Dredged Material Management Plan

NOVEMBER 2000 BASELINE CHARACTERIZATION OF BENTHIC MACROINVERTEBRATE COMMUNITIES AT TWO CANDIDATE DREDGED MATERIAL DISPOSAL SITES IN BUZZARDS BAY

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Dredged Material Management Plan Phase 2C
MEPA Scope Item III

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EXECUTIVE SUMMARY

A comprehensive survey effort was undertaken in November 2000 to characterize baseline physical, chemical, and biological conditions at two candidate dredged material disposal sites in eastern Buzzards Bay and two nearby reference areas. As part of this survey effort, grab samples were collected to characterize the benthic macroinvertebrate communities inhabiting the surface sediments within candidate Sites 1 and 2 and reference areas REF-NEW and REF-2. Using a 0.04 m^2 van Veen grab, samples were collected at a total of 18 sampling stations: six stations within each of Sites 1 and 2 and three stations within each reference area. A single grab sample was collected at each station and sieved through a 0.05 mm screen for identification of benthic macroinvertebrates to the lowest practical taxonomic level (usually species).

The benthic communities at the four sites were found to be comprised of roughly similar proportions of the following major groups (in order of decreasing percent total abundance): annelids (54% to 62%), molluscs (13% to 30%), crustaceans (6% to 12%), nematodes (4% to 7%) and nemerteans (2% to 12%). A grand total of 132,769 individuals belonging to 126 taxa were collected across all four sites, but the majority (76%) of these individuals belonged to a relatively small number of 13 taxa. The most abundant species across all four sites was the polychaete *Mediomastus ambiseta*, which was either the first or second most abundant organism at each site. The following taxa, in decreasing order of total abundance, also were found among the top ten numerical dominants at all four of the sites: the polychaetes *Prionospio perkinsii* and *Aricidea catherinae*, the nemertean *Carinomella lactea*, the bivalve *Macoma tenta*, the gastropod *Cylichna oryzna*, nematodes and ostracods. Oligochaetes, along with the polychaetes *Caraziella hobsonae* and *Nephtys incisa*, were among the top ten numerical dominants at two of the sites, while the polychaete *Ninoe nigripes* and the bivalve *Nucula annulata* were each among the numerical dominants at one site.

Based solely on the similarity among the four sites in the taxa comprising the numerical dominants, it was concluded that they had broadly similar benthic communities at the time of the November 2000 survey. However, more-detailed statistical analyses revealed subtle differences among the sites. For example, Site 2 had higher average abundance, number of taxa, species richness and diversity compared to either Site 1 or the reference areas. A multivariate statistical analysis which took into account both the overlap in the taxa among stations and the differing abundance of each taxon at each station revealed significant differences in community structure between REF-2 and REF-NEW, Site 1 and REF-2, and Site 2 and REF-NEW.

The multivariate statistical differences were due primarily to differing relative abundances of the dominant taxa that were common to all of the sites. These differences were therefore considered to be of questionable ecological relevance, because they merely reflect a "snapshot" view of fluctuating (in space and time) populations of the numerical dominants. The benthic communities found at the four sites in November 2000 were broadly comparable to those found in previous studies of other areas of Buzzards Bay, in terms of many of the same taxa being among the numerical dominants.

EXECUTIVE SUMMARY

Overall, the results of the November 2000 survey indicate that the benthic communities at candidate Sites 1 and 2 and nearby reference areas were dominated by opportunistic taxa, mainly polychaetes. These organisms have high population turnover rates and therefore are capable of recovering rapidly from the physical disturbance associated with dredged material disposal. It is predicted that within several weeks or months, deposits of dredged material placed on the seafloor at either candidate site would become inhabited by a recolonizing benthic community consisting of high numbers of several of the dominant opportunistic taxa found in the present study. Complete recovery of the benthic community (to levels comparable to the ambient seafloor) following dredged material disposal is a longer-term process that may require a year or more.

1.0 INTRODUCTION

1.1 Background

In 1995, the Massachusetts Department of Environmental Management (DEM) proposed to designate an open-water dredged material disposal site within the area of the former Cleveland Ledge Disposal Site (CLDS) in eastern Buzzards Bay (Figure 1-1). On 8 March 1995, the DEM filed an Environmental Notification Form (ENF) describing the proposed site, a circular area having a diameter of 500 yards centered at 41° 36.00' N, 70° 41.00' W, corresponding to the location of the former Buzzards Bay Disposal Site (BBDS) used by U.S. Army Corps of Engineers (Figure 1-2). In the ENF, the DEM indicated that the proposed new BBDS would be designated for the receipt of coarse-grained dredged material only (i.e., silt-clay fraction of 20% or less). Following regulatory response and public comment, the Secretary of Environmental Affairs issued a Certificate on the ENF on May 10, 1995, requiring the preparation of an Environmental Impact Report (EIR) pursuant to the Massachusetts Environmental Policy Act (MEPA). The required scope for the EIR is described in the Certificate (referred to herein as the MEPA Scope).

As part of a larger project to develop a Dredged Material Management Plan (DMMP) for the state of Massachusetts, the Massachusetts Coastal Zone Management Agency (MCZM) has assumed responsibility for addressing the MEPA Scope and preparing the EIR. In March 1998, MCZM filed a Notice of Project Change, proposing to designate the BBDS for all physical categories of dredged material deemed suitable for open ocean disposal (from fine- to coarse-grained), rather than limiting the designation to coarse-grained material only.

In fulfillment of MEPA Scope Item I, MCZM sponsored a Needs Analysis that documented the regional need for a disposal site, estimated the types and quantities of dredged material to be generated, and identified local, regional and state dredged material use and disposal policies (Maguire Group Inc., 1998a). Under MEPA Scope Item II, an Alternatives Analysis was completed to evaluate: 1) the potential environmental benefits and drawbacks of opening an historic disposal site versus identifying a new site, and 2) the feasibility of using the existing Massachusetts Bay Disposal Site (MBDS) or Cape Cod Disposal Site (CCDS; Maguire Group Inc., 1998b).

The Alternatives Analysis concluded that while the CCDS could be used for disposal of material from dredging projects in the northern end of Buzzards Bay, the significant transit distances generally precluded the use of either the CCDS or MBDS as cost-effective options. The Alternatives Analysis also identified several drawbacks to the BBDS as originally proposed by DEM in 1995 (Figure 1-2), including the potential for erosion of fine-grained sediment, limited access by deeper draft hopper dredges, and inadequate long-term capacity. To overcome these drawbacks, it was recommended that deeper and larger areas within and near the historic Cleveland Ledge Disposal Site be considered as potential disposal site locations.

Under MEPA Scope Item III, MCZM is required to collect data to determine the baseline physical and biological characteristics of any proposed disposal site(s), including bathymetry, sediment grain size and chemistry, benthic community structure, bottom currents, fisheries, and water column chemistry. Under contract to MCZM, SAIC conducted a survey in May 1998 involving high-resolution bathymetry and side-scan sonar across a relatively large area encompassing the southern half of the historic Cleveland Ledge Disposal Site (Maguire Group Inc., 1998c). The objective of this reconnaissance survey was to gather data on the physical characteristics of the seafloor to facilitate optimal siting of the proposed BBDS.

In general, the May 1998 study identified areas having water depths greater than 12 m as being preferred disposal locations, because such areas have the potential to limit sediment resuspension and maximize long-term capacity while accommodating access by deep draft hopper dredges. The May 1998 bathymetric data revealed two locations in the surveyed area having water depths greater than 12 m: a basin located near the eastern boundary of the historic Cleveland Ledge Disposal Site ("eastern basin") and an area near the southern boundary ("southern basin"; Figure 1-3). SAIC conducted a second bathymetric survey in October 2000 to characterize in greater detail the bottom topography in the vicinity of the southern basin. The two candidate disposal sites selected for further study under MEPA Scope Item III are located over the southern and eastern basins and designated as Sites 1 and 2, respectively (Figures 1-3 and 1-4).

Site 2 is a rectangular area with dimensions 1000 m × 1700 m (Figure 1-4). It is under consideration as a potential disposal site because it appears to be a predominantly depositional seafloor environment, having sufficient water depth and capacity that has already been affected by past dredged material disposal at the historic Cleveland Ledge Disposal Site. However, this site has the drawback of being close to shallow areas (e.g., Gifford Ledge to the east and the historic Cleveland Ledge "dump top" to the west), which could limit access by deeper draft vessels and potentially represent a hazard to navigation.

The deeper parts of the southern basin occur just outside the southern boundary of the Cleveland Ledge Disposal Site (Figures 1-3 and 1-4). Since deeper areas within Buzzards Bay have the greatest potential to act as containment sites for deposited dredged material, a decision was made to establish candidate Site 1 (a square area measuring 1600 m × 1600 m) over this deeper part of the southern basin.

1.2 Survey Objective

The objective of the November 2000 survey reported here was to characterize the benthic macroinvertebrate communities inhabiting the surface sediments within each of the two candidate sites and two nearby reference areas. This benthic community characterization was one part of a larger November 2000 survey effort undertaken to characterize the baseline physical, chemical, and biological features of the candidate sites and reference areas, as part of an on-going disposal site designation effort.

2.0 METHODS

2.1 Sampling Locations

SAIC collected grab samples for benthic community analysis aboard the M/V *Beavertail* on November 14, 2000. The samples were collected at a total of 18 sampling stations: six stations within Site 1, six within Site 2, three at the "REF-2" reference area located 3,200 m to the west of the center of Site 1, and three at the "REF-NEW" reference area located 2,250 m to the south of the center of Site 1 (Figure 2-1). A single grab sample was collected at each station for benthic community analysis.

The 18 stations within Sites 1 and 2 and the reference areas were selected at random from larger sampling grids used to obtain sediment-profile images at each site. In addition to the single grab collected for benthic community analysis, a second grab sample was obtained at each of the 18 stations for analysis of sediment grain size and chemical contaminant concentrations. The chemistry and grain size results have been reported under separate cover (SAIC 2001).

The stations were distributed throughout Sites 1 and 2 to provide both a basic characterization of the existing benthic community structure and an evaluation of the potential within-site spatial variability in the community. The reference areas were sampled to provide a comparison between the existing conditions at Sites 1 and 2 and those in the immediate surrounding region. The REF-2 reference area was sampled in the past as part of routine environmental monitoring at the former Buzzards Bay Disposal Site conducted by the U.S. Army Corps of Engineers Disposal Area Monitoring System (DAMOS) Program (SAIC 1991). In a later report section (Section 3.4), the results from the present study are compared to those from the past DAMOS monitoring to evaluate temporal trends in benthic community structure at this reference area. No comparable historical data exists for the REF-NEW reference area.

Positioning of the vessel at each station was accomplished using differentially corrected Global Positioning System (DGPS) data in conjunction with Coastal Oceanographic's HYPACK® navigation and survey software. A Trimble DSM212L Differential/GPS receiver was used to obtain raw satellite data and provide vessel position information in the horizontal control of North American Datum of 1983 (NAD 83). The Trimble receiver is a dual function unit, bringing in differential corrections as well as GPS data, to improve overall accuracy of the satellite data to the necessary tolerances. The U.S. Coast Guard differential beacon broadcasting from Chatham, MA (325 kHz) was utilized for real-time satellite corrections due to its geographic position relative to the survey area in eastern Buzzards Bay. Overall, the navigation system allowed the samples to be obtained at each station within ±3 m of the target location.

2.2 Sample Collection

The single sediment grab sample obtained for benthic community analysis at each of the 18 stations was collected using a stainless steel, 0.04 m^2 Young-modified van Veen grab sampler having a maximum penetration depth of 12 cm. Upon arrival on the target station, the grab sampler was set in an open position and lowered to the seafloor on a stainless steel winch wire. Upon reaching the bottom, the device was retrieved, causing the bucket to close and retain a surface sediment sample. The grab sampler was raised on the winch wire and placed on a stand secured to the deck of the survey vessel.

After retrieving the grab sampler, the sediment sample was determined to be acceptable or not. An acceptable grab was characterized as having relatively level, intact sediment over the entire area of the grab, and generally a sediment depth at the center of at least 7 cm. Grabs showing disturbance of the sediment surface or those containing an insufficient volume of sediment were determined to be unacceptable and rejected, resulting in re-deployment of the sampler at the station until an acceptable sample was obtained. The time of collection and geographic position of the sample were recorded both in the field logbook and by the navigation system.

Immediately following retrieval, the entire contents of each acceptable grab sample were transferred to a sieve having a 0.5 mm mesh size. During the sieving process, the sieve was placed on a sieve table, and a gentle flow of water was washed over the sample. Extreme care was taken to ensure that no sample was lost over the side of the sieve while agitating or washing the sample. The organisms and material (e.g., shells, wood, rock fragments, etc.) retained on the screen were placed into a labeled 1-L wide-mouth plastic container. The sample was then preserved using a 6% buffered formalin solution with Rose Bengal added to stain the organisms. Once the cap was secured, the contents were mixed by inverting the container several times. All samples were delivered to Normandeau Associates, Inc. in Bedford, NH for detailed benthic analysis (sorting, identification, and enumeration).

2.3 Sample Processing

At Normandeau Associates' laboratory, each benthic sample was sorted with a dissecting microscope, and the preserved specimens identified and counted. Individual organisms were removed from each sample and placed in vials, then labeled by major taxonomic group. Taxonomists with a specialization within each major taxonomic group proceeded to identify the preserved organisms, typically to species level, with the exception of anthozoans, nemerteans, oligochaetes, and sipunculans.

Selected samples, a minimum of 10% of the total, were randomly chosen and subjected to internal quality control (QC) measures. Evaluations of the accuracy in sorting and organism identification within the selected samples were performed. The quality control check on sorting efficiency involves having a second individual re-sort one in every ten samples processed by each primary sorter. Similarly, the QC check on taxonomic identification requires a different taxonomist to re-identify the specimens in one sample out of every ten. For each sample that was subjected to quality control, at least 95% of the organisms must be counted and identified correctly in order to pass QC. This goal was met by Normandeau Associates for the November 2000 samples from Buzzards Bay.

2.4 Data Analysis

The raw benthic community data received from the laboratory consisted of a standard species list showing the number of individuals of each taxon collected in the single grab sample at each station. Since the Van Veen grab sampled a 0.04 m^2 area of the bottom, the raw sample counts were multiplied by 25 to express abundance herein on a standard "per m^2" basis. Analysis of the benthic community data included both univariate and multivariate statistical approaches, as described in the following sections.

2.4.1 Univariate Statistics

A number of standard univariate statistics were used to summarize the benthic community data at each site, including calculation of both total and average abundance per site, total and average number of taxa, and the percentage breakdown of abundance by both major taxonomic groups and species. Additional analyses were performed to calculate species richness, diversity, and evenness index values for each station (sample), using the PRIMER (Plymouth Routines in Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory, UK (Clarke and Warwick 1994).

Species richness was determined using Margalef's index (*d*), which provides a measure of the number of species (*S*) present for a given number of individuals (*N*) according to the following equation:

$$d = (S\text{-}1)/\log_2 N$$

Diversity was calculated using the Shannon-Weiner (*H'*) index:

$$H' = -\Sigma_i \, p_i \, (\log_2 p_i),$$

where p_i is the proportion of the total count arising from the *ith* species.

Equitability, the evenness of the species distribution, was determined using Pielou's evenness index (*J'*):

$$J' = H' \text{ (observed)}/ \; H' \text{ max},$$

where *H'* max is the maximum possible diversity which would be achieved if all species were equally abundant = $\log_2 (S)$. All three indices were determined using the DIVERSE routine within the PRIMER software package.

For each of the three indices indicated above, a value was calculated for each of the n = 6 stations in each of Sites 1 and 2 and each of the n = 3 stations in each reference area. The individual station values were averaged to produce a mean value for each candidate disposal site and reference area, along with 95% confidence intervals around each mean. Means and 95% confidence intervals likewise were calculated for the parameters "number of taxa" and "number of individuals" (i.e., abundance). The mean values and their 95% confidence intervals were plotted to provide a visual comparison among Sites 1 and 2 and the reference areas. In addition, the Games and Howell method (Sokal and Rohlf 1981) was used to provide a statistical test of the equality of the means. This test was performed in lieu of single classification Analysis of Variance (ANOVA) based on the assumption that the variances were heterogeneous. The Games and Howell method performs unplanned comparisons between pairs of means using a studentized range with specially weighted average degrees of freedom and a standard error based on the averages of the variances of the means (Sokal and Rohlf 1981).

2.4.2 Multivariate Statistics

The univariate statistics described in the previous section each provide a measure of a single community attribute (e.g., species richness, diversity, evenness). In contrast, multivariate statistical techniques involve looking at the benthic community structure as a whole when trying to discern spatial patterns or when comparing among different samples (Clark 1999). The term “benthic community structure” used throughout this report refers to the concept of looking simultaneously at both the taxa that are present and their relative numbers when comparing different samples to each other.

As a hypothetical example, suppose two benthic samples are taken: one from Site A and one from Site B. It is found that the two samples contain exactly the same species, and that the number of individuals of each species is exactly the same in the two samples. Based on these two identical samples, Sites A and B could be described as having identical "benthic community structure" (i.e., exactly the same species present in exactly the same numbers). Conversely, if the samples from Sites A and B had no species in common, the two sites could be described as having completely different benthic community structure. In this latter case, it would theoretically be possible for the two samples to have identical or similar species richness, diversity, or evenness values, because these univariate statistics are based on *numeric* attributes of the community while ignoring the actual taxonomic composition.

The two examples provided in the preceding paragraph represent two hypothetical extremes. In reality, benthic surveys like the one reported here involve sampling at multiple stations at various locations or sites of interest within a common geographic region. Such surveys ultimately result in the production of a table showing the number of individuals of each species found in each sample. Typically, there are species that are common to many of the samples, and species that are only found in a few samples. Likewise, the number of individuals of each species can vary widely among the different samples. The multivariate techniques presented below simply attempt to illustrate the degree of similarity in “community structure” among different samples by taking into account *both* the actual species the samples have in common and the relative abundance of each species.

Using the PRIMER software package, two independent but complimentary multivariate techniques were used to evaluate both the among-station and among-site patterns in overall benthic community structure: hierarchical clustering and non-metric multi-dimensional scaling (MDS). Each of these techniques serves to classify the stations into groups having mutually-similar benthic community structure. As explained in more detail below, the techniques differ in the type of graphic display produced.

Clustering and MDS are non-parametric methods that do not require the data to be transformed to meet underlying statistical assumptions. However, transformations do play an important role in these techniques, that of defining the balance between contributions from common versus rarer species in the measure of similarity among samples. In the present analysis, a decision was made to apply a square root transformation to the species abundance data in order to down-weight the contribution of the numerically dominant taxa while increasing the contribution of the rarer and/or less abundant taxa in assessing the degree of similarity among samples. The net effect of the square root transformation is to provide a deeper and more holistic comparison of the benthic communities inhabiting each station/site. Given the overall study objective of characterizing and comparing the whole community inhabiting each station/site, use of the square root transformation was considered preferable to using untransformed data, where the emphasis would primarily be on the dominant taxa.

Prior to performing the clustering, the abundance values were square-root transformed, and a matrix was then constructed consisting of Bray-Curtis similarity index values (Bray and Curtis 1957) calculated between each possible pair of stations (i.e., pairwise comparisons). Hierarchical agglomerative clustering with group-average linking was then performed on this similarity matrix based on the square-root transformed abundance data (Clarke 1993). Representation of the results was by means of a tree diagram or dendrogram, with the x-axis representing the full set of samples and the y-axis representing the Bray-Curtis similarity level at which two samples or groups are considered to have fused.

MDS attempts to provide an ordination, or "map," of the stations such that distances between stations on the map reflect corresponding similarities or dissimilarities in community structure. Stations that fall in close proximity to one another on the map have similar community structure, while those that are farther apart have dissimilar structure (e.g., few taxa in common or the same taxa at different levels of abundance). Like the cluster analysis, non-metric MDS ordination (Kruskal and Wish 1978) was performed on the matrix of Bray-Curtis similarity index values derived from the square root transformed abundance data (Clark and Green 1988; Clarke 1993). The two-dimensional MDS plot provides a simple and compelling visual representation of the “closeness” of the benthic community structure (i.e., species composition and abundance) between any two samples or sample groups.

Once the MDS map was constructed, the program BIOENV in the PRIMER package was used to examine the relationship between benthic community structure and sediment grain size (Warwick et al. 1990; Clarke and Ainsworth 1993). This was done by superimposing “bubbles” of differing size on the MDS plot, with the diameter of each bubble being directly proportional to the amount of silt-clay in the sediment at each station.

The ANOSIM (Analysis of Similarities) randomisation test within the PRIMER software package was used to test for statistical differences in overall benthic community structure among the four sampled areas (Site 1, Site 2, REF-NEW and REF-2) and between each potential pair of sites (i.e., pairwise comparisons). The ANOSIM procedure is analogous to standard parametric analysis of variance (ANOVA) but is based on a non-parametric permutation procedure applied to the Bray-Curtis similarity matrix underlying the ordination of samples (see Clarke and Green 1988; Clarke 1993). This test involves calculation of a test statistic, R, which reflects the observed differences in Bray-Curtis similarities between sites, contrasted with differences among replicates within sites.

The ANOSIM procedure was used to provide a formal test of the null hypothesis of "no significant difference in overall benthic community structure among the four sites." Following the "global" test for a difference among the four sites, a series of pairwise comparisons was made to test for differences between each site pair. The R-statistic serves to indicate the magnitude of the difference among/between sites and can range from 0 to 1. In general, $R>0.75$ indicates strong separation (i.e., a big difference in overall benthic community structure), $0.75 > R > 0.25$ indicates varying degrees of overlap but generally different community structure, and $R<0.25$ indicates little separation among/between sites. The ANOSIM procedure also calculates a significance level that corresponds to the alpha level (probability of Type I error) in traditional ANOVA.

Following the ANOSIM test for among/between site differences, the program SIMPER in the PRIMER package was used to identify the taxa that were the "key discriminators" in contributing to the difference in benthic community structure between any two sites.

3.0 RESULTS

3.1 Basic Characterization of the Benthic Community at Each Site

The summary statistics for candidate Sites 1 and 2 and the two reference areas are presented in Table 3-1. A complete taxonomic table showing the number of individuals of each taxon found at each station is provided in Appendix A. This table presents the taxonomic results "as received" from the laboratory. In Appendix B, these results are presented for each of the four sites individually (Site 1, Site 2, REF-2, REF-NEW). The four tables comprising Appendix B list the taxa found at each station within each site in descending order of overall abundance. These tables also show the total abundance of each taxa as a percentage of the total overall site abundance. The "ninety percent breakpoint" depicted in these tables therefore serves to denote the numerically most abundant taxa found at each site: more than 90% of all the individuals collected in the grab samples at each site belonged to the taxa above the breakpoint. The following sections provide a summary of the benthic community results by site.

Candidate Site 1

A total of 34,182 individuals (on a "per m^2" basis) belonging 67 taxa were collected at the six stations within Site 1 (Table 3-1). Of this total, the majority (54%) of individuals were annelids (including both Oligochaetes and Polychaetes), followed by molluscs (22%), crustaceans (12%), nematodes (6%), nemerteans (5%), and others (2%, including cnidarians, platyhelminthes, phoronids, echinoderms, and hemichordates; Table 3-1).

Of the 34,182 individuals collected at the six stations in Site 1, over 90% belonged 21 of the 67 total taxa found at the site (Appendix Table B-1). The list of the top ten most-abundant taxa shows that the capitellid polychaete *Mediomastus ambiseta* was numerically dominant within Site 1, accounting for 10.2% of the overall total number of individuals (Table 3-1). Other dominant taxa at Site 1 included ostracods, the polychaetes *Caraziella hobsonae*, *Aricidea catherinae*, *Prionospio perkinsii*, and *Nephtys incisa*, the tellinid bivalve *Macoma tenta*, the gastropod *Cylichna oryza*, nematodes and the nemertean *Carinomella lactea* (Table 3-1). These top ten taxa accounted for a substantial majority (69%) of all the individuals collected within the site.

The average abundance (mean of n = 6 grab samples) at Site 1 was 5,697 individuals per m^2, while the average number of taxa per station was 31 (Table 3-1). Average Shannon diversity (H') was 2.77, while the average evenness was 0.80 and the average species richness was 3.57 (Table 3-1).

Candidate Site 2

A total of 56,833 individuals (on a "per m^2" basis) belonging 107 taxa were collected at the six stations within Site 2. The majority of individuals were annelids (62%), followed by molluscs (13%), crustaceans (10%), nematodes (7%), nemerteans (7%), and others (1%; Table 3-1).

Over 90% of the 56,833 individuals collected at the six stations in Site 2 belonged to 27 of the 107 total taxa found at the site (Appendix Table B-2). Similar to Site 1, the polychaete *Mediomastus ambiseta* was the numerically dominant species at Site 2, accounting for 14.1% of the total number of individuals collected (Table 3-1). Oligochaetes (8.4%) and nematodes (7.3%) were the second and third most abundant taxa. The other dominant taxa at Site 2 also were similar to the dominants at Site 1, including ostracods, the polychaetes *Caraziella hobsonae*, *Aricidea catherinae*, and *Prionospio perkinsii*, the bivalve *Macoma tenta*, the gastropod *Cylichna oryza*, and the nemertean *Carinomella lactea* (Table 3-1). Similar to Site 1, these top ten taxa accounted for the majority (64%) of all the individuals collected within Site 2.

The average abundance (mean of n = 6 grab samples) at Site 2 was 9,472 individuals per m^2, while the average number of taxa per station was 42 (Table 3-1). The average Shannon diversity (H') was 2.96, the average evenness was 0.78, and the average species richness was 4.05 (Table 3-1).

<u>Reference Area REF-2</u>

A total of 25,203 individuals (on a "per m^2" basis) belonging to 60 taxa were collected at the three stations at the REF-2 reference area (Table 3-1). Of this total, the majority of individuals were annelids (59%), followed by molluscs (17%), nemerteans (12%), crustaceans (6%), nematodes (5%), and others (2%; Table 3-1).

Fifteen of the 60 total taxa found at REF-2 accounted for over 90% of the 25,203 total individuals collected (Appendix Table B-3). The numerically dominant species at REF-2 was the spionid polychaete *Prionospio perkinsii*, which accounted for 26.4% of all the individuals collected at the three stations (Table 3-1). *Mediomastus ambiseta* was the second numerical dominant at 15.3%, followed by the nemertean *Carinomella lactea* at 11.5% (Table 3-1). Other taxa in the list of the top ten dominants included the bivalve *Macoma tenta*, the lumbrinerid polychaete *Ninoe nigripes*, nematodes, ostracods, the gastropod *Cylichna oryza*, the polychaete *Aricidea catherinae*, and oligochaetes (Table 3-1). These top ten taxa accounted for a substantial majority (83%) of all the individuals collected at REF-2.

The average abundance (mean of n = 3 grab samples) at REF-2 was 8,401 individuals per m^2, while the average number of taxa per station was 36 (Table 3-1). Average Shannon diversity (H') was 2.57, while the average evenness was 0.71 and the average species richness was 4.05 (Table 3-1).

<u>Reference Area REF-NEW</u>

The overall total organism abundance for the three stations at REF-NEW was 16,551 individuals, which belonged to a total of 41 taxa found at the site (Table 3-1). Fifty-four percent (54%) of all the individuals collected were annelids, followed by molluscs (30%), crustaceans (8%), nematodes (4%), nemerteans (2%), and others (1%; Table 3-1).

Of the 16,551 individuals collected at the three stations at REF-NEW, over 90% belonged to 13 of the 41 total taxa found at the site (Appendix Table B-4). The numerically most-abundant species at REF-NEW was the paraonid polychaete *Aricidea catherinae* (18.3% of all individuals collected), followed closely by the capitellid polychaete *Mediomastus ambiseta* (15.6%) and the bivalve *Nucula annulat*a (14.5%; Table 3-1). Other taxa among the top ten dominants at REF-NEW included ostracods, the gastropod *Cylichna oryza*, the polychaetes *Nephtys incisa* and *Prionospio perkinsii*, the bivalve *Macoma tenta*, nematodes and the nemertean *Carinomella lactea* (Table 3-1). These top ten taxa accounted for a substantial majority (83%) of all the individuals collected at REF-NEW.

The average abundance (mean of n = 3 grab samples) at REF-NEW was 5,517 individuals per m^2, while the average number of taxa per station was 25 (Table 3-1). Average Shannon diversity (H') was 2.50, while the average evenness was 0.78 and the average species richness was 2.79 (Table 3-1).

3.2 Univariate Statistical Comparison Among the Four Sites

One way to evaluate the survey results is to compare the benthic communities found at the four sites in both a qualitative way and using the univariate statistics presented in Table 3-1. Qualitatively, the communities at the four sites were similar in terms of having roughly similar proportions of the "major" taxonomic groups, with the majority of organisms collected in each site being annelids (54% to 62%), followed by molluscs (13% to 30%) and crustaceans (6% to 12%; Table 3-1). Generally, REF-NEW had a higher proportion of molluscs and REF-2 had higher numbers of nemerteans compared to the other sites, but aside from these differences, the breakdown among major taxa at each site was consistent.

It is clear from section 3.1 that the majority of the organisms collected at each site belonged to a relatively small number of taxa, and there was a substantial amount of overlap among the four sites in the taxa comprising the top ten dominants. This is summarized in Table 3-2, which indicates there were 13 taxa comprising the lists of the top ten numerical dominants across all of the sites.

The most abundant species across all four sites was *Mediomastus ambiseta*, which was either the first or second dominant in the top ten list at each site (Table 3-1). The following taxa, in decreasing order of total abundance, also were found among the top ten dominants at all four of the sites: *Prionospio perkinsii*, *Aricidea catherinae, Carinomella lactea*, *Nematoda*, *Macoma tenta*, and *Cylichna oryzna* (Table 3-2). The taxa *Oligochaeta*, *Caraziella hobsonae*, and *Nephtys incisa* were among the top ten numerical dominants at two of the sites, while *Ninoe nigripes* and *Nucula annulata* were each on the top ten list at one site (Table 3-2). The total abundance of the 13 dominant taxa shown in Table 3-2 was 101,300 individuals, compared to an overall total of 132,769 individuals of all taxa collected across all four sites in the November 2000 survey. As indicated in the last column of Table 3-2, this means that 76% of all the individuals collected across all four sites in the November 2000 survey belonged to these 13 dominant taxa. Since a grand total of 126 taxa were collected across all four sites in the survey, these results indicate that there were many taxa represented by a relatively small number of individuals.

Compared to Site 1, Site 2 had both a higher average number of taxa per station (i.e., per grab sample) and a higher average abundance per station (Figure 3-1). However, the statistical test of the equality of these means (Games and Howell method) showed that the differences in average number of taxa and average abundance between Sites 1 and 2, and between the candidate disposal sites and the reference areas, were not significant at the $P = 0.05$ level (Figure 3-1). Likewise, Site 2 had both higher average species richness and higher average diversity than Site 1, but slightly lower evenness (Figure 3-2). The differences between the two candidate sites in the three mean index values shown in Figure 3-2 likewise were not statistically significant at the $P = 0.05$ level, using the Games and Howell method.

It is notable that the difference in average number of taxa per station between Site 2 and REF-NEW that is illustrated in Figure 3-1 was almost, but not quite, statistically significant at the $P = 0.05$ level. However, there *was* a statistically significant difference found between Site 2 and REF-NEW in both average Margelef species richness and average Shannon-Weiner diversity ($P < 0.05$ using the test for equality of means by the Games and Howell method). In contrast, there were no statistical differences detected among Sites 1, 2, or REF-2 in average species richness or diversity, and no significant differences among all four sites in average species evenness ($P > 0.05$, Games and Howell method).

3.3 Multivariate Statistical Comparison Among the Four Sites

In the cluster analysis dendrogram (Figure 3-3, top), the following four groups of stations were identified at the 55% similarity level:

Group 1: Site 2 stations M-10, N-16, M-12, and K-12.
Group 2: Site 1 stations B-6, C-3, G-7, and E-6 together with all three of the REF-NEW stations.
Group 3: Site 1 stations E-4 and G-3 together with Site 2 stations K-14 and J-17
Group 4: All three of the REF-2 stations.

To display more clearly any “site-level” patterns in benthic community structure, the site names were substituted for the station labels in the dendrogram (Figure 3-3, bottom).

In general, the cluster analysis results indicate that there were both among-station and among-site differences in overall benthic community structure. The benthic assemblages found all three stations at REF-2 (Group 4) were more similar to each other (greater than 60% Bray-Curtis similarity) than to any other station group. Four of the six stations at Site 2 (Group 1) likewise had benthic community structure more similar to each other than to any other station group. The three stations at REF-NEW also had similar benthic community structure, and this structure was roughly comparable to that found at four of the six Site 1 stations. Finally, Group 3 included stations from both candidate disposal sites, reflecting both spatial variability in community structure within Sites 1 and 2, and some similarity in benthic communities from selected locations within each site.

The results of the MDS ordination shown in the first panel (Figure 3-4A) do not reveal any particularly obvious station groups. However, when the four groups of stations from the cluster analysis are circled on this plot (Figure 3-4B), it can be seen that there is basic consistency between the cluster analysis and MDS results. Substituting the "site identifier" labels for the station names in the MDS plot (Figure 3-4C) helps to illustrate how the REF-2 stations had a benthic community structure similar to each and somewhat different from most of the other stations/sites. Likewise, the three REF-NEW stations form a cohesive group, but unlike REF-2, the community structure at REF-NEW was similar to that at four of the six Site 1 stations. Four of the six Site 2 stations group loosely together in the MDS plot, but the existence of Group 3 (consisting of Site 1 stations E-4 and G-3 and Site 2 stations K-14 and J-17) serves to illustrate the spatial variability in communities existing within both Sites 1 and 2 and some degree of overlap (i.e., similarity) between these two sites.

The fourth MDS plot (Figure 3-4D) indicates only a loose and inconsistent association between sediment grain size and benthic community structure for the sampled stations. The four stations from Site 2 that form a distinct group (stations M-12, K-12, M-10 and N-16) all had relatively low silt-clay content. The dominance of sand at these four stations likely explains why they possess similar benthic community structure, that was in turn somewhat different from that observed at most of the other, more muddy stations. Likewise, the three REF-2 stations that form a distinct group all had very high silt-clay content. However, the relationship between community structure and grain size is not consistent across all stations/sites. For example, the three REF-NEW stations having very high silt-clay content had community structure different from that at REF-2, but similar to the Site 1 stations having a wide range of grain sizes (Figure 3-4D).

As previously explained in the methods section, the ANOSIM procedure was used to provide a formal test of the null hypothesis of "no significant difference in overall benthic community structure among the four sites." Following the "global" test for a difference among the four sites, a series of pairwise comparisons was made to test for differences between each site pair (Table 3-3). The R statistic for the global test (0.338) fell in the range 0.25 to 0.75, which indicates considerable overlap but a statistically significant difference among the four sites in overall benthic community structure (Table 3-3). Sites 1 and 2 did not differ significantly, but the two reference areas did differ strongly from each other (Table 3-3). Site 2 did not differ significantly from REF-2, but did differ somewhat from REF-NEW. Conversely, Site 1 did not differ significantly from REF-NEW but did differ from REF-2 (Table 3-3).

As described in the methods section, the SIMPER routine within the PRIMER software package was used to examine which taxa contributed most strongly to the significant differences detected between specific sites, as shown in Table 3-3. In general, it was found that these statistical differences were due primarily to differences in the abundance of the numerically-dominant taxa, as might be suspected from a careful examination of the "top ten" lists comprising the bottom row of Table 3-1. For example, *Prionospio perkinsii* contributed very significantly to the strong overall difference in community structure found between REF-2 and REF-NEW. At REF-2, the average abundance of this species was 2,216 individuals/m^2, while at REF-NEW it was 141 individuals/m^2. There were similar major differences between the two sites in the abundance of several other dominant taxa (e.g., *Carinomella lactea*, *Aricidea catherinae*, and *Nucula annulata*) that contributed to the significant dissimilarity in overall community structure detected by the ANOSIM test. Similarly, the taxa contributing most significantly to the statistical difference found between Site 1 and REF-2 included the numerical dominants *Prionospio perkinsii*, *Mediomastus ambiseta*, *Carinomella lactea* and *Caraziella hobsonae*, while Site 2 differed from REF-NEW primarily due to differing abundances of the dominants *Mediomastus ambiseta*, *Aricidea catherinae*, *Nucula annulata*, *Carinomella lactea*, Oligochaetes, and Nematodes.

3.4 Comparison with Results from Other Studies

A significant number of the dominant taxa found by Whitlach et al. (1980) at a station located in western Buzzard Bay were also among the dominants in the present study, including in particular *Nucula annulata*, *Mediomastus ambiseta,* and *Nephtys incisa* (Table 3-4). Hampson (1988) sampled benthic infauna along a transect of stations in western Buzzards Bay, south of New Bedford Harbor, and found the dominant taxa to include *Mediomastus ambiseta*, *Mulinia lateralis*, *Nucula annulata*, *Nephtys incisa*, *Asychis elongata* and *Yoldia limatula* (Table 3-5). Three of these six species also were among the numerical dominants in the present study (Tables 3-2 and 3-5).

In sampling conducted during March 1990 by the U.S. Army Corps of Engineers' Disposal Area Monitoring Program (DAMOS), very high numbers of *Mediomastus ambiseta* were found at stations located in and around the former Buzzards Bay Disposal Site (BBDS) and nearby reference areas (SAIC 1991). Four of the seven dominant taxa found in this 1990 sampling effort were also dominant in the present study, including in particular *Mediomastus ambiseta* as the overall numerical dominant (Table 3-5). The Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP Virginia Province) sampled benthic infauna at several stations in Buzzards Bay during the period 1991 through 1993 (Figure 3-5). Almost all the numerical dominants found in the EMAP sampling were also among the dominants in the present study (Table 3-4).

Reference area REF-2 was sampled both in the present study and in the March 1990 DAMOS sampling effort, allowing a direct comparison of the benthic community results at this location (Table 3-5). The top two numerical dominants in 1990 (the chordate *Ascidiacea* sp. and the paraonid polychaete *Cirrophorus furcatus*) were not found in the November 2000 survey (Table 3-5). Additional 1990 dominants not found in 2000 included *Cnemidocarpa mollis, Cirratulidae* sp., *Tharyx dorsobranchialis,* and *Leptocheirus pinguis* (Table 3-5). Several of the species which were abundant in 1990 (in particular *Mediomastus ambiseta*, but also *Ninoe nigripes*, Oligochaeta, and *Aricidea catherinae*) were also among the numerical dominants in November 2000 (Table 3-5).

The results shown in Tables 3-4 and 3-5 suggest that the benthic communities found at Sites 1 and 2 and the reference areas in November 2000 are broadly comparable to those found in other studies of Buzzards Bay, in terms of being dominated by roughly the same group of relatively few taxa. However, to provide a more detailed comparison of *overall* benthic community structure across different stations/studies, a multivariate approach similar to that described previously was employed. A matrix was prepared containing the species abundance data from: 1) the five EMAP stations (Figure 3-5), 2) the 1990 DAMOS sampling effort at REF-2, and 3) the 18 stations sampled in the present study. The species abundance data were square-root transformed, a matrix of Bray-Curtis similarity values was prepared, and the ordination of stations was determined using both clustering and MDS. The cluster analysis dendrogram and MDS plot resulting from this effort are shown in Figure 3-6.

In both the cluster analysis dendrogram and the MDS ordination, the five EMAP stations (identified by the “VA” prefix) and the REF-2 1990 station (labeled as “2R-1990”) had largely dissimilar benthic community structure. The dendrogram (Figure 3-6, top) shows these six stations linking together at less than about 45% Bray-Curtis similarity. In contrast, the 18 stations sampled in the present study generally link together, as a group, at greater than 45% similarity, with two subgroups (labeled Groups 1 and 2 in the dendrogram) identified at the 50% similarity level. The MDS plot (Figure 3-6, bottom) is consistent with the cluster analysis results in showing how the EMAP stations and REF-2 1990 are separated widely in space (indicating dissimilar community structure), while the stations in the present study form two comparatively tight and closely-spaced groups.

In summary, both representations in Figure 3-6 indicate that the five EMAP stations and station 2R-1990 were largely dissimilar to each other in terms of overall benthic community structure, and, as a group, these six stations were distinctly dissimilar from the 18 stations sampled in November 2000 (the two groups link together in the dendrogram at less than 30% similarity, Figure 3-6 top). Although there was some overlap between the results of the present study and those from previous studies in terms of the consistent presence of a relatively small group of dominant taxa, the multivariate results indicate that overall community structure (which takes into account the presence and abundance of *all* the taxa, both abundant and rare) was essentially different.

4.0 DISCUSSON

The main objective of the November 2000 benthic survey was to provide a baseline characterization of the benthic communities inhabiting four different locations on the seafloor in eastern Buzzards Bay: candidate disposal Sites 1 and 2 and two nearby reference areas. The taxonomic tables provided for each site in Appendix B and the summary statistics (Table 3-1) serve to address this objective. Overall, the communities inhabiting each of the four study sites were comprised of roughly similar proportions of the following major groups (in order of decreasing overall abundance): annelids, molluscs, crustaceans, nematodes, and nemerteans. In addition, the same group of about 13 taxa consistently was among the most abundant organisms in each of the four sites (Table 3-2).

Based solely on the similarity among the four sites in the taxa comprising the numerical dominants, it is possible to conclude that at the time of the November 2000 survey, these sites were inhabited by roughly comparable benthic communities. This conclusion must be viewed in light of two caveats: it is based on ignoring the sub-dominant taxa found at each site at varying levels of abundance, and it ignores the fact that the absolute and relative abundances of the dominant taxa varied considerably among the four sites. In the "bigger picture/longer term" view, it can be argued both that the sub-dominant taxa are of less ecological importance than the dominants, and that the varying abundances of the latter are typical of estuarine benthic communities in general and therefore insignificant at any single point in time. This argument is particularly applicable here, as the four sites were largely dominated by small-bodied, surface-dwelling, opportunistic, "Stage I" polychaetes (e.g., *Mediomastus ambiseta, Prionospio perkinsii*, *Caraziella hobsonae*) known to have high population turnover rates and therefore wide spatial and temporal variance. Thus, it is the consistent presence of the dominants across the four sites, and not their relative proportions, that is of utmost ecological relevance in such a big picture view, and it is possible to conclude that the sites were comparable at the time of the November 2000 survey.

Moving beyond the evaluation based solely on the numerical dominants, the univariate statistics presented in Table 3-1 reveal some differences among the four sites. Site 2 had considerably higher total numbers of individuals and taxa compared to either Site 1 or the reference areas, although on a "per station" average basis these differences were not statistically significant (Figure 3-1). Site 2 also had the highest average diversity and species richness of the four sites, and the differences in average diversity and species richness between Site 2 and REF-NEW *were* statistically significant (Figure 3-2). Four of the six stations in Site 2 were dominated by sand, while the other two had predominantly muddy (i.e., silt-clay) sediments. This greater habitat diversity probably explains the higher average diversity and species richness at this site compared to the other three sites, where most of the stations had predominantly muddy sediments.

The multivariate statistical approaches presented here represent an attempt to go beyond the somewhat simplistic view of benthic community structure afforded by the summary univariate statistics. The techniques employed encompass all of the taxa found in each sample, thereby facilitating an assessment of *overall* community structure as opposed to just looking at the most abundant organisms. Clustering and MDS are non-parametric methods that do not require the data to be transformed to meet underlying statistical assumptions. However, the square root transformation was applied intentionally to the abundance data prior to applying these techniques in order to downweight the contribution of the numerical dominants while increasing the contribution of the rarer taxa in assessing the degree of similarity among samples. The net effect is to provide a deeper and more holistic comparison of the communities inhabiting each station/site. Both clustering and MDS were employed because each technique provides a valuable and recommended "cross-check" on the other (Clarke and Warwick 1994).

There was good agreement between these two techniques in showing the same basic ordination of the stations. The MDS configuration (Figure 3-4) provides the more intuitive representation of the relationships among stations: the degree of overall community similarity between any two stations is simply proportional to their distance apart in the 2-dimensional space of the MDS plot (shorter distance = greater similarity). The basic plot in Figure 3-4A shows that the stations are not *strongly* grouped by site. This is neither remarkable nor unexpected, as there are no *a priori* reasons to expect these four sites, which essentially represent relatively undisturbed and closely spaced patches of the seafloor occurring at similar depths in eastern Buzzards Bay, to have widely differing benthic communities. However, the plot does reveal some degree of within-site consistency and among-site differences in overall community structure, particularly at the two reference areas.

Both the REF-2 and REF-NEW stations group together in Figures 3-3 and 3-4, and this within-site similarity in benthic community structure is attributed both to the physical closeness of the stations within each site and the homogeneity of the substrate (all six of the reference stations had silt-clay content ≥ 90%). Despite the similarity in habitat type between REF-NEW and REF-2, the MDS plot suggests, and the ANOSIM test confirms, a statistically significant difference in overall community structure between the two. As previously indicated, this difference was due mainly to widely differing abundances of several of the numerically dominant taxa, mainly *Prionospio perkinsii*, *Carinomella lactea*, *Aricidea catherinae*, and *Nucula annulata*. The low abundance of *Nucula annulata* at REF-2 is somewhat anomalous, as this species tends to be common and persistent in comparably deep and muddy areas of Buzzards Bay and other parts of coastal, subtidal New England (as part of the "Nephtys incisa-Nucula annulata" equilibrium community *sensu* Sanders (1956), McCall (1977), Rhoads and Boyer (1982)).

The clustering and MDS ordinations further show both similarity and differences in community structure among the stations in Sites 1 and 2. Three of the predominantly muddy stations in Site 1 had community structure similar to that at the three REF-NEW stations. Despite the dominance of sand at Station B-6 (silt-clay content 15%), it was also included in the "REF-NEW/Site 1" station group, but the association is rather tenuous (note the relative closeness of station B-6 and sandy station M-12 in the MDS plot). The sandy stations within Site 2 (M-12, K-12, M-10, and N-16) tended to have comparable and unique community structure, while the two muddy stations in Site 2 (J-17 and K-14) had community structure most similar to that at two of the muddy stations in Site 1 (G-3 and E-4). This "overlap" between Sites 1 and 2 is reflected in the ANOSIM test conclusion of no significant difference in overall community structure between these two sites (Table 3-3).

The ANOSIM test further showed significant differences in overall community structure between Site 1 and REF-2 and between Site 2 and REF-NEW (Table 3-3), and these differences can be visualized by careful examination of the MDS plot in Figure 3-4C. Again, these statistical differences are due primarily to different relative abundances of the dominant taxa that were common to all of the sites, and only secondarily to differences in both the number and occurrence of the "rare" taxa. Therefore, the overall importance or ecological "significance" of these results is at best questionable. More than anything else, the multivariate statistical tests are merely detecting the somewhat random and expected spatial variability in the distribution of a few dominant and functionally-similar (i.e., opportunistic) taxa among the four sites.

While the multivariate techniques are sensitive to the differing proportions of the dominant taxa, resulting in detection of among station/site differences in overall community structure, it is important to note that these results are based solely on a single "snapshot" view of the communities in each site. As previously indicated, populations of several of the key dominant taxa at these sites (i.e., opportunistic Spionid and Capitellid polychaetes) are known to vary widely in space and time, such that the same multivariate analyses applied to these same stations based on sampling at different times are likely to yield quite different results. Additional seasonal sampling would be required to test whether the detected among-site differences are consistent through time, or merely a one-time reflection of the (ever-changing) community structure that happened to exist at each station in November 2000. Assuming the latter is the case, any future assessments of communities at these sites should preferably be based on the more simple "univariate" approach, involving examination of the persistence of the numerical dominants at each site while understanding their relative proportions are likely to fluctuate.

Broadly speaking, the benthic communities found at the four sites in the November 2000 survey were comparable to those found in previous studies of Buzzards Bay, in terms of many of the same taxa being among the dominants (Table 3-4). Similar to the present study, the March 1990 DAMOS sampling effort at BBDS and its nearby reference areas found a *Mediomastus*-dominated community, and it was noted that high abundances of *Mediomastus ambiseta* are likewise characteristic of Cape Cod Bay and, to a lesser extent, Boston Harbor and Massachusetts Bay (SAIC 1991). The comparison of the March 1990 and November 2000 results at REF-2 showed both similarities and differences in the dominant taxa (Table 3-5), attributed in part to variations in grain size found at this location in the two surveys (March 1990 = fine sand, November 2000 = silt-clay).

More-detailed comparisons of results among the different studies are complicated by a variety of factors, including differences in sampling equipment, changes in taxonomic classifications, grain size/depth differences, and seasonal differences. The multivariate analysis (Figure 3-6) showed fairly wide differences in overall community structure between the stations sampled in the present study and those from other studies. This is not particularly surprising, as such an analysis is (again) sensitive to variations in the abundances of many of the dominant taxa in addition to being affected by the complicating factors listed above.

Overall, the results of the November 2000 survey indicate that the benthic communities at candidate Sites 1 and 2 and nearby reference areas are dominated by opportunistic taxa with high population turnover rates and therefore the capability to recover rapidly from the physical disturbance associated with dredged material disposal. It is anticipated that deposits of dredged material placed on the seafloor at either candidate site would become recolonized by benthic organisms within several weeks to several months (in the absence of further physical disturbance). The initial recolonizing community would likely include high numbers of several of the dominant opportunistic taxa found in the present study. Complete recovery of the community (to levels comparable to the ambient seafloor) is a longer-term process that may require a year or more. Candidate Site 2 had both sandy and muddy sediments, while candidate Site 1 and the reference areas had predominantly muddy sediments. Because of the greater apparent benthic habitat diversity at candidate Site 2, it had higher average benthic taxonomic diversity and species richness compared to the other three sites. On this basis, the negative environmental impacts of dredged material disposal at candidate Site 2 might be considered of somewhat greater concern than those at candidate Site 1. This consideration is only one of many factors that will need to be weighed in the future Environmental Impact Report in addressing whether either of the two sites is a preferred location for dredged material disposal.

5.0 CONCLUSIONS

1) The November 2000 survey of candidate disposal Sites 1 and 2 and two nearby reference areas showed that benthic communities inhabiting each of the four study sites were comprised of roughly similar proportions of the following major groups (in order of decreasing overall abundance): annelids, molluscs, crustaceans, nematodes, and nemerteans.

2) The same group of about 13 taxa consistently was among the most abundant organisms in each of the four sites. The capitellid polychaete *Mediomastus ambiseta* was the overall numerical dominant across all four sites. Other dominants at all four sites included the polychaetes *Prionospio perkinsii* and *Aricidea catherinae*, the nemertean *Carinomella lactea*, the molluscs *Macoma tenta* and *Cylichna oryza*, nematodes and ostracods.

3) Based solely on the similarity among the four sites in the taxa comprising the numerical dominants, it was concluded that they had roughly comparable benthic communities at the time of the November 2000 survey.

4) Site 2 had the highest average abundance, number of taxa, species richness and diversity of all the sites.

5) Based on a multivariate analysis involving consideration of all the taxa found at each station, there was no statistical difference in overall benthic community structure found between Sites 1 and 2. Statistically significant differences in overall community structure were detected between REF-2 and REF-NEW, Site 1 and REF-2 and Site 2 and REF-NEW.

6) The benthic communities found at the four sites in November 2000 were roughly comparable to the communities found in previous studies of other areas of Buzzards Bay.

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TABLES

Table 3-1

Summary Statistics for Benthic Community Data from Candidate Sites 1 and 2 and the Two Reference Areas.

	SITE 1	SITE 2	REF-2	REF-NEW
Number of stations (samples)	6	6	3	3
Total number of individuals (all samples combined)	34,182	56,833	25,203	16,551
Total number of taxa (all samples combined)	67	107	60	41
Average no. individuals/m^2 per station (± 1 s.d.)	5,697 ± 1,876	9,472 ± 4,329	8,401 ± 2,974	5,517 ± 1,597
Average no. of taxa per station (± 1 s.d.)	31 ± 6	42 ± 8	36 ± 5	25 ± 4
Avg. Shannon-Wiener diversity (H') ± 1 s.d.	2.77 ± 0.2	2.96 ± 0.19	2.57 ± 0.25	2.50 ± 0.03
Avg. Pielou's evenness (J') ± 1 s.d.	0.80 ± 0.04	0.78 ± 0.04	0.71 ± 0.06	0.78 ± 0.03
Avg. Margelef's species richness (d)	3.57 ± 0.63	4.83 ± 0.91	4.05 ± 0.62	2.79 ± 0.33
Total abundance (all samples combined) of:				
Annelids (% of total)	18,475 (54%)	35,475 (62%)	14,875 (59%)	9,000 (54%)
Molluscs	7,450 (22%)	7,375 (13%)	4,275 (17%)	4,950 (30%)
Crustaceans	4,000 (12%)	5,500 (10%)	1,425 (6%)	1,400 (8%)
Nematodes	2,100 (6%)	4,150 (7%)	1,150 (5%)	700 (4%)
Nemerteans	1,550 (5%)	3,850 (7%)	2,975 (12%)	400 (2%)
Others	607 (2%)	483 (1%)	503 (2%)	101 (1%)
Ten most-abundant taxa (% of total abundance)	Mediomastus ambiseta (10.2%) Ostracoda (8.6%) Caraziella hobsonae (8.1%) Macoma tenta (8.0%) Aricidea catherinae (7.5%) Cylichna oryza (6.8%) Nematoda (6.1%) Prionospio perkinsii (5.2%) Carinomella lactea (4.2%) Nephtys incisa (4.2%)	Mediomastus ambiseta (14.1%) Oligochaeta (8.4%) Nematoda (7.3%) Carinomella lactea (6.7%) Carazziella hobsonae (5.4%) Prionospio perkinsii (5.2%) Ostracoda (4.6%) Aricidea catherinae (4.3%) Macoma tenta (3.9%) Cylichna oryza (3.7%)	Prionospio perkinsii (26.4%) Mediomastus ambiseta (15.3%) Carinomella lactea (11.5%) Macoma tenta (6.2%) Ninoe nigripes (6.0%) Nematoda (4.6%) Ostracoda (4.2%) Cylichna oryza (3.8%) Aricidea catherinae (3.1%) Oligochaeta (2.2%)	Aricidea catherinae (18.3%) Mediomastus ambiseta (15.6%) Nucula annulata (14.5%) Ostracoda (8.3%) Cylichna oryza (7.7%) Nephtys incisa (5.1%) Macoma tenta (4.5%) Nematoda (4.2%) Prionospio perkinsii (2.6%) Carinomella lactea (2.4%)

Table 3-2

List of the 13 Dominant Taxa across all Sites in the November 2000 Survey.

Taxa	Number of sites where taxa was among the top ten numerical dominants	Total no. of individuals across all 4 sites (number per m^2)	Percent of overall total abundance
Mediomastus ambiseta	4	17,900	13%
Prionospio perkinsii	4	11,800	9%
Arcidea catherinae	4	8,825	7%
Carinomella lactea	4	8,550	6%
Nematoda	4	8,100	6%
Ostracoda	4	7,975	6%
Macoma tenta	4	7,300	5%
Cylichna oryza	4	6,650	5%
Oligochaeta	2	6,175	5%
Caraziella hobsonae	2	5,975	5%
Nephtys incisa	2	3,425	3%
Ninoe nigripes	1	4,725	4%
Nucula annulata	1	3,900	3%
Totals		**101,300**	**76%**

Table 3-3

Results of the ANOSIM Significance Test of the Null Hypothesis that there is no Significant Difference in Benthic Community Structure[1] Among/Between Sites.

Test	R-statistic	Significance level	Conclusion[2]
Global test (all sites)	0.338	0.008	s
Pairwise comparisons:			
Site 2 versus REF-NEW	0.395	0.04	s
Site 2 versus Site 1	0.222	0.06	ns
Site 2 versus REF-2	0.216	0.14	ns
Site 1 versus REF-NEW	0.099	0.31	ns
REF-NEW versus REF-2	0.963	0.10	s
Site 1 versus REF-2	0.537	0.012	s

[1]The term "benthic community structure" as used throughout this report is defined by *both* the species present in a sample and their relative abundance. Two sites/samples having exactly the same species present in exactly the same numbers/proportions could be said to have identical benthic community structure.

[2] s = reject null hypothesis, significant difference among/between sites (i.e., $R>0.75$ indicates strong separation or a big difference in overall benthic community structure, while $0.75 > R > 0.25$ indicates varying degrees of overlap but generally different community structure).

[2] ns = accept null hypothesis, no significant difference between sites (i.e., $R<0.25$ indicates little separation among/between sites).

Table 3-4

Benthic Taxa Found to be Among the Numerical Dominants in Other Studies of Buzzard Bay

Study	Sampling Date	Dominant Taxa (note: NOT necessarily listed in order of abundance)	Among Dominants in Present Study?
Whitlach et al. (1980)	Multiple dates through 1975 and 1976	*Nucula annulata*	Yes
		Mediomastus ambiseta	Yes
		Scolelepis bousfieldi	No
		Nephtys incisa	Yes
		Paraonis gracilis	No
		Lumbrinerus tenuis	No
		Aricidea catherinae	Yes
		Cylichna oryza	Yes
		Tubulanus pellucidus	No
		Ninoe nigripes	Yes
Hampson (1988)	August 1987	*Mediomastus ambiseta*	Yes
		Mulinia lateralis	No
		Nucula annulata	Yes
		Nephtys incisa	Yes
		Asychis elongata	No
		Yoldia limatula	No
SAIC (1991)	March 1990	*Mediomastus ambiseta*	Yes
		Ninoe nigripes	Yes
		Oligochaeta	Yes
		Tubulanus pellucidus	No
		Aricidea catherinae	Yes
		Spiophanes bombyx	No
		Cylichnella bidentata	No
EMAP	Summer 1991-93	*Ampelisca* sp.	No
		Aricidea catherinae	Yes
		Macoma tenta	Yes
		Mediomastus ambiseta	Yes
		Nephtys incisa	Yes
		Ninoe nigripes	Yes
		Nucula annulata	Yes
		Oligochaeta	Yes
		Polycirrus sp.	No
		Prionospio perkinsii	Yes

Table 3-5

March 1990 versus November 2000 Comparison of Benthic Community Data at REF-2

1990 Top Ten Taxa (% of total abundance)	2000 Top Ten Taxa (% of total abundance)
Mediomastus ambiseta (11.7%) *Ninoe nigripes* (10.8%) *Aricidea catherinae* (2.7%) Oligochaeta (3.1%) *Ascidiacea* sp. (15.9%) *Cirrophorus furcatus* (12.9%) *Cnemidocarpa mollis* (4.5%) *Cirratulidae* sp. (4.1%) *Tharyx dorsobranchialis* (3.4%) *Leptocheirus pinguis* (3.1%)	*Mediomastus ambiseta* (15.3%) *Ninoe nigripes* (6.0%) *Aricidea catherinae* (3.1%) Oligochaeta (2.2%) *Prionospio perkinsii* (26.4%) *Carinomella lactea* (11.5%) *Macoma tenta* (6.2%) Nematoda (4.6%) Ostracoda (4.2%) *Cylichna oryza* (3.8%)

FIGURES

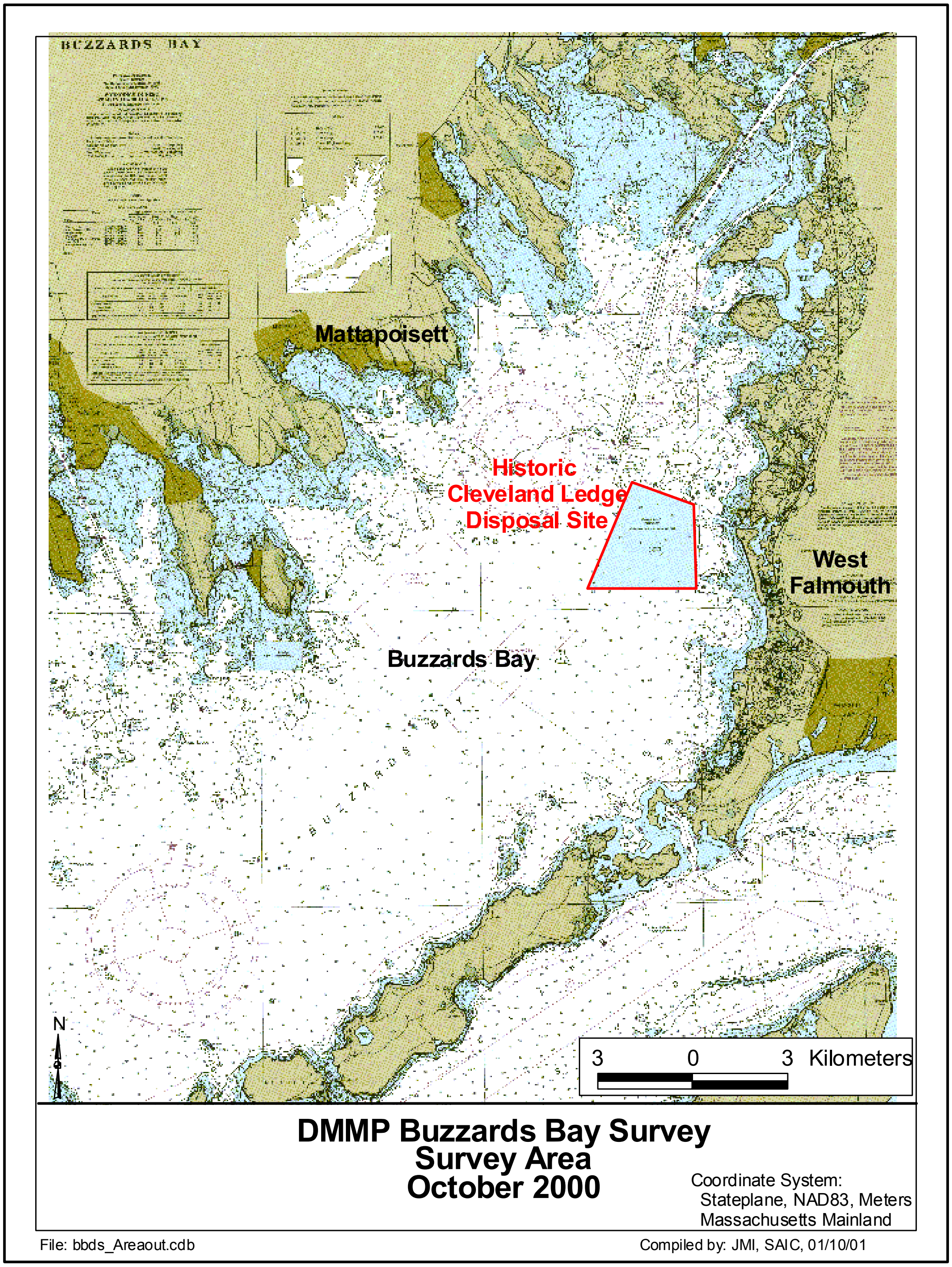

Figure 1-1. General location map showing the boundary of the historic Cleveland Ledge Disposal Site on the eastern side of Buzzards Bay, off of West Falmouth (from NOAA Nautical Chart 13229).

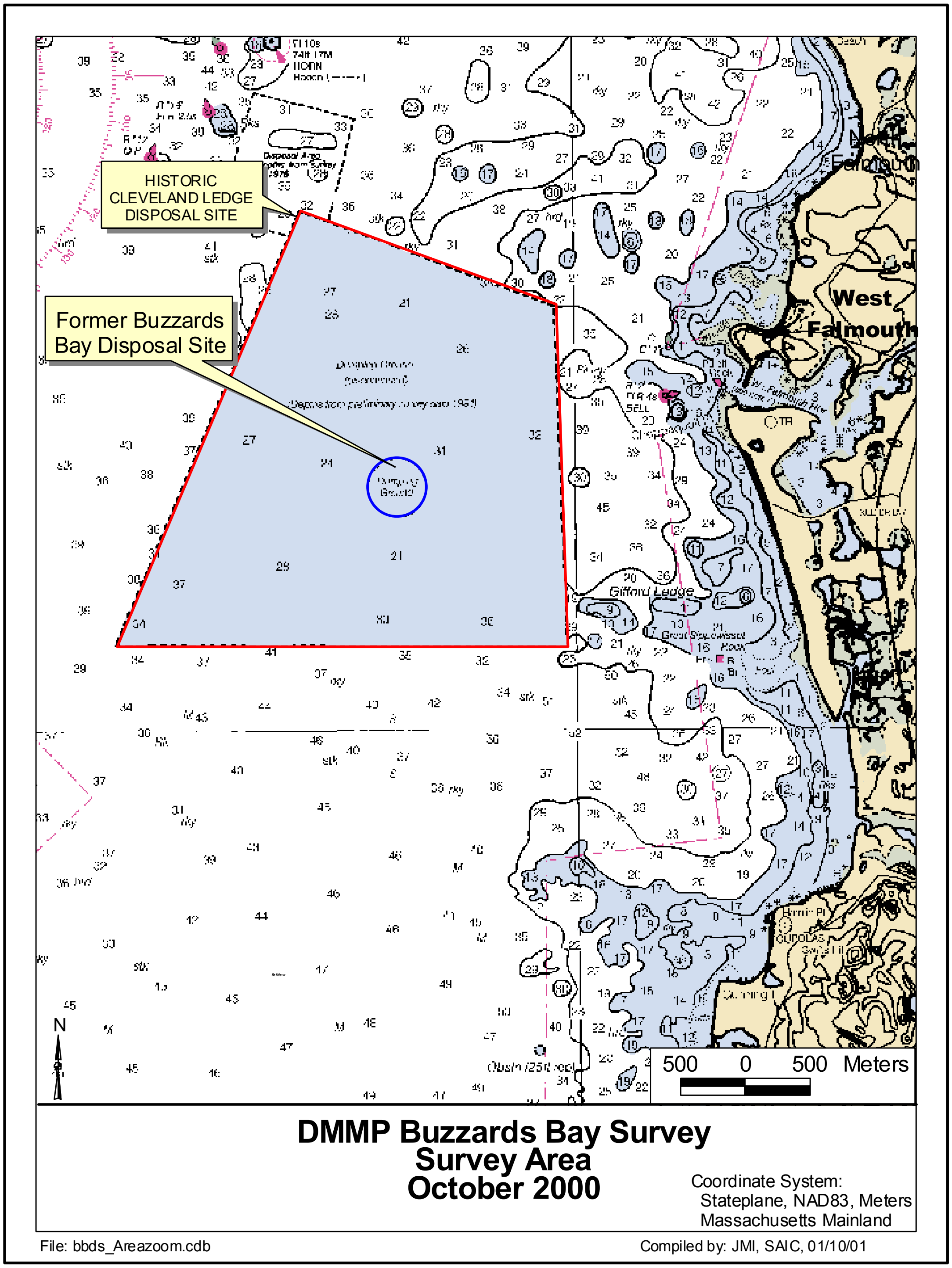

Figure 1-2. Map of the historic Cleveland Ledge Disposal Site showing the location of the former Buzzards Bay Disposal Site (BBDS). In 1995, Massachusetts DEM proposed the designation of a new BBDS in the same location.

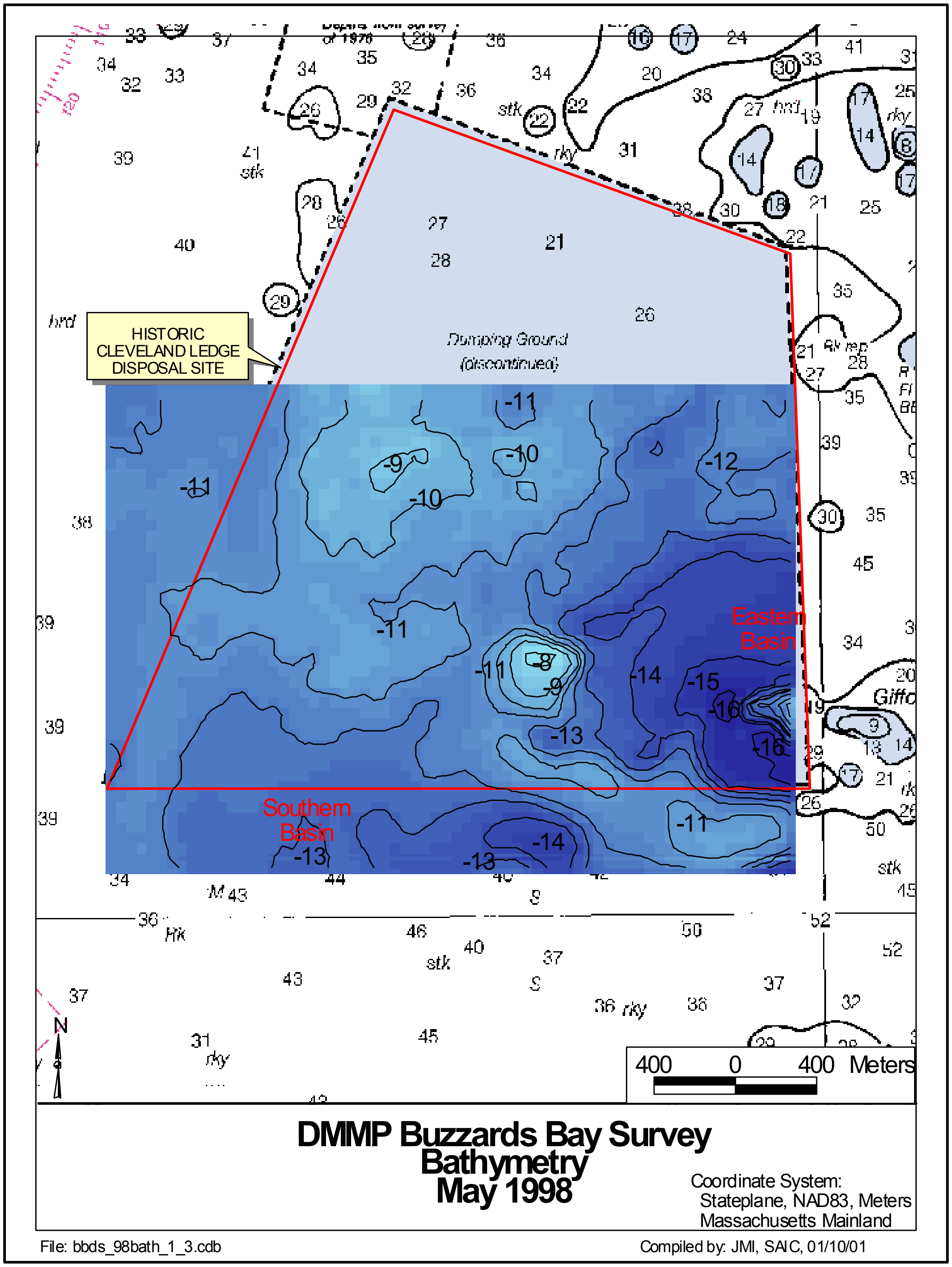

Figure 1-3. Results of the high-resolution bathymetric survey conducted across the southern half of the Cleveland Ledge Disposal Site in May 1998, superimposed on NOAA Nautical Chart 13229. Depths from the bathymetric survey are in meters; nautical chart depth soundings are in feet.

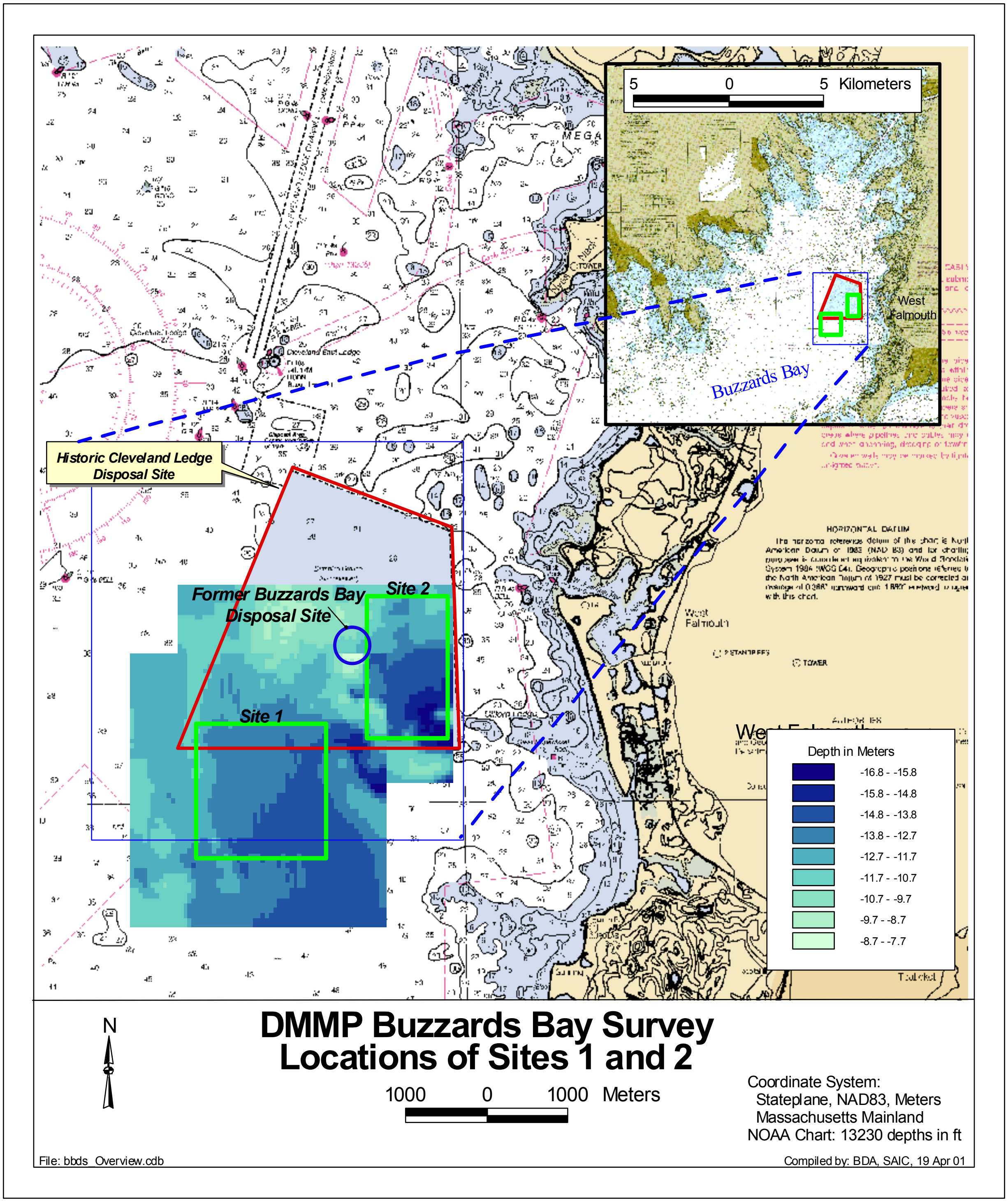

Figure 1-4. Map showing the general location of candidate disposal Sites 1 and 2 within Buzzards Bay and in relation to the historic Cleveland Ledge Disposal Site. Depth contours (in meters) underlying Sites 1 and 2 are from SAIC surveys conducted in May 1998 and October 2000.

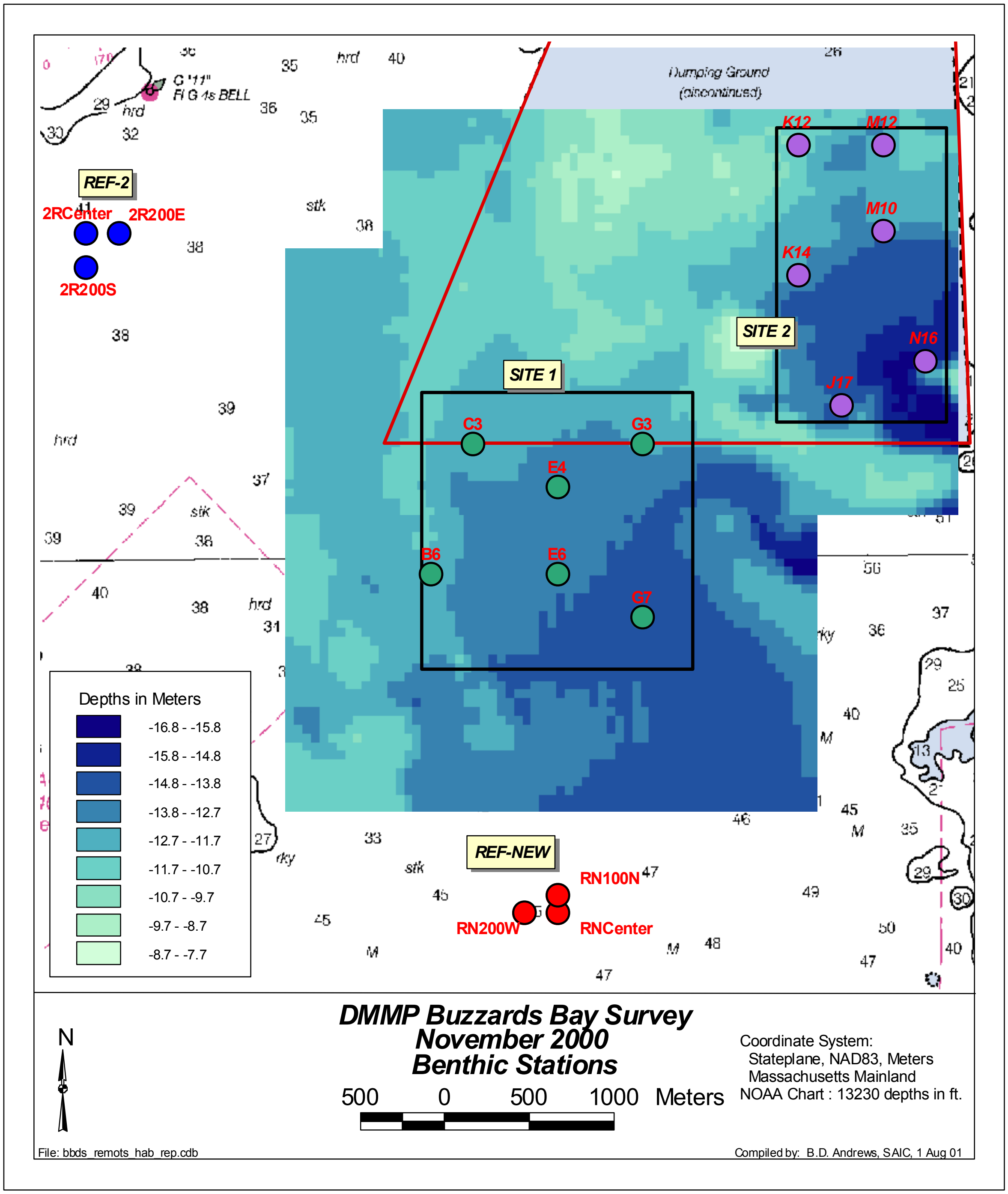

Figure 2-1. Map showing the location of benthic community sampling stations at candidate disposal Sites 1 and 2 and reference areas REF-NEW and REF-2. Color bathymetry results underlying Sites 1 and 2 are in meters, from SAIC surveys conducted in May 1998 and October 2000. Depth values on the underlying NOAA chart are in feet.

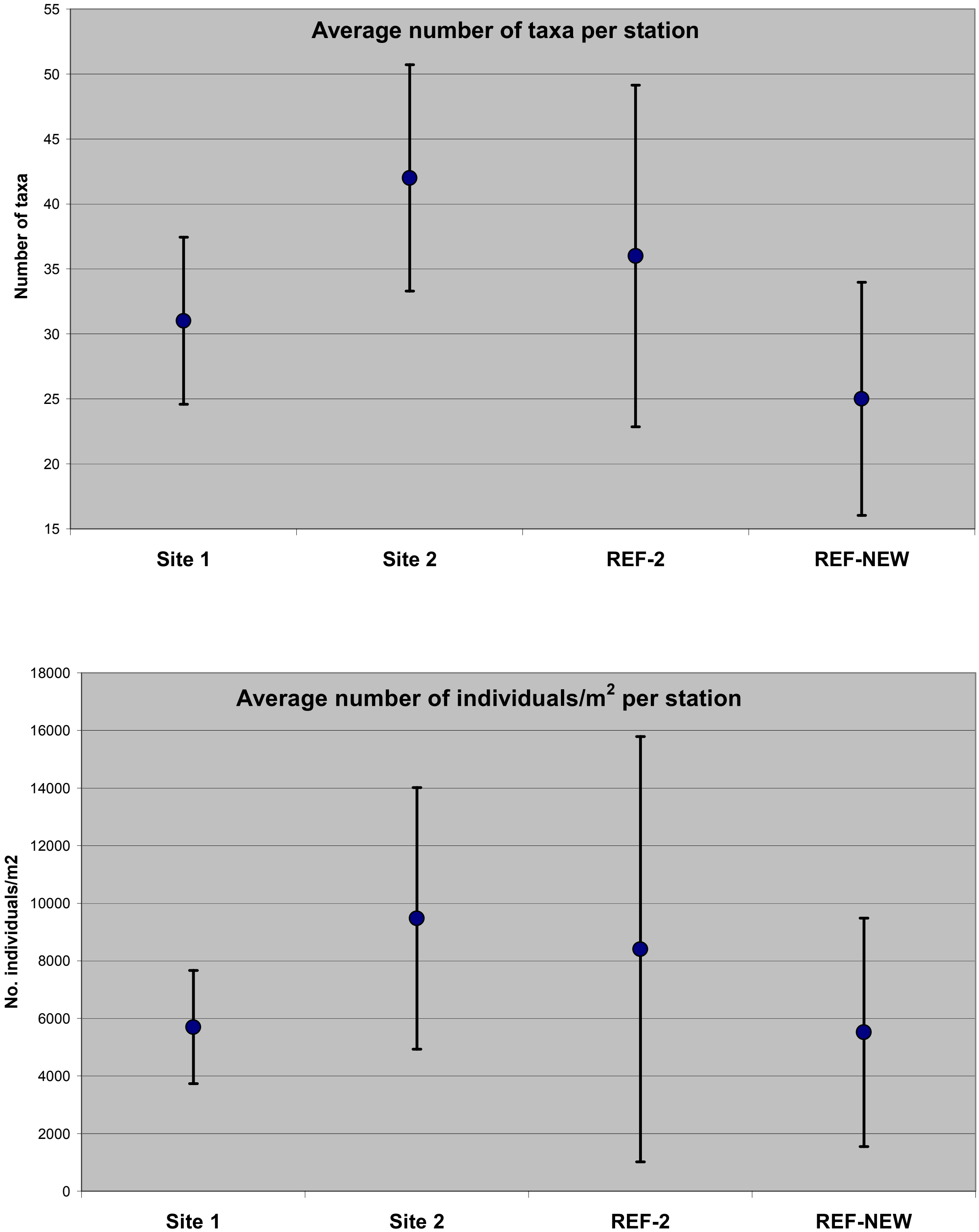

Figure 3-1. Among-site comparisons of average number of taxa per station (top) and average number of individuals/m2 per station (bottom). Error bars are 95% confidence intervals.

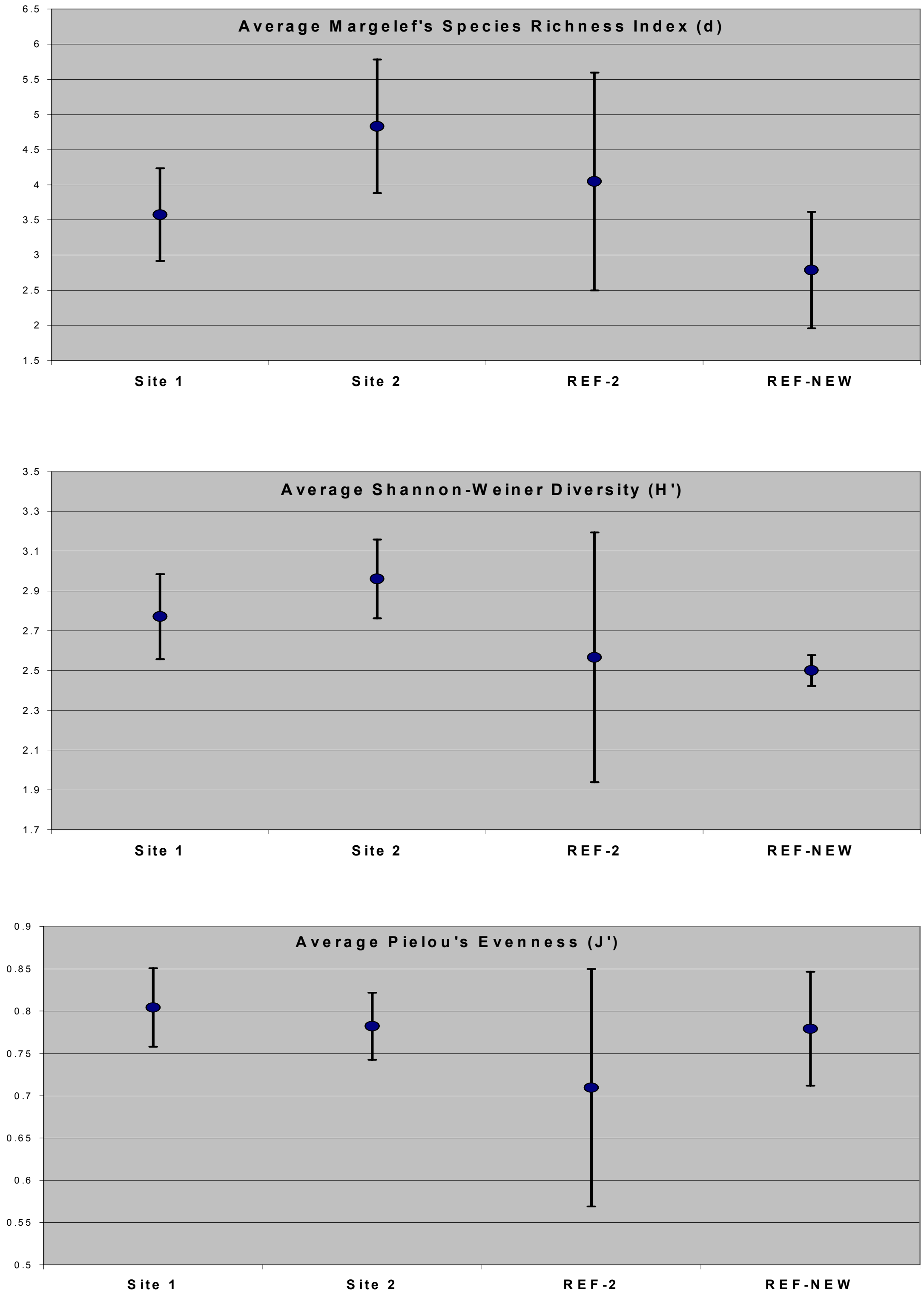

Figure 3-2. Among-site comparisons of average species richness (top), diversity (middle) and evenness (bottom). Error bars are 95% confidence intervals.

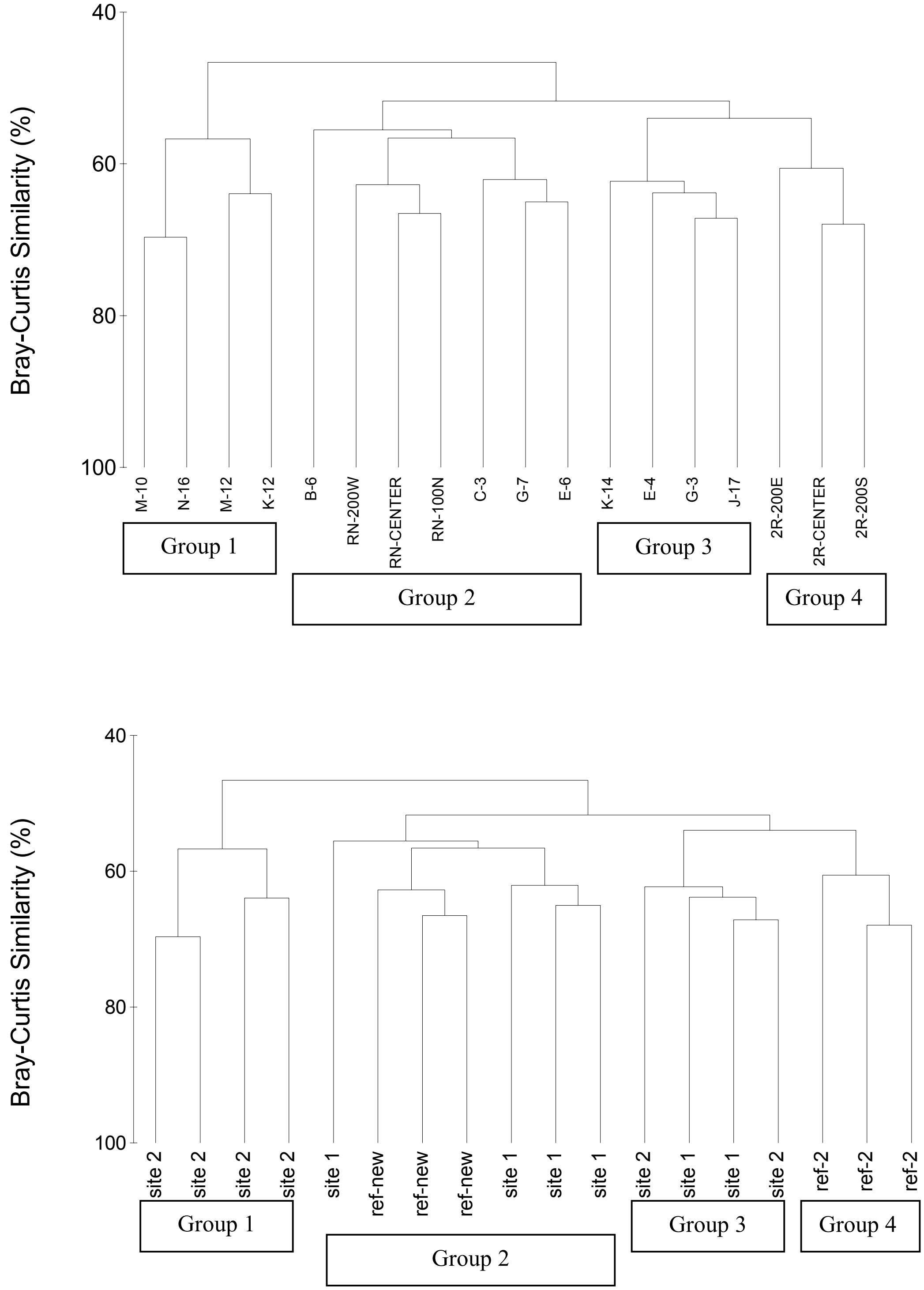

Figure 3-3. Dendrograms for hierarchical clustering of the 18 stations sampled during the November 2000 survey, based on Bray-Curtis similarity. The dendrograms are identical, but in the bottom one, each station label has been replaced with the name of the site where the station was located.

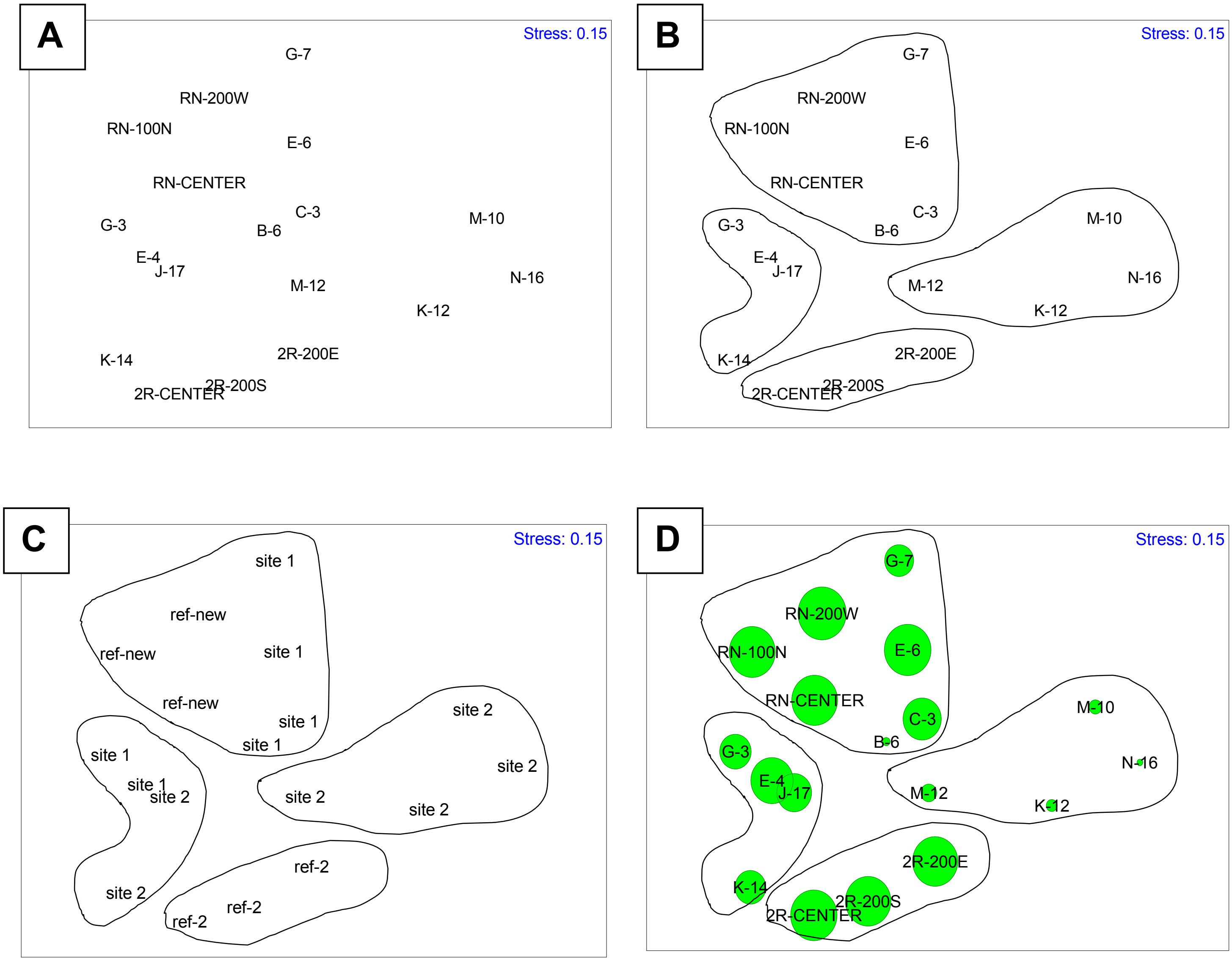

Figure 3-4. A) 2-dimensional MDS configuration of the 18 stations, based on Bray-Curtis similarity in benthic community structure. B) The same MDS plot but with the station groups from the cluster analysis (Figure 3-3) superimposed. C) The same MDS plot but with each station name replaced with the name of its respective site. D) The same MDS plot but with superimposed circles whose size is directly proportional to the amount of silt-clay found in the sediment at each station (i.e., the larger circle, the higher the percentage of silt-clay).

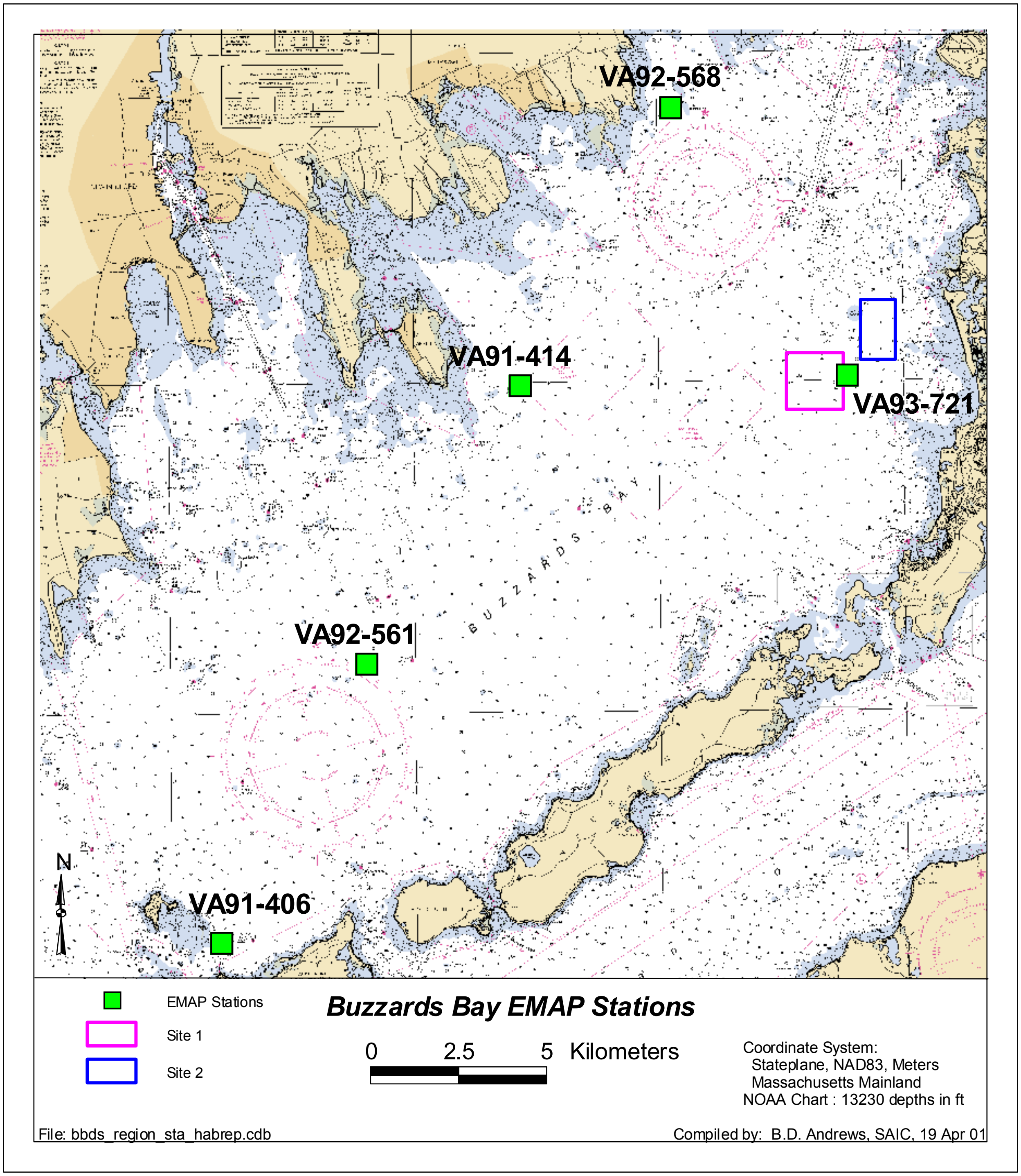

Figure 3-5. Map showing the location of EMAP stations sampled in Buzzards Bay during the summer months over the period 1991 through 1993. The station prefix indicates the year that each station was sampled (e.g., VA91 = 1991).

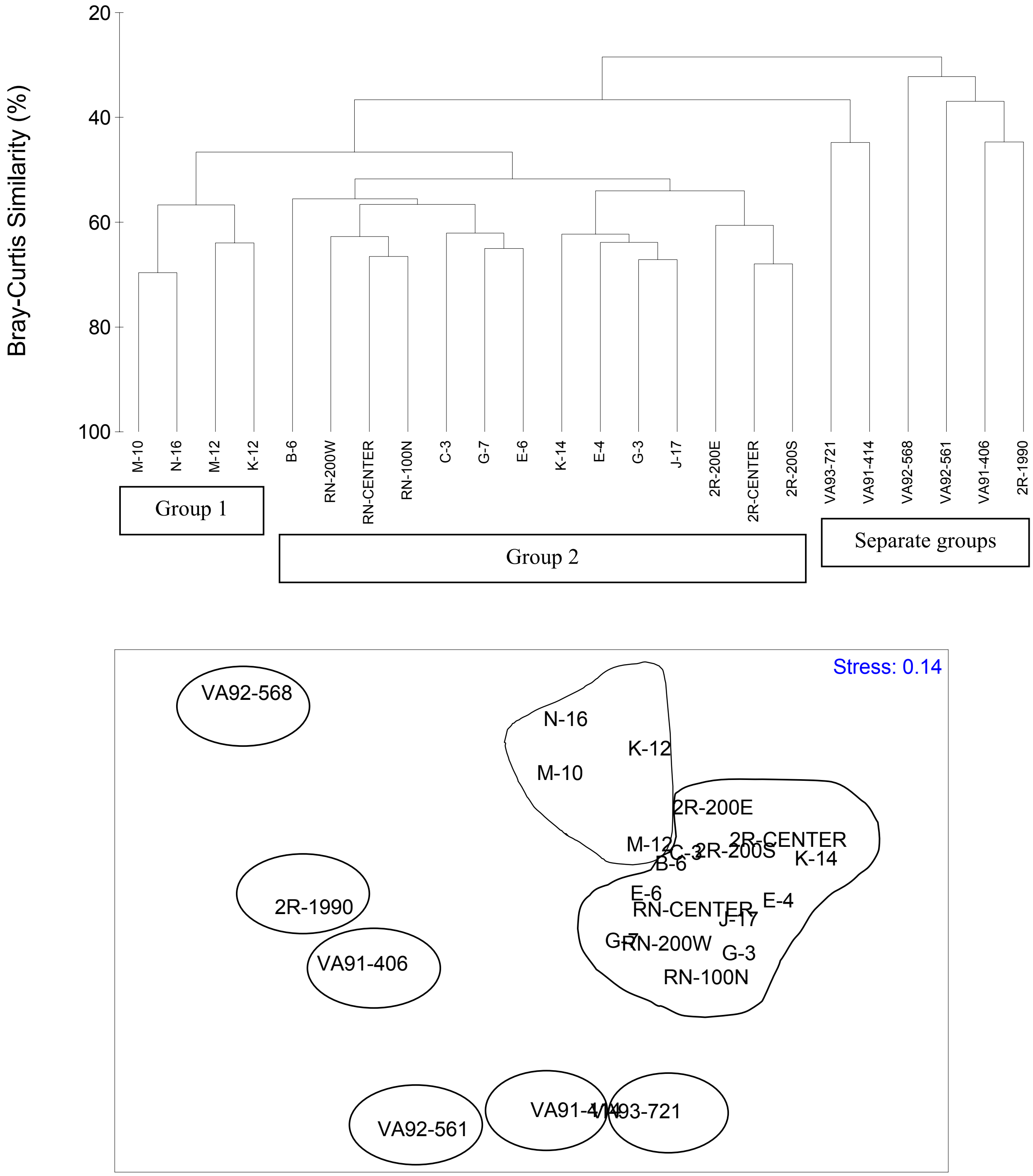

Figure 3-6. Top: dendrogram for hierarchical clustering of 24 benthic sampling stations in Buzzards Bay (18 stations sampled in November 2000, 5 EMAP stations and station REF-2 sampled in 1990), based on Bray-Curtis similarity. Bottom: corresponding 2-dimensional MDS configuration of the 24 stations, with circles around the station groups identified in the cluster analysis.

APPENDIX A

Abundance (No./m2) of Benthic Infauna (Retained on a 0.5 mm mesh seive) collected by a 0.04m2 Grab from Buzzards Bay - November 2000

Taxa	M-10	M-12	RN-CENTER	RN-100N	RN-200W	G-3	G-7	K-12	K-14	E-4	E-6	C-3	B-6	N-16	J-17	2R-CENTER	2R-200E	2R-200S
PORIFERA																	P	
CNIDARIA																		
HYDROZOA		P						P			P	P	P					P
CAMPANULARIA GIGANTEA														P				
PODOCORYNE CARNEA														P				
TUBULARIA SP.	P		P			P		P	P		P		P					P
ANTHOZOA																		
CERIANTHEOPSIS AMERICANUS		25			25		25				25	25						
PLATYHELMINTHES																		
TURBELLARIA									75				25	25		175		25
NEMERTEA		25																25
AMPHIPORUS BIOCULATUS		25									50		25					25
CARINOMELLA LACTEA	650	750	375		25			675	650	500		700	250	575	500	1575	650	675
CEREBRATULUS SP.													25			25		
NEMATODA	975	550	50		650		725	750	25	75	475	750	75	1650	200	75	1050	25
ANNELIDA																		
OLIGOCHAETA	700	275	25	100	25	200	100	425		25	125	125	100	3350	50		500	50
POLYCHAETA																		
ANCISTROSYLLIS HARTMANAE														125				
ANOBOTHRUS GRACILIS								25										
ARABELLA IRICOLOR	25					75								25				50
ARICIDEA (ACMIRA) CATHERINAE	1100	150	1325	1175	525	50	350	250	25	75	375	1250	475	875	50	75	350	350
ASYCHIS ELONGATA	25		75	125	50	75		50	200	50	225	125	50	75	200			
BRANIA WELLFLEETENSIS														25				
CABIRA INCERTA														25				
CAPITELLIDAE														25				
CARAZZIELLA HOBSONAE	2175	25		50	25		550	50			675	1475	75	825		50		
CIRRATULIDAE		50													50	25	25	25
CIRROPHORUS FURCATUS	575		200		175	150	75	75				75	200	750	25			25
CLYMENELLA TORQUATA	25																	
DIOPATRA CUPREA	25					25		25			25							

Abundance (No./m2) of Benthic Infauna (Retained on a 0.5 mm mesh seive) collected by a 0.04m2 Grab from Buzzards Bay - November 2000

Taxa	M-10	M-12	RN-CENTER	RN-100N	RN-200W	G-3	G-7	K-12	K-14	E-4	E-6	C-3	B-6	N-16	J-17	2R-CENTER	2R-200E	2R-200S
DIPOLYDORA SOCIALIS								25					325				100	25
EUCLYMENE COLLARIS	100			100							25	50	25	275			25	
EUCRANTIA VILLOSA	50													100		25	25	25
EUMIDA SANGUINEA	50							25										25
EUNICIDAE								25								50		25
EXOGONE DISPAR	75	25						100						75				
GLYCERA AMERICANA	100	25						75		25				100			25	
GLYCERA SP. 1									25		50			175				
GLYCINDE SOLITARIA	275	50						125	50		25			125				
GONIADIDAE														75				
GYPTIS VITTATA		50																
HETEROMASTUS FILIFORMIS								25										
LEPIDONOTUS SUBLEVIS									25									
LEVINSENIA GRACILIS			200	50						25								
MALDANIDAE	25	25						50	75					300				
MEDIOMASTUS AMBISETA	2250	1325	1600	375	600	175	525	600	150	100	2100	300	275	3050	625	2000	600	1250
MELINNA CRISTATA	100	100	100	50	75	125	25	175	75	100	25	225	75	125	25		50	
MICRONEPHTYS MINUTA			25					25										
MONTICELLINA DORSOBRANCHIALIS	625		25	100				275	75	25	150	575	25	600			25	25
NEPHTYS INCISA	25	200	375	200	275	225	250	75	200	225	250	200	275	100	150	150	50	200
NEREIS GRAYI						25												
NINOE NIGRIPES	375	325	200	75	50	100	150	400	25	125	250	300	325	400	125	375	625	500
NOTOMASTUS LATERICEUS	150	175				25		400	25				25	375		25		25
PECTINARIA GOULDII		25		25		175		50	75				25	25			25	
PHOLOE MINUTA				25				25										
PHYLLODOCE ARENAE	25	25						25			25			25				
PISTA CRISTATA														25				
POLYDORA CORNUTA																50	25	150
POTAMILLA RENIFORMIS								25										
PRIONOSPIO (MINUSPIO) PERKINSII	250	150	100	75	250	750	150	75	1275	50	150	575	100	475	725	4000	950	1700

Abundance (No./m2) of Benthic Infauna (Retained on a 0.5 mm mesh seive) collected by a 0.04m2 Grab from Buzzards Bay - November 2000

Taxa	M-10	M-12	RN-CENTER	RN-100N	RN-200W	G-3	G-7	K-12	K-14	E-4	E-6	C-3	B-6	N-16	J-17	2R-CENTER	2R-200E	2R-200S
PRIONOSPIO HETEROBRANCHIA																		50
PROTODORVILLEA GASPEENSIS							50	25	25	50				25				
SABELLA MICROPHTHALMA			25					50			25							
SABELLARIA VULGARIS	125																	
SCOLELEPIS BOUSFIELDI	50	125	25	50	25	175		275	25	25		25	125	50	275	75	25	
SCOLETOMA SP.	325	200				75	75	300	100	200	50	100	150	350	50			
SPHAEROSYLLIS LONGICAUDA		75						50	25					125				
SPHAEROSYLLIS TAYLORI	50								25									
SPIOCHAETOPTERUS OCULATUS	25	25						25			25	25					25	
SPIONIDAE	25							25	50									
TEREBELLIDAE								25										
THARYX ACUTUS	25		50											25				25
TYPOSYLLIS ALTERNATA	25																	
MOLLUSCA																		
GASTROPODA															25			
ACTEOCINA CANALICULATA		225	25	25		50		25	150	300	100	150	25		150	75	125	125
CREPIDULA SP.			25					25	25		25	75	50			25	25	75
CYLICHNA ORYZA	125	425	575	350	350	500	75	250	725	700	425	475	150		575	625	75	250
FARGOA BARTSCHI												25						
ILYANASSA TRIVITTATA									25									
KURTZIELLA CERINA									25									
MITRELLA LUNATA								50									50	
RICTAXIS PUNCTOSTRIATUS		125	75			25		50	125	25		25		25	50	250	75	25
TECTONATICA PUSILLA																25		
TURBONILLA ELEGANTULA				125					325	75			50	25		25		
TURBONILLA SP.	25			25											25			
TURBONILLA SUMNERI			25					25										
BIVALVIA																		
ANADARA TRANSVERSA								25								50	25	25
CERASTODERMA PINNULATUM															25			

Abundance (No./m2) of Benthic Infauna (Retained on a 0.5 mm mesh seive) collected by a 0.04m2 Grab from Buzzards Bay - November 2000

	M-10	M-12	RN-CENTER	RN-100N	RN-200W	G-3	G-7	K-12	K-14	E-4	E-6	C-3	B-6	N-16	J-17	2R-CENTER	2R-200E	2R-200S
HIATELLA SP.							25											
LAEVICARDIUM MORTONI	25							50						150				
LYONSIA HYALINA														25			25	
MACOMA TENTA	25	150	300	375	75	1325	350		1225	450	75	550			825	825	375	375
MULINIA LATERALIS					25										25	25		
MYSELLA PLANULATA						50												
MYTILIDAE		25	25				50		50						25			
NUCULA ANNULATA		25	800	1000	600	350			100	275	75			100	200	250	25	100
NUCULA SP.	50	25					25	50										
PANDORA GLACIALIS																	25	
PITAR MORRHUANA		50	75	25		25	25		100		25	75	50		125	25		25
TELLINA AGILIS	25			25				125				50	75			25		
TELLINIDAE														25				
YOLDIA LIMATULA		25		25		25			50	50	25		25		25	50		150
YOLDIA SP.										50		25				25		
PYCNOGONIDA																		
ANOPLODACTYLUS LENTUS	25																	
ARTHROPODA																		
CEPHALOCARDIA																		
HUTCHINSONIELLA MACRACANTHA		200			25	75	25					25	25		25		25	125
OSTRACODA	300	650	500	725	150	475	150	475	450	750	475	425	675	400	325	600	200	250
COPEPODA																		
HARPACTICOIDA														25				
CYCLOPOIDA													50					
MALACOSTRACA																		
AMEROCULODES SP.												25						
AMPELISCA ABDITA	475	225			25	100		700	150	25			125	325		50		50
AMPELISCA VADORUM		25						50										
AMPELISCA VERRILLI														100				
EDOTIA TRILOBA	25																	
ERICHTHONIUS BRASILIENSIS								50	100			25						

Abundance (No./m2) of Benthic Infauna (Retained on a 0.5 mm mesh seive) collected by a 0.04m2 Grab from Buzzards Bay - November 2000

	M-10	M-12	RN-CENTER	RN-100N	RN-200W	G-3	G-7	K-12	K-14	E-4	E-6	C-3	B-6	N-16	J-17	2R-CENTER	2R-200E	2R-200S
GAMMARUS SP.									75									25
HETEROMYSIS FORMOSA													25					
IDOTEA PHOSPHOREA																		25
IDUNELLA SP.												25						
JASSA MARMORATA															25			
LEPTOCHEIRUS PINGUIS	125											25	50	25				
LUCONACIA INCERTA												25					25	50
PAGURUS POLLICARIS														25				
PARAMETOPELLA CYPRIS									25									
PINNIXA SAYANA	75	25				50	200				100	50						
POLYONYX GIBBESI								25										
PHORONIDA																		
PHORONIS ARCHITECTA		25					25							50				
BRYOZOA																		
AEVERILLIA SP.								P										
BOWERBANKIA GRACILIS											P							
ECHINODERMATA																		
AMPHIOPLUS ABDITA	50													75		25	25	25
HEMICHORDATA																		
ENTEROPNEUSTA																		
SACCOGLOSSUS KOWALEWSKII				50			25				25		25			75		50
UROCHORDATA																		
BOSTRICHOBRANCHUS PILULARIS		50				175		25	25	25		75	125		25		25	75
TOTAL ABUNDANCE	12750	7075	7200	5325	4025	5650	4025	7700	7050	4400	6475	9050	4575	16725	5525	11800	6275	7125
NUMBER OF UNIQUE TAXA	44	40	28	26	21	30	23	52	40	26	34	36	39	48	28	32	34	42

Note: P indicates Taxa was present

Higher phylogenetic categories (e.g. family, genus) were not included in total number of discrete taxa when lower phylogenetic categories were present.

APPENDIX B

Table B-1. Abundance (number per m^2) of benthic infauna collected at Site 1.

TAXA	Stations G-3	G-7	E-4	E-6	C-3	B-6	Site total	% Total
MEDIOMASTUS AMBISETA	175	525	100	2100	300	275	3475	10.2%
OSTRACODA	475	150	750	475	425	675	2950	8.6%
CARAZZIELLA HOBSONAE	0	550	0	675	1475	75	2775	8.1%
MACOMA TENTA	1325	350	450	75	550	0	2750	8.0%
ARICIDEA (ACMIRA) CATHERINAE	50	350	75	375	1250	475	2575	7.5%
CYLICHNA ORYZA	500	75	700	425	475	150	2325	6.8%
NEMATODA	0	725	75	475	750	75	2100	6.1%
PRIONOSPIO (MINUSPIO) PERKINSII	750	150	50	150	575	100	1775	5.2%
CARINOMELLA LACTEA	0	0	500	0	700	250	1450	4.2%
NEPHTYS INCISA	225	250	225	250	200	275	1425	4.2%
NINOE NIGRIPES	100	150	125	250	300	325	1250	3.7%
MONTICELLINA DORSOBRANCHIALIS	0	0	25	150	575	25	775	2.3%
NUCULA ANNULATA	350	0	275	75	0	0	700	2.0%
OLIGOCHAETA	200	100	25	125	125	100	675	2.0%
SCOLETOMA SP.	75	75	200	50	100	150	650	1.9%
ACTEOCINA CANALICULATA	50	0	300	100	150	25	625	1.8%
MELINNA CRISTATA	125	25	100	25	225	75	575	1.7%
ASYCHIS ELONGATA	75	0	50	225	125	50	525	1.5%
CIRROPHORUS FURCATUS	150	75	0	0	75	200	500	1.5%
PINNIXA SAYANA	50	200	0	100	50	0	400	1.2%
BOSTRICHOBRANCHUS PILULARIS	175	0	25	0	75	125	400	1.2%
NINETY PERCENT BREAKPOINT								
SCOLELEPIS BOUSFIELDI	175	0	25	0	25	125	350	1.0%
DIPOLYDORA SOCIALIS	0	0	0	0	0	325	325	1.0%
AMPELISCA ABDITA	100	0	25	0	0	125	250	0.7%
PECTINARIA GOULDII	175	0	0	0	0	25	200	0.6%
PITAR MORRHUANA	25	25	0	25	75	50	200	0.6%
CREPIDULA SP.	0	0	0	25	75	50	150	0.4%
HUTCHINSONIELLA MACRACANTHA	75	25	0	0	25	25	150	0.4%
TURBONILLA ELEGANTULA	0	0	75	0	0	50	125	0.4%
TELLINA AGILIS	0	0	0	0	50	75	125	0.4%
YOLDIA LIMATULA	25	0	50	25	0	25	125	0.4%
EUCLYMENE COLLARIS	0	0	0	25	50	25	100	0.3%
PROTODORVILLEA GASPEENSIS	0	50	50	0	0	0	100	0.3%
CERIANTHEOPSIS AMERICANUS	0	25	0	25	25	0	75	0.2%
AMPHIPORUS BIOCULATUS	0	0	0	50	0	25	75	0.2%
ARABELLA IRICOLOR	75	0	0	0	0	0	75	0.2%
RICTAXIS PUNCTOSTRIATUS	25	0	25	0	25	0	75	0.2%
YOLDIA SP.	0	0	50	0	25	0	75	0.2%
LEPTOCHEIRUS PINGUIS	0	0	0	0	25	50	75	0.2%
SACCOGLOSSUS KOWALEWSKII	0	25	0	25	0	25	75	0.2%
DIOPATRA CUPREA	25	0	0	25	0	0	50	0.1%
GLYCERA SP. 1	0	0	0	50	0	0	50	0.1%
NOTOMASTUS LATERICEUS	25	0	0	0	0	25	50	0.1%
SPIOCHAETOPTERUS OCULATUS	0	0	0	25	25	0	50	0.1%
MYSELLA PLANULATA	50	0	0	0	0	0	50	0.1%
MYTILIDAE	0	50	0	0	0	0	50	0.1%
CYCLOPOIDA	0	0	0	0	0	50	50	0.1%
TURBELLARIA	0	0	0	0	0	25	25	0.1%
CEREBRATULUS SP.	0	0	0	0	0	25	25	0.1%
GLYCERA AMERICANA	0	0	25	0	0	0	25	0.1%
GLYCINDE SOLITARIA	0	0		25	0	0	25	0.1%
LEVINSENIA GRACILIS	0	0	25	0	0	0	25	0.1%
NEREIS GRAYI	25	0	0	0	0	0	25	0.1%
PHYLLODOCE ARENAE	0	0	0	25	0	0	25	0.1%
SABELLA MICROPHTHALMA	0	0	0	25	0	0	25	0.1%
FARGOA BARTSCHI	0	0	0	0	25	0	25	0.1%
HIATELLA SP.	0	25	0	0	0	0	25	0.1%
NUCULA SP.	0	25	0	0	0	0	25	0.1%
AMEROCULODES SP.	0	0	0	0	25	0	25	0.1%
ERICHTHONIUS BRASILIENSIS	0	0	0	0	25	0	25	0.1%
HETEROMYSIS FORMOSA	0	0	0	0	0	25	25	0.1%
IDUNELLA SP.	0	0	0	0	25	0	25	0.1%
LUCONACIA INCERTA	0	0	0	0	25	0	25	0.1%
PHORONIS ARCHITECTA	0	25	0	0	0	0	25	0.1%
HYDROZOA	0	0	0	1	1	1	3	0.0%
TUBULARIA SP.	1	0	0	1	0	1	3	0.0%
BOWERBANKIA GRACILIS	0	0	0	1	0	0	1	0.0%
Total abundance	5651	4025	4400	6478	9051	4577	34182	
Total number of unique taxa	30	23	26	34	36	39	67	

Table B-2. Abundance (number per m^2) of benthic infauna collected at Site 2.

	Stations							
TAXA	M-10	M-12	K-12	K-14	N-16	J-17	Site total	% Total
MEDIOMASTUS AMBISETA	2250	1325	600	150	3050	625	8000	14.1%
OLIGOCHAETA	700	275	425	0	3350	50	4800	8.4%
NEMATODA	975	550	750	25	1650	200	4150	7.3%
CARINOMELLA LACTEA	650	750	675	650	575	500	3800	6.7%
CARAZZIELLA HOBSONAE	2175	25	50	0	825	0	3075	5.4%
PRIONOSPIO (MINUSPIO) PERKINSII	250	150	75	1275	475	725	2950	5.2%
OSTRACODA	300	650	475	450	400	325	2600	4.6%
ARICIDEA (ACMIRA) CATHERINAE	1100	150	250	25	875	50	2450	4.3%
MACOMA TENTA	25	150	0	1225	0	825	2225	3.9%
CYLICHNA ORYZA	125	425	250	725	0	575	2100	3.7%
AMPELISCA ABDITA	475	225	700	150	325	0	1875	3.3%
NINOE NIGRIPES	375	325	400	25	400	125	1650	2.9%
MONTICELLINA DORSOBRANCHIALIS	625	0	275	75	600	0	1575	2.8%
CIRROPHORUS FURCATUS	575	0	75	0	750	25	1425	2.5%
SCOLETOMA SP.	325	200	300	100	350	50	1325	2.3%
NOTOMASTUS LATERICEUS	150	175	400	25	375	0	1125	2.0%
SCOLELEPIS BOUSFIELDI	50	125	275	25	50	275	800	1.4%
NEPHTYS INCISA	25	200	75	200	100	150	750	1.3%
GLYCINDE SOLITARIA	275	50	125	50	125	0	625	1.1%
MELINNA CRISTATA	100	100	175	75	125	25	600	1.1%
ASYCHIS ELONGATA	25	0	50	200	75	200	550	1.0%
ACTEOCINA CANALICULATA	0	225	25	150	0	150	550	1.0%
MALDANIDAE	25	25	50	75	300	0	475	0.8%
NUCULA ANNULATA	0	25	0	100	100	200	425	0.7%
EUCLYMENE COLLARIS	100	0	0	0	275	0	375	0.7%
RICTAXIS PUNCTOSTRIATUS	0	125	50	125	25	50	375	0.7%
TURBONILLA ELEGANTULA	0	0	0	325	25	0	350	0.6%
NINETY PERCENT BREAKPOINT								
GLYCERA AMERICANA	100	25	75	0	100	0	300	0.5%
EXOGONE DISPAR	75	25	100	0	75	0	275	0.5%
SPHAEROSYLLIS LONGICAUDA	0	75	50	25	125	0	275	0.5%
PITAR MORRHUANA	0	50	0	100	0	125	275	0.5%
LAEVICARDIUM MORTONI	25	0	50	0	150	0	225	0.4%
HUTCHINSONIELLA MACRACANTHA	0	200	0	0	0	25	225	0.4%
GLYCERA SP.1	0	0	0	25	175	0	200	0.4%
PECTINARIA GOULDII	0	25	50	75	25	0	175	0.3%
EUCRANTIA VILLOSA	50	0	0	0	100	0	150	0.3%
TELLINA AGILIS	25	0	125	0	0	0	150	0.3%
ERICHTHONIUS BRASILIENSIS	0	0	50	100	0	0	150	0.3%
LEPTOCHEIRUS PINGUIS	125	0	0	0	25	0	150	0.3%
ANCISTROSYLLIS HARTMANAE	0	0	0	0	125	0	125	0.2%
SABELLARIA VULGARIS	125	0	0	0	0	0	125	0.2%
NUCULA SP.	50	25	50	0	0	0	125	0.2%
AMPHIOPLUS ABDITA	50	0	0	0	75	0	125	0.2%
BOSTRICHOBRANCHUS PILULARIS	0	50	25	25	0	25	125	0.2%
TURBELLARIA	0	0	0	75	25	0	100	0.2%
CIRRATULIDAE	0	50	0	0	0	50	100	0.2%
PHYLLODOCE ARENAE	25	25	25	0	25	0	100	0.2%
SPIONIDAE	25	0	25	50	0	0	100	0.2%
MYTILIDAE	0	25	0	50	0	25	100	0.2%
YOLDIA LIMATULA	0	25	0	50	0	25	100	0.2%
AMPELISCA VERRILLI	0	0	0	0	100	0	100	0.2%
PINNIXA SAYANA	75	25	0	0	0	0	100	0.2%
EUMIDA SANGUINEA	50	0	25	0	0	0	75	0.1%
GONIADIDAE	0	0	0	0	75	0	75	0.1%
PROTODORVILLEA GASPEENSIS	0	0	25	25	25	0	75	0.1%
SPHAEROSYLLIS TAYLORI	50	0	0	25	0	0	75	0.1%
SPIOCHAETOPTERUS OCULATUS	25	25	25	0	0	0	75	0.1%
AMPELISCA VADORUM	0	25	50	0	0	0	75	0.1%
GAMMARUS SP.	0		0	75	0	0	75	0.1%
PHORONIS ARCHITECTA	0	25	0	0	50	0	75	0.1%
ARABELLA IRICOLOR	25	0	0	0	25	0	50	0.1%
DIOPATRA CUPREA	25	0	25	0	0	0	50	0.1%
GYPTIS VITTATA	0	50	0	0	0	0	50	0.1%
SABELLA MICROPHTHALMA	0	0	50	0	0	0	50	0.1%
THARYX ACUTUS	25	0	0	0	25	0	50	0.1%
CREPIDULA SP.	0	0	25	25	0	0	50	0.1%
MITRELLA LUNATA	0	0	50	0	0	0	50	0.1%
TURBONILLA SP.	25	0	0	0	0	25	50	0.1%
CERIANTHEOPSIS AMERICANUS	0	25	0	0	0	0	25	0.0%

(continued)

Table B-2, continued.

TAXA	M-10	M-12	K-12	K-14	N-16	J-17	Site total	% Total
	Stations							
NEMERTEA	0	25	0	0	0	0	25	0.0%
AMPHIPORUS BIOCULATUS	0	25	0	0	0	0	25	0.0%
ANOBOTHRUS GRACILIS	0	0	25	0	0	0	25	0.0%
BRANIA WELLFLEETENSIS	0	0	0	0	25	0	25	0.0%
CABIRA INCERTA	0	0	0	0	25	0	25	0.0%
CAPITELLIDAE	0	0	0	0	25	0	25	0.0%
CLYMENELLA TORQUATA	25	0	0	0	0	0	25	0.0%
DIPOLYDORA SOCIALIS	0	0	25	0	0	0	25	0.0%
EUNICIDAE	0	0	25	0	0	0	25	0.0%
HETEROMASTUS FILIFORMIS	0	0	25	0	0	0	25	0.0%
LEPIDONOTUS SUBLEVIS	0	0	0	25	0	0	25	0.0%
MICRONEPHTYS MINUTA	0	0	25	0	0	0	25	0.0%
PHOLOE MINUTA	0	0	25	0	0	0	25	0.0%
PISTA CRISTATA	0	0	0	0	25	0	25	0.0%
POTAMILLA RENIFORMIS	0	0	25	0	0	0	25	0.0%
TEREBELLIDAE	0	0	25	0	0	0	25	0.0%
TYPOSYLLIS ALTERNATA	25	0	0	0	0	0	25	0.0%
GASTROPODA	0	0	0	0	0	25	25	0.0%
ILYANASSA TRIVITTATA	0	0	0	25	0	0	25	0.0%
KURTZIELLA CERINA	0	0	0	25	0	0	25	0.0%
TURBONILLA SUMNERI	0	0	25	0	0	0	25	0.0%
ANADARA TRANSVERSA	0	0	25	0	0	0	25	0.0%
CERASTODERMA PINNULATUM	0	0	0	0	0	25	25	0.0%
LYONSIA HYALINA	0	0	0	0	25	0	25	0.0%
MULINIA LATERALIS	0	0	0	0	0	25	25	0.0%
TELLINIDAE	0	0	0	0	25	0	25	0.0%
ANOPLODACTYLUS LENTUS	25	0	0	0	0	0	25	0.0%
HARPACTICOIDA	0	0	0	0	25	0	25	0.0%
EDOTIA TRILOBA	25	0	0	0	0	0	25	0.0%
JASSA MARMORATA	0	0	0	0	0	25	25	0.0%
PAGURUS POLLICARIS	0	0	0	0	25	0	25	0.0%
PARAMETOPELLA CYPRIS	0	0	0	25	0	0	25	0.0%
POLYONYX GIBBESI	0	0	25	0	0	0	25	0.0%
TUBULARIA SP.	1	0	1	1	0	0	3	0.0%
HYDROZOA	0	1	1	0	0	0	2	0.0%
CAMPANULARIA GIGANTEA	0	0	0	0	1	0	1	0.0%
PODOCORYNE CARNEA	0	0	0	0	1	0	1	0.0%
AEVERILLIA SP.	0	0	1	0	0	0	1	0.0%
Total abundance	12751	7076	7703	7051	16727	5525	56833	
Total number of taxa	44	40	52	40	48	28		

Table B-3. Abundance (number per m^2) of benthic infauna collected at Ref-2.

TAXA	2R-CENTER	2R-200E	2R-200S	Site total	% Total
		Stations			
PRIONOSPIO (MINUSPIO) PERKINSII	4000	950	1700	6650	26.4%
MEDIOMASTUS AMBISETA	2000	600	1250	3850	15.3%
CARINOMELLA LACTEA	1575	650	675	2900	11.5%
MACOMA TENTA	825	375	375	1575	6.2%
NINOE NIGRIPES	375	625	500	1500	6.0%
NEMATODA	75	1050	25	1150	4.6%
OSTRACODA	600	200	250	1050	4.2%
CYLICHNA ORYZA	625	75	250	950	3.8%
ARICIDEA (ACMIRA) CATHERINAE	75	350	350	775	3.1%
OLIGOCHAETA	0	500	50	550	2.2%
NEPHTYS INCISA	150	50	200	400	1.6%
NUCULA ANNULATA	250	25	100	375	1.5%
RICTAXIS PUNCTOSTRIATUS	250	75	25	350	1.4%
ACTEOCINA CANALICULATA	75	125	125	325	1.3%
POLYDORA CORNUTA	50	25	150	225	0.9%
NINETY PERCENT BREAKPOINT					
TURBELLARIA	175	0	25	200	0.8%
YOLDIA LIMATULA	50	0	150	200	0.8%
HUTCHINSONIELLA MACRACANTHA	0	25	125	150	0.6%
DIPOLYDORA SOCIALIS	0	100	25	125	0.5%
CREPIDULA SP.	25	25	75	125	0.5%
SACCOGLOSSUS KOWALEWSKII	75	0	50	125	0.5%
SCOLELEPIS BOUSFIELDI	75	25	0	100	0.4%
ANADARA TRANSVERSA	50	25	25	100	0.4%
AMPELISCA ABDITA	50	0	50	100	0.4%
BOSTRICHOBRANCHUS PILULARIS	0	25	75	100	0.4%
CIRRATULIDAE	25	25	25	75	0.3%
EUCRANTIA VILLOSA	25	25	25	75	0.3%
EUNICIDAE	50	0	25	75	0.3%
LUCONACIA INCERTA	0	25	50	75	0.3%
AMPHIOPLUS ABDITA	25	25	25	75	0.3%
ARABELLA IRICOLOR	0	0	50	50	0.2%
CARAZZIELLA HOBSONAE	50	0	0	50	0.2%
MELINNA CRISTATA	0	50	0	50	0.2%
MONTICELLINA DORSOBRANCHIALIS	0	25	25	50	0.2%
NOTOMASTUS LATERICEUS	25	0	25	50	0.2%
PRIONOSPIO HETEROBRANCHIA	0	0	50	50	0.2%
MITRELLA LUNATA	0	50	0	50	0.2%
PITAR MORRHUANA	25	0	25	50	0.2%
NEMERTEA	0	0	25	25	0.1%
AMPHIPORUS BIOCULATUS	0	0	25	25	0.1%
CEREBRATULUS SP.	25	0	0	25	0.1%
CIRROPHORUS FURCATUS	0	0	25	25	0.1%
EUCLYMENE COLLARIS	0	25	0	25	0.1%
EUMIDA SANGUINEA	0	0	25	25	0.1%
GLYCERA AMERICANA	0	25	0	25	0.1%
PECTINARIA GOULDII	0	25	0	25	0.1%
SPIOCHAETOPTERUS OCULATUS	0	25	0	25	0.1%
THARYX ACUTUS	0	0	25	25	0.1%
TECTONATICA PUSILLA	25	0	0	25	0.1%
TURBONILLA ELEGANTULA	25	0	0	25	0.1%
LYONSIA HYALINA	0	25	0	25	0.1%
MULINIA LATERALIS	25	0	0	25	0.1%
PANDORA GLACIALIS	0	25	0	25	0.1%
TELLINA AGILIS	25	0	0	25	0.1%
YOLDIA SP.	25	0	0	25	0.1%
GAMMARUS SP.	0	0	25	25	0.1%
IDOTEA PHOSPHOREA	0	0	25	25	0.1%
PORIFERA	0	1	0	1	0.0%
HYDROZOA	0	0	1	1	0.0%
TUBULARIA SP.	0	0	1	1	0.0%
Total abundance	11800	6276	7127	25203	
Total number of unique taxa	32	34	42	60	

Table B-4. Abundance (number per m^2) of benthic infauna collected at Ref-New.

TAXA	Stations RN-CENTER	RN-100N	RN-200W	Site total	% Total
ARICIDEA (ACMIRA) CATHERINAE	1325	1175	525	3025	18.3%
MEDIOMASTUS AMBISETA	1600	375	600	2575	15.6%
NUCULA ANNULATA	800	1000	600	2400	14.5%
OSTRACODA	500	725	150	1375	8.3%
CYLICHNA ORYZA	575	350	350	1275	7.7%
NEPHTYS INCISA	375	200	275	850	5.1%
MACOMA TENTA	300	375	75	750	4.5%
NEMATODA	50	0	650	700	4.2%
PRIONOSPIO (MINUSPIO) PERKINSII	100	75	250	425	2.6%
CARINOMELLA LACTEA	375	0	25	400	2.4%
CIRROPHORUS FURCATUS	200	0	175	375	2.3%
NINOE NIGRIPES	200	75	50	325	2.0%
ASYCHIS ELONGATA	75	125	50	250	1.5%
NINETY PERCENT BREAKPOINT					
LEVINSENIA GRACILIS	200	50	0	250	1.5%
MELINNA CRISTATA	100	50	75	225	1.4%
OLIGOCHAETA	25	100	25	150	0.9%
MONTICELLINA DORSOBRANCHIALIS	25	100	0	125	0.8%
TURBONILLA ELEGANTULA	0	125	0	125	0.8%
EUCLYMENE COLLARIS	0	100	0	100	0.6%
SCOLELEPIS BOUSFIELDI	25	50	25	100	0.6%
PITAR MORRHUANA	75	25	0	100	0.6%
CARAZZIELLA HOBSONAE	0	50	25	75	0.5%
RICTAXIS PUNCTOSTRIATUS	75	0	0	75	0.5%
THARYX ACUTUS	50	0	0	50	0.3%
ACTEOCINA CANALICULATA	25	25	0	50	0.3%
SACCOGLOSSUS KOWALEWSKII	0	50	0	50	0.3%
CERIANTHEOPSIS AMERICANUS	0	0	25	25	0.2%
MICRONEPHTYS MINUTA	25	0	0	25	0.2%
PECTINARIA GOULDII	0	25	0	25	0.2%
PHOLOE MINUTA	0	25	0	25	0.2%
SABELLA MICROPHTHALMA	25	0	0	25	0.2%
CREPIDULA SP.	25	0	0	25	0.2%
TURBONILLA SP.	0	25	0	25	0.2%
TURBONILLA SUMNERI	25	0	0	25	0.2%
MULINIA LATERALIS	0	0	25	25	0.2%
MYTILIDAE	25	0	0	25	0.2%
TELLINA AGILIS	0	25	0	25	0.2%
YOLDIA LIMATULA	0	25	0	25	0.2%
HUTCHINSONIELLA MACRACANTHA	0	0	25	25	0.2%
AMPELISCA ABDITA	0	0	25	25	0.2%
TUBULARIA SP.	1	0	0	1	0.0%
Total abundance	7201	5325	4025	16551	
Total number of unique taxa	28	26	21	41	