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Benthic Recovery Following Sludge Abatement in Boston Harbor:

Part I Baseline Survey 1991
and
Part II Spring 1992 Survey

Massachusetts Water Resources Authority

Environmental Quality Department

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BENTHIC RECOVERY FOLLOWING SLUDGE ABATEMENT IN BOSTON HARBOR:

PART I BASELINE SURVEY 1991 AND PART II SPRING 1992 SURVEY

FINAL REPORT
CONTRACT DELIVERABLE

TO
MASSACHUSETTS WATER RESOURCES AUTHORITY

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PART I

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1.0 INTRODUCTION

The Massachusetts Water Resources Authority (MWRA) is instituting long-term monitoring in Boston Harbor as part of their Sludge Abatement Monitoring Program. Sludge generated at the Deer Island and Nut Island wastewater treatment facilities, until abatement in December 1991, was discharged from a point off the eastern tip of Long Island into Boston Harbor on outgoing tides. Cessation of sludge discharge is part of a progression of changes in MWRA discharge practices that will include diversion of treated effluent from the Harbor to deeper waters in Massachusetts Bay in 1995.

In September 1991, Battelle scientists conducted a survey of Boston Harbor benthic communities. The study included measurements of biotic and abiotic conditions at a variety of sites in the northern and southern regions of the Harbor. The primary purpose was to provide an extensive baseline data set of benthic conditions during the last warm season prior to cessation of sludge input to the Harbor. The study was undertaken with the expectation that future studies will revisit sites occupied during this baseline survey.

This report describes the survey activities and provides the resulting data on geology, chemistry, and biology. Section 2 describes methodology, separated into field sampling and laboratory analyses. The field methods subsection serves as a cruise report deliverable, summarizing station location and samples taken. Thereafter, laboratory processing methods are described for all parameters measured. Section 3 provides data summaries by parameter and site surveyed throughout the Harbor. Section 4 is a discussion of trends that includes a preliminary examination of spatial patterns and relationships among some sedimentary parameters. Additionally, initial recommendations are given for continuing surveys to assess Harbor recovery.

2.0 METHODS

2.1 FIELD OPERATIONS

2.1.1 Navigation

Positioning for the grab sampling and sediment-profile camera work was accomplished with a Northstar 800 Global Positioning System (GPS)/Loran C system. The Northstar system automatically chooses between GPS and Loran C depending on best accuracy. The Northstar GPS system has an absolute accuracy of about 100 m and automatically corrects the latitude/longitude position when in the Loran mode. The Northstar system was interfaced with Battelle's navigation display and logging system, which provided a display of the Harbor coastline and station locations on a color monitor. The system was used to record station locations, which facilitated subsequent plotting of the trackline and station locations.

2.1.2 Station Types and Locations

Locations of potential stations were determined after consideration of historical sampling sites, study of Harbor circulation patterns, and consultation and confirmation with MWRA. These locations were entered into a digitized map of the Harbor as a part of the navigation display and logging system. A hard copy of the locations (latitude/longitude) was available on board during the survey. Because of the need to sample the proper sedimentary environment, these locations served as guidelines for the actual placement of the stations.

Stations were designated as "traditional" or "rapid" according to the type of biological analysis to which the sediments from the station were to be subjected. Sediments from the eight traditional stations, designated T1 through T8, were subjected to complete taxonomic analysis, whereas sediments from the 24 rapid stations, designated R2 through R25, were subjected to modified taxonomic analysis as outlined below. One planned station just outside the Harbor, R1, was not sampled with MWRA concurrence. The latitude and longitude for each grab station are listed in Table 1; full station log details, including location for each individual grab event, are given in the Appendix (Table A-1). The positions of grab stations throughout the Harbor are shown in Figure 1.

2.1.3 Grab Sampling

A modified 0.04-m^2 Young-van Veen biological grab sampler was used to obtain sediment samples for both biological and chemical analyses. The upper surface of the biological grab has screened instead of solid doors. The screened doors minimize the bow wave hitting the surface of the sediment.

At each traditional station four replicate sediment samples were collected. Three grab samples were used for the biological analyses. Each replicate was observed for a variety of features including odor, color, and the presence of debris or animals (details in Table A-1). Each replicate then was washed with filtered seawater over nested 0.5- and 0.3-mm mesh sieves. The >0.5- and >0.3-mm fractions were placed into separate jars, labeled, and fixed with enough borax-buffered 100% formalin to yield a final solution of about 10% formalin. The fourth replicate sample was used for auxiliary analyses: sediment grain size, total organic carbon (TOC) content, *Clostridium perfringens,* and sediment chemistry. Subsamples for each analysis were removed from the upper two centimeters of sediment in the grab sampler with a cleaned, Kynar-coated scoop. For sediment grain size, a 25-gm subsample was taken and placed in a labeled Whirlpak bag. For TOC, a 5- to 10-gm subsample was gathered from the grab and placed into

Table 1. Grab Sample Stations for Boston Harbor 1991 Baseline Survey

Date	Event	Station	Lat/Long	Depth	Time
9/16	40	R19	42°16.92'/70°56.27'	9.7 m	0945
9/16	43	R18	42°17.33'/70°52.67'	7.9 m	1040
9/16	60	T7	42°17.36'/70°58.71'	5.2 m	1225
9/16	66	T6	42°17.61'/70°56.66'	4.9 m	1355
9/16	72	R23	42°17.63'/70°57.00'	10.5 m	1510
9/17	83	T8	42°17.12'/70°54.75'	12.7 m	0835
9/17	92	R25	42°17.48'/70°55.72'	6.8 m	1007
9/17	99	R20	42°19.49'/70°56.10'	9.7 m	1119
9/17	113	T5	42°19.91'/70°57.21'	6.8 m	1242
9/17	122	T3	42°19.81'/70°57.72'	8.1 m	1406
9/17	131	R11	42°19.28'/70°58.48'	7.0 m	1509
9/17	137	R12	42°19.10'/70°58.47'	6.3 m	1541
9/17	143	R13	42°19.03'/70°58.84'	7.2 m	1623
9/17	148	R17	42°18.29'/70°58.63'	8.2 m	1659
9/18	163	R24	42°17.78'/70°57.51'	8.3 m	0833
9/18	169	T1	42°20.95'/70°57.81'	5.6 m	0923
9/18	177	R3	42°21.18'/70°58.37'	5.5 m	1021
9/18	184	T2	42°20.57'/71°00.12'	7.4 m	1110
9/18	192	R8	42°20.66'/70°59.50'	2.8 m	1204
9/18	198	R7	42°20.85'/70°58.53'	5.9 m	1248
9/18	205	R9	42°20.80'/71°00.98'	11.8 m	1321
9/18	211	R10	42°21.32'/71°02.20'	13.5 m	1352
9/18	216	T4	42°18.60'/71°02.49'	3.4 m	1456
9/18	224	R15	42°18.92'/71°01.15'	3.6 m	1632
9/18	229	R14	42°19.25'/71°00.77'	7.9 m	1707
9/20	310	R4	42°21.52'/70°58.78'	8.5 m	0933
9/20	315	R5	42°21.38'/70°58.68'	7.1 m	1025
9/20	322	R2	42°20.66'/70°57.69'	14.5 m	1101
9/20	330	R6	42°20.38'/70°57.64'	17.9 m	1203
9/20	340	R16	42°18.95'/70°57.68'	6.9 m	1348
9/20	344	R21	42°18.53'/70°56.78'	7.0 m	1418
9/20	353	R22	42°18.02'/70°56.37'	8.3 m	1501

Positions listed are for one grab of three or four at a station. Full listing of all grabs is given in Appendix (Table A-1).

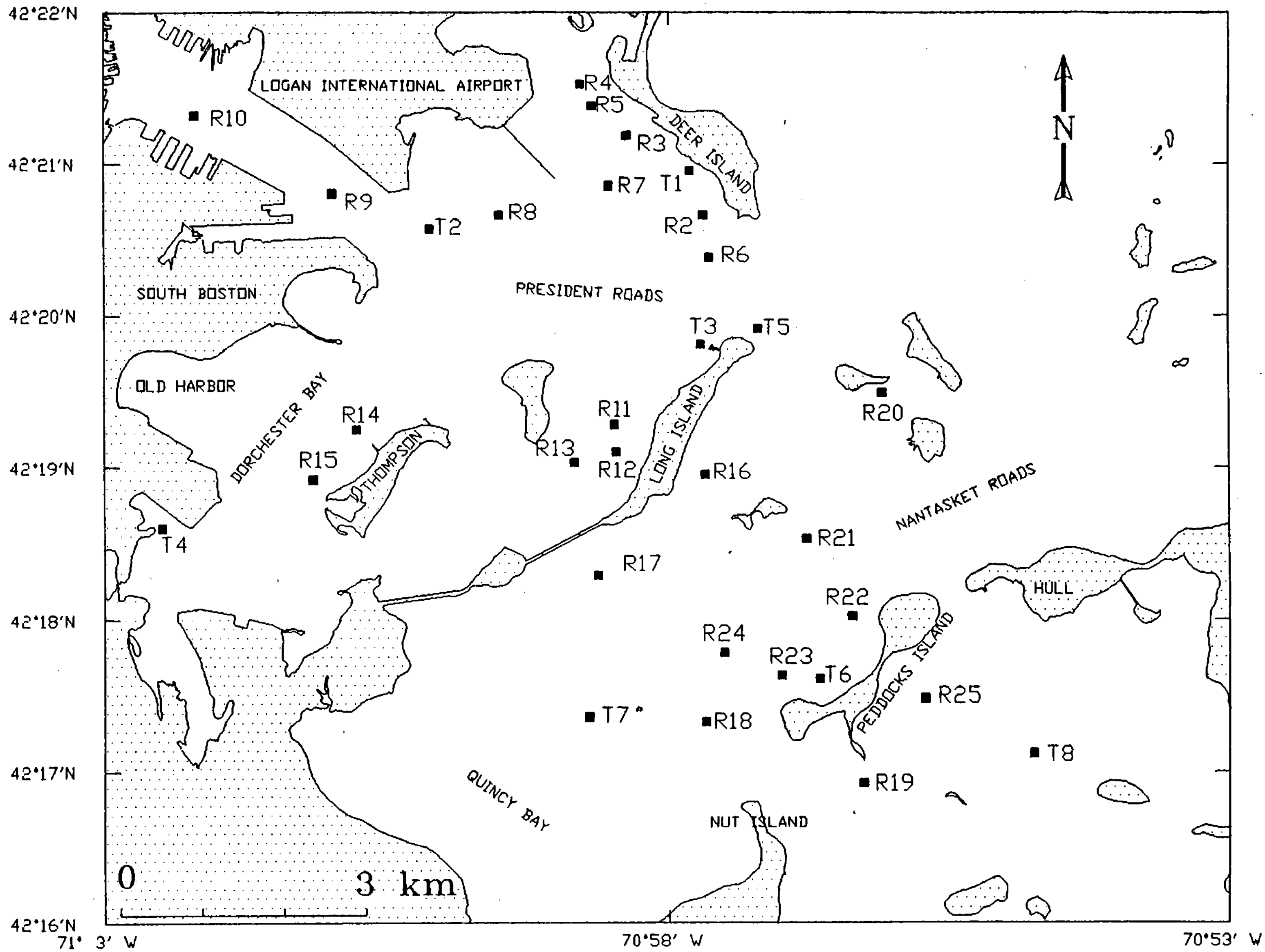


Figure 1. Stations for 1991 Survey: Grab Samples.

a cleaned 25-mL vial. The vial opening was covered with a piece of baked aluminum foil and capped with a Teflon-lined cap. A 5-gm subsample for *Clostridium* analysis was collected and placed in a sterile container provided by MWRA. A 100- to 150-gm subsample to be archived for sediment chemistry analysis was obtained and placed in a cleaned IChem sample jar. After collection, each subsample was labeled and placed in a cooler containing Dry Ice. Upon return to Battelle, subsamples were stored in a freezer until delivered to the appropriate laboratory for analysis. The sediment chemistry subsamples are archived at -20 °C at Battelle.

At each rapid assessment station three replicate grab samples were obtained. Two of the replicates were processed for biological analysis. Each biological sample was washed with filtered seawater over a 0.5-mm-mesh sieve. The material retained on the sieve was placed into a 1-gal. jar and fixed with enough borax-buffered 100% formalin to yield a final concentration of about 10% formalin. The third grab sample was processed as described above for the auxiliary analyses, grain size, TOC, *Clostridium*, and sediment chemistry.

2.1.4 Sediment Profile Imaging

Because of the short time that was available for developing the survey schedule and details, it was possible to schedule the sediment profile camera work only for one day of the survey between the third and fourth days of the grab sampling (September 19, 1992). Both weather and camera problems struck on this day, limiting the data collection well below the standard capacity of the technique. Stations visited are shown in Figure 2 (closely approximating the position of the similarly coded grab stations — navigation details in the Appendix, Table A-2). However, data were not successfully collected at all visited sites. Stations in the southern Harbor were sampled, but because of camera malfunction, no images were obtained. In the northern Harbor, five "replicate" sediment profile images were obtained from three traditional and three rapid stations using a sediment camera and procedures developed by Robert J. Diaz. Images were obtained at Stations T2, T3, T4, R4, R7, and R11. Little penetration into the sediment was achieved at T1, T5, and R13, presumably because of a less muddy environment (see Results).

2.1.5 Core Collection

Sediment cores were collected by divers from Battelle and the Ecosystems Center (Marine Biological Laboratory, Woods Hole) at four stations in the Harbor on September 23, 1991; these cores were returned to the laboratory for measurements of sediment-water exchange rates of dissolved gases and nutrients. Station positions approximated the positions of Stations T2, T3, T7, and T8 within several hundred meters (Figure 3, precise details in Appendix). T2 was intentionally moved about 150 meters to the East to add an extra margin of safety for divers and be well clear of ship traffic transiting to the Inner Harbor. Core Station T8 was slightly to the North of Grab Station T8, by about 0.05′ of latitude (about 90 m, or within the limits of precision of the navigation), but may have crossed a transition between muddier (grab) and sandier (core) benthic environments (see also Kelly and Nowicki, 1992). Results of benthic flux studies of denitrification, metabolism, and nutrients are reported separately (Kelly and Nowicki, 1992; Giblin *et al.*, 1992). Video camera observations of the conditions of the sediments and the coring operation at three stations were made by Battelle. A copy of the video tape has been provided to the MWRA.

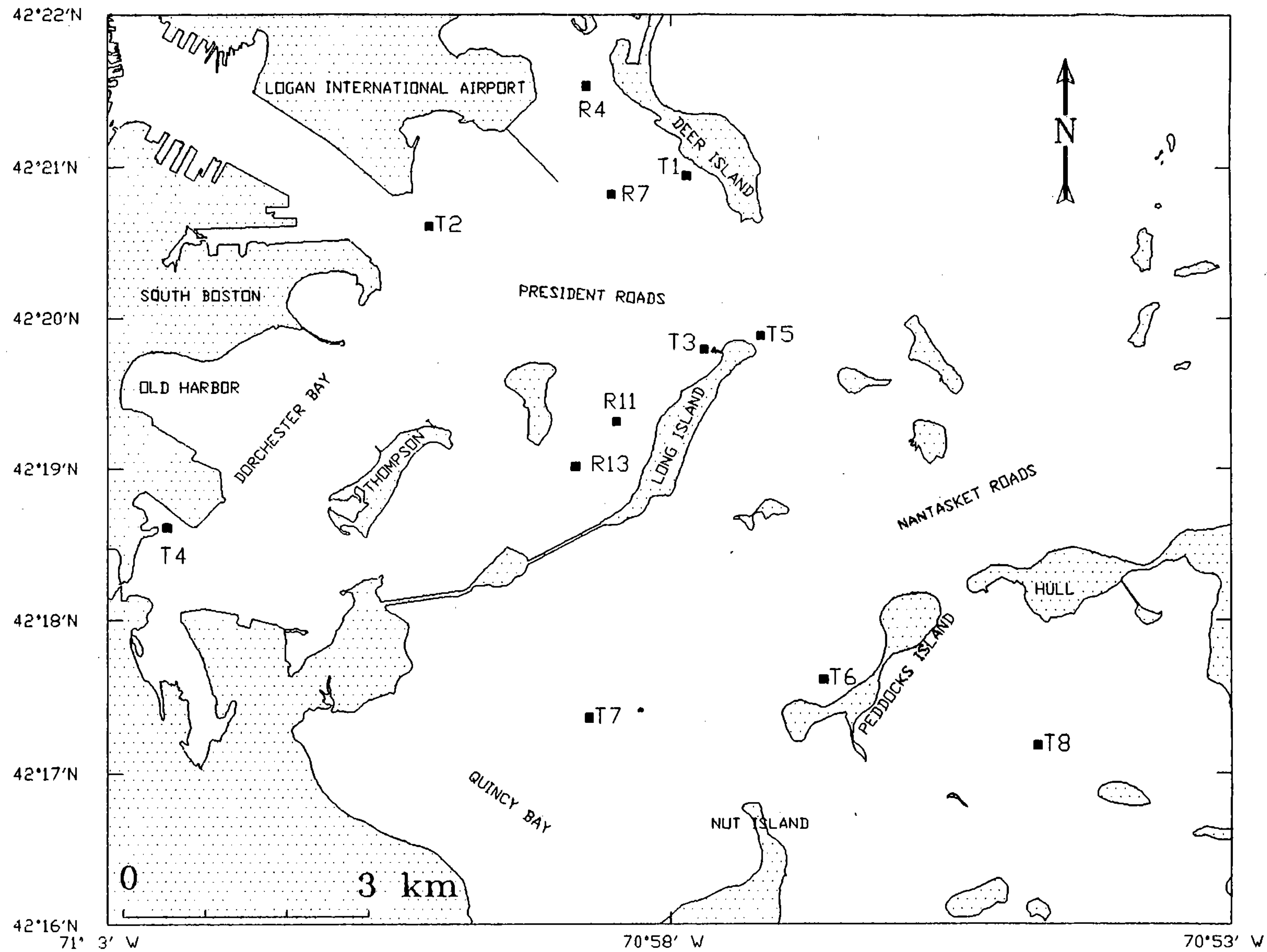


Figure 2. Stations for 1991 Survey: Sediment Profile Camera.

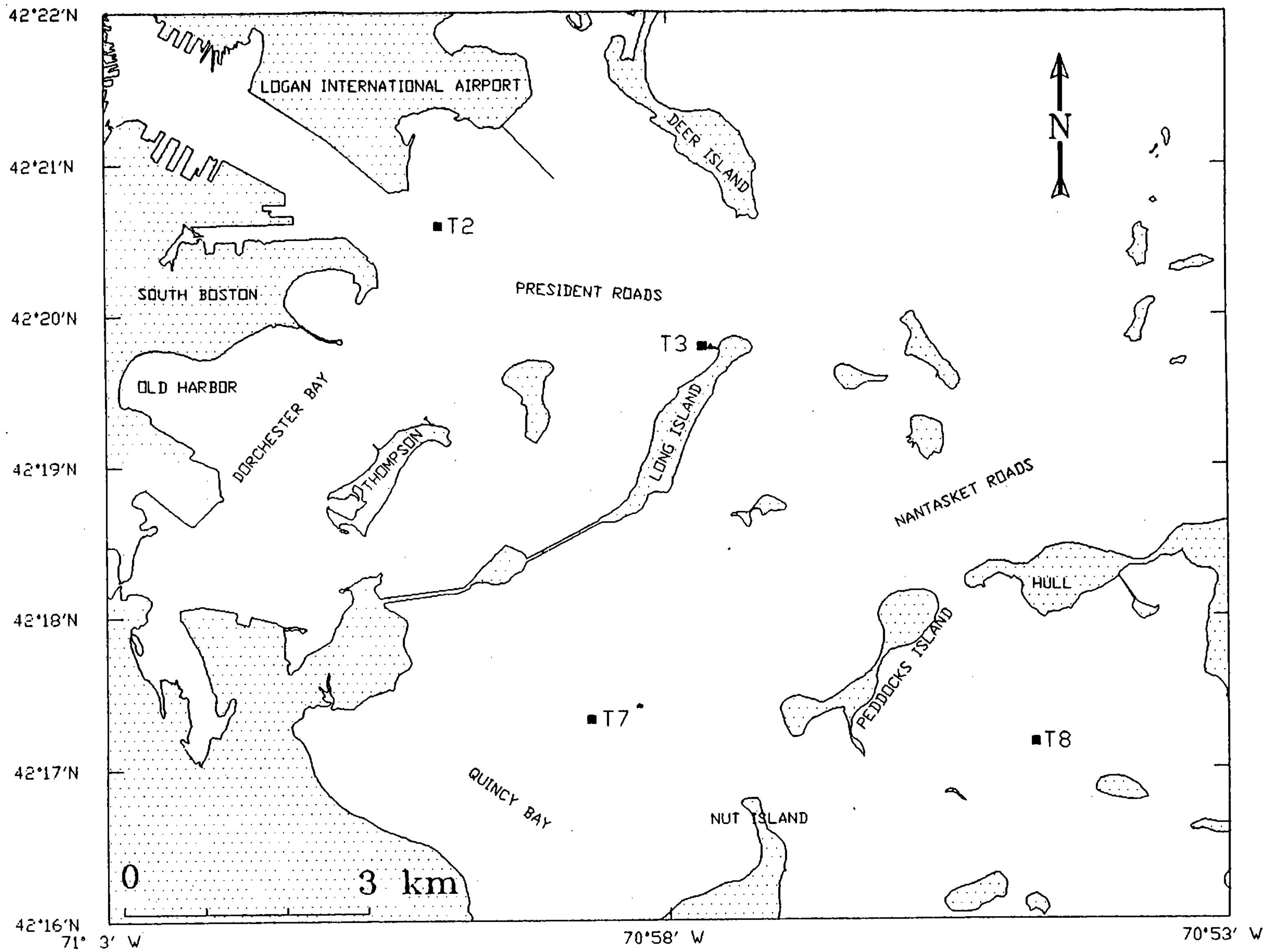


Figure 3. Stations for 1991 Survey: Cores for Benthic Flux Studies.

2.1.6 Other Sampling

As described in the original work plan, we had hoped to include one half-day of trawling for groundfish and mobile epifauna. However, because of the time required to complete fully the grab sampling (the full 4 days allotted), trawling was not possible.

2.1.7 Sample Documentation, Custody, and Quality Assurance/Quality Control

All sampling events were recorded into the navigational system and appropriately recorded in navigation and sediment log record books, with any changes documented. All collected samples were tracked by standard Battelle recording and tracking procedures, including use of bar-coded forms. Transfer of samples were recorded to fulfill chain-of-custody requirements. Resultant data files and values in this report have been verified by standard data validation procedures.

2.1.8 Summary of Samples Collected

A summary of the number and types of samples collected during the September 1991 survey is presented in Table 2.

2.2 LABORATORY METHODS: SAMPLE PROCESSING AND ANALYSIS

2.2.1 Benthic Infauna: Traditional

The benthic macrofauna collected at the eight traditional stations were processed by Battelle's subcontractor, Cove Corporation. Cove Corp. sorted and identified all organisms to lowest taxa possible. For each taxona, counts of individual organisms were made and tabulated. The 0.5-mm sieve fraction and the 0.3-mm sieve fraction were analyzed separately. Sorting time for the 0.3-mm fraction was unusually lengthy relative to samples from many other geographic areas. Three replicates (from separate 0.04-m^2 grab samples) were completed for each station and each size fraction. Only two 0.3-mm fraction replicates from Station T5 were sorted; the third was improperly preserved and lost. Thus, a total of 47 samples were analyzed.

2.2.2 Benthic Infauna: Rapid Assessment Technique

At the 24 rapid stations, duplicate 0.04-m^2 grab samples were collected as for the traditional stations. Material retained on a 0.5-mm sieve was preserved and analyzed by Dr. Roy Kropp of Battelle and Eugene Ruff (Battelle's subcontractor, Ruff Systematics), according to the procedures detailed next.

Figure 4 is an overview of the treatment of sample material and the data generated by the method. Prior to laboratory processing, an estimate of the settled depth of the sediment in each 1-gallon jar (14.5 cm diam.) was made by placing a millimeter rule against the outside of the jar and recording the depth of the sediment in the jar. For samples not settling evenly, two measurements, high and low, were obtained. The midpoint of these measurements was entered into the data file. To facilitate sorting, samples were stained overnight in a saturate solution of Rose Bengal. Laboratory processing was initiated with a visual inspection of the sample to determine the presence or absence of a "heavy fraction," typically mollusc shells or rocks. If a heavy fraction was present the sample was poured into a 0.5-mm-mesh sieve and rinsed with freshwater to remove the formalin. The sample was then placed in a large

Table 2. Summary of Samples Collected on September 1991 Survey.

Sample Type	T Stations (8)	R Stations (24)	Total	Status
Benthic Infauna				
0.5-mm fraction	24	48	72	Analyzed
0.3-mm fraction	24	0	24	Analyzed[a]
Grain Size	8	24	32	Analyzed
TOC	8	24	32	Analyzed
Clostridium	8	24	32	Analyzed
Chemistry	8	24	32	Frozen Archived
Sediment Profile Images	15[b]	15[c]	30	Analyzed
Benthic DNF/O_2 fluxes	8[d]	0	8	Analyzed[e]

[a]Only 23 samples were analyzed; one replicate was not properly preserved and was lost.
[b]Excluding 9 attempts in which the camera did not penetrate the substratum.
[c]Excluding 4 attempts in which the camera did not penetrate the substratum.
[d]Two cores at each of 4 stations.
[e]Results presented in Kelly and Nowicki (1992).

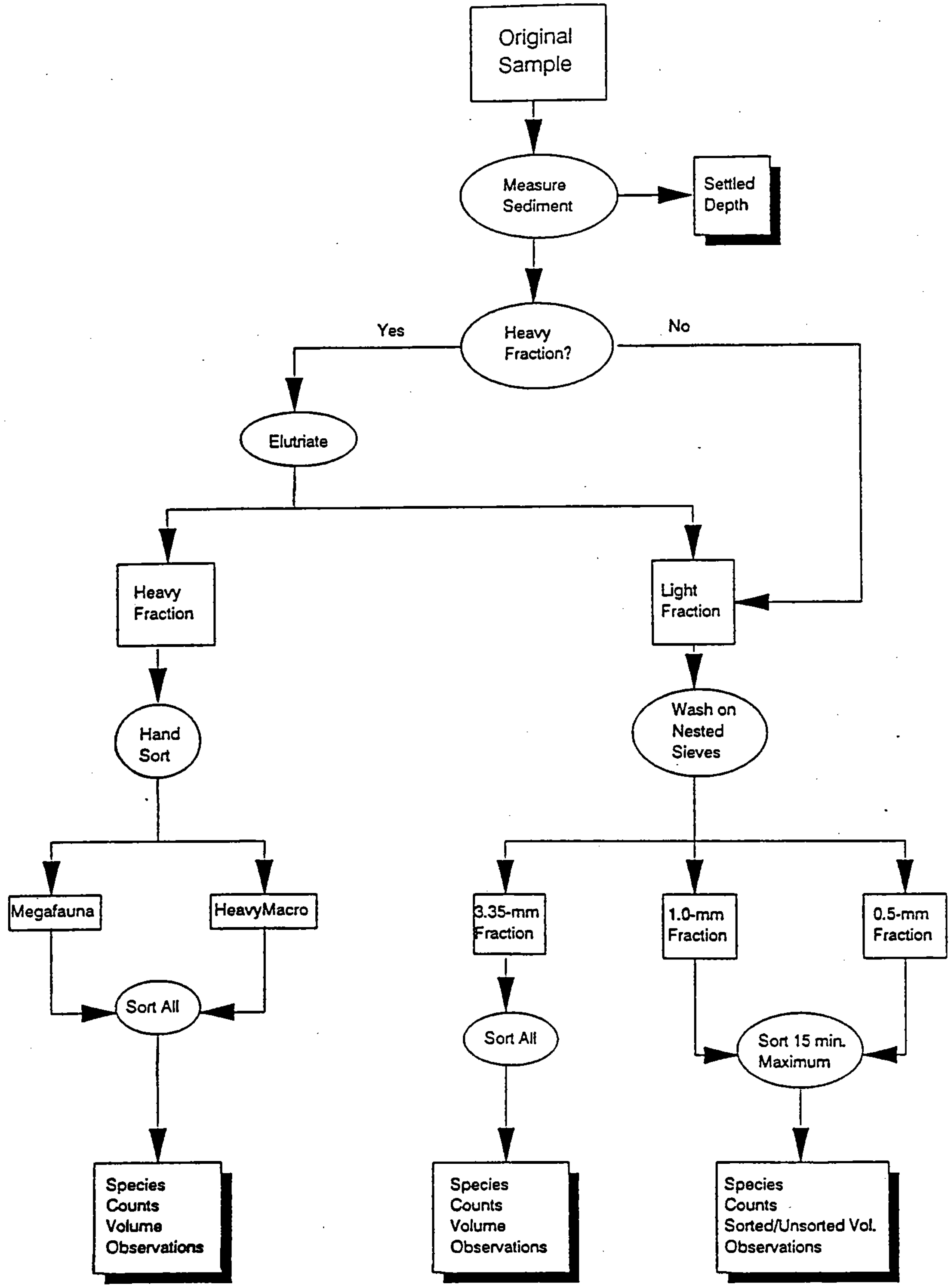


Figure 4. Rapid Assessment: Macrofauna Sample Processing Scheme.

dishpan for elutriation. Elutriation was accomplished by adding enough water to the pan to cover the sediment sample and carefully agitating the sample by rocking the pan back and forth to bring relatively light material into suspension. Agitation was followed by decanting the water into a 0.5-mm-mesh sieve. The process was repeated until it appeared that no more material was being suspended in the water above the sample. The material retained on the sieve was termed the "fine fraction" and that remaining in the pan the "heavy-macro fraction." Any "megafauna," e.g., a seastar, remaining was removed, placed into a labeled jar, and covered with 70% ethanol. The heavy-macro fraction was placed in a jar, labeled, and covered with 70% ethanol. The fine fraction was rinsed over a stack of nested 3.35-, 1.0-, and 0.5-mm-mesh sieves. The material remaining on the sieves was placed in separate labeled jars and covered with 70% ethanol. Each fraction was named after the mesh size of the sieve on which it was retained. If no heavy fraction was present, the sample was washed over the nested sieves as described above for the fine fraction. All fractions were delivered to the taxonomists for analysis.

Any megafauna present was identified and counted. All sediment in the heavy-macro and 3.35-mm fractions was examined; all organisms present were removed and identified to the lowest possible taxonomic level. Sediment in the 1.0- and 0.5-mm fractions of each replicate was sorted by the two expert taxonomists, who removed all organisms encountered. The maximum time allowed to sort a fraction was 15 minutes. After the expiration of the time limit, the sorted residue and any material not sorted were placed in separate labeled jars and covered with 70% ethanol. Any noteworthy observations regarding the nature of the sediment, such as the type of debris, were recorded. All organisms removed during sorting were identified to the lowest possible taxonomic level within a short time period (about 5 min) and counted. The volume of each the sorted and not-sorted residues was obtained by pouring the residue into a graduated cylinder and allowing it to settle for three minutes.

2.2.3 Sediment Grain Size

Battelle's subcontractor, Geo/Plan Associates, performed the surface-sediment grain-size analysis for the full 32 stations, with three randomly selected samples analyzed in triplicate. Their procedures followed standard marine sample sieve and pipette methods (Folk, 1974). Wet-sieved material less than 62 μm in diameter (silt and clays) were further fractionated by pipette analysis. Final results are expressed in the size categories of gravel, sand, silt, and clay as percentage by weight. Triplicate analyses on a subset of samples were analyzed and met specified data quality criteria for the analyses.

2.2.4 Total Organic Carbon

Sediment samples (5-10 g wet, from the upper 2 cm) were processed by Battelle's subcontractor, Global Geochemistry Corporation. Samples were dried, crushed, and homogenized. Inorganic carbon was removed through acidification prior to combustion of a subsample and detection of liberated carbon dioxide in a LECO (Laboratory Equipment Corporation) analyzer. Blanks and standards were run after no more than every 9 sediment samples. Five samples were run in duplicate to determine variability and ensure that analyses provided acceptable limits of precision.

2.2.5 *Clostridium perfringens*

Samples for *C. perfringens*, maintained in a refrigerator, were transferred to Ken Keay of the MWRA after the conclusion of the survey. These samples then were processed by MWRA's contractor and the results provided by MWRA to Battelle. Battelle was provided tabular data on spore counts and the number of spores per gram dry weight of sediment.

2.2.6 Sediment Camera Imaging

Collection and analysis of sediment profile photographs, using both visual and computer-assisted image analysis, was performed by Battelle's subcontractor, R.J. Diaz and Daughters. The system used is a Surface and Profile Imaging Camera (SPI). The data analysis and interpretation results in information on a number of parameters, briefly described here and more fully elsewhere (e.g., Rhoads and Germano, 1986; Diaz and Schaffner, 1988; Diaz, manuscript in review).

Digitized image statistics are the actual pixel densities from the digitized image. They are used to compare the color and contrast changes that occur within an image and between sets of images; changes in pixel densities can delineate boundaries of various types within the sediments.

Other parameters measured include, where applicable: depth of penetration, surface relief, depth of apparent redox potential discontinuity (RPD) layer, color contrast of apparent RPD, area of anoxic sediment, area of oxic sediment, voids, other inclusions (methane bubbles, mud clasts, shells), burrows, a variety of surface features (tubes, epifauna, pelletized layer, shell, mud clasts), sediment grain size (Wentworth size classes), and dredged material or other discontinuous sediment layers. All parameters, either measured quantitatively by the computer image analysis or qualitatively by visual inspection, help to characterize the condition of the sediment. General description of the utility of the various measures is in the Appendix (Table A-4).

Sufficient camera penetration provided successful computer and visual analysis from five replicate images at three traditional stations and three rapid stations.

2.2.7 Archived Sediment

The collected surface sediment sample (about 100-150 g) at each traditional and rapid station was transferred to Battelle Ocean Sciences in Duxbury, logged, and placed in a cold-temperature freezer (-20 °C). This material remains available for appropriate analysis as desired.

2.3 DATA ANALYSIS

For the traditional station, for a number of analyses, the 0.3-mm and 0.5-mm fractions for benthic macrofauna were combined and termed total. Additionally, where total taxa at a station are reported, the value discounts redundant taxa across the three replicates. Some analyses, as identified, were performed only on taxa identifiable to species. In general, simple statistics of mean parameter values at station (if $n > 1$) are provided in tabular form and full data are in the Appendix.

For macrofauna data, a one-way Analysis of Variance (ANOVA) and a planned statistical comparison (Student-Newman-Kuels Test) was performed using standard SAS (SAS Institute, 1985) processing software programs.

Cluster analysis employed normal (Q mode) numerical classification to order samples into groups according to their similarity. For macrofauna, the Normalized Expected Species Shared (NESS; Grassle and Smith, 1976) algorithm was used as the similarity measure. For clustering sediment parameters, data had highly different ranges, so a standard Z-score transformation within parameter was performed, and the appropriate similarity measure of Euclidean distance was then used.

3.0 RESULTS

3.1 BENTHIC INFAUNA (TRADITIONAL STATIONS)

Full taxonomic identifications and counts are provided in the Appendix for each of the 0.5-mm (Table A-5) and 0.3-mm (Table A-6) fractions at the eight traditional stations. Data include, for each replicate (0.04-m^2) grab, species (or lowest identifiable taxa) and counts, several diversity measures (treating all taxa as separate), and summary statistics for the station. The results given next primarily emphasize station summary data.

Table 3 summarizes, by sieve fraction, numbers of taxa and individuals. There was variation across stations in the importance of the two sieve fractions (0.3 mm vs. 0.5 mm). The 0.3-mm fraction made a majority contribution to total individuals and/or taxa in the case of several stations in the northern Harbor (T1, T2, T4), particularly at Station T4. At the other stations the 0.5-mm fraction contributed greater than 50% of the taxa and individuals.

For taxa, the total number (sum of non-redundant taxa from three replicates) ranged from 12 to 74 across stations. For number of individuals, the range was 170 to 7,080 per station. Expressed on an area basis (Table 3 numbers are per three 0.04 m^2 grabs), the range was 1.4×10^3 to 5.9×10^4 individuals per m^2.

The number of individuals was lowest at three northern Harbor stations (T4, T2, and T5), which also had the lowest numbers of taxa (Table 3). Two northern Harbor stations (T1, T3) near the sludge and effluent outfalls off Deer Island and Long Island had higher numbers, as did the three southern Harbor stations (T6, T7, T8). These spatial patterns, described by measures of species richness and abundance, are also illustrated in Figures 5 and 6.

The top five dominant taxa for the traditional stations are shown in Table 4. Several taxa were dominant at at least 50% of the stations. Oligochaeta were present in high numbers at five stations, reaching a peak at Station T3. The other taxa appearing as dominant at a minimum of four stations were the polychaetes, *Streblospio benedicti* and *Aricidea catherinae*, and an amphipod group, *Ampelisca* spp. complex. *S. benedicti* was a dominant at three northern Harbor stations and T7 in Quincy Bay. *S. benedicti* and oligochaeta were present, albeit sometimes as only 1 individual, at every station (Appendix Tables A-5 and A-6). Both *A. catherinae* and *Ampelisca* were dominant at the three southern Harbor stations (T6, T7, T8), and although having lesser numbers at T3, were among the dominant there. In general the northern Harbor stations tended to be dominated highly by one or two taxa, whereas southern Harbor stations had numbers spread more evenly across a few taxa (Table 4).

Despite cross-station distribution of a few dominants, all eight traditional stations had their own unique top dominant list (Table 4). Indeed, Figure 7 shows that replicates at a station often group together before clustering with their most taxonomically-related neighbor. This feature of within-station variability being generally small relative to station-to-station variability is a little less pronounced if the cluster is based on only the 0.5-mm fraction (Figure 8).

In spite of the replicate similarity and thus a station individuality, a pattern of station associations was evident. Considering the total fraction taxa list (Figure 7), stations cluster with nearest measured geographic neighbors, with one exception (T3) (Figure 9). Stations T5 and T1 either side of President Roads in the outer Harbor were closely associated, as were Stations T4 and T2 towards inner reaches in the northern region. In contrast, Station T3, around the tip of Long Island westward from the sludge outfall, clustered with T6 (both had high oligochaeta - Table 4) followed by T6's southern region neighbors, T7 and T8.

Table 3: Total Taxa and Abundance at Traditional Stations (3 Replicate Grabs) Sampled during September 1991

Parameter	Sieve Fraction	Station[a] T4	T2	T5	T7	T1	T3	T6	T8
Number of Taxa	0.5 mm	3	7	11	21	30	31	35	63
	0.3 mm	10	9	4	18	23[c]	19	21	40
	Total	12	13	13	28	38[c]	35	40	74
Number of individuals	0.5 mm	24	23	208	1798	565	5483	4836	3515
	0.3 mm	413	147	96[b]	1225	1173[c]	1597	1805	3214
	Total	437	170	304[b]	3023	1738	7080	6641	6729

[a]Stations are ordered from left to right by increasing number of taxa. Stations underlined are in the southern region of the Harbor.
[b]Only 2 replicates for 0.3 mm fraction. Both 0.3 mm and total were projected to 3 replicates.
[c]Excludes Insecta.

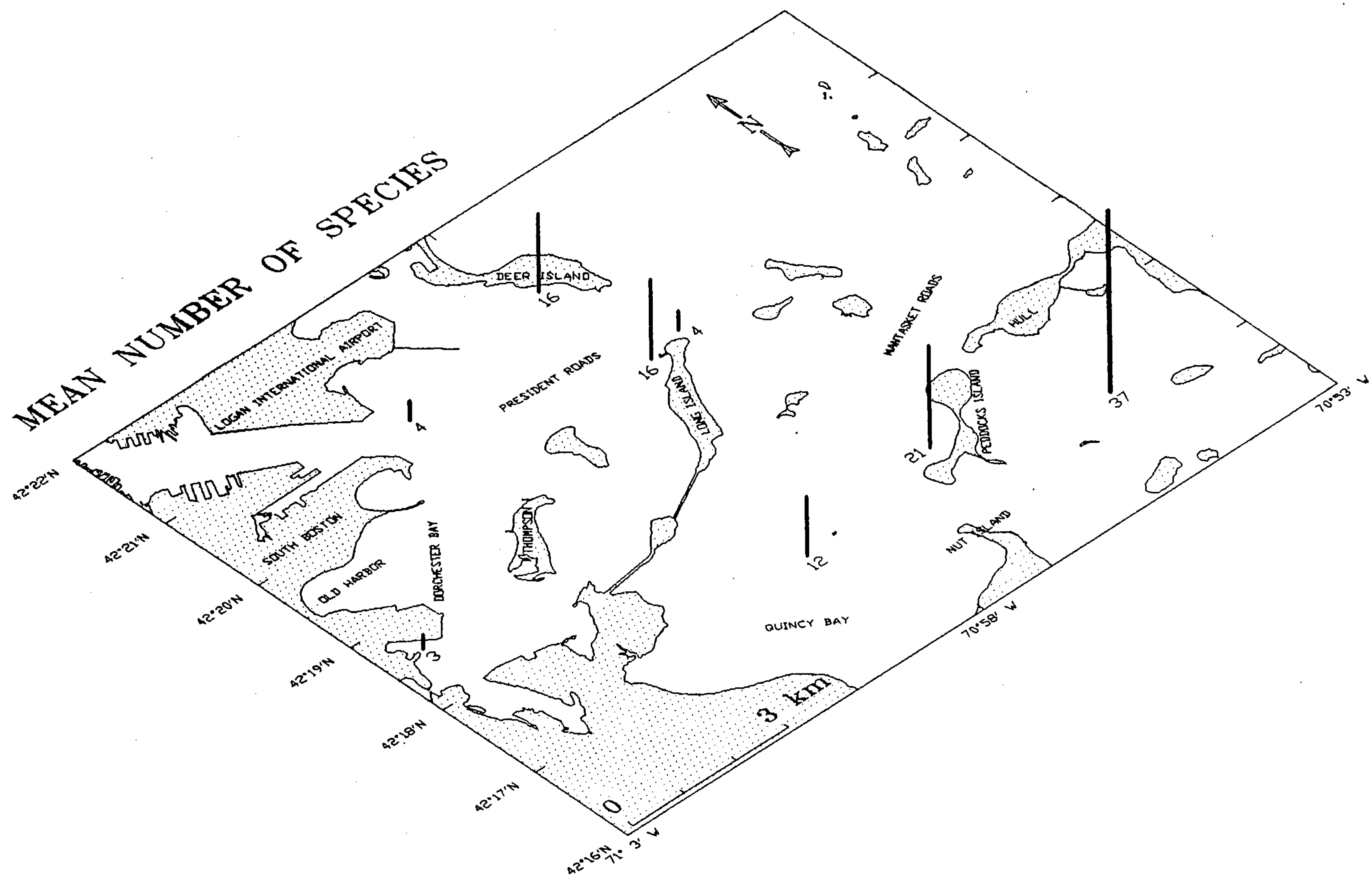


Figure 5. Macrofauna Species Richness at Traditional Stations.
Mean number of taxa from total fraction identifiable to *species per replicate grab*.
Note these numbers differ (by a factor of 2 to 3) from Table 3, where the cumulative number of *total taxa across three replicates* are presented.

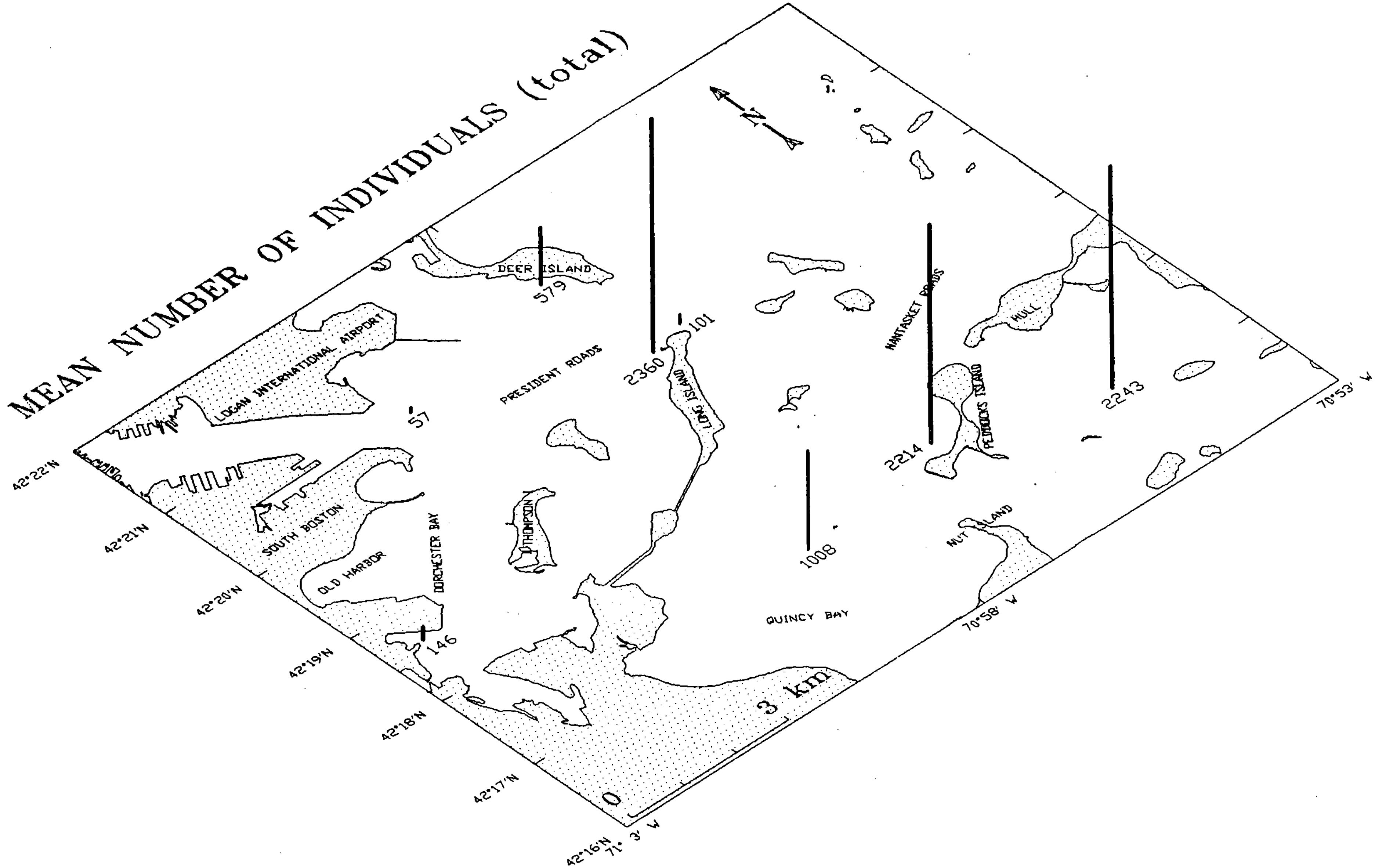


Figure 6. Macrofauna Abundance at Traditional Stations.

Table 4. Abundance of Top 5 Taxa at Traditional Stations (3 Replicate Grabs).

TAXA	Station[a] T4	T2	T5	<u>T7</u>	T1	T3	<u>T6</u>	<u>T8</u>
Oligochaeta		54 (32%)	177 (65%)		796 (46%)	6073 (86%)	1984 (30%)	
Streblospio benedicti	343 (78%)	72 (42%)		1192 (39%)	323 (19%)			
Microphthalmus aberrans					133 (8%)	288 (4%)		
Tharyx cf. acutus	2 (0.5%)				98 (6%)			
Polydora cornuta					74 (4%)		480 (7%)	
Polydora sp.	7 (2%)							
Bivalvia		16 (19%)						
Gastropoda		8 (5%)	9 (3%)					
Crangon septemspinosa	5 (1%)	8 (5%)						
Turbellaria	72 (16%)							
Aricidea catherinae				198 (7%)		262 (4%)	1765 (27%)	2445 (36%)
Ampelisca spp. complex				868 (29%)		109 (2%)	1838 (28%)	1182 (18%)
Phoxocephalus holbolli						59 (0.8%)	133 (2%)	
Nassarius vibex			44 (16%)					
Capitella spp. complex			(7%)	18				
Gammarus sp.			10 (4%)					
Mya arenaria				189 (6%)				
Ensis directus				142 (5%)				
Nucula delphinodonta								739 (11%)
Exogone hebes								239 (4%)
Polygordius sp.								222 (3%)

[a]Stations are ordered from left to right by increasing number of taxa (see previous table). Stations underlined are in the southern region of the Harbor.

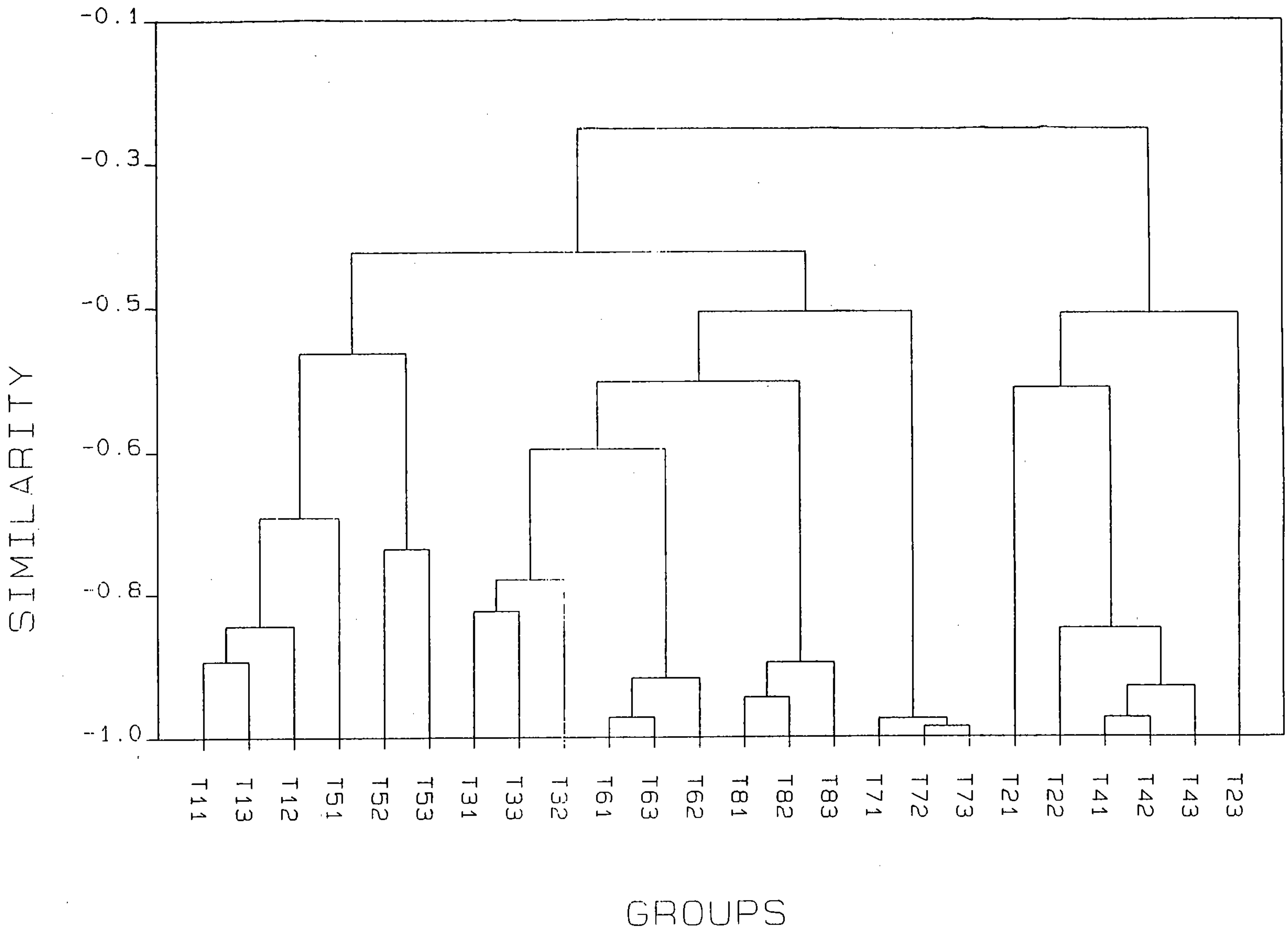


Figure 7. Cluster Dendrogram of Replicate Grab Samples (Total Taxa) of Traditional Stations.

Performed on taxa *identifiable to species* using the cluster algorithm NESS without data transformation.

Note that coding gives station code followed by replicate grab (1, 2, or 3).

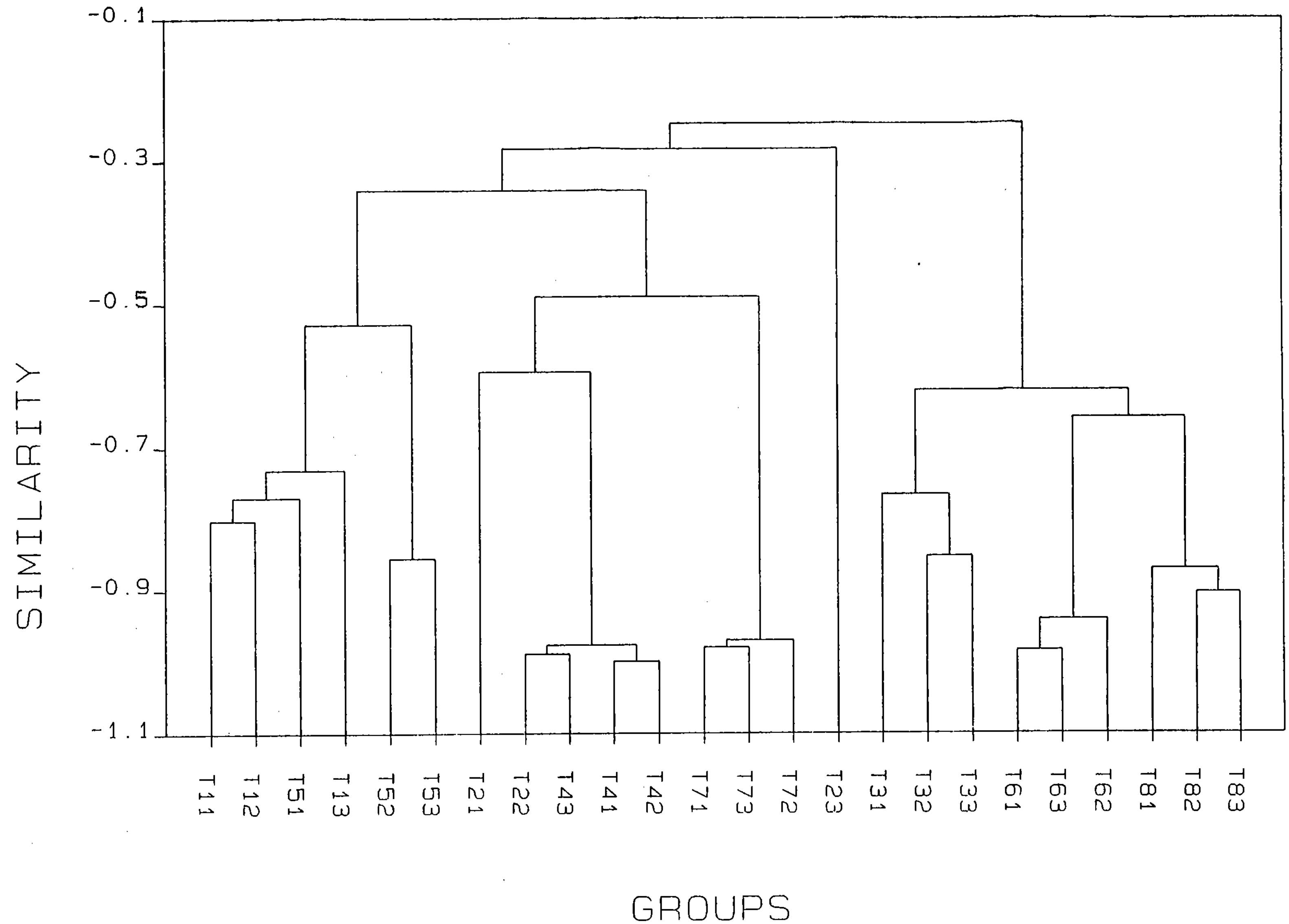


Figure 8. Cluster Dendrogram of Replicate Grab Samples (0.5-mm Fraction Only) of Traditional Stations.

Performed on taxa *identifable to species* using the cluster algorithm NESS without data transformation. Note that coding gives station code followed by replicate grab (1, 2, or 3).

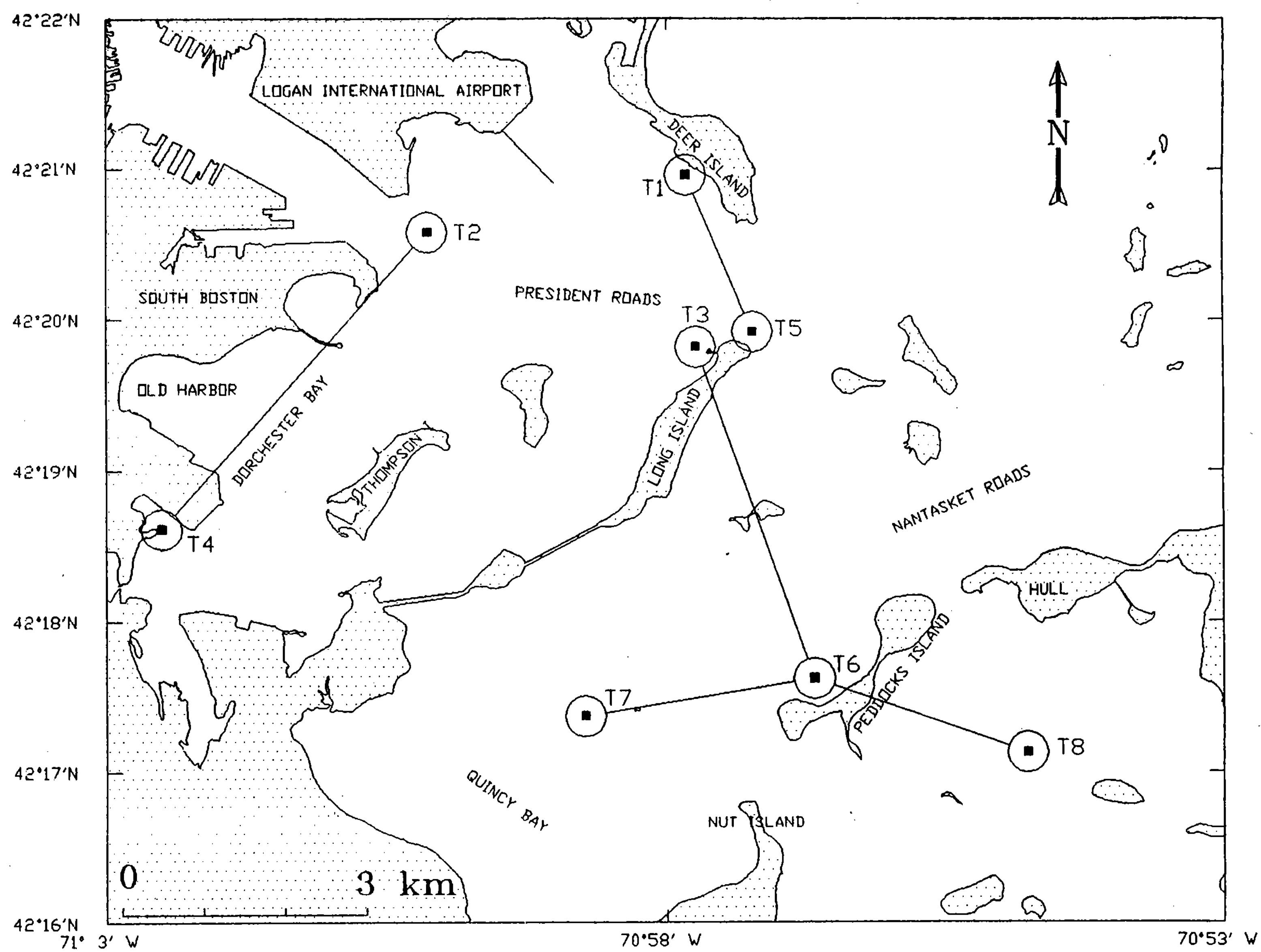


Figure 9. Traditional Station Associations in Boston Harbor.
Based on total macrofauna community clusters shown in Figure 7.

In addition to similarity based on taxonomic *composition*, Station T3 was also more similar to the southern region as judged by *numbers* of organisms (Figure 6). Based on one-way ANOVA and a Student-Newman-Keuls Test for planned comparisons (Appendix, Table A-7), the mean number of individuals was not different among T3, T8, T6, and T7. T7 overlapped with the remaining stations, but T3, T8, and T6 had significantly (alpha = 0.05) greater abundance than T1, T4, T5, and T2 (Table 3).

3.2 BENTHIC INFAUNA (RAPID ASSESSMENT)

The data resulting from the processing of replicate 0.04-m^2 grabs at the 24 rapid stations were extensive (Appendix, Tables A-8 to A-11). In looking at the sample jars, it appeared that the amount of material retained on the field sieve (0.5 mm) had a geographic pattern. Our measurement of the settled particulate material (detritus and fauna) in the jars confirmed that stations in the northern Harbor usually had less material (Figure 10). To some degree the settled-volume variation obviously coincided with the numbers of taxa in 0.5- and 1.0-mm fractions (i.e., less material, fewer taxa — see below). However, we did not attempt to correlate settled depth with other environmental or biological measures and here only offer it as a tentative but rapid, visual, and simple measure of station character that roughly coincides with many gross-scale geographic distinctions apparent in the data. Settled-volume estimates of different size fractions of this material are also given in the Appendix (Tables A-8 to A-11).

For the taxonomic aspect of the rapid assessment, data are displayed in entirety for duplicate station samples of the 0.5- and 1.0-mm fractions (Tables 5 and 6), which constituted the bulk of individuals for many species. For both tables the stations are ordered left to right to run from the northernmost stations to the southernmost stations. The percent of the material sorted varies (see tables). For example, because of the greater amount in the southern samples, less was sorted for those stations (given the time constraints set by the procedure [Section 2] than for most northern stations, where 100% of each sample was examined.

The main result evident in Tables 5 and 6 is that the northern stations have fewer taxa than the southern stations, with only minor exceptions (perhaps R8 and R15). Table values have not been normalized for the fraction sorted, but since it was generally less at stations with higher abundances, normalization will heighten geographic distinctions. With closer inspection of the numbers in the table, it is evident also that northern stations have lower numbers of individuals for those taxa that are present. Stations R4 and R5 (on the Deer Island flats) and R9 and R10 (into the inner Harbor) were among the most faunistically depauperate. Stations R21 - R23 (north of Peddocks Island) were among the richest in species and numbers.

The tables also are useful for seeing quickly which taxa were fairly ubiquitous and which had more restricted distribution. For example, in the former category (0.5-mm and 1.0 fractions) were the Oligochaeta, missing only in a small area covered by Stations R4, R5, and R7. A common deposit-feeding gastropod, *Nassarius vibex*, occurred throughout most stations in the 1.0-mm fraction, missing only at neighboring Stations R14 and R15. *Tellina agilis* was not high in numbers but appeared at many points throughout the Harbor. *Streblospio benedicti* was very common, but absent from the R21 - R24 region.

A number of species, including *Aricidea catherinae*, and *Ampelisca* spp.complex, were centered in the R20 - R24 region, but could be found in low numbers elsewhere. These in particular may be taxa to watch for increased numbers with recovery in the northern Harbor region. Some species seemed more

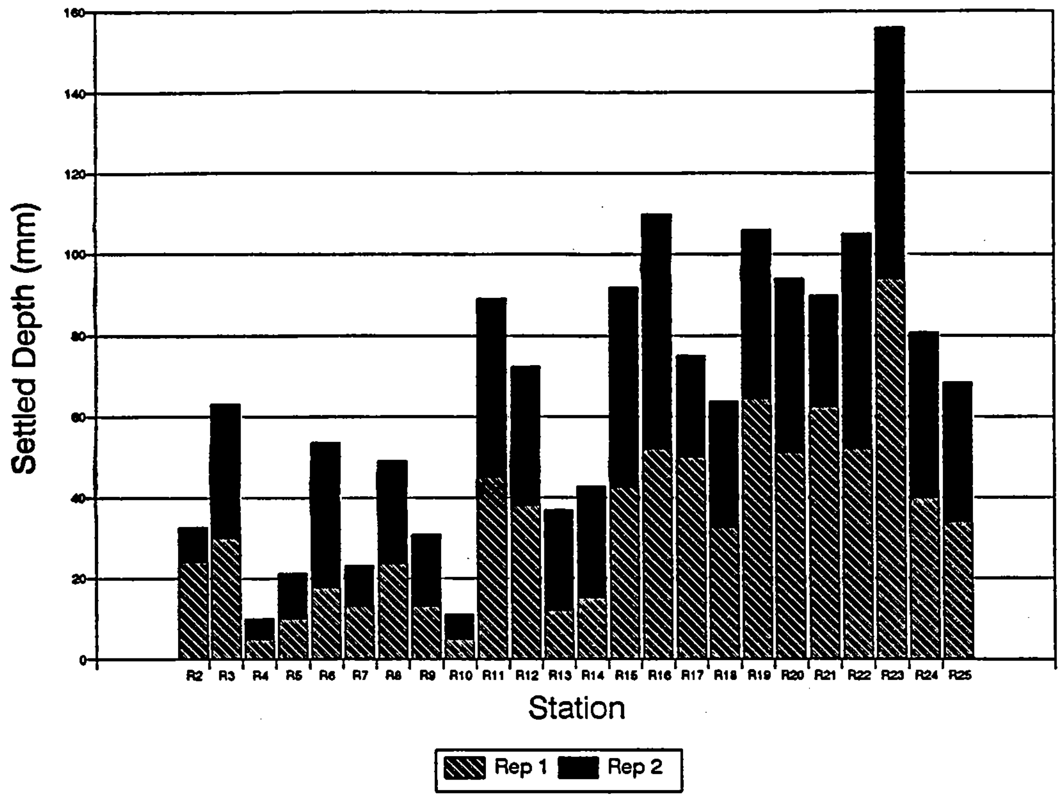


Figure 10. Material Collected at Rapid Stations by 0.5-mm Field Sieving.
Settled depth was measured in 14.5-cm diameter gallon jars in the laboratory prior to sample processing. Stations to the left were in the northern Harbor (R2 - R15), to the right were in the southern Harbor (R16 - R25).

characteristic to a small cluster of stations (*Phoxocephalis holbolli,* Lumbrineris), sometimes quite restricted spatially. For example, *Nucula delphinodata* was present only at R21 - R23. *N. delphindonta,* a community type-species usually thought to be indicative of a fairly undisturbed deposit-feeding community, was only found at T6 and T8 of the traditional stations, with T6 being part of the R21 - R23 region.

In general, the rapid station macrofauna geographic results were similar to those for traditional stations. Clearly, they help extend understanding and provide spatial resolution on the distribution and relative abundance of macrofauna in the Harbor.

Figure 11 offers an example of another use of the rapid data — display of all taxa at a station according to the sieve fraction they were retained on. Station R2 lies in the heart of a relatively depauperate area just inside Deer Island and is contrasted with a station in the center of the southern region (R24). Species richness and abundance differences at the two stations are obvious. The most abundant organism at R2 was relatively large (*Nassarius vibex*), whereas most of the highly abundant taxa at R24 were in the smaller, 1.0-mm or 0.5-mm, fractions.

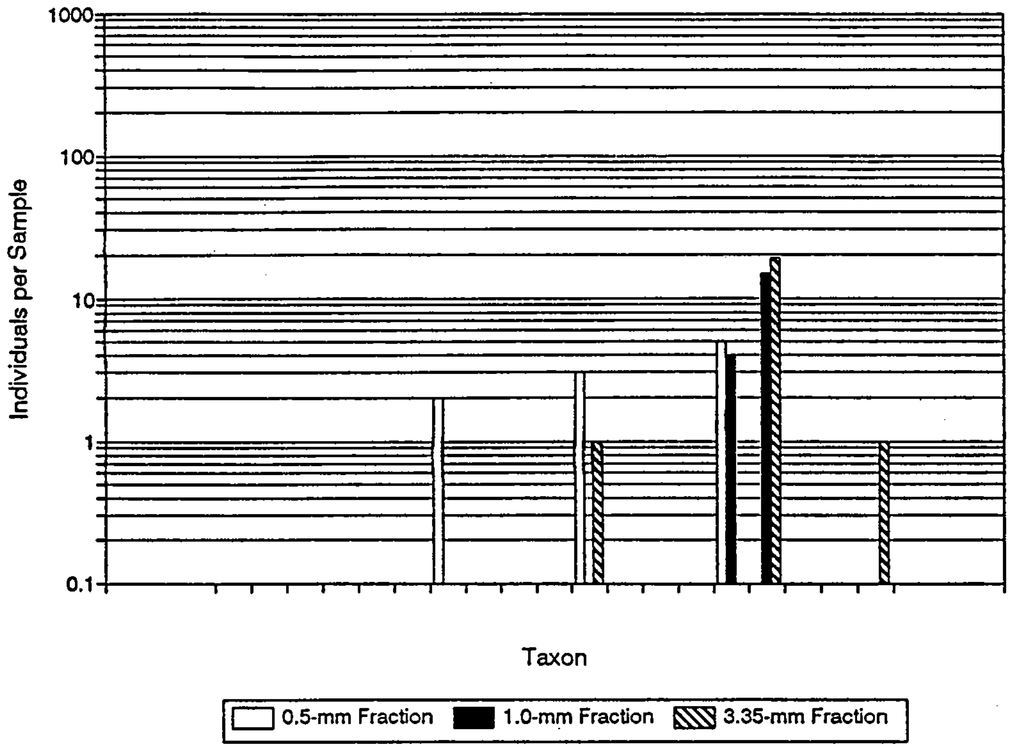
Other interesting size patterns may result from further analysis within or among stations, but results of the size fractions must be interpreted cautiously. For example, one numerous species at R24 in the 3.35-mm fraction was *Cirratulis grandis*, a cirratulid polychaete, whose tentacles, not strictly body form, apparently caused many individuals to be caught on the 3.35-mm sieve rather than the 1.0-mm sieve. One must also remember that traditional stations in the general area of R2, for example, had a high proportion of individuals in even smaller size categories (0.3-mm fraction).

3.3 SEDIMENT GRAIN SIZE

Data on the surface-sediment grain-size distribution at the 32 stations are given in Table 7. Gravel, sand, silt, and clay fractions are given as a percentage of total weight. The gravel fraction includes large shells; this was significant only at three stations. Results can also be expressed by normalizing the smaller size fractions after removal of the gravel category (Appendix, Table A-12).

Using normalized data, triangle plots show all stations (Figure 12). There was a range in percent sand from over 90% (R19, R8, T5) to low values of 27% (R4) and 12 % (T8); inversely corresponding, the percentage of highest silt at R4 and T8 (52%) and lowest at R19, R8, and T5. Variations in sand between sand and silt fractions primarily create the vertical dispersion in Figure 12. There were smaller variations in the percentage of clay, mostly between 1 and 20%, with the exceptions of T8 and R22, which had relatively high clay content (>30%). In general, the traditional stations and rapid stations displayed about the same range of conditions.

An example Harbor pattern, using percentage of silt as the measure, is given in Figure 13. There was a tendency towards higher percentage of silt in the northern Harbor, especially as compared to the southern region between Long Island and Peddocks Island (more sandy). However, there are pockets of low silt stations on Deer Island flats as well as high silt in two Hingham Bay stations.



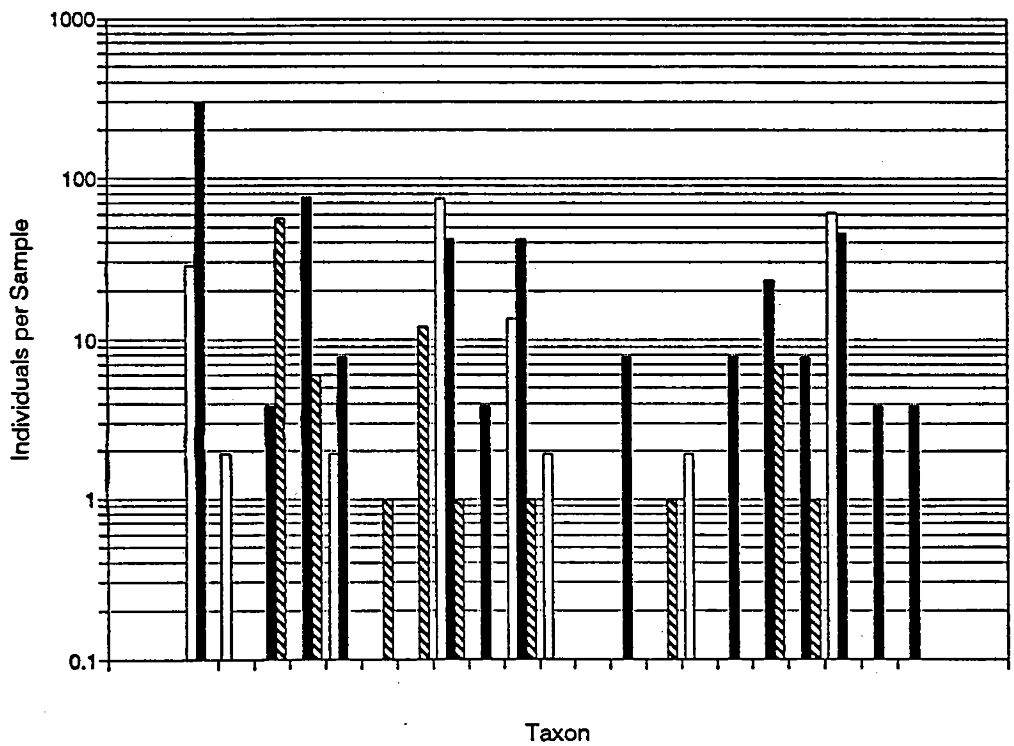


Figure 11. Comparison of Macrofauna Abundance at Station R2 (Northern Harbor) and Station R24 (Southern Harbor).

Data have been normalized for differences in percentage of collected sample that was sorted. Values were summed across two replicates.

Table 7. Sediment Parameters at the 32 Boston Harbor Stations.

Station	Gravel %	Sand %	Silt %	Clay %	TOC (wt %)	*Clostridium* (Spores/g Dry Wt.)
T1	1.3	83.6	11.9	3.2	2.64	11700
T2	0.2	63.6	27.8	8.5	1.75	22900
T3	0.0	44.1	39.1	16.8	3.69	207000
T4	0.0	32.3	48.6	19.1	3.70	30000
T5	0.3	93.4	4.2	2.1	1.46	30400
T6	0.1	65.6	25.1	9.2	1.81	29400
T7	1.8	57.3	27.3	13.6	2.73	13700
T8	0.0	12.1	52.2	35.7	0.87	7330
R2	0.5	54.6	33.8	11.1	2.87	73200
R3	0.0	52.9	38.8	8.2	1.90	60900
R4	0.0	27.2	52.1	20.7	2.51	85600
R5	0.0	36.8	48.7	14.5	2.33	35100
R6	0.2	78.2	20.3	1.3	0.99	5080
R7	0.0	48.9	38.0	13.1	2.83	99100
R8	6.6	87.8	5.4	0.2	0.28	1030
R9	1.0	68.9	22.1	8.0	1.73	30500
R10	0.3	85.4	9.6	4.8	3.36	30800
R11	0.1	41.9	43.0	15.0	3.57	92400
R12	0.0	40.9	44.5	14.7	3.53	60600
R13	0.7	45.6	40.4	13.2	3.32	18800
R14	15.3	57.2	20.9	6.7	2.69	19200
R15	15.5	42.0	30.7	11.9	2.00	43500
R16	0.6	71.0	20.0	8.4	2.54	26900
R17	0.0	42.5	42.7	14.8	3.32	19100
R18	0.6	56.2	31.1	12.1	3.04	18000
R19	15.7	79.8	2.6	1.8	0.56	2330
R20	0.2	46.3	37.6	15.9	3.34	76400
R21	1.2	71.4	18.8	8.6	2.27	31300
R22	0.7	46.9	20.2	32.2	2.99	44400
R23	0.8	76.4	14.6	8.2	3.07	24800
R24	0.0	61.4	27.3	11.3	2.67	11200
R25	0.0	37.8	45.9	16.3	2.86	42700

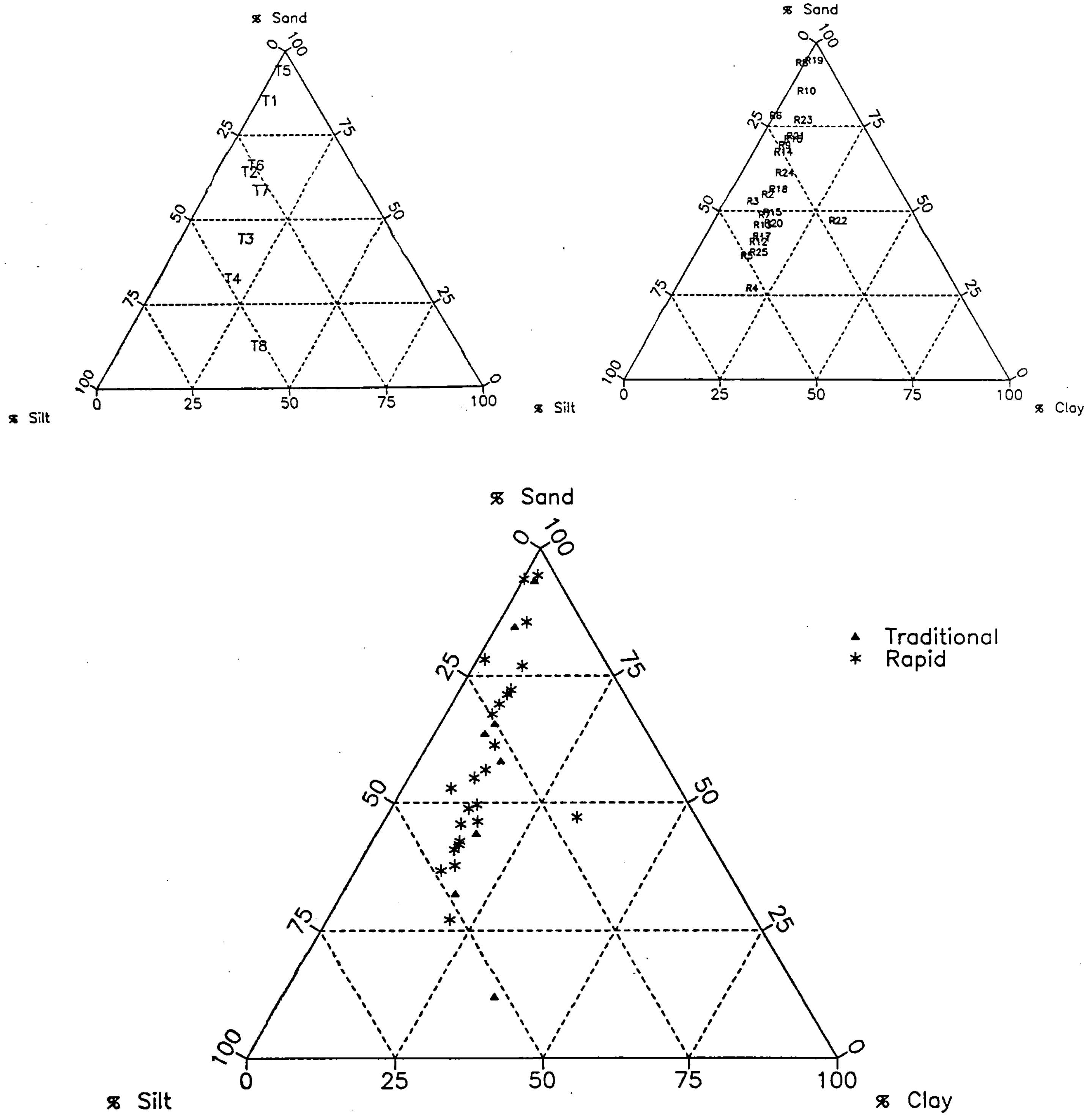


Figure 12. Sediment Grain Size at 32 Boston Harbor Stations.
Data were normalized after removing gravel fraction. Shadow figures give station codes.

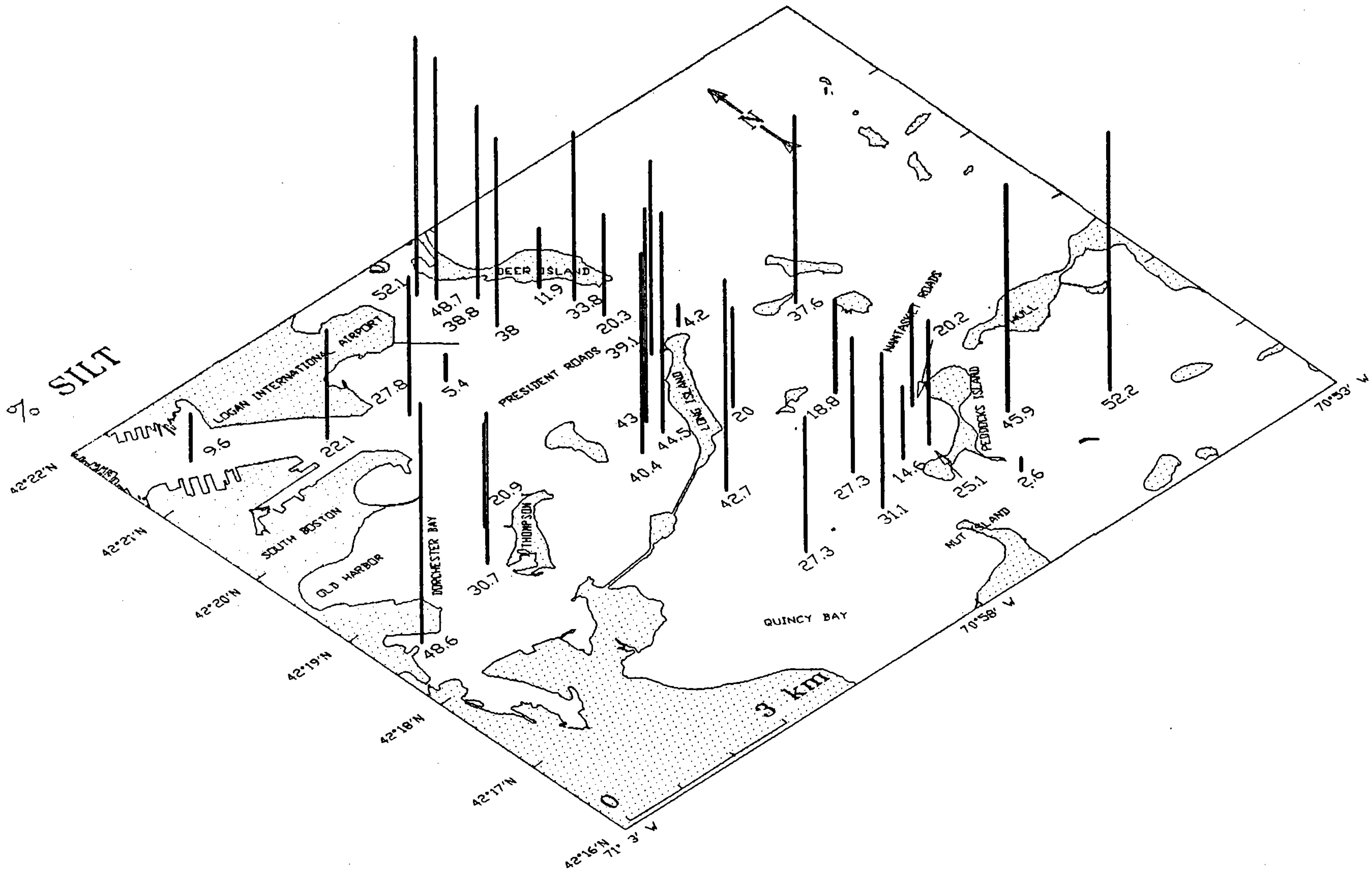


Figure 13. Percentage of Silt at the 32 Boston Harbor Stations.

Data were not normalized for gravel fraction.

3.4 TOTAL ORGANIC CARBON (TOC)

The sediment organic carbon content as a weight percent ranged from a low of 0.28% at R8 to high values at T3 (3.69%) and T4 (3.7%) (Table 7). The mean value for the 32 stations was 2.48% TOC. Duplicate analysis of five samples resulted in a mean standard deviation (n= 2 replicates) of 0.08% TOC. Finally, the rapid and traditional stations had a similar range of TOC.

Figure 14 gives results of TOC analyses throughout the Harbor. A region of high TOC runs along the station transect just north of Long Island (T3, R11 - R12) extending off the southern tip (R17), as well as to the inner western station, T4, near Fox Point. The inner Harbor Station R9 and the outer Harbor station (R20) also had high TOC. There were several low-TOC locations, with no particular spatial coherence, amidst the rest of the field having little distinct geographic pattern.

Figure 15 shows the result of comparing grain size and TOC across the stations. Using the fraction of silt + clay (= [1 - sand fraction] after normalization), there is a broad relation, with lower TOC at less silt + clay content. However, even omitting the muddy-low TOC point (T8), the scatter is high. Being a "muddier" or a sandier site does not alone fully determine the TOC content.

3.5 *CLOSTRIDIUM PERFRINGENS*

Counts of spores per gram dry weight of sediment (gds) are provided for each station in Table 7. Of the 32 stations, four had counts in the range of 10^3 spores gds^{-1}. Two of these stations (R6, R8) were in the northern Harbor, and two (R19, T8) were in the southern Harbor. Most of the stations (27) had counts in the range of 10^4 spores gds^{-1}. One station (T3) had a count of 2.07×10^5 spores gds^{-1}.

Previous, although limited, measurements of MWRA sludge solids recorded counts of 7×10^6 spores per gram dry weight (K. Keay, personal communication). The highest counts for this survey of Harbor sediments, thus were less than 3% of recorded sludge source values ($2 \times 10^5 / 7 \times 10^6$).

In general, highest counts were found in the northern rather than southern Harbor (Figure 16). In particular the highest counts were in two regions: (1) stations of the transect inside of Deer Island and (2) stations (T3, R11, R12) running along the northern side of Long Island away from its eastern tip, the source of sludge. Indeed, the highest counts were in a presumed depositional area (Station T3) most proximal to the sludge outfall (near Station T5, itself in a slightly more physically dynamic region and with more sandy sediments).

In general, the distributions of *Clostridium* and TOC had some similarities, which can be seen in the plot of log (*Clostridium*) vs. TOC Figure 17. Particularly at higher values of TOC, there is variation in *Clostridium* counts. There was a cluster of stations with relatively lower counts relative to TOC content (i.e., a group of points fell below a central trend connecting highest and lowest values). Analysis did not suggest that this cluster of stations (including T1, T4, and T7) had an obvious geographic orientation. The pattern in Figure 17 could also be interpreted as having a break in slope at about 2% TOC, with less strong relationship between the two parameters at higher concentrations.

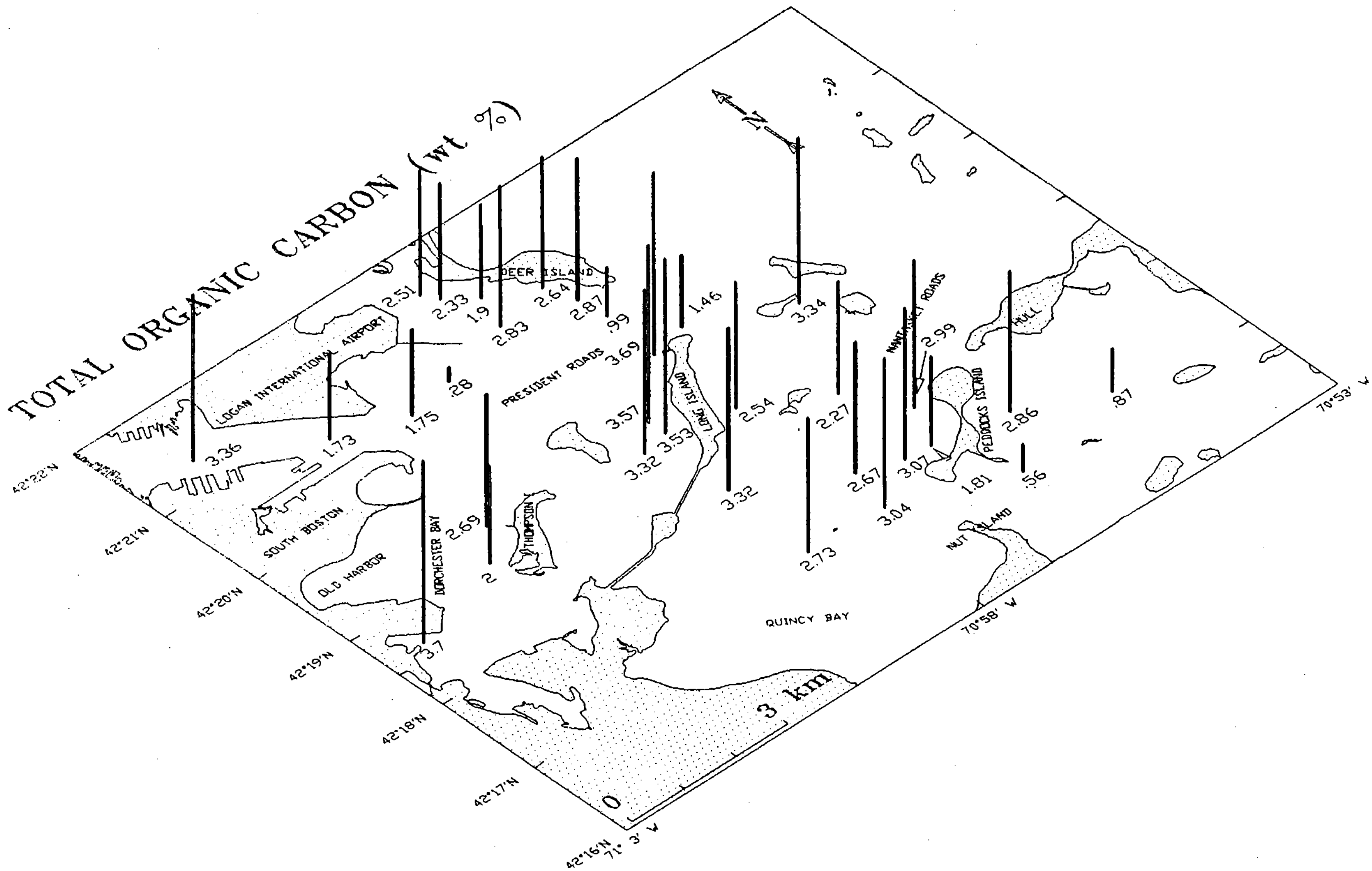


Figure 14. Total Organic Carbon at the 32 Boston Harbor Stations.

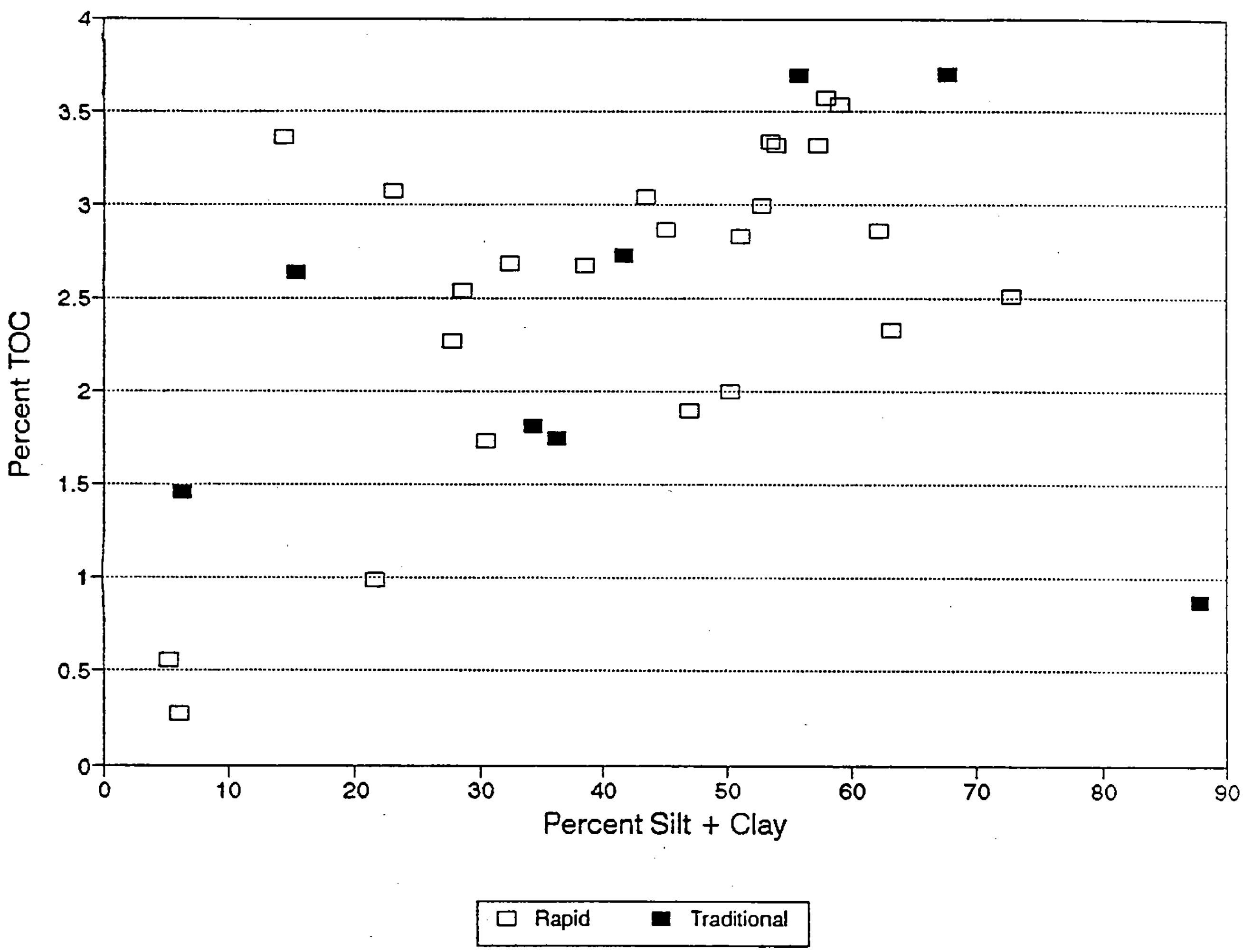


Figure 15. Relation Between Grain Size and TOC at the 32 Boston Harbor Stations.

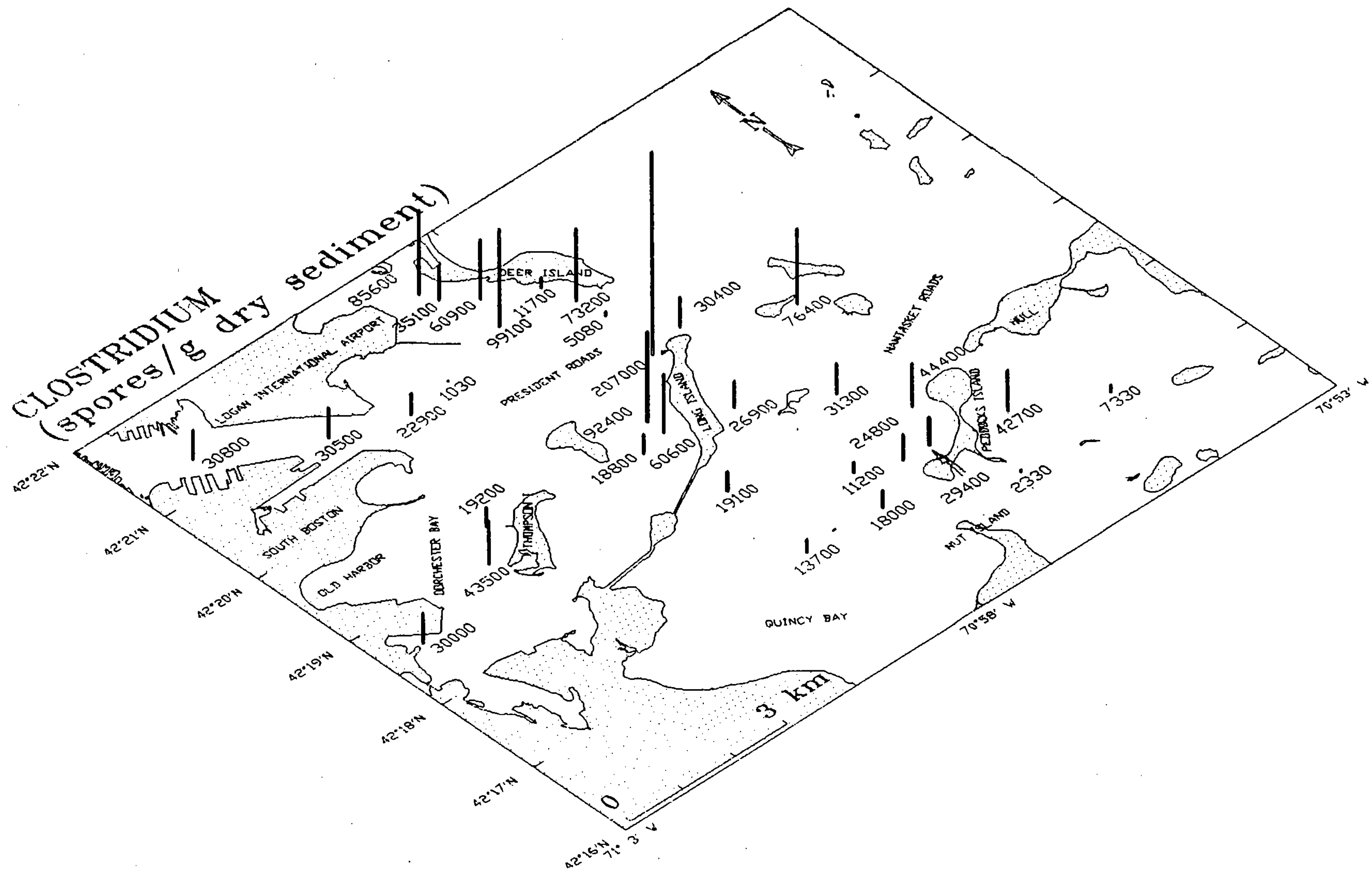


Figure 16. *Clostridium* **Spore Counts at the 32 Boston Harbor Stations.**

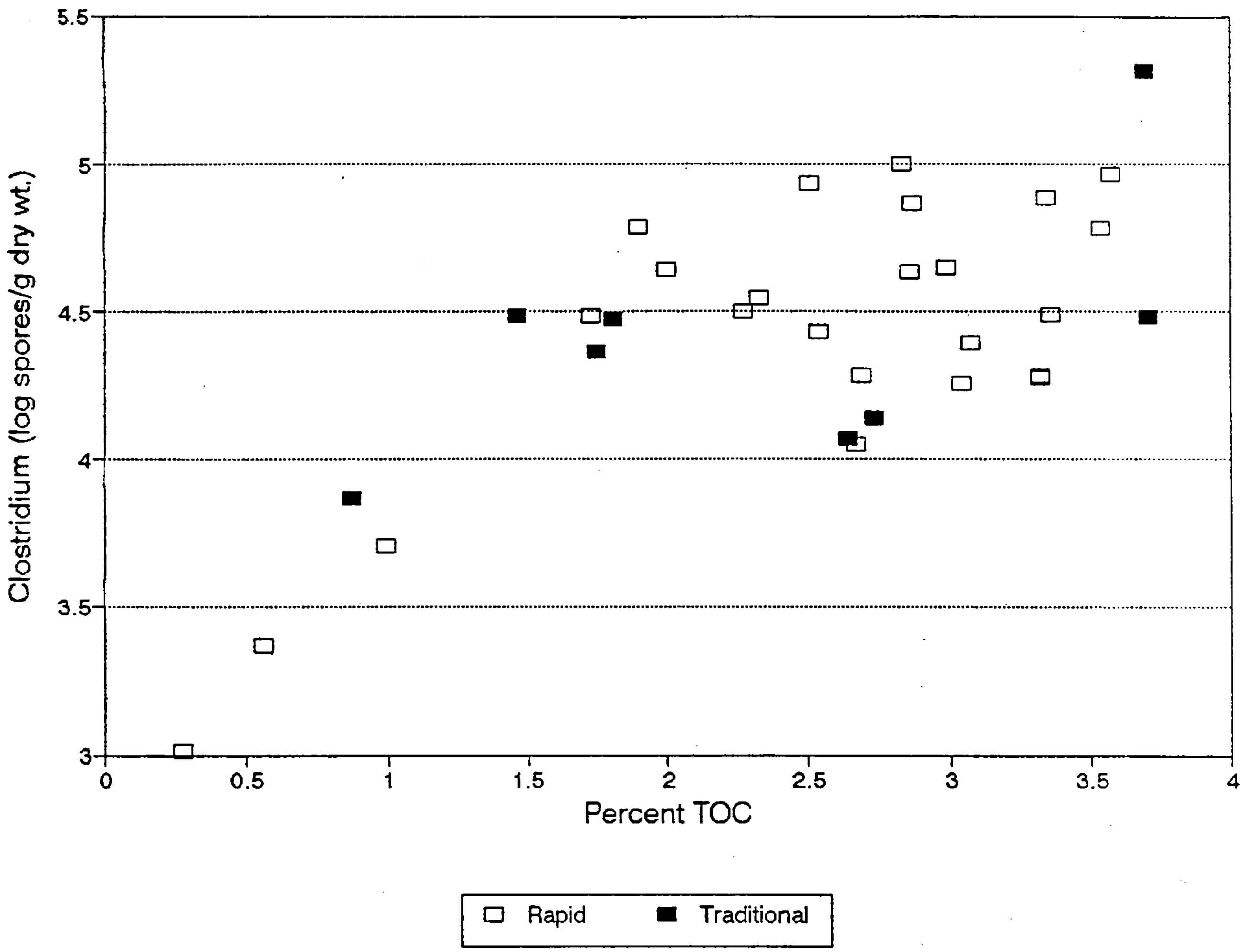


Figure 17. Relation Between TOC and *Clostridium* at the 32 Boston Harbor Stations.

3.6 SEDIMENT CAMERA IMAGING

As discussed, both inclement weather and initial equipment problems limited data collection via this rapid assessment technique, and scheduling did not allow for additional sampling days. Little camera penetration was achieved at Stations T1, T5, and R13 and the presumption of the camera analysis was that these were harder bottom stations, perhaps fine sands (Table 8). All three of these stations were successfully sampled by the grab sampler, direct grain size analysis indicated both T1 and T5 had a high percent of sand, supporting camera assumptions. In contrast, R13 was a muddy situation as determined by grab sampling; the bottom in that region may be patchy on a small scale, for the difference between grab sample location and camera location (Tables A-1 vs. A-2) was small (about 0.02′ Latitude and 0.01′ Longitude, where 0.01′ = about 18 m), within the limits of the navigation.

For those stations where camera drops were successful, computer analysis (Table A-13, A-14) and summary visual analysis (Table 8) are provided. A set of slides of these images are provided with this report. The principal result for the six stations in the northern Harbor that were characterized was that the stations were not distinctly different by imaging parameters, which is as expected, given results of sediment analysis of this and previous surveys. All six were characterized as silty or mud (silt-clay), which in general corresponds to the grab-sample data (Table 7), and had a fairly similar range of Redox Potential Discontinuity (RPD) depth of 0 to 2 cm (Table 8). Finally, several visual observations on station profiles (T2, T4, R7) indicated highly reduced areas near the surface of these stations.

3.7 OTHER OBSERVATIONS

Underwater videotaping during core collecting at stations T7, T2, and T3 showed visual differences in the sediment character. The most striking image, confirming the sediment camera results in the northern Harbor region, were the highly reduced sediments apparent at T3 (and to lesser extent T2). When core plugs were pulled out of the sediments, currents swept away black resuspended sediments from the resulting holes (which thus were termed "smokers").

Table 8. Sediment Profile Image Visual Analysis for Boston Harbor Stations.

Data for penetration and RPD depth are approximate. See Tables A-13, A-14 for exact measurements.

				SURFACE		SUBSURFACE FEATURES				
STATION	PEN. DEPTH	RANGE RPD DEPTH	SEDI. TYPE	SEDI-WATER INTERFACE	TUBES	INFAUNA TYPE	BURROWS	VOIDS TYPE	DEPTH	COMMENTS
T1-1	0cm		SF?	E/U,R						Hard bottom
T1-2	0		SF?	E/U,R,SH						Hard bottom
T1-3	0		?							Hard bottom
T1-4	0		SF?	E/U,R,SH						Hard bottom
T1-5	<1	?	SF	U,R,SH						Hard bottom, Gastropod?
T2-1	9	0-2cm	SI,MU	E						Highly reduced areas near surface
T2-2	8	0-2	SI,MU	U	?					Highly reduced areas near surface
T2-3	9	0-2	SI,MU	E,BU?						
T2-4	9	0-3	SI,MU	E						Chalky streaks in aerobic layer
T2-5	10	0-3	SI,MU	E				2G	7,7cm	Highly reduced areas near surface
T3-1	11	0-2	SI,MU	E						
T3-2	11	0-2	SI,MU	E	FEW?					
T3-3	11	0-2	SI,MU	E						
T3-4	11	0-2	SI,MU	E	?					
T3-5	11	0-2	SI,MU	E,CA						
T4-1	12	0-2	SI,MU	E						Dark sediment
T4-2	15	0-1	MU	E						
T4-3	15	0-1	MU	E/U,M?						Highly reduced areas near surface
T4-4	17	<1	MU	U,P				1G	11cm	
T4-5	17	0-2	MU	E						Highly reduced areas near surface
T5-1	0		?							Hard bottom
T5-2	0		?							Hard bottom
T5-3	0		?							Hard bottom
T5-4	0		?							Hard bottom
T6	No Images									
T7	No Images									
T8	No Images									
R4-1	9	0-1	SI,MU	E	?					
R4-2	11	0-1	SI,MU	E/U,M?,FL?						
R4-3	12	0-2	SI,MU	E/U,P?	?					
R4-4	12	0-2	SI,MU	U,CA,D?						
R4-5	12	0-2	SI,MU	U,P,CA?						
R7-1	5	0-2	SI,MU	E						
R7-2	6	0-1	SI,MU	E	1 LG?					
R7-3	9	0-2	SI,MU	E,M?	?					Highly reduced areas near surface
R7-4	7	0-2	SI,MU	E						
R7-5	7	0-1	SI,MU	U,P?orBU?						
R11-1	10	0-2	SI,MU	E	SOME?					Gastropod
R11-2	11	0-2	SI,MU	E	SOME					
R11-3	8	0-1	SI,MU	U,D						
R11-4	12	0-2	SI,MU	E	SOME?					
R11-5	10	0-2	SI,MU	E/U,P?,SH	SOME?					
R13-1	<1	?	SF?	U,D?,SH?						Hard bottom
R13-2	0		?							Hard bottom
R13-3	0		?							Hard bottom
R13-4	0		SF?	U,R,SH						Hard bottom

SH = SHELL HASH E = EVEN, SMOOTH FEW = 1 - 6 M = MOUND
SI = SILT U = UNEVEN SOME = 7 - 24 D = DISTURBED
SF = FINE SAND C = CLAST MANY = >24 F = FLOCK LAYER
MU = MUD P = PIT O = OXIC G = GAS FILLED VOID
R = PEBBLES,ROCKS BU = BURROW OPENING A = ANOXIC LG = LARGE

4.0 DISCUSSION OF STATION TRENDS AND RECOMMENDATIONS FOR FURTHER SURVEYS

4.1 SPATIAL PATTERNS IN THE SEDIMENTARY ENVIRONMENT

By keying on an individual sedimentary parameter, such as percentage of silt (Figure 13), one gains an understanding of the benthic environment of the Harbor as variable and patchy at both large and fine spatial scales. The diversity of the Harbor's sediments contrasts with the notion of the Harbor's water column as fairly homogeneous, which could be inferred by broad-scale monitoring of water-quality measures (e.g., Robinson *et al.*, 1990). Although the waters are indeed actively mixed by tides and winds, fine-scale sampling of the water column has provided evidence that distinct regional water masses within the Harbor can be identified (Battelle, 1991).

For the sediments, results showing one sediment parameter plotted vs. another (e.g., Figure 15) demonstrate considerable scatter and thus reinforce the notion of the Harbor's sediment environment as heterogeneous. On the other hand, the scatter in parameter—parameter plots including anthropogenically influenced parameters (e.g., Figures 15, 17) may simply suggest that regional (or highly localized) conditions act in some areas to override a Harbor-wide trend that otherwise would be possible given that waters are well mixed.

Looking at spatial distributions across several types of sediment parameters, in contrast to keying on one, brings some regional features into focus. Thus viewed, as next discussed, the results of this sediment survey suggest strong patterns, which in part coincide with regional features evident in the most thorough geological mapping of the Harbor to date (Knebel *et al.*, 1991).

Using measured sediment parameters (grain-size categories, TOC, and *Clostridium)*, we performed a cluster analysis after Z-score transformation within parameter (to standardize their relative importance to the cluster). Several groupings of the 32 stations were apparent from the resulting dendrogram (Figure 18), and these are graphically illustrated in Figure 19. One principal cluster was a broad regional association of stations along Deer Island flats, along Long Island, and in the protective "hummock" of the outer Harbor Islands (R20), a location where discharged sludge particles occasionally may be transported (K. Keay, personal communication). A subgrouping of this first cluster (Figure 18) included R5, T3, R13, and R17 in the same region, as well as R25 and T4 outside of the region, but also within depositional environments as categorized by Knebel *et al.* (1991) (Figure 20). A second major grouping broadly encompassed the region between Long Island and Peddocks Island and into Quincy Bay (T7), which was coupled also with the inner Harbor transect (R9, R10, T2) and also T1 (outside of the main depositional region along Deer Island flats). In general, the cluster covers much of the south central Harbor's area classified as sediment reworking (Figure 20), a category into which T1 most likely falls (Figure 20). R6 and T5, straddling President Roads was a distinct grouping, somewhat associated with the second grouping, but from a distinctly erosional environment (Figure 20). The remainder of the stations were more individualistic in terms of their characteristics, excepting the R14/R15 cluster in a depositional area north of Thompson Island. The relation among parameters at those six stations did not adhere to a pattern, and each of these stations appears to be in either an area of high spatial heterogeneity or a transition between different sedimentary environments.

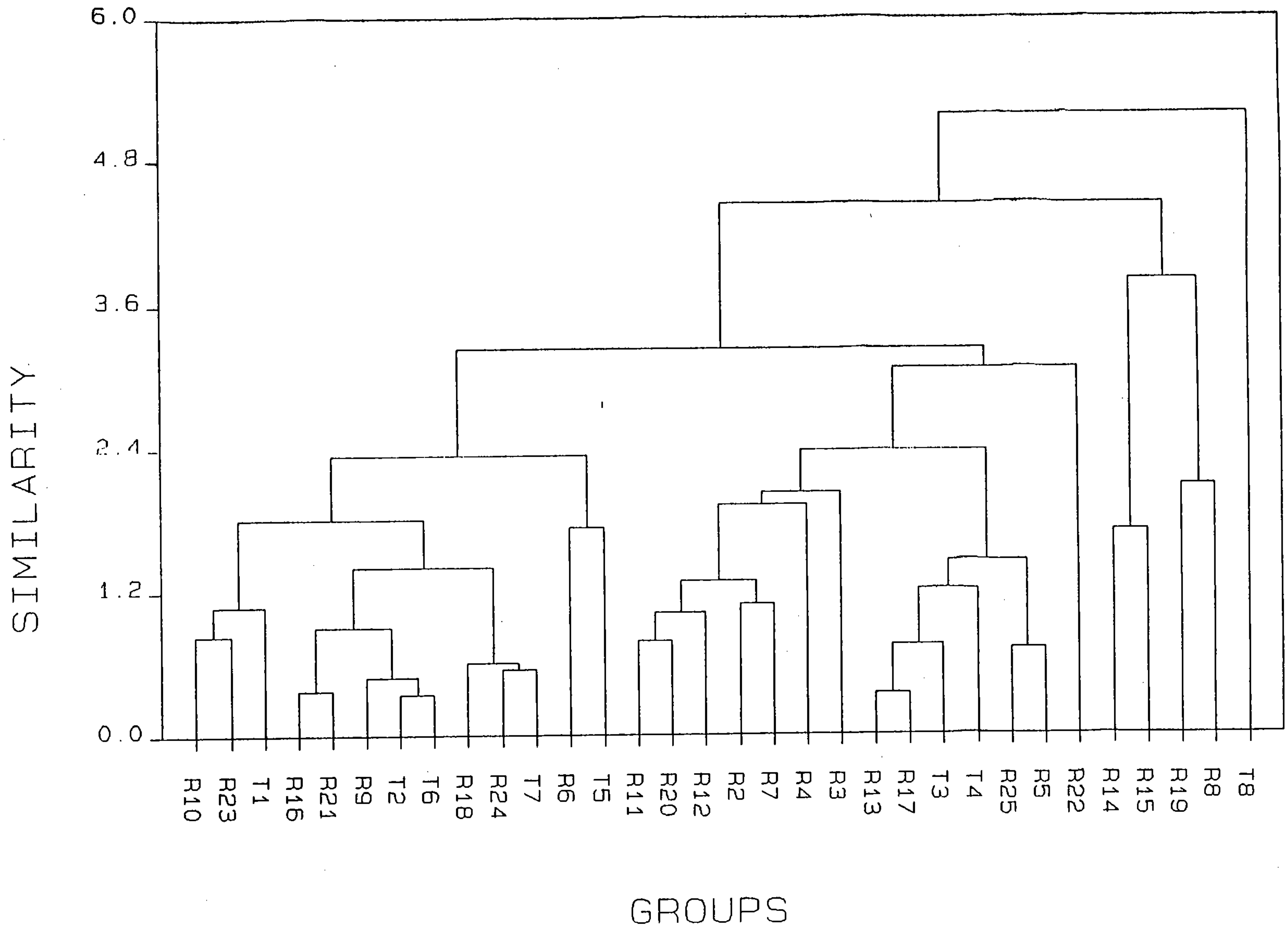


Figure 18. Cluster Dendrogram of 32 Stations Based on Sediment Parameters.
Data included % gravel, sand, silt and clay; TOC; and *Clostridium*.
Clustering used a Euclidean distance algorithm after Z-score standardization for each parameter.

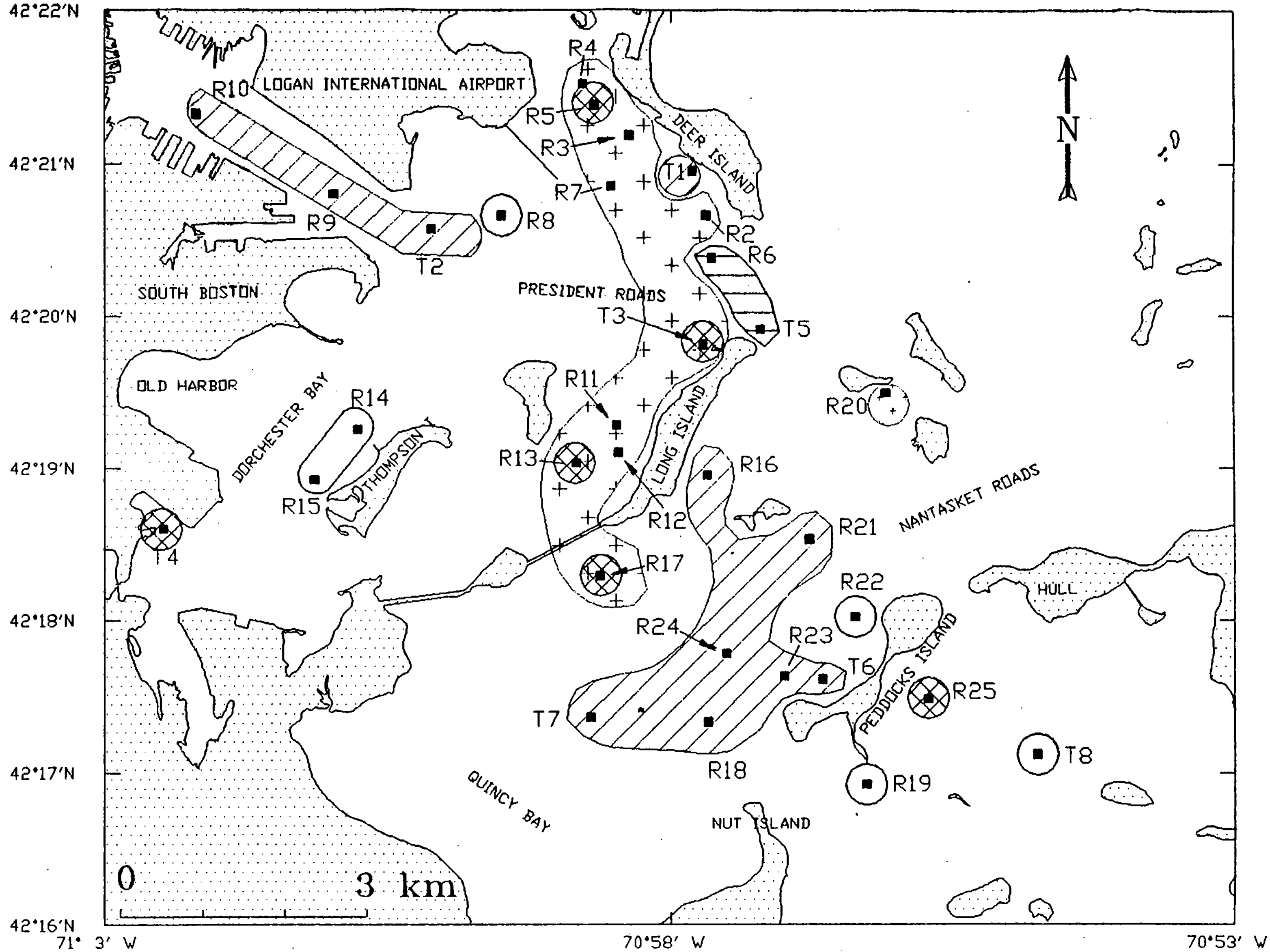


Figure 19. Sedimentary Environment Regions Among the 32 Boston Harbor Stations.

Groupings were based on the data of Table 7, as clustered in Figure 18.

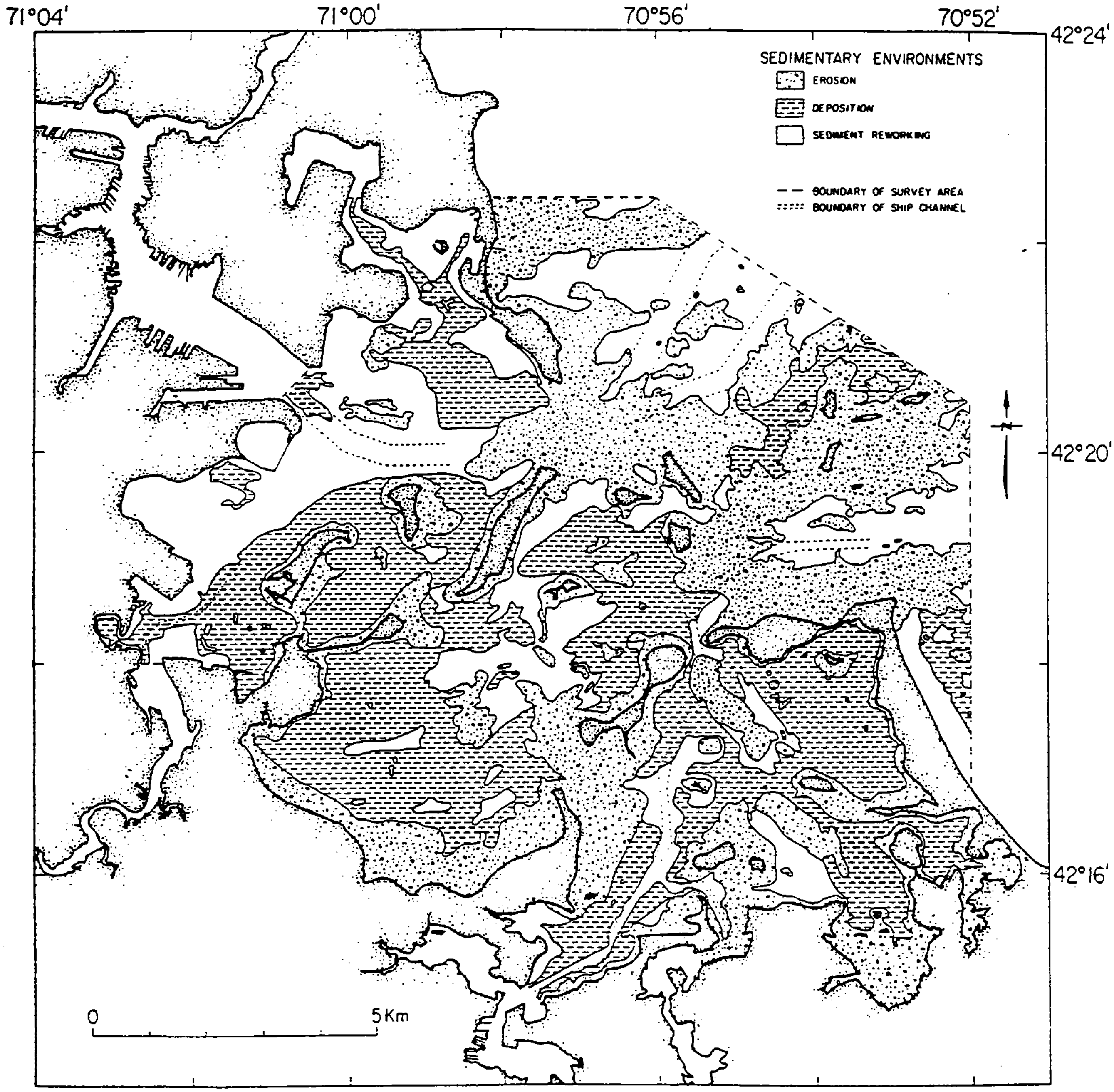


Figure 20. Mapping of Major Sedimentary Environments in Boston Harbor.
Based on geological features measured throughout the Harbor [From Knebel *et al.*, 1991].

4.2 SPATIAL PATTERNS OF BENTHIC MACROFAUNA

Traditional stations were well chosen in the sense that they had a strong individual signature. Replicate grabs, to a high degree, were similar, and replicates, for the most part, were more alike within a station than among stations. Thus, there was strong pattern at the finest spatial scales of the study.

To some extent, the macrofaunal patterns at the Harbor-wide scale and from the traditional station data contrast with the sedimentary environment patterns. The main example involves Station T3 in the heart of the environmental region proximal to major MWRA discharges, and which had highest *Clostridium* and high TOC. Station T3, although clearly with its own taxonomic signature, had a number of characteristics similar to the southern group of T6, T7, and T8. Note that the southern group (excepting T8) itself is proximal to MWRA effluent discharge north of Nut Island, but nevertheless the southern group in general had less TOC and *Clostridium* counts.

In a preliminary effort to look at whether certain select, sometimes dominant, species at the traditional stations might be correlated strongly with an environmental variable and thus be potential indicators, we examined the plots of the abundance of Oligochaeta, *Aricidea catherinae, Streblospio benedicti,* and *Ampelisca* spp. vs. grain size, TOC, and *Clostridium*. No strong patterns were evident, probably an indication that these fauna are not selectively related to one environmental variable. However, high scatter in biological-environmental plots partially may be a function of the small number of sites, where one station easily skews the results.

Inspection of the rapid station data (Tables 5 and 6) suggest a tentative conclusion that regional features are evident in the macrobenthos and many roughly coincide with the environmental characterization. At the least, a northern-southern Harbor distinction was apparent from the pattern shown by the tables, with fewer numbers and fewer taxa to the north.

Further analyses of the data should be completed, but provisionally, the regions in the north most likely heavily influenced by MWRA sludge or effluent discharge (Battelle, 1991) seem fairly coherent and distinct with respect to the macrobenthic community, especially after stratifying samples by sediment parameters within a region (e.g., R6, T1, and T5 are environmentally a bit different from T3 and others in that geographic region). Studies should continue to focus on the Long Island — Deer Island region as one prime indicator region of recovery from sludge abatement, and later effluent diversion.

4.3 MONITORING RECOVERY FROM SLUDGE ABATEMENT

Harbor recovery could involve events at different spatial scales and as mediated by complex physical dynamics operating over a wide range of temporal and spatial scales. It may be difficult to document the interaction and pace of broad-scale ecological changes with highly localized events, and this presents a primary challenge for a monitoring program. To add to the challenge, there are concomitant changes in other potential sources of perturbation occurring currently, and the ecological response to one current change — abatement of sewage-sludge discharge — has to be observed against a background "noise" of response to multiple and cumulative change.

Given the backdrop, it is encouraging that survey data appear to allow identification of some environmental and biological regions within the Harbor. MWRA should continue to employ, and if possible enhance, the regional sampling framework to assess the signals of change in relation to MWRA source reductions.

The expectations for biological change in terms of sludge recovery could include expansion of organisms now dominant elsewhere toward regions with high TOC/*Clostridium* as the sediment quality of those regions changes. It is difficult to know if changes along Long Island, for example, would lead to a benthic community more like the south-central region north of Nut and Peddocks Island because the latter area is influenced by present effluent discharge, much as the inner Deer Island region is likely influenced by effluent discharge in President Roads. We need more than one sampling station within identifiable regions to provide greater statistical power for assessing changes.

The general study/sampling strategy recommended from this preliminary assessment of the baseline data is as follows and could be updated with further statistical analyses of the data presented in this report:

- Continue monitoring the macrobenthos at the eight traditional stations. These provide a solid, broad base for the whole Harbor. Sampling should include a colder season (March/April), as well as again in the warm season (August/September). Sampling should continue with nested 0.5- over 0.3-mm sieves.
- Continue and perhaps expand the rapid biological assessment stations. For the cold survey, it would be advantageous to supplement the traditional stations with at least two rapid stations from the Deer Island flats region, two from those fringing Long Island to supplement T3, one or two in the south-central region to supplement T6/T7, one in Hingham Bay to supplement T8, and perhaps one in the inner Harbor to supplement T2. For the summer survey, again measure the 24 rapid stations, and consider supplemental stations randomly chosen within major environmental regions to further round out coverage and provide maximal ability to document regional recovery.

The present traditional stations provide good overall spatial representation and regional type, with one exception (below). Importantly, these stations provide a firm statistical foundation for assessing change in that there was strong coherence among replicate grabs, and the stations each had some unique features in spite of regional associations. In short, the power to assess temporal change at a given station relative to other stations may aid in examining cause and effect in a situation where both broad-scale (Harbor-wide) change and more localized changes may be realized from reduction of some point-source discharges that can be mixed effectively throughout a wide region.

There was no traditional station representative of the main region inside Deer Island (T1 was in a pocket somewhat different from R2, R3, R4, R5, and R7). Since the total 0.5-mm fraction from the rapid assessment is available, was collected by the same method, and represents the same size sample, one of these R stations could provide a baseline for 1991 if analyzed fully; a 0.3-mm sieve fraction however was not collected. We suggest including in future surveys an additional station for full traditional analyses from among the group of present R stations on Deer Island Flats.

The present rapid stations successfully provided spatial resolution and seem to allow definition of environmental and biological regions within the Harbor. Additionally, the rapid technique provided a partially analyzed sample, which can be completed fully with only minor additional effort if the need arises. For example, where a traditional station of the regional group appeared to change relative to others and relative to a source reduction, R stations within that group could be used to test for evidence of regional change.

A few additional rapid stations might be considered, both in time and space. With respect to time, as indicated above, additional R stations should be included in a colder-season 1992 sampling. Sludge discharge just ceased in December 1991. Since it would be prior to onset of warmer temperatures, this first 1992 sampling may well provide additional baseline information; thus, it may be wise to obtain additional samples, stratified by region as indicated, for future reference.

With respect to space, there should be additional consideration to provide supplemental R stations. In particular, stations in the heart of Quincy Bay and Hingham Bay would better define those regions; the importance of those regions is that some stations in them (T7, T8) may serve, statistically, as less affected "reference sites." As noted above, one traditional station (T8) may not be fully representative of its geographic region, which is characterized by several patches of different sediment types (Figure 20). Station T8 may be at or near a sedimentary environment transition zone. Nevertheless, the species composition suggested a less disturbed condition than most places surveyed in the Harbor, which alone compels continued monitoring; but if small-scale spatial variability compromises successful re-sampling then it has less utility as reference condition. This potential problem could be overcome by supplemental sampling via the rapid assessment approach.

5.0 ACKNOWLEDGMENTS

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APPENDIX A

Table A-1. Field Log for Grabs at Each Station, including Navigation and Comments.						
Station	**Date and Time (EDT)**	**Grab**	**Latitude Longitude**	**LORAN Time Delays**	**Depth (m)**	**Comments**
R19	09/16/91	1	42°16.92'N 70°56.23'W	14031.3 25809.2	8.8	Grab 3/4 full, sloping slightly on both sides. Considerable shell hash and sand over anoxic mud.
		2	42°16.92'N 70°56.27'W	14031.5 25809.5	9.7	Good grab, 3/4 full. Sand and shell hash overlying anoxic mud.
		3	42°16.92'N 70°56.28'W	14031.5 25809.5	9.6	Grab good, 3/4 full, sloping on both sides. Much shell hash. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
R18	09/16/91	1	42°17.33'N 70°57.67'W	14038.6 25822.0	7.9	Good full grab, level, brown floc overlying anoxic mud. Much organic matter.
		2	42°17.30'N 70°57.70'W	14038.6 25822.0	8.0	Good full level grab. Brown floc overlying anoxic mud.
		3	42°17.30'N 70°57.70'W	14038.6 25821.9	7.8	Good level grab, 3/4 full. Brown floc overlying anoxic mud. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
T7	09/16/91	1	42°17.59'N 70°58.52'W	14042.7 25829.6	5.3	Grab 3/4 full, sloping on both sides. Lots of shell hash overlying anoxic mud. Lots of dead mussel shells.
		2	42°17.49'N 70°58.56'W	14043.5 25829.4	4.1	Grab 1/2 to 3/4 full, sloping. Much shell hash. Difficult to acquire good samples. Decided to move to a location where mud is expected (approximately 200 m southwest of original location). Will call new location T7A.
T7A	09/16/91	1	42°17.36'N 70°58.71'W	14044.9 25829.6	5.2	Good grab 3.4 full. Undisturbed — brown floc overlying anoxic mud.
		2	42°17.37'N 70°58.70'W	14044.9 25829.6	5.0	Good grab 3/4 full. Same as Rep. 1.
		3	42°17.37'N 70°58.69'W	14044.9 25829.6	5.2	Same as Reps 1 and 2.
		4	42°17.38'N 70°58.70'W	14044.9 25829.6	5.0	3/4 full grab. Undisturbed surface. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
T6	09/16/91	1	42°17.61'N 70°56.66'W	14030.6 25816.3	4.9	Good grab, 3/4 full. Sloping on one side. Brown surface over anoxic mud and silt. Lots of detritus.
		2	42°17.60'N 70°56.66'W	14030.7 25816.2	5.1	3/4 full grab. Same as Rep. 1. Snails observed.
		3	42°17.60'N 70°56.66'W	14030.6 25816.2	5.1	Good grab. 3/4 to full. Same as Reps. 1 and 2. Milk worm and hermit crab observed.

Table A-1. Field Log for Grabs at Each Station, including Navigation and Comments. *(continued)*

Station	Date and Time (EDT)	Grab	Latitude Longitude	LORAN Time Delays	Depth (m)	Comments
		4	42°17.60'N 70°56.67'W	14030.8 25816.3	5.0	Full grab. Same as Reps. 1, 2, and 3. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
R23	09/16/91	1	42°17.63'N 70°57.00'W	14032.6 25818.8	10.5	Full grab. Lots of detritus.
		2	42°17.64'N 70°57.00'W	14032.7 25818.9	10.4	3/4 full. Good grab level surface. Lots of detritus brown floc overlying anoxic mud and silt.
		3	42°17.64'N 70°57.00'W	14032.5 25818.9	10.7	3/4 full grab. Same as Reps. 1 and 2. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
T8	09/17/91	1	42°17.12'N 70°54.75'W	14020.6 25799.6	12.7	1/2 to 3/4 full grab. Undisturbed surface sloping on all sides. Much detritus. Fine silt. Snails.
		2	42°17.12'N 70°54.75'W	14020.6 25799.6	12.7	1/2 to 3/4 full grab. Acceptable. Sediments undisturbed and sloping on all sides. Fine silt. Snails.
		3	42°17.12'N 70°54.75'W	14020.6 25799.6	12.3	Full grab (removed foot pads). Slightly overpenetrated. Sediments undisturbed sloping on one side. Same as Reps. 1 and 2.
		4	42°17.12'N 70°54.75'W	14020.7 25799.7	12.6	Full grab. Same as Reps. 1, 2, and 3. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
R25	09/17/91	1	42°17.48'N 70°55.72'W	14025.1 25808.8	6.8	3/4 full. Good undisturbed grab. Surface level. Brown floc overlying anoxic mud. Amphipods and polychaetes. Much detritus.
		2	42°17.49'N 70°55.72'W	14025.0 25808.6	6.7	Same as Rep. 1.
		3	42°17.49'N 70°55.72'W	14025.1 25808.6	6.7	Same as Reps. 1 and 2. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
R20	09/17/91	1	42°19.49'N 70°56.10'W	14017.8 25823.1	9.7	Rocks at planned site. Moved site towards Gallops Island. 3/4 full undisturbed grab. Surface level. Brown floc overlying anoxic mud. considerable detritus. Shrimp and polychaetes.
		2	42°19.50'N 70°56.09'W	14017.4 25822.8	9.0	Same as Rep. 1. Good 3/4 full grab.
		3	42°19.50'N 70°56.09'W	14017.5 25823.0	9.3	Same as Reps. 1 and 2. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.

Table A-1. Field Log for Grabs at Each Station, including Navigation and Comments. *(continued)*						
Station	**Date and Time (EDT)**	**Grab**	**Latitude Longitude**	**LORAN Time Delays**	**Depth (m)**	**Comments**
T5	09/17/91	1	42°19.90'N 70°57.21'W	14022.9 25833.4	6.9	Full grab. Sediment black anoxic. Lots of silt. Organic smell. Near Long Island outfall. Sediment surface level.
		2	42°19.91'N 70°57.21'W	14022.2 25833.2	6.8	3/4 full grab. Same as Rep. 1.
		3	42°19.92'N 70°57.20'W	14022.3 25832.9	7.0	3/4 full grab. Same as Reps. 1 and 2.
		4	42°19.91'N 70°57.21'W	14022.6 25833.1	7.1	3/4 full grab. Surface sloping on 1 side. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
T3	09/17/91	1	42°19.81'N 70°57.72'W	14026.8 25836.6	8.1	Full grab. Surface undisturbed and level. Brown floc over anoxic mud. Much detritus, light silt.
		2	42°19.80'N 70°57.71'W	14026.7 25836.5	7.7	Full grab. Same as Rep. 1
		3	42°19.80'N 70°57.70'W	14026.5 25836.4	7.8	Same as Reps 1 and 2.
		4	42°19.80'N 70°57.72'W	14026.8 25836.6	7.9	Same as Reps. 1, 2, and 3. Decon grab with acetone and DCM. Using 0.04 m^2 grab with bio screens.
R11	09/17/91	1	42°19.28'N 70°58.48'W	14034.2 25839.0	7.0	Full grab. Surface undisturbed level. Brown floc overlying black mud. Lots of detritus. Polychaetes.
		2	42°19.30'N 70°58.50'W	14034.1 25839.1	6.9	Full grab. Surface undisturbed and level. Same as Rep. 1.
		3	42°19.30'N 70°58.50'W	14034.1 25839.1	6.9	Same as Reps. 1 and 2. Decon grab using acetone and DCM. Using 0.04 m^2
R12	09/16/91	1	42°19.10'N 70°58.47'W	14035.3 25837.9	6.3	Grab full. Surface undisturbed and level. Brown floc over anoxic mud. Much detritus. Shrimp.
		2	42°19.09'N 70°58.47'W	14034.9 25837.8	5.9	Same as Rep. 1
		3	42°19.10'N 70°58.48'W	14035.0 25837.8	6.0	Same as Reps. 1 and 2. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
R13	09/17/91	1	42°19.03'N 70°58.84'W	14037.7 25840.2	7.2	1/2 to 3/4 full grab. Surface undisturbed level. Much detritus. Polychaetes.
		2	42°19.05'N 70°58.82'W	14037.5 25840.1	7.1	Same as Rep. 1.

Table A-1. Field Log for Grabs at Each Station, including Navigation and Comments. *(continued)*

Station	Date and Time (EDT)	Grab	Latitude Longitude	LORAN Time Delays	Depth (m)	Comments
		3	42°19.03'N 70°58.85'W	14037.8 25840.2	7.4	Same as Rep. 1. Decon grab. Using 0.04 m^2 grab with bio screens. Decon using acetone/DCM.
R17	09/17/91	1	42°18.29'N 70°58.63'W	14039.9 25834.3	8.2	3/4 to full grab. Surface level and undisturbed. Brown floc overlying anoxic mud. Much detritus.
		2	42°18.29'N 70°58.63'W	14039.8 25834.4	8.0	Same as Rep. 1.
		3	42°18.29'N 70°58.63'W	14039.8 25834.3	8.1	Same as Reps. 1 and 2. Decon grab using acetone and DCM. Using 0.04 m^2 grab with bio screens.
R24	09/18/91	1	42°17.78'N 70°57.52'W	14035.4 25823.5	7.9	3/4 full grab (0.04 m^2). Surface level flat. Detritus visible.
		2	42°17.78'N 70°57.51'W	14035.0 25823.0	8.3	Same as Rep. 1.
		3	42°17.78'N 70°57.51'W	14035.2 25823.3	7.5	Same as Reps 1 and 2. Grab clean with acetone and DCM. 0.04 m^2 grab with bio screens.
T1	09/18/91	1	42°20.95'N 70°57.81'W	14021.6 25843.6	5.6	3/4 full grab level Sed. Many polychaetes, worms, shrimp. Construction on shore.
		2	42°20.95'N 70°57.81'W	14021.8 25843.7	5.3	3/4 full. Level Sed. Same as Rep. 1.
		3	42°20.95'N 70°57.81'W	14021.7 25843.6	5.4	Identical to Reps. 1 and 2.
		4	42°20.95'N 70°57.81'W	14021.7 25843.7	5.4	Grab 0.04 m^2 with bioscreens. Clean with DCM and acetone. Identical to Reps. 1, 2, and 3.
R3	09/18/91	1	42°21.18'N 70°58.37'W	14024.3 25849.2	5.1	3/4 full grab. Easy sieve. Polychaetes.
		2	42°21.18'N 70°58.37'W	14024.0 25849.0	5.3	Identical to Rep. 1. 3/4 full.
		3	42°21.18'N 70°58.37'W	14023.7 25848.9	5.2	Same as Reps. 1 and 2. Cleaned for Chem. Coast Guard reported oil slick in area — no visual. 0.04 m^2 grab with screens.
T2	09/18/91	1	42°20.57'N 71°00.12'W	14038.6 25858.4	7.4	3/4 full grab. No worms. Strong odor. Sediment level flat.
		2	42°20.57'N 71°00.12'W	14038.4 25858.1	7.1	Same as Rep. 1.
		3	42°20.58'N 71°00.12'W	14038.2 25858.0	7.4	Identical to Reps. 1 and 2.

Table A-1. Field Log for Grabs at Each Station, including Navigation and Comments. *(continued)*

Station	Date and Time (EDT)	Grab	Latitude Longitude	LORAN Time Delays	Depth (m)	Comments
		4	42°20.58'N 71°00.11'W	14038.5 25858.2	7.1	Grab cleaned with DCM and acetone. Level surface. 3/4 full. 0.04 m^2 grabs with bio screens.
R8	09/18/91	1	42°20.66'N 70°59.50'W	14034.1 25854.2	2.8	Sand gravel. 3/4 full grab.
		2	42°20.66'N 70°59.50'W	14034.2 25854.2	2.8	Same as Rep. 1. Fine sand. Many worms and worm tubes.
		3	42°20.66'N 70°59.50'W	14034.5 25854.4	2.6	Cleaned with DCM and acetone. Identical to Reps. 1 and 2. 0.04 m^2 grab with bio screens.
R7	09/18/91	1	42°20.85'N 70°58.53'W	14027.1 25848.5	5.9	3/4 full. Strong odor. Black anoxic. No life.
		2	42°20.85'N 70°58.54'W	14027.0 25848.3	6.1	Same as Rep. 1
		3	42°20.85'N 70°58.54'W	14027.0 25848.4	5.7	Same as Reps. 1 and 2. Cleaned with DCM and acetone. 0.04 m^2 grab with bio screens.
R9	09/18/91	1	42°20.80'N 71°00.98'W	14043.1 25865.7	11.8	3/4 full. Dark thin sediment. Few sand shrimp.
		2	42°20.81'N 71°00.99'W	14043.3 25865.8	11.7	3/4 full. Dark thin sediment. Some sand shrimp. No polychaete. Some clam worms.
		3	42°20.82'N 71°00.99'W	14043.0 25866.0	11.7	Same as Reps. 1 and 2. Grab cleaned with DCM and acetone. 0.04 m^2 grab with bio screens.
R10	09/18/91	1	42°21.32'N 71°02.20'W	14048.4 25877.5	13.5	3/4 full. Fine sediment. Sieving down to low volume. No life.
		2	42°21.31'N 71°02.20'W	14048.4 25877.3	12.9	Same as Rep. 1.
		3	42°21.31'N 71°02.20'W	14048.5 25877.4	13.0	Clean with DCM and acetone. 3/4 full. Same as Reps. 1 and 2. 0.04 m^2 grab with bio screens.
T4	09/18/91	1	42°18.60'N 71°02.49'W	14063.6 25864.2	3.4	3/4 full grab. Sulfide bacteria on surface, strong odor, black fine sediment.
		2	42°18.60'N 71°02.49'W	14063.6 25864.4	3.4	Same as Rep. 1
		3	42°18.60'N 71°02.48'W	14063.4 25864.3	3.8	Same as Reps. 1 and 2.
		4	42°18.59'N 71°02.48'W	14063.6 25864.3	4.2	Same as Reps. 1, 2, and 3. Cleaned grab with DCM and acetone. 0.04 grab with bio screens.
R15	09/18/91	1	42°18.93'N 71°01.13'W	14053.3 25856.4	3.6	3/4 full. Mussels and shell fragments, crabs. Black fine silt.

Table A-1. Field Log for Grabs at Each Station, including Navigation and Comments. *(continued)*

Station	Date and Time (EDT)	Grab	Latitude Longitude	LORAN Time Delays	Depth (m)	Comments
		2	42°18.92'N 71°01.15'W	14053.0 25856.3	3.6	Same as Rep. 1.
		3	42°18.92'N 71°01.15'W	14053.1 25856.4	3.6	Same as Reps. 1 and 2. Cleaned with DCM and acetone. 0.04 m^2 grab with bio screens.
R14	09/18/91	1	42°19.25'N 71°00.77'W	14049.3 25855.5	7.9	3/4 grab. Brown fine silt. Juvenile shrimp, crabs, shell fragments.
		2	42°19.25'N 71°00.77'W	14049.1 25855.5	7.8	Same as Rep.1.
		3	42°19.25'N 71°00.77'W	14049.3 25855.5	7.9	Same as Reps. 1 and 2. Grab cleaned with DCM and acetone. 0.04 m^2 grab with bio screens.
R4	09/20/91	1	42°21.52'N 70°58.76'W	14025.2 25854.1	9.0	9/18/91. Heavy oil slick visible at 10:50. Move to next station. 9/20/91. Fine black silt strong odor. 3/4 full grab. No life forms.
		2	42°21.52'N 70°58.78'W	14025.3 25854.2	8.5	Same as Rep. 1
		3	42°21.52'N 70°58.78'W	14025.3 25854.2	8.7	Same as Reps. 1 and 2. Cleaned with DMC and acetone. 0.04 m^2 grab with bio screens
R5	09/20/91	1	42°21.38'N 70°58.68'W	14025.3 25852.6	7.1	3/4 full grab. Fine black silt. Strong odor. Level surface.
		2	42°21.38'N 70°58.67'W	14025.3 25852.6	7.0	Same as Rep. 1.
		3	42°21.38'N 70°58.69'W	14025.4 25852.6	7.1	Identical to Reps. 1 and 2. Cleaned with DMC and acetone. 0.04 m^2 grab with bio screens.
R2	09/20/91	1	42°20.66'N 70°57.69'W	14022.4 25841.4	14.5	3/4 full. Strong odor. Fine black silt. Few snails.
		2	42°20.66'N 70°57.70'W	14022.5 25841.4	14.6	Same as Rep. 1.
		3	42°20.67'N 70°57.68'W	14022.4 25841.3	14.1	Same as Reps. 1 and 2. Cleaned with DMC and acetone.
R6	09/20/91	1	42°20.38'N 70°57.64'W	14023.5 25839.4	17.9	3/4 full. Polychaetes. Snails. Dark Gray. Moderate odor.
		2	42°20.38'N 70°57.64'W	14023.5 25839.4	18.0	Same as Rep. 1.
		3	42°20.37'N 70°57.64'W	14023.5 25839.3	17.9	Same as Reps. 1 and 2. Cleaned with DMC and acetone. Many snails. Little detritus. 0.04 m^2 grab with bio screens.

Table A-1. Field Log for Grabs at Each Station, including Navigation and Comments. *(concluded)*						
Station	**Date and Time (EDT)**	**Grab**	**Latitude Longitude**	**LORAN Time Delays**	**Depth (m)**	**Comments**
R16	09/20/91	1	42°18.96'N 70°57.70'W	14030.7 25831.5	7.0	Much detritus. Arthropods. Gray. No odor. 3/4 full grab. Level surface.
		2	42°18.95'N 70°57.68'W	14030.7 25831.4	6.9	Same as Rep. 1.
		3	42°18.96'N 70°57.68'W	14030.6 25831.4	6.9	Same as Reps. 1 and 2. Cleaned with DCM and acetone. 0.04 m^2 grab with bio screens.
R21	09/20/91	1	42°18.53'N 70°56.78'W	14026.8 25822.3	7.0	3/4 full detritus. Some arthropods. Mild odor. Grayish. Many sand shrimp. Juvenile crabs. some polychaete worms.
		2	42°18.54'N 70°56.78'W	14026.8 25822.4	6.3	Same as Rep. 1.
		3	42°18.53'N 70°56.78'W	14026.8 25822.3	6.5	Identical to Reps. 1 and 2. Cleaned with DMC and acetone. 0.04 m^2 grab with bio screens.
R22	09/20/91	1	42°18.02'N 70°56.37'W	14026.6 25816.5	8.3	3/4 full. Arthropods. Clam worms and tubes. Snails. 2 or 3 different species of polychaetes. Gray. No odor.
		2	42°18.02'N 70°56.36'W	14026.6 25816.5	8.4	Same as Rep. 1.
		3	42°18.02'N 70°56.36'W	14026.6 25816.4	8.3	Cleaned with DMC and acetone. Identical to Reps. 1 and 2. 0.04 m^2 grab with bio screens.

Table A-2. Sediment Profile Camera Imaging Station Locations.

Station	Depth(m)	Lat/Long	TD-1/TD-2	Photo Times
* T 6	5.9	42°17.61/70°56.64	14030.6/25816.2	(1) 10:03 (2) 10:17 (3) 10:18 (4) 10:19 (5) 10:21 (6) 10:22
* T 8	12.9	42°17.18/70°54.73	14020.2/25799.8	(1) 10:56 (2) 10:57 (3) 10:58 (4) 10:59 (5) 11:00
* T 7	5.7	42°17.36/70°58.73	14045.0/25829.8	(1) 11:35 (2) 11:37 (3) 11:38 (4) 11:39 (5) 11:40
T 4	4	42°18.60/71°02.47	14063.4/25864.2	(1) 15:02 (2) 15:03 (3) 15:05 (4) 15:05 (5) 15:06
T 2	10.9	42°20.61/71°00.15	14038.6/25858.7	(1) 15:33 (2) 15:36 (3) 15:37 (4) 15:38 (5) 15:39
T 1	6.8	42°20.94/70°57.86	14026.7/25836.3	(1) 15:56 (2) 15:57 (3) 15:58 (4) 15:59 (5) 16:00

*Camera malfunction; no data collected.

Table A-2. Sediment Profile Camera Imaging Station Locations.
(concluded)

Station	Depth(m)	Lat/Long	TD-1/TD-2	Photo Times
T 3	6.8	42°19.79/70°57.70	14026.7/25836.3	(1) 16:16 (2) 16:17 (3) 16:18 (4) 16:19 (5) 16:20
T 5	3.6	42°19.88/70°57.20	14023.0/25833.3	(1) 16:34 (2) 16:35 (3) 16:36 (4) 16:37 (5) 16:38
R 4	7.8	42°21.53/70°58.75	14025.0/25853.9	(1) 17:02 (2) 17:03 (3) 17:04 (4) 17:04 (5) 17:05
R 7	7.0	42°20.82/70°58.53	14027.2/25848.2	(1) 17:19 (2) 17:20 (3) 17:21 (4) 17:22 (5) 17:23
R 11	7.0	42°19.31/70°58.48	14034.1/25839.2	(1) 17:41 (2) 17:42 (3) 17:43 (4) 17:43:30 (5) 17:44
R 13	4.6	42°19.01/70°58.85	14038.0/25840.2	(1) 17:56 (2) 17:57 (3) 17:57:30 (4) 17:58 (5) 17:59

Table A-3. Core Sample Locations.

Station	Core No.	Depth (m)	Lat/Long	TD's	H_2O Temp (°C)	Site Desc.
T 7	1A, 1B	6	42°17.32/70°58.7	14045.12/25829.39	15.9	Brown sand w/shell
T 8	2A, 2B	13	42°17.17/70°54.73	14020.24/25799.78	15.4	Hard sand
T 2	3A, 3B	12	42°20.59/71°00.04	14037.96/25857.84	16.5	Fine silt
T 3	4A, 4B	7	42°19.79/70°57.69	14026.73/25836.36	15.1	Fine silt

Table A-4. Description of Parameters Measured by Sediment Profile Camera. [From Diaz and Schaffner, 1988.]

Measurement	Method	Usefulness
a -Depth of Penetration	Average of maximum and minimum distance from sediment surface to bottom of prism window.	Penetration depth is a good indicator of sediment compaction.
b -Surface Relief	Maximum minus minimum depth of penetration.	If the camera is level this is a good measure of small scale bed roughness, on the order of 15cm (prism window width).
c -Digitized Image Statistics 1. Pixel densities for total image 2. Pixel densities for areas of interest	Actual range of densities the digitizing camera detects from the sediment profile image.	For cross comparisons of images, it is necessary to have measurements relying upon image pixel density done on a similar intensity range.
d -Depth of apparent RPD Layer	Area of apparently oxic layer (g) divided by width of image. Maximum and minimum distances from sediment surface to top of RPD layer are also measured.	Gives a good indication of D.O. conditions in the bottom waters and the degree of biogenic activity in muddy sediments.
e -Color Contrast of apparent RPD	Contrast between oxic and anoxic layers is determined from light intensity level density slicing of digitized and specially enhanced image.	Establishes boundary of RPD. Knowledge of whether the RPD is straight or convoluted will be of use in understanding biological and physical processes.
f -Area of Anoxic Sediment	Select desired pixel density for boundary between oxic and anoxic, count anoxic pixels, and convert to area.	When calculated to a constant depth of penetration and combined with oxic layer area, a good understanding of RPD dynamics can be obtained.
g -Area of Oxic Sediment	As in f, except use oxic pixel count.	When calculated to a constant depth of penetration and combined with anoxic layer area, a good understanding of RPD dynamics can be obtained.
h -Voids	Number counted, depth of each from surface measured, area of each delineated.	Presence of oxic voids is a good indicator of deep-living fauna and high biogenic activity.
i -Other Inclusions	Number counted, depth of each from surface of each delineated, area of each delineated.	Often other inclusions such as methane gas or mud clasts are indicative of certain processes and are helpful in understanding recent events.
j -Burrows	Number counted, depth of penetration of each from surface measured.	Burrow presence is a good indication of deep-living fauna and high biogenic activity.
k -Surface Features		
1. Tubes	Counted and speciated.	Presence of these features is indicative of recent biological and physical processes.
2. Epifauna	Counted and speciated.	
3. Pelletized Layer	Thickness and area delineated.	
4. Shell	Qualitative estimate of coverage.	
5. Mud Clasts	Qualitative estimate of coverage.	
l -Sediment Grain Size	Determined from comparison of image to images of known grain size.	Provides modal estimate of grain size and sediment layering.
m -Dredged Material or other layers	Measure thickness above original sediment surface and delineate area.	Location, thickness and type of material provide quantitative measures for assessing impacts on benthos from dredged material and other natural or anthropogenic events.

Table A-5. Macrofauna (>0.5-mm) at Traditional Stations.

STUDY SITE = BOSTON HARBOR
STATION = T1
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.5 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Oligochaeta	27	116	24	55.7
Streblospio benedicti	18	112	15	48.3
Ampelisca spp. complex	5	38	5	16.0
Polydora cornuta	1	38	1	13.3
Nassarius vibex	8	22	7	12.3
Tellina agilis	2	11	7	6.7
Microphthalmus aberrans	8	12	0	6.7
Nephtys caeca	4	5	8	5.7
Tharyx cf. acutus	1	12	2	5.0
NINETY PERCENT BREAKPOINT				
Clymenella torquata	3	1	2	2.0
Mya arenaria	0	4	2	2.0
Edotea tribola	1	5	0	2.0
Crangon septemspinosa	1	2	3	2.0
Balanus crenatus	0	4	1	1.7
Paranaitis speciosa	0	3	0	1.0
Ninoe nigripes	0	1	2	1.0
Cirratulidae	0	3	0	1.0
Capitella spp. complex	0	3	0	1.0
Pectinaria granulata	0	2	0	0.7
Spio armata	0	2	0	0.7
Photis sp.	0	2	0	0.7
Prionospio steenstrupi	0	1	0	0.3
Pholoe minuta	0	1	0	0.3
Lyonsia hyalina	0	1	0	0.3
Mediomastus californiensis	0	1	0	0.3
Ensis directus	0	1	0	0.3
Exogone hebes	0	1	0	0.3
Macoma balthica	0	1	0	0.3
Gastropoda	1	0	0	0.3
Cancer irroratus	0	1	0	0.3
TOTAL NUMBER OF TAXA	13	29	13	
TOTAL NUMBER OF INDIVIDUALS	80	406	79	
SHANNON-WEINER DIVERSITY	1.975	2.181	2.121	
SIMPSON'S DOMINANCE INDEX	0.194	0.181	0.163	
SPECIES RICHNESS	2.74	4.66	2.75	
EVENNESS	0.77	0.65	0.83	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	30
MEAN NUMBER OF INDIVIDUALS	188.3
SHANNON-WEINER DIVERSITY	2.230
SIMPSON'S DOMINANCE INDEX	0.175
SPECIES RICHNESS	5.54
EVENNESS	0.66

Table A-5. Macrofauna (>0.5-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T2
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.5 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Crangon septemspinosa	0	1	7	2.7
Streblospio benedicti	3	2	0	1.7
Oligochaeta	3	0	1	1.3
Mytilus edulis	1	0	2	1.0
Nassarius vibex	0	0	1	0.3
NINETY PERCENT BREAKPOINT				
Neomysis americana	0	0	1	0.3
Gastropoda	1	0	0	0.3

	REP 1	REP 2	REP 3
TOTAL NUMBER OF TAXA	4	2	5
TOTAL NUMBER OF INDIVIDUALS	8	3	12
SHANNON-WEINER DIVERSITY	1.255	0.637	1.234
SIMPSON'S DOMINANCE INDEX	0.313	0.556	0.389
SPECIES RICHNESS	1.44	0.91	1.61
EVENNESS	0.91	0.92	0.77

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	7
MEAN NUMBER OF INDIVIDUALS	7.7
SHANNON-WEINER DIVERSITY	1.678
SIMPSON'S DOMINANCE INDEX	0.221
SPECIES RICHNESS	2.95
EVENNESS	0.86

Table A-5. Macrofauna (> 0.5-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T3
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.5 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Oligochaeta	2417	522	1777	1572.0
Aricidea (Acmira) catherinae	71	84	69	74.7
NINETY PERCENT BREAKPOINT				
Microphthalmus aberrans	188	1	10	66.3
Ampelisca spp. complex	26	30	33	29.7
Nassarius vibex	32	16	10	19.3
Phoxocephalus holbolli	7	26	24	19.0
Tellina agilis	19	27	6	17.3
Mytilus edulis	9	6	1	5.3
Edotea tribola	10	1	2	4.3
Streblospio benedicti	1	0	8	3.0
Tharyx cf. acutus	6	1	1	2.7
Polydora cornuta	2	4	0	2.0
Mya arenaria	1	0	3	1.3
Ninoe nigripes	2	1	1	1.3
Gastropoda	0	3	0	1.0
Exogone hebes	1	1	1	1.0
Neanthes virens	1	0	1	0.7
Pholoe minuta	2	0	0	0.7
Lyonsia hyalina	1	1	0	0.7
Nemertinea	2	0	0	0.7
Gammarus sp.	1	0	1	0.7
Capitella spp. complex	1	0	1	0.7
Crangon septemspinosa	2	0	0	0.7
Spio armata	0	1	0	0.3
Asabellides oculata	0	1	0	0.3
Cirratulidae	0	0	1	0.3
Bivalvia	0	1	0	0.3
Polydora sp.	0	0	1	0.3
Ensis directus	0	1	0	0.3
Crepidula sp.	0	1	0	0.3
Ascidiacea	1	0	0	0.3
TOTAL NUMBER OF TAXA	23	20	19	
TOTAL NUMBER OF INDIVIDUALS	2803	729	1951	
SHANNON-WEINER DIVERSITY	0.646	1.134	0.473	
SIMPSON'S DOMINANCE INDEX	0.749	0.531	0.831	
SPECIES RICHNESS	2.77	2.88	2.38	
EVENNESS	0.21	0.38	0.16	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	31
MEAN NUMBER OF INDIVIDUALS	1827.7
SHANNON-WEINER DIVERSITY	0.698
SIMPSON'S DOMINANCE INDEX	0.743
SPECIES RICHNESS	3.99
EVENNESS	0.20

Table A-5. Macrofauna (>0.5-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T4
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.5 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Streblospio benedicti	2	2	14	6.0
Crangon septemspinosa	2	2	1	1.7
NINETY PERCENT BREAKPOINT				
Aoridae	1	0	0	0.3

	REP 1	REP 2	REP 3
TOTAL NUMBER OF TAXA	3	2	2
TOTAL NUMBER OF INDIVIDUALS	5	4	15
SHANNON-WEINER DIVERSITY	1.055	0.693	0.245
SIMPSON'S DOMINANCE INDEX	0.360	0.500	0.876
SPECIES RICHNESS	1.24	0.72	0.37
EVENNESS	0.96	1.00	0.35

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	3
MEAN NUMBER OF INDIVIDUALS	8.0
SHANNON-WEINER DIVERSITY	0.675
SIMPSON'S DOMINANCE INDEX	0.608
SPECIES RICHNESS	0.96
EVENNESS	0.61

Table A-5. Macrofauna (>0.5-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T5
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.5 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Oligochaeta	64	45	18	42.3
Nassarius vibex	17	8	19	14.7
Capitella spp. complex	4	6	8	6.0
NINETY PERCENT BREAKPOINT				
Gammarus sp.	1	1	4	2.0
Tellina agilis	1	2	2	1.7
Tharyx cf. acutus	0	1	1	0.7
Streblospio benedicti	2	0	0	0.7
Neanthes virens	0	0	1	0.3
Mytilus edulis	0	0	1	0.3
Polydora sp.	0	0	1	0.3
Microphthalmus aberrans	1	0	0	0.3

	REP 1	REP 2	REP 3
TOTAL NUMBER OF TAXA	7	6	9
TOTAL NUMBER OF INDIVIDUALS	90	63	55
SHANNON-WEINER DIVERSITY	0.930	0.967	1.616
SIMPSON'S DOMINANCE INDEX	0.544	0.537	0.256
SPECIES RICHNESS	1.33	1.21	2.00
EVENNESS	0.48	0.54	0.74

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	11
MEAN NUMBER OF INDIVIDUALS	69.3
SHANNON-WEINER DIVERSITY	1.225
SIMPSON'S DOMINANCE INDEX	0.427
SPECIES RICHNESS	2.36
EVENNESS	0.51

Table A-5. Macrofauna (>0.5-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T6
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.5 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Ampelisca spp. complex	764	258	670	564.0
Aricidea (Acmira) catherinae	455	478	466	466.3
Oligochaeta	336	182	382	300.0
Polydora cornuta	122	63	201	128.7
NINETY PERCENT BREAKPOINT				
Phoxocephalus holbolli	41	12	66	39.7
Mediomastus californiensis	18	15	32	21.7
Nassarius vibex	19	30	14	21.0
Lumbrineris hebes	17	11	16	14.7
Tellina agilis	10	9	20	13.0
Spio armata	11	13	5	9.7
Ninoe nigripes	12	5	5	7.3
Nucula delphinodonta	9	5	5	6.3
Monticellina baptisteae	4	5	2	3.7
Phyllodoce mucosa	3	3	4	3.3
Mytilus edulis	2	2	3	2.3
Crangon septemspinosa	3	1	2	2.0
Pholoe minuta	0	1	2	1.0
Cirratulidae	1	0	1	0.7
Mya arenaria	0	1	1	0.7
Lyonsia hyalina	0	1	1	0.7
Corophium spp.	0	0	2	0.7
Prionospio steenstrupi	1	0	0	0.3
Bivalvia	0	0	1	0.3
Gastropoda	0	1	0	0.3
Turtonia minuta	0	0	1	0.3
Diastylidae	0	0	1	0.3
Edotea tribola	0	0	1	0.3
Nemertinea	0	0	1	0.3
Leptocheirus pinguis	0	0	1	0.3
Pygospio elegans	0	0	1	0.3
Gammarus sp.	0	0	1	0.3
Eteone longa	1	0	0	0.3
Tharyx cf. acutus	0	0	1	0.3
Pagurus longicarpus	0	0	1	0.3
Cancer irroratus	0	0	1	0.3

Table A-5. Macrofauna (> 0.5-mm) at Traditional Stations.
(continued)

TOTAL NUMBER OF TAXA	19	20	32
TOTAL NUMBER OF INDIVIDUALS	1829	1096	1911
SHANNON-WEINER DIVERSITY	1.597	1.643	1.733
SIMPSON'S DOMINANCE INDEX	0.276	0.278	0.235
SPECIES RICHNESS	2.40	2.71	4.10
EVENNESS	0.54	0.55	0.50

TOTAL STATION STATISTICS	
TOTAL NUMBER OF TAXA	35
MEAN NUMBER OF INDIVIDUALS	1612.0
SHANNON-WEINER DIVERSITY	1.692
SIMPSON'S DOMINANCE INDEX	0.248
SPECIES RICHNESS	4.60
EVENNESS	0.48

Table A-5. Macrofauna (>0.5-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T7
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.5 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Ampelisca spp. complex	282	263	279	274.7
Streblospio benedicti	144	268	122	178.0
Aricidea (Acmira) catherinae	51	52	31	44.7
Mya arenaria	31	30	35	32.0
Ensis directus	30	24	28	27.3
NINETY PERCENT BREAKPOINT				
Nassarius vibex	24	19	13	18.7
Oligochaeta	6	8	3	5.7
Crangon septemspinosa	5	6	5	5.3
Polydora cornuta	0	5	6	3.7
Capitella spp. complex	4	3	0	2.3
Tellina agilis	1	3	0	1.3
Tharyx cf. acutus	3	0	1	1.3
Mulinia lateralis	1	1	0	0.7
Lyonsia hyalina	1	1	0	0.7
Exogone hebes	0	0	2	0.7
Nephtyidae	0	2	0	0.7
Pandora sp.	0	1	0	0.3
Polygordius sp.	0	0	1	0.3
Crepidula sp.	1	0	0	0.3
Leptocheirus pinguis	0	0	1	0.3
Lumbrineris hebes	1	0	0	0.3

	REP 1	REP 2	REP 3
TOTAL NUMBER OF TAXA	15	15	13
TOTAL NUMBER OF INDIVIDUALS	585	686	527
SHANNON-WEINER DIVERSITY	1.552	1.506	1.451
SIMPSON'S DOMINANCE INDEX	0.308	0.310	0.345
SPECIES RICHNESS	2.20	2.14	1.91
EVENNESS	0.57	0.56	0.57

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	21
MEAN NUMBER OF INDIVIDUALS	599.3
SHANNON-WEINER DIVERSITY	1.534
SIMPSON'S DOMINANCE INDEX	0.310
SPECIES RICHNESS	3.13
EVENNESS	0.50

Table A-5. Macrofauna (> 0.5-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T8
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.5 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Ampelisca spp. complex	211	274	637	374.0
Aricidea (Acmira) catherinae	162	162	416	246.7
Nucula delphinodonta	61	86	127	91.3
Nassarius vibex	57	58	63	59.3
Clymenella torquata	12	69	76	52.3
Tellina agilis	48	44	40	44.0
Spiophanes bombyx	20	6	93	39.7
Polydora cornuta	25	41	44	36.7
Oligochaeta	17	15	36	22.7
Lumbrineridae	29	13	25	22.3
Exogone hebes	39	12	7	19.3
Phoxocephalus holbolli	7	9	34	16.7
Polygordius sp.	35	2	8	15.0
Pygospio elegans	23	13	5	13.7
Edotea tribola	4	4	27	11.7
NINETY PERCENT BREAKPOINT				
Lyonsia hyalina	4	11	17	10.7
Tharyx cf. acutus	6	9	10	8.3
Monticellina baptisteae	6	7	7	6.7
Phyllodoce mucosa	4	4	11	6.3
Lumbrineris hebes	5	6	7	6.0
Crangon septemspinosa	4	12	1	5.7
Orchomenella minuta	1	0	14	5.0
Nephtys caeca	3	5	6	4.7
Prionospio steenstrupi	5	7	2	4.7
Unciola sp.	2	5	6	4.3
Ensis directus	4	2	6	4.0
Cirratulidae	4	1	6	3.7
Mytilus edulis	1	1	8	3.3
Microphthalmus aberrans	0	1	9	3.3
Mediomastus californiensis	1	1	6	2.7
Leptocheirus pinguis	1	0	7	2.7
Spio armata	0	5	2	2.3
Diastylidae	1	1	4	2.0
Parougia caeca	1	0	5	2.0
Corophium crassicorne	4	1	0	1.7
Capitella spp. complex	0	1	3	1.3
Mya arenaria	1	1	1	1.0
Hiatella arctica	1	0	2	1.0
Thracia sp.	1	2	0	1.0
Phoronis sp.	1	0	2	1.0
Ascidiacea	0	0	3	1.0
Astarte undata	1	1	0	0.7
Nemertinea	0	0	2	0.7
Ninoe nigripes	0	1	1	0.7
Corophium tuberculatum	0	1	1	0.7

Table A-5. Macrofauna (>0.5-mm) at Traditional Stations.
(concluded)

Gammarus sp.	1	0	1	0.7
Pagurus longicarpus	0	2	0	0.7
Pagurus sp.	0	1	1	0.7
Polycirrus sp. A	1	0	1	0.7
Glycera dibranchiata	0	0	1	0.3
Corophium spp.	0	0	1	0.3
Pholoe minuta	0	0	1	0.3
Cerastoderma pinnulatum	0	1	0	0.3
Ampharete arctica	0	1	0	0.3
Turtonia minuta	0	1	0	0.3
Photis sp.	0	0	1	0.3
Pherusa affinis	0	0	1	0.3
Bivalvia	0	0	1	0.3
Eteone longa	0	0	1	0.3
Typosyllis sp.	0	1	0	0.3
Harmothoe imbricata	0	0	1	0.3
Musculus sp.	0	1	0	0.3
Asabellides oculata	1	0	0	0.3

TOTAL NUMBER OF TAXA	41	45	53	
TOTAL NUMBER OF INDIVIDUALS	815	902	1798	
SHANNON-WEINER DIVERSITY	2.567	2.465	2.315	
SIMPSON'S DOMINANCE INDEX	0.129	0.150	0.192	
SPECIES RICHNESS	5.97	6.47	6.94	
EVENNESS	0.69	0.65	0.58	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	63
MEAN NUMBER OF INDIVIDUALS	1171.7
SHANNON-WEINER DIVERSITY	2.484
SIMPSON'S DOMINANCE INDEX	0.162
SPECIES RICHNESS	8.77
EVENNESS	0.60

Table A-6. Macrofauna (>0.3-mm) at Traditional Stations.

STUDY SITE = BOSTON HARBOR
STATION = T1
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.3 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Oligochaeta	101	374	154	209.7
Streblospio benedicti	37	88	53	59.3
Microphthalmus aberrans	56	51	6	37.7
Tharyx cf. acutus	18	43	22	27.7
Gastropoda	15	16	19	16.7
Polydora cornuta	0	33	1	11.3
NINETY PERCENT BREAKPOINT				
Bivalvia	7	12	6	8.3
Capitella spp. complex	0	20	0	6.7
Polydora sp. (larval)	4	8	1	4.3
Gammarus sp.	0	5	0	1.7
Turbellaria	1	1	2	1.3
Mediomastus californiensis	0	3	0	1.0
Pholoe minuta	0	3	0	1.0
Insecta	0	0	3	1.0
Mya arenaria	0	2	0	0.7
Ampelisca spp. complex	0	2	0	0.7
Aricidea (Acmira) catherinae	1	1	0	0.7
Lyonsia hyalina	0	1	0	0.3
Balanus sp.	0	1	0	0.3
Edotea tribola	0	1	0	0.3
Ensis directus	0	1	0	0.3
Corophium spp.	0	1	0	0.3
Nemertinea	0	1	0	0.3
Mytilidae	0	1	0	0.3

TOTAL NUMBER OF TAXA	9	23	10
TOTAL NUMBER OF INDIVIDUALS	240	669	267
SHANNON-WEINER DIVERSITY	1.577	1.640	1.332
SIMPSON'S DOMINANCE INDEX	0.266	0.344	0.385
SPECIES RICHNESS	1.46	3.38	1.61
EVENNESS	0.72	0.52	0.58

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	24
MEAN NUMBER OF INDIVIDUALS	392.0
SHANNON-WEINER DIVERSITY	1.633
SIMPSON'S DOMINANCE INDEX	0.327
SPECIES RICHNESS	3.85
EVENNESS	0.51

Table A-6. Macrofauna (>0.3-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T2
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.3 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Streblospio benedicti	40	14	13	22.3
Oligochaeta	20	24	6	16.7
Bivalvia	5	7	4	5.3
NINETY PERCENT BREAKPOINT				
Gastropoda	3	2	2	2.3
Turbellaria	0	0	2	0.7
Lyonsia hyalina	2	0	0	0.7
Aricidea (Acmira) catherinae	1	0	0	0.3
Tharyx cf. acutus	1	0	0	0.3
Photis sp.	0	0	1	0.3

	REP 1	REP 2	REP 3
TOTAL NUMBER OF TAXA	7	4	6
TOTAL NUMBER OF INDIVIDUALS	72	47	28
SHANNON-WEINER DIVERSITY	1.218	1.122	1.460
SIMPSON'S DOMINANCE INDEX	0.394	0.373	0.293
SPECIES RICHNESS	1.40	0.78	1.50
EVENNESS	0.63	0.81	0.82

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	9
MEAN NUMBER OF INDIVIDUALS	49.0
SHANNON-WEINER DIVERSITY	1.330
SIMPSON'S DOMINANCE INDEX	0.338
SPECIES RICHNESS	2.06
EVENNESS	0.61

Table A-6. Macrofauna (>0.3-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T3
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.3 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Oligochaeta	683	238	436	452.3
Microphthalmus aberrans	88	0	1	29.7
NINETY PERCENT BREAKPOINT				
Aricidea (Acmira) catherinae	13	10	15	12.7
Ampelisca spp. complex	9	7	4	6.7
Polydora sp. (larval)	5	7	3	5.0
Gastropoda	10	2	2	4.7
Bivalvia	10	1	3	4.7
Photis sp.	7	4	2	4.3
Gammarus sp.	4	8	0	4.0
Mediomastus californiensis	0	4	2	2.0
Streblospio benedicti	1	1	3	1.7
Tharyx cf. acutus	4	0	1	1.7
Edotea tribola	1	1	0	0.7
Phoxocephalus holbolli	0	2	0	0.7
Mytilidae	1	0	0	0.3
Unciola sp.	0	1	0	0.3
Mya arenaria	0	1	0	0.3
Nemertinea	1	0	0	0.3
Lyonsia hyalina	1	0	0	0.3

TOTAL NUMBER OF TAXA	15	14	11
TOTAL NUMBER OF INDIVIDUALS	838	287	472
SHANNON-WEINER DIVERSITY	0.784	0.840	0.415
SIMPSON'S DOMINANCE INDEX	0.676	0.691	0.855
SPECIES RICHNESS	2.08	2.30	1.62
EVENNESS	0.29	0.32	0.17

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	19
MEAN NUMBER OF INDIVIDUALS	532.3
SHANNON-WEINER DIVERSITY	0.743
SIMPSON'S DOMINANCE INDEX	0.726
SPECIES RICHNESS	2.87
EVENNESS	0.25

Table A-6. Macrofauna (>0.3-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T4
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.3 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Streblospio benedicti	84	112	129	108.3
Turbellaria	30	18	24	24.0
NINETY PERCENT BREAKPOINT				
Polydora sp. (larval)	4	1	2	2.3
Tharyx cf. acutus	0	1	1	0.7
Bivalvia	1	0	1	0.7
Paranaitis speciosa	0	0	1	0.3
Leitoscoloplos sp.	0	0	1	0.3
Oligochaeta	0	0	1	0.3
Exogone arenosa	0	0	1	0.3
Photis sp.	1	0	0	0.3

	REP 1	REP 2	REP 3
TOTAL NUMBER OF TAXA	5	4	9
TOTAL NUMBER OF INDIVIDUALS	120	132	161
SHANNON-WEINER DIVERSITY	0.789	0.485	0.705
SIMPSON'S DOMINANCE INDEX	0.554	0.739	0.665
SPECIES RICHNESS	0.84	0.61	1.57
EVENNESS	0.49	0.35	0.32

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	10
MEAN NUMBER OF INDIVIDUALS	137.7
SHANNON-WEINER DIVERSITY	0.687
SIMPSON'S DOMINANCE INDEX	0.650
SPECIES RICHNESS	1.83
EVENNESS	0.30

Table A-6. Macrofauna (> 0.3-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T5
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.3 mm

TAXA	REP 2	REP 3	MEAN
Oligochaeta	24	26	25.0
Gastropoda	3	6	4.5
NINETY PERCENT BREAKPOINT			
Gammarus sp.	0	4	2.0
Nemertinea	0	1	0.5

	REP 2	REP 3
TOTAL NUMBER OF TAXA	2	4
TOTAL NUMBER OF INDIVIDUALS	27	37
SHANNON-WEINER DIVERSITY	0.349	0.881
SIMPSON'S DOMINANCE INDEX	0.802	0.533
SPECIES RICHNESS	0.30	0.83
EVENNESS	0.50	0.64

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	4
MEAN NUMBER OF INDIVIDUALS	32.0
SHANNON-WEINER DIVERSITY	0.707
SIMPSON'S DOMINANCE INDEX	0.634
SPECIES RICHNESS	0.87
EVENNESS	0.51

Table A-6. Macrofauna (>0.3-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T6
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.3 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Oligochaeta	426	359	299	361.3
Aricidea (Acmira) catherinae	60	220	86	122.0
Ampelisca spp. complex	74	10	62	48.7
Polydora cornuta	42	20	32	31.3
NINETY PERCENT BREAKPOINT				
Bivalvia	12	3	10	8.3
Gastropoda	6	6	6	6.0
Photis sp.	5	1	9	5.0
Phoxocephalus holbolli	12	0	2	4.7
Gammarus sp.	2	2	4	2.7
Polydora sp. (larval)	6	1	0	2.3
Streblospio benedicti	5	1	1	2.3
Lyonsia hyalina	1	0	3	1.3
Mya arenaria	2	1	0	1.0
Edotea tribola	3	0	0	1.0
Phyllodoce mucosa	1	0	2	1.0
Corophium spp.	0	1	1	0.7
Nucula delphinodonta	1	0	1	0.7
Unciola sp.	0	0	1	0.3
Aoridae	0	0	1	0.3
Tharyx cf. acutus	1	0	0	0.3
Ninoe nigripes	0	1	0	0.3

TOTAL NUMBER OF TAXA	17	13	16
TOTAL NUMBER OF INDIVIDUALS	659	626	520
SHANNON-WEINER DIVERSITY	1.326	1.013	1.409
SIMPSON'S DOMINANCE INDEX	0.444	0.454	0.377
SPECIES RICHNESS	2.47	1.86	2.40
EVENNESS	0.47	0.39	0.51

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	21
MEAN NUMBER OF INDIVIDUALS	601.7
SHANNON-WEINER DIVERSITY	1.314
SIMPSON'S DOMINANCE INDEX	0.412
SPECIES RICHNESS	3.13
EVENNESS	0.43

Table A-6. Macrofauna (>0.3-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T7
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.3 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Streblospio benedicti	212	176	270	219.3
Mya arenaria	22	28	43	31.0
Bivalvia	35	23	20	26.0
Oligochaeta	32	23	17	24.0
Aricidea (Acmira) catherinae	10	34	20	21.3
Ensis directus	19	13	28	20.0
Gastropoda	32	18	9	19.7
Polydora cornuta	14	17	21	17.3
NINETY PERCENT BREAKPOINT				
Ampelisca spp. complex	11	13	20	14.7
Tharyx cf. acutus	9	6	1	5.3
Polydora sp. (larval)	4	3	0	2.3
Nephtyidae	2	3	1	2.0
Microphthalmus aberrans	2	3	0	1.7
Capitella spp. complex	1	3	0	1.3
Tellinidae	0	1	2	1.0
Lyonsia hyalina	2	0	0	0.7
Turbellaria	1	0	0	0.3
Ampharetidae	0	0	1	0.3

	REP 1	REP 2	REP 3
TOTAL NUMBER OF TAXA	16	15	13
TOTAL NUMBER OF INDIVIDUALS	408	364	453
SHANNON-WEINER DIVERSITY	1.792	1.891	1.525
SIMPSON'S DOMINANCE INDEX	0.298	0.264	0.378
SPECIES RICHNESS	2.50	2.37	1.96
EVENNESS	0.65	0.70	0.59

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	18
MEAN NUMBER OF INDIVIDUALS	408.3
SHANNON-WEINER DIVERSITY	1.763
SIMPSON'S DOMINANCE INDEX	0.313
SPECIES RICHNESS	2.83
EVENNESS	0.61

Table A-6. Macrofauna (>0.3-mm) at Traditional Stations.
(continued)

STUDY SITE = BOSTON HARBOR
STATION = T8
COLLECTION DATE = SEPTEMBER 1991
SIEVE SIZE = 0.3 mm

TAXA	REP 1	REP 2	REP 3	MEAN
Aricidea (Acmira) catherinae	319	617	769	568.3
Nucula delphinodonta	93	178	194	155.0
Exogone hebes	65	57	59	60.3
Polygordius sp.	54	59	64	59.0
Oligochaeta	24	22	80	42.0
Lyonsia hyalina	25	33	42	33.3
Tharyx cf. acutus	29	29	29	29.0
Microphthalmus aberrans	1	5	54	20.0
NINETY PERCENT BREAKPOINT				
Ampelisca spp. complex	4	8	48	20.0
Turbellaria	18	26	15	19.7
Bivalvia	8	10	12	10.0
Lumbrineridae	4	7	8	6.3
Monticellina baptisteae	4	3	8	5.0
Parougia caeca	1	0	14	5.0
Pygospio elegans	7	1	5	4.3
Polydora cornuta	5	3	5	4.3
Edotea tribola	3	4	6	4.3
Maldanidae	0	1	7	2.7
Nemertinea	0	3	4	2.3
Gammarus sp.	3	3	1	2.3
Mytilidae	0	1	5	2.0
Tellina agilis	3	1	2	2.0
Gastropoda	1	1	3	1.7
Phyllodoce mucosa	1	0	3	1.3
Mediomastus californiensis	1	2	1	1.3
Spiophanes bombyx	0	2	2	1.3
Metopella angusta	1	0	3	1.3
Spio armata	0	2	1	1.0
Photis sp.	0	1	2	1.0
Mya arenaria	0	1	1	0.7
Corophium spp.	1	1	0	0.7
Prionospio steenstrupi	1	1	0	0.7
Polydora sp. (larval)	0	2	0	0.7
Streblospio benedicti	0	1	0	0.3
Leitoscoloplos sp.	1	0	0	0.3
Terebellidae	1	0	0	0.3
Capitella spp. complex	0	1	0	0.3
Spissula solidissima	0	0	1	0.3
Pholoe minuta	0	0	1	0.3
Stenthoe minuta	0	0	1	0.3

Table A-6. Macrofauna (>0.3-mm) at Traditional Stations.
(concluded)

TOTAL NUMBER OF TAXA	27	32	33
TOTAL NUMBER OF INDIVIDUALS	678	1086	1450
SHANNON-WEINER DIVERSITY	1.919	1.641	1.863
SIMPSON'S DOMINANCE INDEX	0.261	0.358	0.310
SPECIES RICHNESS	3.99	4.43	4.40
EVENNESS	0.58	0.47	0.53

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	40
MEAN NUMBER OF INDIVIDUALS	1071.3
SHANNON-WEINER DIVERSITY	1.841
SIMPSON'S DOMINANCE INDEX	0.313
SPECIES RICHNESS	5.59
EVENNESS	0.50

Table A-7. Statistical Tests for Significant Station Differences in Abundance of Macrofauna at Traditional Stations.

ONE-WAY ANOVA FOR TOTAL FRACTION 15:30 Thursday, January 16, 1992 5

Analysis of Variance Procedure

Dependent Variable: TOT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	22291911.83333330	3184558.83333333	8.74	0.0002
Error	16	5826920.00000000	364182.50000000		
Corrected Total	23	28118831.83333330			

R-Square	C.V.	Root MSE	TOT Mean
0.792775	55.51326	603.47535161	1087.08333333

Source	DF	Anova SS	Mean Square	F Value	Pr > F
STN	7	22291911.83333330	3184558.83333333	8.74	0.0002

Table A-7. Statistical Tests for Significant Station Differences in Abundance of Macrofauna at Traditional Stations. *(concluded)*

ONE-WAY ANOVA FOR TOTAL FRACTION 15:30 Thursday, January 16, 1992 6

Analysis of Variance Procedure

Student-Newman-Keuls test for variable: TOT

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 16 MSE= 364182.5

Number of Means	2	3	4	5	6	7	8
Critical Range	1044.5289	1271.4209	1409.7264	1509.5808	1587.6683	1651.7081	1705.9249

Means with the same letter are not significantly different.

SNK Grouping		Mean	N	STN
	A	2360.0	3	T3
	A			
	A	2243.0	3	T8
	A			
	A	2213.7	3	T6
	A			
B	A	1007.7	3	T7
B				
B		579.3	3	T1
B				
B		145.7	3	T4
B				
B		101.0	3	T5
B				
B		56.7	3	T2

Table A-12. Sediment Parameter with Grain Size Fractions Normalized by Removing Gravel.

Station	Sand	Silt	Clay	TOC (wt %)	*Clostridium* (Spores/g Dry Wt.)
T1	84.7	12.1	3.2	2.64	11700
T2	63.7	27.8	8.5	1.75	22900
T3	44.1	39.1	16.8	3.69	207000
T4	32.3	48.6	19.1	3.70	30000
T5	93.7	4.3	2.1	1.46	30400
T6	65.7	25.1	9.2	1.81	29400
T7	58.3	27.8	13.9	2.73	13700
T8	12.1	52.2	35.7	0.87	7330
R2	54.9	34.0	11.1	2.87	73200
R3	52.9	38.8	8.2	1.90	60900
R4	27.2	52.1	20.7	2.51	85600
R5	36.8	48.7	14.5	2.33	35100
R6	78.3	20.3	1.3	0.99	5080
R7	48.9	38.0	13.1	2.83	99100
R8	94.0	5.8	0.2	0.28	1030
R9	69.5	22.4	8.1	1.73	30500
R10	85.6	9.6	4.8	3.36	30800
R11	41.9	43.0	15.0	3.57	92400
R12	40.9	44.5	14.7	3.53	60600
R13	45.9	40.7	13.3	3.32	18800
R14	67.5	24.6	7.9	2.69	19200
R15	49.7	36.3	14.1	2.00	43500
R16	71.4	20.1	8.5	2.54	26900
R17	42.5	42.7	14.8	3.32	19100
R18	56.5	31.2	12.2	3.04	18000
R19	94.7	3.1	2.2	0.56	2330
R20	46.4	37.7	15.9	3.34	76400
R21	72.3	19.0	8.7	2.27	31300
R22	47.2	20.4	32.4	2.99	44400
R23	77.0	14.7	8.3	3.07	24800
R24	61.4	27.3	11.3	2.67	11200
R25	37.8	45.9	16.3	2.86	42700

Table A-13. Computer Analysis I for Sediment Profile Camera Data.

STATION	IMAGE AREAS IN CM2 TOTAL	AERO	ANERO	VOIDS	% IMAGE AREAS STAND. TO 15 CM TOTAL	AERO	ANERO	VOIDS
T1	No Penetration							
T2-1	117.3	15.5	101.8	0.0	56.4	7.5	92.5	0.0
T2-2	105.4	15.9	89.4	0.0	50.9	7.7	92.3	0.0
T2-3	125.6	17.2	108.5	0.0	60.8	8.3	91.7	0.0
T2-4	124.0	29.8	94.2	0.0	59.8	14.4	85.6	0.0
T2-5	137.1	26.1	110.6	0.4	65.9	12.6	87.3	0.2
T3-1	147.7	18.5	129.2	0.0	71.3	8.9	91.1	0.0
T3-2	148.5	19.3	129.1	0.0	71.4	9.3	90.7	0.0
T3-3	149.6	11.3	138.3	0.0	72.2	5.5	94.5	0.0
T3-4	150.5	16.3	134.2	0.0	72.4	7.9	92.1	0.0
T3-5	147.9	14.0	134.0	0.0	71.6	6.8	93.2	0.0
T4-1	167.9	15.3	152.6	0.0	80.5	7.3	92.7	0.0
T4-2	212.0	11.4	200.6	0.0	102.3	5.5	94.5	0.0
T4-3	211.6	10.4	201.2	0.0	101.8	5.0	95.0	0.0
T4-4	234.9	5.9	228.5	0.5	113.7	2.8	96.9	0.2
T4-5	237.8	8.3	229.5	0.0	115.1	4.0	96.0	0.0
T5	No Penetration							
T6	No Images							
T7	No Images							
T8	No Images							
R4-1	120.6	7.0	113.6	0.0	58.0	3.4	96.6	0.0
R4-2	152.7	4.8	147.9	0.0	73.9	2.3	97.7	0.0
R4-3	170.0	13.8	156.1	0.0	82.0	6.7	93.3	0.0
R4-4	163.5	7.6	155.8	0.0	79.1	3.7	96.3	0.0
R4-5	165.0	8.9	156.1	0.0	79.1	4.2	95.8	0.0
R7-1	41.5	11.7	29.8	0.0	30.7	8.6	91.4	0.0
R7-2	87.5	6.1	81.4	0.0	42.2	2.9	97.1	0.0
R7-3	119.2	16.9	102.3	0.0	57.3	8.1	91.9	0.0
R7-4	101.2	16.6	84.5	0.0	48.7	8.0	92.0	0.0
R7-5	102.4	8.7	93.8	0.0	49.3	4.2	95.8	0.0
R11-1	139.0	19.7	119.3	0.0	67.1	9.5	90.5	0.0
R11-2	155.4	14.5	140.9	0.0	75.2	7.0	93.0	0.0
R11-3	114.4	6.7	107.7	0.0	55.4	3.2	96.8	0.0
R11-4	169.2	12.8	156.4	0.0	81.4	6.2	93.8	0.0
R11-5	142.6	14.4	128.2	0.0	68.2	6.9	93.1	0.0
R13	No Penetration							

Table A-14. Computer Analysis II for Sediment Profile Camera Data.

STATION		PENETRATION MIN	MAX	AVE.	SURFACE RELIEF	RPD MIN	MAX	AVE. DEPTH
T1	No Penetration							
T2-1		8.4	9.0	8.5	0.6	0.0	1.8	1.1
T2-2		6.9	8.5	7.6	1.7	0.0	2.1	1.2
T2-3		8.9	9.3	9.1	0.5	0.0	1.6	1.2
T2-4		8.8	9.3	9.0	0.6	0.0	2.8	2.2
T2-5		9.5	10.3	9.9	0.8	0.0	2.8	1.9
T3-1		10.5	10.9	10.7	0.4	0.0	2.1	1.3
T3-2		10.5	10.9	10.7	0.4	0.0	2.4	1.4
T3-3		10.7	11.2	10.8	0.5	0.0	2.1	0.8
T3-4		10.6	10.9	10.9	0.3	0.0	1.9	1.2
T3-5		10.3	11.0	10.7	0.7	0.0	2.1	1.0
T4-1		11.9	12.5	12.1	0.6	0.0	1.7	1.1
T4-2		15.3	15.6	15.3	0.3	0.0	1.5	0.8
T4-3		15.0	15.7	15.3	0.7	0.0	1.4	0.7
T4-4		14.1	18.8	17.1	4.7	0.0	0.6	0.4
T4-5		17.4	18.0	17.3	0.6	0.0	1.6	0.6
T5	No Penetration							
T6	No Images							
T7	No Images							
T8	No Images							
R4-1		8.6	8.8	8.7	0.3	0.0	1.3	0.5
R4-2		10.7	11.5	11.1	0.9	0.0	1.0	0.3
R4-3		12.1	13.0	12.3	1.0	0.0	2.0	1.0
R4-4		10.2	14.5	11.9	4.3	0.0	1.9	0.6
R4-5		11.0	12.7	11.9	1.7	0.0	2.0	0.6
R7-1		4.2	4.7	4.6	0.5	0.2	1.5	1.3
R7-2		6.2	6.8	6.3	0.6	0.0	1.4	0.4
R7-3		8.4	8.9	8.6	0.5	0.0	1.6	1.2
R7-4		7.1	7.8	7.3	0.8	0.0	2.2	1.2
R7-5		6.5	7.8	7.4	1.3	0.0	1.1	0.6
R11-1		10.0	10.9	10.1	0.9	0.0	2.1	1.4
R11-2		11.2	11.8	11.3	0.6	0.0	1.8	1.1
R11-3		6.1	9.7	8.3	3.6	0.0	0.8	0.5
R11-4		12.0	13.1	12.2	1.1	0.0	2.0	0.9
R11-5		9.9	10.7	10.2	0.8	0.0	1.7	1.0
R13	No Penetration							

PART II

SPRING 1992 SURVEY

CONTENTS OF PART II

FIGURES

TABLES

1.0 INTRODUCTION

The Massachusetts Water Resources Authority (MWRA) is instituting long-term monitoring in Boston Harbor as part of its Sludge Abatement Monitoring Program. Sludge generated at the Deer Island and Nut Island wastewater treatment facilities, until abatement in December 1991, was discharged from a point off the eastern tip of Long Island into Boston Harbor on outgoing tides. Cessation of sludge discharge is part of a progression of changes in MWRA discharge practices that will include diversion of treated effluent from the Harbor to deeper waters in Massachusetts Bay in 1995.

In September 1991, Battelle scientists conducted a survey of Boston Harbor benthic communities. The study included measurements of biotic and abiotic conditions at a variety of sites in the northern and southern regions of the Harbor. The primary purpose was to provide an extensive baseline data set of benthic conditions during the last warm season prior to cessation of sludge input to the Harbor. The study was undertaken with the expectation that future studies will revisit sites occupied during this baseline survey. Results from this survey are presented in Part I of this document.

In April 1992, Battelle conducted a second survey of the Boston Harbor benthos. The objectives of this survey were to provide for the continued monitoring of the benthic environment during the period following the abatement of sludge discharges into Boston Harbor, obtain sediment biological and chemical samples from each of the eight traditional stations established during the September 1991 survey. Core samples for benthic flux measurements were also gathered by diving at two stations (T3, T8) of the April grab survey; flux results will be reported separately.

This Part (II) of the document describes the survey activities and provides the resulting data on geology, chemistry, and biology. Section 2 describes methodology, separated into field sampling and laboratory analyses. The field methods subsection serves as a cruise report deliverable, summarizing station location and samples taken. Thereafter, laboratory processing methods are described for all parameters measured. Section 3 provides data summaries by parameter and site surveyed throughout the Harbor. Section 4 is a discussion of trends that includes a preliminary examination of spatial patterns and time trends with respect to species distribution.

2.0 METHODS

2.1 FIELD OPERATIONS

2.1.1 Navigation

Positioning for the grab sampling and sediment-profile camera work was accomplished with a Northstar 800 Global Positioning System (GPS)/Loran C system as described in Part I, Section 2.1.1.

2.1.2 Station Types and Locations

Sediments from the eight traditional stations sampled during the September 1991 survey, designated T1 through T8, were collected and subjected to complete taxonomic analysis. One planned station located at the northeast tip of Long Island, T5, was not sampled because only gravelly sediments could be found on the site. With MWRA concurrence, a "rapid" station, R6, was substituted for T5 and sampled successfully. The latitude and longitude for each grab station are listed in Table 1; full

Table 1. Grab Sample Stations for Boston Harbor April 1992

Date	Event	Station	Latitude/ Longitude	Depth m	Time
4/23	36	T6	42°17.62'N 70°56.67'W	5.1	1149
	40	T7	42°17.35'N 70°58.72'W	5.6	1255
	43	T4	42°18.62'N 71°02.45'W	5.9	1406
	50	T1	42°20.95'N 70°57.83'W	5.7	1507
	52	T3	42°19.79'N 70°57.70'W	9.5	1647
4/24	54	T2	42°20.55'N 71°00.11'W	8.7	0855
	56	R6	42°20.43'N 70°57.69'W	13.8	1120
	62	T8	42°17.11'N 70°54.73'W	11.7	1355

Positions listed are for one grab of three or four at a station. Full listing of all grabs is given in Appendix (Table B).

station log details, including location for each individual grab event, are given in the Appendix (Table B-1). The positions of grab stations throughout the Harbor are shown in Figure 1.

2.1.3 Grab Sampling

A modified 0.04-m^2 Young-van Veen biological grab sampler was used to obtain sediment samples for both biological and chemical analyses. The upper surface of the biological grab has screened instead of solid doors. The screened doors minimize the bow wave hitting the surface of the sediment.

At each station four replicate sediment samples were collected. Three grab samples were used for the biological analyses. Each replicate was observed for a variety of features including odor, color, and the presence of debris or animals (details in Table B-1). Each replicate then was washed with filtered seawater over nested 0.5- and 0.3-mm mesh sieves. The >0.5- and >0.3-mm fractions were placed into separate jars, labeled, and fixed with enough borax-buffered 100% formalin to yield a final solution of about 10% formalin. The fourth replicate sample was used for auxiliary analyses: sediment grain size, total organic carbon (TOC) content, and sediment chemistry. Subsamples for each analysis were removed from the upper two centimeters of sediment as described in Part I, Section 2.1.3. Samples for all auxiliary analyses have been archived at −20 °C at Battelle.

2.1.4 Ancillary Core Collection

Sediment cores were collected by divers from Battelle and the Ecosystems Center (Marine Biological Laboratory, Woods Hole) at two stations in the Harbor on April 21, 1992; these cores were returned to the laboratory for measurements of sediment-water exchange rates of dissolved gases and nutrients. Station positions approximated, within several hundred meters, the positions of Stations T3 and T8 (see Figure 1). Results of benthic flux studies of denitrification, metabolism, and nutrients will be reported separately.

2.1.5 Sample Documentation, Custody, and Quality Assurance/Quality Control

All sampling events were recorded into the navigational system and appropriately recorded in navigation and sediment log record books, with any changes to proposed procedures documented. All collected samples from replicate grabs were tracked by standard Battelle recording and tracking procedures. Transfer of samples was recorded to fulfill chain-of-custody requirements. Resultant data files and values in this report have been verified by standard data validation procedures.

2.1.6 Summary of Samples Collected

A summary of the number and types of samples collected during the April 1992 survey is presented in Table 2.

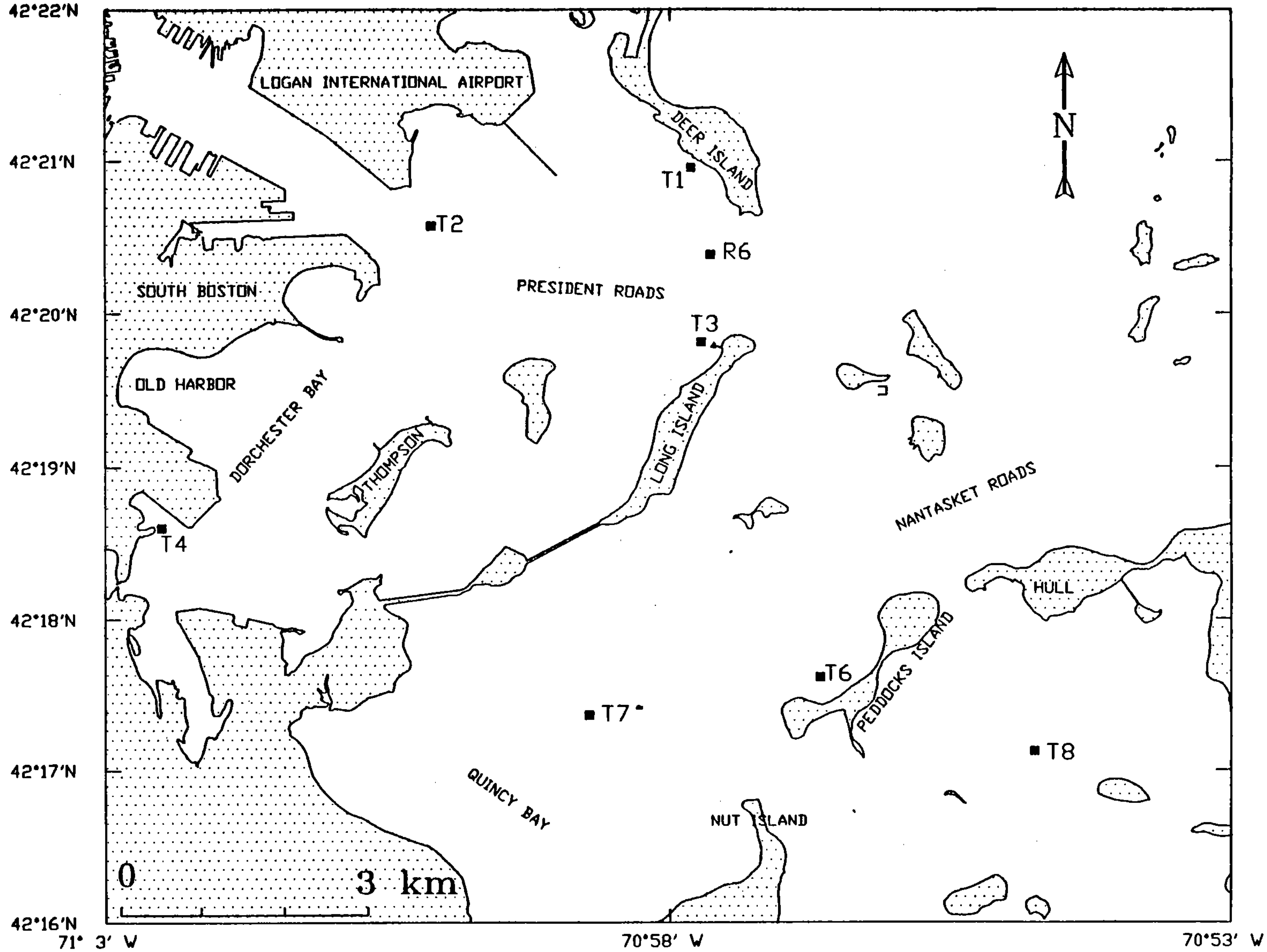

Figure 1, Stations for April 1992 Survey: Grab Samples.

Table 2. Summary of Samples Collected on April 1992 Survey

Sample Type	T Stations (8)	Status
Benthic Infauna		
0.5-mm fraction	24	Analyzed
0.3-mm fraction	24	Analyzed[a]
Grain Size	8	Frozen, Archived
TOC	8	Frozen, Archived[b]
Chemistry	8	Frozen, Archived
Benthic DNF/O_2 fluxes	6[c]	Analyzed[b]

[a]Only 23 samples were analyzed; one replicate was lost.
[b]To be analyzed under a separate task.
[c]Three cores at each of 2 stations.

2.2 LABORATORY METHODS: SAMPLE PROCESSING AND ANALYSIS

2.2.1 Benthic Infauna: Traditional

The benthic macrofauna collected at the eight traditional stations were processed by Battelle's subcontractor, Cove Corporation. Cove Corporation sorted and identified all organisms to lowest taxa possible. For each taxon, counts of individual organisms were made and tabulated. The 0.5-mm sieve fraction and the 0.3-mm sieve fraction were analyzed separately. Three replicates (from separate 0.04-m^2 grab samples) were completed for each station and each size fraction. Only two 0.3-mm fraction replicates from Station T7 were sorted; the jar containing the third was broken and the sample was lost. Thus, 47 samples were analyzed.

2.2.2 Archived Sediment

The surface sediment samples collected at each station for auxiliary analyses were transferred to Battelle Ocean Sciences in Duxbury, logged, and placed in a cold-temperature freezer (-20 °C). This material remains available for appropriate analysis as desired.

2.3 DATA ANALYSIS

For each station, for a number of analyses, the 0.3-mm and 0.5-mm fractions for benthic macrofauna were combined and termed total. Additionally, where total taxa at a station are reported, the value discounts redundant taxa across the three replicates. Some analyses, as identified, were performed only on taxa identifiable to species. Because only two replicates of the 0.3-mm fraction were available for Station T7, a third "replicate" was established by using the mean of these two replicates. In general, simple statistics of mean parameter values at a station (if $n > 1$) are provided in tabular form and full data are in the Appendix.

For macrofauna abundance data, a one-way Analysis of Variance (ANOVA) and a planned statistical comparison [Student-Newman-Keuls (SNK) Test] was performed on the April 1992 data using standard SAS (SAS Institute, 1985) processing software programs. A two-way ANOVA, followed by the SNK Test, was used to compare the September 1991 and April 1992 macrofauna data.

Cluster analysis employed normal (Q mode) numerical classification to order samples into groups according to their similarity. For macrofauna, the Normalized Expected Species Shared (NESS; Grassle and Smith, 1976) and Bray-Curtis (Boesch, 1977) algorithms were used as the similarity measures.

3.0 RESULTS

3.1 BENTHIC INFAUNA (TRADITIONAL STATIONS)

Full taxonomic identifications and counts are provided in the Appendix for the 0.5-mm (Table B-2) and 0.3-mm (Table B-3) fractions at each of the eight stations sampled in April 1992. Data include, for each replicate (0.04-m^2) grab, species (or lowest identifiable taxa) and counts, several diversity measures (treating all taxa as separate), and summary statistics for the station. The results given next primarily emphasize station summary data.

Table 3 summarizes, by sieve fraction, numbers of taxa and individuals. The 0.5-mm fraction made a majority contribution to total individuals and/or taxa at each station. The 0.5-mm fraction contributed 74 to 87% of the total abundance at T3 and the southern stations (T6, T7, T8), but 62 to 71% of the total at the northern stations (T1, T2, T4, R6). At each station, the 0.5-mm fraction contained 77 to 91% of the taxa.

For taxa, the total number (sum of nonredundant taxa from three replicates) ranged from 19 to 65 across stations. For number of individuals, the range was 1264 to 6082 per station. Expressed on an area basis (Table 3, numbers are per three 0.04 m^2 grabs), the range was 1.1×10^4 to 5.1×10^4 individuals per m^2.

The number of individuals was lowest at three of the northern Harbor stations (T4, T2, R6) and one southern Harbor station (T7). These four stations also had the lowest numbers of taxa (Table 3). Two northern Harbor stations (T1, T3), near the (obsolete) sludge and (extant) effluent outfalls off Deer Island and Long Island, and two of the southern Harbor stations (T6, T8) had higher numbers. These spatial patterns, described by measures of species richness and abundance, are also illustrated in Figures 2 and 3.

The top five dominant taxa for the traditional stations are shown in Table 4. Five taxa were dominant at at least 50% of the stations. Oligochaetes were among the dominant taxa at all eight stations, being most abundant at Stations T6, T1, and T3. The blue mussel, *Mytilus edulis*, appeared as a top-five dominant at six stations. *Mytilus*, relatively uncommon in the September 1991 survey, was most numerous at Stations T1, T6, and T3. Other taxa appearing as dominant at a minimum of four stations were the polychaetes *Streblospio benedicti*, *Aricidea catherinae*, and *Tharyx* cf. *acutus*. *S. benedicti* was a dominant at three northern Harbor stations (T1, T2, T4) and T7 in Quincy Bay, whereas *A. catherinae* was a dominant taxon at the three southern Harbor stations (T6, T7, T8) and at T3. *Tharyx* cf. *acutus* was one of the dominant taxa only at the five northern Harbor stations. Several taxa, *S. benedicti*, oligochaetes, *Mytilus edulis*, *Tharyx* cf. *acutus*, and *Ampelisca* spp. were present at every station, although occasionally at low numbers (Appendix Tables B-2 and B-3). In general, the northern Harbor stations tended to be dominated mainly by one or two taxa, whereas southern Harbor stations had numbers spread more evenly across a few taxa (Table 4). For example, the percent abundance of the top two taxa at northern stations ranged from 60-84%, whereas the range for the southern stations was 50-67%.

Cluster analysis of the total macrofauna community (Figures 4 and 5) shows that replicates at a station group together before clustering with their most taxonomically similar neighbor. This pattern of within-station variability being generally small relative to station-to-station variability also holds if clusters are based on only the 0.5-mm fraction (Figures 6 and 7).

However, in spite of station individuality, patterns of station associations were evident that reflected differences in the clustering algorithms used. The pattern revealed by Bray-Curtis, in which similarity is strongly influenced by abundant taxa (Boesch, 1977), showed what may be interpreted loosely as more "inner" Harbor (T2 with T7, then T4) and more "outer" Harbor (T1 and T3 with R6, then with T6 and T8) assemblages. NESS, in which similarity is sensitive to the presence of rare taxa (Grassle and Smith, 1976), showed a slightly different pattern of three-station groups. Station T7 clustered with Stations T1 and T3, then with Station R6. Station T6 clustered with the former stations. Inner northern Harbor Stations T2 and T4 formed a cluster. Station T-8 was distinct, clustering only with all the other stations considered as a group.

Table 3. Total Taxa and Abundance at Traditional Stations (3 Replicate Grabs) Sampled during April 1992

Parameter	Sieve Fraction	Station[a] T4	R6	T2	T7	T3	T6	T1	T8
Number of Taxa	0.5 mm	17	25	24	32	41	49	53	54
	0.3 mm	10	14	20	13	23	27	27	30
	Total	19	28	31	35	47	54	59	65
Number of Individuals	0.5 mm	923	783	1637	1916	2150	4523	3170	2701
	0.3 mm	386	481	886	278[b]	656	1559	1644	738
	Total	1309	1264	2523	2194	2806	6082	4814	3439

[a]Stations are ordered from left to right by increasing number of total taxa. Stations underlined are in the southern region of the Harbor.
[b]Only 2 replicates for 0.3 mm fraction. Both 0.3 mm and total were projected to 3 replicates.

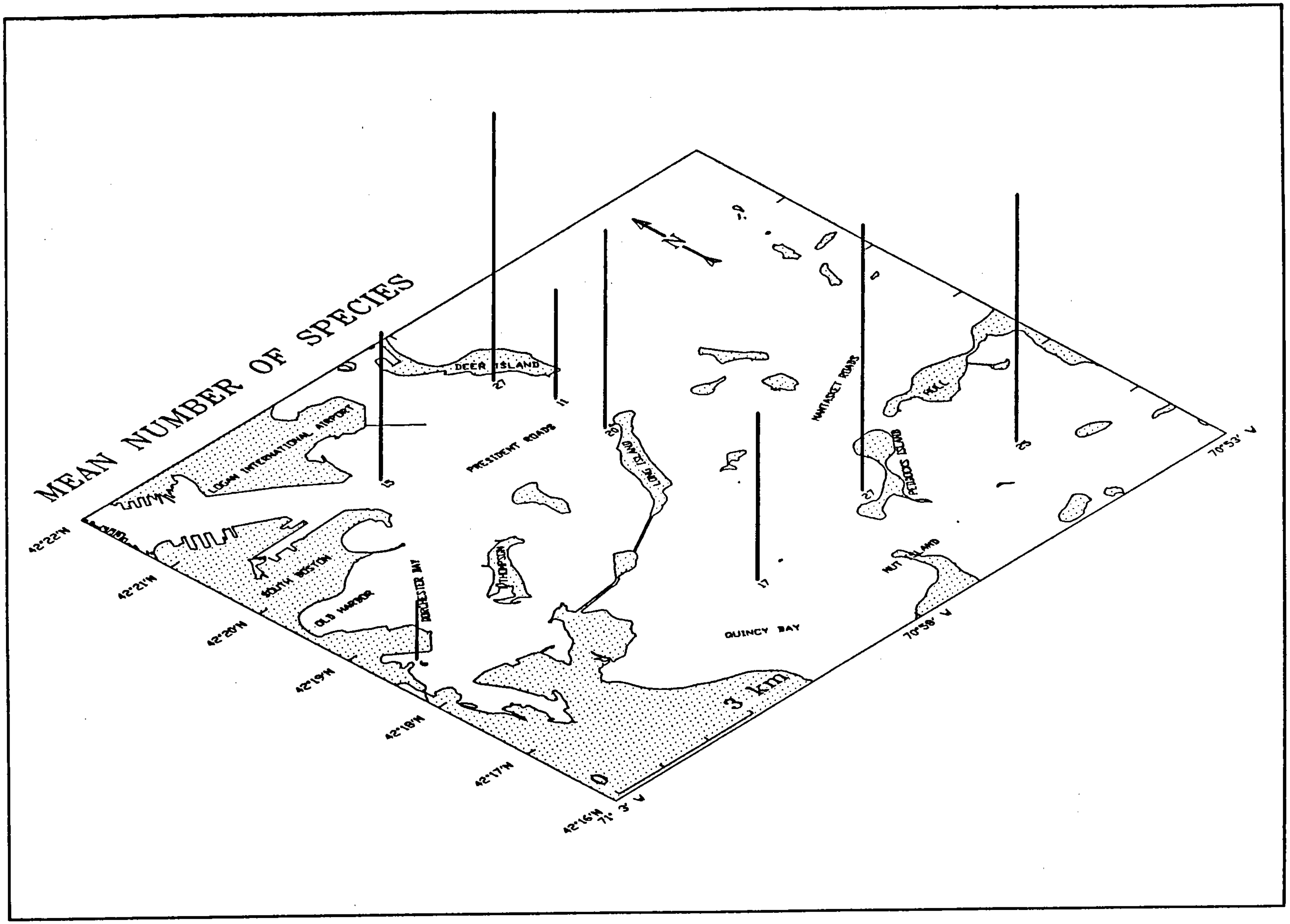

Figure 2. Macrofauna Species Richness at Stations Sampled during April 1992.
Mean number of taxa from total fraction identifiable to *species per replicate grab*. Note these numbers differ from Table 3, where the cumulative number of *total taxa across three replicates* are presented.

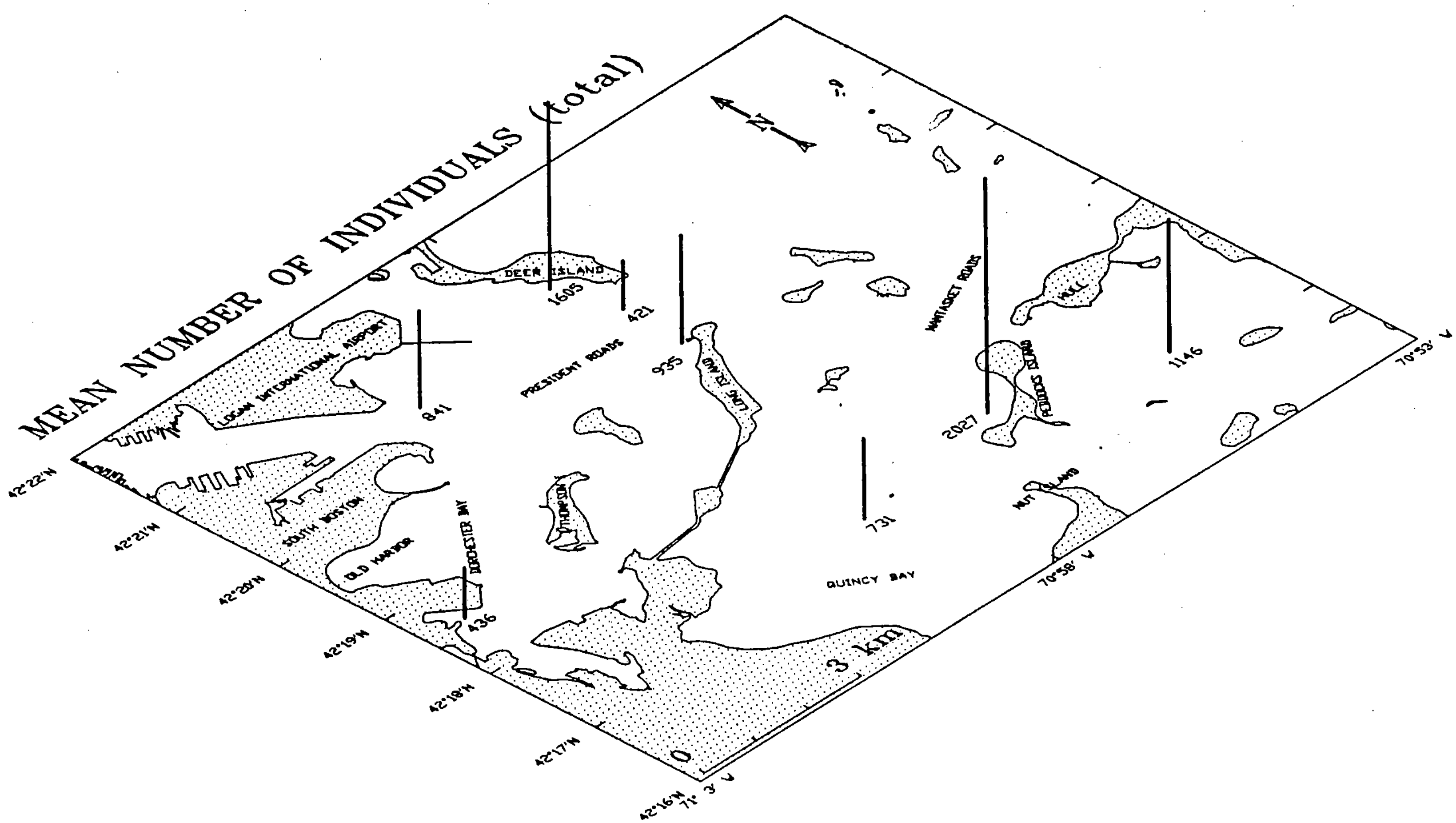

Figure 3. Macrofauna Abundance at Stations Sampled during April 1992.

Table 4. Abundance of Top 5 Taxa at Traditional Stations (3 Replicate Grabs) Sampled during April 1992

TAXA	STATION[a] T4	R6	T2	T7	T3	T6	T1	T8
Oligochaeta	130 (10%)	82 (6%)	197 (8%)	129 (6%)	1589 (57%)	3239 (53%)	3051 (63%)	180 (5%)
Streblospio benedicti	485 (37%)		1456 (58%)	985 (45%)			126 (3%)	
Microphthalmus aberrans							410 (9%)	
Tharyx cf. *acutus*	10 (1%)	32 (3%)	132 (5%)		118 (4%)		134 (3%)	
Polydora cornuta	10 (1%)			144 (7%)				
Dyopedos monacanthus						98 (2%)		
Tellina agilis								174 (5%)
Mytilus edulis	29 (2%)	102 (8%)	76 (3%)		112 (4%)	113 (2%)	250 (5%)	
Aricidea catherinae				75 (3%)	170 (6%)	850 (14%)		1225 (36%)
Ampelisca sp. complex				445 (20%)	126 (4%)	874 (14%)		
Phoxocephalus holbolli						98 (2%)		
Nassarius vibex		87 (7%)						
Capitella spp. complex	610 (47%)	661 (52%)	113 (4%)					
Exogene hebes								354 (10%)
Polygordius sp.								493 (14%)

[a]Stations are ordered from left to right by increasing number of taxa (see previous Table). Stations underlined are in the southern region of the Harbor.

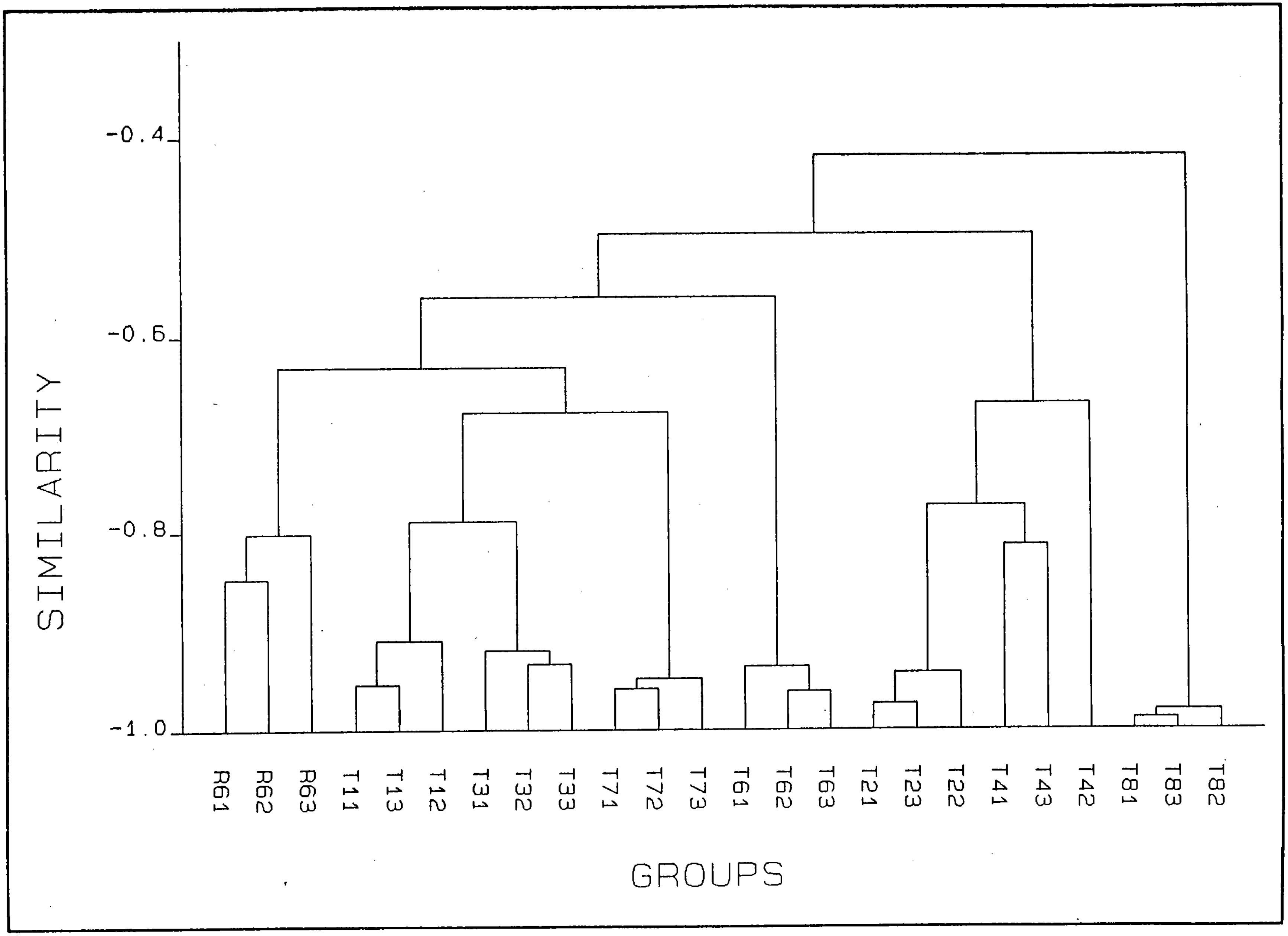

Figure 4. Cluster Dendrogram of Replicate Grab Samples (Total Taxa) of Stations Sampled during April 1992.
Performed on taxa *identifiable to species* using the cluster algorithm NESS without data transformation.
Note that coding gives station code followed by replicate grab (1, 2, or 3).

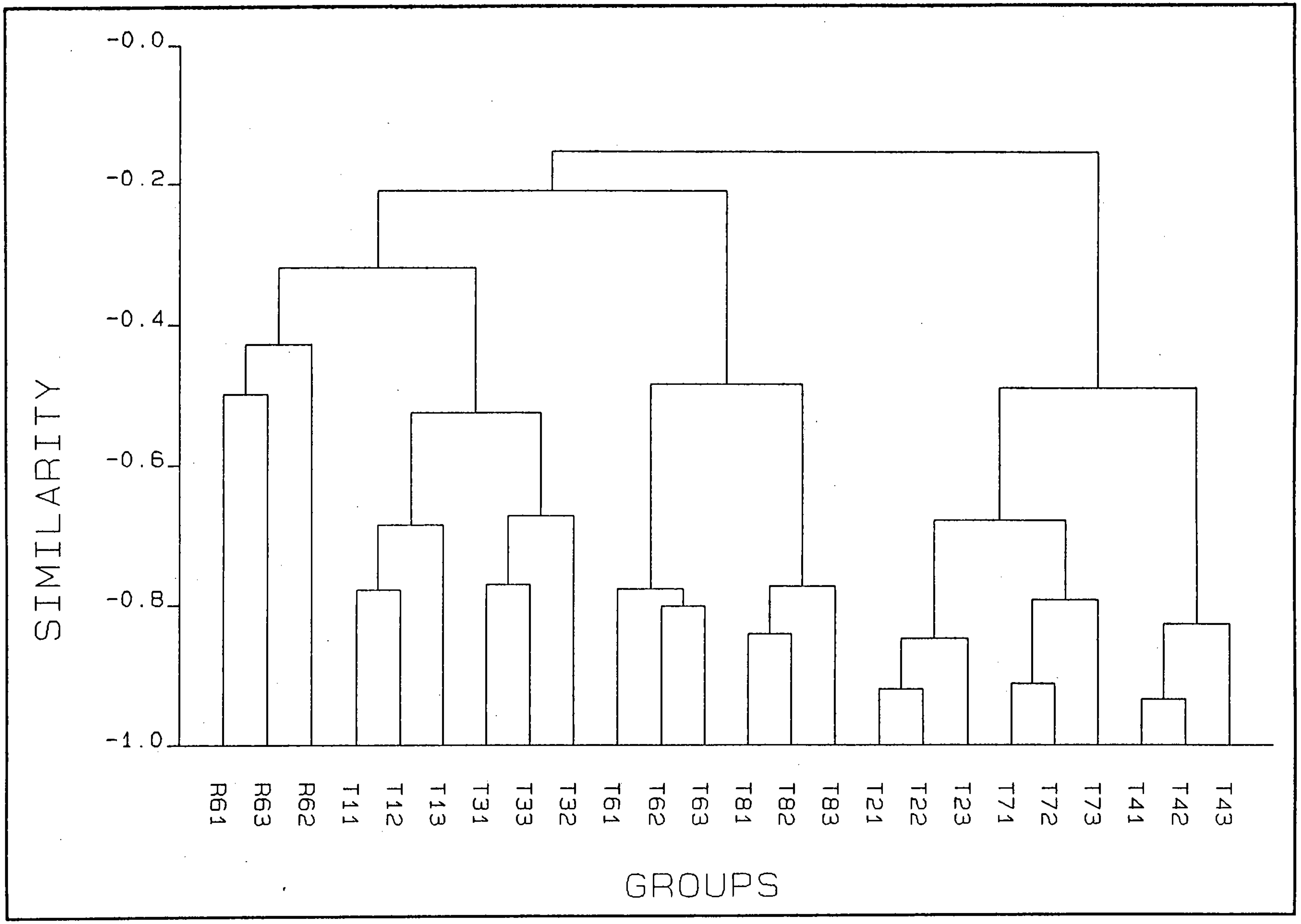

Figure 5. Cluster Dendrogram of Replicate Grab Samples (Total Taxa) of Stations Sampled during April 1992.
Performed on taxa *identifiable to species* using the cluster algorithm Bray Curtis without data transformation.
Note that coding gives station code followed by replicate grab (1, 2, or 3).

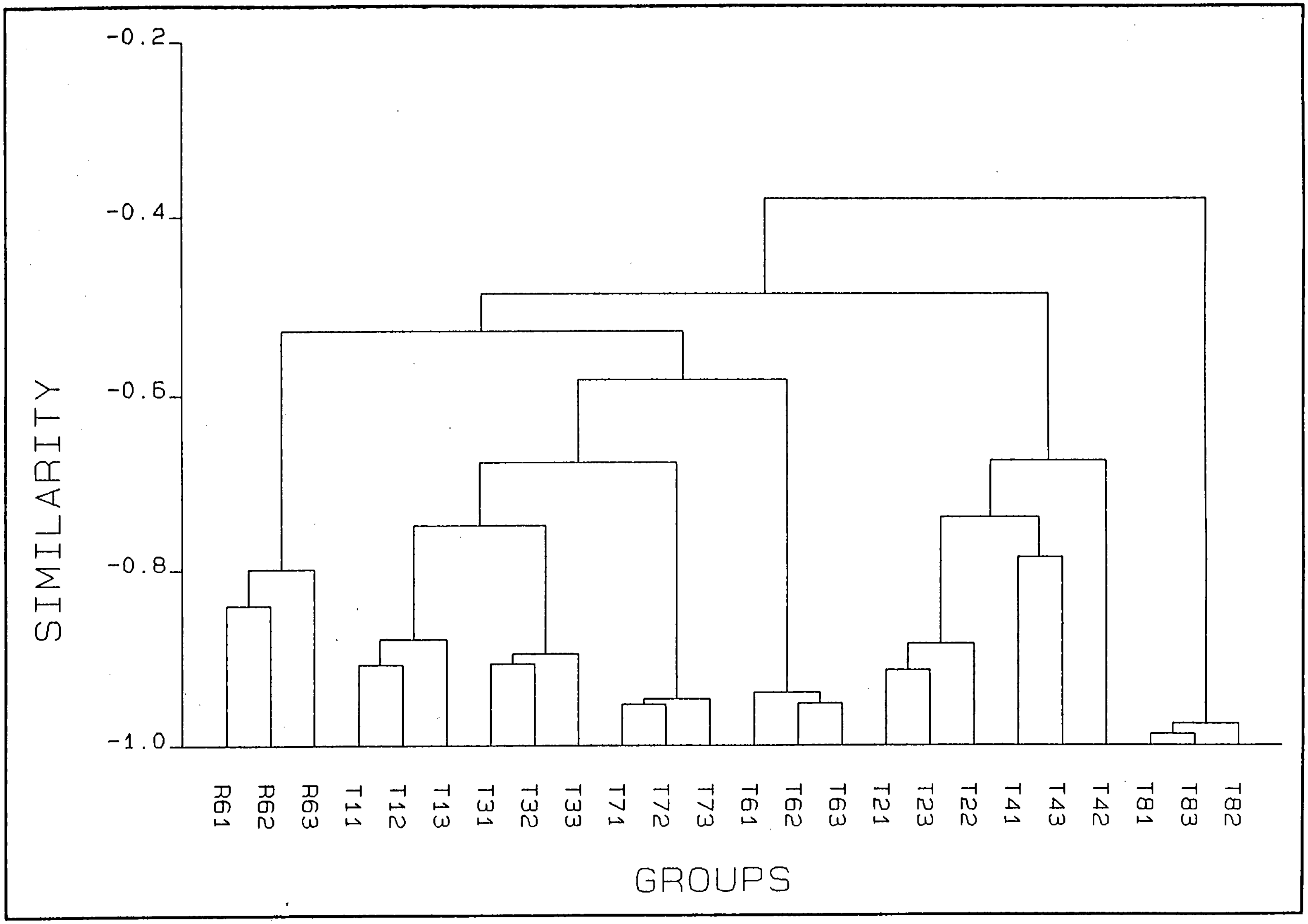

Figure 6. Cluster Dendrogram of Replicate Grab Samples (0.5 mm Fraction Only) of Stations Sampled during April 1992.

Performed on taxa *identifiable to species* using the cluster algorithm NESS without data transformation.

Note that coding gives station code followed by replicate grab (1, 2, or 3).

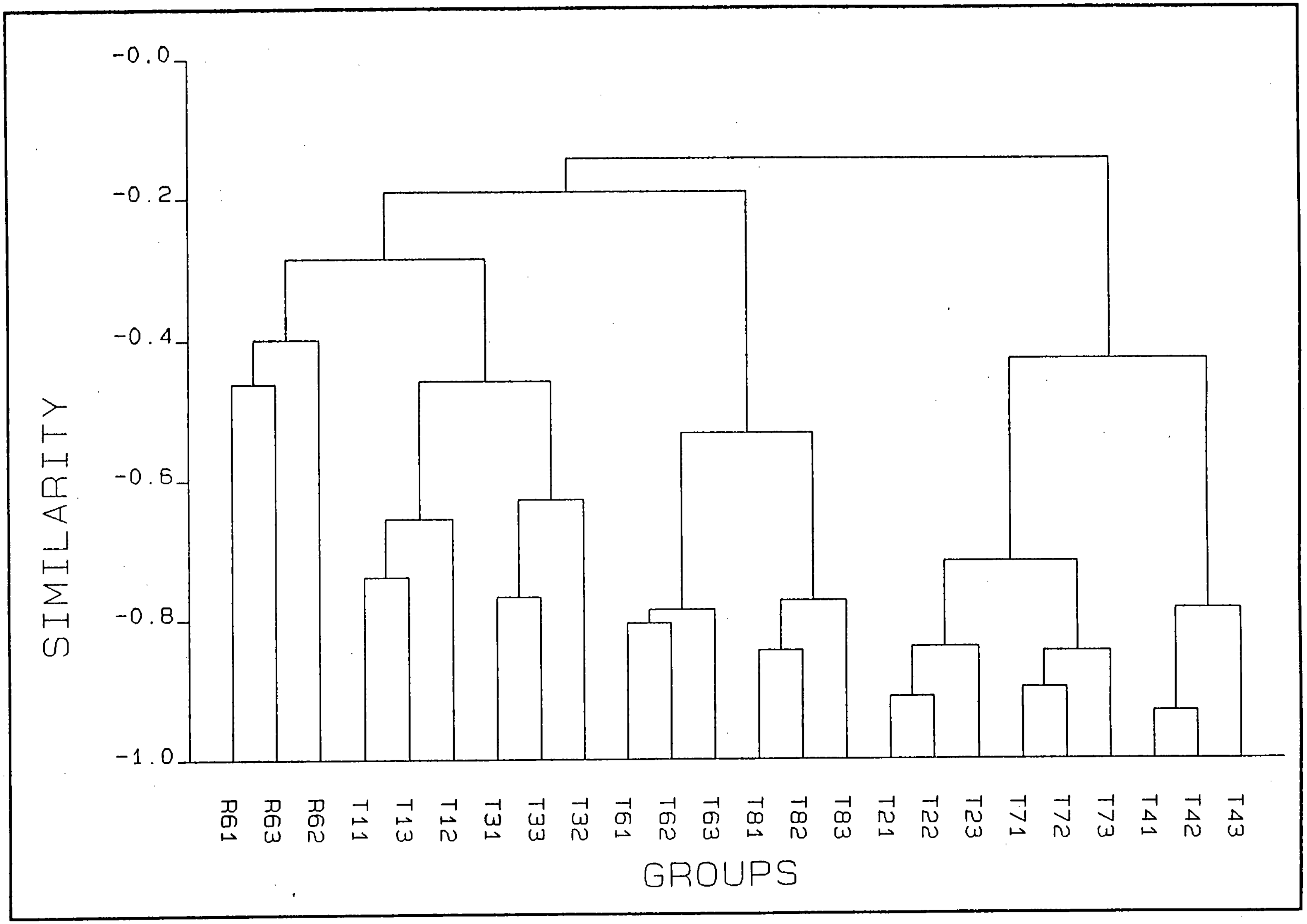

Figure 7. Cluster Dendrogram of Replicate Grab Samples (0.5 mm Fraction Only) of Stations Sampled during April 1992.
Performed on taxa *identifiable to species* using the cluster algorithm Bray Curtis without data transformation.
Note that coding gives station code followed by replicate grab (1, 2, or 3).

Based on one-way ANOVA and a Student-Newman-Keuls Test for planned comparisons (Appendix, Table B-4), the mean number of individuals was not different between T6 and T1. T1 also overlapped with T8, but T6 had significantly ($\alpha = 0.05$) greater abundance than T8, T3, T2, T7, T4, and R6. Abundance at the latter six stations did not differ (Table 3).

4.0 DISCUSSION OF STATION TRENDS

4.1 SEPTEMBER 1991 — APRIL 1992 COMPARISONS

The ratio between September 1991 (fall) and April 1992 (spring) total macrofauna abundance was consistent, i.e., the ratios fell between 5:1 and 1:5 at most stations (Figure 8). Total abundance at Station T2 was greater in the spring than in the fall as indicated by a spring:fall ratio greater than 5:1. Results of a two-way ANOVA and a Student-Newman-Keuls Test for planned comparisons (Appendix, Table B-5) showed that there were no significant differences ($\alpha = 0.05$) in the mean number of individuals present at a station in the fall as compared to the spring. Combining all replicates from spring and fall sampling, mean abundance was significantly greater at stations T6, T8, and T3, than at stations T2, R6, T4, and T5. Abundance at T1 overlapped that at all other stations and at T7 overlapped that at all stations except T6. The total number of taxa found at each station was also fairly consistent between fall and spring, although all stations except T8 had more taxa present in the spring (Figure 9).

For each station, the abundance of the dominant taxa (as listed in Table 5) in the fall was plotted versus that in the spring (Figures 10 through 13). For illustration, we contrasted T5 (fall) and R6 (spring); results (Part I) indicated these were similar faunistically and environmentally, but the comparison must be interpreted with caution. The abundance of most station-specific dominant taxa was consistent between the two sampling periods, although there were some notable exceptions. At station T1, *Mytilus edulis, Polydora socialis,* and *Spio setosa* were relatively abundant in the spring, but were not present in the fall. At station T2, most of the dominant taxa were more numerous in the spring, including several taxa not present in the fall. The situation at stations T4 and T5/R6 was similar, with some taxa occurring in the spring that were not present in the fall. The abundance of most of the dominant taxa at stations T6 and T7 were consistent between sampling periods, with a few taxa newly occurring in the spring. Station T8 provided the counterexample to the above trend. Though many of the dominant taxa were present in consistent numbers, many were more abundant in the fall than in the spring. Five of the dominant taxa in the fall did not occur in the spring samples.

For selected taxa, abundance at each station in the fall also was plotted versus that for the spring (Figures 14 through 16). Abundance of three annelids — oligochaetes, *Streblospio benedicti,* and *Aricidea catherinae* — were consistent between spring and fall. Oligochaetes, which were absent from station T4 in the fall, did appear in relatively high numbers there in the spring. At station T2, *S. benedicti* showed about a twenty-fold increase in abundance in the spring as compared to the fall. *Ampelisca* spp. complex showed approximately 17- and 23-fold decreases in numbers from fall to spring at stations T1 and T8, respectively. *Ampelisca* also appeared at low numbers at stations T2, T5/R6, and T4 in the spring, whereas this genus had not been present in the fall. The blue mussel, *Mytilus edulis,* showed dramatic increases in abundance (i.e., spring:fall ratios greater than 5:1) in the spring at all stations except T8.

The individuality of several stations was not affected by differences in sampling periods. NESS cluster analysis (sensitive to rare taxa) revealed that spring and fall replicates grouped together for stations T8, T6, T7, and T5/R6 (Figure 17). Replicates from spring and fall samples from stations T2 and T4

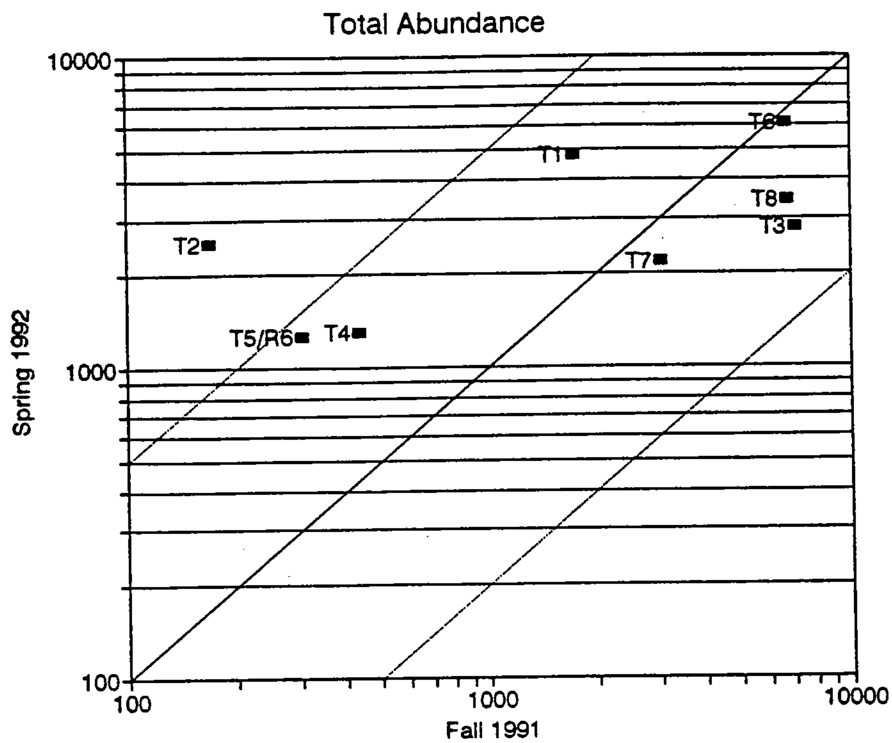

Figure 8. September 1991 - April 1992 Comparison: Total Macrofauna Abundance

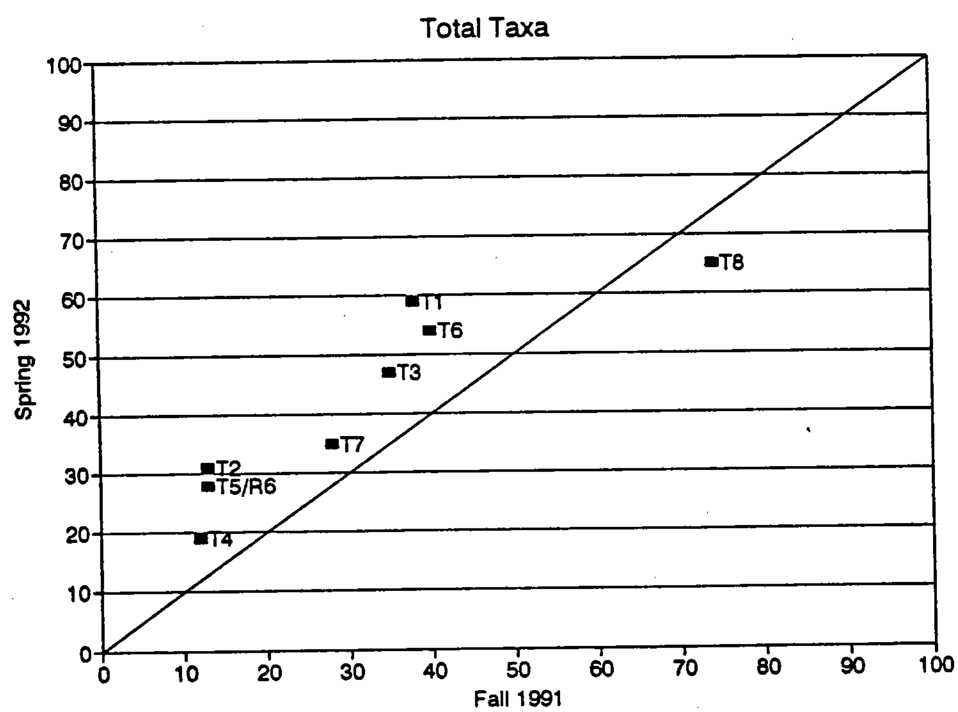

Figure 9. September 1991 - April 1992 Comparison: Total Number of Taxa.

Table 5. Taxa Used in Fall versus Spring Comparisons — Codes as Used in Figures 10 through 13.

Code	Taxon	Major Taxon
Amp	*Ampelisca* spp. complex	Amphipoda
Arc	*Aricidea catherinae*	Polychaeta
Cap	*Capitella* spp. complex	Polychaeta
Clt	*Clymenella torquata*	Polychaeta
Crs	*Crangon septemspinosa*	Decapoda
Dym	*Dyopedos monacanthus*	Amphipoda
Edt	*Edotea triloba*	Isopoda
End	*Ensis directus*	Bivalvia
Exh	*Exogone hebes*	Polychaeta
Lep	*Leptocheirus pinguis*	Amphipoda
Luh	*Lumbrineris hebes*	Polychaeta
Lyh	*Lyonsia hyalina*	Bivalvia
Mec	*Mediomastus californiensis*	Polychaeta
Mia	*Microphthalmus aberrans*	Polychaeta
Mob	*Monticellina baptisteae*	Polychaeta
Mya	*Mya arenaria*	Bivalvia
Mye	*Mytilus edulis*	Bivalvia
Nav	*Nassarius vibex*	Gastropoda
Nec	*Nephtys caeca*	Polychaeta
Nud	*Nucula delphinodonta*	Bivalvia
Oli	Oligochaeta	Oligochaeta
Orm	*Orchomenella minuta*	Amphipoda
Phh	*Phoxocephalus holboli*	Amphipoda
Phm	*Phyllodoce mucosa*	Polychaeta
Ply	Polygordius	Polychaeta
Poc	*Polydora cornuta*	Polychaeta
Poq	*Polydora quadrilobata*	Polychaeta
Pos	*Polydora socialis*	Polychaeta
Prs	*Prionospio steenstrupi*	Polychaeta
Pye	*Pygospio elegans*	Polychaeta
Spb	*Spiophanes bombyx*	Polychaeta
Spl	*Spio limicola*	Polychaeta
Sps	*Spio setosa*	Polychaeta
Stb	*Streblospio benedicti*	Polychaeta
Tea	*Tellina agilis*	Bivalvia
Tha	*Tharyx* cf. *acutus*	Polychaeta
Tur	Turbellaria	Turbellaria

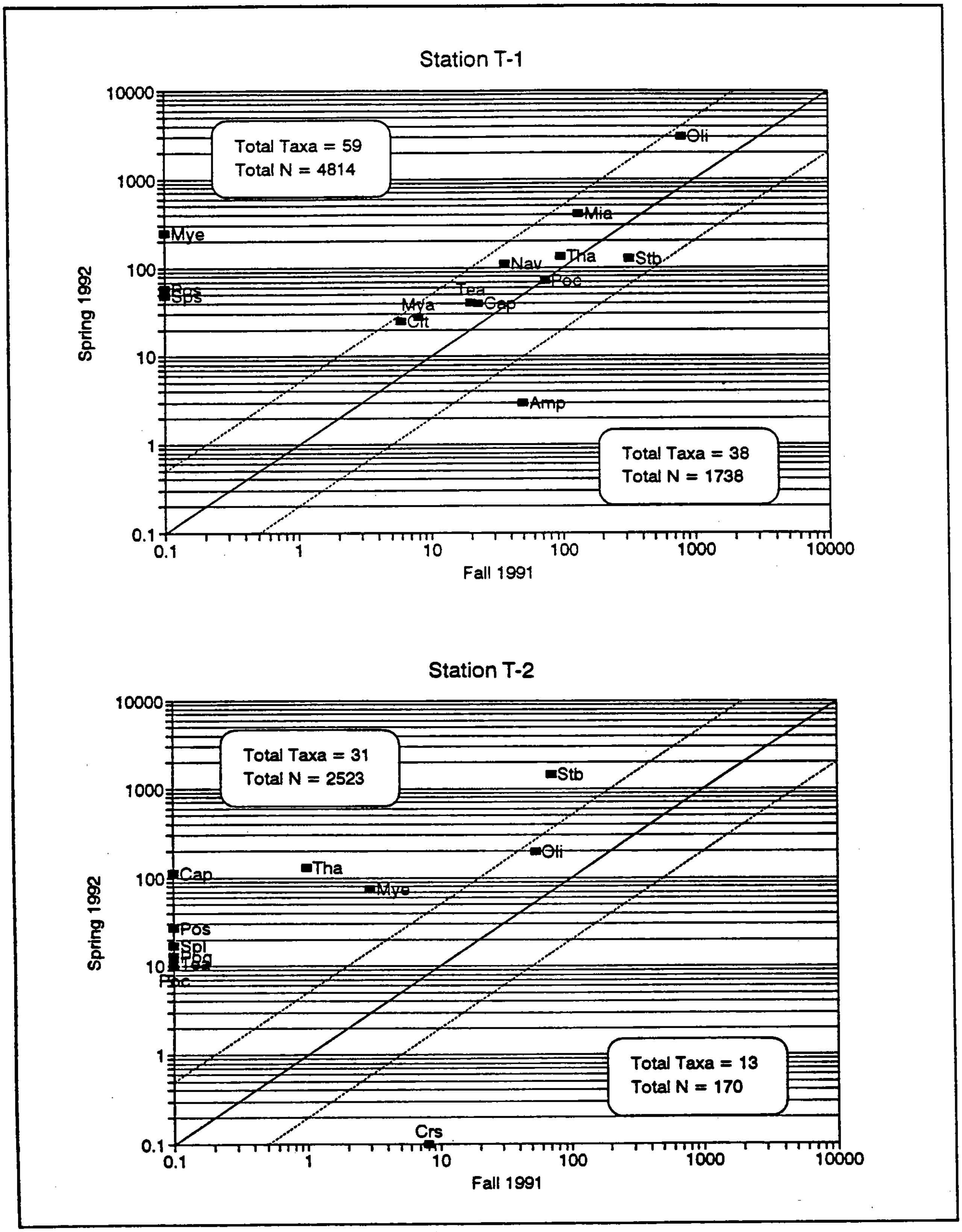

Figure 10. September 1991 - April 1992 Comparison: Dominant Taxa at T1 and T2.

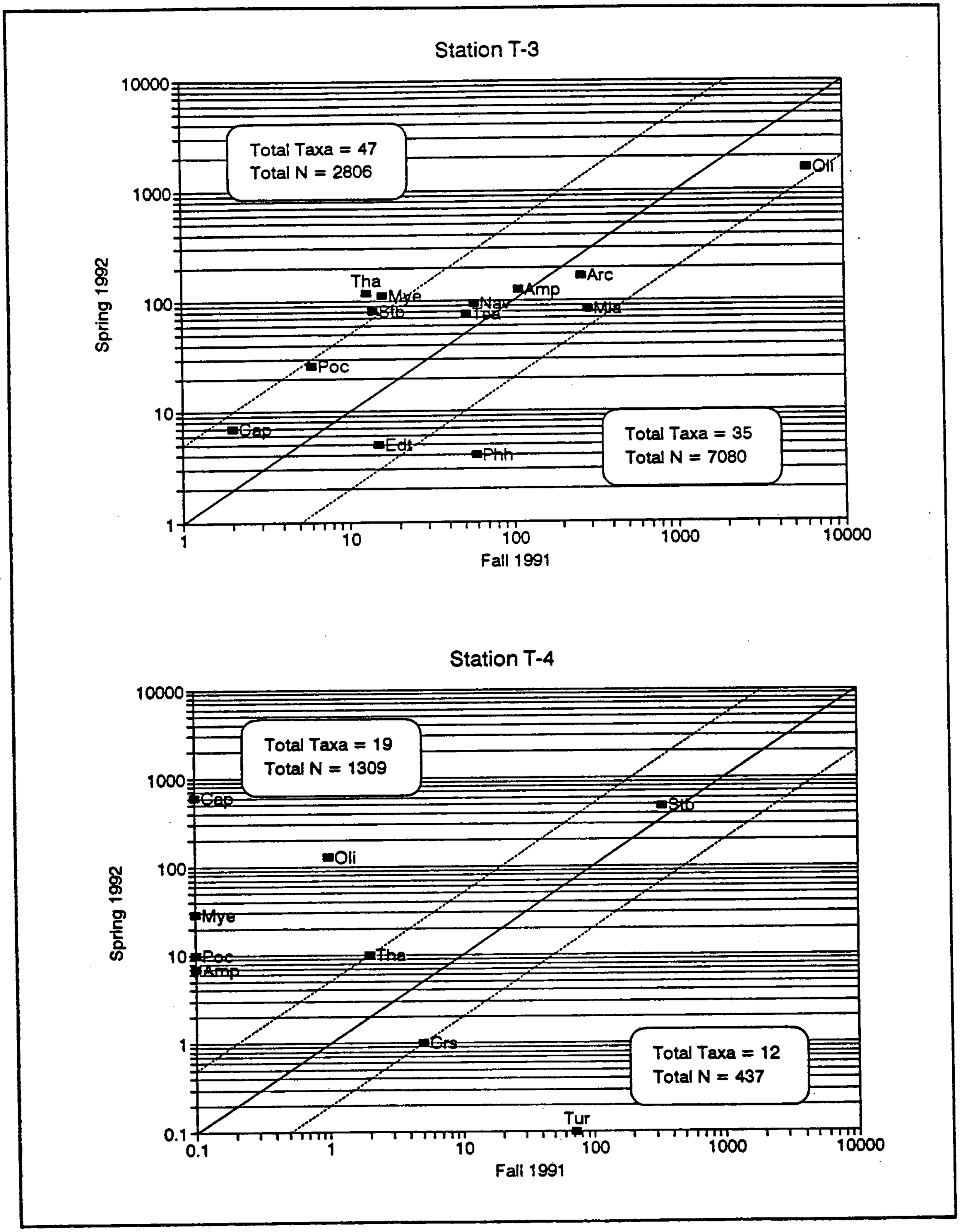

Figure 11. September 1991 - April 1992 Comparison: Dominant Taxa at T3 and T4.

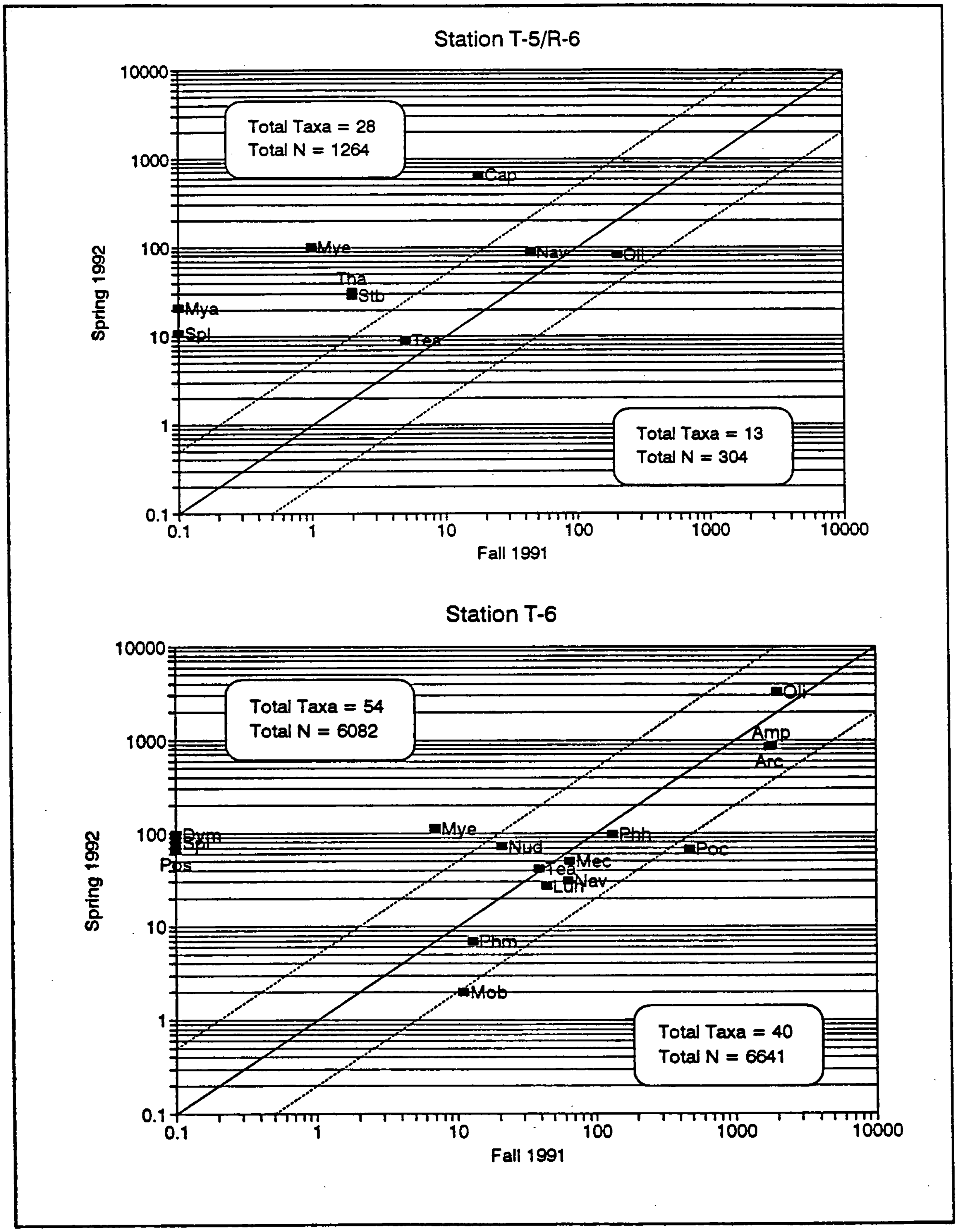

Figure 12. September 1991 - April 1992 Comparison: Dominant Taxa at T5/R6 and T6.

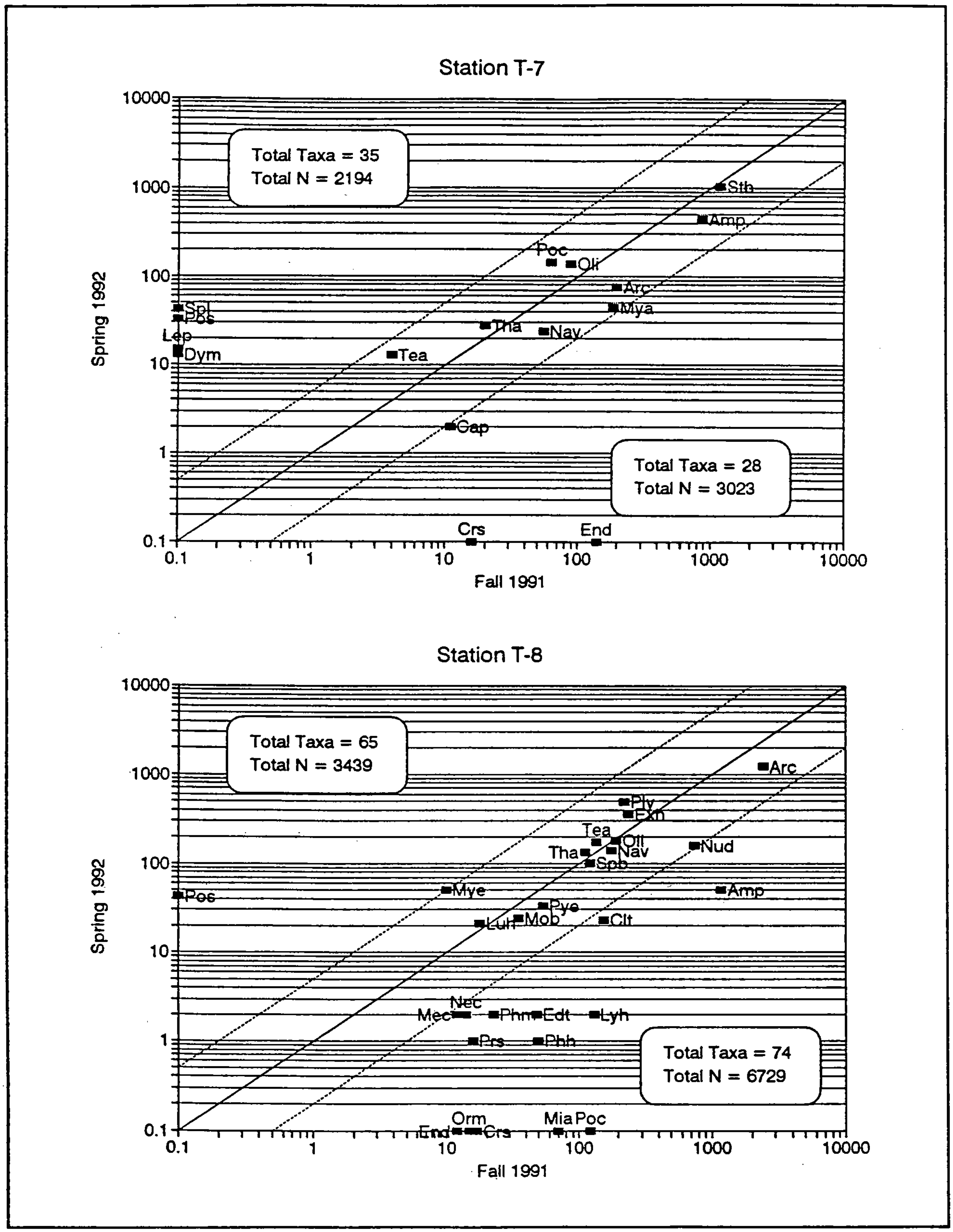

Figure 13. September 1991 - April 1992 Comparison: Dominant Taxa at T7 and T8.

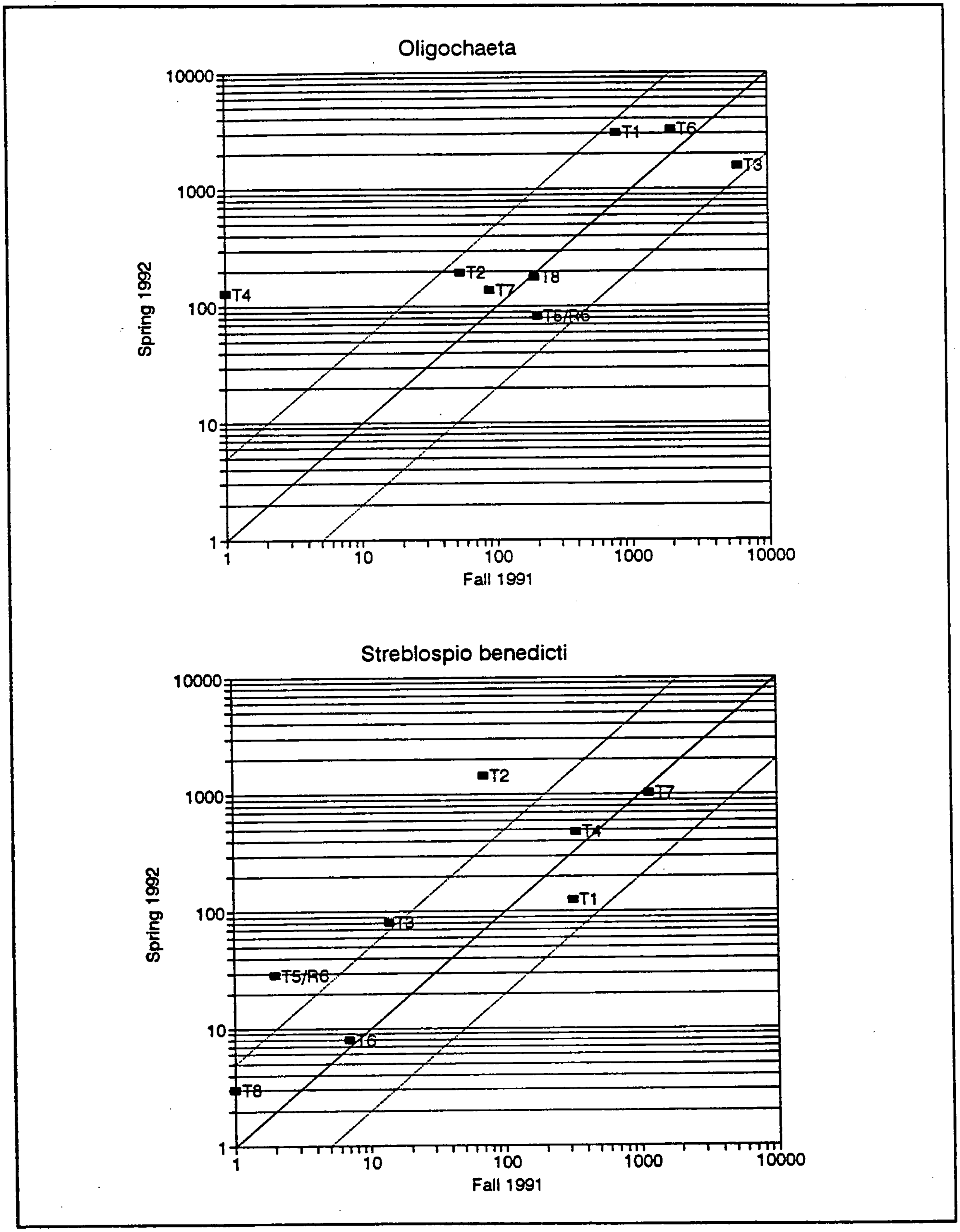

Figure 14. September 1991 - April 1992 Comparison: *Oligochaeta* and *Streblospio benedicti*.

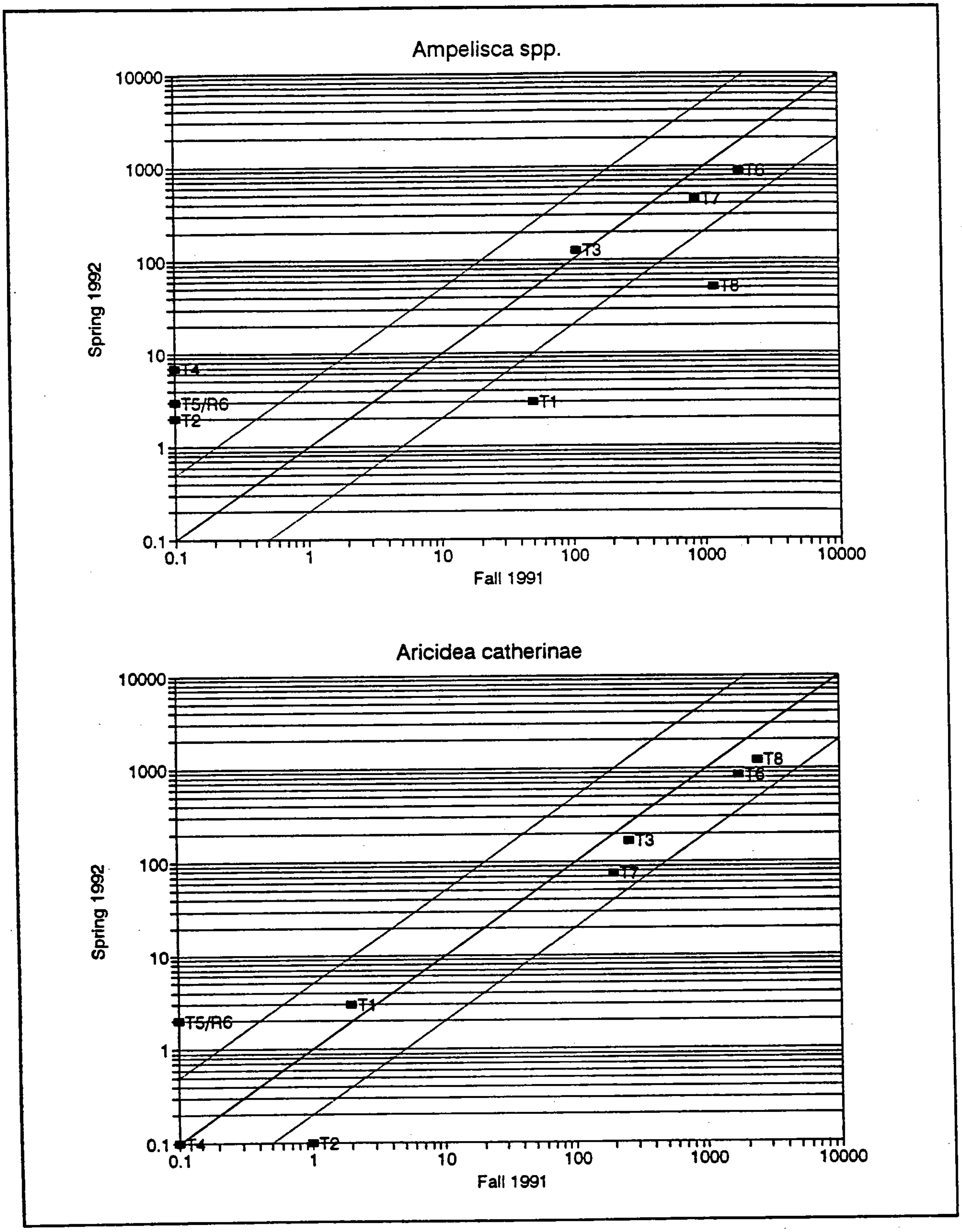

Figure 15. September 1991 - April 1992 Comparison: ***Ampelisca*** **and** ***Aricidea catherinae.***

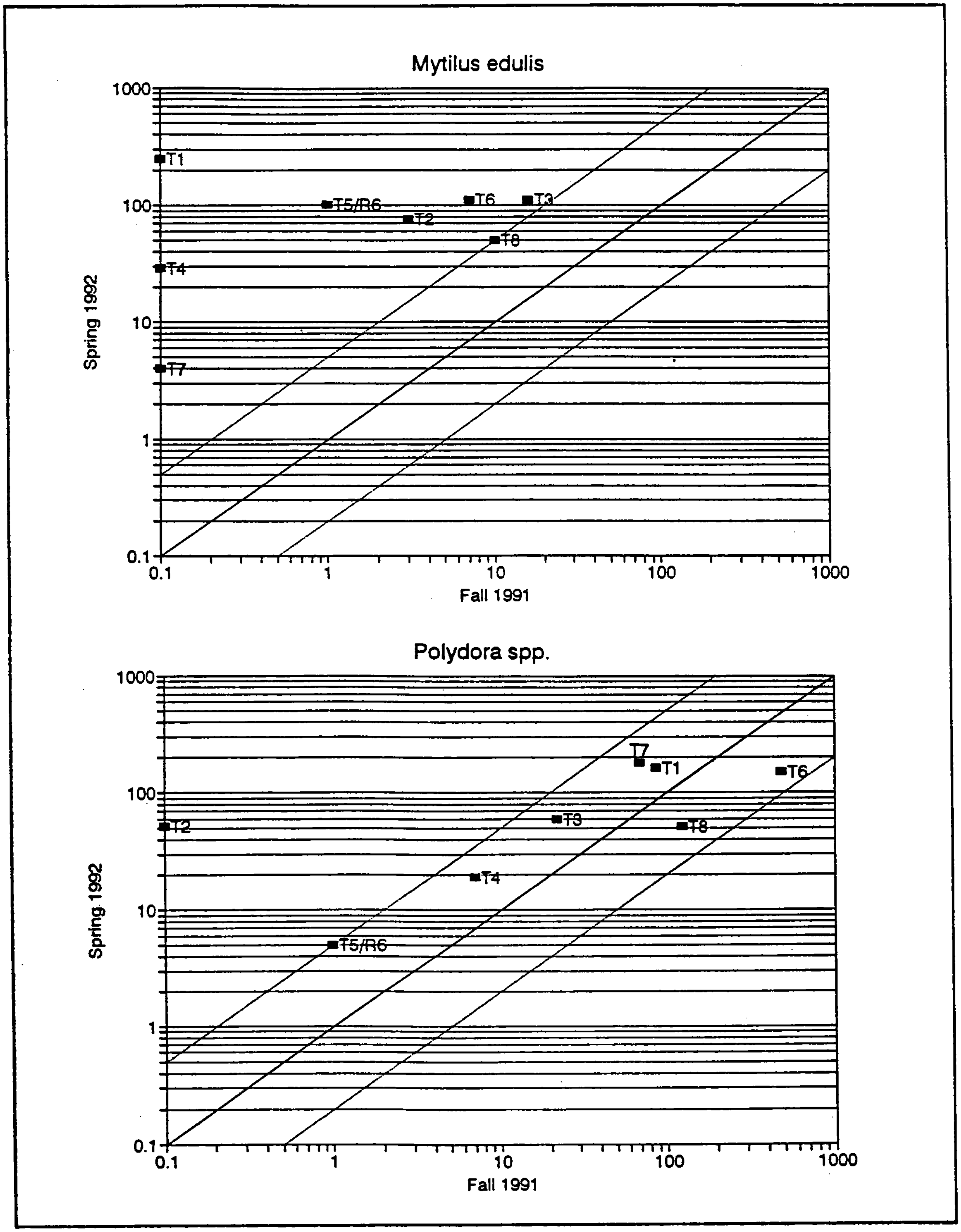

Figure 16. September 1991 - April 1992 Comparison: *Mytilus edulis* and *Polydora*.

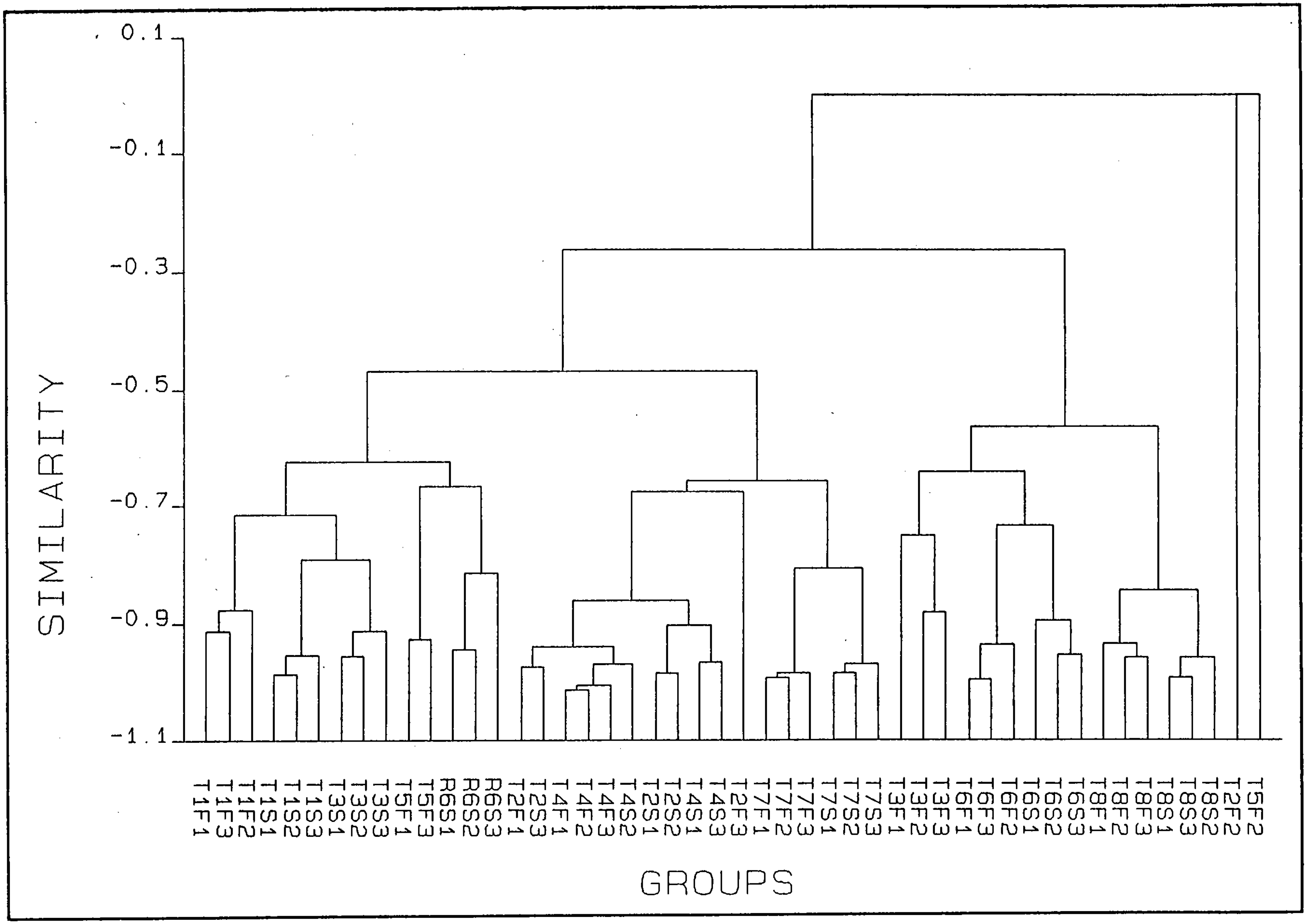

Figure 17. September 1991 - April 1992 Comparison: NESS Cluster Analyses.

Performed on taxa *identifiable to species* using the cluster algorithm NESS without data transformation.

Note that coding gives station code followed by sampling season (S or F) and replicate grab (1, 2, or 3).

showed different affinities, the former clustering with spring and fall samples from T1 and the latter T3 samples grouping with T6 and T8. Using NESS, the Harbor can be roughly separated into three regions (Figure 17): an inner region consisting of stations T2, T4, and T7; one outer region comprising stations T1, T5/R6, and spring T3 (all in the northern Harbor); and another outer region represented by T6, T8, (southern Harbor) and fall T3 (northern Harbor).

Cluster analysis using the Bray-Curtis algorithm (influenced by abundant taxa) suggested a slightly different division of the Harbor into three areas (Figure 18). Stations T2 and T7 were highly associated, then being joined by T4 and T1 (fall only). Stations T3 and T1 (spring), coupled with R6, form a tight geographic grouping of the area from Deer Island to Long Island. Stations T6 and T8 constitute a southern Harbor area. Note that Station T5, which was sampled only during the fall of 1991, differed substantially from all other stations.

4.2 MONITORING RECOVERY FROM SLUDGE ABATEMENT

Summarizing, the faunal results from the 1991 and 1992 traditional surveys provided several notable findings. Each below, in some way relates to the task of monitoring to detect recovery in response to modification of discharge practices.

1. **Stations have taxonomic individuality**
   Replicate grabs, by and large, showed coherency in species and abundances. In many cases, all three grabs of a station from a survey appeared more like each other than any other grabs. In terms of monitoring, this result provides well defined conditions for statistical purposes.

2. **Taxonomic identity/faunal abundances shifted only slightly with season at all stations**
   Total abundances ranged from markedly higher to slightly lower at a given station in the spring compared to the previous fall. All stations but T8 had more taxa in the spring. A spring set of small molluscs (especially *Mytilus*) and more ubiquitous distribution of small opportunistic polychaetes and a few amphipods, each contributed to the seasonal phenomenon. Even then, many stations were most like themselves in the previous season. The list of dominant organisms at most stations was similar in spite of season, although the precise rank order sometimes shifted a bit. Of all stations, only T4 had striking new top dominants (*Capitella* and oligochaetes) in the spring, although *Capitella* and *Mytilus* were among dominants at R6 spring and not T5 fall.

3. **Faunal similarity among stations was apparent within some geographic areas**
   Despite the degree of station individuality in space and time, groups of stations were associated on the basis of similar faunal composition. The strength and nature of station groupings varied slightly with sieve size, the measure of similarity used, and with season. The most consistent station groupings, in spite of these factors, were geographically defined: a more inner Harbor type (principally T2 and T4), a more southern Harbor type (principally T6 and T8), and the cluster in the northern outer Harbor near Deer Island and Long Island. Monitoring could continue to examine regional changes as a basis for documenting recovery, with traditional stations supplemented by more extensive regional coverage through rapid assessment methods.

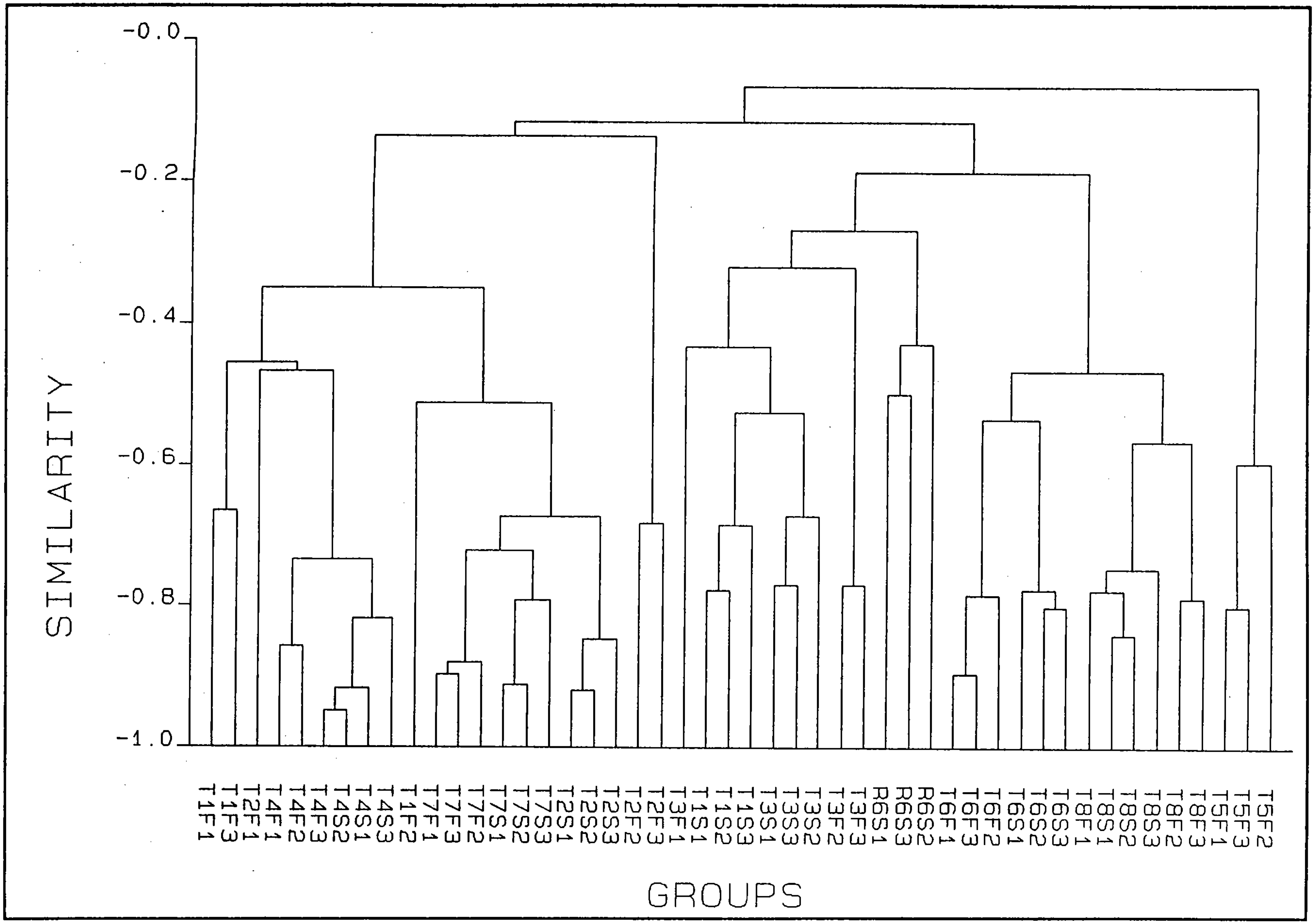

Figure 18. September 1991 - April 1992 Comparison: Bray Curtis Cluster Analyses.
Performed on taxa *identifiable to species* using the cluster algorithm Bray Curtis without data transformation.
Note that coding gives station code followed by sampling season (S or F) and replicate grab (1, 2, or 3).

4. **Curiously, the northern outer Harbor region appeared to have strongest examples where spring and fall grab replicates had split affinities for station groups**
   The split varied with similarity measure used (Figures 17, 18). For example, using Bray-Curtis for clustering, T1 fall grouped most strongly with T4, while T1 spring clustered with T3 fall and spring. In contrast, using NESS, T3 spring clustered with T1 fall and spring, while T3 fall clustered with T6, as described in Part I of this report. Note also that T5 could not be relocated and the small depositional patch it may have represented near a somewhat gravelly bottom in the vicinity of the old sludge outfall may no longer be present. Since these stations are in the region of past sludge discharge (especially T3) and present effluent discharge (especially T1), it is interesting to note the time variability, which may or may not be related to sludge abatement. Whether the variability is a first hint of response to changes in discharge practices is in no way certain and present data do not suggest much in terms of statistical trends; but continued monitoring will tell.

5.0 ACKNOWLEDGMENTS

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APPENDIX B

Table B-1. Field Log for Grabs at Each Station, including Navigation and Comments.

Station	Date and Time (EDT)	Grab	Latitude Longitude	LORAN Time Delays	Depth (m)	Comments
T6	4/23/92	1	42°17.62'N 70°56.67'W	14030.7 25816.4	5.1	Amphipod tubes. Gastropods and amphipods present, polychaetes present. Very fine silt.
		2				Amphipod tubes. Gastropods and amphipods present, large polychaetes present. Possible amphipod egg clusters. *Nereis* clamworms. Nemertean sp. present.
		3				Same as Replicates 1 and 2.
		4				Same as Replicates 1 and 2.
T7		1	42°17.35'N 70°58.72'W	14045.1 25829.7	5.6	Amphipod tubes and small clams present. Bamboo worms.
		2				
		3				Crushed mussel and clam shells, no live mussels or clams.
		4				
T4		1	42°18.62'N 71°02.45'W		5.9	Strong odor, fine clay, nothing living. One Nemertean worm (alive).
		2				Same as Replicate 1.
		3				
		4				
T1		1	42°20.95'N 70°57.83'W	14022.1 25844.2	5.7	Coarse sediment mixed with clay. Gastropods and empty tubeworms present. Polychaetes also present.
		2				
		3				
		4				

Table B-1. Field Log for Grabs at Each Station, including Navigation and Comments. (continued)

Station	Date and Time (EDT)	Grab	Latitude Longitude	LORAN Time Delays	Depth (m)	Comments
T3		1	42°19.79'N 70°57.70'W	14026.7 25836.4	9.5	Silty, somewhat smelly. Nemerteans present.
		2				
		3				
		4				
T2	4/24/92	1	42°20.55'N 71°00.11'W	14038.7 25858.2	8.7	Black fine sediment, mixed with brown clay. Few nemerteans.
		2				Same as Replicate 1.
		3				Same as Replicate 1.
		4				Possible algal film on surface of grab.
R6		1	42°20.43'N 70°57.69'W	14023.6 25840.1	13.8	Black, anoxic, strong odor, lots of gastropods present, some clay.
		2				
		3				
		4				
T8		1	42°17.11'N 70°54.73'W	14020.5 25799.6	11.7	
		2				Tubeworms and gastropods. Fine sand.
		3				
		4				Some type of egg mass on the surface.

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992

STUDY SITE = BOSTON HARBOR
STATION = T1
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.5mm

TAXA	REP 1	REP 2	REP 3	MEAN
NEMERTINEA				
Nemertinea	3	0	0	1.0
ANNELIDA				
Oligochaeta	1014	374	523	637.0
Microphthalmus aberrans	94	48	170	104.0
Streblospio benedicti	33	38	38	36.3
Tharyx cf. acutus	33	39	36	36.0
Polydora cornuta	23	17	33	24.3
Polydora socialis	25	13	20	19.3
Spio setosa	11	9	29	16.3
Capitella spp. complex	14	7	13	11.3
Polynoidae	16	11	4	10.3
Cirratulidae	7	12	12	10.3
Clymenella torquata	12	1	12	8.3
Spio spp.	1	8	5	4.7
Polydora quadrilobata	3	5	4	4.0
Spio armata	4	0	6	3.3
Mediomastus californiensis	4	3	1	2.7
Lumbrineris hebes	2	1	4	2.3
Exogone hebes	3	0	4	2.3
Nephtys caeca	4	1	2	2.3
Polydora spp.	0	7	0	2.3
Ninoe nigripes	0	3	1	1.3
Maldanidae	1	0	2	1.0
Aricidea (Acmira) catherinae	1	1	1	1.0
Pholoe minuta	2	0	1	1.0
Terebellidae	0	2	0	0.7
Polygordius sp.	0	1	1	0.7
Spio filicornis	1	0	0	0.3
Paranaitis speciosa	1	0	0	0.3
Pionosyllis sp.	1	0	0	0.3
Spiophanes bombyx	1	0	0	0.3
GASTROPODA				
Nassarius vibex	44	37	31	37.3
Crepidula sp.	0	1	0	0.3
Nudibranchia	0	1	0	0.3
BIVALVIA				
Mytilus edulis	27	71	2	33.3
Mya arenaria	12	12	4	9.3
Tellina agilis	7	4	3	4.7
Spissula solidissima	0	1	0	0.3
Bivalvia	0	0	1	0.3
CRUSTACEA				
Balanus sp.	22	13	1	12.0
Photis pollex	2	0	6	2.7
Ischyrocerus anguipes	0	1	6	2.3
Orchomenella minuta	1	3	0	1.3
Ampelisca spp. complex	0	2	1	1.0
Dyopedos monacanthus	2	0	1	1.0
Corophium bonellii	3	0	0	1.0
Pagurus longicarpus	1	0	2	1.0

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

Edotea tribola	2	0	0	0.7
Jassa marmorata	0	0	1	0.3
Cancer irroratus	0	1	0	0.3
Caprellidae	0	1	0	0.3
Corophium insidiosum	0	1	0	0.3
Gammarus lawrencianus	1	0	0	0.3
Gammarus sp.	0	1	0	0.3

TOTAL NUMBER OF TAXA	38	36	35
TOTAL NUMBER OF INDIVIDUALS	1438	751	981
SHANNON-WEINER DIVERSITY	1.441	2.081	1.829
SIMPSON'S DOMINANCE INDEX	0.505	0.271	0.321
SPECIES RICHNESS	5.09	5.29	4.94
EVENNESS	0.40	0.58	0.51

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	53
MEAN NUMBER OF INDIVIDUALS	1056.7
SHANNON-WEINER DIVERSITY	1.790
SIMPSON'S DOMINANCE INDEX	0.379
SPECIES RICHNESS	7.47
EVENNESS	0.45

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992
(Continued)

STUDY SITE = BOSTON HARBOR
STATION = T2
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.5mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Streblospio benedicti	376	353	479	402.7
Capitella spp. complex	40	40	20	33.3
Oligochaeta	21	36	40	32.3
Spio spp.	23	32	10	21.7
Tharyx cf. acutus	12	9	7	9.3
Polydora socialis	6	8	13	9.0
Spio limicola	7	5	5	5.7
Polydora quadrilobata	2	9	2	4.3
Polydora cornuta	1	6	2	3.0
Spio filicornis	1	1	2	1.3
Nephtyidae	0	2	0	0.7
Spio setosa	1	1	0	0.7
Euchone incolor	0	1	1	0.7
Asabellides oculata	0	1	0	0.3
Paranaitis speciosa	0	0	1	0.3
Syllidae	0	1	0	0.3
Polydora spp.	0	0	1	0.3
GASTROPODA				
Nassarius vibex	0	2	0	0.7
BIVALVIA				
Mytilus edulis	3	28	14	15.0
Tellina agilis	1	1	2	1.3
Mya arenaria	0	1	2	1.0
CRUSTACEA				
Edotea tribola	0	1	1	0.7
Ampelisca spp. complex	1	0	1	0.7
Photis pollex	0	0	1	0.3
TOTAL NUMBER OF TAXA	14	20	19	
TOTAL NUMBER OF INDIVIDUALS	495	538	604	
SHANNON-WEINER DIVERSITY	1.009	1.401	0.964	
SIMPSON'S DOMINANCE INDEX	0.588	0.448	0.636	
SPECIES RICHNESS	2.10	3.02	2.81	
EVENNESS	0.38	0.47	0.33	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	24
MEAN NUMBER OF INDIVIDUALS	545.7
SHANNON-WEINER DIVERSITY	1.154
SIMPSON'S DOMINANCE INDEX	0.555
SPECIES RICHNESS	3.65
EVENNESS	0.36

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T3
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.5mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Oligochaeta	358	139	814	437.0
Aricidea (Acmira) catherinae	72	24	71	55.7
Streblospio benedicti	11	25	36	24.0
Microphthalmus aberrans	21	39	2	20.7
Tharyx cf. acutus	8	11	18	12.3
Polydora cornuta	10	7	9	8.7
Polydora socialis	10	7	4	7.0
Spio spp.	4	6	11	7.0
Polynoidae	7	4	7	6.0
Polydora quadrilobata	1	2	5	2.7
Capitella spp. complex	0	4	3	2.3
Asabellides oculata	2	0	4	2.0
Spio limicola	0	2	3	1.7
Ninoe nigripes	3	0	0	1.0
Cirratulidae	0	2	0	0.7
Prionospio steenstrupi	0	0	1	0.3
Polydora spp.	0	0	1	0.3
Fabricinae sp.	0	0	1	0.3
Nephtys caeca	1	0	0	0.3
Nereis sp.	0	0	1	0.3
Eteone longa	0	0	1	0.3
Clymenella torquata	0	1	0	0.3
Spiophanes bombyx	0	0	1	0.3
Mediomastus californiensis	0	0	1	0.3
GASTROPODA				
Nassarius vibex	40	28	27	31.7
Crepidula sp.	0	1	1	0.7
BIVALVIA				
Mytilus edulis	23	14	23	20.0
Tellina agilis	16	3	18	12.3
Mya arenaria	4	0	1	1.7
Lyonsia hyalina	3	0	0	1.0
Yoldia limatula	1	0	0	0.3
Nucula delphinodonta	0	0	1	0.3
CRUSTACEA				
Ampelisca spp. complex	72	15	39	42.0
Photis pollex	4	6	5	5.0
Dyopedos monacanthus	4	2	8	4.7
Edotea tribola	1	1	3	1.7
Phoxocephalus holbolli	1	0	3	1.3
Diastylis sculpta	1	0	2	1.0
Gammarus sp.	0	1	1	0.7
Argissa hamatipes	0	0	1	0.3
Pagurus sp.	1	0	0	0.3
TOTAL NUMBER OF TAXA	26	23	34	
TOTAL NUMBER OF INDIVIDUALS	679	344	1127	
SHANNON-WEINER DIVERSITY	1.834	2.203	1.336	

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992
(Continued)

SIMPSON'S DOMINANCE INDEX	0.308	0.199	0.530
SPECIES RICHNESS	3.83	3.77	4.70
EVENNESS	0.56	0.70	0.38

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	41
MEAN NUMBER OF INDIVIDUALS	716.7
SHANNON-WEINER DIVERSITY	1.714
SIMPSON'S DOMINANCE INDEX	0.387
SPECIES RICHNESS	6.08
EVENNESS	0.46

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T4
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.5mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Capitella spp. complex	240	50	180	156.7
Streblospio benedicti	98	99	143	113.3
Oligochaeta	13	18	32	21.0
Polydora cornuta	5	4	1	3.3
Tharyx cf. acutus	5	2	2	3.0
Hypereteone heteropoda	2	0	0	0.7
Polynoidae	1	0	0	0.3
Cirratulidae	0	1	0	0.3
Leitoscoloplos sp.	0	1	0	0.3
Microphthalmus aberrans	0	0	1	0.3
Spio spp.	1	0	0	0.3
Polydora quadrilobata	0	0	1	0.3
BIVALVIA				
Mytilus edulis	7	0	6	4.3
Mya arenaria	1	0	0	0.3
CRUSTACEA				
Ampelisca spp. complex	4	2	1	2.3
Crangon septemspinosa	0	0	1	0.3
Balanus sp.	1	0	0	0.3
TOTAL NUMBER OF TAXA	12	8	10	
TOTAL NUMBER OF INDIVIDUALS	378	177	368	
SHANNON-WEINER DIVERSITY	1.081	1.160	1.105	
SIMPSON'S DOMINANCE INDEX	0.472	0.404	0.398	
SPECIES RICHNESS	1.85	1.35	1.52	
EVENNESS	0.44	0.56	0.48	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	17
MEAN NUMBER OF INDIVIDUALS	307.7
SHANNON-WEINER DIVERSITY	1.166
SIMPSON'S DOMINANCE INDEX	0.400
SPECIES RICHNESS	2.79
EVENNESS	0.41

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = R6
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.5mm

TAXA	REP 1	REP 2	REP 3	MEAN
NEMERTINEA				
Nemertinea	1	0	0	0.3
ANNELIDA				
Capitella spp. complex	183	95	178	152.0
Oligochaeta	21	5	11	12.3
Streblospio benedicti	18	4	1	7.7
Spio spp.	6	4	8	6.0
Tharyx cf. acutus	8	7	3	6.0
Spio limicola	3	6	2	3.7
Polydora quadrilobata	3	1	1	1.7
Cirratulidae	2	2	0	1.3
Sabellidae	0	1	0	0.3
Spio setosa	0	1	0	0.3
Nephtyidae	1	0	0	0.3
Nephtys caeca	1	0	0	0.3
Exogone hebes	1	0	0	0.3
GASTROPODA				
Nassarius vibex	70	7	10	29.0
Crepidula sp.	0	1	0	0.3
BIVALVIA				
Mytilus edulis	29	5	39	24.3
Mya arenaria	11	6	4	7.0
Tellina agilis	1	0	0	0.3
CRUSTACEA				
Ischyrocerus anguipes	0	0	6	2.0
Gammarus sp.	0	0	5	1.7
Edotea tribola	4	1	0	1.7
Ampelisca spp. complex	1	2	0	1.0
Gammarus lawrencianus	2	0	0	0.7
Photis pollex	0	1	0	0.3
TOTAL NUMBER OF TAXA	19	17	12	
TOTAL NUMBER OF INDIVIDUALS	366	149	268	
SHANNON-WEINER DIVERSITY	1.714	1.572	1.262	
SIMPSON'S DOMINANCE INDEX	0.301	0.418	0.468	
SPECIES RICHNESS	3.05	3.20	1.97	
EVENNESS	0.58	0.55	0.51	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	25
MEAN NUMBER OF INDIVIDUALS	261.0
SHANNON-WEINER DIVERSITY	1.633
SIMPSON'S DOMINANCE INDEX	0.366
SPECIES RICHNESS	4.31
EVENNESS	0.51

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T6
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.5mm

TAXA	REP 1	REP 2	REP 3	MEAN
NEMERTINEA				
Nemertinea	5	2	3	3.3
ANNELIDA				
Oligochaeta	334	956	663	651.0
Aricidea (Acmira) catherinae	248	275	326	283.0
Spio limicola	20	37	22	26.3
Polydora cornuta	43	8	17	22.7
Polydora socialis	17	20	30	22.3
Mediomastus californiensis	11	15	24	16.7
Spio spp.	5	18	23	15.3
Lumbrineris hebes	8	8	11	9.0
Polydora quadrilobata	6	3	5	4.7
Polynoidae	4	3	7	4.7
Streblospio benedicti	3	2	2	2.3
Phyllodoce mucosa	1	1	4	2.0
Capitella spp. complex	0	3	2	1.7
Nephtyidae	0	3	1	1.3
Spio armata	2	0	0	0.7
Monticellina baptisteae	0	0	2	0.7
Prionospio steenstrupi	0	1	1	0.7
Ninoe nigripes	1	0	1	0.7
Pygospio elegans	1	1	0	0.7
Cirratulidae	1	1	0	0.7
Asabellides oculata	2	0	0	0.7
Tharyx cf. acutus	1	1	0	0.7
Pholoe minuta	0	2	0	0.7
Neanthes virens	0	1	0	0.3
Lumbrineridae	0	1	0	0.3
Lumbrineris acicularum	0	1	0	0.3
Polygordius sp.	0	1	0	0.3
GASTROPODA				
Nassarius vibex	20	8	3	10.3
BIVALVIA				
Mytilus edulis	19	21	48	29.3
Nucula delphinodonta	33	8	19	20.0
Tellina agilis	11	8	18	12.3
Mya arenaria	0	0	3	1.0
Petricola pholadiformis	2	1	0	1.0
Bivalvia	0	0	1	0.3
CRUSTACEA				
Ampelisca spp. complex	298	214	362	291.3
Phoxocephalus holbolli	31	28	39	32.7
Dyopedos monacanthus	8	46	20	24.7
Photis pollex	1	3	3	2.3
Diastylis sculpta	2	3	0	1.7
Ischyrocerus anguipes	0	0	4	1.3
Edotea tribola	0	2	2	1.3
Orchomenella minuta	0	0	3	1.0

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992
(Continued)

Unciola irrorata	1	0	1	0.7
Leptocheirus pinguis	0	2	0	0.7
Corophium spp.	1	0	1	0.7
Corophium tuberculatum	0	1	0	0.3
PHORONIDA				
Phoronis sp.	2	0	0	0.7
ECHINODERMATA				
Echinoidea	1	0	0	0.3
TOTAL NUMBER OF TAXA	33	37	33	
TOTAL NUMBER OF INDIVIDUALS	1143	1709	1671	
SHANNON-WEINER DIVERSITY	2.018	1.602	1.873	
SIMPSON'S DOMINANCE INDEX	0.205	0.357	0.245	
SPECIES RICHNESS	4.54	4.84	4.31	
EVENNESS	0.58	0.44	0.54	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	49
MEAN NUMBER OF INDIVIDUALS	1507.7
SHANNON-WEINER DIVERSITY	1.859
SIMPSON'S DOMINANCE INDEX	0.261
SPECIES RICHNESS	6.56
EVENNESS	0.48

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T7
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.5mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Streblospio benedicti	301	296	271	289.3
Polydora cornuta	50	74	20	48.0
Oligochaeta	66	19	28	37.7
Aricidea (Acmira) catherinae	21	39	15	25.0
Spio limicola	19	14	10	14.3
Polydora socialis	12	8	13	11.0
Tharyx cf. acutus	6	10	8	8.0
Nephtyidae	2	3	6	3.7
Spio spp.	6	1	2	3.0
Leitoscoloplos sp.	4	0	2	2.0
Asabellides oculata	1	4	1	2.0
Eteone longa	1	3	0	1.3
Microphthalmus aberrans	0	4	0	1.3
Polydora quadrilobata	0	0	3	1.0
Cirratulidae	0	0	2	0.7
Glycera dibranchiata	0	1	0	0.3
Spio setosa	0	0	1	0.3
Capitella spp. complex	0	1	0	0.3
Paranaitis speciosa	0	1	0	0.3
GASTROPODA				
Nassarius vibex	4	8	12	8.0
BIVALVIA				
Mya arenaria	22	12	10	14.7
Pandora sp.	4	4	2	3.3
Tellina agilis	1	3	3	2.3
Mytilus edulis	0	3	1	1.3
Spissula solidissima	1	0	0	0.3
CRUSTACEA				
Ampelisca spp. complex	140	192	113	148.3
Leptocheirus pinguis	6	5	4	5.0
Dyopedos monacanthus	7	4	2	4.3
Corophium insidiosum	0	0	1	0.3
Orchomenella minuta	1	0	0	0.3
Pagurus longicarpus	0	0	1	0.3
Gammarus sp.	1	0	0	0.3
TOTAL NUMBER OF TAXA	22	23	24	
TOTAL NUMBER OF INDIVIDUALS	676	709	531	
SHANNON-WEINER DIVERSITY	1.837	1.800	1.751	
SIMPSON'S DOMINANCE INDEX	0.260	0.264	0.313	
SPECIES RICHNESS	3.22	3.35	3.67	
EVENNESS	0.59	0.57	0.55	

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	32
MEAN NUMBER OF INDIVIDUALS	638.7
SHANNON-WEINER DIVERSITY	1.840
SIMPSON'S DOMINANCE INDEX	0.272
SPECIES RICHNESS	4.80
EVENNESS	0.53

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T8
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.5mm

TAXA	REP 1	REP 2	REP 3	MEAN
NEMERTINEA				
Nemertinea	8	5	1	4.7
ANNELIDA				
Aricidea (Acmira) catherinae	472	434	289	398.3
Polygordius sp.	170	137	124	143.7
Exogone hebes	104	28	51	61.0
Spiophanes bombyx	45	29	27	33.7
Tharyx cf. acutus	37	26	12	25.0
Oligochaeta	22	28	14	21.3
Polydora socialis	17	15	11	14.3
Pygospio elegans	11	7	9	9.0
Clymenella torquata	7	13	3	7.7
Lumbrineris hebes	10	6	5	7.0
Capitella spp. complex	8	2	2	4.0
Monticellina baptisteae	3	3	3	3.0
Leitoscoloplos sp.	2	3	2	2.3
Spio spp.	1	2	3	2.0
Polydora quadrilobata	5	1	0	2.0
Maldanidae	3	2	1	2.0
Cirratulidae	3	0	2	1.7
Polynoidae	3	2	0	1.7
Spio limicola	2	2	0	1.3
Parougia caeca	2	0	1	1.0
Dodecaceria sp.	1	0	1	0.7
Nephtys caeca	1	1	0	0.7
Phyllodoce mucosa	2	0	0	0.7
Mediomastus californiensis	0	1	1	0.7
Streblospio benedicti	2	0	0	0.7
Ninoe nigripes	0	2	0	0.7
Nephtyidae	0	1	0	0.3
Glycera dibranchiata	1	0	0	0.3
Prionospio steenstrupi	1	0	0	0.3
Spio armata	0	1	0	0.3
Terebellidae	0	1	0	0.3
Lumbrineris acicularum	0	1	0	0.3
GASTROPODA				
Nassarius vibex	30	83	28	47.0
BIVALVIA				
Nucula delphinodonta	48	42	22	37.3
Tellina agilis	30	23	23	25.3
Mytilus edulis	14	8	9	10.3
Lyonsia hyalina	1	1	0	0.7
Pitar morrhuanus	0	1	0	0.3
Mya arenaria	0	1	0	0.3
Turtonia minuta	1	0	0	0.3
Petricola pholadiformis	0	1	0	0.3
Pandora sp.	1	0	0	0.3

Table B-2. Macrofauna (> 0.5 mm) at Stations Sampled in April 1992 *(Continued)*

CRUSTACEA				
Ampelisca spp. complex	21	18	12	17.0
Unciola irrorata	3	0	2	1.7
Balanus sp.	1	2	2	1.7
Dyopedos monacanthus	0	4	0	1.3
Corophium crassicorne	2	0	0	0.7
Edotea tribola	1	0	1	0.7
Limnoria lignorum	1	0	0	0.3
Phoxocephalus holbolli	0	0	1	0.3
Corophium spp.	0	0	1	0.3
PHORONIDA				
Phoronis sp.	0	0	3	1.0
UROCHORDATA				
Ascidiacea	1	0	0	0.3
TOTAL NUMBER OF TAXA	41	37	31	
TOTAL NUMBER OF INDIVIDUALS	1098	937	666	
SHANNON-WEINER DIVERSITY	2.171	2.071	2.073	
SIMPSON'S DOMINANCE INDEX	0.226	0.251	0.236	
SPECIES RICHNESS	5.71	5.26	4.61	
EVENNESS	0.58	0.57	0.60	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	54
MEAN NUMBER OF INDIVIDUALS	900.3
SHANNON-WEINER DIVERSITY	2.150
SIMPSON'S DOMINANCE INDEX	0.235
SPECIES RICHNESS	7.79
EVENNESS	0.54

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992

STUDY SITE = BOSTON HARBOR
STATION = T1
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.3mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Oligochaeta	418	321	401	380.0
Spio spp.	36	31	36	34.3
Microphthalmus aberrans	35	7	56	32.7
Tharyx cf. acutus	13	3	10	8.7
Polynoidae	6	10	5	7.0
Streblospio benedicti	10	4	3	5.7
Polydora spp.	1	8	4	4.3
Capitella spp. complex	4	1	1	2.0
Exogone hebes	2	0	0	0.7
Nephtyidae	1	1	0	0.7
Orbiniidae	0	0	1	0.3
Terebellidae	0	1	0	0.3
Lumbrineridae	1	0	0	0.3
Cirratulidae	0	0	1	0.3
Polydora quadrilobata	1	0	0	0.3
Paranaitis speciosa	0	1	0	0.3
Fabricinae sp.	0	0	1	0.3
BIVALVIA				
Mytilus edulis	63	48	39	50.0
Tellina agilis	6	9	12	9.0
Nucula delphinodonta	2	0	0	0.7
Bivalvia	1	0	1	0.7
CRUSTACEA				
Balanus sp.	9	3	2	4.7
Ischyrocerus anguipes	0	4	0	1.3
Gammarus sp.	1	2	1	1.3
Photis pollex	1	0	2	1.0
Orchomenella minuta	0	2	0	0.7
Dyopedos monacanthus	1	0	0	0.3

	REP 1	REP 2	REP 3
TOTAL NUMBER OF TAXA	20	17	17
TOTAL NUMBER OF INDIVIDUALS	612	456	576
SHANNON-WEINER DIVERSITY	1.281	1.214	1.194
SIMPSON'S DOMINANCE INDEX	0.485	0.513	0.504
SPECIES RICHNESS	2.96	2.61	2.52
EVENNESS	0.43	0.43	0.42

TOTAL STATION STATISTICS	
TOTAL NUMBER OF TAXA	27
MEAN NUMBER OF INDIVIDUALS	548.0
SHANNON-WEINER DIVERSITY	1.267
SIMPSON'S DOMINANCE INDEX	0.498
SPECIES RICHNESS	4.12
EVENNESS	0.38

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T2
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.3mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Spio spp.	115	154	90	119.7
Streblospio benedicti	80	78	90	82.7
Tharyx cf. acutus	52	31	21	34.7
Oligochaeta	30	46	24	33.3
Capitella spp. complex	4	6	3	4.3
Nephtyidae	4	1	1	2.0
Lumbrineridae	1	2	0	1.0
Polynoidae	1	1	0	0.7
Polydora spp.	0	1	1	0.7
Ampharetidae	0	0	1	0.3
Polydora cornuta	1	0	0	0.3
Fabricinae sp.	0	0	1	0.3
Opheliidae	0	1	0	0.3
Paranaitis speciosa	0	1	0	0.3
BIVALVIA				
Mytilus edulis	20	8	3	10.3
Tellina agilis	3	3	1	2.3
Mya arenaria	0	1	0	0.3
CRUSTACEA				
Photis pollex	0	2	0	0.7
Ischyrocerus anguipes	1	0	1	0.7
Dyopedos monacanthus	0	1	0	0.3
TOTAL NUMBER OF TAXA	12	16	12	
TOTAL NUMBER OF INDIVIDUALS	312	337	237	
SHANNON-WEINER DIVERSITY	1.647	1.572	1.431	
SIMPSON'S DOMINANCE INDEX	0.243	0.291	0.307	
SPECIES RICHNESS	1.92	2.58	2.01	
EVENNESS	0.66	0.57	0.58	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	20
MEAN NUMBER OF INDIVIDUALS	295.3
SHANNON-WEINER DIVERSITY	1.599
SIMPSON'S DOMINANCE INDEX	0.271
SPECIES RICHNESS	3.34
EVENNESS	0.53

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T3
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.3mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Oligochaeta	96	60	122	92.7
Spio spp.	42	56	30	42.7
Tharyx cf. acutus	28	22	31	27.0
Microphthalmus aberrans	20	0	2	7.3
Streblospio benedicti	3	2	4	3.0
Polynoidae	4	3	1	2.7
Polydora spp.	3	0	1	1.3
Ampharetidae	1	2	1	1.3
Aricidea (Acmira) catherinae	3	0	0	1.0
Lumbrineridae	1	0	1	0.7
Cirratulidae	2	0	0	0.7
Nephtyidae	0	0	1	0.3
Leitoscoloplos sp.	0	0	1	0.3
Sabellidae	0	1	0	0.3
Exogone hebes	0	1	0	0.3
BIVALVIA				
Mytilus edulis	27	1	24	17.3
Tellina agilis	18	14	7	13.0
Lyonsia hyalina	1	0	0	0.3
CRUSTACEA				
Dyopedos monacanthus	0	5	3	2.7
Photis pollex	2	5	0	2.3
Gammarus sp.	0	2	0	0.7
Diastylis sculpta	1	0	0	0.3
Munna sp.	1	0	0	0.3
TOTAL NUMBER OF TAXA	17	13	14	
TOTAL NUMBER OF INDIVIDUALS	253	174	229	
SHANNON-WEINER DIVERSITY	1.946	1.713	1.527	
SIMPSON'S DOMINANCE INDEX	0.207	0.247	0.332	
SPECIES RICHNESS	2.89	2.33	2.39	
EVENNESS	0.69	0.67	0.58	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	23
MEAN NUMBER OF INDIVIDUALS	218.7
SHANNON-WEINER DIVERSITY	1.847
SIMPSON'S DOMINANCE INDEX	0.245
SPECIES RICHNESS	4.08
EVENNESS	0.59

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T4
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.3mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Streblospio benedicti	49	51	45	48.3
Capitella spp. complex	74	33	33	46.7
Oligochaeta	10	31	26	22.3
Polydora spp.	4	2	2	2.7
Hypereteone heteropoda	3	0	1	1.3
Spio spp.	2	1	0	1.0
Microphthalmus aberrans	0	0	1	0.3
Tharyx cf. acutus	0	1	0	0.3
Fabricinae sp.	0	0	1	0.3
BIVALVIA				
Mytilus edulis	3	0	13	5.3
TOTAL NUMBER OF TAXA	7	6	8	
TOTAL NUMBER OF INDIVIDUALS	145	119	122	
SHANNON-WEINER DIVERSITY	1.213	1.218	1.475	
SIMPSON'S DOMINANCE INDEX	0.381	0.329	0.266	
SPECIES RICHNESS	1.21	1.05	1.46	
EVENNESS	0.62	0.68	0.71	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	10
MEAN NUMBER OF INDIVIDUALS	128.7
SHANNON-WEINER DIVERSITY	1.383
SIMPSON'S DOMINANCE INDEX	0.305
SPECIES RICHNESS	1.85
EVENNESS	0.60

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = R6
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.3mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Capitella spp. complex	123	46	36	68.3
Spio spp.	91	38	27	52.0
Oligochaeta	28	13	4	15.0
Tharyx cf. acutus	8	6	0	4.7
Streblospio benedicti	5	1	0	2.0
Aricidea (Acmira) catherinae	2	0	0	0.7
Spio setosa	0	1	0	0.3
Mediomastus californiensis	1	0	0	0.3
Nephtyidae	0	1	0	0.3
Polynoidae	0	1	0	0.3
BIVALVIA				
Mytilus edulis	15	6	8	9.7
Tellina agilis	5	2	1	2.7
CRUSTACEA				
Gammarus sp.	4	3	2	3.0
Ischyrocerus anguipes	0	0	3	1.0
TOTAL NUMBER OF TAXA	10	11	7	
TOTAL NUMBER OF INDIVIDUALS	282	118	81	
SHANNON-WEINER DIVERSITY	1.472	1.602	1.372	
SIMPSON'S DOMINANCE INDEX	0.309	0.274	0.323	
SPECIES RICHNESS	1.60	2.10	1.37	
EVENNESS	0.64	0.67	0.70	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	14
MEAN NUMBER OF INDIVIDUALS	160.3
SHANNON-WEINER DIVERSITY	1.526
SIMPSON'S DOMINANCE INDEX	0.301
SPECIES RICHNESS	2.56
EVENNESS	0.58

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T6
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.3mm

TAXA	REP 1	REP 2	REP 3	MEAN
ANNELIDA				
Oligochaeta	296	527	463	428.7
Spio spp.	56	47	68	57.0
Nephtyidae	0	4	4	2.7
Polynoidae	4	0	0	1.3
Lumbrineridae	0	1	1	0.7
Aricidea (Acmira) catherinae	1	0	0	0.3
Streblospio benedicti	1	0	0	0.3
Microphthalmus aberrans	1	0	0	0.3
Polydora spp.	1	0	0	0.3
Capitella spp. complex	1	0	0	0.3
Tharyx cf. acutus	1	0	0	0.3
Ampharetidae	1	0	0	0.3
Spio limicola	0	1	0	0.3
Phyllodoce mucosa	0	1	0	0.3
Polydora socialis	0	1	0	0.3
GASTROPODA				
Gastropoda	1	0	0	0.3
BIVALVIA				
Mytilus edulis	11	4	10	8.3
Nucula delphinodonta	7	2	3	4.0
Tellina agilis	3	1	1	1.7
Bivalvia	1	0	0	0.3
Petricola pholadiformis	1	0	0	0.3
CRUSTACEA				
Dyopedos monacanthus	0	15	9	8.0
Photis pollex	0	1	2	1.0
Orchomenella minuta	2	1	0	1.0
Ischyrocerus anguipes	1	0	0	0.3
Gammarus sp.	1	0	0	0.3
Amphipoda	0	0	1	0.3
TOTAL NUMBER OF TAXA	19	13	10	
TOTAL NUMBER OF INDIVIDUALS	391	606	562	
SHANNON-WEINER DIVERSITY	0.956	0.570	0.670	
SIMPSON'S DOMINANCE INDEX	0.595	0.763	0.694	
SPECIES RICHNESS	3.02	1.87	1.42	
EVENNESS	0.32	0.22	0.29	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	27
MEAN NUMBER OF INDIVIDUALS	519.7
SHANNON-WEINER DIVERSITY	0.738
SIMPSON'S DOMINANCE INDEX	0.693
SPECIES RICHNESS	4.16
EVENNESS	0.22

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T7
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.3mm

TAXA	REP 1	REP 2	MEAN
ANNELIDA			
Streblospio benedicti	52	65	58.5
Spio spp.	14	19	16.5
Oligochaeta	8	8	8.0
Tharyx cf. acutus	3	0	1.5
Nephtyidae	1	1	1.0
Lumbrineridae	2	0	1.0
Paranaitis speciosa	1	0	0.5
Leitoscoloplos sp.	1	0	0.5
Microphthalmus aberrans	0	1	0.5
Capitella spp. complex	1	0	0.5
Polynoidae	1	0	0.5
Opheliidae	1	0	0.5
BIVALVIA			
Tellina agilis	4	2	3.0
TOTAL NUMBER OF TAXA	12	6	
TOTAL NUMBER OF INDIVIDUALS	89	96	
SHANNON-WEINER DIVERSITY	1.463	0.967	
SIMPSON'S DOMINANCE INDEX	0.379	0.505	
SPECIES RICHNESS	2.45	1.10	
EVENNESS	0.59	0.54	

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	13
MEAN NUMBER OF INDIVIDUALS	92.5
SHANNON-WEINER DIVERSITY	1.254
SIMPSON'S DOMINANCE INDEX	0.441
SPECIES RICHNESS	2.65
EVENNESS	0.49

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992 *(Continued)*

STUDY SITE = BOSTON HARBOR
STATION = T8
COLLECTION DATE = APRIL 1992
SIEVE SIZE = 0.3mm

TAXA	REP 1	REP 2	REP 3	MEAN
PLATYHELMINTHES				
Turbellaria	0	0	5	1.7
NEMERTINEA				
Nemertinea	0	0	3	1.0
ANNELIDA				
Exogone hebes	79	31	61	57.0
Oligochaeta	29	33	54	38.7
Polygordius sp.	18	25	19	20.7
Spio spp.	18	25	16	19.7
Tharyx cf. acutus	27	18	13	19.3
Aricidea (Acmira) catherinae	10	12	8	10.0
Capitella spp. complex	4	8	3	5.0
Monticellina baptisteae	5	3	7	5.0
Pygospio elegans	3	2	1	2.0
Cirratulidae	3	1	1	1.7
Polynoidae	0	5	0	1.7
Leitoscoloplos sp.	2	1	1	1.3
Polydora spp.	2	1	0	1.0
Parougia caeca	1	0	1	0.7
Ampharetidae	1	0	0	0.3
Dorvilleidae sp. A	1	0	0	0.3
Streblospio benedicti	1	0	0	0.3
GASTROPODA				
Gastropoda	0	1	0	0.3
BIVALVIA				
Tellina agilis	26	48	24	32.7
Nucula delphinodonta	21	23	5	16.3
Mytilus edulis	7	6	6	6.3
CRUSTACEA				
Amphipoda	1	1	0	0.7
Gammarus sp.	0	2	0	0.7
Diastylidae	0	1	0	0.3
Ischyrocerus anguipes	0	1	0	0.3
Tanaissus psammophilus	0	1	0	0.3
PHORONIDA				
Phoronis sp.	0	1	0	0.3
HEMICHORDATA				
Enteropneusta	0	0	1	0.3
TOTAL NUMBER OF TAXA	20	23	18	
TOTAL NUMBER OF INDIVIDUALS	259	250	229	

Table B-3. Macrofauna (> 0.3 mm) at Stations Sampled in April 1992
(Continued)

SHANNON-WEINER DIVERSITY	2.298	2.465	2.203
SIMPSON'S DOMINANCE INDEX	0.146	0.108	0.157
SPECIES RICHNESS	3.42	3.98	3.13
EVENNESS	0.77	0.79	0.76

TOTAL STATION STATISTICS

TOTAL NUMBER OF TAXA	30
MEAN NUMBER OF INDIVIDUALS	246.0
SHANNON-WEINER DIVERSITY	2.413
SIMPSON'S DOMINANCE INDEX	0.124
SPECIES RICHNESS	5.27
EVENNESS	0.71

Table B-4. Statistical Tests for Significant Station Differences in Abundance of Macrofauna at Stations Sampled During April 1992.

1-WAY ANOVA SPRING TOTAL ABUNDANCE 10:33 Monday, June 22, 1992 1

General Linear Models Procedure
Class Level Information

Class	Levels	Values
STAT	8	R6 T1 T2 T3 T4 T6 T7 T8

Number of observations in data set = 24

1-WAY ANOVA SPRING TOTAL ABUNDANCE 10:33 Monday, June 22, 1992 2

General Linear Models Procedure

Dependent Variable: TOTN TOTAL ABUNDANCE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	6638101.16666667	948300.16666667	11.29	0.0001
Error	16	1344138.66666667	84008.66666667		
Corrected Total	23	7982239.83333333			

R-Square	C.V.	Root MSE	TOTN Mean
0.831609	28.58172	289.84248596	1014.08333333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
STAT	7	6638101.16666667	948300.16666667	11.29	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
STAT	7	6638101.16666667	948300.16666667	11.29	0.0001

1-WAY ANOVA SPRING TOTAL ABUNDANCE 10:33 Monday, June 22, 1992 3

General Linear Models Procedure

Table B-4. Statistical Tests for Significant Station Differences in Abundance of Macrofauna at Stations Sampled During April 1992. *(Concluded)*

Student-Newman-Keuls test for variable: TOTN

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 16 MSE= 84008.67

Number of Means	2	3	4	5	6	7	8
Critical Range	501.67558	610.64928	677.07588	725.03484	762.53939	793.29699	819.33671

Means with the same letter are not significantly different.

SNK Grouping		Mean	N	STAT
	A	2027.3	3	T6
	A			
B	A	1604.7	3	T1
B				
B	C	1146.3	3	T8
	C			
	C	935.3	3	T3
	C			
	C	841.0	3	T2
	C			
	C	731.3	3	T7
	C			
	C	436.3	3	T4
	C			
	C	421.3	3	R6

2-WAY ANOVA FALL + SPRING TOTAL ABUNDANCE 10:33 Monday, June 22, 1992 4

General Linear Models Procedure
Class Level Information

Class	Levels	Values
CRU	2	F1 S1
STAT	9	R6 T1 T2 T3 T4 T5 T6 T7 T8

Table B-5. Statistical Tests for Significant Station Differences in Abundance of Macrofauna — Fall 1991 versus April 1992.

Number of observations in data set = 48

General Linear Models Procedure

Dependent Variable: TOTN TOTAL ABUNDANCE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	21504484.00000000	2389387.11111111	6.19	0.0001
Error	38	14660535.66666660	385803.57017544		
Corrected Total	47	36165019.66666660			

R-Square	C.V.	Root MSE	TOTN Mean
0.594621	59.12248	621.13088007	1050.58333333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
CRU	1	63948.00000000	63948.00000000	0.17	0.6862
STAT	8	21440536.00000000	2680067.00000000	6.95	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
CRU	1	179274.66666667	179274.66666667	0.46	0.4996
STAT	8	21440536.00000000	2680067.00000000	6.95	0.0001

General Linear Models Procedure

Student-Newman-Keuls test for variable: TOTN

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 38 MSE= 385803.6
WARNING: Cell sizes are not equal.

Table B-5. Statistical Tests for Significant Station Differences in Abundance of Macrofauna — Fall 1991 versus April 1992. *(Concluded)*

Harmonic Mean of cell sizes= 4.909091

Number of Means	2	3	4	5	6	7	8	9
Critical Range	802.59065	966.89526	1065.0779	1135.0874	1189.3611	1233.5842	1270.8372	1302.9774

Means with the same letter are not significantly different.

SNK Grouping			Mean	N	STAT
	A		2120.5	6	T6
	A				
B	A		1694.7	6	T8
B	A				
B	A		1647.7	6	T3
B	A				
B	A	C	1092.0	6	T1
B		C			
B		C	854.0	6	T7
		C			
		C	448.8	6	T2
		C			
		C	421.3	3	R6
		C			
		C	291.0	6	T4
		C			
		C	90.7	3	T5

2-WAY ANOVA FALL + SPRING TOTAL ABUNDANCE 10:33 Monday, June 22, 1992 7

General Linear Models Procedure

Student-Newman-Keuls test for variable: TOTN

NOTE: This test controls the type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha= 0.05 df= 38 MSE= 385803.6

Number of Means	2
Critical Range	362.98528

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	CRU
A	1087.1	24	F1
A			
A	1014.1	24	S1

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