephalus holbolli
Ampharete arctica
Euchone elegans
Clymenura dispar
Paraphoxus epistomus
Sthenelais limicola
Ensis directus
Harmothoe extenuata
Exogone hebes
Schistomeringos caeca
Phyllodoce arenae
Clymenella torquata
Chaetozone setosa
Nereis grayi
Ptilanthura tricarina
Pholoe minuta
Tharyx annulosus
Leptocheirus pinguis
Erichthonius rubricornis
Ampelisca vadorum
Siphonoecetes smithianus
Lyonsia hyalina

Table 5 (continued)

Species Group 13B

Diastylis quadrispinosa
Unciola irrorata
Byblis serrata
Astyris sp. #1
Phascolion strombi
Cerastoderma pinnulatum
Exogone naidina
Clymenella zonalis
Spiophanes bombyx
Echinarachnius parma
Tharyx acutus
Lumbrineris tenuis
Scalibregma inflatum
Axiognathus squamata
Eudorella pusilla
Diastylis sculpta
Polydora socialis
Polycirrus eximius
Ampelisca agassizi
Unciola inermis

Table 6. Mean densities/m^2 and rankings of dominant species at stations with highest fractions of gravel (≥5.2%) and silt/clay (≥3%).

	Gravel Stations		Silt/Clay Stations	
	Rank	$\overline{x}$	Rank	$\overline{x}$
Polydora socialis	1	877	2	1088
Goniadella gracilis	2	454	32	18
Clymenella zonalis	3	438	4	260
Unciola inermis	4	426	5	186
Exogone naidina	5	397	12	93
Lumbrinerides acuta	6	173	41	9
Tharyx acutus	7	145	11	103
Aricidea catherinae	8	125	43	4
Echinarachnius parma	9	122	7	182
Spiophanes bombyx	10	120	3	278
Ampelisca agassizi	19	39	1	2199
Eudorella pusilla	21	34	6	182
Clymenella torquata	41	2	8	178
Cerastoderma pinnulatum	12	70	9	149
Astyris sp. #1	16	48	10	111

Gravel stations: 6, 58, 59, 62, 66, 67, 71 78

Silt/clay stations: 1, 13, 18, 33, 34, 35, 55, 70, 91

Species \ Station group	Habitat Types								
	Ridges	Shallow flanks		Deep flanks			Swales		Shelf Break
	9	1	3	2	4	8	5	6	7
Parapionosyllis longicirrata	7								
Nephtys picta	8								
Hemipodus roseus	9								
Exogone hebes *	10								
Echinarachnius parma *	3	2	1	1	2	1	7	2	
Goniadella gracilis *	1		2	8					
Lumbrinerides acuta *	2		4	7					
Spiophanes bombyx *	5	1	8	9	3		3	7	
Clymenella zonalis *	6	7	5	3	10	6	4		
Aricidea catherinae	4		6						
Euchone elegans		3							
Paraphoxus epistomus *		4							4
Diastylis sculpta		8							
Glycera dibranchiata		10							
Byblis serrata		9			9				
Diasytlis quadrispinosa		5	10		7			8	
Unciola irrorata *		6		10					
Tharyx acutus *			3	2	1		9	4	
Exogone naidina			7		4		6		
Clymenura dispar			9	6					
Astyris sp. #1				4	5	2	10	5	
Phascolion strombi				5	8				
Unciola inermis					6		5		
Cerastoderma pinnulatum						3			
Astarte undata						4			
Axiognathus squamata						5			
Crenella glandula						9			
Phoxocephalus holbolli						10			
Cyclocardia borealis						7			7
Sipuncula sp. #2						8			
Eudorella pusilla							8		
Ampelisca agassizi *							2	1	
Polydora socialis							1	6	
Filograna implexa								3	
Scalibregma inflatum *								9	8
Lumbrineris tenuis *								10	3
Chone nr. americana									1
Scoloplos armiger									2
Notomastus latericeus *									5
Terebellidae sp. #1									6
Hippomedon propinquus									9
Spio filicornis									10

Table 7. Mean rankings of numerically dominant species at each of the station groups (see figure 9). Station groups are combined into five habitat types in the manner of Boesch et al. (1977b). *-species in common with Boesch et al. (1977b).

Table 8. Comparisons of dominant species (ranked in top ten, based on density) found at proximate stations in NMFS (1974) and VIMS (1975-76) surveys. Data for 1975-76 are taken from Boesch et al., 1977.

* - Dominant species in both NMFS and VIMS surveys.
# - Means of two grabs; other 1974 data are from single grabs.

Station	Rank	Species	Mean Density (no./m²)	Species	Mean Density (no./m²)
		FALL 1975		WINTER 1976	
B1	1	Tharyx sp. (P)	1412	Cirratulidae (Tharyx) (P)	1820
	2	Scalibregma inflatum (P)	498	Byblis serrata (Am)	291
	3	Chaetozone setosa (P)	217	Spiophanes bombyx (P)	283
	4	Spiophanes bombyx (P)	187	Scalibregma inflatum (P)	226
	5	Caulleriella sp. (P)	173	*Lumbrineris impatiens (P)	222
	6	*Diastylis bispinosa (C)	170	Syllidae (P)	142
	7	Exogone hebes (P)	167	*Unciola irrorata (Am)	123
	8	Euchone sp. A (P)	158	Euchone sp. A (P)	118
	9	*Lumbrineris impatiens (P)	145	*Diastylis bispinosa (C)	95
	10	Nicolea venustula (P)	130	Erichthonius rubricornis (Am)	87
		SPRING 1976		SUMMER 1976	
B1	1	Byblis serrata (A)	535	Cirratulidae (P)	1066
	2	Erichthonius rubricornis (A)	511	Byblis serrata (A)	375
	3	*Unciola irrorata (A)	495	*Unciola irrorata (A)	223
	4	*Diastylis bispinosa (C)	202	Spiophanes bombyx (P)	223
	5	Cirratulidae (P)	163	*Lumbrineris impatiens (P)	198
	6	*Lumbrineris impatiens (P)	127	Erichthonius rubricornis (A)	182
	7	Ampelisca agassizi (A)	103	Scalibregma inflatum (P)	92
	8	*Mitrella sp. (G)	102	Syllidae (P)	90
	9	*Echinarachnius parma (E)	87	Aglaophamus circinata (P)	87
	10	Ampelisca vadorum (A)	85	Nereis grayi (P)	85

(#)		MAY 1974 DOMINANTS	no./m²	MAY 1974 DENSITIES OF OTHER VIMS DOMINANTS	no./m²
44	1	*Echinarachnius parma	380	Scalibregma inflatum	15
	2	Diastylis sculpta	225	Chaetozone setosa	40
	3	*Mitrella sp. (Astyris sp.#1)	195	Spiophanes bombyx	30
	4	Clymenella torquata	115	Caulleriella sp.	0
	5	Eudorella pusilla	105	Exogone hebes	0
	5	*Diastylis quadrispinosa (=bispinosa)	105	Euchone sp.	0
	7	Tharyx acutus	85	Nicolea venustula	0
	8	*Unciola irrorata	80	Byblis serrata	50
	9	Cerastoderma pinnulatum	75	Erichthonius rubricornis	5
	10	*Lumbrineris tenuis (=impatiens)	70	Ampelisca agassizi	15
				Ampelisca vadorum	10
				Aglaophamus circinata	30
				Nereis grayi	10
				Cirratulidae	0
				Syllidae	0

Table 9. Comparisons of dominant species (ranked in top ten, based on density) found at proximate stations in NMFS (1974) and VIMS (1975-76) surveys. Data for 1975-76 are taken from Boesch et al., 1977.

* - Dominant species in both NMFS and VIMS surveys.
\# - Means of two grabs; other 1974 data are from single grabs.

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
B2	1	*_Coniadella gracilis_ (P)	608	_Ampelisca vadorum_ (Am)	1092
	2	*_Lumbrinerdes acuta_ (P)	513	Syllidae (P)	896
	3	_Exogone hebes_ (P)	418	_Byblis serrata_ (Am)	866
	4	_Exogone verugera_ (P)	305	Cirratulidae (P)	768
	5	_Polygordius_ sp. 1 (Ar)	296	_Unciola irrorata_	500
	6	_Aricidea suecica_ (P)	270	*_Scalibregma inflatum_ (P)	281
	7	_Caulleriella_ sp. (P)	230	*_Spiophanes bombyx_ (P)	231
	8	*_Scalibregma inflatum_ (P)	222	_Polygordius_ sp. 1 (Ar)	143
	9	*_Tharyx_ sp. (P)	200	_Tanaissus liljeborgi_ (T)	138
	10	*_Praxillella_ sp. A. (P)	193	*_Lumbrinerides acuta_ (P)	137
		SPRING 1976		SUMMER 1976	
B2	1	_Unciola irrorata_ (A)	912	_Unciola irrorata_ (A)	666
	2	Syllidae (P)	443	Cirratulidae (P)	200
	3	*_Coniadella gracilis_ (P)	401	_Cirolana polita_ (I)	175
	4	*_Lumbrinerides acuta_ (P)	373	_Erichthonius rubricornis_ (A)	167
	5	_Ampelisca vadorum_ (A)	346	_Byblis serrata_ (A)	160
	6	_Byblis serrata_ (A)	316	_Ampelisca vadorum_ (A)	152
	7	Cirratulidae (P)	263	*_Coniadella gracilis_ (P)	128
	8	*_Scalibregma inflatum_ (P)	143	*_Lumbrinerides acuta_ (P)	127
	9	_Erichthonius rubricornis_ (A)	140	Syllidae (P)	100
	10	*_Echinarachnius parma_ (E)	130	*_Scalibregma inflatum_ (P)	78

(#)		MAY 1974 DOMINANTS	no./m^2	MAY 1974 DENSITIES OF OTHER VIMS DOMINANTS	no./m^2
7	1	*_Echinarachnius parma_	630	_Unciola irrorata_	25
	2	_Phascolion strombi_	90	_Exogone hebes_	10
	3	*_Lumbrinerides acuta_	85	_Exogone verugera_	0
	4	*_Goniadella gracilis_	70	_Polygordius_ sp.	0
	5	*_Tharyx acutus_	65	_Aricidea suecica_	0
	6	_Astyris_ sp. #1	55	_Caulleriella_ sp.	10
	6	*_Spiophanes bombyx_	55	_Ampelisca vadorum_	0
	8	_Hemipodus roseus_	45	Syllidae	0
	9	*_Clymenura dispar_ (=_Praxillella_ sp. #1)	40	_Byblis serrata_	5
	10	*_Scalibregma inflatum_	30	Cirratulidae	0
				Tanaissus liljeborgi	0
				Erichthonius rubricornis	5
				Cirolana polita	10

Table 10. Comparisons of dominant species (ranked in top ten, based on density) found at proximate stations in NMFS (1974) and VIMS (1975-76) surveys. Data for 1975-76 are taken from Boesch et al., 1977.

* - Dominant species in both NMFS and VIMS surveys.

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
B3	1	**Ampelisca agassizi* (Am)	9273	**Ampelisca agassizi* (Am)	9839
	2	*Diastylis bispinosa* (C)	704	*Unciola irrorata* (Am)	523
	3	*Unciola irrorata* (Am)	381	*Notomastus latericeus* (P)	443
	4	*Photis dentata* (Am)	313	*Diastylis bispinosa* (C)	368
	5	*Leptocheirus pinguis* (Am)	248	*Photis dentata* (Am)	336
	6	*Clymenella torquata* (P)	245	Syllidae (P)	311
	7	*Notomastus latericeus* (P)	235	*Eudorella pusilla* (C)	208
	8	*Scalibregma inflatum* (P)	210	*Chone infundibuliformis* (P)	188
	9	*Eudorella pusilla* (C).	182	*Erichthonius rubricornis* (A)	142
	10	*Laonice cirrata* (P)	163	Cirratulidae (*Tharyx*)(P)	133
		SPRING 1976		SUMMER 1976	
B3	1	**Ampelisca agassizi* (A)	11,685	**Ampelisca agassizi* (A)	8355
	2	*Unciola irrorata* (A)	706	*Unciola irrorata* (A)	813
	3	*Photis dentata* (A)	288	*Photis dentata* (A)	649
	4	**Phascolion strombi* (Si)	268	*Notomastus latericeus* (P)	466
	5	*Mysella ovata* (B)	261	*Erichtonius rubricornis* (A)	256
	6	*Erichthonius rubricornis* (A)	228	*Nereis grayi* (P)	250
	7	*Notomastus latericeus* (P)	175	*Polydora* sp. (P)	248
	8	*Eudorella pusilla* (C)	150	*Scalibregma inflatum* (P)	225
	9	Syllidae (P)	135	*Eudorella pusilla* (C)	135
	10	*Chone infundibuliformis* (P)	127	*Lumbrineris impatiens* (P)	132

MAY 1974 DOMINANTS

			no./m^2
5	1	**Ampelisca agassizi*	11660
	2	*Filograna implexa*	5320
	3	*Polydora socialis*	1470
	4	*Echinarachnius parma*	480
	5	*Spiophanes bombyx*	430
	6	*Spiophanes wigleyi*	370
	7	*Potamilla reniformis*	350
	8	Sipuncula No. 2	330
	9	*Polycirrus eximius*	280
	10	**Phascolion strombi*	260

MAY 1974 DENSITIES OF OTHER VIMS DOMINANTS

	no./m^2
Unciola irrorata	50
Photis dentata	130
Leptocheirus pinguis	20
Notomastus latericeus	140
Laonice cirrata	30
Mysella planulata	40
Erichthonius rubricornis	20
Chone infundibuliformis (= nr. americana)	30
Polygordius sp.	0
Diastylis bispinosa (= quadrispinosa)	70
Eudorella pusilla	240
Clymenella torquata	10
Scalibregma inflatum	30
Laonice cirrata	30
Syllidae	0
Tharyx sp.	30
Nereis grayi	0
Lumbrineris impatiens (= tenuis)	0

Table 11. Comparisons of dominant species (ranked in top ten, based on density) found at proximate stations in NMFS (1974) and VIMS (1975-76) surveys. Data for 1975-76 are taken from Boesch et al., 1977.

* - Dominant species in both NMFS and VIMS surveys.

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
B4	1	**Goniadella gracilis* (P)	1039	**Goniadella gracilis* (P)	636
	2	*Praxillella* sp. A (P)	793	*Praxillella* sp. A (P)	508
	3	*Aricidea suecica* (P)	666	Syllidae (P)	345
	4	**Lumbrinerides acuta* (P)	436	*Aricidea suecica* (P)	281
	5	**Parapionosyllis longicirrata* (P)	331	**Lumbrinerides acuta* (P)	276
	6	*Tharyx* sp. (P)	218	**Aricidea cerrutii* (P)	207
	7	*Polygordius* sp.1 (Ar)	188	*Polygordius* sp. 1 (Ar)	147
	8	**Clymenella zonalis* (P)	173	**Tanaissus liljeborgi* (T)	73
	9	Syllidae	155	Cirratulidae (P)	73
	10	**Protodorvillea kefersteini*	118	Oligochaeta	62
		SPRING 1976		SUMMER 1976	
B4	1	**Goniadella gracilis* (P)	445	**Goniadella gracilis* (P)	388
	2	**Lumbrinerides acuta* (P)	315	**Lumbrinerides acuta* (P)	236
	3	*Aricidea suecica* (P)	112	*Unciola irrorata* (A)	213
	4	*Praxillella* sp. A. (P)	112	*Aricidea cerrutii* (P)	177
	5	*Unciola irrorata* (A)	110	**Spiophanes bombyx* (P)	127
	6	**Harmothoe extenuata* (P)	110	*Praxillella* sp. A. (P)	123
	7	**Clymenella zonalis* (P)	75	**Clymenella zonalis* (P)	100
	8	*Phoxocephalus holbolli* (A)	73	*Aricidea suecica* (P)	85
	9	*Chiridotea arenicola* (I)	53	Cirratulidae (P)	50
	10	*Echinarachnius parma* (E)	47	**Harmothoe extenuata* (P)	45

		MAY 1974 DOMINANTS	no./m^2	MAY 1974 DENSITIES OF OTHER VIMS DOMINANTS	no./m^2
59	1	**Goniadella gracilis*	820	*Praxillella* sp. (=*Clymenura dispar*)	20
	2	**Lumbrinerides acuta*	490	*Aricidea suecica*	0
	3	**Macroclymene zonalis*	390	*Tharyx* sp.	30
	4	**Tanaissus liljeborgi*	210	*Polygordius* sp.	0
	5	**Parapionosyllis longicirrata*	120	*Streptosyllis arenae*	10
	6	**Protodorvillea kefersteini*	90	*Unciola irrorata*	10
	7	**Harmothoe extenuata*	80	*Phoxocephalus holbolli*	0
	7	**Aricidea catherinae (=cerruti)*	80	*Chiridotea arenicola*	30
	9	*Phyllodoce arenae*	40	*Echinarachnius parma*	0
	9	*Exogone naidina*	40	Syllidae	0
	9	*Nephtys picta*	40	Cirratulidae	0
	9	**Spiophanes bombyx*	40	Oligochaeta	0

Table 12. Comparisons of dominant species (ranked in top ten, based on density) found at proximate stations in NMFS (1974) and VIMS (1975-76) surveys. Data for 1975-76 are taken from Boesch et al., 1977.

* - Dominant species in both NMFS and VIMS surveys.

Station	Rank	Species	Mean Density (no./m^2)	Species	Mean Density (no./m^2)
		FALL 1975		WINTER 1976	
E3	1	*_Goniadella graciles_ (P)	288	Syllidae _(Exogone)_	758
	2	*_Spiophanes bombyx_ (P)	253	*_Goniadella gracilis_ (P)	435
	3	Cirratulidae (P)	236	Cirratulidae (P)	283
	4	*_Praxillella_ sp. A. (P)	233	_Polygordius_ sp.1 (Ar)	197
	5	*_Echinarachnius parma_ (E)	122	*_Praxillella_ sp. A. (P)	193
	6	*_Trichophoxos epistomus_ (Am)	103	*_Ampelisca vadorum_ (Am)	185
	7	_Exogone hebes_ (P)	90	*_Echinarachinius parma_ (E)	130
	8	*_Lumbrinerides acuta_ (P)	85	*_Clymenella zonalis_ (P)	117
	9	_Scalibregma inflatum_ (P)	75	*_Lumbrinerides acuta_ (P)	102
	10	_Mitrella_ sp. (G)	70	*_Trichophoxus epistomus_ (Am)	85
		SPRING 1976		SUMMER 1976	
E3	1	_Ampelisca agassizi_ (A)	1176	*_Goniadella gracilis_ (P)	218
	2	*_Goniadella gracilis_ (P)	571	*_Ampelisca vadorum_ (A)	145
	3	Syllidae (P)	251	_Unciola irrorata_ (A)	140
	4	_Unciola irrorata_ (A)	210	*_Echinarachnius parma_ (E)	100
	5	Cirratulidae (P)	180	Syllidae (P)	93
	6	_Erichthonius rubricornis_ (A)	163	*_Praxillella_ sp. A. (P)	90
	7	_Janira alta_ (I)	153	*_Trichophoxus epistomus_ (A)	72
	8	*_Lumbrinerides acuta_ (P)	147	*_Spiophanes bombyx_ (P)	63
	9	*_Ampelisca vadorum_ (A)	145	Cirratulidae (P)	62
	10	_Melita dentata_ (A)	140	*_Lumbrinerides acuta_ (P)	57

		MAY 1974 DOMINANTS	no./m^2	MAY 1974 DENSITIES OF OTHER VIMS DOMINANTS	no./m^2
92	1	*_Echinarachnius parma_	1280	Cirratulidae	0
	2	_Polydora socialis_	310	_Exogone hebes_	50
	3	*_Clymenella zonalis_	310	_Scalibregma inflatum_	0
	4	*_Lumbrinerides acuta_	250	_Mitrella_ sp. (=_Astyris_ sp. #1)	30
	5	*_Goniadella gracilis_	150	_Ampelisca agassizi_	0
	6	*_Ampelisca vadorum_	140	Syllidae	0
	7	*_Spiophanes bombyx_	120	_Unciola irrorata_	50
	8	*_Clymenura dispar_ (=_Praxillella_ sp. A)	110	_Erichthonius rubricornis_	0
	9	_Harmothoe extenuata_	80	_Janira alta_	0
	9	_Aricidea cerruti_	80	_Melita dentata_	0
	9	_Tharyx acutus_	80	_Exogone_ sp.	0
	9	_Paraphoxus_ (= _Trichophoxus_) _epistomus_	80	_Polygordius_ sp.	0

identified to species; some taxa identified to the genus or higher level were probably the same species in both surveys; 3) a number of species were apparently assigned different names in the two surveys; and 4) some species which we collected but have not considered (e.g., oligochaetes and archiannelids) may also have been in common.

Polychaetes were the taxon with the most species in our collections, containing 45% of the species found. They were followed by crustaceans (23%) and molluscs (22%). This order agrees with the VIMS findings for the Middle Atlantic shelf (Boesch et al., 1977). Ten species (Echinarachnius parma, Unciola irrorata, Spiophanes bombyx, Tharyx acutus, Clymenura dispar, Glycera dibranchiata, Scalibregma inflatum, Astyris sp. #1, Diastylis quadrispinosa and Clymenella zonalis) were present at ≥75% of our stations.

Numbers of species per 0.1 m^2 grab sample (Table 4) ranged from 12 (station 81) to 79 (station 5) in subarea A and from 34 species (station 88) to 78 (station 91) in subarea B. Total numbers of individuals varied between 51 (station 81) and 2409 (station 5) in subarea A and from 151 (station 93) to 378 (station 92) in subarea B.

Diversity values (Table 4) were somewhat lower than those in the VIMS study, ranging from 1.72 (station 53) to 3.21 (station 32) in subarea A and from 2.23 (station 90) to 3.69 (station 91) in subarea B. VIMS reported values of approximately 2.1 to 4.7 for subarea A and 2.0 to 5.5 for subarea B. The discrepancy may be partly explained by VIMS' use of smaller-mesh sieves and collection of samples during all seasons.

4.4.2. Station Similarities

The nine groups of stations present at the 0.3 similarity level in Figure 9 probably represent a high estimate of the number of distinct habitats one could expect to find within our two subareas. However, the distribution of these station groups (Figures 9-10) does illustrate some obvious relationships to bathymetry and topography.

Station group 9 includes stations in the northwest corner of subarea A, which constitutes the terrace or plateau of Tiger Scarp. Group 7 consists of three stations in the eastern half of subarea B, a region classified by Boesch et al. (1977) as "shelf break". Group 2 appears to represent the deeper portions of flanks of sand ridges such as at stations 16, 18, 47 and 70, while groups 1 and 3 are the upper portions or shallow flanks of ridges, as at stations 7, 12 and 30. Station groups 4, 5, 6, and 8 appear to denote areas of gentler relief. Some stations in the latter two groups, however, are located in slight depressions which had relatively high percentages of silt/clay (Figure 6), and are thus considered "swale" groups.

4.4.3. Species Groups

The 14 species groups (Figure 11, Table 5) did not appear to be as distinct or clearly related to various habitats as were the station groups. This must be at least partly due to the relatively homogeneous environment sampled, and/or fairly wide sediment tolerances of many BCT species. Also, as Boesch et al. (1977) found for their megabenthos species groups, the basic subdivisions in our inverse dendrogram were determined to some extent by whether a species was rare or abundant rather than by its affinities to other species or to particular habitats. Thus group 13, the first group separated in the dendrogram, contains many of our commonest species (group 13 does include several species characteristic of fine sediment or swale environments). The next group formed, 12, also contains many common species; some of these dominate ridge-type habitats but are also present, in lower densities, in other strata. The remaining groups contain less ubiquitous species and undoubtedly represent an ill-defined continuum between the extremes of ridge and swale. None of the groups bears a close similarity to any of the species groups listed by Boesch et al. (1977). Since the 150 species which were included in the VIMS clustering represented a much wider range of habitats, from nearshore waters to the continental slope, one would expect more distinct groupings in their collections and no precise correspondence between the two sets of species groups.

That there is at least some ecological basis for our species groups is indicated by the fact that congeners were generally separated into different groups; of the 21 species pairs included in the cluster analysis, only two (*Unciola irrorata* and *U. inermis*, *Diastylis quadrispinosa* and *D. sculpta*) were found within the same cluster group. Both these pairs are in the rather indistinct group 13B. Members of each of the two genera with three species (*Ampelisca* and *Philine*) were also segregated by cluster group. Boesch et al. (1977) found many examples of such habitat segregation by congeners. This segregation indicates that some congeners may be of special value in characterizing different habitats in the BCT.

4.4.4. Animal-Sediment Relationships

The rankings of species abundant in our coarsest and finest sediments (Table 6) reveal three basic groupings. Seven species had comparable rankings and mean densities in fine and coarse sediments. Three species (*Echinarachnius parma*, *Tharyx acutus*, *Astyris sp. #1*, *Clymenella zonalis*, *Polydora socialis*, *Unciola inermis* and *Cerastoderma pinnulatum*) thus had sediment tolerances at least as wide as the range encountered in our sampling. Three species were clearly more successful in the coarser sediments (*Goniadella gracilis*, *Lumbrinerides acuta* and *Aricidea catherinae*), and another three species were much more abundant in fines (*Ampelisca agassizi*, *Eudorella pusilla* and *Clymenella torquata*). The two remaining species in Table 6 were abundant in both extremes of sediment type, but Spiophanes bombyx was somewhat more common in fine than coarse sediments, while the reverse was true for *Exogone naidina*.

Comparing these relationships with Boesch et al. (1977b)'s ranking of species against habitat types (assuming our coarse-fine gradient is comparable to their ridge-swale or exposed-deep sheltered), we find good agreement for the habitats of *Tharyx*, *Goniadella*, *Lumbrinerides*, *Ampelisca* and *Spiophanes*. *Echinarachnius* and *zonalis* were closer to the exposed end in the VIMS ranking than in ours. This may be because the entire area (E) used in the VIMS analysis is deeper and more sheltered than were most of our stations. The remaining eight species in Table 6 are not listed for VIMS area E.

Table 7 represents a ranking of abundant species from all of our nine station groups according to the habitat gradient of Boesch et al. (1977b), to permit more precise comparison with the VIMS data for their area E. The order of species in Table 7 thus represents a scale from exposed to deep sheltered habitats. This treatment shows agreement with the coarse-fine classification above (Table 6) in that five of the six species noted as characteristic of our coarsest or finest sediments were also ranked in the ridge and swale habitats, respectively, of Table 7 (*Clymenella torquata* does not appear in Table 7). There is also good agreement with Boesch et al. (1977b) on the positions of ten of the 13 species in common with the VIMS Area E list (*Echinarachnius*, *Goniadella*, *Lumbrinerides*, *Clymenella zonalis*, *Paraphoxus*, *Unciola*, *Tharyx*, *Ampelisca*, *Lumbrineris* and *Notomastus*). *Scalibregma* is slightly more toward the deep sheltered end, and *Spiophanes* slightly toward the exposed end, in our list; *Exogone* is much closer to the exposed end in Table 7 than in the VIMS list. Our remaining 29 species are not in common with those of VIMS Area E, which, again, is deeper and closer to the shelf break than were most of our stations.

Pratt (1973) divides the MAB into three broad faunal zones based on sediment type. Of the species in Table 7, *Nephtys*, *Spiophanes*, *Goniadella*, *Aricidea* and *Echinarachnius* are listed by Pratt among characteristic members of the sand fauna, and *Scalibregma*, *Astarte*, *Ampelisca*, *Unciola irrorata* and cumaceans as typical of silty-sand environments. Our intensive sampling has revealed several faunal assemblages, related to bathymetry and topography, in an area which basically consists of fairly uniform sands. This is in agreement with the concept of Boesch et al. (1977) that "macrobenthic communities are not homogeneous across the shelf in any synecologically meaningful sense".

4.4.5 Temporal Stability of BCT Fauna

Comparisons of fauna from proximate stations in the NMFS and VIMS surveys (Tables 8-12) indicate moderate stability of populations of dominant species between 1974 and 1976. Stations compared, their distances apart and sediment types are discussed in Section 3. Again, we feel the faunal comparisons reflect a minimum similarity between surveys. We would expect higher similarity if 1) NMFS and VIMS station locations corresponded exactly; 2) the same sieve size was used in both surveys; and 3) species were identified by the same taxonomists. We suspect that in several instances a common species was given different names in two surveys. Discussions and exchange of specimens with VIMS scientists have solved this latter problem for most dominant species. A station-by-station comparison of fauna from the two surveys follows.

B1 vs 44: Five of the ten dominant species in the May 1974 (NMFS) samples were also listed as dominant in one or more of VIMS' seasonal collections during 1975-76 (Table 8), and nine more VIMS dominants were also present in our collections. The sand dollar, *Echinarachnius parma*, (mostly juveniles) was much more common in 1974; this is also seen in comparisons of other proximate stations. Three amphipods, *Byblis serrata*, *Unciola irrorata* and *Erichthonius rubricornis*, were more abundant in the latter three of VIMS' seasonal samplings than in 1974.

B2 vs 7: Seven of our ten most abundant species were dominants in 1975-76 (Table 9). Two species characteristic of ridge environments, *Goniadella gracilis* and *Lumbrinerides acuta*, had 1974 rankings similar to the mean of their 1975-76 positions. *Echinarachnius parma* was much more abundant in 1974, while *Ampelisca vadorum* was abundant in 1975-76 but not found in 1974. Six other VIMS dominants were also present in our samples.

B3 vs 5: As noted in Section 2.4, the greatest disparity in silt/clay content of stations compared was between B2 and 5. These stations also had the lowest number of dominants in common, two (Table 10). Overall faunal composition is more similar than this would indicate, because this swale habitat is dominated by high densities of *Ampelisca agassizi* in all collections - numbers of *A. agassizi* were comparable between our sample ($11,660/m^2$). In addition, 15 other VIMS dominants were present though not dominant in our collection. In May 1974 we also found large numbers of three species not listed among the VIMS dominants - *Echinarachnius parma*, and the polychaetes, *Polydora socialis* and *Filograna implexa* (a small serpulid). The amphipods, *Unciola irrorata* and *Photis dentata*, were consistently more abundant in 1975-76. [We sampled station B3 in April 1978, and found the domination by *Ampelisca agassizi* to continue; mean densities were $7,440/m^2$, ± 246 (SEM)].

B4 vs 59: Collections were quite similar between 1974 and 1975-76. The eight top-ranked species in our survey were listed as dominants in one or more VIMS collections, and another five VIMS dominants were present in our sample (Table 11). This is a typical ridge area, as shown by the abundance of *Goniadella* and *Lumbrinerides* in all three years. Densities of these species were also fairly consistent over time. We found 820 *Goniadella*/m^2 vs. a mean of 627.5 for the VIMS seasonal samplings, and there were 490 *Lumbrinerides*/m^2 in 1974 vs. 315.8 in 1975-76. *Clymenella zonalis* was another species commonly found in all three years. *Parapionosyllis longicirrata* and *Protodorvillea kefersteini* were abundant in May 1974 and fall 1975 before apparently declining in numbers, while *Aricidea catherinae* and *Spiophanes bombyx* were common in 1974 and 1976 but not in 1975. Only *Aricidea suecica* and *Praxillella* sp. among consistent VIMS dominants were not found in 1974.

E3 vs 92: This is the only comparison we have made for subarea B. Assemblages were quite similar between the two surveys, with eight of our 12 dominants also listed as VIMS dominants (Table 12). This is another area in which *Echinarachnius* was much more prevalent in 1974, and *Unciola* in later sampling. One ridge stenotope, *Lumbrinerides*, was slightly more abundant in 1974 while another, *Goniadella*, was more common in 1975-76. Densities of *Ampelisca vadorum* in 1974 were almost identical to those in three of four VIMS cruises. The 1974 dominant, *Paraphoxus epistomus*, was also dominant during three of four seasons in 1975-76. Another four VIMS dominants were found in our sample, in slightly lower numbers.

To recapitulate, the fauna of our BCT subareas appear to show a moderate stability between spring 1974 and summer 1976. Qualitative similarity between NMFS and VIMS collections, in terms of dominant species found, was quite good at a minimum of three of the five station pairs. Some species were clearly more abundant over wide areas in 1974 (e.g., Echinarachnius and Astyris), while others had greater densities in 1975-76 (including Unciola, Byblis and Erichthonius). Conversely, populations of several species characteristic of distinct habitats, such as Ampelisca agassizi (swales) and Lumbrinerides and Goniadella (ridges) were more stable temporally.

Boesch et al. (1977) also noted large fluctuations in densities of some species, and much greater stability for others. Overall, the macrofauna of the VIMS seasonal collections showed "persistent integrity...at a given station, if adequately relocated, collections from one season to another are very similar... If this persistence is shown to continue over longer periods of time, confidence in projections from 'baseline' conditions would improve...The feasibility of detection of impacts of oil and gas development on the macrobenthos should be relatively good". It is safe to say that inclusion of the May 1974 data strengthens these statements. In several cases similarity was greater between NMFS samples and some VIMS seasonal collections than within the VIMS collections alone, so the "persistent integrity" of the fauna and feasibility of impact detection may be even greater than those reported by Boesch et al. (1977).

Given the problems noted above in comparing data from the two studies (different station locations, sieve sizes and taxonomists), the comparisons do indicate that stability of the BCT benthos appears adequate for monitoring and predictive purposes. Populations of ridge and swale dominants appear especially promising in this regard.

4.4.6 Submersible and Miscellaneous Observations

Submersible observations were made in subarea A during the summers of 1975 and 1976. The two-man submersible, Nekton Gamma, was made available from General Oceanographics of Irvine, California through contract with NOAA's Manned Undersea Science and Technology Office.

Three dives were made across the face of Tiger Scarp, near stations 57 and 64. Observers on these dives recorded coarser sediments and lower epifaunal diversity and abundance on the terrace on top of the scarp than on its face or at the bottom. Sediments at the bottom, which was fairly level, were covered with a thin layer of fine silty material which was easily resuspended when disturbed by the submersible.

Five dives were made in other portions of subarea A, near stations 1 and 2, 6, 12 and 13, 32 and 51. These dives generally revealed a small-scale topography (ripple marks) on a relatively flat bottom. The ripple marks, approximately 10 cm high and 1-1.5 m from crest to crest, were very common. The troughs between the crests contained greater amounts of shell hash and fine particulate matter. Large clusters of tubes (possibly Ampeliscidae) were seen in patches, usually along the flanks and in the troughs of the ripple marks. This distribution pattern was also seen for the numerous anthozoans, *Ceriantheopsis americanus*, present. The sand dollar, *Echinarachnius parma*, was the species observed most frequently on these dives. Larger specimens appeared to prefer the crests of the ripple marks, although *E. parma* was observed over the entire bottom.

Pratt (1973) and Boesch et al. (1977) also note presence of these ripple marks over portions of the continental shelf. Our submersible observations on faunal distributions relative to the ripple marks indicate that this small-scale bottom relief may be an important determinant of faunal variability within a larger habitat such as a ridge or swale.

Two species which were rarely represented in our grab samples, yet were seen regularly during the dives throughout subarea A, were a small, greyish, ca. 3 cm. opisthobranch (probably *Pleurobranchaea* or *Dendronotus*), and a pinkish shrimp (probably *Dichelopandalus leptocerus*). Also observed were numerous small mounds with small holes in the centers, created by unidentified infaunal species.

One other organism not included in our species list but possibly important in BCT benthic assemblages is the foraminiferan, *Astrorhiza limnicola*. *Astrorhiza* appeared to be a dominant species, in terms of biomass, in several of our samples.

4.4.7. SUMMARY

1. Our collections contained 284 species; almost half of these were polychaetes, followed by crustaceans and molluscs.
2. Our 93 stations were clustered by their species compositions into 9 groups which were for the most part clearly related to the topography and bathymetry of the two subareas.
3. We clustered species into 14 groups, several of which were weakly related to distinct habitats such as ridge and swale. Most relationships were obscure; a number of species was abundant in all habitats. This may be explained by the relatively narrow range of sediment types in the study areas, and/or wide sediment tolerances by many species.
4. Submersible observations revealed some species and small-scale topographical relief (ripple marks) not noted in our remote sampling, but perhaps important to the ecology of the BCT benthos.
5. Comparisons of dominant species in 1974 and 1975-76 collections at proximate stations (Section 4.4.5.) indicate that temporal stability of the fauna is adequate for purposes of impact prediction and monitoring.

Section 5. BENTHIC RESOURCE SPECIES OF THE BCT AREA

Demersal finfish of the outer shelf will be covered in a later NMFS report, and so are not discussed here. This section includes data on seven commercially valuable shellfish species which will not be included in the finfish report. Adults of these species were not sampled quantitatively in our benthic survey; however, we have compiled recent NMFS data on distribution and abundance, and NMFS plus published information on contaminant levels, in these species, to provide "baseline" information for the BCT and surrounding areas.

5.1 DISTRIBUTION AND ABUNDANCE

We will concentrate on two species abundant in our BCT subareas - the sea scallop, *Placopecten magellanicus*, and ocean quahog, *Arctica islandica*. Populations of the surf clam, *Spisula solidissima*, and red crab, *Geryon quinquidens*, are centered inshore and offshore of the BCT, respectively. Northern lobsters, *Homarus americanus*, and rock and Jonah crabs, *Cancer* spp., do occur in and migrate across the BCT. Approximate distributions and abundances for the sea scallop, ocean quahog and surf clam are presented below as density contours; more detailed data are available from NMFS.

Ocean quahog: Distribution and abundance for January - March 1977 are shown in Figure 12. Data are based on collections made throughout the MAB, between the 30 and 270 foot (9.1 and

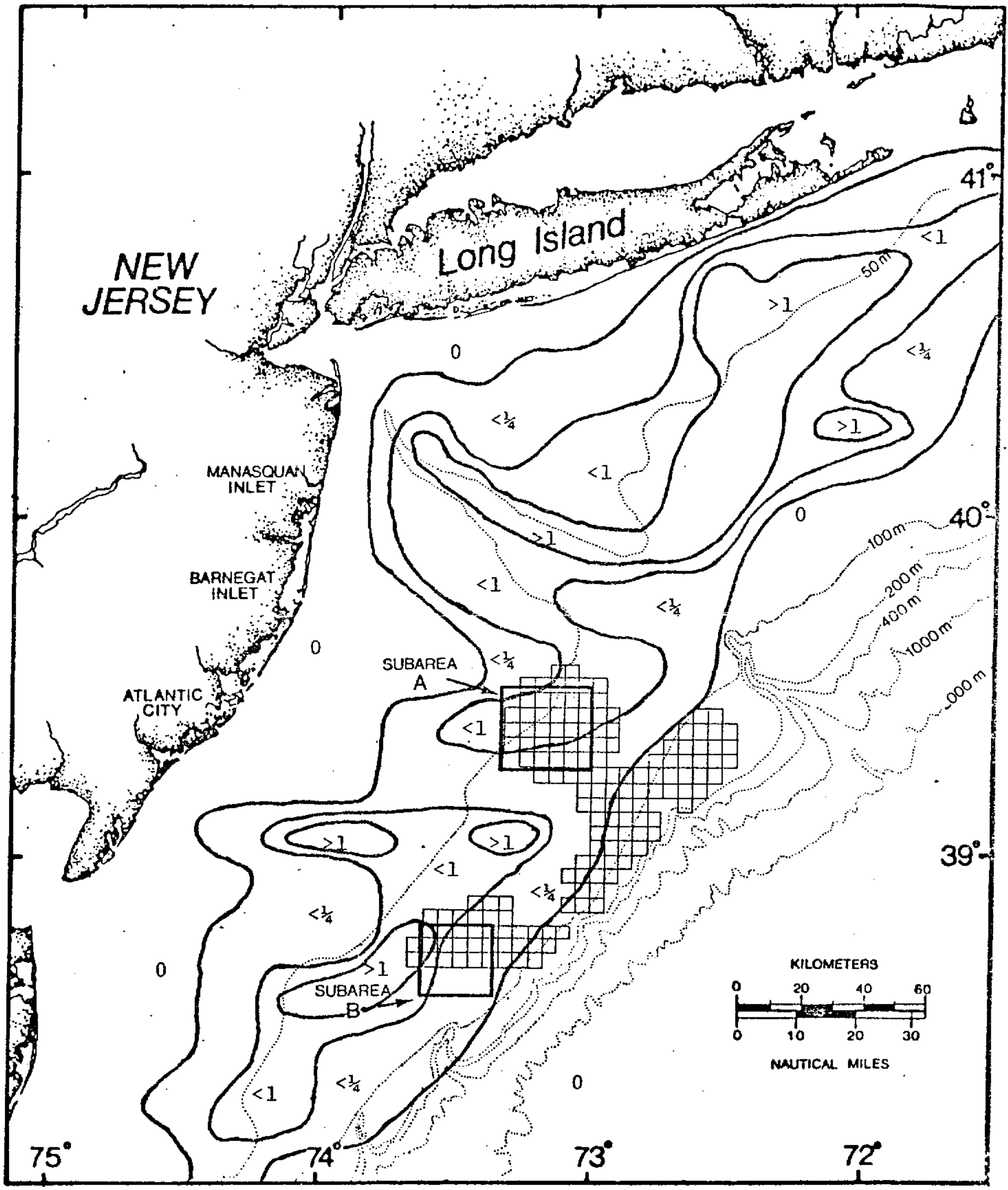

Figure 12. Distribution and abundance of ocean quahogs in the northern MAB, January-March 1977. Contours at 0, ¼, and 1 bushel/4-min. tow.

82.3 m) depth contours, using four-minute tows of a hydraulic clam dredge with 48-inch knife (NMFS, 1977). Tows were made every 10 miles on east-west transects which were 10 miles apart.

Peak abundances of ocean quahogs off New Jersey were found in depths of 37-55 m. Densities of $\geq$1 bushel/tow were found at 11.4% of all New Jersey stations.

Sea scallop: Distribution and abundance (Figure 13) are taken from an August 1975 survey (MacKenzie, Merrill and Serchuk, in press). Scallops were sampled with 15 minute, 3.5 knot tows of a standard 10-foot (3.1 m) sea scallop dredge. Ninety-nine stations in the MAB were sampled, located on eight inshore-offshore transects between Long Island and Cape Hatteras, in depths of 26-148 m. Scallops were taken from sand and gravel bottoms at 57 of the 99 MAB stations. As Figure 13 shows, highest densities of scallops in the MAB were found in waters east of New Jersey, including some areas covered by BCT lease tracts.

Surf clam: This species was also sampled on the January-March 1977 survey, using the methodology described for *Arctica* (NMFS, 1977). Off New Jersey, surf clams were most abundant at depths of 18-37 m (Figure 14). (Merrill and Ropes (1969) report the surf clam's depth range to be from the low tide mark to approximately 43 m). Stocks were low in this traditionally fished area; catches of >¼ bushel were made at only 1% of the New Jersey stations, compared to 11% of stations in a 1976 survey. Surf clams exper-

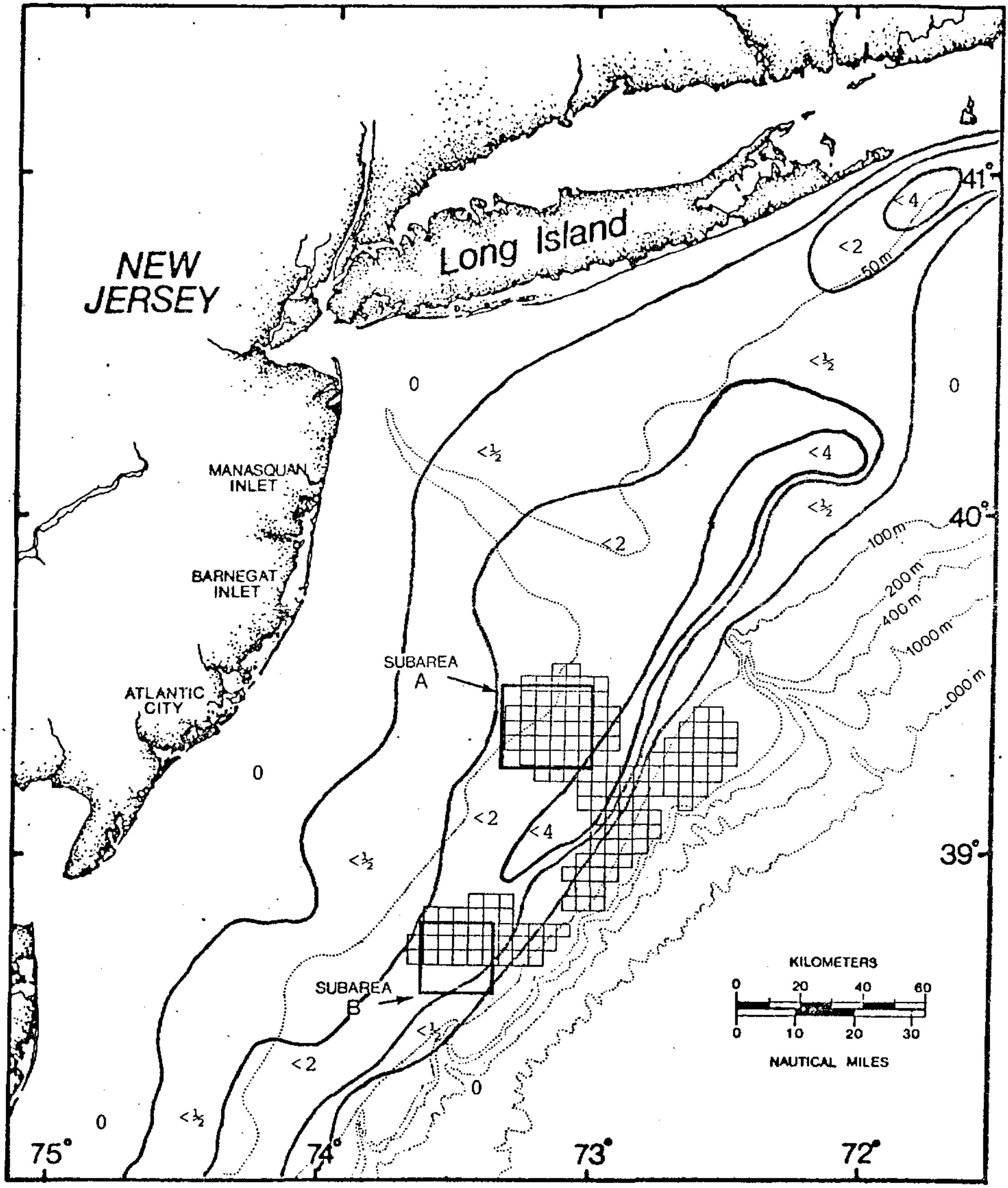

Figure 13. Distribution and abundance of sea scallops in the northern MAB, August 1975. Contours at 0, ½, and 2 bushels/15-min. tow.

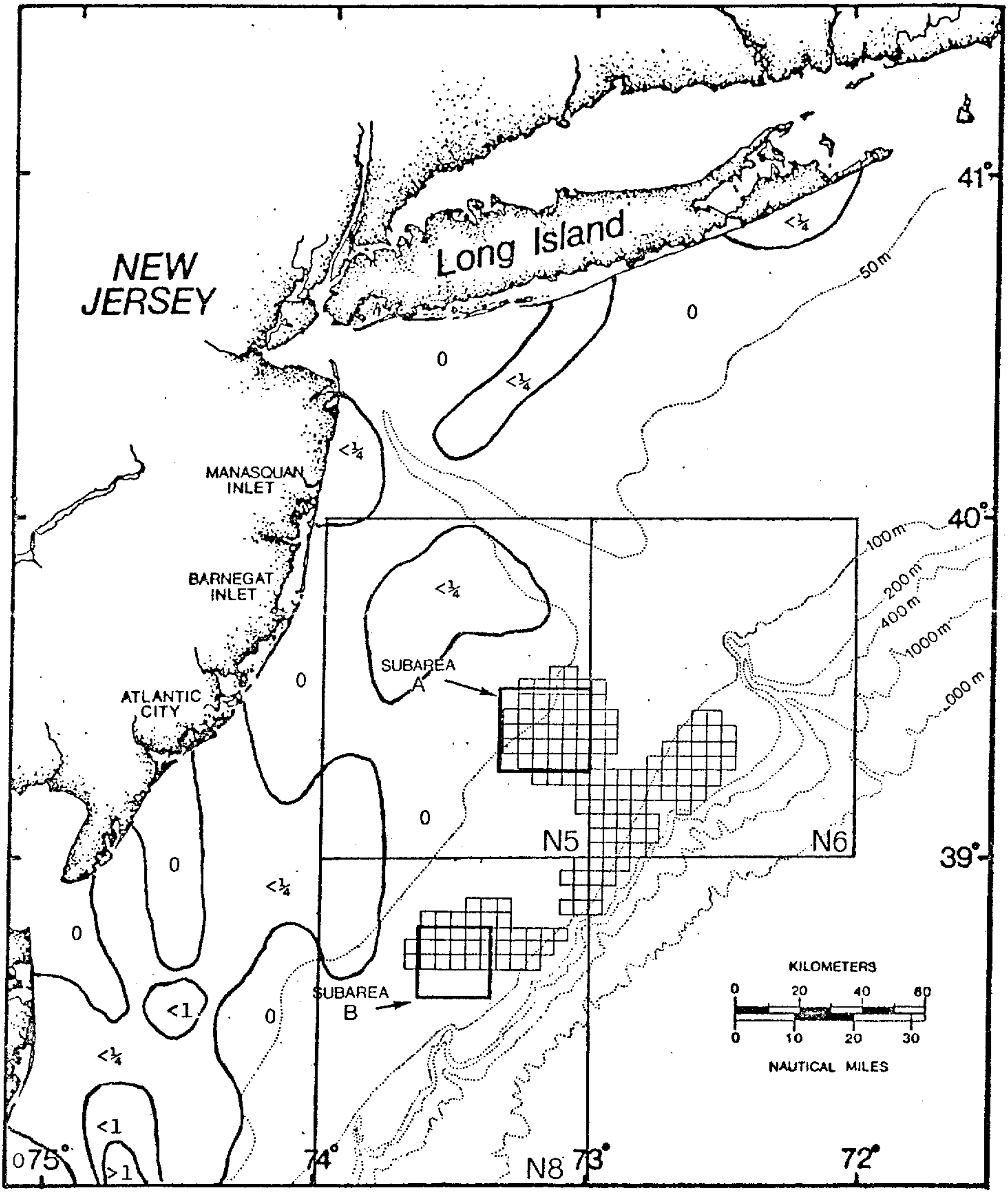

Figure 14. Distribution and abundance of surf clams in the northern MAB, January-March 1977. Contours at 0, ¼, and 1 bushel/4-min. tow. Blocks N5, N6 and N8 refer to Table 13.

ienced significant mortalities due to the 1976 hypoxia off New Jersey, as did ocean quahogs.

Northern lobster: The lobster has distinct populations in inshore and offshore waters. The latter stocks are found in commercial concentrations from the outer shelf to 700 m depths on the continental slope, and undergo extensive inshore-offshore migrations (Cooper and Uzmann, 1971). Hennemuth (1976) indicates that highest densities of lobsters off New Jersey are found just beyond the 100 m bathymetry, with sizeable populations also present further inshore.

Lobster landings for the state of New Jersey, which include both inshore and offshore stocks, are given by Halgren (1977). From 1972 through 1974, overall landings were fairly uniform with an average of 584,121 kg/yr. This is broken down into annual means of 191,617 kg captured in inshore (within 12 miles) lobster pots, 174,092 kg for offshore pots, and 218,412 kg taken by otter trawls. New Jersey landings declined to 383,992 kg in 1975. A further decline in 1976 was attributed in part to the hypoxia problem.

Red crab: This is a deepwater species; in a 1974 NMFS survey, red crabs were found on the continental slope at depths of 274-1463 m (Wigley, Theroux and Murray, 1975). None of the nominated BCT tracts overlap these depths, but several tracts appear to lie within 10 km of the upper depth limit. Off New Jersey, an average of 14 crabs (6.9 kg) per 30 minute otter trawl tow was reported for depths of less than 175 fm (320 m), and 96 crabs (26.2 kg) per tow in 175-225 fm (320-412 m). Photographs taken on the same survey revealed an estimated 60.3 lb./acre (11.1 kg/hectare) of crabs in the ≤320 m zone, and 74.5 kg/ha at 320-412 m. Red crab stocks off New Jersey were somewhat smaller than those of southern New England waters.

Cancer crabs: We have no detailed information on distribution and abundance of these species in the MAB. Williams and Wigley (1977) figure both species as occurring in the BCT area, with populations of *Cancer borealis* extending out to 100 m, and *C. irroratus* found slightly inshore of this.

5.2. CONTAMINANT LEVELS IN RESOURCE SPECIES

NMFS (1978) has recently completed a Microconstituents Resource Survey, begun in 1971, of concentrations of 15 metals in over 200 species of marine fish and shellfish. Samples were collected from all United States waters, and were analyzed using atomic absorption spectroscopy. Summarized results (in ppm, wet wt.) are available for each 1° latitude by 1° longitude block in the MAB. All but a very small portion of the BCT lease tract area is included within three blocks (N5, N6 and N8 in Figure 14). Data on metals in five benthic resource species for these three blocks are presented in Table 13.

Table 13. Means ($\bar{x}$), standard deviations (s) and sample sizes (n) for concentrations of nine heavy metals in five benthic resource species in and near the BCT lease tract areas. All values are in ppm wet weight. Areas covered are:

N5: 39-40°N, 73-74°W; N6: 39-40°N, 72-73°E; N8: 38-39°N, 73-74°W. Block locations are shown in Figure 14. (from NMFS, 1978)

		Sea Scallop			Surf Clam	Ocean Quahog	Rock Crab	Northern Lobster		
		N5	N6	N8	N5	N5	N6	N5	N6	N8
Hg	n	4	2	4	14	33	2	89	18	10
	$\bar{x}$	0.114	0.098	0.131	0.070	0.072	0.155	0.563	0.355	0.551
	s	0.025	0.004	0.028	0.008	0.014	0.021	0.352	0.259	0.377
Pb	n	4	2	4	14	33	2			
	$\bar{x}$	1.425	2.150	1.221	0.709	1.075	1.205			
	s	0.651	0.141	0.553	0.028	0.025	0.205			
As	n				14	33	1			
	$\bar{x}$				2.596	2.957	17.525			
	s				0.429	0.615				
Cr	n	4	2	4	14	33	2			
	$\bar{x}$	0.416	0.425	0.424	0.658	0.945	0.841			
	s	0.038	0.035	0.032	0.136	0.288	0.751			
Ag	n	4	2	4	14	33	2			
	$\bar{x}$	0.118	0.128	0.123	0.228	1.342	0.381			
	s	0.037	0.025	0.036	0.550	0.654	0.112			
Cu	n	4	2	4	14	33	2			
	$\bar{x}$	0.398	0.468	0.589	2.749	4.345	19.915			
	s	0.042	0.166	0.282	1.224	1.407	9.595			
Zn	n	4	2	4	11	33	1			
	$\bar{x}$	3.54	4.58	3.35	17.36	11.52	51.56			
	s	1.28	1.66	0.50	3.87	3.11				
Cd	n	4	2	4	14	33	2			
	$\bar{x}$	0.101	0.103	0.108	0.130	0.40	0.335			
	s	0.011	0.011	0.009	0.136	0.102	0.304			
Se	n									
	$\bar{x}$						2.120	1.444		
	s							0.354		

More detailed data are available for metals in surf clams and ocean quahogs, based on atomic absorption analysis of specimens collected in a 1974 MAB survey (Wenzloff et al., in prep.). Results of this survey indicated that concentrations of metals were generally higher in quahogs than in surf clams, and that levels in both species increased moving northward from Cape Hatteras to the New York Bight. Table 14 shows average wet weight values of nine metals in surf clams and quahogs, for each of three 30' latitude zones which together include all BCT lease tract areas. Concentrations found to the south of our study area are also included in Table 14, to serve as "background" levels.

Pesch, Reynolds and Rogerson (1977) measured concentrations of 13 metals in sea scallops taken in and near two dumpsites located 65-74 km SE of Delaware Bay. Low or background concentrations for metals most likely to be introduced by oil-related activities (see Section 6.2.4) appear to be approximately 1-3 ppm <u>dry</u> weight for Ni and Cr, and 11-20 ppm for V. Highest levels found were: Ni, 14.7 ppm; Cr, 6.9; V, 45.7.

The VIMS benchmark program has included analysis of metals in sea scallops, red, rock and Jonah crabs, as well as in a number of other species important in MAB benthic communities (Harris et al., 1977). The VIMS study also reports values on a dry weight basis, but some comparisons with NMFS data will be possible when

Table 14. Summaries of heavy metal concentrations found in surf clams (_Spisula solidissima_) and ocean quahogs (_Arctica islandica_) by latitude. At each station a single analysis was run on 4-6 homogenized clams, using atomic absorption spectroscopy (from Wenzloff et al., in prep.).

	Surf Clam	Metal Concentrations (ppm, wet weight)								
Range of Latitude	n[1]	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
40°00' - 39°30'	11	1.18	2.39	0.13	0.70	2.96	<0.08	0.39	<0.7	18.3
39°30' - 39°00'	11	1.05	2.17	0.15	0.69	3.45	<0.08	0.08	<0.7	14.8
39°00' - 38°30'	13	0.94	1.91	<0.13	0.65	3.38	<0.08	0.60	<0.7	11.3
36°30' - 36°00'	3	0.19	1.46	<0.14	<0.48	2.88	<0.05	----	<0.7	9.6
	Ocean Quahog									
40°00' - 39°30'	9	1.55	3.09	0.43	<0.70	4.94	<0.06	<0.50	<1.2	13.2
39°30' - 39°00'	9	1.27	2.56	0.39	<0.80	4.18	<0.07	<0.50	<0.9	13.1
39°00' - 38°30'	5	1.21	2.34	0.42	<1.0	5.10	<0.08	<0.55	<1.2	13.2
38°30' - 36°30'	6	0.58	2.41	0.39	<1.1	2.84	<0.06	<0.59	<0.9	10.4

[1] Number of stations within the indicated range.

final VIMS results become available, since Harris et al. (1977) present wet:dry weight ratios for many species.

Data on hydrocarbon concentrations in MAB biota are scarcer. VIMS has analyzed hydrocarbons in sea scallops, ocean quahogs, rock and Jonah crabs, and several other benthic species (MacIntyre, 1977). NMFS is presently measuring hydrocarbons in surf clams, blue mussels, lobsters, rock crabs, sand shrimp and polychaetes (as well as plankton and several fish species) from the New York Bight. We found no other information on hydrocarbon levels in resource species of the outer shelf. Boehm and Quinn (1977) have measured hydrocarbons in ocean quahogs from a dredge spoil disposal site and control areas in Rhode Island Sound. Total hydrocarbons in the quahogs ranged from 2.6-6.5 ppm wet weight. Interestingly, these values did not reflect sediment concentrations, which varied by more than two orders of magnitude - sediments in control areas had 1-56 ppm hydrocarbons, while the highest value measured in disposal site sediments was 301 ppm.

Section 6. THE BENTHOS AND OIL-RELATED ACTIVITIES

6.1 INTRODUCTION

The following discussion attempts to summarize available data relating the benthos of the MAB's outer shelf to possible impacts of oil exploration and development. Impacts are arbitrarily divided into 5 categories: 1) physical presence of rigs, platforms, and pipelines; 2) physical effects of drilling muds and cuttings, plus pipeline jetting; 3) impacts of oil; 4) effects of other contaminants introduced by oil exploration and production; and 5) cumulative effects involving all the above plus stresses such as those associated with offshore generating stations, deepwater ports, sand and gravel mining, ocean dumping, atmospheric and estuarine inputs, and anoxia events. We will not attempt an exhaustive review of laboratory and field information on these impacts. A number of reviews exist on these subjects; we will direct the interested reader to further information in the pertinent sections.

In assessing possible impacts, we have uncritically accepted estimates from the Department of Interior's (1976) final environmental statement for maximum volumes of the various materials to be discharged, areas covered, and the timeframes involved.

Conclusions are presented, based on our data and available literature, and recommendations made for future studies and management strategies.

6.2 POSSIBLE OIL-RELATED IMPACTS

6.2.1. Physical Presence of Rigs, Platforms, and Pipelines

Impacts of these structures will center on a reduction in potential area for commercial fishing. We will consider only possible effects on resource shellfishing - finfish of the area will be the subject of a later NMFS report. As noted in the previous chapter, resource shellfish abundant in the study area are the ocean quahog and the sea scallop. Lobsters, rock and Jonah crabs are also present. Commercial populations of the surf clam are inshore of the BCT tracts but could be affected by pipeline corridors (see Figure 14).

The Department of Interior (1976) has estimated that the maximum area which would be closed to commercial trawling at any one time due to presence of drilling rigs and production platforms in the BCT would be 3240 acres (1311 hectares), which is about 0.9% of the size of our subarea A. A slightly greater acreage would actually be affected, since ship's turning radii in keeping well away from the structures must be considered (Dept. of Interior, 1976).

Closure of areas around pipelines would increase the acreage of quahog and shellfish beds lost to fishing, and would also impinge on surf clam beds. Rauck (1977) discussed the possibility of barring trawling from within 500 m of the Ekofisk pipelines; this would result in the loss of 115 n mi^2 (39,316 ha) of the

German, Danish and Norwegian continental shelves. In the MAB, assuming closure of a 1000 m wide swath around a maximum 917 km of pipeline (figure from Dept. of Interior, 1976), 91,427 ha would be lost to shellfishing. This represents 70 times the area lost around platforms. However, the present intention is to bury these pipelines, and the final environmental statement does not consider closing areas around them.

Allen et al. (1977) predicted that presence of production platforms on Georges Bank [perhaps 30, compared to an estimated 10-50 for the MAB] would cause ∿0.06% loss in total fish catch if pipelines between platforms were buried, and about 0.2% if unburied. These losses were considered insignificant to the industry as a whole. The same statement probably applies to closure of areas due to physical structures in the MAB.

Presence of platforms could have beneficial effects on resource shellfish as well. The closing of areas near them could protect some spawning stocks (Pequegnat, 1974), if populations around platforms aren't otherwise impacted (by cuttings, spills, etc). The platforms also serve as attachment sites for epifauna, but effects of structures on benthos <u>per se</u> may be less beneficial; compaction of the bottom, litter, and/or contaminant buildup under platforms may exclude infauna (and finfish which feed on them) from these areas (Pequegnat, 1974). Buildup of contaminants in platform epifauna and in their predators was not found to be a major problem off California (Mearns and Moore, 1976).

Platforms are important sportfishing sites in the Gulf of Mexico, but are not expected to significantly increase sportfishing in the MAB due to their distance from shore (Keimpf, 1977). Overall effects of physical structures in this area should thus be negligible.

6.2.2. Effects of Physical Disturbances (Pipeline Jetting, Drilling Muds and Cuttings)

Physical impacts of these activities can include burial, rendering substrate unsuitable for habitation or larval settlement, and clogging of feeding and respiratory structures. These problems have been reviewed by several authors (Harrison, 1967; Morton, 1977; Pratt et al., 1973a; Saila et al., 1968; Sherk, 1971; Slotta et al., 1974).

There is some indication that actual burial will pose little threat, at least to the shellfish resources of the outer shelf. The ocean quahog can avoid burial by burrowing upward through as much as 15 cm of medium or fine sand and 4 cm of finer sediments (Pratt et al., 1973a). This species can also form "blowholes" to the surface when covered by up to 17 cm of silt/clay, although it was considered doubtful that the clams could long survive in such a state. Younger individuals were more active than adults and had greater success in reaching the surface in fine sediments.

Sea scallops, lobsters and crabs may be sufficiently mobile to avoid burial by muds and cuttings. Many of the smaller infauna would undoubtedly be eliminated from areas with extensive accumulation of these materials, although Saila et al., (1972) found that three small estuarine species could reach the surface after burial by 6-24 cm of dredge spoils.

Substrate alteration may pose a greater threat than actual burial, but effects should still be largely confined to areas near rigs and pipelines. Drilling muds have the greatest potential for altering substrates. Effects of these muds will vary with the species and original substrates involved. While some sand-adapted species are expected to be intolerant of drilling muds, others apparently can adapt easily. Saila et al., (1972) reported that fine sediments dumped in Rhode Island Sound were recolonized by members of surrounding sand-bottom assemblages, including the amphipod, *Ampelisca agassizi*, dominant in many BCT areas. This indicated that "colonization was independent of quality of underlying sediment where the hydrographic regime was suitable". At this dumpsite, many samples from sediments which had been in place from one to three years had as many benthic species as did the surrounding natural sediment (Pratt et al., 1973b). Reid and Frame (1977) found fairly complete recolonization of a large non-toxic spoil pile in Long Island Sound within two years. Smaller piles, such as those represented by the drilling muds, may be recolonized more quickly. McCauley, Parr and Hancock (1977) report recovery of infauna in two weeks following a small (8,000 yd^3) spoil disposal operation.

Impacts of suspended sediments will be somewhat more widespread, especially where filter-feeding organisms are involved. Sherk (1971) noted that suspended sediments could affect respiration, rate of water transport, efficiency of filtering mechanisms, and energy needed for maintenance in filter feeders. High concentrations of suspended materials caused gill clogging and abrasion; impaired respiration, feeding and excretion; and reduced larval growth and survival. Chronic exposure lowered productivity of benthic populations. Short-term exposure is less of a problem; Saila et al., (1972) felt that most marine animals could withstand exposure to high concentrations of suspended solids for short periods. Of course, while initial dumping of muds and cuttings might only cause short-term turbidity, subsequent erosion and bioturbation could make the condition chronic.

In the MAB, a gradient of impact of suspended sediments should exist, depending on current regimes and the nature of the suspended materials. Effects of jetting sand in burying pipeline, for instance, should be spatially and temporally small, because the sand will rapidly be redeposited. Also, the benthic fauna of sandy shelf areas, adapted to dynamic sediments, should be tolerant of these stresses. Worst case effects will involve introduction or disturbance of finer sediments in deep waters of the outer shelf. Here suspended materials may persist longer in an area, due to the less dynamic current regimes, and the fauna may be less adapted to suspended sediments. On sandy areas of the shelf, effects will be greatest in swales and other depressions; possible contaminant buildup and oxygen depletion in these areas are discussed below. A similar situation holds for pipeline jetting and placement. Most effects on the benthos will occur in a narrow band around the pipelines.

Results of the impending survey monitoring an exploratory drilling operation will be a great aid in understanding impacts of these physical disturbances in the MAB. As with presence of physical structures, we expect only relatively minor impacts from physical disturbances, most of which will occur only in the exploratory and early production phases.

6.2.3. Exposure to Oil

A number of reviews concerning effects of oil on marine biota are available (e.g., Anderson et al., 1974; Anderson, 1975; Boesch, Hershner and Milgram, 1974, Evans and Rice, 1974; Hyland and Schneider, 1976; Jeffries and Johnson, 1975; Moore et al., 1974; National Academy of Sciences, 1975). We will consider only the portions of these reviews which pertain to the offshore benthos. Emphasis will be on effects of crude oils, the principal threat from the proposed development in our study area. We follow the example of Hyland and Schneider (1976) in separating effects measured at the organism level (largely through laboratory studies) from those at population and higher levels (often determined from post-spill studies).

6.2.3. Organism level

Hyland and Schneider (1976) have summarized laboratory data on concentrations of oil components directly lethal to various taxa and life stages. Significantly, crude oils are among the least toxic of petroleum substances commonly tested. For instance, lethal concentrations of crude oil were generally in the neighborhood of 100 times those of kerosene, 200 times lethal doses of No. 2 fuel oil, and a thousand times estimated concentrations of soluble aromatics (the most toxic component of oil) required to cause laboratory mortalities. Thus major impacts of crudes should be limited to areas where they exist in relatively high concentrations.

There are of course differences in toxicity among crude oils. Renzoni (1975) reported Nigerian crude to be more toxic than Prudhoe Bay or Kuwait crude to sperm and eggs of two bivalves, *Crassostrea virginica* and *Mulinia lateralis*. Byrne and Calder (1977), using larvae of the quahog clam, *Mercenaria* sp., found LC_{50} values of 13.1, 5.3 and 0.11 ppm for 6-day exposures to water-soluble fractions of Kuwait, Southern Louisiana and Florida Bay crude oils, respectively.

Toxicity of oils to invertebrates also varies from taxon to taxon. Hyland and Schneider (1976) list the following lethal levels (in ppm) of crude oil for taxa common in our collecting: gastropods, 10^4 -10^5; bivalves, 10^4 -10^5; benthic crustaceans, 10^3 -10^4; and "other benthic organisms", including polychaetes, 10^3 -10^4. We could find no information for several other groups which are abundant in the BCT, such as echinoderms and sipunculids.

Jeffries and Johnson (1975) consider molluscs to be particularly susceptible to oil impacts, due to their atypical mode of processing food. Molluscan amebocytes can apparently remove hydrocarbons from feeding currents; the amebocytes then may plug the renal sac. In the quahog, *Mercenaria mercenaria*, chronically exposed to hydrocarbons, this clogging can lead to death.

Amphipod crustaceans are another group with high sensitivity to oil. Lee, Welch and Nicol (1977) report aqueous extracts of oils to be more toxic to two amphipod species than to shrimp or polychaetes. Extracts of No. 2 fuel oil were toxic to the amphipods at lower concentrations than were crude oil extracts (0.8 vs 2.4 ppm). Among the amphipods, members of the family Ampeliscidae have been shown to be especially sensitive to hydrocarbons, and thus good indicators of oil contamination (Sanders, Grassle and Hampson, 1972). This is very pertinent here, since ampeliscids are important in the BCT's benthic communities. They are also common in diets of demersal finfish of the area (Musick and Sedberry, 1977).

As a rule, oils are lethal to eggs, larvae and juveniles at lower concentrations than to adults. Hyland and Schneider (1976) list 10^2-10^3 ppm as the concentrations of crude oil lethal to larvae of various groups. Byrne and Calder (1977), however, note that while in many species the youngest stages are most sensitive, for some organisms early stages appear as resistent as adults.

Sublethal effects of oil are often seen at concentrations far lower than those which are directly toxic. A sampling of data on benthic invertebrate species, from the review of Hyland and Schneider (1976) with some recent addition, is given in Table 15. Note that sublethal responses to crude oil, for in-

Table 15. Sublethal effects of various petroleum products on selected species (modified from Hyland and Schneider, 1976).

Species	Type of oil	Concentration	Effect
Eggs and larvae:			
Homarus americanus (lobster)	Venezuelan crude	6 ppm	delayed molt
Strongylocentrotus purpuratus (urchin)	Bunker C extracts	0.1-1 ppm	Interference with egg development
Melitta quinquiesperforata (sand dollar)[1]	Kuwait crude, No. 2 fuel oil (water-soluble fractions)	0.6 ppm	Fuel oil depressed respiration, larval development. Crude much less toxic
Balanus (barnacle)	"oil"	10-100 ppm	Abnormal development
Pachygrapsus marmoratus (crab)	"oil"	10-100 ppm	Initial increase in respiration
Adults:			
H. americanus	Crude, kerosene	10 ppm	Influenced chemoreception, feeding times, stress behavior, aggression, grooming
H. americanus	Crude	10 ppm	Delayed feeding
Pollicipes polymerus (barnacle)	Crude	Field study after blowout	Apparent decreased adult brooding; no recruitment in oiled areas
Gammarus oceanus, *Onisimus affinis* (amphipods), *Mesidotea entomon* (isopod)	3 crudes	oil-tainted food	Avoidance by amphipods, not isopod
Uca pugnax (crab)	No. 2 fuel oil	Field observations (W. Falmouth)	Adverse effects on sexual behavior; mortalities in heavily oiled areas

Table 15. (continued)

Species	Type of Oil	Concentration	Effect
Pachygrapsus crassipes (crab)	Naphthalene	1 ppb	Inhibition of feeding
P. crassipes	Crude	Extracts	Inhibition of feeding and of response to sex pheromone
Nassarius obsoletus (snail)	Kerosene	1-4 ppb	Reduced chemotectic perception of food
Mytilus edulis, *Modiolus demissus* (mussels)	Crude	1 ppm	Increased respiration, decreased feeding and assimilation
M. edulis	No. 2 fuel oil (water-soluble fraction)	10 ppb-1 ppm	Decreased filtering and byssal thread attachment
M. edulis	No. 2 fuel oil	collected after spill	Inhibited gonad development
Mya arenaria (soft shell clam)[2]	No. 6 fuel oil	spill site	Carbon gains half those of unoiled population
Crassostrea virginica (oyster)	Naphthalene	1 ppm	Gill cilia irritation
C. virginica, *Aequipectin irradians* (scallop)	waste motor oil	>20 ppm	Lesions in branchial vein and gastrointestine of oyster; in mantle, gill and kidney of oyster

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[1] From Nicol et al., 1977.

[2] From Gilfillian et al., 1976.

stance, are often in the 1-10 ppm range, compared to the 10^3-10^5 ppm discussed above for direct toxic effects. Chemosensory functions appear most sensitive, with inhibition of feeding and of reactions to pheromones reported at as low as 1 ppb.

6.2.3.2. Population, community and ecosystem levels:

Much of the information on subtidal benthic community responses has been obtained by observing effects of large oil spills. Documented effects have ranged from undetectable to widespread and long-lasting, depending on such factors as type of oil spilled, water depths, temperature, prevailing winds and currents, and types of sediments affected. The *Argo Merchant* spill off Nantucket, Mass., occurred in an area of turbulent waters and coarse, dynamic sediments. Two months after the spill, slight oil contamination was measured at stations within 5 km of the spill; five months after this, only sediments under the *Argo*'s bow were still contaminated (Hoffman and Quinn, 1978). The spill caused no detectable decrease in density or diversity of the area's interstital fauna (Pratt, 1978). Sublethal effects on the benthos were detected (depressed gill tissue respiration in the scallop, *Placopecten*, and mussel, *Modiolus*, from oiled areas), but these effects disappeared within two months (Thurberg and Gould, 1978).

Effects reported to date of the Ekofisk blowout have also been small (Anon., 1977). Obviously, in these instances it may require several years of careful monitoring over a wide area to conclusively state that effects were minimal.

At the other extreme, several spills have had severe, long-term effects on benthos. Perhaps best studied of these is the spill of No. 2 fuel oil at West Falmouth, Mass., in 1969. Much of the spilled oil reached the fine sediments of sheltered marshes and subtidal areas where it penetrated to depths as great as 58 cm (Blumer et al., 1970). There the stability and anoxic condition of the sediments delayed the oil's weathering. Almost all benthic macrofauna were eliminated from heavily oiled areas, and sensitive species were affected in peripheral locations (Sanders, Grassle and Hampson, 1972). Early recolonization was by opportunists such as the polychaete *Capitella capitata* rather than by prespill community dominants. Toxic effects, tainted clams and incomplete recovery were still evident eight years later (Sanders, 1977).

The *Torrey Canyon* spill off Cornwall, England, in 1967, also had long-lasting effects, although in this case impacts are best documented for the intertidal biota, and these impacts are partly due to the use of a toxic detergent (Smith, 1968). Some rocky areas were denuded of biota. As at West Falmouth, initial colonization involved an unstable community dominated by a single species, in this case an alga. Stability increased as grazers returned and the community became more complex. Essentially complete recovery required 5 to 10 years (Kerr, 1977).

The Arrow spill of Bunker C fuel oil in Chedabucto Bay, Nova Scotia, in 1970 illustrates the gradients of impacts which can occur under differing conditions. The estimated half-life for self-cleansing of exposed rocky shores after this spill was 1½-2 years (Vandermeulen, 1977). Low-energy shores of lagoons and estuaries would require at least ten times this for removal of half the oil, and the half-life for removal of total sediment-bound oil would be greater than 25 years. Biological recovery followed a similar pattern. In the more quickly cleansed areas, the half-life for recovery of biota was about four years. In the finer sediments of protected areas, the recovery half-life was estimated at greater than 10-20 years. These fine sediments have acted as a large sink, and are slowly releasing oil back into the water. Aromatic portions of the Bunker C are persisting far longer than the less toxic aliphatic components. Populations of the soft-shell clam, *Mya arenaria*, have shown a continuous decline since 1970 in the areas where oil has persisted. A recovery half-life of 10 years has been estimated for *Mya* in the oiled sediments. Clams surviving the chronic contamination have lower growth rates than those from non-oiled areas (Vandermeulen, 1977).

One major conclusion which can be drawn from these spill studies is that impacts are controlled by circumstances surrounding the oil inputs. Weathering processes are effective in dispersing and detoxifying oils spilled in open, high-energy areas. Where inputs are continuous or the oil reaches fine sediments in protected areas, effects are greater and recovery much slower (Kerr, 1977).

6.2.3.3. Predicted effects on BCT benthos:

The benthos is often thought more susceptible to oil impacts than are plankton or nekton, since benthic substrates tend to accumulate oil, and sessile benthic species are unable to avoid the contamination (Hyland and Schneider, 1976). Such characteristics will be mitigated if most oil inputs to the BCT area occur at the surface; in these instances substantial dispersion and weathering will take place before any oil reaches bottom. Hyland and Schneider (1976) note that only 1% of all oil introduced to the marine environment comes from offshore production, and most of this oil is quickly diluted and dispersed. Stewart and Devanney (1978), however, argue that blowouts and pipeline leaks may indeed be a significant source of oil, perhaps more so than tanker spills. Connor and Howarth

(1977) feel that much of any oil spilled during exploration and production on Georges Bank would reach the sediments and accumulate there. They are unconvinced that the [smaller quantities of] oil on Georges Bank can be exploited without serious risk to fisheries and the environment.

Assuming that significant quantities of oil do reach bottom in the BCT, one can attempt to use existing field and laboratory data, and ecological theory, to predict impacts to the benthos. Boesch (1974) describes faunal response to perturbations as being a function of both resistance to environmental change and resiliency, or speed of recovery from changes. Boesch argues that communities in stressful environments may have more resistance and resiliency than those in more stable regimes. Recent findings for the deep sea benthos (Grassle, 1977) indicate that, at least in terms of time required for recovery, communities of the most stable environments are at the low end of the resiliency scale.

We feel that a majority of the continental shelf fauna falls slightly toward the resilient-resistant end of the spectrum, since much of the shelf benthic habitat is subject to the physical stresses of shifting and suspended sediments. The fauna should thus be relatively resilient, although it is less certain whether resistance to introduced contaminants such as oil will be as great as resistance to the physical rigors of the shelf environment. Outer shelf benthic habitats are more stable, so we can expect greater response to oil contamination, and slower recovery. Oil would also be more likely to accumulate and persist in these outer shelf areas, due to their higher proportions of fine sediments and less dynamic currents. Coarse sediments in shallow waters will be least likely to accumulate oil. Boesch, Kraeutner and Serafy (1977) note that the productive swale areas are susceptible due to the fine sediments which accumulate there.

A number of other factors help determine reactions to oil contamination. As noted above, tolerance to oil varies from taxon to taxon; molluscs and some amphipods would probably be affected to a greater extent than most polychaetes, for instance. Type of larva will also be important in determining recovery, in the admittedly improbable event that oil contamination decimates populations over wide areas. Species with large numbers of planktonic larvae will show substantial recolonization much sooner than taxa having benthic or brooded larvae, with their limited powers of dispersal. It is significant that many of the BCT's important benthic species, including four orders of peracarid crustaceans (Cumacea, Tanaidacea, Isopoda and Amphipoda), brood their larvae and thus would only slowly recolonize any large areas from which they had been eliminated. Conversely, the seven resource species discussed above all have pelagic larvae, so their initial recolonization may be more rapid. The ultimate return of populations to pre-spill age distributions, however, would require a longer period of time for slow-growing, long-lived species such as the lobster, red crab and ocean quahog than for most of the small, numerically important species found in our collections.

The recovery process is further complicated if opportunistic species dominate the early recolonization process, as was reported for the West Falmouth and _Torrey Canyon_ incidents. A number of opportunists are found in the MAB. Soon after the 1976 hypoxia incident off New Jersey, areas affected were recolonized by dense populations of the tube-dwelling polychaetes _Asabellides oculata_, _Spiophanes bombyx_ and _Polydora socialis_ (Steimle and Radosh, in prep.). Such dense opportunist populations in oil-impacted areas may delay reestablishment of the original assemblages, but the length of possible delay is difficult to estimate.

We have not yet considered oil effects on the planktonic larvae or food sources of benthic fauna. Recovery from a spill will be slower if both adults and larvae are affected. If impacts are limited to the water column, effects on entire larval populations should be slight, although some portions of populations may be eliminated (Hyland and Schneider, 1976).

Oil in high concentrations can also retard phytoplankton productivity; however, we suspect direct effects on adults and larvae of benthic species will be more important than any reduction in their food source.

Finally, oil contamination could lead to fouling of fishing gear and tainting of the flesh of resource species. Michael (1977) considers tainting the most probable and long-lasting impact of oil contamination. Michael notes than "any fishery where the animals are in direct contact with the sea floor is vulnerable if oil reaches the sediments". Tainting of oysters is one of the few clear impacts of oil production in the Gulf of Mexico (National Academy of Sciences, 1975). Boehm and Quinn (1977b) report that hydrocarbons chronically accumulated by filter feeders are strongly retained and only very slowly depurated; ocean quahogs moved from a hydrocarbon-contaminated to a ocean area had significant depuration only after 120 days. Very slow depuration has also been reported for blue mussels (Fossato and Canzonier, 1976) and soft clams (Vandermeulen, 1977).

We conclude that 1) impacts of the oil itself are potentially much greater than those for other contaminants, drilling muds and cuttings, or laying of pipelines; 2) risks to the outer shelf benthos may be less than for sheltered inshore areas, but some risks are still present; 3) response and recovery of the OCS benthos will depend on habitat and species affected; and 4) if large quantities of oil do reach the bottom in the less turbulent, fine sediment environment of swales or the outer shelf, via a blowout, pipeline leak or chronic precipitation of oil-laden particulates from the water column, acute and long-lasting effects can be expected.

6.2.4. Other Contaminants

A number of contaminants other than oil are likely to be introduced to the MAB through exploration and production activities. Among these contaminants (in estimated order of increasing threat to the benthos) are: high salinities and anoxic conditions related to brines (formation waters) < heavy metals ≈ oil spill dispersants. We ignore impacts associated with sewage materials and equipment-cleaning solvents, which will be treated on the rigs and platforms to meet Environmental Protection Agency standards (Dept. of Interior, 1976).

6.2.4.1. Formation waters:

Formation waters will be introduced in large quantities, with an estimated maximum of 31 million gallons per day during peak production (Dept. of Interior, 1976). Apparently, these waters typically mix and disperse rapidly, so that only localized "plumes" and effects occur. The only conditions under which we can envision formation waters causing significant harm to the benthos would be during months when the water column is highly stratified, with bottom waters low in dissolved oxygen (as during the hypoxia event of 1976, when oxygen levels were <1 ppm over most of our subarea A of the BCT at some time - Steimle, 1977). If the brines were considerably denser than surface waters, they could sink below the thermocline largely intact and contribute to oxygen deficiencies, especially in topographically low areas.

It is difficult to quantify the extent to which formation waters could add to the stresses of a hypoxia situation. Supposing the waters did sink intact, and formed a bottom layer 5 m high, the maximum of 31 million gallons (117 x 10^6 l) /da of formation waters would cover an area of 23, 436 m^2 (or 153 m on a side). In a year, 5.6 km^2 of bottom ($\sim$0.4% of subarea A) could be covered. If the formation waters mixed with existing oxygen-deficient bottom waters, larger areas (though still small relative to the size of the BCT) would be influenced. The high salinities involved, and possibly generation of hydrogen sulfide, could add to the cumulative stress.

6.2.4.2. Heavy metals:

Formation waters may also contain hydrocarbons (whose effects are discussed above) and heavy metals. Metals can also be introduced via pipeline jetting (especially if pipes are laid through dumping grounds) and drilling muds, and are present in the oil itself.

Chromium and barium are the metals most likely to be introduced in significant quantities in drilling muds. We know of no data on effects of barium on marine biota. Effects of chromium have been fairly well documented in laboratory studies. Oshida et al. (1976) showed that toxicity of Cr to the polychaete, *Neanthes arenaceodentata*, was dependent on the form of Cr present. Hexavalent Cr was quite toxic, with 7-day LC_{50} values of 1.4-1.9 ppm. In long-term experiments (three generations, 440 days) reproduction ceased at 0.1 ppm and brood size was reduced at 12.5 ppb. *Neanthes* was much more tolerant of trivalent Cr; 7-day exposures to 12.5 ppm caused less than 5% mortality, and survivors showed no adverse effects in long-term studies.

Reish et al. (1976) reported Cr to be moderately toxic to *Neanthes* and another polychaete, *Capitella capitata*. Toxicity was generally greatest for Hg and Cu, followed by Zn and Cr; with Pb and Cd least toxic. Twenty-eight day LC_{50}s were 0.55 and 0.28 ppm Cr for adult *Neanthes* and *Capitella*, respectively. Cr was unusual in being slightly more toxic to adults than to juveniles. Reish and Carr (1978) found significant suppression of reproduction in the polychaete *Ctenodrilus seratus* at 50 ppb Cr; this was roughly two orders of magnitude lower than the 96 h LC_{50} for Cr.

The two metals most prevalent in oils are nickel and vanadium. In this case, little is known of vanadium's toxicity, while nickel has been well studied. Calabrese et al. (1977) showed effects of Ni on larval oysters and hard clams to be relatively small; the order of toxicity for oyster larvae was Hg>Ag>Cu>Ni, and for clam larvae Hg>Cu>Ag>Zn>Ni. Ni (as well as Cd, Mn, Pb and Zn) was several orders of magnitude less toxic than Cu to ocean quahogs in 168-hour static acute toxicity tests at 10°C (Eisler, 1977). Eisler noted that toxicity was strongly correlated with temperature. In Mya arenaria, he found bioaccumulation of Ni to be less than for Mn, Zn, Cu and Pb.

The four metals discussed above, and most others, have much in common with oils in terms of affinities and gross effects. Most metals, like oils, have a higher affinity for sediments and suspended matter than for water. Concentration and persistence of metals will be greatest in fine sediments. Metals can be directly toxic or have sublethal impacts, and often affect larvae and juveniles to a greater extent than adults. The threat of bioconcentration is present for metals as for hydrocarbons. Life history characteristics (such as generation time and larval type) determining recolonization by biota after oil contamination are also pertinent to recovery from effects of metals. These topics were covered in some detail in the section on oil effects and will not be further discussed here.

Studies to date have not reported large increases in metals due to oil-related activities in the Gulf of Mexico (Shinn, 1974; Monaghan, 1975) or off California (Mearns and Moore, 1976; Ray et al., 1978). We expect this will also be the case for MAB exploration and development.

6.2.4.3. Dispersants and detergents:

Materials used to combat oil slicks can be more toxic than the oil itself. The review by Hyland and Schneider (1976) indicates dispersants to be about as toxic as kerosene, and 100 times as toxic as crude oil, to a wide range of organisms. BP 1002 dispersant inhibited growth in the snail, *Littorina littorea*, at 30 ppm, and larvae of the oyster, *Ostrea edulis*, at 1 ppm; larval polychaetes, *Sabellaria spinulosa*, displayed abnormal irritability at 0.5-1.0 ppm. Another polychaete, *Capitella capitata*, showed decreased survival and fecundity at 0.01-10 ppm of a detergent (Hyland and Schneider, 1976). Reish et al. (1974) cited a study reporting that exposure of *Capitella* to sublethal concentrations of a detergent caused lethal abnormalities in second generation larvae. A review by Reish et al. (1975) indicated that fish and bivalves were more sensitive than crustaceans to all dispersants except oil emulsants.

The toxicity of dispersants has also been borne out by post-spill studies. Dispersants are considered responsible for part of the impact from the Torrey Canyon sinking (Kerr, 1977). Effects of the Arrow spill would probably have been greater had dispersants been used in that incident (Thomas, 1973).

Recently-developed dispersants are less toxic than those formerly in use (Reish et al., 1975). In the past decade, use of dispersants in U. S. waters has been virtually precluded except to prevent fire or loss of life. This sentiment may now be changing, and use of dispersants to combat offshore spills could again become an accepted strategy (Cowell, 1977).

6.2.5. Cumulative Impacts

The final environmental statement (Dept. of Interior, 1976) contains a section dealing with this subject. Effects of 1) additional oil and gas sales, 2) sewage outfall, 3) existing tanker pollution, 4) surface runoff, 5) deepwater ports, 6) offshore nuclear generating stations, 7) ocean dumping, and 8) inshore dredging are covered. Other impacts to consider in the MAB might include atmospheric fallout of contaminants, sand and gravel mining, commercial and recreational fishing, natural fluctuation as in temperature and salinity, and unusual phenomena such as the plankton bloom and subsequent hypoxia of summer of 1976.

The EIS notes that effects of chronic oil exposure alone are poorly understood; predicting impacts of oil combined with other stresses is thus highly speculative. We agree with this evaluation, and can only add two points. 1) It would appear the BCT as a whole has to date not been heavily affected by man's activities (witness the low levels of sediment metals reported above). 2)However, the entire New York Bight ecosystem may be somewhat stressed, as shown by the elevated metals levels in surf clams and ocean quahogs, and the 1976 hypoxia. New threats to this system should be carefully evaluated and monitored.

6.3 CONCLUSIONS

Our major conclusions, based on the present study and a review of pertinent literature, are:

1. Sediments of our subareas A and B of the BCT are predominantly sands, with small but important variations related to bottom topography. Low concentrations of several heavy metals indicate the sediments are relatively uncontaminated.

2. The benthic fauna of the BCT have a mesoscale spatial variability; assemblages are strongly related to sediment type and bottom topography. Swale areas and other depressions appear to support the highest biomasses. These topographic lows, and outer shelf areas with appreciable amounts of fine sediments, are most vulnerable to oil-related impacts.

3. Temporal stability of the benthic fauna appears fairly good. This indicates that the faunal baselines can be used in predicting and detecting oil-related impacts.

4. In addition to their value as indicators, a number of BCT benthic species are prominent in the diets of demersal fish, and would perhaps figure heavily in contaminant uptake and transfer through food webs. Also, at least three shellfish species found in the BCT subareas (lobster, sea scallop, and ocean quahog) are of considerable commercial importance.

5. The benthos of the outer shelf is relatively less threatened by oil-related activities than are inshore systems, due to the nature of the activities as well as the environments involved. The outer shelf benthos may, however, be more vulnerable than offshore plankton or nekton.

6. Most impacts associated with offshore exploration and development (due to presence of structures, pipeline jetting, disposal of drilling muds, cuttings and formation waters and their associated heavy metals) should be localized in time and space. The greatest threat is posed by the oil itself.

7. Impacts of oil, and subsequent recovery, will vary with substrate and species affected. Areas with sandy sediments and dynamic currents should be quickly cleansed of most oil (unless it is chronically introduced). Extensive recolonization of these areas by species with pelagic larvae is expected within one to two spawning cycles. Finer sediments in less turbulent waters will retain the oil much longer, perhaps as long as a decade. Species without pelagic larvae may require several

generations to recolonize any large areas from which they are eliminated. A disproportionate number of the important (numerically and as forage) benthic species fall into this category.

6.4 RECOMMENDATIONS

The following suggestions are offered as strategies designed to minimize impacts to the BCT benthos:

1. Oil-related activities should avoid the productive, vulnerable environment of swales and other depressions if possible. However, we suspect that technological and economic considerations will dictate use of some of these areas. Also, despite any precautions taken, some of the contaminants, drilling muds and cuttings would eventually reach these depressions. We therefore recommend, as a minimum, studying these depressions preferentially in any monitoring surveys, to determine worst case effects should impacts occur. The proposed survey of effects of an exploratory drilling operation should be sited in a swale and take place during maximum stratification of the water column.

2. Resource shellfish should be closely monitored for population changes, sublethal effects and contaminant uptake. Findings should be compared to distributions and contaminant levels presented in this report.

3. Monitoring studies should reoccupy sites for which data (VIMS, NMFS) already exist. Methodology should allow comparison with past studies, and all available data should be used in

assessing impacts. Management strategies should be updated as new findings (on recolonization of oiled sediments, impacts of exploratory drilling, etc.) become available.

4. Pipeline-laying should give wide berth to dumpsites and outfall areas, to prevent remobilization of contaminants.

5. Fates and effects of formation waters should be carefully examined. If these waters do not quickly dissipate, consideration should be given to mechanically aerating them or mixing them into the water column (as by use of diffusers), especially when the water column is stratified and bottom waters are low in oxygen.

6. Bioassays should be run with samples of crude oil from the MAB as soon as these are available, to determine toxicity of this oil relative to other crudes.

7. Dispersants should also be tested on MAB biota before these solvents are used to combat oil spills on the outer shelf.

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