2000 outfall benthic monitoring report

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2000 Outfall Benthic Monitoring Report

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Executive Summary

The Outfall Benthic Surveys began in 1992 as part of the Benthic (Sea-Floor) Monitoring component of the MWRA Harbor and Outfall Monitoring (HOM) program. This study is designed to address three main concerns relative to the response of the benthic community to MWRA's relocation of the effluent discharge into Massachusetts Bay: eutrophication, contaminants, and particulate inputs. The Outfall Benthic Surveys provide quantitative measurements of benthic community structure and patterns of contaminant concentrations within sediments of Massachusetts and Cape Cod Bays. The pre-discharge monitoring has provided an extensive understanding of the baseline conditions and changes through time. After effluent discharge into the Bay begins, the focus of the program will change from the collection of baseline data to an evaluation of the effects of the discharge on the Bay ecosystems. Outfall surveys conducted after September 2000 will provide the data required for a quantitative assessment of the effects of discharged effluent on sediment chemistry and benthic infauna communities. The objectives of the monitoring program following the initiation of effluent discharge into the Bay are (1) to monitor versus NPDES permit requirements, (2) to test whether or not the discharge-related impacts are within the limits predicted by the SEIS, and (3) to determine if changes in the system exceed Contingency Plan thresholds (MWRA 2001).

The August 2000 outfall benthic survey was conducted before effluent discharge began at the new outfall and ended the collection of baseline data from each of the benthic monitoring program's four components: sediment profile images (SPI), geochemical properties, contaminants, and sewage tracers in sediment, benthic infaunal community, and hardbottom community. Sediment profile images (SPI) are collected to monitor the general condition of the softbottom benthic habitats in western Massachusetts Bay. In 2000, SPI were collected from 23 western Bay stations. Sediment geochemistry studies, conducted via the collection of sediment grab samples, consist of grain-size analysis, total organic carbon (TOC) content determination, and periodically contaminant concentration analyses. The presence of a sewage tracer, *Clostridium perfringens*, is quantified during these studies. In addition, samples at four stations for the contaminant special study were collected in August and November of 2000. The presence of a sewage tracer, *Clostridium perfringens*, was also quantified during these studies. Infaunal communities in Massachusetts Bay and Cape Cod Bay are monitored via the collection of samples from 20 nearfield and 11 farfield stations. All stations were sampled in 2000. Because of the preponderance of hard substrates in the vicinity of the outfall, semi-quantitative studies of the epifaunal communities associated with them are conducted yearly. In 2000, a remotely operated vehicle was used to collect still photographs and videotapes from all hardbottom stations except station T2-5. This station was not surveyed in 2000 because of its proximity to a work barge and inclusion in a no-anchor zone. Summaries of the 2000 results from the components follow.

Sediment Profile Images

Sediment surfaces at the nearfield stations continue to be dominated by biogenic structures and organism activity in 2000. Most stations with fine sediments had high densities of polychaete tubes, at least one tube per square centimeter, based on tubes that were within one centimeter of the prism faceplate. Most of the cobble and pebble size sediments were covered with a thin layer of fine sediments and tubes, along with organisms such as sponges or hydroids. A similar sediment drape was observed at many ROV transects. However, the draped sediments seen in the SPI images appeared to be thinner in 2000 relative to 1999. The presence of bedforms increased in 2000 relative to 1999 when there was little evidence of bedforms at sandy stations. Both the increase in bedforms and decrease in sediment drape point to an increased bottom energy climate in 2000 relative to 1999. Overall, the sedimentary environment did not change much in 2000. Sediments at many stations continue to be either heterogeneous ranging from silts-clays to cobbles, or homogeneous sands or silt-clays.

The depth of the apparent color RPD layer continued to reflect the dominance of biological processes at many of the stations in 2000. The averaged apparent color RPD layer depth ranged from 1.7 cm at Station NF19 to 3.8 cm at Station NF07. The grand average RPD layer depth for all stations in 2000 was 2.6 cm (0.62 SD, 0.13 SE) and was statistically the same as in 1999, which was 2.5 cm. Overall, the analysis of benthic community and SPI data point to a lessening of physical stress at the nearfield stations in 2000 relative to the last few years (Kropp *et al*., 1999, 2000).

While the distribution of sediment textures at benthic habitats in the nearfield study area appeared to be dominated by physical processes, surface features were dominated by biogenic activity based on the 2000 SPI survey. Even station NF02 that appeared completely dominated by physical processes had many small tubes on the surface of pebbles. Feeding mounds or tubes were the dominant surface biogenic structures and occurred at all stations. Subsurface biogenic structures and organisms were also common and widely distributed. The predominance of biological activity at most stations, 21 of 23 showing some form of biogenic activity, was indicative of a well developed fauna that was characterized as being intermediate to advanced in successional stage (Stage II to III). The slight increase in the average organism sediment index (OSI) also indicated that biological processes continued to be important. Overall, it appeared that biological processes continued to be prominent in 2000 relative to the last few years.

The sampling design, with 23 stations in the nearfield area, provided more than sufficient statistical power for a t-test with a 95% confidence interval and 90% power to detect a 50% change in mean RPD layer depth over the entire study area from one year to the next. Based on the variation in the 2000 data, five stations would yield a test with a 95% confidence interval and 90% power. With eight stations, power would increase to 99%.

Sediment Geochemistry

Generally, the spatial distribution and temporal response of grain-size and total organic carbon (TOC) in 2000 were not substantially different from previous years (1992–1999). However, *Clostridium perfringens* abundances decreased in 1998–2000 for stations located closer to the Harbor (20-km of Deer Island Light), suggesting that the documented reductions in effluent solids loading during the 1990s (Werme and Hunt 2001) also reflect a reduction in *Clostridium* spore loads that is being seen in nearby sediments.

The abundance of *Clostridium perfringens* decreased in 1998–2000 from earlier years and appeared to decrease with distance from Boston Harbor. Yearly mean values of *Clostridium perfringens* (normalized to percent fines) for near-in stations (< 20 km) showed a decrease in abundance in 1998–2000 relative to earlier years. In contrast, stations further away from Deer Island Point (> 20 km) were on average relatively constant from 1992–2000. The constancy in results within distance classifications after normalization to fine grained sediments supports expectations (Parmenter and Bothner 1993) that *Clostridium perfringens* spores are preferentially attached to fine grained particles and are transported with fine sediments.

Further, trends in another effluent marker, total LAB, strengthen the observation that sediments in Western Massachusetts Bay reflect the cleaner effluent that is now being discharged. Concentrations of total LAB measured at near-in stations (<20 km) decreased markedly (60 to 80%) in 1995 compared to previous years; with sustained lower concentrations observed in 1999 and 2000. While primary treatment came on-line in 1995, there is no clear evidence that it resulted in the marked decrease in total LAB concentrations. Rather, the largest decrease in LAB loadings to the Harbor occurred in the late 1980s and early 1990s when Proctor and Gambel cleaned up their industrial discharge to the south system and closed their plant (personal communication, Ken Keay, MWRA 2002). The observed decrease in 1995 may therefore be attributed to a combination of removal of discharge from the Harbor (*i.e*., Proctor and Gambel discharge), facility improvements, and natural attenuation.

Sediment Contaminants

The principal component analysis (PCA), the *Clostridium perfringens* regional analysis, and the correlation analyses identify multiple regions in physical and chemical terms. In the nearfield, with Massachusetts Bay, there are a series of stations with heterogeneous sediments in relatively close proximity to the historic leading source of contaminants (*i.e.*, Boston Harbor). Nearfield stations are generally equidistant from the source. The major factors influencing the concentration of contaminants and sewage tracers are primarily related to grain size factors suggestive of different sediment depositional environments. The nearfield PCA showed that the primary factors responsible for the variance in the data were sand content and metals (especially Cr, Zn, Pb, Cu and Ni).

In contrast, the sediments at farfield stations were generally less physically heterogeneous but were substantially more spatially dispersed. The *Clostridium perfringens* and total LAB regional analysis showed that the proximity to the historic source of sewage contaminants influenced the concentration of *Clostridium perfringens* and total LAB.

Within each of these distinct regions, the spatial distribution of contaminant parameters in 2000 was not substantially different from previous years (1992-1999). Similarly, with the exception of total LAB (and *Clostridium perfringens*, above), the temporal response of contaminants was not substantially different over time.

While none would be expected, results from the October 2000 Nearfield Contaminant Special Study (NCSS) did not show a rapid increase in sediment contaminants following startup of the new diffuser which came online in September 2000.

Baseline mean values for organic and metal contaminants in the nearfield were well below the MWRA thresholds. Further, the significant increase in values are well within the range of detection and MWRA thresholds are at least 2.5 times higher than the level of significant increase, suggesting that the ability to detect changes in contaminant concentrations prior to thresholds is high.

Infaunal Communities

The nine year period during which the nearfield has been sampled as part of the MWRA monitoring program can be considered in two contrasting periods, an early, five-year period of an infaunal community in substantial flux and a later, four-year period of relative infaunal community consistency. Mean infaunal abundance for the years 1992 through 1996 was relatively low and variable (see text box), whereas the period 1997 through 2000 was characterized by relatively high and consistent infaunal abundance. The number of species per sample and log-series alpha diversity shows patterns somewhat similar to that of abundance, albeit with some differences. Species numbers and log-series alpha diversity reached a peak in 1997 and have shown a gradual, but consistent decline since. Nonetheless, separating values for those metrics by the two time periods mentioned above, both show higher, more consistent means for the latter four years than for the earlier five years. The more traditional diversity metrics, Shannon's *H'* and Pielou's *J'*, do not show the pattern apparent in the other metrics.

The character of numerical dominance in the nearfield infaunal community changed considerably from 1992–1996 to 1997–2000. During the years 1992 and 1994, the spionid polychaete *Spio limicola* was the most abundant species in the nearfield, accounting for 22% and 24% of the infaunal abundance found in those years, respectively. In 1993, the year after the large 1992 storm, the polychaetes *Aricidea* *catherinae* and *Mediomastus californiensis* were the most numerous taxa. In 1995, the relative abundance of *Spio limicola* decreased and its role as the most abundant taxon was taken by the spionid *Prionospio steenstrupi*. During this early period, the numerical dominance of *Prionospio steenstrupi*, although clearly established by 1995–1996, was not overwhelming. In the early years of the monitoring program, the alternating predominance of *Spio limicola* and another spionid, *Dipolydora socialis*, in 1992–1995 indicated that the prevalence of one species or the other during alternate years might be related to stochastic events related to the timing of larval settlement. However, within the context of the nine-year data set, there is not a pattern of alternating predominance, but rather one of a very strongly predominant species, *Prionospio steenstrupi*, that increased its numerical influence on the nearfield community structure in the years 1995–1999, concomitant with substantially decreased abundances of *Spio limicola* and *Dipolydora socialis*. The relative contribution of *Prionospio steenstrupi* to total infaunal abundance during this later period has been as high as 39%. The general pattern of a shift in numerical dominance was also seen in the farfield fauna indicating that the phenomenon was very likely Bay-wide, not just restricted to the nearfield and probably not simply a by-product of the 1992 storm that affected primarily the nearfield community.

Despite the small-scale variability in species numbers evident during the nine years of the study, larger-scale (Bay-wide) variability in species richness has been small. The mean number of species found in the Bay system per year during the nine years of the program was 254 (standard deviation = 21). There has been little year-to-year variation around this mean value, as indicated by the low coefficient of variation value of about 8%. The total species pool present in the Bay system at this point in the study is estimated to be 434 species, including a core group of 140 species present in every year of the study to date. This pattern of inherent large-scale consistency in species richness despite considerable small-scale variability and the substantial year-to year change is similar to that reported for widely disparate taxa (rodent and bird species, plant families) and time scales (tens to thousands of years).

Station clusters from the 1992 to 2000 years multivariate analysis exhibited patterns related to both strong and weak within-station similarity through time. Strong within-station similarity through time was exhibited by stations FF10 and NF05, which formed exclusive groups. A third station group was near exclusive for station NF02, with one occurrence of NF24 for 1994. Overall, these three stations (FF10, NF05, NF02) tended to be physically dominated through time with heterogeneous sediments. The heterogeneous sediment stations FF12 and FF13 comprised another group that included all but two year/station combinations. Weak within-station similarity was exhibited by stations FF10 and NF07 that were members of four station groups over the nine year period. Temporally, more of the station groups split between 1994 and 1995 than any other two consecutive years. Three groups were composed only of stations sampled prior to 1995. Five groups were comprised only of stations sampled after 1994, except NF18 in 1994 that was part of one of these five groups. Six additional station groups all contained multi-year station occurrences. The strongest temporal signal in the data set was in one group of stations, which contained about half of the stations sampled in 1992 and a quarter of the stations in 1994, but that also included one 1993 station (NF14). These stations were primarily those with finer sediments.

The primary pattern in the farfield station clusters from the combined 1992 to 2000 analysis was related to the strong within-station similarity through time and secondarily to temporal trends. At the five group level farfield stations separated into two distinct clusters. One cluster, which was composed of four subgroups, tracked temporal changes at the deepest farfield stations FF04, FF05, FF11, and FF14, and station FF01 that was only sampled in 1992 and 1993. The other cluster, which consisted of four station groups, was characterized by high within-station similarity. Several groups were all exclusive station groups. The Cape Cod Bay stations FF06 and FF07 comprised one group and stations FF01A, FF09 and FF10 being III, and near Boston Harbor stations FF12 and FF13 comprised another. Overall, the 1992 to 1999 farfield infaunal data was dominated primarily by both strong spatial differences between stations and secondarily by temporal trends. Temporal trends at the deepest stations (FF04, FF05, FF11, and

FF14) were more pronounced than spatial differences between these same stations. The reverse was the case at shallower stations located to the north (FF01A and FF09) and in Cape Cod Bay (FF06 and FF07).

Overall, the 1992 to 2000 infaunal community was not dominated by any strong trend. The dendrogram produced by the cluster analysis was heavily concatenated or chained (the tendency of a group to join the dendrogram at the end) and indicated that within group station affinities were stronger than between groups. Thus the primary feature structuring the 1992 to 2000 infauna was the within station similarity through time. Temporal trends were best represented by the pre and post 1994/1995 collections. At the 14-group level 17 of the 23 stations had the majority of the year/station occurrences within a single cluster group.

Hardbottom Communities

The pattern of benthic community structure in the hardbottom areas was remarkably consistent during the 1996–2000 time period. The dendrograms defined by hierarchical classification analysis were remarkably similar among the four years. Good examples of this can be seen at the northern reference sites (T7 and T9), the southernmost reference sites (T8), and the top of the drumlin north of the outfall (T1-3, T1-4, T2-2, and T2-3). Frequently instances of waypoints differing in their cluster designation among the years appeared to reflect slight lateral shifts in relation to drumlin topography (Table 6-6). This was quite noticeable at T1-5 where in 1996 and 1999 the community was dominated by coralline algae (Cluster 1) and in 1997, 1998, and 2000 it was not (Cluster 3). A close examination of the map reveals that the areas surveyed at this site in 1996 and 1999 were nearer to the top of the drumlin. Another example of this can be seen at T2-1 where the community surveyed in 1998 (Cluster 3) differed from that found in the other four years (Cluster 2). The area surveyed at this site in 1998 was located slightly down the flank of the drumlin and was not dominated by algae. The remaining instances of differences in cluster group designation among years appeared to be related to the generally patchy nature of the hardbottom habitats.

Communities dominated by upright algae were found on the tops of drumlins on either side of the diffuser (T1-1, T2-2, T2-3, T2-4 and T4/6-4) and at all three of the northern reference sites (T7-1, T7-2 and T9-1). In contrast, coralline algae dominated the benthic communities on top of a drumlin located northwest of the diffuser (T1-2, T1-3 and T1-4), at 2 of the southwestern reference sites (T8-1 and T8-2), and at some of the drumlin flank sites. Two of the flank sites located just south of the diffuser (T4-3 and T6-1) had exceptionally low abundances of coralline algae and were relatively depauperate when compared to the other sites. The diffuser heads that were surveyed were colonized by *Metridium senile* and *Asterias vulgaris* (T2-5 and Diffuser #44). Some of the outlier areas represented the most extreme habitats that were surveyed, flat sand and cobble pavement at T4-1 (in 1998 and 1999) and very large boulders with heavy sediment drape at T10-1. These patterns also generally agreed with the results obtained in 1995. No attempt at a direct community analysis comparison with the 1995 data was made, because of the limited number and non-random collection of the 35-mm images taken during that year.

The identification of several voucher specimens clarified some of the taxonomic difficulties typically associated with “remote” data collection. Significantly, the taxon previously called *Lithothamnion* spp. was found to consist of at least five coralline algal species, none of which can be identified solely by studying photographs or videotape. Therefore, this taxon has been renamed “coralline algae” and all pink encrusting coralline species treated as one. Also, a red filamentous alga that was previously known as *Asparagopsis hamifera* was reidentified as *Ptilota serrata*.

1. INTRODUCTION

The Outfall Benthic Surveys began in 1992 as part of the Benthic (Sea-Floor) Monitoring component of the MWRA Harbor and Outfall Monitoring (HOM) program. This study is designed to address three main concerns relative to the response of the benthic community to MWRA's relocation of the effluent discharge into Massachusetts Bay: eutrophication, contaminants, and particulate inputs. The Outfall Benthic Surveys provide quantitative measurements of benthic community structure and patterns of contaminant concentrations within sediments of Massachusetts and Cape Cod Bays. The pre-discharge monitoring has provided an extensive understanding of the baseline conditions and changes through time. Outfall surveys conducted after September 2000 will provide the data required for a quantitative assessment of the effects of discharged effluent on sediment chemistry and benthic infauna communities. The objectives of the monitoring program following the initiation of effluent discharge into the Bay are (1) to monitor versus NPDES permit requirements, (2) to test whether or not the discharge-related impacts are within the limits predicted by the SEIS, and (3) to determine if changes in the system exceed Contingency Plan thresholds (MWRA 2001).

The August 2000 outfall benthic survey was conducted just before effluent discharge began at the new outfall and ended the collection of baseline data from each of the benthic monitoring program's four components: sediment profile images (SPI), geochemical properties, contaminants, and sewage tracers in sediment, benthic infaunal community, and hardbottom community. The results and analyses of the sediment profile images collected from 23 western Bay stations are presented in Section 3. Sediment geochemistry studies, conducted via the collection of sediment grab samples, consist of grain-size analysis, total organic carbon (TOC) content determination, and periodically contaminant concentration analyses. Contaminant sampling and analysis as part of MWRA's baseline monitoring occurred annually from 1992 through 1995. In May 1996, the Outfall Monitoring Task Force determined the sediment contaminant baseline was adequate, and that analyses could stop until discharge resumed. At the time, outfall startup was expected to occur in 1997 or 1998. Given the delayed outfall startup, MWRA decided to supplement the baseline by collecting contaminant samples at all 31 stations in 1999 and expanding on the contaminant special study in August 2000, sampling at 8 nearfield stations instead of the 4 normally occupied by that study. The presence of a sewage tracer, *Clostridium perfringens*, was also quantified during these studies. These studies are presented in Section 4. Infaunal communities in Massachusetts Bay and Cape Cod Bay are monitored via the collection of samples from 20 nearfield and 11 farfield stations. All stations were visited in 2000. Analyses of the infaunal communities are described in Section 5 and include an evaluation of infaunal communities in relation to the suite of sediment geochemical parameters measured. Because of the preponderance of hard substrates in the vicinity of the outfall, semi-quantitative studies of the epifaunal communities associated with them are conducted yearly. In 2000, a remotely operated vehicle was used to collect still photographs and videotapes from all hardbottom stations except station T2-5, which was occupied by a work barge during the survey. Analyses of the hardbottom survey data constitute Section 6. This report also includes a programmatic evaluation of each of the components. This evaluation is presented in Section 7.

The raw data for all of these studies are available from MWRA.

2. FIELD OPERATIONS

By Jeanine D. Boyle

2.1 Sampling Design

2.1.1 Softbottom

Sediment Samples—The nearfield benthic surveys, conducted annually in August, are designed to provide spatial coverage and local detail of faunal communities inhabiting depositional environments within about 8 km of the diffuser. Samples for sediment chemistry and benthic infauna were collected at 20 nearfield stations (Figure 2-1). The target locations for the nearfield stations are listed in the CW/QAPP (Kropp and Boyle 2001). The actual locations of each grab sample collected are listed in Appendix A-1.

Farfield benthic surveys, also conducted annually in August each year, are designed to contribute reference and early-warning data on softbottom habitats in Massachusetts and Cape Cod Bays. Grab samples were collected at 11 stations in Massachusetts and Cape Cod Bays (Figure 2-2) for infaunal and chemical analyses. The target locations for the farfield stations are listed in the CW/QAPP (Kropp and Boyle 2001). Sampling in the Stellwagon Bank National Marine Sanctuary (Stations FF04 and FF05) was conducted under sampling permit SBNMS-06-98. The actual locations of each grab sample collected are listed in Appendix A-1.

The Nearfield Contaminant Special Study Surveys are designed to examine the possible short-term impacts of the new outfall discharge on sedimentary contaminant concentrations and their interrelationships with possible sedimentary organic carbon changes in depositional environments near the effluent outfall. Contaminant Special Study surveys are conducted three times per year (February, August, and October) now that the outfall is operational. The Nearfield Contaminant Special Study stations include; NF08, NF22, NF24, and FF10. Criteria used to select these four locations were:

- Historically, stations (except FF10) were comprised of fine grained material (>50% sand/silt);
- Stations were in relatively stable areas (except for FF10, grain size composition >50% sand/silt over the period monitored);
- Stations (except FF10) had high total organic carbon (TOC) content, relative to other locations nearby (at least 1% TOC);
- Stations were within the zone of increased particulate organic carbon deposition predicted by the Bay Eutrophication Model (BEM, Hydroqual and Normandeau, 1995); and
- Selection of these stations complements and expands on stations (NF12, NF17) periodically sampled by the USGS.

Stations FF10, NF08, and NF24 lie on a line extending to the northwest from the west end of the diffuser and along with NF12, separately sampled by the USGS, provide a spatial gradient extending from the diffuser (Figure 2-1). This gradient extends towards the predicted high deposition area. Station NF22 lies to the southwest of the west end of the diffuser and is along the projected long-term effluent transport path from the diffuser. Station FF10 extends the area of impact sampled under the contaminant special studies task and represents a farfield location near the center of the high deposition location predicted by the BEM model and is a sandier location.

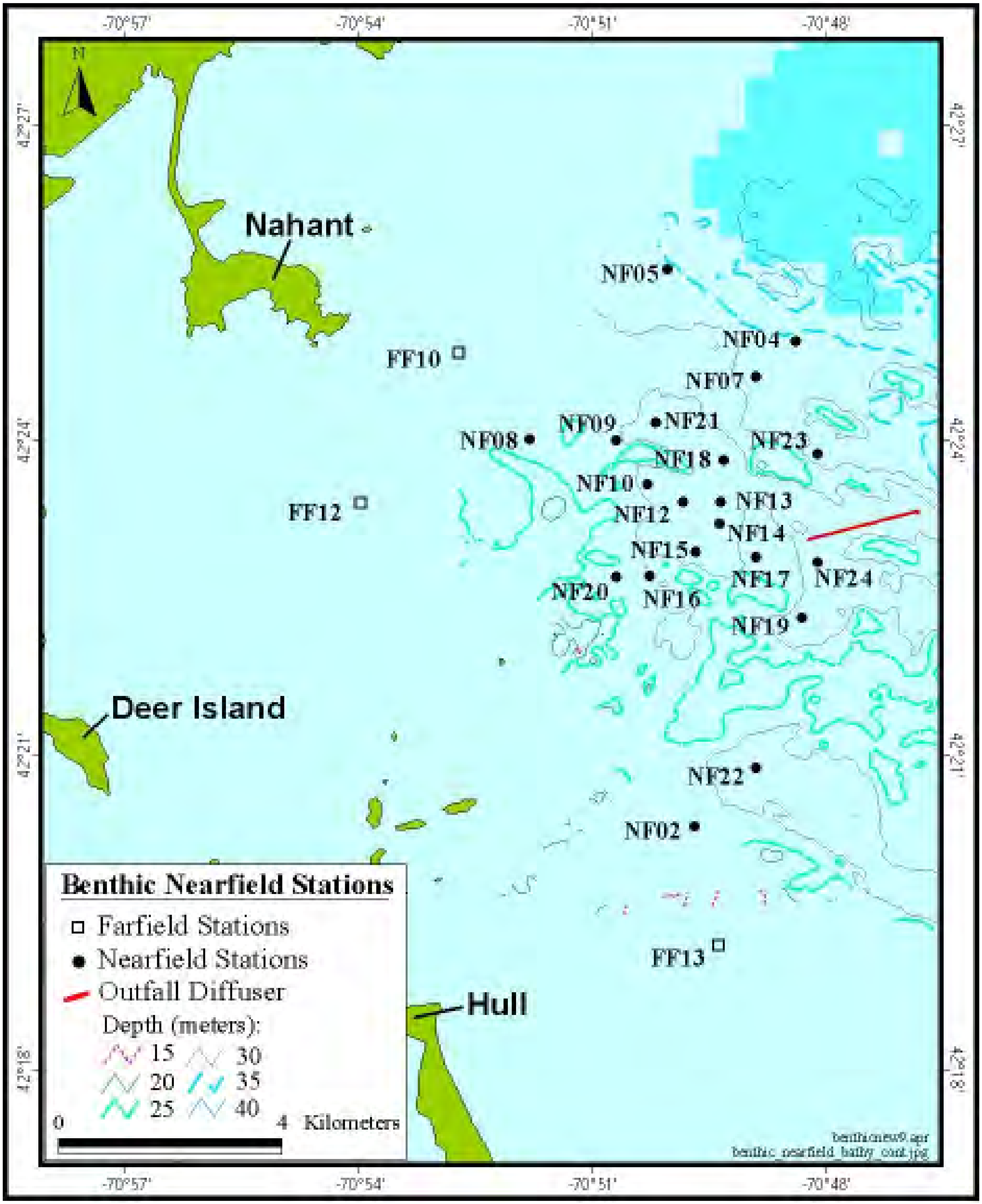

Figure 2-1. Locations of nearfield and selected farfield grab stations sampled in August 2000.

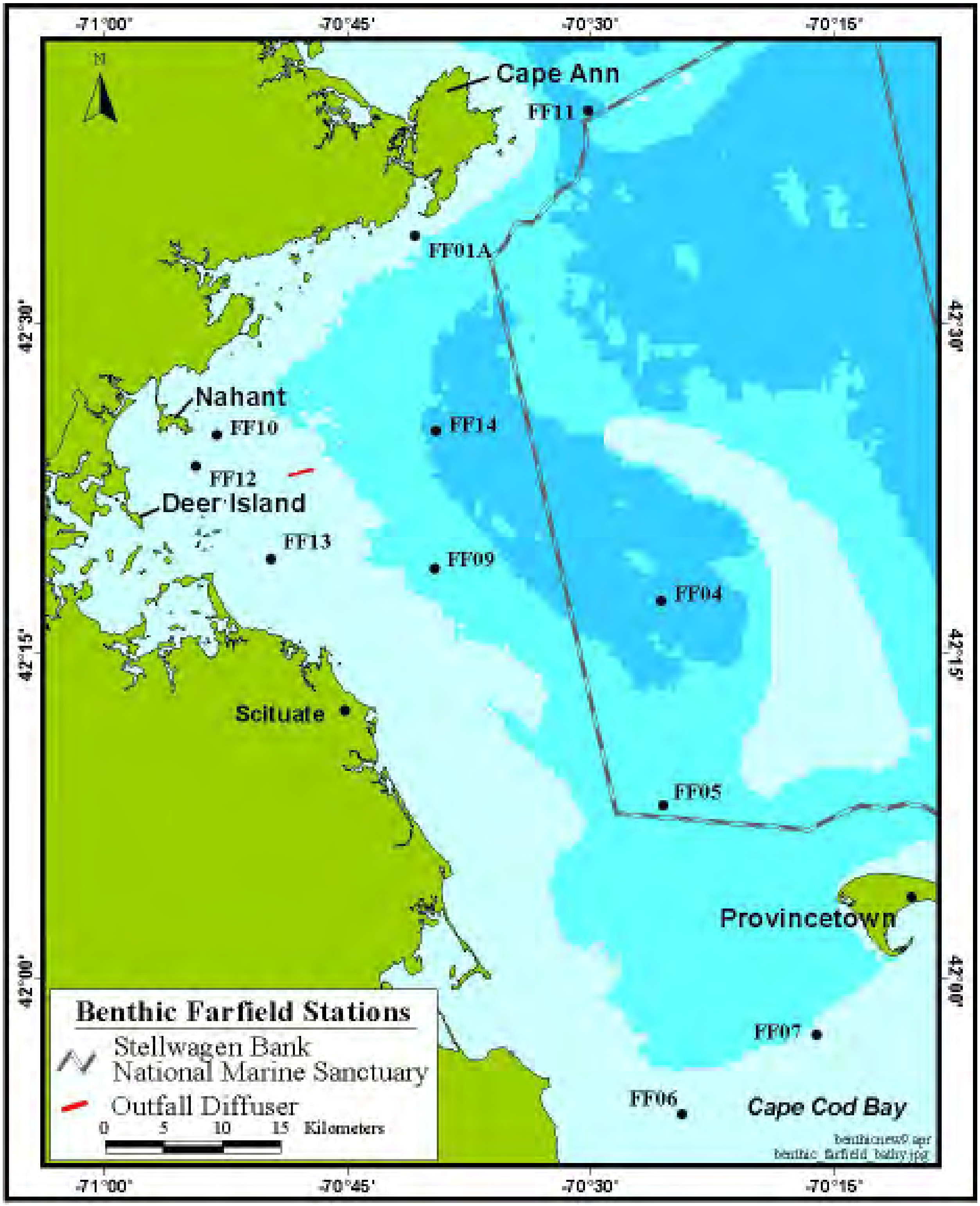

Figure 2-2. Locations of farfield grab stations sampled in August 2000.

Sediment Profile Images—The Nearfield Sediment Profile Image surveys are conducted in August of each year at 20 nearfield and 3 farfield stations (Figure 2-1) to give an area-wide, qualitative/ semi-quantitative assessment of sediment quality and benthic community status that can be integrated with the results of the more localized, quantitative surveys to determine sedimentary conditions near the outfall. Furthermore, these surveys provide rapid comparison of benthic conditions to the benthic triggering thresholds. Traditional sediment profile imagery (35-mm slides) allows a faster evaluation of the benthos to be made than can be accomplished through traditional faunal analyses. A more rapid analysis of the SPI data was accomplished by fitting the profile camera prism with a digital video camera arranged to view the same sediment profile as the 35-mm film camera. The target locations for the SPI sampling are the same as those for the nearfield grab sampling effort. The actual locations of all sediment profile images collected are listed in Appendix A-2.

2.1.2 Hardbottom

Because of the relative sparseness of depositional habitats in the nearfield and in the vicinity of the diffusers, a continuing study of hardbottom habitats has been implemented to supplement the softbottom studies. The nearfield hardbottom surveys are conducted in June of each year. Videotape footage and 35-mm slides were taken at 20 waypoints along six transects and at three additional discrete waypoint (T9-1, T10-1 and Diffuser 44). Station T2-5 was not sampled this year (Figure 2-3) because of its proximity to a work barge, and inclusion in a no-anchor zone.

2.2 Surveys/Samples Collected

The dates of the outfall benthic surveys and the numbers of samples collected on them are listed in Table 2-1.

Table 2-1. Survey dates and numbers of samples collected on benthic surveys in 2000.

Survey	ID	Date(s)	Samples Collected								
			Inf	TOC	Gs	Cp	C	Tm	SPI	35	V
Nearfield Benthic	BN001	23, 25, 26, 28, 31 Aug 2000	26	28	28	28	13	13	–	–	–
Farfield Benthic	BF001	22, 25, 26, 27 Aug 2000	33	23	23	23	7	7	–	–	–
SPI	BR001	22, 23, 24 Aug 2000	–	–	–	–			150	–	23
Hardbottom	BH001	26, 27, 28 June 2000	–	–	–	–			–	~792	42
Nearfield Contaminant	BC002	23, 25, 31 Aug 2000	–	12	12	12	12		–	–	–
Nearfield Contaminant	BC003	28 November 2000		12	12	12	12				

Key:

Inf, Infauna
Gs, grain size
C, contaminant
35, 35-mm slides (hardbottom)
Tm, trace metals
TOC, total organic carbon
Cp, *clostridium perfringens*
SPI, individual sediment profile images (slides)
V, video segments (hardbottom)

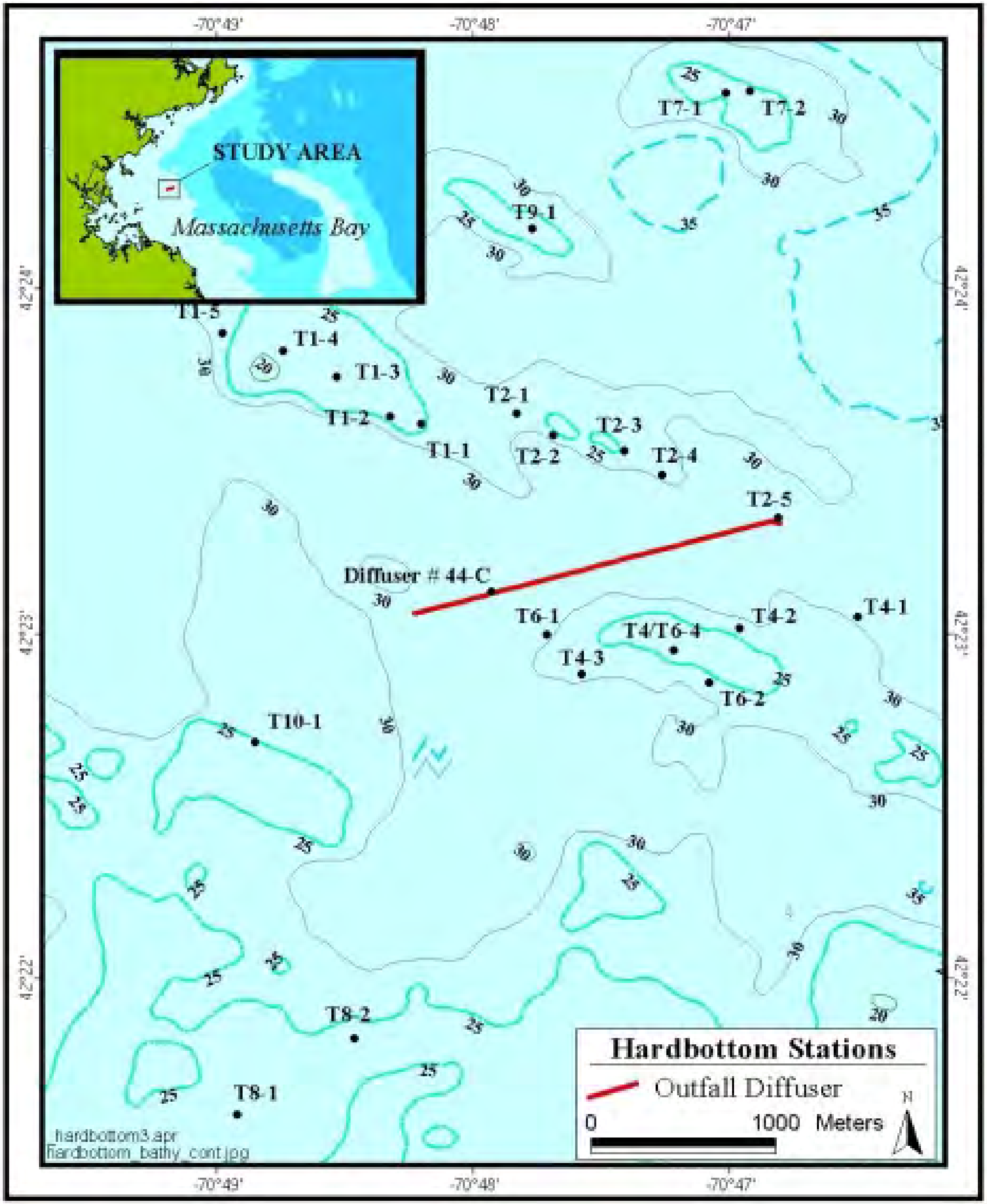

Figure 2-3. Locations of hardbottom stations sampled in June 2000. Station T2-5 was not sampled in 2000 due to its proximity to the no-anchor zone.

2.3 Field Methods Overview

The following is a brief overview of the methods and protocols used on the benthic surveys. More detailed descriptions of the methods are contained in the CW/QAPP (Kropp and Boyle 2001).

2.3.1 Vessel / Navigation

Vessel positioning during benthic sample operations was accomplished with the BOSS Navigation system. This system consists of a Northstar differential global positioning system (DGPS) interfaced to the on-board BOSS computer. Data were recorded and reduced using NAVSAM data acquisition software. The GPS receiver has six dedicated channels and is capable of locking into six satellites at one time. The system was calibrated with coordinates obtained from USGS navigation charts at the beginning and end of each survey day.

At each sampling station, the vessel was positioned as close to target coordinates as possible. The NAVSAM navigation and sampling software collected and stored navigation data, time, and station depth every 2 seconds throughout the sampling event, and assigned a unique ID to each sample when the sampling instrument hit bottom. The display on the BOSS computer screen was set to show a radius of 30 m around the target station coordinates (6, 5-m rings) for all MWRA benthic surveys. A station radius of up to 30 m is considered acceptable for sediment sampling in Massachusetts Bay.

2.3.2 Grab Sampling

Nearfield/Farfield Benthic Surveys—The Nearfield/Farfield Benthic Survey BN001/BF001 was conducted in August 2000. At all 11 farfield stations and 3 nearfield stations (NF12, NF17, and NF24), a 0.04-m^2 modified van Veen grab sampler was used to collect 3 replicate samples for infaunal analysis and 2 replicate samples for *Clostridium perfringens*, sediment grain size, and TOC analyses. At each of the remaining 18 nearfield stations, 1 grab sample for infaunal analysis and one grab sample for *C. perfringens*, sediment grain size, and TOC content were collected. In addition, subsamples for contaminant analysis were collected from the “chemistry” grab at stations NF12, NF17, FF12, FF13, and the four Contaminant Special Study stations. Infaunal samples were sieved onboard the survey vessel over a 300-μm-mesh sieve and fixed in buffered formalin. The “chemistry” sample was skimmed off the top 2 cm of the grab by using a Kynar-coated scoop, and was homogenized in a clean glass bowl before being distributed to appropriate storage containers. The TOC and contaminant samples were frozen, whereas the *C. perfringens* and grain size samples were placed on ice in coolers.

Nearfield Contaminant Special Study—The August Contaminant Special Study Survey (BC002) was conducted in conjunction with the nearfield/farfield benthic survey, BN/BF001. The November 2000 Contaminant Special Study Survey (BC003) was the first benthic monitoring survey conducted after outfall startup. Three replicate samples from each of the contaminant special study stations were collected for the analysis of TOC, grain size, *Clostridium*, and contaminants (organic and metals). Samples were collected from the top 2 cm of the 0.01m^2 Kynar-coated grab and processed as described above.

2.3.3 SPI

During the August 2000 SPI Survey (BR001), a Hulcher Model Minnie sediment profile camera fitted with a digital video camera, to allow for real-time viewing of the sediment profiles, was deployed three times at each station. The profile camera was set to take two pictures, using Fujichrome 100P slide film, on each deployment at 2 and 12 seconds after bottom contact. In the event that sediments were soft the two-picture sequence would ensure that the sediment-water interface would be photographed before the prism window over penetrated. The combination of video and film cameras ensured accurate and reliable collection of sediment profile images. Any replicates that appeared to be disturbed during deployment were retaken. Mr. Randy Cutter conducted the survey. Problems with the video camera prevented narration during the nearfield sampling, but Mr. Cutter and Dr. Robert Diaz (the SPI Senior Scientist) agreed that the lack of audio would not compromise the evaluation. Mr. Cutter recorded the date, time, station, water depth, photo number and estimated camera penetration in his field log. Each touch down of the camera was marked as an event on the NAVSAM©. The video image was recorded for use as part of the "Quick Look" analysis of nearfield conditions. A comparison of the RPDs estimated from the "Quick Look" versus those from the stills analysis is presented in section 3.

2.3.4 Hardbottom

The June 2000 Hardbottom Survey (BH001) of the nearfield examined 20 waypoints distributed along 6 transects (T1, T2, T4, T6, T7, and T8), plus 3 additional waypoints (T9-1, T10-1, and Diffuser 44). A MiniRover MK II ROV equipped with a Benthos low-light, high-resolution video camera, a Benthos Model 3782 35-mm minicamera with strobe, 150 W halogen lamps, a compass, and a depth gauge was deployed from the survey vessel to obtain the necessary video and slides. The ROV was guided as close to the bottom as possible so that the clarity of the video and photographs was maximized. Approximately 20 minutes of video footage per waypoint were recorded along a randomly selected heading. Along this route, still photographs were taken as selected by the Senior Scientist, Dr. Barbara Hecker, until an entire (36 exposure) roll of 35-mm film was exposed at each waypoint.

The date, time, and ROV depth were recorded on the videotapes and appeared on the video monitor during the recording. The start of and stop of each video tape, the start of each roll of film, and the capture of each 35-mm image were recorded as "events" on the NAVSAM© system. The time displayed on the video monitor (and recorded on the tape) was synchronized with the NAVSAM© clock. When a still photograph was taken, the event and frame-identifying observations (made by the Senior Scientist) were recorded on the videotape. On the first day of sampling it was found that the audio was not operational, but because the data are recorded manually at the same time, analysis was not compromised. The NAVSAM© produced labels that were attached to each video cartridge and each film canister. All slides were developed onboard to monitor camera performance. Slides were labeled manually at the lab after mounting. All slides were scanned into electronic images and copied onto a CD for archival.

3. 2000 SEDIMENT PROFILE CAMERA RECONNAISSANCE OF NEARFIELD BENTHIC HABITATS

by Robert Diaz

3.1 Materials and Methods

3.1.1 Field Methods

The 20 nearfield and 3 farfield stations were sampled August 22, 23, and 24, 2000. Sediment profile images, both film and video, were collected at all stations (Figure 3-1). Problems with the film advance electronics in the profile camera caused the loss of one of three replicate images from Stations NF13 and NF17. Two of three replicate images were lost from Stations NF14, NF16, and NF20. For these eight replicates, the recorded video was used to estimate sediment and biological variables. Field methods are detailed in section 2.3.3.

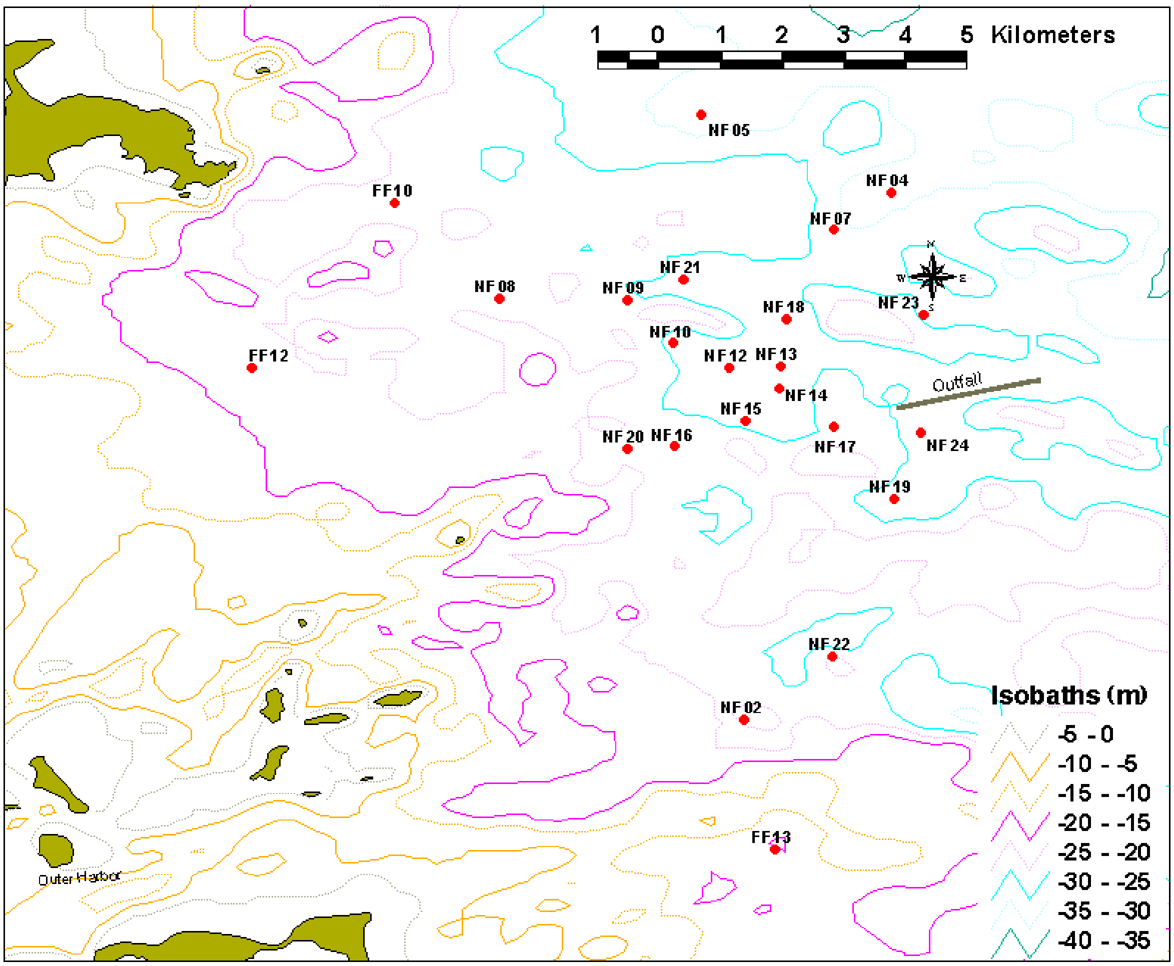

Figure 3-1. Nearfield SPI station locations.

3.1.2 Quick Look Analysis

The Quick Look analysis was developed in 1998 to meet the needs of rapid data turn around for assessment of benthic triggers, one of which is an area-wide 50% reduction in the average depth of the redox potential discontinuity (RPD) layer (MWRA 1997). The exposed film was developed August 24, 2000, the last day of field operations, and the Quick Look analysis was completed August 28, 2000. See Kropp *et al*. (1999) for details on the Quick Look analysis.

3.1.3 Image Analysis

The sediment profile images were first analyzed visually by projecting the images and recording all features seen into a preformatted standardized spreadsheet file. The images were then digitized using a Nikon 2000 scanner and analyzed using the Adobe PhotoShop and NTIS Image programs. Data from each image were sequentially saved to a spreadsheet file for later analysis. Details of how these data were obtained can be found in Diaz and Schaffner (1988), Rhoads and Germano (1986), and Kropp *et al*. (1999).

3.2 Results and Discussion

3.2.1 Quick Look vs. Detailed Analyses

Overall there was a high degree of correspondence between the Quick Look and detailed analyses (Table 3-1). The correlation between the two analyses for the apparent color RPD layer depth, one of the benthic trigger parameters (MWRA 1997), was 0.69 ($n = 22$, $p = <0.001$) with the detailed analysis tending to be higher relative to the Quick Look analysis, but overall not significantly higher (paired *t*-test, $p = 0.065$), the reverse was the case for the 1999 data. The absolute difference between the two analyses averaged 0.4 cm (SD = 0.30) for the 22 nearfield stations that had either measured or RPD layer depths were greater than prism penetration. The maximum RPD depth differed between the two analyses was 1.2 cm at Station NF10 (Table 3-1).

3.2.2 2000 Nearfield Sediment Profile Image Data

3.2.2.1 Physical processes and sediments

Grain size ranged from cobbles and pebbles (for example FF10, FF13, or NF02) to mixed sandy-silt-clay sediments (NF08, NF10, or NF21) (Table 3-2, Figure 3-2). Heterogeneous sediments, when three or more textural end-members (silt, sand, gravel, pebble, or cobble) were present in the three station replicates, occurred at Stations FF13, NF02, and NF20. Homogeneous sandy sediments occurred at five stations (FF12, NF04, NF13, NF17, and NF23) and 13 stations had homogeneous fine sediments (Table 3-2). Sediment layering was seen at Station NF05 with a fine-sand layer over silty-clay and at Station NF07 with silty fine-sand over clayey sediments. The modal grain size descriptors were fine-sand-silt-clay (FSSICL) and occurred at six stations. Within station variation of sediment type was highest at the heterogeneous stations with individual replicates ranging from fine-sandy silt to silty pebble-cobbles (FF13) and lowest at finer sediment stations where all replicates had the same sediment type. Grain size for all three replicates was the same at 10 of the 23 stations. Stations FF10 and NF02 had the most spatial heterogeneity in sediment type with each of the replicates having a different sediment type.

Table 3-1. Comparison of August 2000 nearfield station averaged apparent color RPD layer depth from the Quick Look and detailed computer analyses of SPI images. Delta is the difference between the two analyses. Negative sign indicates detailed analysis produced a deeper RPD layer depth estimate.

Station	Quick Look (cm)	AVG Detailed SPI Images (cm)	Delta (cm)
FF10	IND*	IND	
FF12	1.6	2.0	–0.4
FF13	1.5	> 2.0	–0.5
NF02	> 3.0	> 2.2	0.8
NF04	> 2.8	> 2.8	0.0
NF05	2.5	3.1	–0.6
NF07	3.0	3.8	–0.8
NF08	3.2	3.1	0.1
NF09	2.5	2.9	–0.4
NF10	2.1	3.3	–1.2
NF12	2.5	3.1	–0.6
NF13	> 2.5	> 2.6	–0.1
NF14	2.5	> 1.9	0.6
NF15	2.0	1.9	0.1
NF16	2.8	2.9	–0.1
NF17	> 3.0	> 3.4	–0.4
NF18	1.8	2.5	–0.7
NF19	1.3	1.7	–0.4
NF20	2.5	2.0	0.5
NF21	3.5	3.5	0.0
NF22	2.5	2.9	–0.4
NF23	> 3.0	> 2.7	0.3
NF24	1.6	1.8	–0.2

* IND = RPD was indeterminate.
> = RPD layer depth was greater than prism penetration.

Table 3-2. Station summary of SPI parameters for the August 2000 survey of the nearfield area. Data from all replicates were averaged for quantitative parameters and summed for qualitative parameters (for example, the presence of tubes in one replicate resulted in a + for the station).

Surface Features						Subsurface Features										
Stat	Pen. (cm)	SR (cm)	RPD (cm)	Sediment Type	Surface Features	Bed-forms	Amp	StkA	Tubes	Layers	Wrm	Bur	Oxic Voids	Anaer Voids	Succ Stage	OSI
FF10	0.0	1.5	.	GR to PB	BIO/PHY	-	-	-	+	-	.	.	.	.	I?	.
FF12	5.3	1.9	2.0	VFS	BIO/PHY	+	-	+	+	-	3.3	4.0	0.0	0.0	I/II	5.3
FF13	2.8	1.8	>2.0	SI to CB	BIO/PHY	-	-	-	+	-	1.7	2.3	0.3	0.0	I/II	5.7
NF02	1.1	3.1	>2.2	MSCS to CB, SH	PHY	-	-	-	+	-	0.0	0.0	0.0	0.0	I?	5.0
NF04	2.8	1.4	>2.8	FS	BIO/PHY	+	-	-	+	-	0.0	0.0	0.0	0.0	I/II	6.3
NF05	6.5	1.0	3.1	FS/SICL	BIO	-	+	+	+	GS	2.0	4.3	1.0	0.0	II/III	8.3
NF07	14.4	0.9	3.8	SIFS/CL	BIO	-	-	-	+	GS	7.0	7.7	3.0	0.0	II/III	9.7
NF08	17.5	0.9	3.1	SIFS	BIO	-	-	-	+	CL	3.0	2.7	1.3	0.3	II	7.3
NF09	8.4	2.1	2.9	FSSI	BIO	-	-	+	+	-	7.7	5.7	2.0	0.0	III	9.3
NF10	10.0	0.6	3.3	FSSICL	BIO	-	-	-	+	-	13.0	6.3	1.0	0.0	III	10.0
NF12	17.1	1.1	3.1	FSSICL	BIO	-	-	-	+	-	5.7	5.3	4.0	0.0	III	9.3
NF13	2.7	1.2	>2.6	FSMS to PB	BIO/PHY	-	-	-	+	-	0.0	0.0	0.0	0.0	I/II	6.0
NF14	6.0	1.1	>1.9	FSSICL to PB	BIO/PHY	-	-	-	+	-	0.0	0.0	0.7	0.0	II	5.7
NF15	4.8	1.2	1.9	FSSI to PB	BIO/PHY	+	-	-	+	-	4.0	3.3	0.0	0.0	II	6.0
NF16	7.0	1.4	2.9	FSSI to PB	BIO	-	-	-	+	-	1.3	4.0	1.0	0.0	II/III	8.0
NF17	3.2	>0.3	>3.4	FSMS to PB	BIO	+	-	-	+	-	0.0	0.0	0.0	0.0	I/II	7.0
NF18	5.6	1.6	2.5	FSSICL	PHY	+	-	-	+	-	5.7	3.7	0.0	0.0	II	6.7
NF19	9.0	2.2	1.7	FSSICL to CB	BIO/PHY	-	-	-	+	-	3.7	3.3	1.0	0.0	II	6.0
NF20	4.6	2.8	>2.0	SIFS to PB	BIO/PHY	-	-	-	+	-	0.0	1.0	0.0	0.0	I/II	5.0
NF21	16.2	0.8	3.5	SIFS	BIO	-	-	-	+	-	6.0	5.7	3.3	0.0	III	10.0
NF22	14.9	1.3	2.9	SIFS	BIO	-	-	-	+	-	5.0	5.0	2.3	0.0	II/III	8.7
NF23	2.7	1.1	>2.7	FSMS to GR	BIO/PHY	+	-	-	+	-	0.0	0.0	0.0	0.0	I/II	6.0
NF24	9.3	1.9	1.8	FSSICL	BIO	-	-	-	+	-	12.3	4.3	0.7	0.0	II/III	6.7

> At least one replicate had an RPD layer deeper than the prism penetration.

Key:

Stat. = Station
Pen = Average prism penetration depth
SR = Average surface relief across the 15 cm width of the prism face plate
RPD = Average depth of the apparent color RPD
Sediment Type:

FS = Fine-sand	FS/SICL = Sand layer over silty	CB = Cobble	
FSMS = Fine-Medium-sand	GR = Gravel	SH = Shell	
FSSICL = Fine-sand-silt-clay		PB = Pebble	SIFS = Silty Fine-sand
MSCS = Medium-Coarse-sand		FSSI = Fine-sandy Silt	SICL = Silty Clay
VFS = Very Fine-sand		SI = Silt	SIFS/CL = Silty Fine-sand layer over clay

Surface = Predominant sediment surface structuring process: BIO = Biogenic, PHY = Physical
Bedforms = Presence/Absence of small bedforms or sand waves
Amp = *Ampelisca* tubes
StkA = Stick amphipod biogenic structures, likely the genus *Dyopedos*
Tube = Worm tubes: MAT = tubes dense enough to form a mat over surface
Layers = Sediment layering: GS = Grain size layering, CL = Color layering
Wrm = Subsurface infaunal worms, average number per image
Burr = Infaunal burrows, average number per image
Oxic Voids = Water filled inclusions in sediment, active biogenic features, average number per image
Anaer Voids = Water filled inclusions in sediment, relic biogenic features, average number per image
SS = Estimated successional stage
OSI = Organism Sediment Index

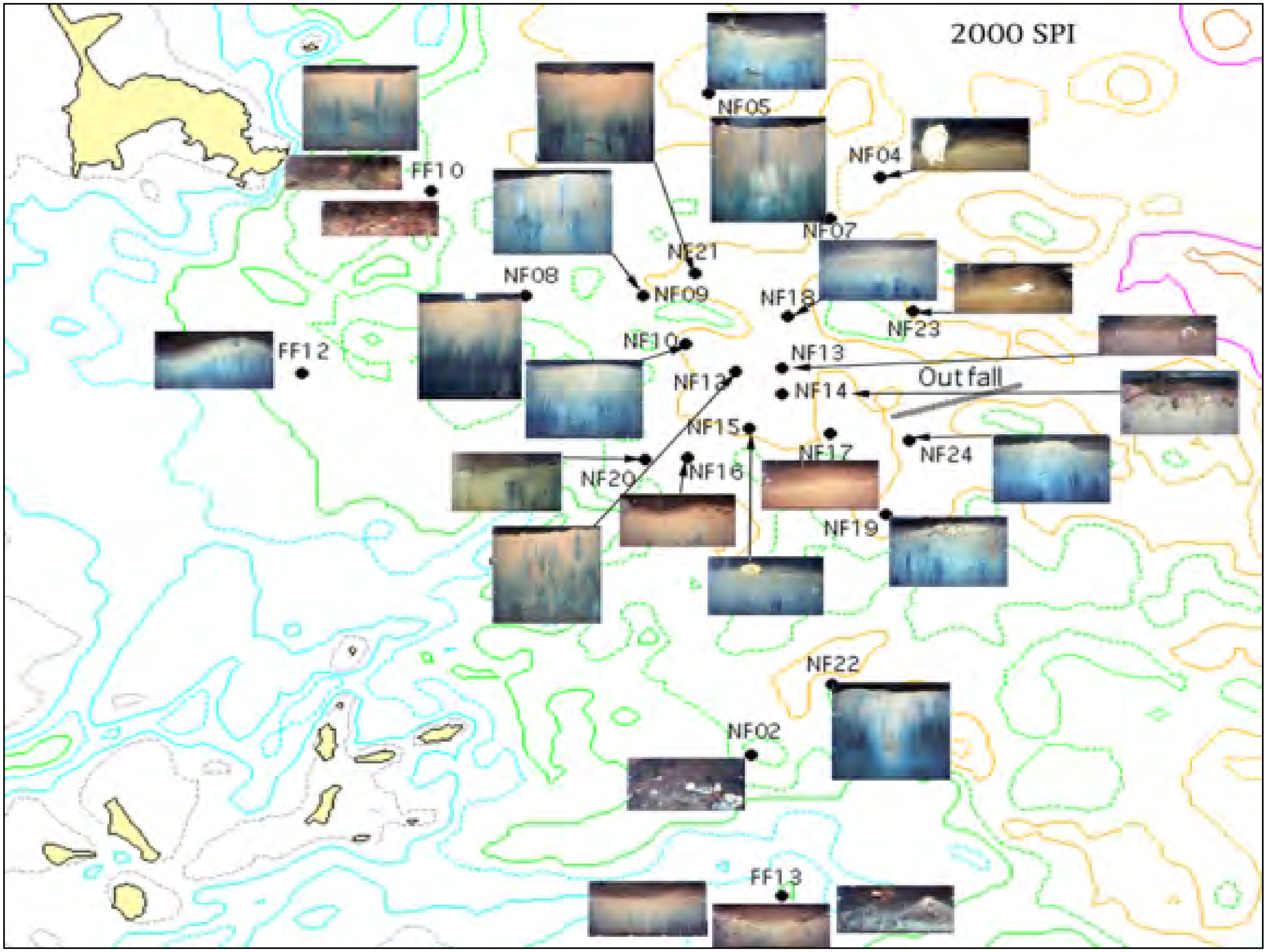

Figure 3-2. Nearfield stations with representative SPI images, August 2000.

The finest grain-size associated with the ten stations that had pebble or cobble, indicative of high kinetic energy or transport bottoms, varied. The finest sediment at Station FF10 was gravel, at NF02, NF13, and NF17 it was various sizes of sand, and at the six other stations it was silts and clays. Pure sands, also indicative of higher bottom energy, were seen at Stations FF12 and NF04 (Figure 3-3). Bedforms typically associated with higher energy sandy bottoms were seen at six stations, which was an increase in occurrence over the last several years. The increase in bedforms from 1999 to 2000 may be related to storm activity that would resuspend and transport bottom sediments. In the absence of storm-induced bottom currents, benthic organisms would tend to wipe out physical structures such as bedforms during quiescent periods, as seen in 1998 and 1999, when biogenic activity at the sediment surface increased. Homogeneous finer sediments, fine-sand-silt-clay, and silt-clay were concentrated to the northwest of the outfall but also occurred to the south (Figure 3-3).

The correspondence between the SPI image and grab sediment analysis was adequate, given the divergent approach with which the two methods sampled the sediments (Table 3-3). Both methods indicated the sediments were heterogeneous in some areas and homogeneous in other areas. The three replicate SPI images sampled a broader area at a station and provided estimates of spatial and end member variability of sediments, particularly for coarse sediments. The grab samples and grain-size analysis provided better estimates of the fine sediment end members. To compare the two methods, the grab data were converted to a Wentworth classification as described in Folk (1974) and the shell, pebble, and cobble were removed from the SPI data (Table 3-3). These very coarse end members were removed because the grab would not have sampled them.

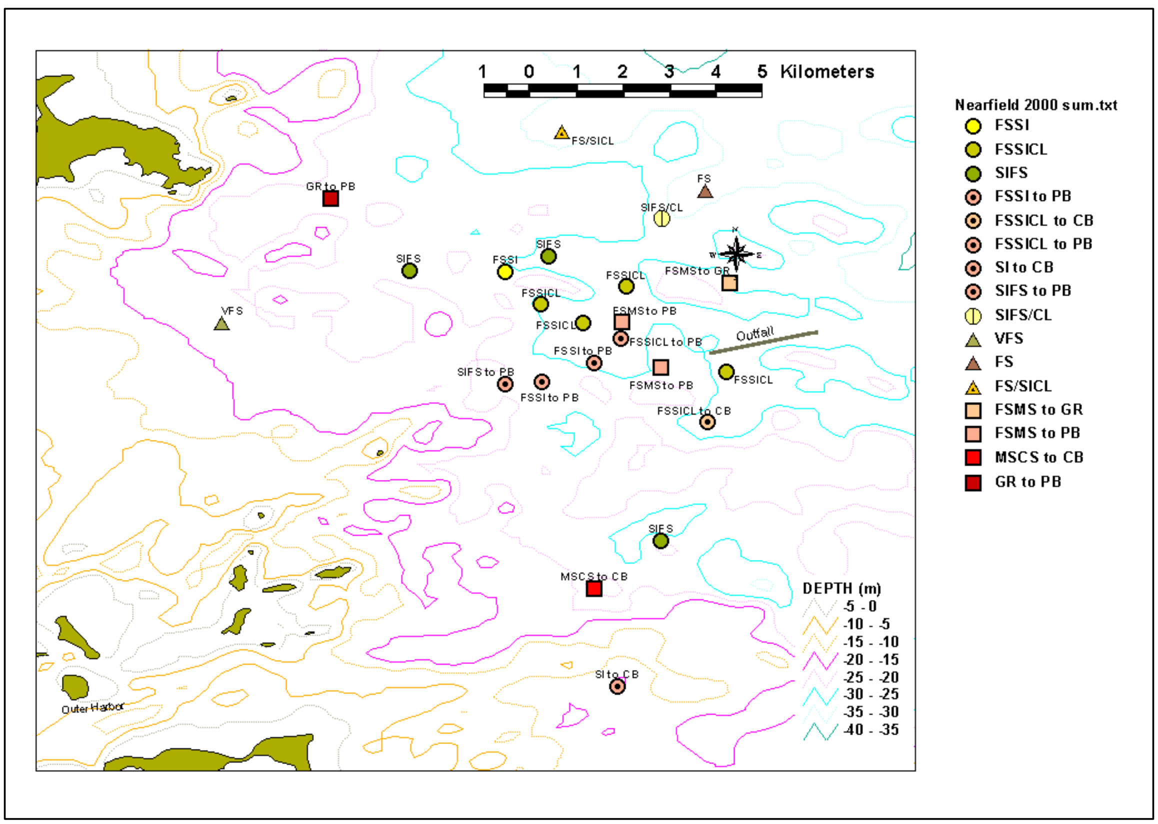

Figure 3-3. Distribution of estimated sediment types at nearfield stations based on SPI, August 2000.

Prism penetration and sediment grain size were closely related with lowest penetration at hard sand-gravel-pebble-shell bottoms (for example FF10 and NF02). The range of average station penetration was 0.0 (FF10) to 17.5 cm (NF08), and it reflected the dichotomy of nearfield benthic habitats, where habitats tended to have either coarser and heterogeneous, or finer and homogenous, sediments (Table 3-2, Figure 3-2).

Surface relief or bed roughness was approximately the same in both physically and biologically dominated habitats. In physically dominated sandy and coarse habitats surface relief ranged from 1.6 to 3.1 cm and was caused by pebble/rocks or bedforms (NF02 or NF04). In muddy habitats surface relief was lower and ranged from 0.3 to 2.1 cm and was typically irregular surfaces, caused by biogenic activity of benthic organisms. Biological surface roughness ranged from feeding mounds (NF22) and tubes (NF09) to colonies of hydroids (FF10).

3.2.2.2 Apparent Color RPD Depth

Average apparent color RPD layer depth could not be determined at Station FF10 because the prism did not penetrate the gravel-pebbly sediments (Table 3-2). For the other 22 stations the RPD layer depth ranged from 1.7 cm (NF19) to 3.8 cm (NF07). For an individual replicate the shallowest RPD was 1.0 cm at NF22-1 and the deepest measured RPD was 4.3 cm at NF12-1. At the seven porous sand and gravel stations the apparent color RPD layer depths were deeper than the prism penetration (expressed with a > in Table 3-2). For these stations, prism penetration was then assumed to be at least a conservative minimum estimate of the RPD layer depth and was included in the calculation of the average RPD layer depth. The average RPD layer depth for all stations was 2.6 cm (0.62 SD, 0.13 SE) with the inclusion of stations that had shallow penetration at least as minimal estimates of RPD depth. At many stations, biogenic activity in the form of burrow structures increased the depth to which oxic sediments penetrated.

Sediments that appeared to be oxic, lite-brown to reddish in color, extended >10 cm below the sediment-water-interface at Stations NF09 and NF12. The deepest RPD layers occurred in the vicinity of the outfall to the west and north (Figure 3-4) with mixed sediments and high levels of biogenic activity (NF22).

The variance of the average station RPD layer was analyzed to determine the sensitivity of SPI for estimating a 50% change in the apparent color RPD over the study area. The MWRA (1997) has set this amount of change in the depth of the RPD layer as a critical trigger level for assessing outfall effects. In order to detect a 50% change in RPD layer depth over the study area from one year to the next with a 95% confidence interval and 90% power, would require approximately five stations. This was based on the assumption that a t-test would be used to assess the significance of the difference between the current year average relative to the previous year, that a 50% change would be 1.3 cm (half of the average RPD for 2000), and that the variance of the 2000 data was representative of the population of RPD depths (Zar 1999, page 132-133). Six stations would give a 95% confidence interval and power and eight stations would increase the power to 99%.

3.2.2.3 Biogenic Activity

The sediment surface at about half the stations (11 of 23) was dominated by a combination of biogenic and physical processes. At ten stations biological processes dominated, whereas physical processes dominated only at two stations. Biogenic structures associated with activities of successional stage II and III fauna dominated at biologically accommodated stations. The surface biogenic structures observed included biogenic whips or sticks made by amphipods (NF05, NF09, FF12) are likely in the genus *Dyopedos* (Mattson and Cedhagen 1989). *Dyopedos monacanthus* occurred at nine grab stations in 2000 including Station NF12 (Section 5). Other biogenic features were small and large worm tubes (NF23), epibenthic organisms (FF13), burrow openings (NF12), feeding pits (NF09), biogenic mounds (NF10)

Table 3-3. Comparison of sediment grain-size determined by SPI and grab sample analyses for 2000 nearfield stations. Only sediment fractions from gravel to silt-clay are compared. Coarser sediments were sampled by SPI, but not by the grab sampler.

SPI Data			Grab Data					
Station	Cobble/ Pebble	Gravel, Sands Fines*	Gravel, Sands Fines	Mean Phi	Gravel %	Sand %	Silt %	Clay %
FF10	PB	GR	GR, FSSI	2.06	22	59	13	6
FF12		VFS	FSSI	3.98	3	68	22	6
FF13	CB	GE, FSSI, SI	FSSICL	5.73	0	29	48	22
NF02	CB	GR, MSCS, MSGR	MSCS	2.38	3	88	5	3
NF04		FS	FS	2.61	0	94	3	3
NF05		FS/SICL	FS, SICL	4.31	1	60	24	15
NF07		SIFS/CL	FSSI	4.40	0	57	28	15
NF08		SIFS	SIFS	5.39	0	33	53	13
NF09		FSSI	FSSI	4.6	0	61	26	12
NF10		FSSICL	FSSICL	4.86	0	53	34	13
NF12		FSSICL	FSSICL	5.38	0	35	48	17
NF13	PB	FSMS	FS	2.2	2	94	2	3
NF14	PB	FSSICL	GR, XX, SI	1.15	36	53	7	4
NF15	PB	FSSI	FSSI	2.79	4	81	10	5
NF16	PB	FSSI	FSSI	2.99	10	64	16	10
NF17	PB	FSMS	FS	1.98	0	98	1	1
NF18		FSSICL	GR, XX, SI	.83	48	41	7	4
NF19	CB	FSSICL	FSSI	1.5	38	48	7	7
NF20	PB	GR, SIFS	GR, FSSI	.86	39	51	6	5
NF21		SIFS	SIFS	5.17	0	41	44	15
NF22		SIFS	FSSI	4.28	3	55	30	13
NF23		GR, FSMS	GR, MS	1.64	12	83	3	2
NF24		FSSICL	FSSICL	4.85	0	46	40	14

* Composite of all sediment classes seen in the three replicate images.

and shells (NF02). Subsurface biogenic structures and actives were associated with infaunal organisms and included active oxic burrows (NF18), water filled oxic voids (NF10), and water filled anoxic voids (NF08). Free burrowing infaunal worms occurred at 15 stations. At stations NF10 and NF24 the average number of worms was >12 per image with a maximum of 15 worms at NF10-2 (Table 3-2).

3.2.2.4 Successional Stage and Organism Sediment Index

The modal successional stage was estimated to be Stage II and occurred at five stations. Another five stations appeared to have combined traits of both Stage II and III communities and seven stations with a combination of Stage I and II communities. The four stations with the most advanced successional stage (Stage III) were NF09, NF10, NF12, and NF21. The high degree of biogenic sediment reworking observed in many images was consistent with Stage II and III successional designation. Stations FF10 and NF02 appeared to have the lowest overall successional stage designation (Stage I) with little indication of biogenic activity other than a few worms (Table 3-2). Lower successional stage stations clustered around the western end of the outfall and were encircled by higher stages stations (Figure 3-5).

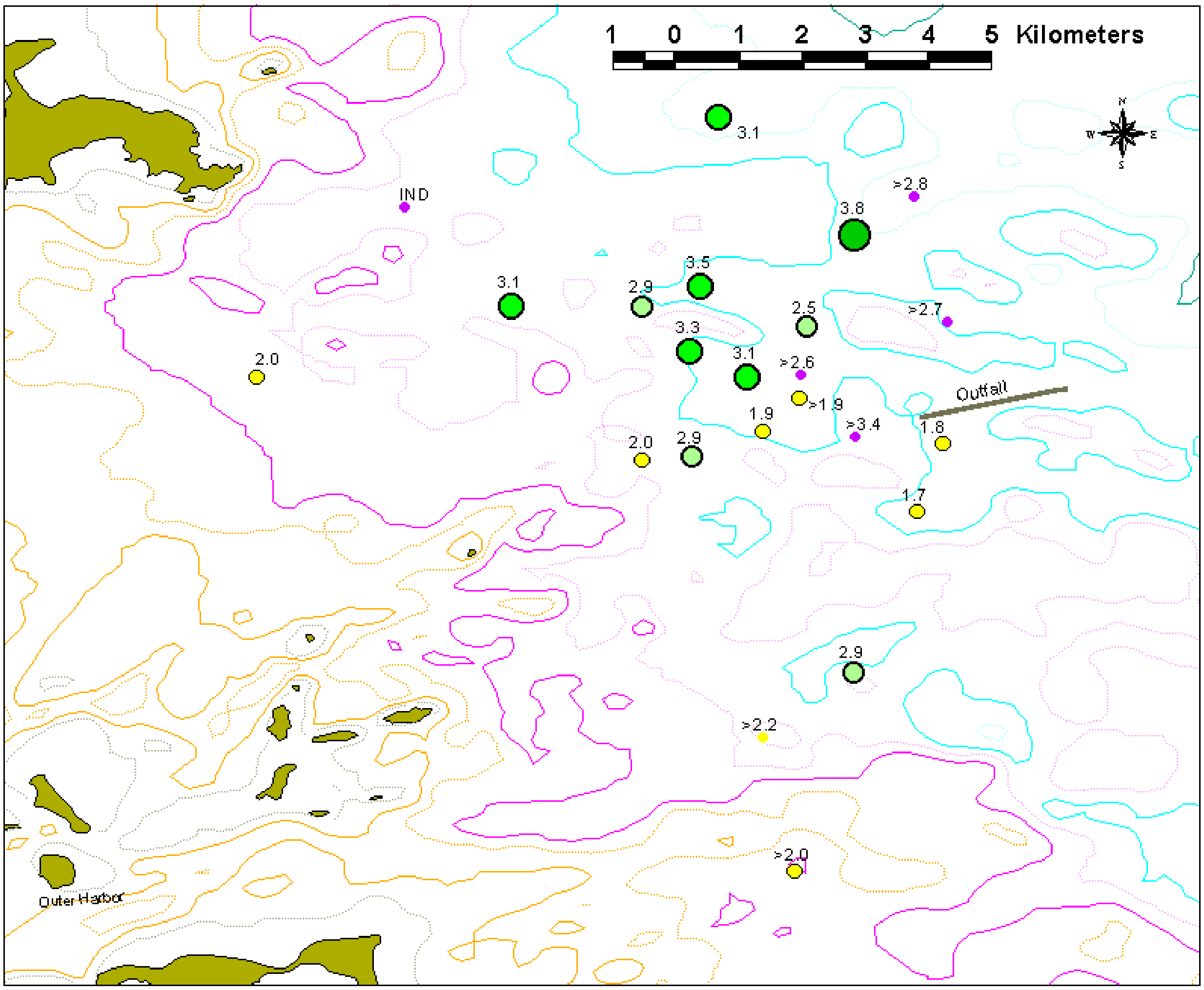

Figure 3-4. Distribution of estimated apparent color RPD layer depth at nearfield stations based on SPI, August 2000.

The average Organism Sediment Index (OSI) at the nearfield stations was 7.2 (1.39 SD, 0.35 SE). Rhoads and Germano (1986) developed the OSI for assessing stress in estuarine and coastal embayments and found that OSI values <6 were associated with benthic communities under some form of stress, either from organic loading or physical processes, while higher values were associated with well developed communities. Five stations had OSI values <6 all of which appeared to be physically stressed with Stations FF12, FF13, and NF02 having heterogeneous or sandy sediments, and Stations NF14 and NF20 having finer sediments with moderate to heavy sediment drape over coarse sediment components (Table 3-2). The range in OSI values was greater in 2000 relative to 1999, from 5.0 to 10.0 and 5.3 (NF19) to 8.5 (NF17), respectively (Figure 3-6, Table 3-3).

3.3 Summary of 2000 SPI Data

Sediment surfaces at the nearfield stations continue to be dominated by biogenic structures and organism activity in 2000. Most stations with fine sediments had high densities of polychaete tubes, at least one tube per cm^2, based on tubes that were within one cm of the prism faceplate. Most of the cobble and pebble size sediments were covered with a thin layer of fine sediments and tubes, along with organisms

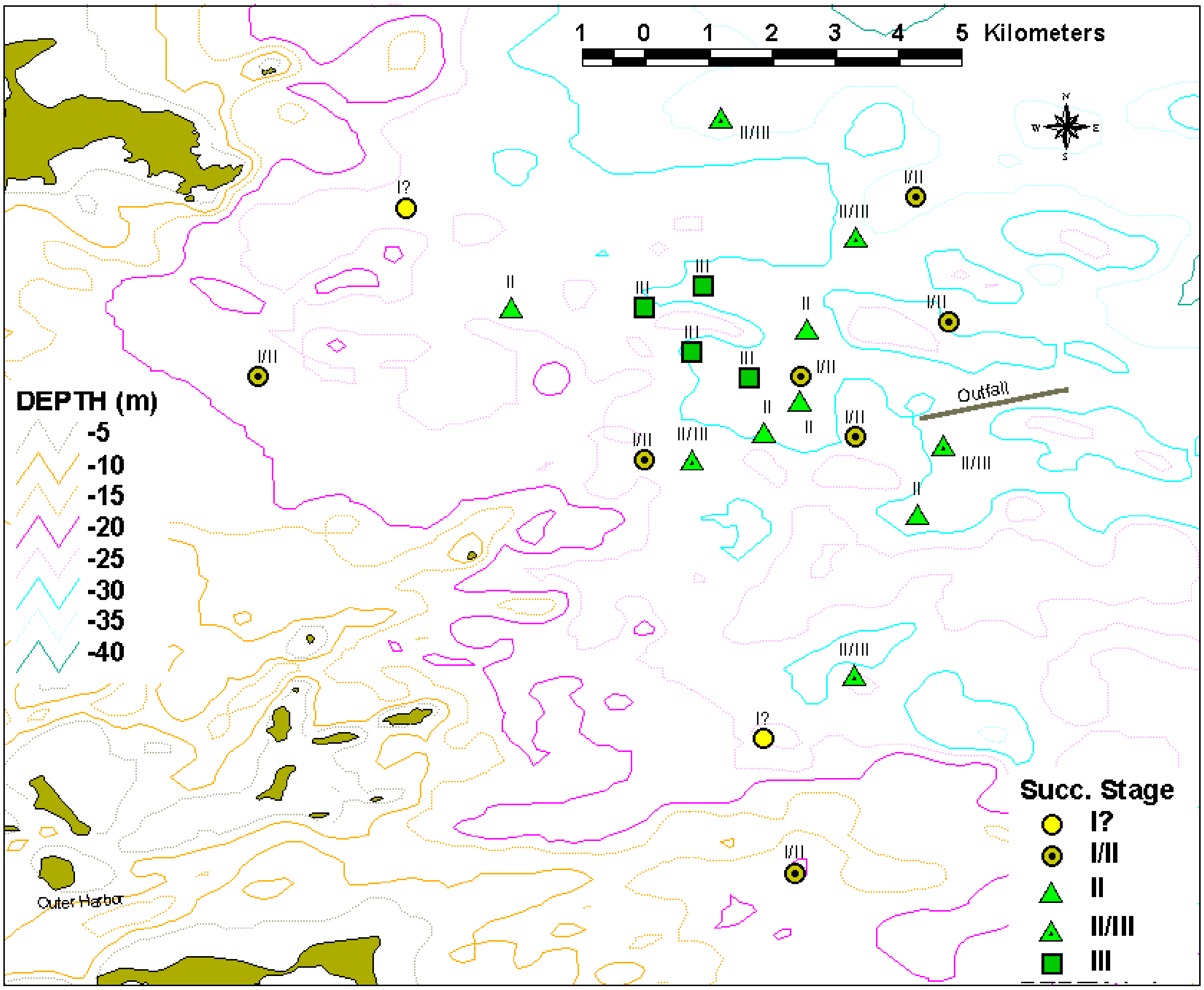

Figure 3-5. Distribution of estimated successional stage at nearfield stations based on SPI, August 2000.

such as sponges or hydroids. A similar sediment drape was observed at many of the ROV transects. However, the draped sediments seen in the SPI images appeared to be thinner in 2000 relative to 1999. The presence of bedforms increased in 2000 relative to 1999, when there was little evidence of bedforms at sandy stations. Both the increase in bedforms and decrease in sediment drape point to an increased bottom energy climate in 2000 relative to 1999. Overall, the sedimentary environment did not change much from 1999 to 2000. Sediments at many stations continue to be either heterogeneous, ranging from silts-clays to cobbles, or homogeneous, ranging from sands or silt-clays.

The depth of the apparent color RPD layer continued to reflect the dominance of biological processes at many of the stations in 2000. The averaged apparent color RPD layer depth ranged from 1.7 cm at Station NF19 to 3.8 cm at Station NF07 (Table 3-2). The grand average RPD layer depth for all stations in 2000 was 2.6 cm (0.62 SD, 0.13 SE) and was statistically the same as in 1999, which was 2.5 cm. Overall, along with the increased energy climate noted above, the analysis of benthic community and SPI data points to a lessening of physical stress at the nearfield stations in 2000 relative to the last few years (Kropp *et al*., 1999, 2000).

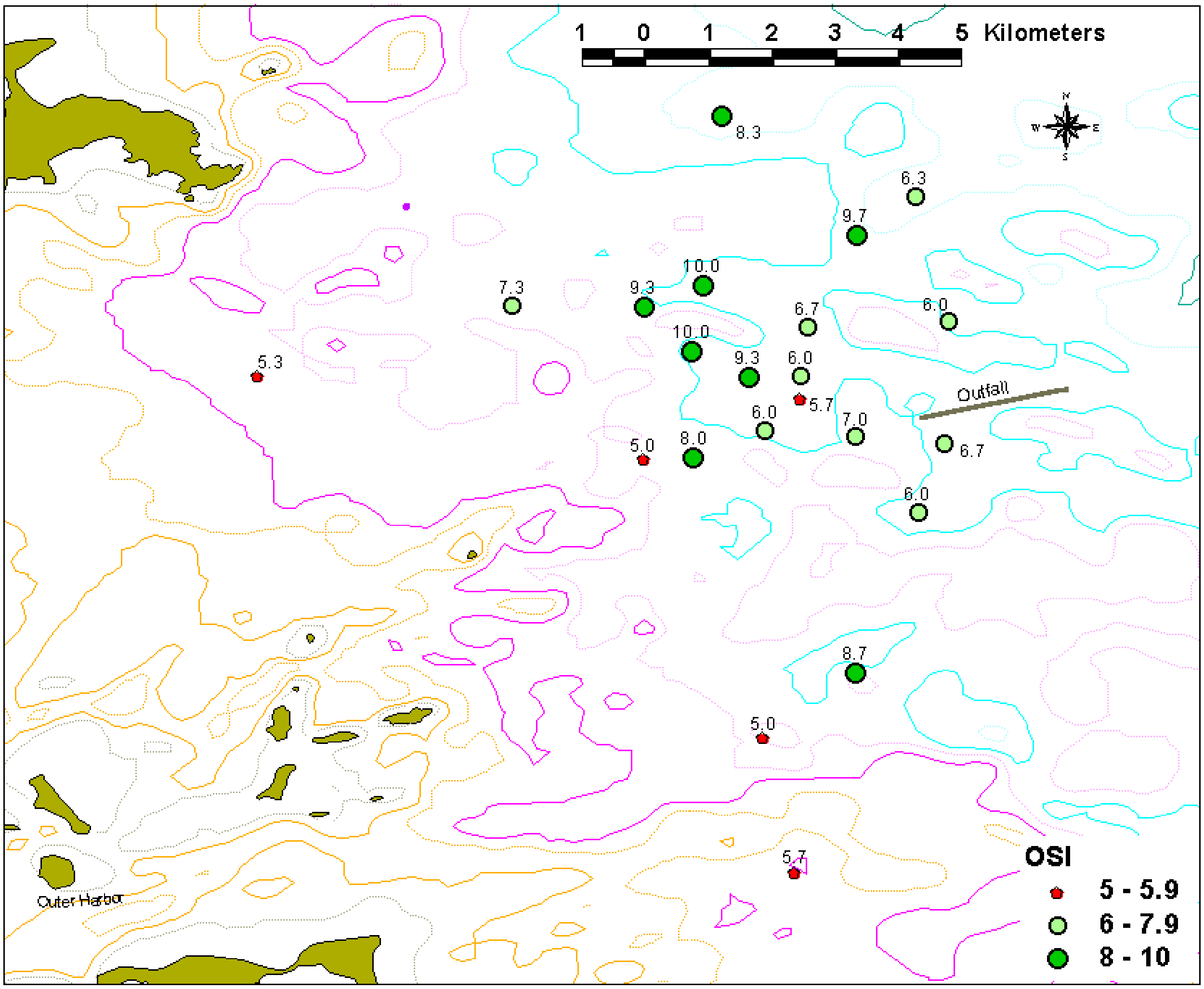

Figure 3-6. Distribution of the Organism Sediment Index (OSI) at nearfield stations based on SPI, August 2000.

While the distribution of sediment textures at benthic habitats in the nearfield study area appeared to be dominated by physical processes, surface features were dominated by biogenic activity based on the 2000 SPI survey. Even station NF02, which appeared to be completely dominated by physical processes, had many small tubes on the surface of pebbles. Feeding mounds or tubes were the dominant surface biogenic structures and occurred at all stations. Subsurface biogenic structures and organisms were also common and widely distributed. The predominance of biological activity at most stations, 21 of 23 showing some form of biogenic activity, was indicative of a well developed fauna that was characterized as being intermediate to advanced in successional stage (Stage II to III). The slight increase in the average organism sediment index (OSI) also indicated that biological processes continued to be important. Overall, it appeared that biological processes continued to be prominent in 2000 relative to the last few years.

The sampling design, with 23 stations in the nearfield area, provided more than sufficient statistical power for a t-test with a 95% confidence interval and 90% power to detect a 50% change in mean RPD layer depth over the entire study area from one year to the next. Based on the variation in the 2000 data, five stations would yield a test with a 95% confidence interval and 90% power. With eight stations, power would increase to 99%.

3.4 Long-term Trends in Nearfield SPI Data

Approximately 14 of the 23 nearfield stations were primarily silty (4 to 5 Phi) to very-fine-sand (3 to 4 Phi). The other nine stations were sands or coarser grained. Of the finer sediment stations, half were consistent through time with little or no variation in sediment type over the years, for example NF09 and NF22. The other half of the finer sediment stations had years where coarser sediments were present, mostly pebbles or cobbles laying on the sediment surface, for example NF16 and NF24 (Table 3-4). Grain size variation between the estimated major modal fine sediment descriptors (VFS, FSSI, SIFS, and FSSICL) was not more about two Phi units. Coarser sediment stations were about evenly split with five being sands and four pebble/cobble. Four of the coarser sediment stations exhibited a coarsening through time, for example FF10 and NF17, and three were variable from year to year (NF02, NF20 and NF23) (Table 3-4). Station NF02 was particularly variable in time, alternating between finer and coarser sediments from 1992 to 2000. Of the coarser sediment stations only sandy Stations FF12 and NF04 were consistent through time.

Shallow prism penetration and/or coarse pebble/cobble sediments complicated long-term assessment of the depth of the apparent color RPD when the RPD was below the prism penetration depth. For the purpose of assessing nearfield area wide trends in RPD, data that were qualified as greater than prism penetration were also included. Overall, analysis of variance and Tukey's multiple comparison test indicated that the average RPD layer depth in 1992 and 1995 was deeper, by about 1 cm, relative to 1997 and 1998 (Figure 3-7) and that in 1999 and 2000 RPD layer depth had increased and was the same as 1992 and 1995. Factors that may have lead to the shallower RPD layer depths in 1997 were a lessening of biogenic activity or the shift in sampling from summer (August) to fall (October). All but one of the stations was sampled in October.

The shallowing in RPD after 1995 and the 1999 rebound were likely linked to the interaction of physical and biological process at work in structuring bottom communities. Blake *et al*. (1998) and Kropp *et al*. (2000) concluded that bottom instability (waves and currents) leads to a patchy mosaic of successional Stage I pioneering communities, which are associated with shallower RPD measurements. Stage I communities dominated the nearfield area from 1992 to 1997, with Stage II communities dominating from 1998 to 2000. It also seemed that factors responsible for the depth of the RPD layer were acting at the regional scale in the nearfield because yearly patterns in RPD depth were consistent across stations.

In 1995 the first signs of amphipod tubes, characteristic of Stage II community development, were seen in the nearfield SPI images (Stations NF05, NF04, NF16, NF21, Hilbig *et al*., 1997). In 1999 and 2000 the wide spread occurrence of Stage II communities, and Stage III in 2000, was a key factor in the deepening of the RPD layers. From 1998 to 2000 there appeared to be an increase in the amount of surface and subsurface biogenic activity, relative to previous years, which was also related to the increase in Stage II and III species. Most of the biogenic activity was related to burrowing organisms that created feeding mounds and pits in the sediment surface and small surface tube-building worms.

Table 3-4. Comparison of sediment grain-size by year for each of the nearfield stations. See Table 2 for abbreviations.

Station	1992	1995	1997	1998	1999	2000
FF10	VFS	.	VFS	VFS	CB to SIFS	PB to GR
FF12	.	.	VFS	FS	FS	VFS
FF13	.	.	SIFS	SIFS	CB to FSSI	CB to SI
NF02	VFS	CS	SIFS	PB to GR	CB to FSSI	CB to MSCS
NF04	FS	FS	VFS	FS	GR to FS	FS
NF05	FS	VFS	VFS	VFS	FS/SICL	FS/SICL
NF07	VFS	VFS	VFS	VFS	SIFS	SIFS/CL
NF08	VFS	SIFS	VFS	VFS	SIFS	SIFS
NF09	VFS	VFS	VFS	VFS	FSSI	FSSI
NF10	VFS	VFS	VFS	VFS	FSSICL	FSSICL
NF12	VFS	SI	SIFS	SIFS	FSSICL	FSSICL
NF13	FS	FS to VFS	FS	PB to SIFS	FSMS	PB to FSMS
NF14	FS	VFS	VFS	PB to VFS	PB to SIFS	PB to FSSICL
NF15	FS	VFS	VFS	GR to FS	PB to FSSI	PB to FSSI
NF16	VFS	SIFS	VFS	SIFS	FSSICL	PB to FSSI
NF17	FS	FS	FS	FS	GR to FSMS	PB to FSMS
NF18	VFS	VFS	VFS	GR to VFS	PB to SIFS	FSSICL
NF19	.	CS to VFS	VFS	FSSICL	FSSICL	CB to FSSICL
NF20	VFS	CS to VFS	GR to FSMS	GR to SICL	PB to SIFS	PB to SIFS
NF21	.	SIFS	VFS	SIFS	SIFS	SIFS
NF22	.	SIFS	SIFS	SIFS	SIFS	SIFS
NF23	.	CS to VFS	FS	FS	PB to FSSICL	GR to FSMS
NF24	.	SI	SIFS	FSSICL	PB to FSSICL	FSSICL

The Organism Sediment Index (OSI) of Rhoads and Germano (1986) indicated that, on average, for some the years, benthic communities in the nearfield were subjected to some form of stress (values of the OSI <6). The most likely source of stress being physical processes because water and sediment quality within the nearfield was always good (see Section 4). However, the lower values for 1997 may be related to the additional stress of seasonal change as all but one of the stations were sampled in October while other years were all sampled in August. Analysis of variance, followed by Tukey's multiple comparison test, indicated that 1997 was lower than the other years, except 1995, and that yearly average OSI was the same for 1992, 1995, and 1998 through 2000 (Figure 3-8). The general physical and biological conditions at the nearfield stations reflect the physically dynamic nature of the processes that dominate the area. The 1998 through 2000 data indicated an increasing trend in the importance of biological processes that may have started in 1995.

The six collections at the nearfield stations from 1992 to 2000 provide a database that is sufficient to assess changes in the apparent color redox potential discontinuity (RPD) layer depth as described in the MWRA monitoring plan (MWRA 1997). An area wide reduction of 50% in average RPD layer depth was set as the trigger point for detecting change that may be related to operation of the outfall. Given the variance in RPD data between the 23 stations and six years sampled a comparison with at least a 95% confidence interval and 95% power for comparing next year's data with previous years is assured.

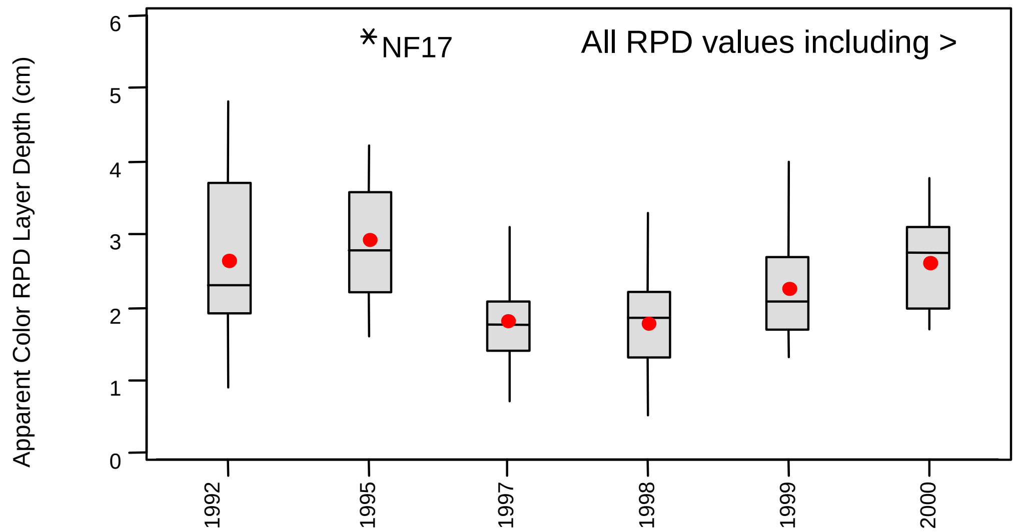

Figure 3-7. Apparent color RPD layer depth (cm) summarized by year for all data from nearfield stations. Bar is median, dot is mean, box is interquartile range, and whiskers are total range of data. Outliers are represented with an asterisk.

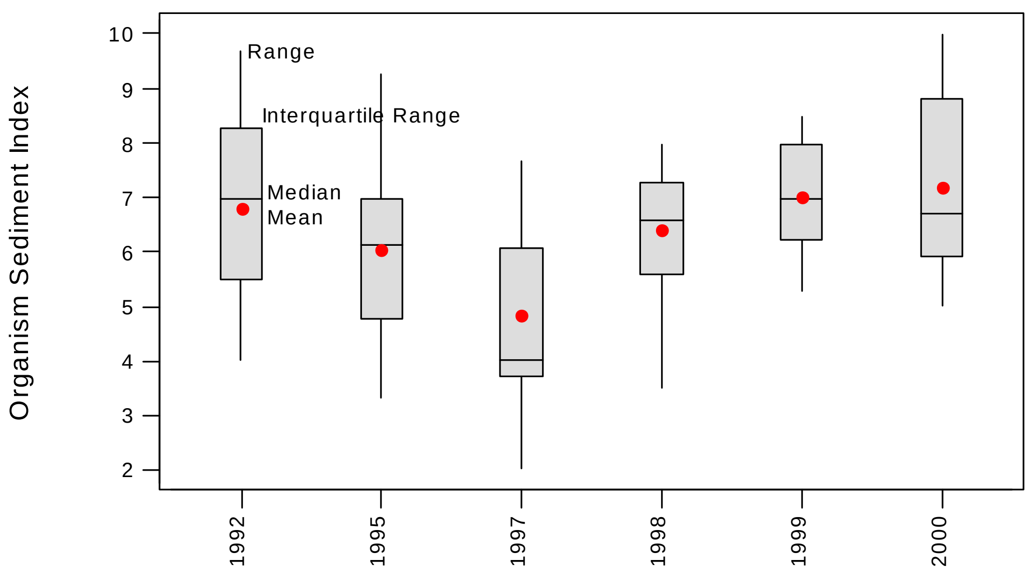

Figure 3-8. Organism Sediment Index summarized by year for all data from nearfield stations.

4. ANALYTICAL CHEMISTRY

by Deirdre T. Dahlen, Stacy L. Abramson, and Stephen Emsbo-Mattingly

4.1 Methods

4.1.1 Grain Size, Total Organic Carbon, and *Clostridium perfringens*

Laboratory procedures followed those outlined in the Benthic Monitoring CW/QAPP (Kropp and Boyle, 2001). Summaries of the procedures are provided below.

Grain Size—Samples were analyzed for grain size by a sequence of wet sieving and dry sieving. Methodologies followed Folk (1974). The sand/gravel fraction was separated from the mud fraction. This sand/gravel fraction was transferred to a 200-mL beaker, decanted, and dried overnight at 95 ºC. The dried sand/gravel fraction was mixed by hand to disaggregate the material, and then dry-sieved on stacked −1-, 0-, 1-, 2-, 3-, and 4-phi sieves. Each size class was weighed to the nearest 0.1 mg on a top-loading balance. Particles smaller than 4 phi were analyzed using the pipette method. Data were presented in weight percent by size class. In addition, the gravel:sand:silt:clay ratio and a numerical approximation of mean size and sorting (standard deviation) were calculated. Grain size determinations were made by GeoPlan Associates.

Total Organic Carbon (TOC)—A portion of the sample to be analyzed for TOC content was dried at 70ºC for 24–36 hours and ground to a fine powder. The sample was treated with 10 % HCl to remove inorganic carbon and dried at 70 ºC for 24 hours. Between 10 and 500 mg of dry, finely ground, and homogenized sample were weighed to the nearest 0.1 mg and placed in a crucible that had been pre-combusted for 4 hours at 500 ºC. A Coulometric Carbon Analyzer was used to determine the TOC content of the samples. TOC determinations were performed by Applied Marine Sciences, Inc., according to SOP AMS-TOC94.

***Clostridium perfringens*—**Sediment extraction methods for determination of *Clostridium perfringens* spores followed those developed by Emerson and Cabelli (1982), as modified by Saad (1992). The filters for enumeration of *Clostridium perfringens* spores were incubated anaerobically at 44.5 ºC for 24 hours. Following incubation, the filter was exposed to ammonium hydroxide for 15–30 seconds. Yellowish colonies that turn red to dark pink upon exposure were counted as *Clostridium perfringens*. Data are reported here as colony-forming units (cfu) per gram dry weight of sediment. This analysis was performed by MTH Environmental Associates.

4.1.2 Contaminants

Analyses of sediments for organic constituents and metals were performed following methods outlined in Table 4-1. Samples were analyzed for the parameters listed in Table 4-2, including linear alkyl benzenes (LABs), polycyclic aromatic compounds (PAH), polychlorinated biphenyls (PCBs), chlorinated pesticides, and metals. Analytical methods followed general NS&T methodologies (Peven *et al*., 1993a, Peven *et al*., 1993b). More detailed information is provided in the CW/QAPP (Kropp and Boyle 2001).

Table 4-1. Parameters and methods of analysis for organic constituents and metals.

Parameter	Unit of Measurement	Method	Reference
Linear Alkylbenzenes	ng/g	GC/MS	Battelle SOP 5-157
Polycyclic Aromatic Compounds	ng/g	GC/MS	Battelle SOP 5-157
Polychlorinated Biphenyls/ Pesticides	ng/g	GC/ECD	Battelle SOP 5-128
Major Metals (Al, Fe)	% Dry Weight	EDXRF	KLM Technical Procedure 7-40.48
Trace Metals (Cr, Ni, Pb, Zn, Cu)	μg/g	EDXRF	KLM Technical Procedure 7-40.48
Trace Metals (Ag, Cd, and Hg)	μg/g	ICP-MS (Ag, Cd) CVAA (Hg) GFAA (as required)	Battelle SOP MSL-I-022 Battelle SOP MSL-I-016 Battelle SOP MSL-I-029

4.1.3 Statistical Analysis, Data Terms, and Data Treatments

Statistical Analysis—numerical analyses techniques used to evaluate sediment chemical data included correlation and principal component analyses.

Correlation analysis was performed on sediment grain size, TOC, *Clostridium perfringens*, and contaminant data to examine the correlation between these parameters. Probability values were taken from Rohlf and Sokal (1969).

Principal components analysis (PCA) was employed to evaluated sediment grain size, TOC, *Clostridium perfringens* and contaminant data for individual sample replicates from August surveys only. A log transformation of *Clostridium perfringens*, total PAH, total PCB, total DDT, and total LAB was performed to minimize bias associated with the large range of parameter values. Such analyses are an effective means of comparing multiple analyte results from many samples (Gabriel 1971, Boon *et al*., 1984, Wold *et al*., 1987, Oygard *et al*., 1988, Stout 1991, de Boer *et al*., 1993, Kannan *et al*., 1998). PCA has the additional advantage of being able to convey the complex chemical differences or similarities among many samples in a visual manner that is more easily understood.

PCA was performed by using Ein*Sight (Version 4.0; Infometrix, Inc., Seattle, WA).

Table 4-2. Sediment chemistry analytical parameters.

Parameter	Parameter	Parameter
Polycyclic Aromatic	**Polychlorinated Biphenyls**	
Compounds		**Metals**
Naphthalene	Cl2(8)	Al Aluminum
C_1-Naphthalenes	Cl3(18)	Cd Cadmium
C_2-Naphthalenes	Cl3(28)	Cr Chromium
C_3-Naphthalenes	Cl4(44)	Cu Copper
Acenaphthylene	Cl4(52)	Fe Iron
Acenaphthene	Cl4(66)	Pb Lead
Biphenyl	Cl4(77)	Hg Mercury
Dibenzofuran	Cl5(101)	Ni Nickel
Fluorene	Cl5(105)	Ag Silver
C_1-Fluorenes	Cl5(118)	Zn Zinc
C_2-Fluorenes	Cl5(126)	
C_3-Fluorenes	Cl6(128)	**Physical Sediment**
Dibenzothiophene	Cl6(138)	**Parameters/Sewage Tracers**
C_1-Dibenzothiophenes	Cl6(153)	Grain Size
C_2-Dibenzothiophenes	Cl7(170)	Gravel
C_3-Dibenzothiophenes	Cl7(180)	Sand
Phenanthrene	Cl7(187)	Silt
Anthracene	Cl8(195)	Clay
C_1-Phenanthrenes/Anthracenes	Cl9(206)	phi<-1
C_2-Phenanthrenes/Anthracenes	Cl10(209)	−1<phi<0
C_3-Phenanthrenes/Anthracenes		0<phi<1
C_4-Phenanthrenes/Anthracenes	**Chlorinated Pesticides**	1<phi<2
Fluoranthene	Aldrin	2<phi<3
Pyrene	Dieldrin	3<phi<4
C_1-Fluoranthenes/Pyrenes	Endrin	4<phi<8 (silt)
Benz(a)anthracene	Hexachlorobenzene	phi>8 (clay)
Chrysene	Lindane	Total Organic Carbon
C_1-Chrysenes	Mirex	*Clostridium perfringens*
C_2-Chrysenes	2,4-DDD	Linear Alkyl Benzenes
C_3-Chrysenes	2,4-DDE	Phenyl decanes (C_{10})
C_4-Chrysenes	2,4-DDT	Phenyl undecanes (C_{11})
Benzo(b)fluoranthene	4,4-DDD	Phenyl dodecanes (C_{12})
Benzo(k)fluoranthene	4,4-DDE	Phenyl tridecanes (C_{13})
Benzo(e)pyrene	4,4-DDT	Phenyl tetradecanes (C_{14})
Benzo(a)pyrene	DDMU	
Perylene	Cis-chlordane	
Indeno(1,2,3-c,d)pyrene	Heptachlor	
Dibenzo(a,h)anthracene	Heptachlorepoxide	
Benzo(g,h,i)perylene	Trans nonachlor	
Benzothiazole		

Data Terms—In the discussion of nearfield results, the term nearfield refers to all nearfield stations plus farfield stations FF10, FF12, and FF13. These farfield stations were included in the nearfield analyses because of their geographic association with the Massachusetts Bay outfall and Boston Harbor and the potential for transport of carbon from the outfall (see the Bays Eutrophication Model, Fitzpatrick *et al*., 2000). Similarly, the term farfield refers to all farfield stations, excluding FF10, FF12, and FF13.

Farfield station FF08 was also excluded since this station was only sampled in 1992 and represented a very different geographic location relative to the routinely monitored farfield sites. For the chemistry interrelationship correlations, nearfield stations NF12, NF17, and NF24 were included in the farfield analyses. These stations were included because they are depositional sites characteristic of western Massachusetts Bay.

Data Treatments—In the discussion of bulk sediment and contaminant data, the following terms are used.

- Percent Fines – sum of percent silt and clay
- Total PAH (also referred to as TPAH) – sum of concentrations of all PAH compounds listed in Table 4-2, excluding Benzothiozole
- Total PCB (also referred to as TPCB) – sum of concentrations of all PCB congeners listed in Table 4-2
- Total Pesticide (also referred to as TP) – sum of concentrations of Aldrin, Dieldrin, Endrin, Hexachlorobenzene, Lindane, and Mirex
- Total DDT (also referred to as TDDT) – sum of concentrations of the six DDT, DDE, and DDD compounds listed in Table 4-2
- Total Chlordane (also referred to as TC) – sum of concentrations of Cis-chlordane, Heptaclor, Heptachlorepoxide, and Trans nonachlor
- Total LAB (also referred to as TLAB) – sum of concentrations of C_{10} – C_{14} LABs listed in Table 4-2

In cases where an individual analyte was not detected, a value of 0.0 was assigned to that analyte.

Mean parameter (*e.g.*, total PAH) values were determined for three categories:

- Station Mean – Average of all station replicates; laboratory replicates were averaged to determine a single value prior to calculation of station means. Station means were determined for each parameter within a given sampling year. Station mean values were used in the chemistry correlation analyses to determine the correspondence within bulk sediment properties and against contaminants in the nearfield and farfield.
- Nearfield Baseline Mean – Average of all nearfield stations including FF10, FF12, and FF13 sampled during August surveys only; each field sample replicate was treated as an individual sample. Nearfield baseline mean values were determined for each parameter within a given sampling year and were used to assess temporal trends in the nearfield from 1992–2000.
- Farfield Baseline Mean – Average of all farfield stations, excluding FF10, FF12, and FF13 sampled during August surveys only; each field sample replicate was treated as an individual sample. Farfield baseline mean values were determined for each parameter within a given sampling year and were used to assess temporal trends in the farfield from 1992–2000.

Yearly "mean values" and 95 % confidence intervals were determined for representative sewage tracers (*e.g*., *Clostridium perfringens*, total LAB) to evaluate the spatio/temporal distribution of sewage tracers at all nearfield and farfield stations from 1992–2000. Yearly mean values were determined as a function of distance from Deer Island Light, as follows:

- Harbor near-in group (< 10 km) – Average of all stations sampled during August surveys and that are within 10 km of Deer Island Light. Stations included all Harbor stations (T01 – T08 and T05A) plus nearfield station NF01 (sampled in 1992 only) and farfield station FF12. These stations are under the general influence of all discharges into the harbor including rivers, effluent, and CSOs.
- Mid-distance group (>10 km but <20 km) – Average of all stations sampled during August surveys and that are more than 10 km but less than 20 km of Deer Island Light. Stations included all nearfield stations plus farfield stations FF10 and FF13. These stations experience substantial influence from the water exchange at the harbor mouth.
- Mid-distance group (> 20 km but < 40 km) – Average of all stations sampled during August surveys and that are more than 20 km but less than 40 km of Deer Island Light. Stations included FF09 and FF14. These stations are generally not under the direct influence of the effluent but experience transport of materials from harbor or other locations.
- Far-distance group (> 40 km) – Average of all stations sampled during August surveys and that are more than 40 km from Deer Island Light. Stations included FF04, FF05, FF06, and FF07. These stations are generally not under the direct influence of the effluent but experience transport of materials from harbor or other locations.

Three farfield stations were excluded from the above listed groupings: FF01 (sampled in 1992 and 1993 only), FF01A (sampled since 1994), and FF11. These three stations are located in the northern part of Massachusetts Bay. Since the long-term transport of sediments and particle associated contaminants along the coast is from north to south (Parmenter and Bothner 1993; Bothner *et al.*, 1994), with some onshore-offshore component, we decided to exclude data from these "upstream" stations. To compare contaminant concentrations between these northern farfield stations and the southern farfield stations, *Clostridium perfringens* concentrations in individual sample replicates (raw and normalized to % fines) were compared between FF01A or FF11 and the farfield stations in the appropriate distance group (Mid-distance group > 20 km but <40 km and Far-distance group, respectively). *Clostridium perfringens* station mean values and the upper 95% means and lower 95% means for both FF01A and FF11 (northern farfield stations) fell within the ranges of values measured at the other farfield stations in each distance group (Table 4-3). The *Clostridium perfringens* normalized values for FF01A were very similar to values measured at FF09 (Table 4-3 and Figure 4-1). FF11 raw and normalized values were similar to those measured at FF06 (within 12% of the station mean value). Therefore, even if these northern stations had been included in their respective distance-group means, it would not be anticipated that these values would significantly lower the distance-group mean values.

Sediment grain size results were evaluated by using ternary plots to visually display the distribution of gravel plus sand, silt and clay in sediment collected from nearfield and farfield stations.

Results from sediment grain size, total organic carbon (TOC), *Clostridium perfringens*, and contaminant analyses were compared from all stations by using histogram plots.

The numerical approximate mean phi, referred to simply as mean phi in the text, was calculated by weighting each class fraction measured and summing the weighted fractions (Table 4-4). These data were calculated and reported by GeoPlan Associates.

Table 4-3. Comparison of *Clostridium perfringens* station mean values (cfu/gdw) between northern (N) and southern (S) farfield stations[a].

Data Type	Parameter	Mid-distance group (> 20 km but < 40 km)		Far-distance group (> 40 km)	
		FF01A (N)	FF09/FF14 (S)	FF11 (N)	FF04 - FF07 (S)
Raw	Station Mean	900	677/1250	1530	800 – 2220
	Upper 95% Mean	1150	800/1460	2060	952 – 2840
	Lower 95% Mean	655	554/1040	1000	648 – 1610
Normalized to %Fines	Station Mean	44	41/16	19	13 – 24
	Upper 95% Mean	50	49/19	27	17 – 30
	Lower 95% Mean	37	33/14	12	9 – 17

[a]Station mean values reported were determined using data for all years.

Table 4-4. An example of numerical approximate mean phi determination.

phi Class	Weight Factor[1]	% Fraction Measured (station FF10[2])	Weighted Fraction[3]
phi<-1	−1.5	22.5	-0.3374
−1<phi<0	−0.5	5.4	-0.027
0<phi<1	0.5	8.27	0.04135
1<phi<2	1.5	14.59	0.2189
2<phi<3	2.5	19.9	0.49742
3<phi<4	3.5	10.5	0.3675
4<phi<8	6	13.17	0.79
phi>8	9	5.7	0.513
Sum of weighted fractions Numerical approximate mean phi[4]			2.06

[1] Weight Factor represents middle of the phi class range
[2] FF10 results presented here represent average data from the triplicate FF10 sample collected from the August 2000 survey
[3] Weighted Fraction = (Weight Factor)*(%Fraction Measure/100)
[4] Numerical approximate mean phi = Sum of weighted fractions

4.2 Results and Discussion

Bulk sediment and contaminant results for all nearfield and farfield samples (August surveys only) were evaluated separately to examine spatial and temporal characteristics. Nearfield and farfield station mean values are reported in Appendix C (bulk sediment — Appendix C-1; organic contaminants — Appendix C-2; metal contaminants — Appendix C-3). All sediment results are discussed in terms of dry weight using station, nearfield baseline, and farfield baseline mean values.

PCA was used to visualize the intersample and intervariable relationships among the sediment chemical data. PCA yields a distribution of samples (*e.g.*, sediment samples) in *n*-dimensional space, where *n* is the number of variables (*e.g.*, PAH). The Euclidean distances between sample points on these factor score plots are representative of the variance captured in each principal component (PC). In simpler terms, samples that cluster together are chemically similar and outliers are chemically distinct. A factor loading is calculated for each variable (*e.g.*, PAH) contributing to each PC. A crossplot of the factor loadings for the first few PCs reveals the individual variables responsible for the variance in each PC.

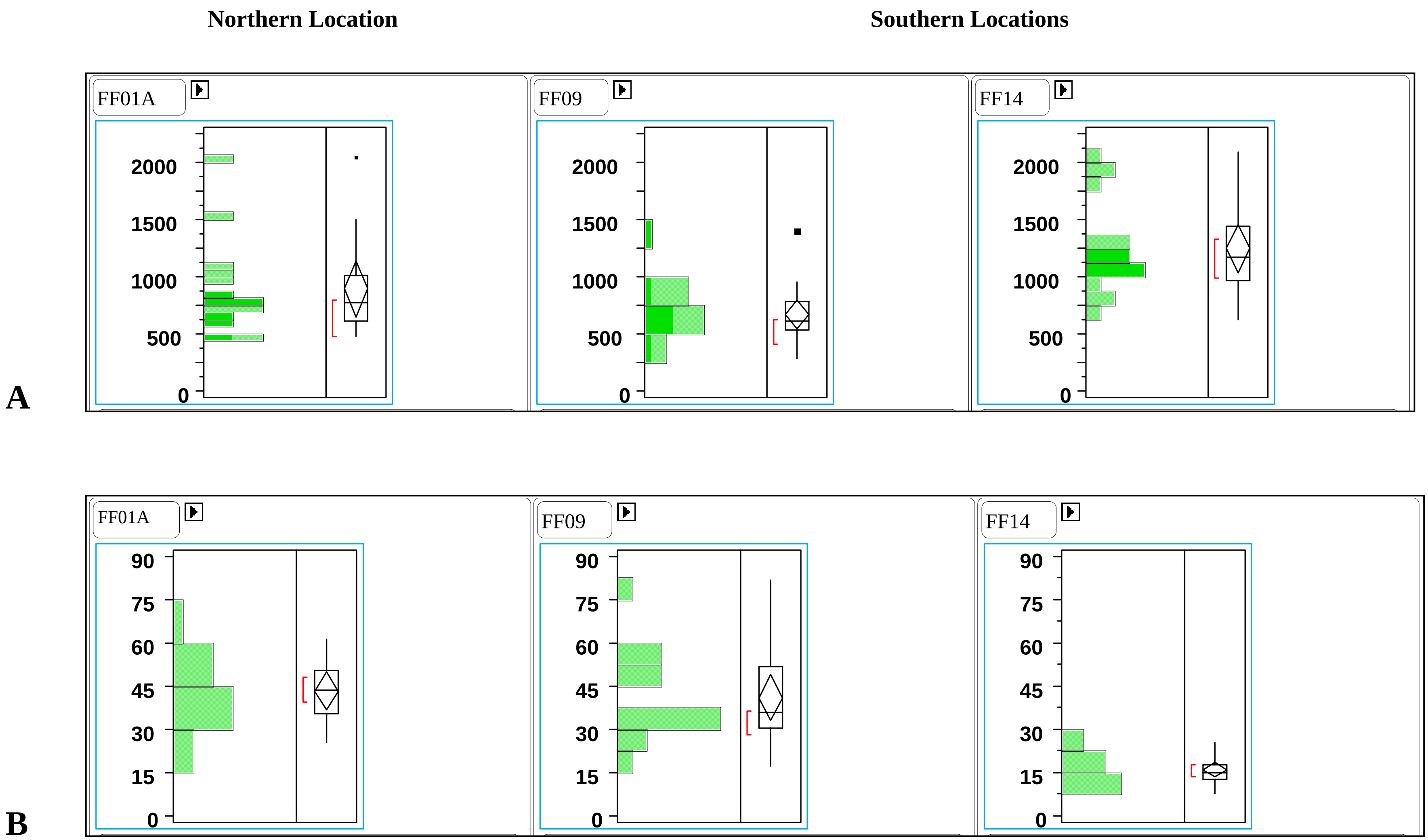

Figure 4-1. Box plots comparing *Clostridium perfringens* individual replicate values (A – raw cfu/g dw and B – normalized to % fines) between northern (FF01A) and southern farfield stations. The quantile box plot shows selected quantities on the response axis. The box shows the median as a line across the middle and the quartiles (25th and 75th percentiles) as its ends. The means diamond identifies the mean of the sample and the 95% confidence interval about the mean.

4.2.1 Nearfield Chemistry 1992–2000

Temporal Characteristics—Nearfield baseline mean values and 95 % confidence intervals were determined for bulk sediment properties, *Clostridium perfringens*, and contaminant parameters as described in Section 4.1.3. With the exception of *Clostridium perfringens* and total LAB, the temporal response of the nearfield baseline for bulk sediment and contaminant parameters showed relatively constant means without substantial variability (see Figure 4-2 for representative parameters). The 95 % confidence intervals generally overlapped across all sampling years, suggesting that the spatial distribution of contaminants was not substantially different over time. 2000 nearfield baseline concentration of TOC was slightly elevated but still within the historical range of concentrations (Figure 4-2 a). Subsequent review of 2000 and 2001 TOC data has revealed that TOC values for selected stations are unusually high (*e.g.*, YR2000 stations FF10, NF14 and NF20; YR2001 stations NF12, NF14 and NF18). YR2001 data are undergoing further review, however YR2000 TOC samples are no longer available for reanalysis and as a result there is no way to verify that these data are suspect. The nearfield baseline means for *Clostridium perfringens* have shown lower abundance and less variability since 1997 and 2000 concentrations were the lowest measured during the baseline period (Figure 4-5b). Trends in *Clostridium perfringens* and total LAB are discussed in greater detail in Section 4.2.3.

Spatial Characteristics-PCA was performed on a multi-year/multi-parameter data set, using individual replicate results from August surveys only, to determine if the spatial distribution of bulk sediment and contaminant parameters in 2000 was substantially different from 1992-1999 patterns. Physical and chemical data from all nearfield stations including FF10, FF12, and FF13 were evaluated (Figure 4-3). The chemical data were divided by the fractional percentage of fine particles in an attempt to normalize the effect of sediment properties on the distribution of contaminant parameters (Figure 4-4). The physical and chemical parameters included in the data set were sand, silt, clay, TOC, Clostridium perfringens (CPERF), total PAH (TPAH), total PCB (TPCB), total DDT (TDDT), total LAB (TLAB), and metals (Al, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Ag, Zn). PCA can only be performed on a common set of parameters. Data from 1996, 1997, and 1998 (August surveys) were excluded from the PCA because a complete set of common parameters (*i.e.*, contaminants) was not available. In addition, contaminant data for 2000 were only available for NF08, NF12, NF17, NF24, FF10, FF12, and FF13.

In summary, the PCA results revealed a trend in the sample data that resembled a dilution curve driven primarily by the relative abundance of sand and selected metals; predominantly, Cr, Zn, Pb, Cu, and Ni (Figure 4-3). The majority of the samples in the data set grouped in the upper left corner due to higher sand and lower contaminant levels. This sample grouping spread and thinned towards the lower right as the sand content decreased and the contaminant level rose (Figure 4-3a). The locations that separated most clearly from the dense sample group were NF08, NF02, NF12, and NF24. The samples collected in 2000 plotted relatively near samples collected from the same location between 1992 and 1999. The close proximity of samples from the same location indicated a similar chemical and physical composition that remained constant over period in which samples were collected.

When normalized to percent fines (clay plus silt), the differences in metals composition became more apparent (Figure 4-4). Figure 4-4a presents a tight cluster of samples in quadrant 3 containing a large majority of samples. The normalization procedure pulled the more distinct locations from Figure 4-3 back into the larger sample group. By contrast, samples from location NF17 were most chemically distinct over multiple years due to higher Cr and lower Pb relative to Zn. Other sampling locations diverted from the larger sample grouping, but these deviations did not include samples collected in 2000; consequently, no major changes were evident during the 2000 sampling season.

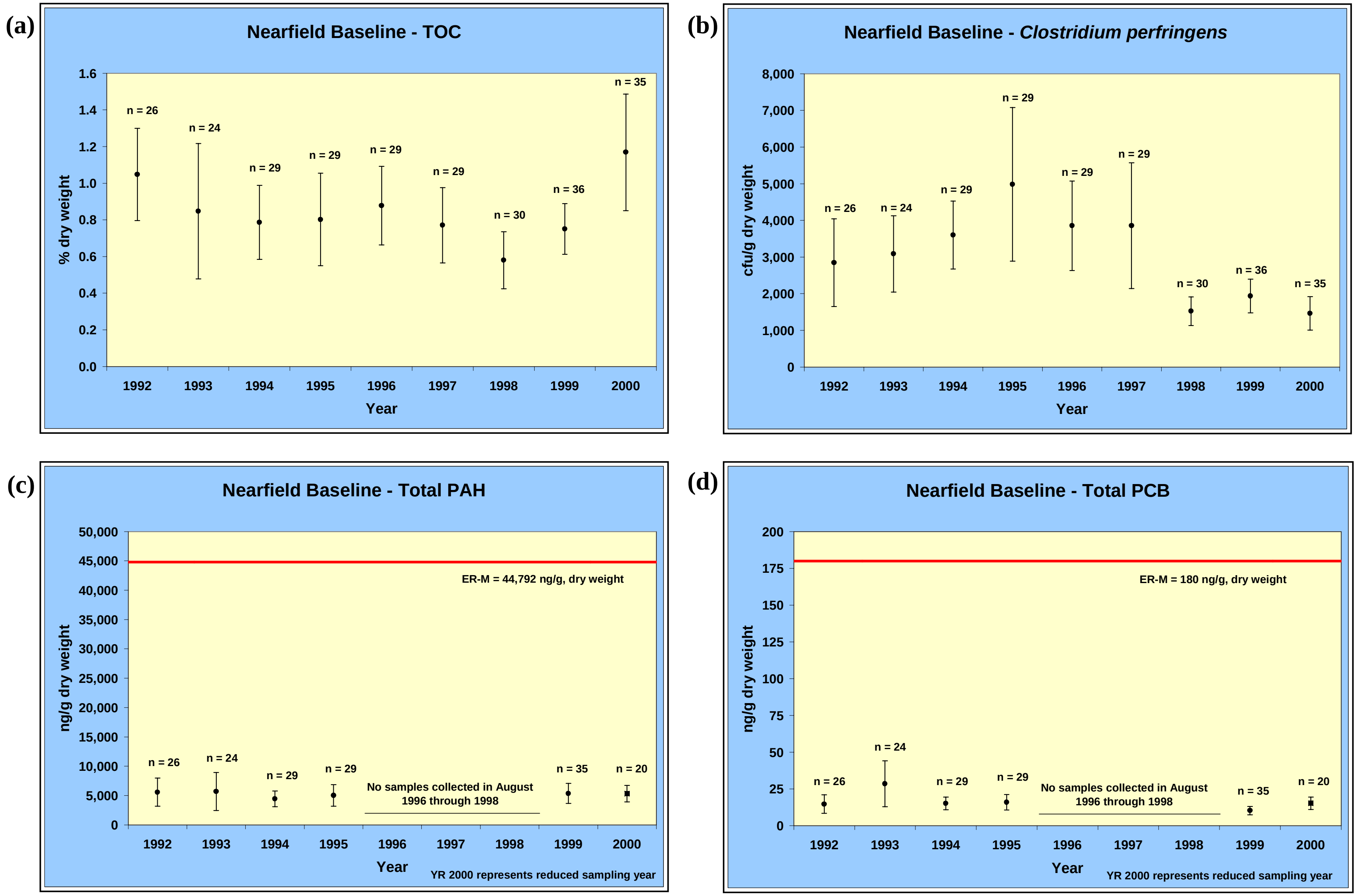

Figure 4-2. Nearfield baseline from 1992 to 2000 for TOC, *Clostridium perfringens*, total PAH, and PCB. Error bars depict 95% confidence intervals. Monitoring thresholds based on Long *et al*. (1995) ER-M values as defined by MWRA.

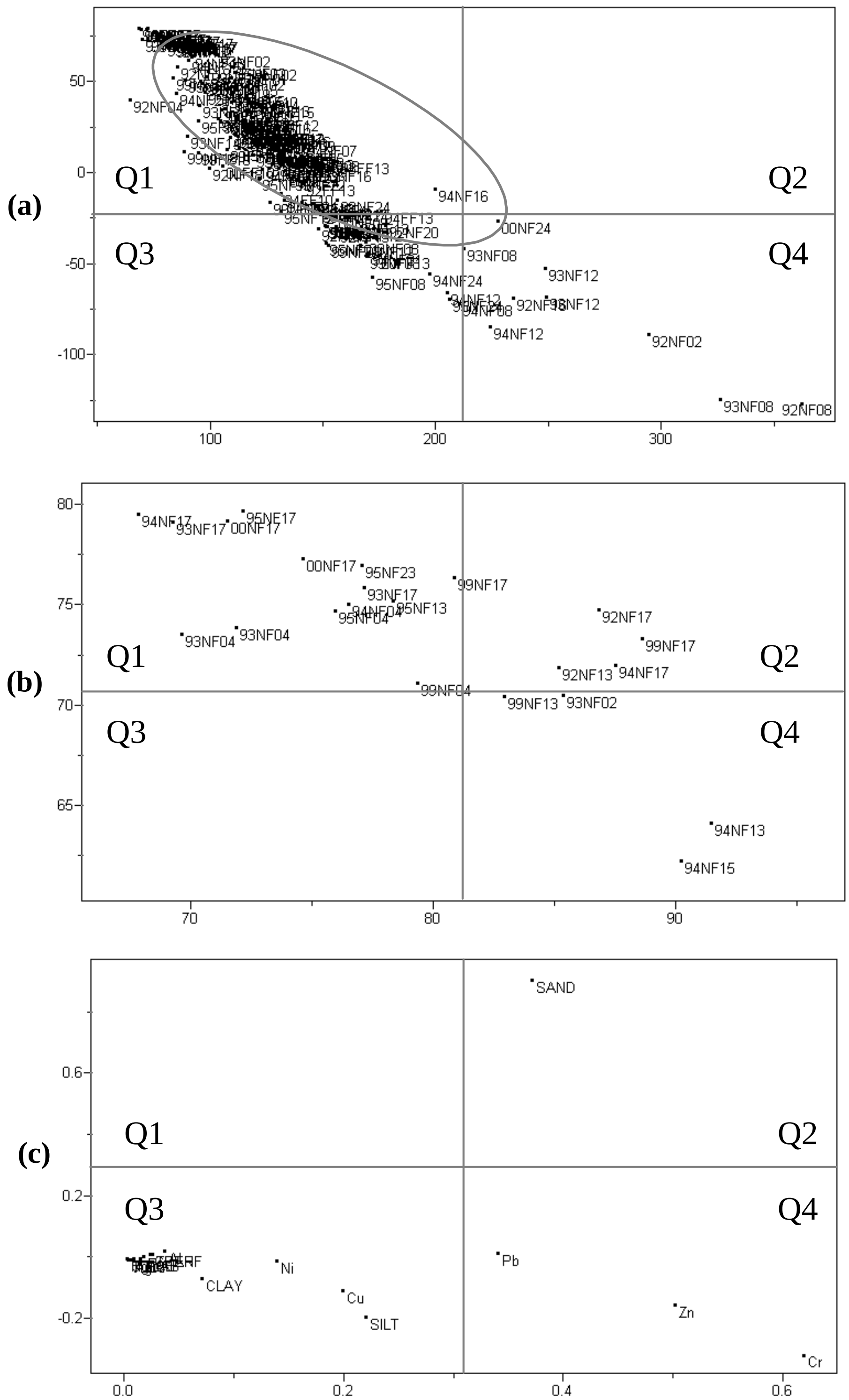

Figure 4-3. Results from principal components analysis of the nearfield plus farfield stations FF10, FF12, FF13 from 1992 to 2000: (a) factor score plot showing the distribution of stations, (b) magnified view of the stations grouped in quadrant Q1, and (c) factor loading plots with principal components. Factor 1 (x-axis) and 2 (y-axis) accounted for 88% and 9% of the variability, respectively. All samples collected in 2000 are contained in the circle.

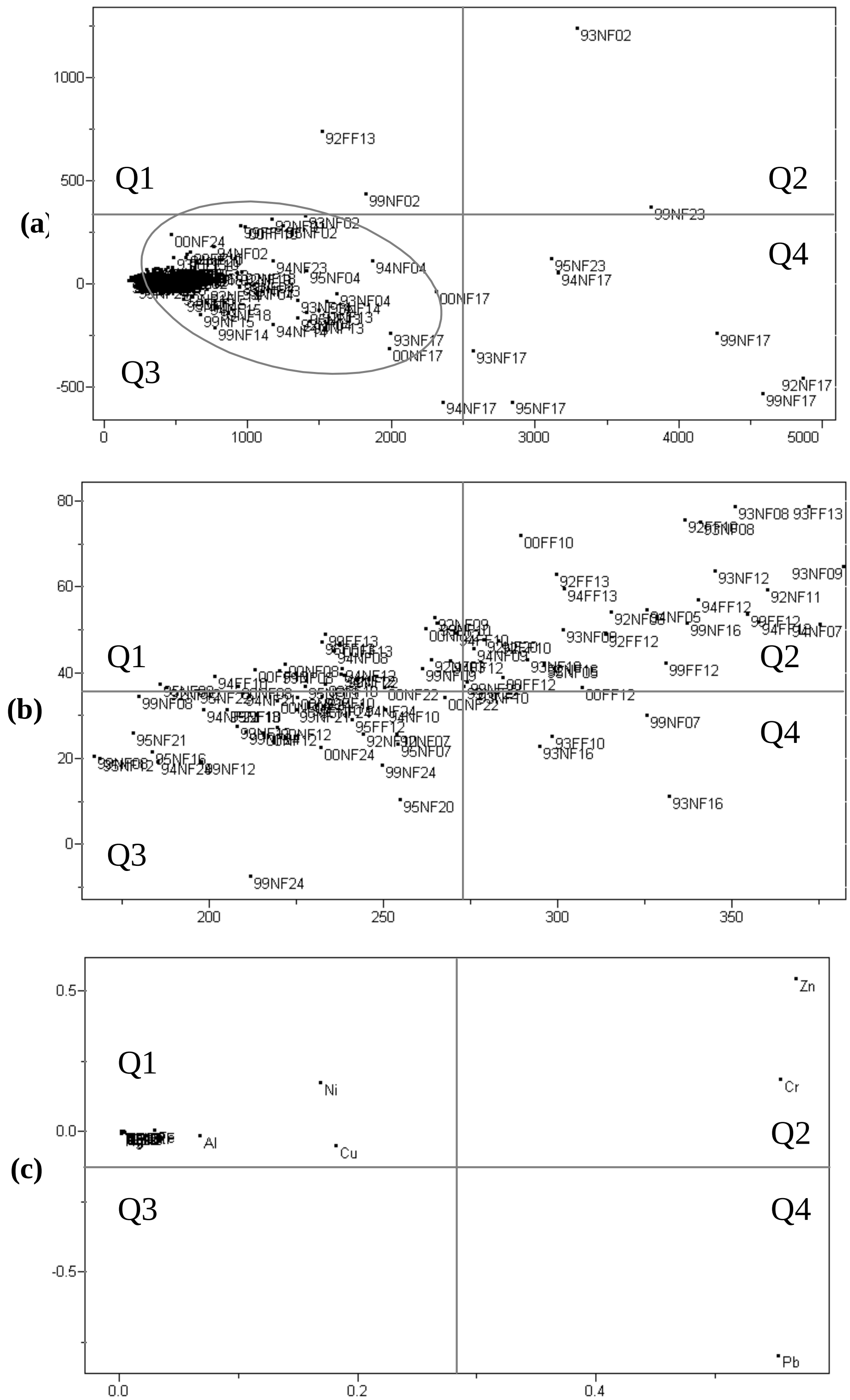

Figure 4-4. Results from principal components analysis of the nearfield plus farfield stations FF10, FF12, FF13 normalized to percent fines from 1992 to 2000: (a) factor score plot showing the distribution of stations, (b) magnified view of the stations grouped in quadrant Q1, and (c) factor loading plots with principal components. Factor 1 (x-axis) and 2 (y-axis) accounted for 96% and 2% of the variability, respectively. All samples collected in 2000 are contained in the circle.

4.2.2 Farfield Chemistry 1992–2000

Temporal Characteristics—Farfield baseline mean values and 95 % confidence intervals were determined for bulk sediment properties, *Clostridium perfringens*, and contaminant parameters as described in Section 4.1.3. Farfield baseline mean values for organic and some metal (Hg, Ag, Cu, Cd) contaminants were consistently less than nearfield baseline mean values. Farfield baseline mean values for Pb and Cr were fairly similar to nearfield baseline mean values. In contrast, farfield baseline mean values for Al, Fe, Ni, and Zn were generally higher, with Ni being 20–50 % higher than nearfield baseline mean values.

With few exceptions (gravel, *Clostridium perfringens*), the temporal response of the baseline for bulk sediment and contaminant parameters showed fairly constant means without substantial variability (see Figure 4-5 for representative parameters). The 95 % confidence intervals generally overlapped across all sampling years, suggesting that the spatial distribution of contaminants was not substantially different between sampling years. The farfield baseline mean values for *Clostridium perfringens* were more variable across all sampling years (Figure 4-5b). Farfield baseline means in 1995–1997 were generally higher compared to yearly mean values determined in 1992–1994 and 1998–2000. 2000 farfield baseline means appeared to continue a downward trend since 1997. Trends in *Clostridium perfringens* are discussed in greater detail in Section 4.2.3.

Spatial Characteristics-PCA was performed on a multi-year/multi-parameter data set, using individual replicate results from August surveys only, to determine if the spatial distribution of bulk sediment and contaminant parameters in 2000 was substantially different from 1992-1999 patterns. Physical and chemical data from all farfield stations including NF12, NF17, and NF24 were evaluated (Figure 4-6). The physical and chemical parameters included in the data set were sand, silt, clay, TOC, Clostridium perfringens (CPERF), total PAH (TPAH), total PCB (TPCB), total DDT (TDDT), total LAB (TLAB), and metals (Al, Cd, Cr, Cu, Fe, Pb, Hg, Ni, Ag, Zn). PCA can only be performed on a common set of parameters. Data from 1996, 1997, and 1998 (August surveys) were excluded from the PCA because a complete set of common parameters (*i.e.*, contaminants) was not available. The only farfield stations sampled in 2000 were FF10, FF12, and FF13. These stations were located in close proximity with the nearfield samples and were discussed with these samples in Section 4.2.1.

As demonstrated previously for the nearfield data, the PCA results revealed a trend in the sample data that resembled a dilution curve driven primarily by the relative abundance of sand and selected metals; predominantly, Cr, Zn, Pb, Cu, and Ni (Figure 4-6). Samples with high sand and low contaminant levels grouped in the upper left corner of Figure 4-6a. By contrast, samples with lower sand and higher contaminant levels grouped in the bottom right. The sand content of NF17 and NF12 generally represented the high and low extremes, respectively. The majority of the farfield samples spanned quadrants 3 and 4. Farfield sample locations FF01 and FF09 plotted in quadrant 1 largely because these samples contained more sand. In general, the physical and chemical measurements by sample location were relatively consistent during the 1992 to 1999 period.

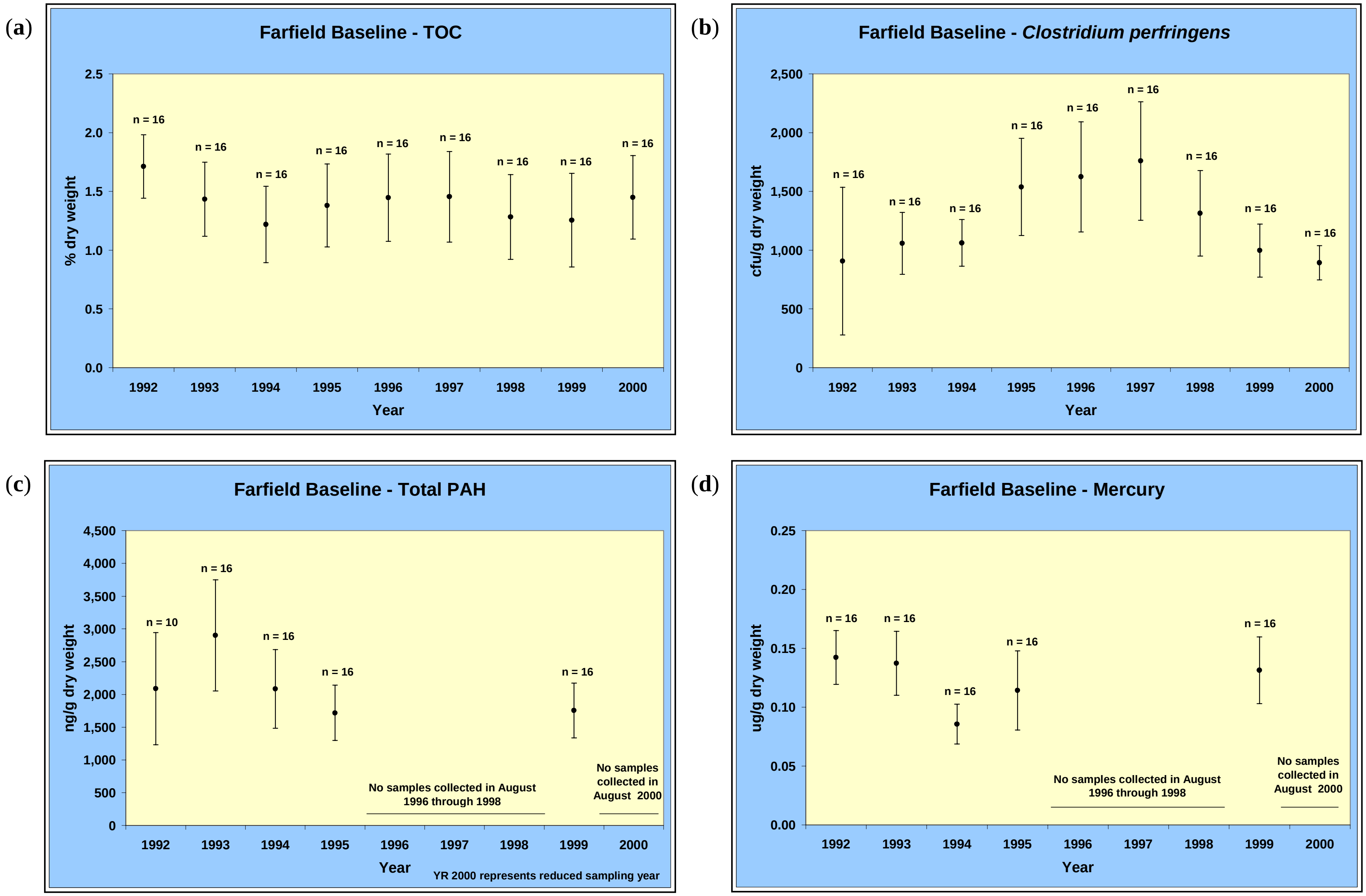

Figure 4-5. Farfield baseline from 1992 to 2000 for TOC, *Clostridium perfringens*, total PAH, and mercury. Error bars depict 95% confidence intervals.

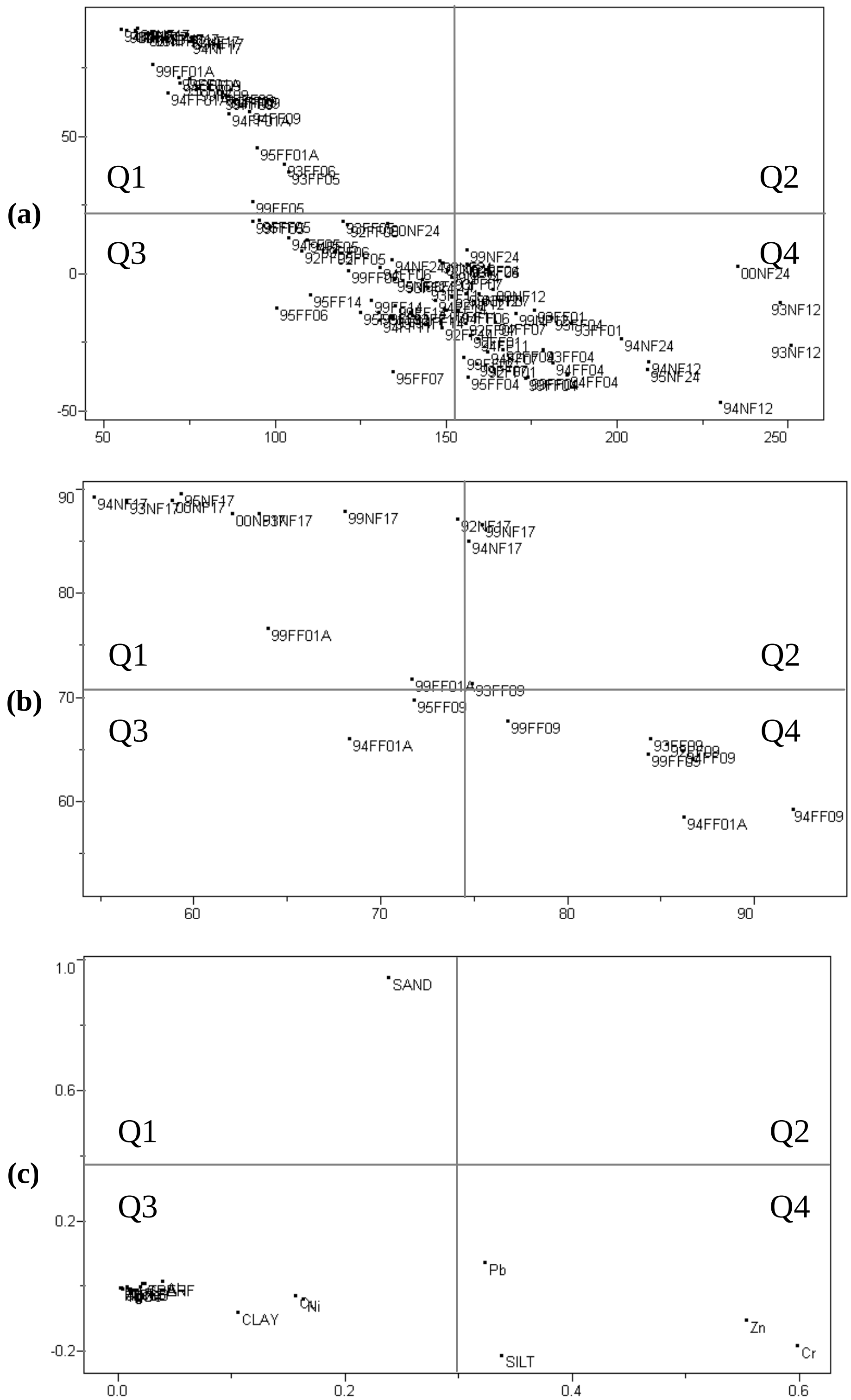

Figure 4-6. Results from principal components analysis of the farfield stations plus NF12, NF17, and NF24 from 1992 to 2000: (a) factor score plot showing the distribution of stations, (b) magnified view of the stations grouped in quadrant Q1, and (c) factor loading plots with principal components. Factor 1 (x-axis) and 2 (y-axis) accounted for 89% and 8% of the variability, respectively.

4.2.3 Spatio/Temporal Response of Sewage Tracers 1992–2000

The spatio/temporal distribution of *Clostridium perfringens* at all nearfield and farfield (excluding northern farfield stations FF01, FF01A, and FF11) stations from 1992–2000 (August surveys only) was evaluated to determine if the gradient in *Clostridium perfringens* observed by USGS (Parmenter and Bothner 1993) is consistent or has changed as harbor cleanup has proceeded. The USGS study observed decreasing spore density (normalized to percent fines) in bottom sediments with distance from Boston Harbor.

The gradient in *Clostridium perfringens* densities (raw and normalized to percent fines) with distance from Boston Harbor (defined as the Deer Island Light) was evaluated for the period 1992–2000. Each sampling year showed trends consistent with USGS findings and indicated that *Clostridium perfringens* densities decreased with distance from Boston Harbor. *Clostridium perfringens* showed a trend toward decreasing abundance in 1998–2000 from earlier years (see Figure 4-7 for representative years). There is a wide range in abundance of *Clostridium perfringens* for stations within 20 km of Deer Island Light (Figure 4-7). In contrast, stations further away from Deer Island Light consistently have lower spore densities (Figure 4-7). Variability in abundance of *Clostridium perfringens* at stations further from Deer Island Light decreased when results were normalized to percent fines, indicating that grain size is likely a major controlling factor (Figure 4-7) in addition to proximity to source.

Clostridium perfringens results were re-evaluated based on four distance classifications including a Harbor near-in group (<10 km), two mid-distance groups (>10 km but <20 km and >20 km but <40 km) and a far-distance group (>40 km) from Deer Island Light. Yearly means (raw and normalized to percent fines) and 95 % confidence intervals were determined for the four distance classifications. Yearly means values of *Clostridium perfringens* (normalized to percent fines) for near-in stations (<20 km) showed a decrease in abundance in 1998–2000 relative to earlier years (Figure 4-8 a,c). In contrast, stations further away from Deer Island Light (>20 km) were less variable from 1992–2000 (Figure 4-8 a,c). The constancy in results within distance classifications after normalization to fine grained sediments supports expectations (Parmenter and Bothner 1993) that *Clostridium perfringens* spores are preferentially attached to fine grained particles and are transported with fine sediments. The decreasing abundance observed in 1998–2000 for near-in stations (<20 km) does not appear to be method related,[1] as the yearly means for all distance categories did not decrease equally. Instead, the trend toward decreasing abundance was most notable for stations within 20 km of Deer Island Light.

Clostridium perfringens abundance in 1998–2000 for near-in stations (<20 km) did decrease by more than 30% from abundances measured in earlier years. Further, Harbor wide concentrations of *Clostridium perfringens* also showed decreasing abundance in 1998–2000 compared to 1996–1997 values (Kropp *et*

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[1] MTH Environmental Associates, the laboratory that performed the *Clostridium perfringens* analyses, was contacted to help address the following questions:

- *Have the methods used to determine spore densities changed from earlier years?*
- *What is the likely inter-laboratory variability and what level of differences would be considered "real?"*

MTH verified that the methods used to determine spore densities have not changed from earlier years. MTH indicated that there have been no studies looking at the issue of inter-laboratory variability with regard to *Clostridium perfringens* levels in marine sediments. However, based on MTH's experience with marine sediments, observed decreases in abundance of 30% or more do suggest "real differences" in the system provided that samples have been collected and analyzed consistently over time.

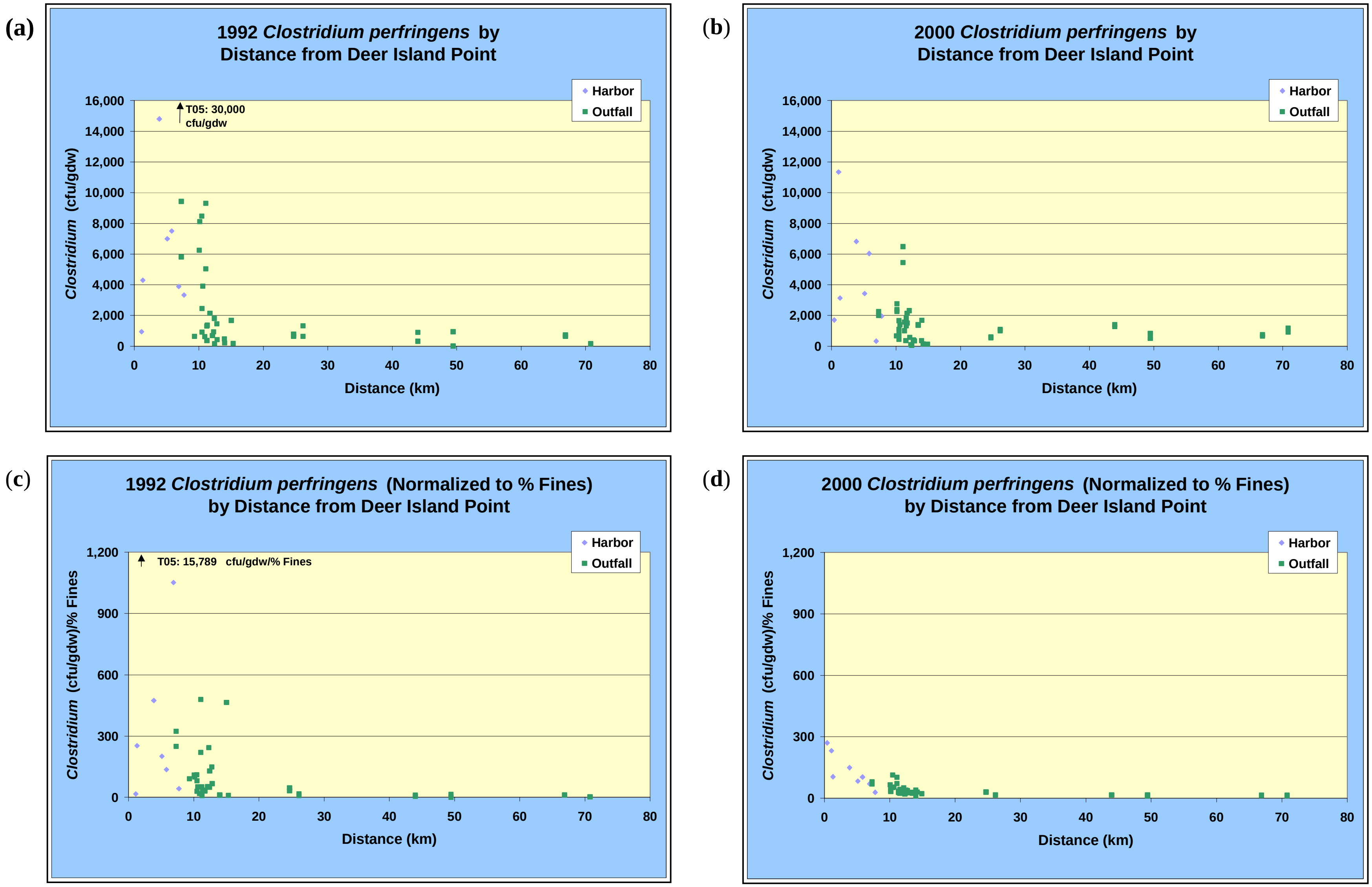


Figure 4-7. Distribution of *Clostridium perfringens* (raw and normalized to percent fines) with distance from Deer Island Light in 1992 and 2000.

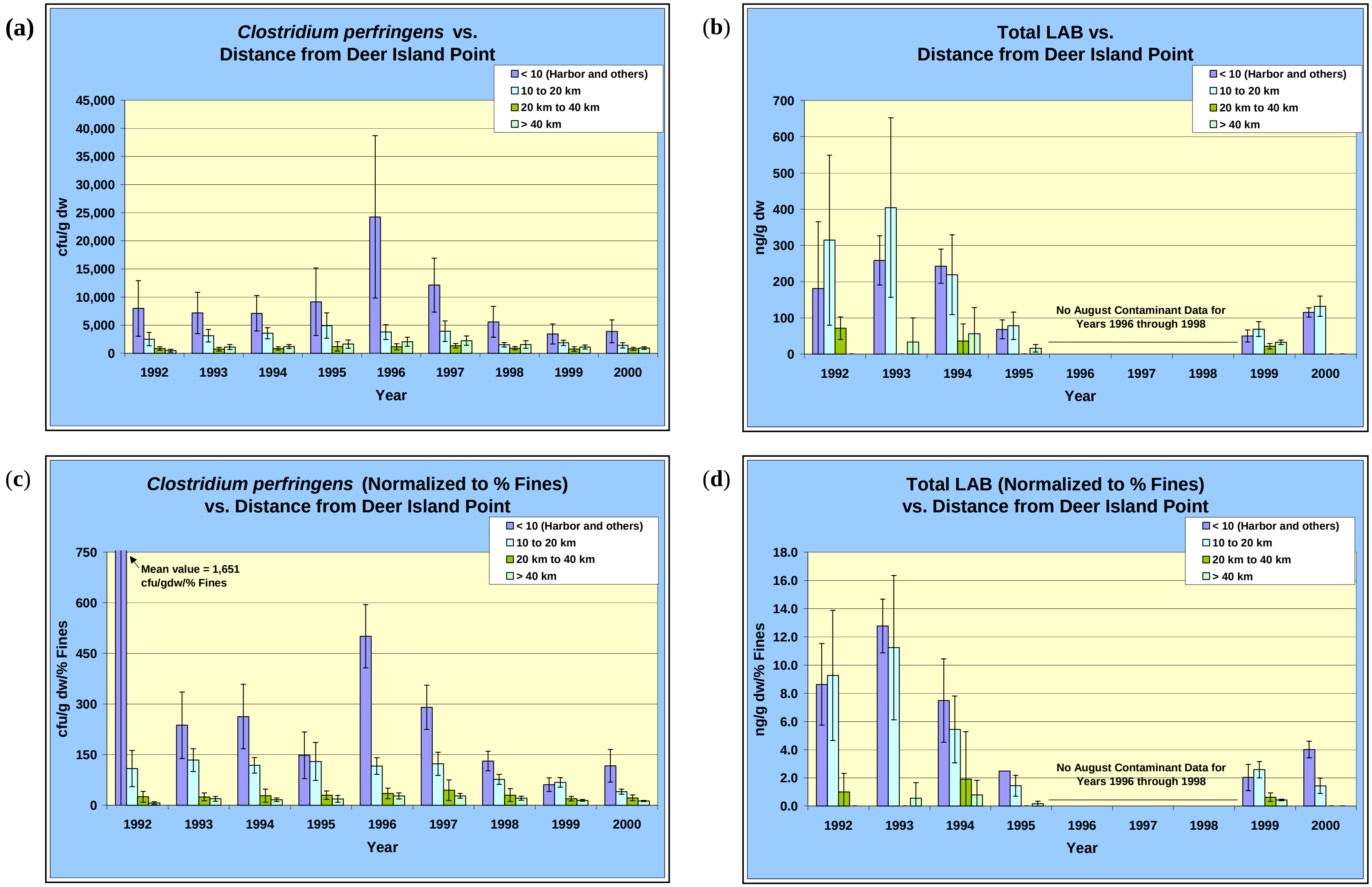


Figure 4-8. Yearly mean concentrations of *Clostridium perfringens* and total LAB (raw and normalized to percent fines) by distance classification from Deer Island Light (1992–2000). Error bars depict 95% confidence intervals.

al., 2000). Thus, the decreasing abundance of *Clostridium perfringens* suggesting that the documented reductions in effluent solids loading during the 1990s (Werme and Hunt, 2001) also reflect a reduction in *Clostridium* spore loads that is being seen in nearby sediments.

Further, trends in another effluent marker, total LAB, strengthen this observation. Concentrations of total LAB measured at near-in stations (<20 km) decreased markedly (60 to 80%) in 1995 compared to previous years; with sustained lower concentrations observed in 1999 and 2000 (Figure 4-8 b,d). While primary treatment came on-line in 1995, there is no clear evidence that it resulted in the marked decrease in total LAB concentrations. The largest decrease in LAB loadings to the Harbor occurred in the late 1980s and early 1990s when Proctor and Gambel installed pretreatment equipment to cleanup their industrial discharge to the south system (*i.e.*, reduction in surfactant loadings to the influent) and subsequently closed their plant (personal communication with Ken Keay, 2002). The observed decrease in 1995 may therefore be attributed to a combination of removal of discharge from the Harbor (*i.e.*, Proctor and Gambel discharge), facility improvements, and natural attenuation. Silver, another sewage tracer, was fairly constant over time and did not show the marked decrease observed with *Clostridium perfringens* and total LAB.

4.2.4 Chemistry Interrelationships

The correspondence within bulk sediment properties and against contaminants was evaluated for all nearfield and farfield stations (August surveys only) by using correlation analysis.

Nearfield—Station mean values for nearfield stations were used in the correlation analysis and the results are presented in Table 4-5. Grain size correlated strongly with TOC across all years ($r = 0.774$, $n = 112$, $p < 0.01$). Bulk sediment properties also correlated well with organic and metal contaminants across all years (Table 4-5, Figure 4-9). The correlation between contaminants and bulk sediment properties (percent fines, TOC) were generally similar, with correlations against TOC being slightly higher overall.

Table 4-5. Correspondence within bulk sediment properties and against contaminants in the nearfield, 1992–2000 (including farfield stations FF10, FF12, and FF13).

Parameter	Correspondence with Percent Fines			Correspondence with TOC		
	r	*n*	*p*	*r*	*n*	*p*
Percent Fines	1.000	112	<0.01	0.774	112	<0.01
TOC	0.774	112	<0.01	1.000	112	<0.01
Clostridium perfringens	0.626	112	<0.01	0.598	112	<0.01
Total PAH	0.657	112	<0.01	0.712	112	<0.01
Total PCB	0.701	112	<0.01	0.791	112	<0.01
Total DDT	0.713	112	<0.01	0.732	112	<0.01
Total LAB	0.528	112	<0.01	0.675	112	<0.01
Al	0.625	112	<0.01	0.555	112	<0.01
Cd	0.679	112	<0.01	0.767	112	<0.01
Cr	0.822	112	<0.01	0.865	112	<0.01
Cu	0.715	112	<0.01	0.864	112	<0.01
Fe	0.669	112	<0.01	0.698	112	<0.01
Pb	0.713	112	<0.01	0.858	112	<0.01
Hg	0.712	112	<0.01	0.793	112	<0.01
Ni	0.808	112	<0.01	0.771	112	<0.01
Ag	0.692	112	<0.01	0.785	112	<0.01
Zn	0.781	112	<0.01	0.858	112	<0.01

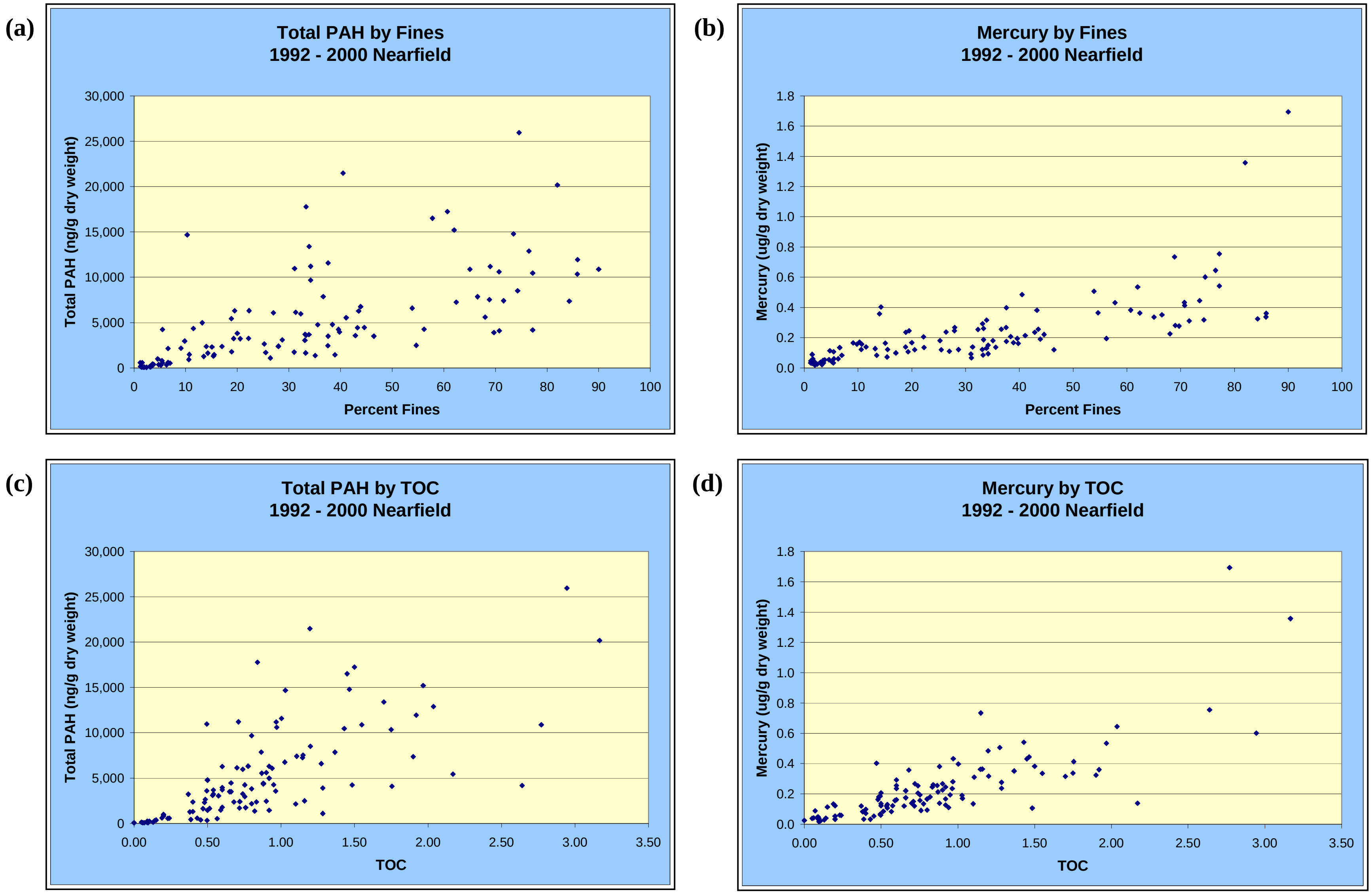


Figure 4-9. Correspondence between bulk sediment properties and representative contaminants (total PAH, mercury) in the nearfield from 1992 to 2000.

The correlation coefficients for total LAB, Cu, and Pb were notably stronger (20–28 % higher *r* value) when the correlation was performed against TOC as compared to grain size. The evaluation confirms that the contaminant variability in the nearfield is dominated by grain size and TOC.

Farfield—Station mean values for farfield stations (including stations NF12, NF17, and NF24) were used in the correlation analysis and the results are presented in Table 4-6. Grain size and TOC were strongly correlated ($r = 0.923$, $n = 98$, $p < 0.01$). Although the regression coefficients were high, the correspondence between bulk sediment properties and most contaminants (exceptions include Al, Fe, Ni, and Zn) was generally not as strong as the correspondence observed in the nearfield. This suggests perhaps that the concentrations in the farfield are influenced by factors other than the proximity to source and depositional properties of the station.

Table 4-6. Correlation coefficients within bulk sediment properties and against contaminants in the farfield 1992–2000 (excluding FF10, FF12, FF13; including NF12, NF17, and NF24).

Parameter	Correspondence against Percent Fines			Correspondence against TOC		
	r	***n***	***p***	***r***	***n***	***p***
Percent Fines	1.000	98	<0.01	0.923	98	<0.01
TOC	0.923	98	<0.01	1.000	98	<0.01
Clostridium perfringens	0.362	98	<0.01	0.394	98	<0.01
Total PAH	0.336	57	<0.05	0.312	57	<0.05
Total PCB	0.485	57	<0.01	0.542	57	<0.01
Total DDT	0.543	57	<0.01	0.531	57	<0.01
Total LAB	0.158	57	>0.05	0.208	57	>0.05
Al	0.734	57	<0.01	0.744	57	<0.01
Cd	0.516	57	<0.01	0.627	57	<0.01
Cr	0.715	57	<0.01	0.761	57	<0.01
Cu	0.577	57	<0.01	0.619	57	<0.01
Fe	0.836	57	<0.01	0.914	57	<0.01
Pb	0.556	57	<0.01	0.640	57	<0.01
Hg	0.333	57	<0.05	0.400	57	<0.01
Ni	0.847	57	<0.01	0.913	57	<0.01
Ag	0.469	57	<0.01	0.491	57	<0.01
Zn	0.832	57	<0.01	0.901	57	<0.01

4.2.5 Contaminant Special Study 1998–2000

Contaminant Special Study surveys were conducted in October 1998, August 1999, August 2000, and October 2000. Sediment samples were collected in triplicate at NF08, NF22, NF24, and FF10 to address possible short-term transport and impact with a focus on high TOC/depositional areas. The October 2000 sampling represented the first post-discharge sampling event.

Bulk sediment and contaminant results from the replicate analyses of sediment samples are reported in Table 4-7 and Appendix C. Data are presented as station mean values and standard deviation of the triplicate analyses. All results are reported on a dry weight basis to three significant figures.

Table 4-7. Contaminant special study bulk sediment and contaminant parameters determined from 1998 to 2000.

Station	Sampling Event	Units	Total PAH[b,c] ng/g	Total PCB[b] ng/g	Total DDT[b] ng/g	Total Chlordane[b] ng/g	Total Pesticide[b] ng/g	Total LAB[b] ng/g	Dieldrin ng/g	Al pct	Cd µg/g	Cr µg/g	Cu µg/g	Fe pct	Pb µg/g
		ER-M[a]	44792	180	46.1	6 [d,e]	NA	NR	8	NR	9.6	370	270	NR	218
NF08	Oct-98	Mean	6760	26.9	11	0.681	0.737	290	0.329	5.79	0.244	115	31.7	2.73	49.3
		Stdev	2350	7.14	10.7	0.123	0.24	53.3	0.0604	0.255	0.0599	15.1	3.93	0.164	3.5
	Aug-99	Mean	7400	18.7	6.32	0.378	0.0824	128	ND	5.52	0.221	95.4	32.4	2.61	50.9
		Stdev	1480	6.48	7.01	0.0782	0.0736	22.2	ND	0.387	0.0363	20.6	7.6	0.166	6.22
	Aug-00	Mean	7850	25.5	3.89	0.497	0.661	168	0.499	5.47	0.222	108	35	2.64	52
		Stdev	1460	6.9	1.12	0.201	0.0803	35.1	0.119	0.135	0.0696	7.05	2.51	0.0416	5.77
	Oct-00	Mean	6770	14.5	2.29	0.336	0.443	81.4	0.345	6.57	0.396	124	36.1	2.7	52.3
		Stdev	6170	16.8	2.39	0.352	0.338	99	0.271	0.252	0.105	26.4	3.25	0.0569	7.46
NF22	Oct-98	Mean	3900	11.1	2.51	0.266	0.141	184	0.129	5.9	0.107	73.4	21.8	2.57	40
		Stdev	705	2.68	0.443	0.0573	0.122	18.9	0.112	0.0208	0.0198	8.78	2.68	0.0839	2.9
	Aug-99	Mean	4430	11.7	2.56	0.238	0.176	91.3	0.176	6.01	0.109	74	25.4	2.66	45.9
		Stdev	606	2.45	0.389	0.206	0.306	8.27	0.306	0.224	0.00613	8.75	2.75	0.0814	1.51
	Aug-00	Mean	3560	12.8	1.88	0.246	0.429	142	0.259	5.25	0.122	73.1	24.7	2.63	44.7
		Stdev	997	2.35	0.396	0.0934	0.124	10.5	0.00793	0.221	0.0255	5.17	2.29	0.0666	2.64
	Oct-00	Mean	3860	10.3	1.64	0.212	0.338	80.78	0.267	5.69	0.206	73.7	25.8	2.49	46.8
		Stdev	389	0.351	0.61	0.01	0.0424	14.83	0.0219	0.3	0.0299	11.2	3.39	0.04	8.06
NF24	Oct-98	Mean	17100	20.7	3.96	0.274	0.227	191	0.181	5.74	0.108	95.1	31.2	2.52	55.4
		Stdev	20200	9.79	2.01	0.266	0.283	54.8	0.243	1.04	0.0686	56.2	9.58	0.803	23.5
	Aug-99	Mean	7260	12.6	6.28	0.127	ND	72.7	ND	5.74	0.103	83	32.9	2.73	68.3
		Stdev	805	0.694	6.77	0.22	ND	15.4	ND	0.371	0.0188	9.14	2.42	0.0819	9.76
	Aug-00	Mean	6580	15.2	2.67	0.269	0.316	131	0.289	5.72	0.104	80.4	28.6	2.48	53.1
		Stdev	1510	2.03	0.741	0.0473	0.0555	4.83	0.0523	0.223	0.00983	9.94	4.46	0.217	9.34
	Oct-00	Mean	7900	13.6	1.34	0.255	0.295	83.51	0.176	6.57	0.198	71	27.4	2.35	59.3
		Stdev	1320	0.571	0.386	0.0421	0.204	5.10	0.158	0.739	0.00964	17.3	4.94	0.116	8.52
FF10	Oct-98	Mean	2120	5.88	2.22	0.103	0.00617	79.2	ND	5.32	0.0646	70.1	15.1	1.83	31.4
		Stdev	135	1.87	1.9	0.09	0.0107	12.6	ND	0.0208	0.064	8.33	2.93	0.109	1.51
	Aug-99	Mean	3230	2.62	0.587	0.0281	ND	25.6	ND	5.07	0.0713	56.9	20.6	2.05	28.5
		Stdev	1930	0.448	0.302	0.0487	ND	14.2	ND	0.335	0.0104	11.4	10.8	0.311	3.03
	Aug-00	Mean	5440	5.43	1.2	0.185	0.313	54.1	0.197	5.26	0.0814	62.9	13.9	2.53	29.5
		Stdev	1500	1.69	0.413	0.0569	0.206	23.5	0.0441	0.264	0.0356	7.98	1.08	0.219	0.35
	Oct-00	Mean	5840	19.2	2.97	0.471	0.508	95.73	0.4	5.09	0.153	58.8	13.6	1.96	31.6
		Stdev	3430	12.7	2.09	0.337	0.267	66	0.208	0.34	0.00404	19.7	1.46	0.109	1.45

Table 4-7. Contaminant special study bulk sediment parameters and contaminant determined from 1998 to 2000. (cont.)

Station	Sampling Event	Units	Hg µg/g	Ni µg/g	Ag µg/g	Zn µg/g	Sand pct	Gravel pct	Silt pct	Clay pct	Fines[b] pct	Mean phi pct	TOC pct	*Clostridium* cfu/gdw
		ER-M	0.71	51.6	3.7	410	NR	NR	NR	NR	NR	NR	NR	NR
NF08	Oct-98	Mean	0.344	21.7	0.901	79.6	48.5	1.7	38.6	11.1	49.8	4.71	1.31	4590
		Stdev	0.0485	0.48	0.17	9.22	13.8	2.94	13.8	2.85	16.7	0.818	0.275	361
	Aug-99	Mean	0.311	19.1	0.918	79.4	26.3	2.03	59.6	12	71.6	5.48	1.11	3660
		Stdev	0.0849	4.05	0.223	15.2	6.53	3.44	3.65	2.85	5.19	0.201	0.285	1150
	Aug-00	Mean	0.351	24.2	0.916	78.4	33.4	0.0778	53.3	13.2	66.5	5.35	1.37	2460
		Stdev	0.119	2.19	0.249	4.3	4.05	0.107	3.48	2.4	4.15	0.126	0.254	267
	Oct-00	Mean	0.356	25	0.903	88	30.4	3.13	51.9	14.5	66.4	5.26	1.39	5620
		Stdev	0.0597	1.79	0.185	10.6	4.82	5	1.99	0.839	2.8	0.271	0.124	1290
NF22	Oct-98	Mean	0.351	19.8	0.593	63.4	51.8	2.5	34.6	11.1	45.8	4.5	0.693	3230
		Stdev	0.0695	3.1	0.101	3.35	1.28	4.07	5.18	0.777	5.27	0.483	0.19	534
	Aug-99	Mean	0.381	23.2	0.66	65.6	52.8	3.97	32.2	11.1	43.3	4.33	0.88	2660
		Stdev	0.112	2.66	0.096	1.01	3.66	3.6	3.76	1.93	5.47	0.325	0.171	315
	Aug-00	Mean	0.236	25.5	0.498	64.8	54.5	2.63	30.1	12.8	42.9	4.28	0.963	1620
		Stdev	0.0479	2.09	0.021	2.72	3.35	1.46	2.33	0.702	3.02	0.166	0.131	269
	Oct-00	Mean	0.29	21.7	0.49	68.2	49.2	0.833	37.7	12.2	50	4.73	0.957	3730
		Stdev	0.0207	1.15	0.014	3.2	2.25	0.503	1.4	0.681	1.94	0.082	0.042	87.4
NF24	Oct-98	Mean	0.322	19.9	0.698	72.3	38.7	0.667	46.1	14.5	60.6	5.06	1.07	2610
		Stdev	0.179	7.8	0.427	28.4	34.7	0.833	28.9	8.38	35.5	1.52	0.51	1760
	Aug-99	Mean	0.362	24.2	0.488	79.1	37.5	0.167	47.7	14.7	62.4	5.18	1.15	2140
		Stdev	0.0889	2.7	0.04	5.77	4.28	0.289	5.88	2.72	4.16	0.101	0.058	354
	Aug-00	Mean	0.507	23.1	0.373	136	45.9	0.2	39.6	14.3	53.9	4.85	1.27	1370
		Stdev	0.44	0.79	0.109	105	6.97	0.2	4.77	2.1	6.86	0.322	0.127	25.2
	Oct-00	Mean	0.275	20.4	0.278	70.1	49.4	0.233	38	12.4	50.4	4.71	1.05	2830
		Stdev	0.0378	0.7	0.033	6.89	2.38	0.252	1.65	0.872	2.43	0.145	0.031	1020
FF10	Oct-98	Mean	0.272	15	0.302	43.8	58.6	1.68	30.6	9.11	39.7	4.72	0.493	1630
		Stdev	0.256	1.7	0.013	1.97	20.8	1.44	18.2	4.03	22.2	0.92	0.091	180
	Aug-99	Mean	0.107	17.7	0.269	55.9	59.6	21.1	15	4.33	19.3	2.27	0.54	1190
		Stdev	0.0067	9.99	0.055	12.9	18.7	17.6	10.3	1.96	12.3	1.22	0.137	72.1
	Aug-00	Mean	0.138	22.7	0.16	57.2	58.7	22.5	13.2	5.7	18.9	2.06	2.17	1170
		Stdev	0.0376	4.17	0.041	3.95	15.9	23.9	7.56	4.04	11.6	1.51	2.5	450
	Oct-00	Mean	0.113	16	0.128	46.7	65.1	9.17	19.5	6.32	25.8	3.36	0.603	1220
		Stdev	0.0023	1.38	0.012	4.04	4.46	10.6	4.79	1.42	6.17	0.527	0.241	261

[a] From Long *et al*. (1995)
[b] Grain size and contaminant groups defined in Section 4.1.3
[c] Total PAH reported was calculated from an extended list of individual PAHs that were not included in the ERM total PAH group (Long 1995)
[d] ERM value is for Total Chlordane
[e] From Long and Morgan (1991)

Grain Size—With the exception of NF08 and FF10 in October 1998, patterns in sediment composition from October 1998 to October 2000 were consistent at each of the Contaminant Special Study stations (Figure 4-10). Sediment from NF08 contained considerably less silt and more sand in October 1998 compared to later sampling events (August 1999 and 2000; October 2000). Sediment from FF10 contained more silt and less gravel in October 1998 compared to later sampling events (Figure 4-10). With some exceptions, the relative variability in sand, silt and clay content between sample triplicates was fairly consistent between October 1998 and October 2000. The relative variability in silt content between sample triplicates at NF08 was approximately six to nine times more variable in October 1998 compared to results from later sampling events (Table 4-7). Sand, silt and clay composition at NF24 was also 3 to 19 times more variable in October 1998 compared to results from later sampling years (Table 4-7). Grain size composition between sample triplicates at FF10 in October 2000 was generally two to five times less variable compared to earlier years (October 1998; August 1999 and 2000).

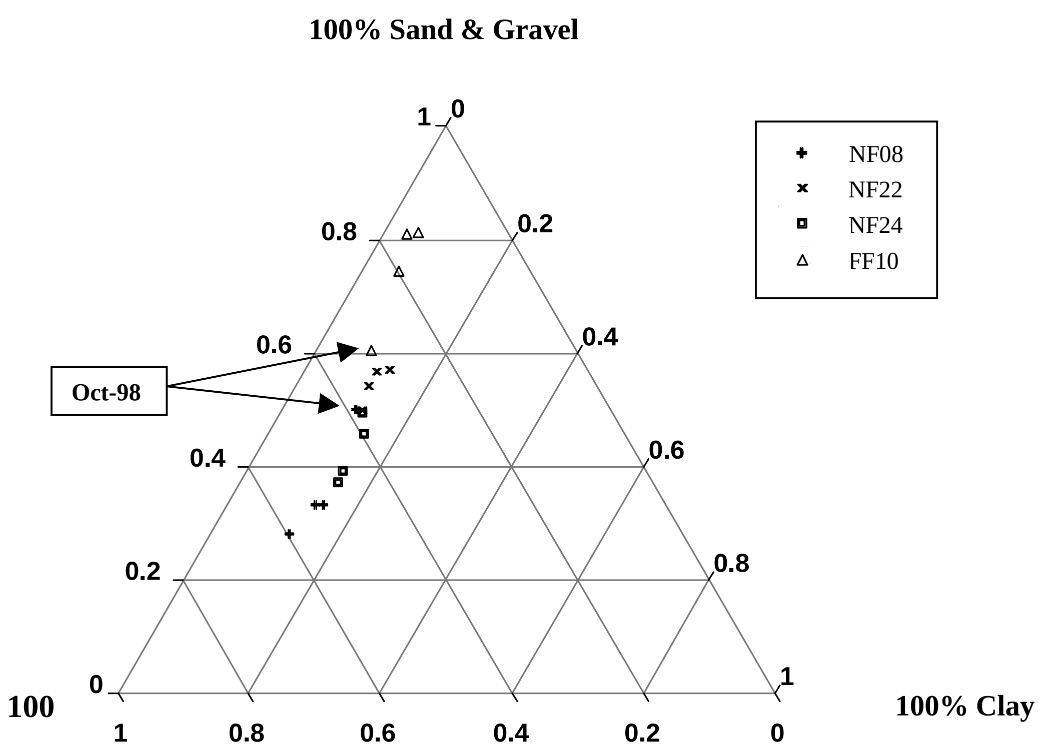


Figure 4-10. Grain size composition at Special Contaminant Study stations from 1998 to 2000.

TOC—Station mean concentrations of TOC for each of the four Contaminant Special Study stations from October 1998 to October 2000 are shown in Figure 4-11. With the exception of station FF10 in August 2000, concentrations of TOC were generally consistent from 1998 to 2000 (Figure 4-11). Mean concentrations of TOC at the three nearfield stations were generally higher than at farfield station FF10 (Figure 4-11). TOC values measured in October 2000 (post-discharge) were similar to August 2000 values (pre-discharge).

With the exception of FF10, precision between sample triplicates was generally tighter in October 2000 compared to earlier sampling events (Figure 4-11, Table 4-7).

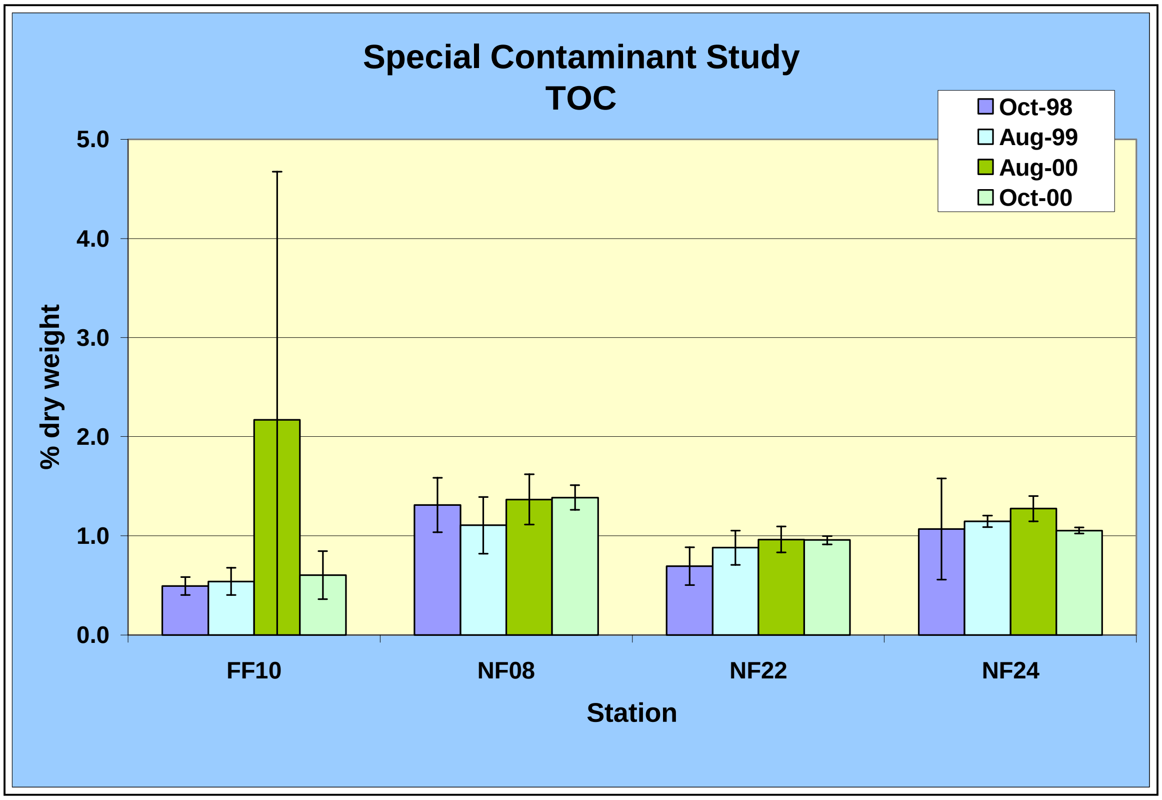


Figure 4-11. TOC content at Special Contaminant Study stations from 1998 to 2000. Error bars depict 95% confidence intervals.

***Clostridium perfringens*—**Station mean abundances of *Clostridium perfringens* for each of the four Contaminant Special Study stations from October 1998 to October 2000 are shown in Figure 4-12. The temporal pattern in *Clostridium perfringens* densities was consistent among the three nearfield stations (NF08, NF22, and NF24). From October 1998 to August 2000, *Clostridium perfringens* densities decreased by 46 – 50% at these stations. In October 2000, however, station mean concentrations were about 2 times higher compared to August 2000 values and were similar to or higher than October 1998 levels. Mean concentrations of *Clostridium perfringens* at FF10 were more consistent over time and were generally 1.5 to 4 times lower than at the nearfield stations.

With few exceptions, relative variability (measured as coefficient of variation) between sample triplicates was generally less than 30% at all Contaminant Special Study stations over time. Exceptions included NF24 in October 1998 (67% CV), NF08 in August 1999 (32% CV), FF10 in August 2000 (39% CV), and NF24 in October 2000 (36% CV).

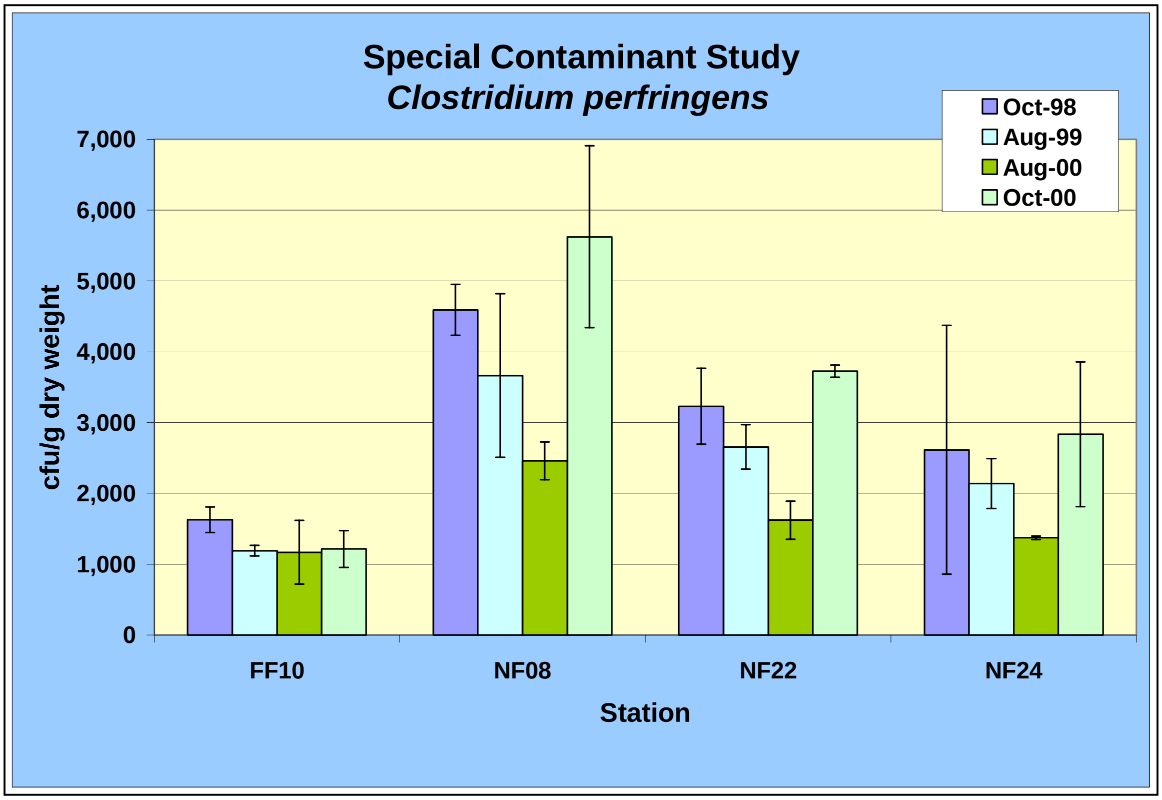


Figure 4-12. *Clostridium perfringens* density (cfu/gdw) at Special Contaminant Study stations from 1998 to 2000. Error bars depict 95% confidence intervals.

Contaminants—With the exception of NF24 in October 1998, station mean values for total PAH were generally consistent from October 1998 to October 2000 (Figure 4-13). The concentration of total PAH at NF24 in October 1998 was two times higher than 1999 and 2000 values. However, one of the replicates from NF24 had anomalously high PAH content in October 1998, and had this replicate been excluded then the station mean values for total PAH would be fairly constant over time.

Trends in total LAB concentrations were consistent over time at the nearfield stations. Station mean concentrations of total LAB were highest in October 1998, decreased by more than 50% in August 1999, increased again in August 2000 and decreased in October 2000 to the lowest values measured over time (Table 4-7). Station mean concentrations of total LAB at FF10 showed similar trends over time with the exception that the station mean concentration of total LAB increased in October 2000 rather than decreasing.

With the exception of FF10, station mean values for total PCB were fairly consistent from October 1998 to October 2000, with slightly higher concentrations during October events overall (Figure 4-13). From October 1998 to August 2000, concentrations of total PCB at FF10 were 2 to 7 times lower compared to nearfield station (NF08, NF22, and NF24) values. In October 2000 (post-discharge), station mean values for total PCB at FF10 were approximately three to four times higher than August 2000 values. Even so, station mean values for total PCB at FF10 in October 2000 were generally only slightly higher compared to values measured at nearfield stations (NF08, NF22, NF24) in October 2000.

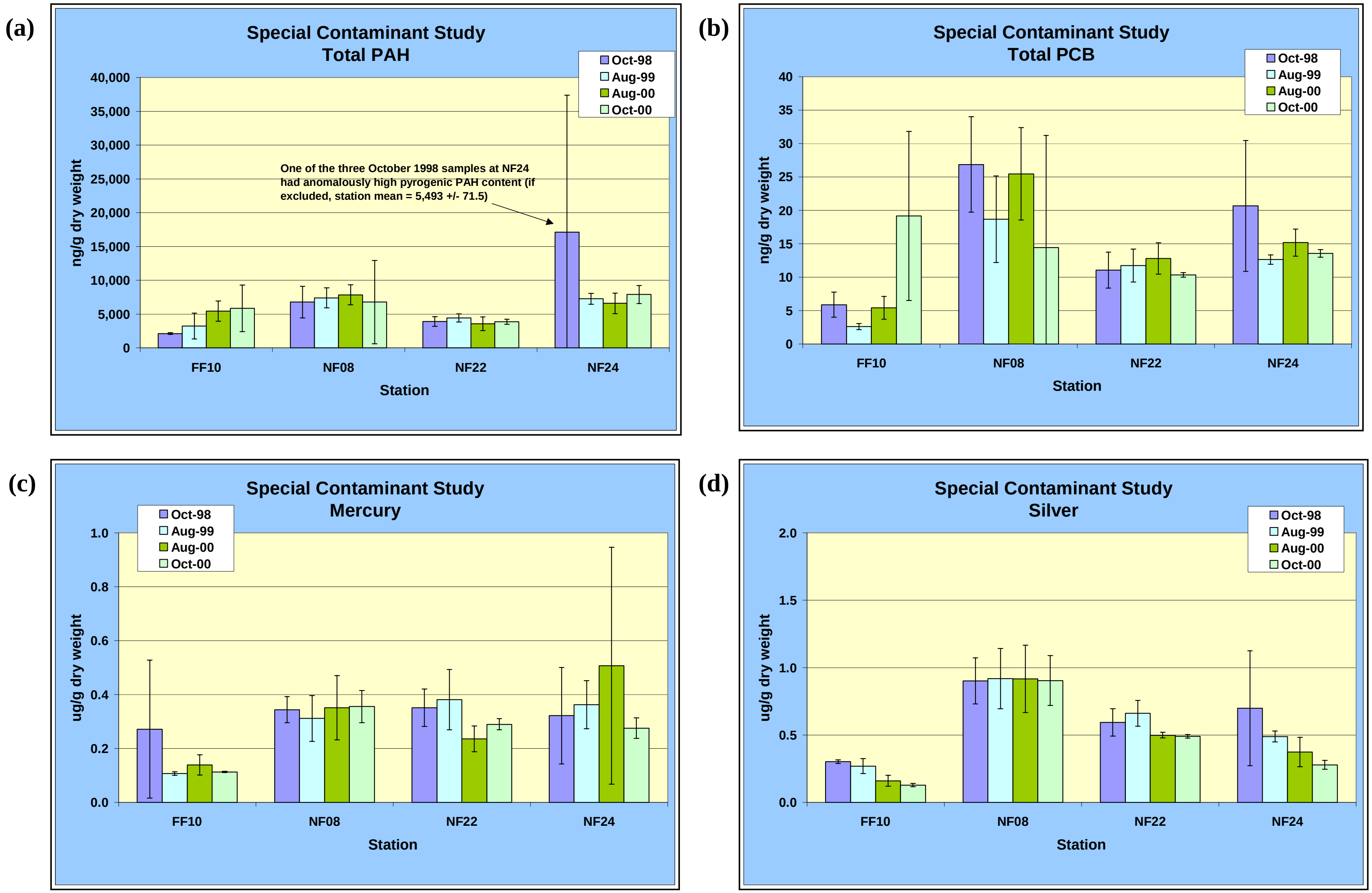


Figure 4-13. Distribution of representative contaminants (total PAH, total PCB, mercury, silver) at Special Contaminant Study stations from 1998 to 2000. Error bars depict 95% confidence intervals.

With the exception of FF10 in October 1998, station mean values for mercury were fairly similar from October 1998 to October 2000 (Figure 4-13). Station mean values for silver were very consistent over time at stations NF08 and NF22, but appeared to decrease since October 1998 at stations FF10 and NF24 (Figure 4-13).

While none would be expected, results from the October 2000 NCSS did not show a rapid increase in sediment contaminants following startup of the new diffuser which came online in September 2000.

Chemistry Interrelationships—Correspondence within bulk sediment properties and against contaminants was evaluated for all Contaminant Special Study stations (NF08, NF22, NF24, FF10) sampled in October 1998, August 1999, August 2000, and October 2000. Correspondence was evaluated using the individual replicates from each station, not station mean values. Grain size was strongly correlated with TOC ($r = 0.729$, $n = 47$, $p < 0.01$) (Table 4-8 and Figure 4-14). With the exception of total DDT, the correlation between contaminants and bulk sediment properties (percent fines, TOC) was generally similar to or stronger when the correlation was performed against TOC compared to correlations against percent fines (Table 4-8). In addition, the correlation between metal contaminants and bulk sediment properties was consistently much stronger than correlations between organic contaminants and bulk sediment properties (Figure 4-15).

Table 4-8. Correspondence within bulk sediment properties and against contaminants at Contaminant Special Study stations for October 1998, August 1999, August 2000, and October 2000.

Parameter	Correspondence against Percent Fines			Correspondence against TOC [a]		
	r	***n***	***p***	***r***	***n***	***p***
Percent Fines	1.000	48	<0.01	0.729	47	<0.01
TOC [a]	0.729	47	<0.01	1.000	47	<0.01
Clostridium perfringens	0.546	48	<0.01	0.580	47	<0.01
Total PAH [b]	0.364	47	<0.05	0.664	46	<0.01
Total PCB	0.497	48	<0.01	0.630	47	<0.01
Total DDT	0.363	48	<0.05	0.239	47	>0.05
Total LAB	0.371	48	<0.05	0.481	47	<0.01
Al	0.528	48	<0.01	0.514	47	<0.01
Cd	0.489	48	<0.01	0.621	47	<0.01
Cr	0.700	48	<0.01	0.836	47	<0.01
Cu	0.722	48	<0.01	0.818	47	<0.01
Fe	0.566	48	<0.01	0.736	47	<0.01
Pb	0.710	48	<0.01	0.747	47	<0.01
Hg	0.497	48	<0.01	0.509	47	<0.01
Ni	0.333	48	<0.05	0.618	47	<0.01
Ag	0.719	48	<0.01	0.692	47	<0.01
Zn [c]	0.693	47	<0.01	0.873	46	<0.01

[a] Anomolously high TOC value for one of the three replicates at FF10 in August 2000 – data excluded from correlation analysis

[b] Anomolously high total PAH value for one of the three replicates at NF24 in October 1998 – data excluded from correlation analysis

[c] Anomolously high Zn value for one of the three replicates at NF24 in August 2000 – data excluded from correlation analysis

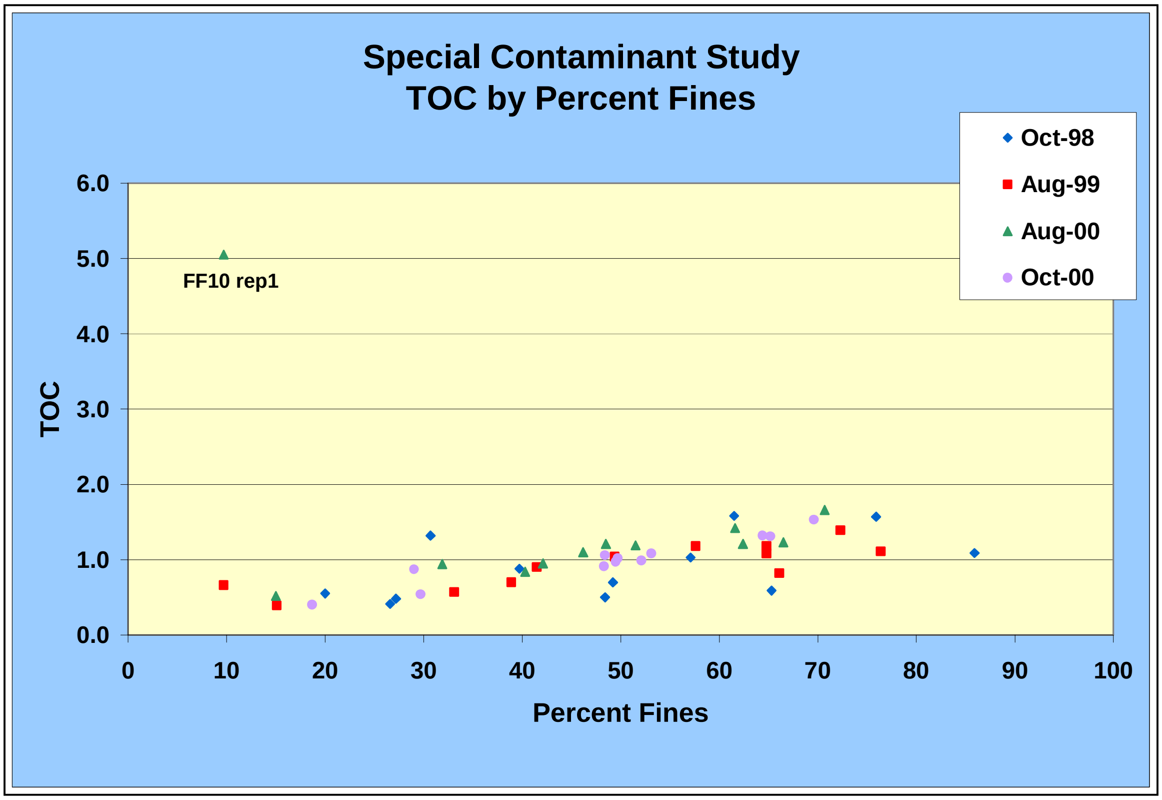


Figure 4-14. Correspondence within bulk sediment properties at Special Contaminant Study stations from 1998 to 2000.

Comparison to Nearfield—Results presented in the Kropp *et al.* (2000) showed that the temporal response of the baseline for representative organic and metal contaminants was similar for both the Contaminant Special Study stations and the nearfield. August and October 2000 contaminant results from the Contaminant Special Study stations were generally similar to October 1998 and August 1999 results (Figure 4-13), suggesting that the four Contaminant Special Study stations continue to be reasonably representative of the nearfield.

4.3 Comparison of Baseline Data to Thresholds

Nearfield baseline levels were established for contaminants in sediment based on the mean aerial distribution for nearfield stations. Baseline and 95 % confidence intervals were determined for each sampling year from 1992–2000 (August surveys only) and were evaluated against the MWRA monitoring thresholds based on the Long *et al*. (1995) ER-M values (Table 4-9). Note that the list of PAHs included in the Long (1995) ER-M total PAH summation differs from the list of PAHs included in the total PAH summations presented in this report. However, the total PAH values presented in this report are more conservative because they include many more PAHs compared to Long (1995). Also, note that nearfield contaminant results from 2000 are from a limited sampling year. These data are included in Table 4-9 and Figure 4-16 for illustrative purposes only; formal threshold testing will only be conducted when contaminant data are available for all nearfield stations. The temporal response of the baseline for organic and metal contaminants showed relatively constant means without substantial variability (see Figures 4-2 c,d and 4-16 for representative parameters). Baseline mean values for any given year (*i.e.*, 2000) were generally representative of the baseline over time (1992–2000) and were well below ER-M thresholds (Table 4-11).

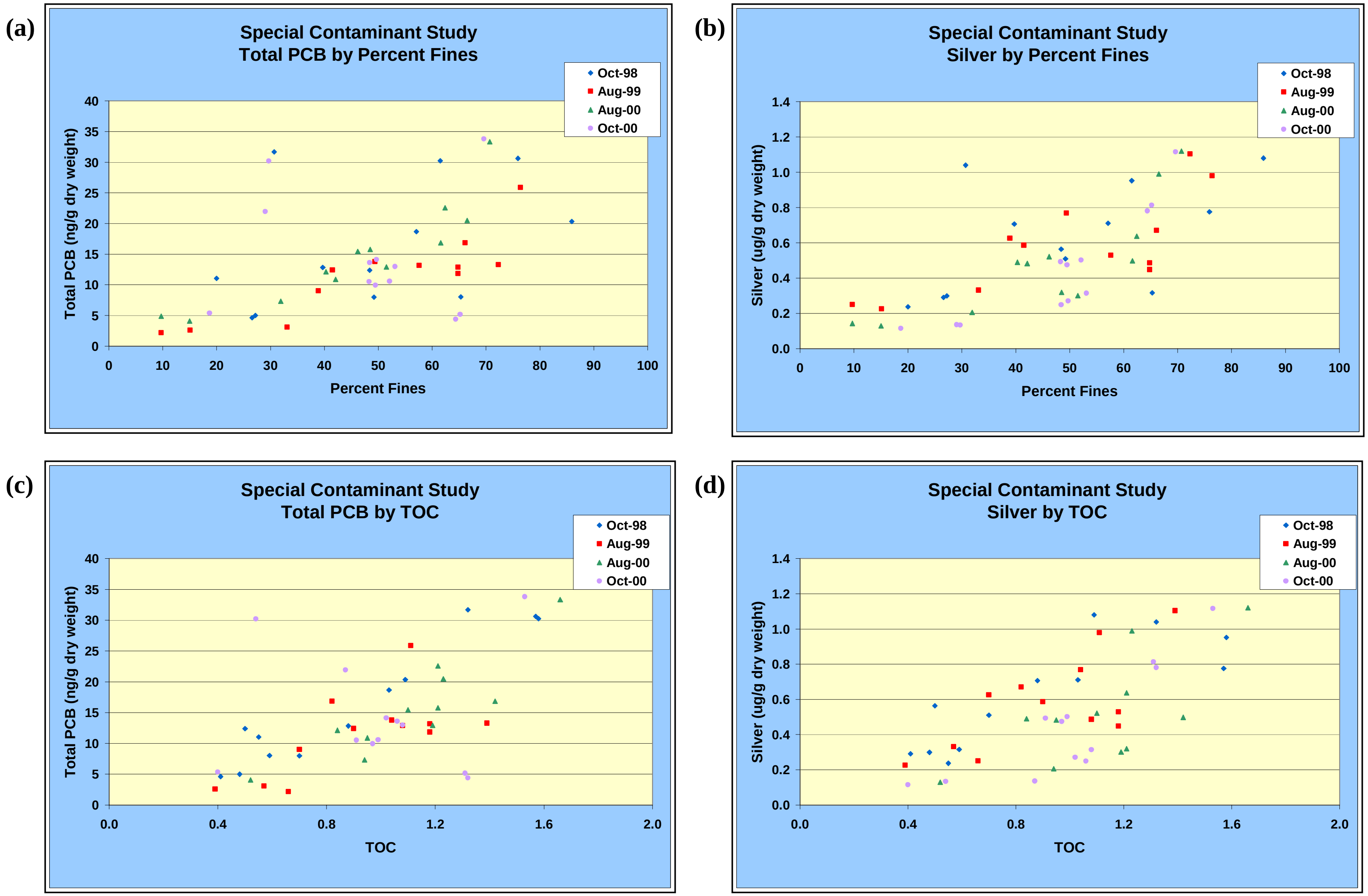
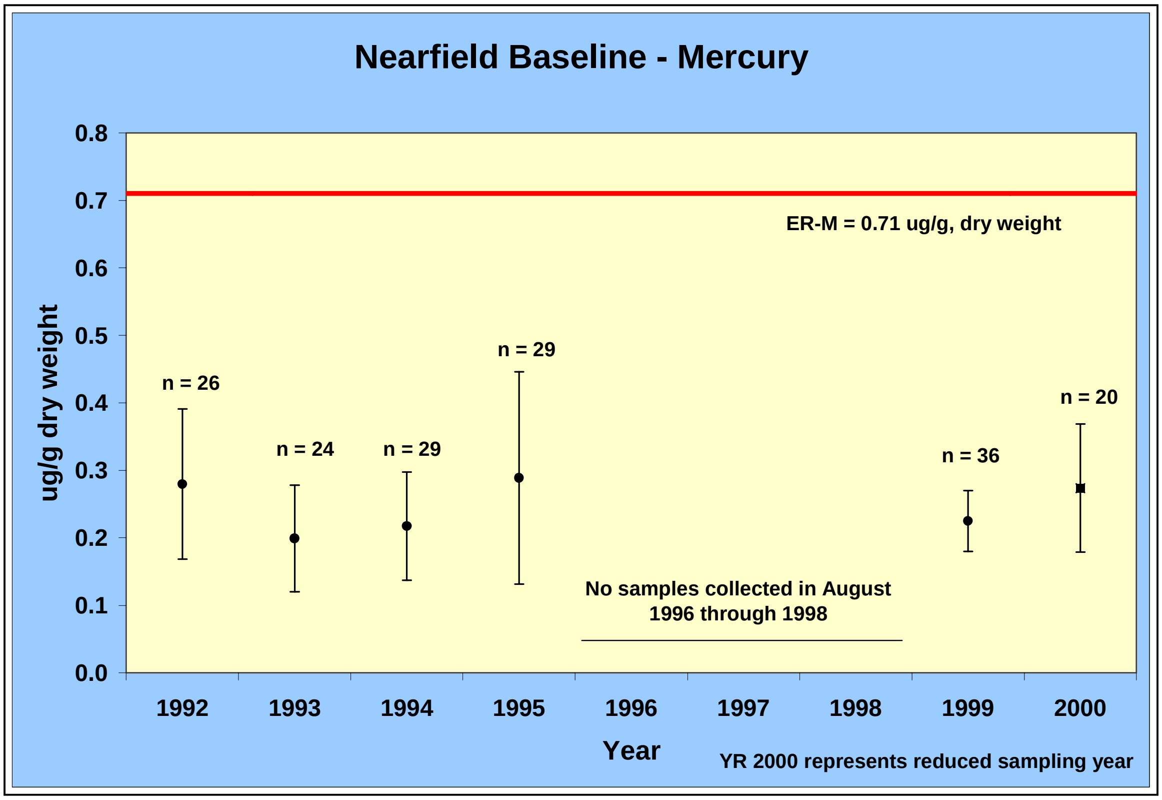


Figure 4-15. Correspondence between bulk sediment properties and representative contaminants (total PCB, silver) at Special Contaminant Study stations from 1998 to 2000.



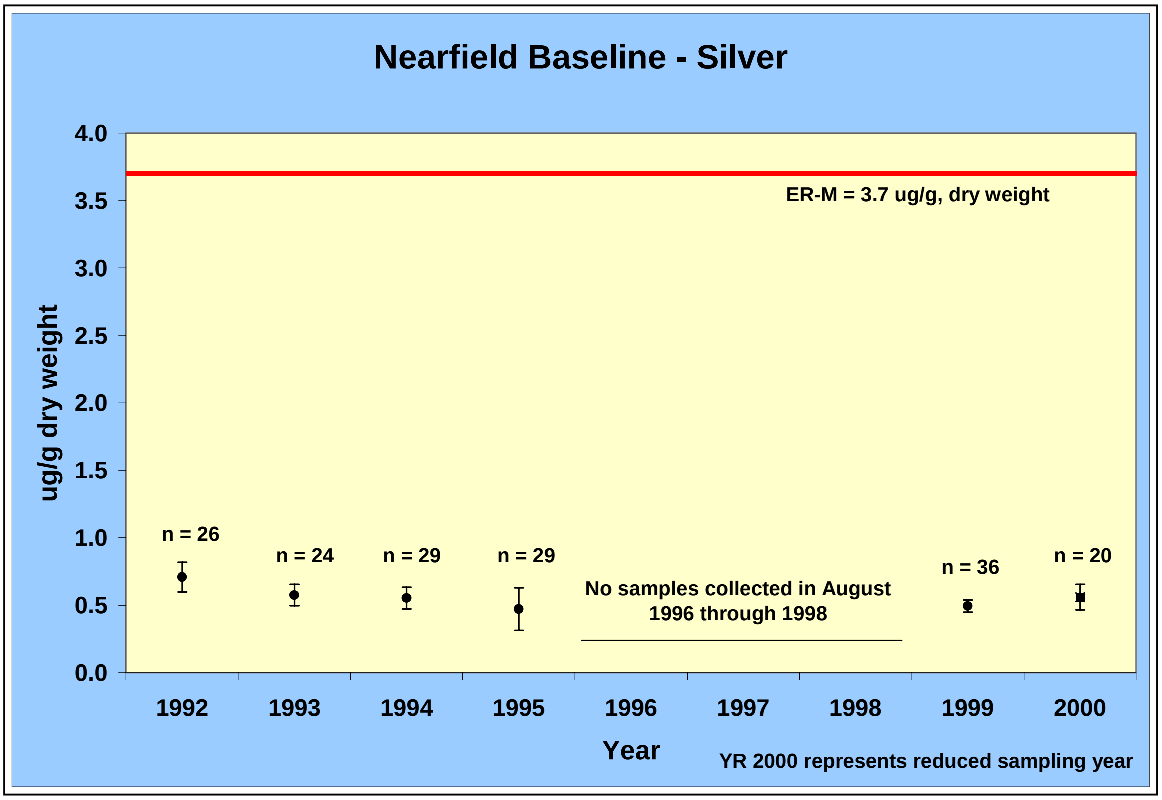


Figure 4-16. Baseline comparison to thresholds in the nearfield from 1992 to 2000. Error bars depict 95% confidence intervals.

Table 4-9. Comparison of annual nearfield baseline mean concentrations and thresholds (ER-M) for the period 1992–2000[a].

Parameter	Units (dry weight)	ER-M [b]	1992		1993		1994		1995 [c]		1999		2000	
			Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Total PAH[d,e]	ng/g	44792	5560	6230	5690	8090	4430	3650	5030	5030	5360	5130	5330	3220
Total PCB[d]	ng/g	180	14.7	16.3	28.6	39.1	15.2	11.9	16	14.5	10.3	8.66	15.3	9.78
Total DDT[d]	ng/g	46.1	3.3	3.5	3.82	5.44	5.27	6.53	2.59	3.12	2.7	3.2	2.36	1.42
Total Chlordane[d]	ng/g	6 [f,g]	0.108	0.322	0.52	0.652	0.862	0.826	0.0372	0.139	0.175	0.193	0.311	0.225
Total Pesticide[d]	ng/g	NA	1.18	2.11	1.12	0.993	4.04	2.85	0.269	0.281	0.0664	0.152	0.442	0.26
Total LAB[d]	ng/g	NR	299	542	392	568	221	282	77.7	97	68	59	130	77.1
Al	µg/g	NR	5.26	0.686	4.97	0.938	5.14	1.13	4.55	1.02	4.98	0.858	5.26	0.713
Cd	µg/g	9.6	0.189	0.218	0.228	0.255	0.153	0.136	0.175	0.123	0.0896	0.0644	0.131	0.088
Cr	µg/g	370	85.1	56	80.2	60.1	86.8	44.6	64.8	39.6	61.9	23.3	77.2	26.4
Cu	µg/g	270	27.6	23.9	26.1	19.2	22.8	12.5	19.2	13.1	23.2	9.33	25.6	12.1
Fe	µg/g	NR	2.31	0.733	2.15	0.829	2.25	0.676	1.8	0.535	2.33	0.446	2.45	0.542
Pb	µg/g	218	47.2	23.6	42.9	20.7	43.8	14.5	43	17	44.2	13.8	44.7	12.4
Hg	µg/g	0.71	0.28	0.29	0.199	0.198	0.217	0.22	0.289	0.432	0.225	0.138	0.274	0.217
Ni	µg/g	51.6	18.2	7.63	18.5	8.9	17	7.49	15.5	6.32	17.3	6.82	22	7.06
Ag	µg/g	3.7	0.707	0.902	0.575	0.719	0.553	0.495	0.471	0.332	0.493	0.314	0.559	0.504
Zn	µg/g	410	69.7	45	60.8	38.8	56.9	23.7	56.6	27.2	59.2	19.1	74.7	47.4
Gravel	pct	NR	8.04	17.3	4.03	10.7	4.08	9.09	3.3	6.5	5.9	11.3	7.89	14.7
Sand	pct	NR	59.5	23.6	68	22.8	60	26.1	61.4	26.9	59.6	23.5	57.3	20.7
Silt	pct	NR	24.7	18.3	23.1	20.2	28.1	22.1	25.5	21.5	26.2	19.8	24.8	18.1
Clay	pct	NR	7.74	6.95	4.88	3.98	7.79	6.55	9.8	14.4	8.3	5.92	9.94	6.05
Fines[d]	pct	NR	32.5	24.3	28	23.7	35.9	27.7	35.3	28	34.5	24.9	34.8	23.7
TOC	pct	NR	1.05	0.656	0.847	0.924	0.786	0.555	0.802	0.695	0.75	0.422	1.17	0.96
Clostridium	cfu/g	NR	2850	3110	3090	2600	3600	2540	4980	5750	1940	1410	1460	1370

[a] The 2000 data represent a reduced sampling year and cannot be compared to the threshold. Data are included for illustrative purposes.
[b] From Long *et al*. (1995)
[c] No contaminant data collected for August surveys conducted from 1996 to 1998.
[d] Grain size and contaminant groups defined in Section 4.1.3
[e] Total PAH reported was calculated from an extended list of individual PAHs that were not included in the ERM total PAH group (Long 1995)
[f] ER-M value is for Total Chlordane
[g] From Long and Morgan (1991)
NR = Not regulated

To establish when significant increases above the baseline would be detected, a statistical value was established. The significant increase value was set as the 95th percentile upper confidence limit (based on the "t" distribution) of the mean of the annual means. The significant increase values are well within the range of detection; suggesting change can be detected well in advance of threshold issues (Table 4-10). Moreover, each threshold is at least 2.5 times higher than the level of significant increase.

Table 4-10. Comparison of baseline mean concentrations, significantly increased levels, and threshold at the nearfield.

Parameter	Baseline Mean[a]	Baseline Standard Error	N	Significant Increase[b]	Warning Level[c]	Ratio between Threshold and Significant Increase
Total PAH[d, e]	5210	225	5	5690	44800	7.9
Total PCB[d]	17	3.07	5	23.5	180	7.7
Total DDT[d]	3.54	0.487	5	4.57	46.1	10.1
Total Chlordane[d]	0.34	0.155	5	0.67	6	9.0
Cd	0.167	0.0229	5	0.216	9.6	44.5
Cr	75.8	5.2	5	86.8	370	4.3
Cu	23.8	1.45	5	26.9	270	10.0
Pb	44.2	0.784	5	45.9	218	4.8
Hg	0.242	0.0179	5	0.28	0.71	2.5
Ni	17.3	0.528	5	18.4	51.6	2.8
Ag	0.56	0.0414	5	0.648	3.7	5.7
Zn	60.6	2.39	5	65.7	410	6.2
Clostridium perfringens	3020	399	9	3760	NR	NA

[a] Mean concentration of Annual Means, 1992–1995 and 1999 (No August contaminant data available for 1996, 1997, and 1998; 2000 represents a reduced sampling year and data not threshold relevant).

[b] The significant increase is the concentration at which an increase from the baseline mean is considered statistically significant at the 0.05 level (*i.e.*, 95th percent UCL = mean + $t_{0.1,n-1}$ * S.E.).

[c] Based on ER-M sediment quality guidelines from Long *et al*. (1995). Values reported to three significant figures.

[d] Contaminant groups defined in Section 4.1.3

[e] Total PAH reported was calculated from an extended list of individual PAHs that were not included in the ERM total PAH group (Long 1995)

[f] ERM value is for Total Chlordane

[g] From Long and Morgan (1991)

4.4 Conclusions

The principal component analysis (PCA), the *Clostridium perfringens* regional analysis, and the correlation analyses identify multiple regions in physical and chemical terms. In the nearfield, within Massachusetts Bay, there is a series of stations with heterogeneous sediments in relatively close proximity to the historic leading source of contaminants (*i.e.*, Boston Harbor). Nearfield stations are generally equidistant from the source. The major factors influencing the concentration of contaminants and sewage tracers are primarily related to grain size factors suggestive of different sediment depositional environments. The nearfield PCA showed that the primary factors responsible for the variance in the data were sand content and metals (especially Cr, Zn, Pb, Cu and Ni).

In contrast, the farfield stations were generally less physically heterogeneous in terms of sediments but were substantially more spatially dispersed. The *Clostridium perfringens* and total LAB regional analysis showed that the proximity to the historic source of sewage contaminants influenced the concentration of *Clostridium perfringens* and total LAB.

The above picture of the two disparate regions with different controlling factors agrees well with the correlation analyses run on the data from the two regions. Correlations between contaminants and the bulk sediment properties (that appear to control contaminant concentrations in that region) are quite high, with r^2 of 50% or higher for most parameters. Those correlations were generally weaker for farfield stations (organic contaminants in particular), further supporting the evaluation of the primary controlling variables in the farfield being other than the depositional nature of a station.

Within each of these distinct regions, the spatial distribution of bulk sediment properties and contaminant parameters in 2000 was not substantially different from previous years (1992-1999). Similarly, with the exception of *Clostridium perfringens* and total LAB, the temporal response of bulk sediment properties and contaminants was not substantially different over time. *Clostridium perfringens* abundances decreased in 1998–2000 (total LAB also decreased since 1994) for stations located closer to the Harbor (20-km of Deer Island Light), suggesting that the documented reductions in effluent solids loading during the 1990s (Werme and Hunt, 2001) also reflect a reduction in *Clostridium* spore loads that is being seen in nearby sediments. Baseline mean values for organic and metal contaminants in the nearfield were well below the MWRA thresholds.

5. 2000 SOFTBOTTOM INFAUNAL COMMUNITIES

by Robert J. Diaz and Roy K. Kropp

5.1 Methods

5.1.1 Laboratory Analyses

Samples were rinsed with fresh water over 300-μm-mesh screens and transferred to 70–80% ethanol for sorting and storage. To facilitate the sorting process, all samples were stained in a saturated, alcoholic solution of Rose Bengal at least overnight, but no longer than 48 h. After rinsing with clean alcohol, small amounts of the sample were placed in glass dishes, and all organisms, including anterior fragments of polychaetes, were removed and sorted to major taxonomic categories such as polychaetes, arthropods, and mollusks. After samples were sorted, the organisms were sent to taxonomists (Appendix D-1) for identification and enumeration. Identifications were made at the lowest practical taxonomic level, usually species.

During shipboard or laboratory processing, some soft-bodied specimens in eight samples were partially damaged such that the identifications and counts of these taxa may be uncertain. The affected samples were NF12-1, NF12-3, NF15, NF21, NF22, NF24-1, NF24-2, and FF05-2. As part of the current analyses, data from those samples were examined semi-quantitatively to determine whether or not the damage impacted the data.

5.1.2 Data Analyses

Preliminary Data Treatment—Prior to performing any of the analyses of the 2000 and 1992–2000 MWRA datasets, several modifications were made. Several non-infaunal taxa were excluded (listed in Appendix D-2). Because the 2000 sampling represents the final year of the baseline period, several modifications were made to the Massachusetts Bay database (BMBSOFT) to reduce the likelihood that taxonomic uncertainty would affect data analyses and interpretation. Specifically, several provisional species (*i.e.*, those not referable to any known species) were represented in the data by very few individuals (in most cases only one) or were found only during one survey. Also, no specimens of these taxa were present in the MWRA reference collection. Because the true identities of these taxa are uncertain and not likely to be known a decision was made to transfer them to appropriate unidentified higher-level taxa. For example, Nemertea sp. D was found only in 1992 and was represented by a single individual. Therefore, it was merged with the unidentified, higher-level taxon Nemertea spp. A complete list of these taxonomic changes is included in Appendix D-2. Turbellarians were identified to species in only 1993 and 1994, but have been identified only to phylum during the other years of the program. Therefore, data for Turbellaria sp. 1 and sp. 2 were pooled in the database with data for Turbellaria spp.

For previous analyses, data for several taxa often were pooled. Usually this involved pooling data for a taxon identified to a level higher than species (*e.g.*, genus) with those data for a species within the higher taxon. This pooling was done only when only a single species of the higher taxon was identified. For example, *Byblis gaimardi* (an amphipod) was the only species of the genus found, so that any amphipods identified only to the genus (*Byblis* spp.) were treated as if they were *B. gaimardi*. However, in more than one instance in recent years, a second species has been identified in a genus or family whose spp. level data were formerly treated like *Byblis* spp., calling into question the pooling of spp. and species level data for that taxon. Because of the need to have consistent merge rules for the calculation of the benthic thresholds, this type of data pooling was <u>not</u> done for the 2000 data analyses. Because the identification of some taxa has been inconsistent through the duration of the project, data for some species were pooled. For example, species of the polychaete genus *Pholoe* have been inconsistently identified only as *Pholoe minuta*

(1992–1994) or as *Pholoe tecta* and *Pholoe minuta* (1995–2000). For the 2000 report, all worms identified as either species were pooled and called *Pholoe minuta*. All such changes are listed in Appendix D-2.

During the preliminary examination of the data prior to conducting any analyses, it was determined that a global taxonomic change made in 1998 was erroneous. In 1998, all specimens previously identified as Enchytraeidae sp. 1 (Oligochaeta) were renamed *Grania postclitellochaeta longiducta*. This change affected data analyzed from 1995 to 1998 (and eventually 1999). It was possible to reconstruct and correct the data for all of the affected years. That correction is summarized in Appendix D-2.

Calculations of abundance included all infaunal taxa occurring in each sample, whether identified to species level or not. Calculations based on species (diversity, evenness, number of species) included only those taxa identified to species level, or treated as such. Prior to such analyses, the data were scanned and a few taxa identified to a taxonomic level other than species (*e.g.*, genus) were chosen (because they were unique) to be included in the species-level calculations. Again, to help create stable merge rules for the threshold calculations, fewer such designations were done than for previous analyses. These are listed in Appendix D-2.

A list of all taxa identified from infaunal samples during the Outfall Monitoring Program (1992–2000) is contained in Appendix D-3.

Designation of Nearfield and Farfield Stations—For these analyses, the stations termed “nearfield” include all stations having NF designations plus stations FF10, FF12, and FF13. This was done to allow all western Massachusetts Bay Stations to be included in a single analysis. Stations termed “farfield” include all stations having FF designations, except stations FF10, FF12, and FF13. For some analyses, this data set also included the three nearfield stations at which triplicate infaunal grab samples are collected (NF12, NF17, NF24).

5.1.3 Diversity Analysis

The software package BioDiversity Professional, Version 2 (© 1997 The Natural History Museum / Scottish Association for Marine Science) was used to perform calculations of total species, log-series alpha, Shannon’s Diversity Index (*H'*), the maximum *H'* (Hmax), and Pielou’s Evenness (*J'*). Calculations made by the software were validated for the 1999 analyses by comparing values for these parameters and for total individuals calculated for the 1998 nearfield and farfield infaunal data (Kropp *et al.*, 2000) with those made by BioDiversity Pro. Calculations made by BioDiversity for all parameters except log-series alpha were the same as those reported in Kropp *et al.*, (2000). Values calculated by BioDiversity Pro for log-series alpha were 0.01–0.02 higher than those previously reported. However, when rounded to 0.1, both sets of calculations yielded the same values. The results of the validation are given in Appendix D-3 of Kropp *et al.* (2001). Because the same version of BioDiversity Pro was used for the current analyses, the validation exercise was not repeated. BioDiversity Pro is available at http://www.sams.ac.uk/dml/projects/benthic/bdpro/index.htm. Magurran (1988) describes all of the diversity indices used here.

Shannon’s *H'* was calculated by using $\log_2$ because that is closest to Shannon’s original intent. Pielou’s (1966) *J'*, which is the observed *H'* divided by Hmax, is a measure of the evenness component of diversity. BioDiversity Pro also provides a calculation of abundance that includes only species-level taxa. This number was compared to the abundance calculations based on all taxa to determine the proportion of the Massachusetts Bay infauna that was identifiable to species.

5.1.4 Total Species Richness Analysis

The general approach outlined by Brown *et al*. (2001) was used to examine total species richness in the Massachusetts Bay system (*i.e*., nearfield and farfield combined). The purpose of this analysis was to detect large-scale patterns in species richness that might offer insights not available from analyses performed at smaller scales (*i.e*., per sample). The first step in the analysis was to pool data from all nearfield and farfield stations within one year, then to create a simple presence-absence matrix in which a species was counted as "present" if it appeared in at least one station during the year, that is, no weight was given to abundance or the numbers of stations at which a species occurred. After the matrix was constructed, the next step determined the year-to-year change in the composition of species present in the Massachusetts Bay system by tallying the number of species present in one year that were not present in the preceding year and the number absent in a year that were present the year before. The next step examined the effect on species richness if either appearances of species or disappearances of species was the only process operating on the system. This was done by using the 1992 data set as a starting point and tallying the numbers of initial appearances in any following year of species that were not seen in 1992 (appearances) and by counting the number initial disappearances in any following year of species that were found in 1992. The final results were plotted graphically.

5.1.5 Cluster & Ordination

Cluster analyses were preformed with the program COMPAH96 (available on E. Gallagher's web page, http://www.es.umb.edu/edgwebp.htm), originally developed at the Virginia Institute of Marine Science in the early 1970's. The station and species cluster groups were generated using unweighted pair group mean average sorting (UPGMA) and chord normalized expected species shared (CNESS) to express resemblance (Gallagher 1998). For calculation of CNESS the random sample size constant was set to 15 (Kropp *et al.*, 2000). Principle component (PCA) and Canonical Correlation analyses were used for assessing the strength of cluster group membership based on sediment, sediment profile image, hydrocarbon, and heavy metal data. Both analyses were preformed using SAS (SAS Institute, Inc., Cary, NC).

5.2 Results and Discussion

5.2.1 2000 Sample Handling Problem

The potential impact of the sample handling problem on the data analyses was semi-quantitatively examined by comparing the total abundance and the proportion identified to species level for each sample collected in 2000 to those collected in 1992–1999. Additionally, the abundance of annelids and proportion of those identified to species were examined for the 2000 data only. Regarding total abundance and the proportion identified, only three samples had values outside the range of values obtained for 1992–1999 (Appendix D-4). For station NF12, replicate 1, the proportion identified was the lowest (88%) among any of the study years, but was very similar to 1999 (89–90%). For station NF15, the proportion identified was slightly lower (91%) than it was from 1995 to 1999 (94–96%), but was not the lowest value for the study years (90% in 1994). For station NF22, the lowest total abundance (1,434 individuals) and lowest proportion identified (84%) encountered during the nine years of the study occurred in 2000. However, both values may have been continuing the steadily decreasing trend for each measure that began in 1996 (abundance) and 1997 (proportion identified) rather than representing an impact of the sample handling problem. Nothing in the 2000-only comparison of the annelid data suggested that the handling problem had any impact on the data. Based on these simple analyses, it appears that the sample handling problem probably did not adversely impact the data analyses reported in the following sections.

5.2.2 2000 Nearfield Descriptive Community Measures

Abundance—Among individual nearfield samples collected in 2000, infaunal abundance varied about four-fold, ranging from 1,434 to 4,623 individuals/0.04 m^2 (35,850–115,575/m^2) at stations NF22 and NF24 (rep 1), respectively (Table 5-1). Among the 6 replicated nearfield stations, mean abundance per sample (standard deviation, sd) ranged from 1,798 (sd, 119) to 4,182 (sd, 530) individuals/0.04 m^2 at stations NF17 and FF13, respectively (Figure 5-1).

Table 5-1. Summary of ecological variables for samples collected from nearfield stations in 2000.

Station	Replicate	Abundance (Total)	Abundance (Species)[a]	Proportion Identified	Total Species	*H'*	*J'*	Log-series Alpha	Hmax
FF10	1	2077	1619	78%	75	4.37	0.7	16.3	6.2
FF10	2	1827	1687	92%	72	2.92	0.47	15.3	6.2
FF10	3	2604	2395	92%	71	3.25	0.53	13.8	6.2
FF12	1	2882	2556	89%	52	2.87	0.5	9.3	5.7
FF12	2	2618	2422	93%	48	2.98	0.53	8.5	5.6
FF12	3	2478	2292	92%	50	3.33	0.59	9.0	5.6
FF13	1	3570	3335	93%	50	3.22	0.57	8.4	5.6
FF13	2	4469	4070	91%	55	2.83	0.49	9.0	5.8
FF13	3	4506	4117	91%	56	3.13	0.54	9.2	5.8
NF02	1	2792	2454	88%	65	2.95	0.49	12.3	6.0
NF04	1	1933	1611	83%	70	4.31	0.7	14.9	6.1
NF05	1	1574	1380	88%	87	4.39	0.68	20.6	6.4
NF07	1	3294	3174	96%	86	3.35	0.52	16.3	6.4
NF08	1	2092	1875	90%	71	3.67	0.6	14.6	6.2
NF09	1	2963	2724	92%	83	4.17	0.65	16.2	6.4
NF10	1	2504	2296	92%	85	4.30	0.67	17.4	6.4
NF12	1	1652	1451	88%	55	4.08	0.71	11.3	5.8
NF12	2	3851	3534	92%	77	3.75	0.6	13.9	6.3
NF12	3	2568	2334	91%	64	3.92	0.65	12.2	6.0
NF13	1	2043	1804	88%	75	4.14	0.66	15.8	6.2
NF14	1	4206	3449	82%	72	4.11	0.67	12.9	6.2
NF15	1	2810	2562	91%	75	3.97	0.64	14.5	6.2
NF16	1	2268	2101	93%	62	2.86	0.48	12.0	6.0
NF17	1	1889	1139	60%	56	4.27	0.74	12.4	5.8
NF17	2	1663	1202	72%	51	3.72	0.66	10.8	5.7
NF17	3	1843	1421	77%	43	3.84	0.71	8.4	5.4
NF18	1	2499	2242	90%	87	3.99	0.62	18.0	6.4
NF19	1	3429	3320	97%	71	3.44	0.56	12.8	6.2
NF20	1	2538	2259	89%	69	3.08	0.5	13.5	6.1
NF21	1	2312	2124	92%	56	3.24	0.56	10.6	5.8
NF22	1	1434	1208	84%	57	4.11	0.7	12.4	5.8
NF23	1	1788	1200	67%	62	4.30	0.72	13.9	6.0
NF24	1	4623	4481	97%	66	2.39	0.4	11.0	6.0
NF24	2	1827	1725	94%	60	3.00	0.51	12.1	5.9
NF24	3	1582	1536	97%	51	2.84	0.5	10.2	5.7
	Total	91008	81099	89%					

[a]Abundance of individuals identified to species level.

Annelid worms were the most abundant higher infaunal taxon among the 2000 nearfield samples (Table 5-2). Annelids accounted for more than 80 % of the infauna at 15 nearfield stations, with the highest percentage (95.3 %) at station NF24. Molluscs typically were the second highest contributors to infaunal abundance (13 of 23 samples). The highest proportions of molluscs occurred at stations NF23 (20.5 %) and NF17 (18.7 %). Crustaceans (no pycnogonids were found in the 2000 nearfield samples) were the second most abundant taxon at 10 stations. The highest proportions of crustaceans occurred at stations NF04 (38.2 %), NF18 (37.6 %), and NF17 (36.5 %).

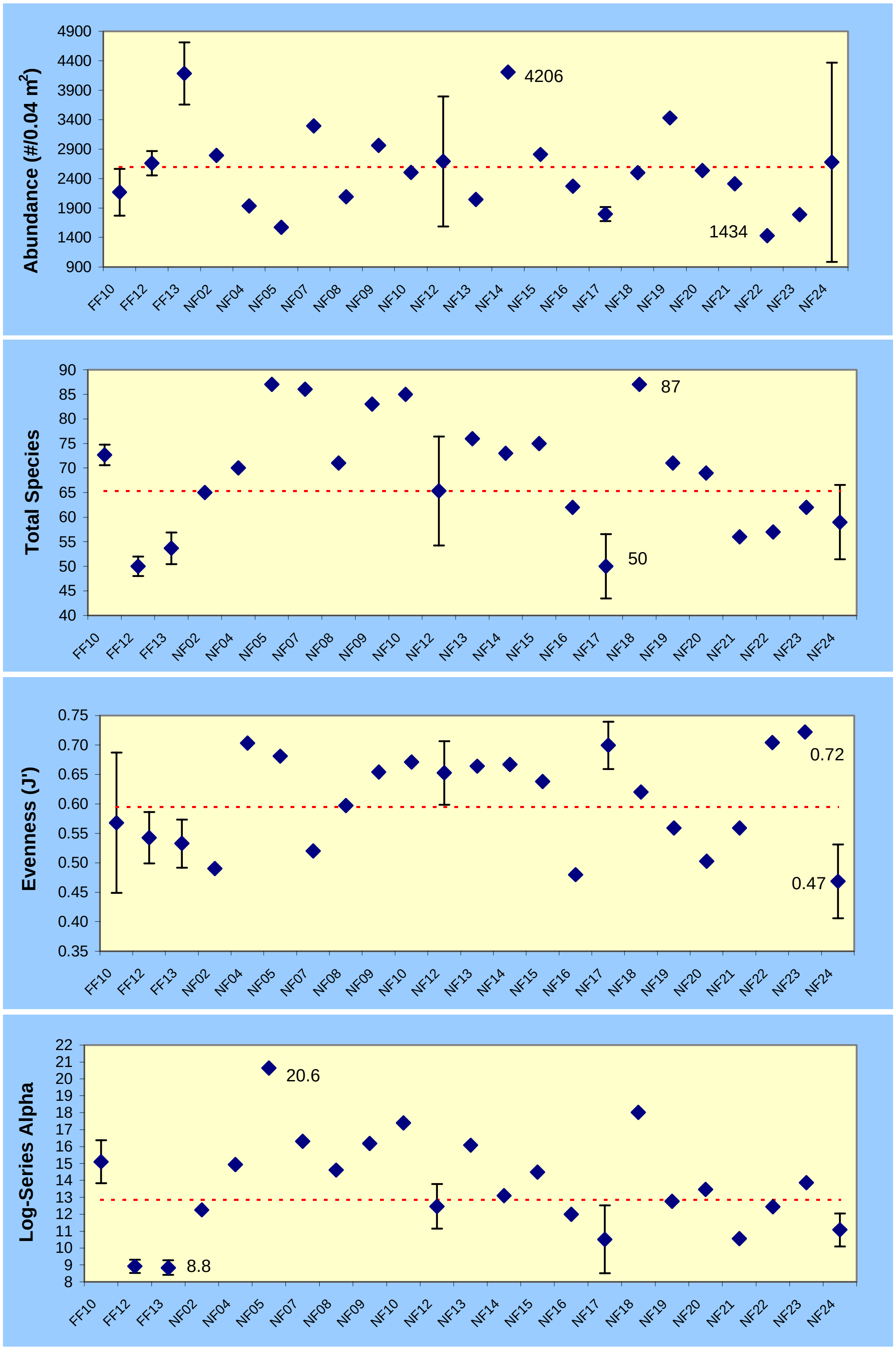


Figure 5-1. Infaunal total abundance, numbers of species, evenness, and log-series alpha values for 2000 nearfield stations. The maximum and minimum values observed in 2000 are labeled and the nearfield yearly mean value is indicated by the dashed line.

Table 5-2. Relative contribution of higher-level taxa to infaunal abundance among 2000 nearfield samples. Average values are shown.

	Total Abundance[a]					Percent			
	Annelida	**Crustacea**	**Mollusca**	**Other**	**Total**	**Annelida**	**Crustacea**	**Mollusca**	**Other**
FF10	1557	212	368	32	2169	71.8%	9.8%	17.0%	1.5%
FF12	2516	42	28	73	2659	94.6%	1.6%	1.1%	2.8%
FF13	3418	638	52	73	4182	81.7%	15.3%	1.2%	1.8%
NF02	2351	124	270	47	2792	84.2%	4.4%	9.7%	1.7%
NF04	829	739	227	138	1933	42.9%	38.2%	11.7%	7.1%
NF05	1045	310	200	19	1574	66.4%	19.7%	12.7%	1.2%
NF07	2846	82	303	63	3294	86.4%	2.5%	9.2%	1.9%
NF08	1834	90	66	102	2092	87.7%	4.3%	3.2%	4.9%
NF09	2536	105	286	36	2963	85.6%	3.5%	9.7%	1.2%
NF10	2160	151	133	60	2504	86.3%	6.0%	5.3%	2.4%
NF12	2465	51	116	59	2690	91.6%	1.9%	4.3%	2.2%
NF13	1124	648	212	59	2043	55.0%	31.7%	10.4%	2.9%
NF14	2248	991	795	172	4206	53.4%	23.6%	18.9%	4.1%
NF15	2356	107	259	88	2810	83.8%	3.8%	9.2%	3.1%
NF16	2067	20	100	81	2268	91.1%	0.9%	4.4%	3.6%
NF17	540	657	337	265	1798	30.0%	36.5%	18.7%	14.7%
NF18	1237	940	268	54	2499	49.5%	37.6%	10.7%	2.2%
NF19	2814	99	453	63	3429	82.1%	2.9%	13.2%	1.8%
NF20	2225	78	186	49	2538	87.7%	3.1%	7.3%	1.9%
NF21	2158	16	104	34	2312	93.3%	0.7%	4.5%	1.5%
NF22	1355	8	47	24	1434	94.5%	0.6%	3.3%	1.7%
NF23	975	344	366	103	1788	54.5%	19.2%	20.5%	5.8%
NF24	2551	36	58	32	2677	95.3%	1.4%	2.2%	1.2%

[a]Abundance of individuals identified to species level.

Numbers of Species—The total numbers of species per individual nearfield sample collected in 2000 varied slightly more than two-fold, ranging from 43 to 87 at station NF17 (rep 3) and stations NF05 and NF18, respectively (Table 5-1). Among the 6 replicated nearfield stations, mean (sd) numbers of species per sample ranged from 50 (sd, 2.0 and 6.6) species at stations FF12 and NF17 to 73 (sd, 2.1) species at station FF10 (Figure 5-1).

Among the higher taxa, annelid worms contributed the highest percentage of species, accounting for about 41–65 % of the species collected at each nearfield station (Table 5-3). Crustaceans and molluscs accounted for about 9–36 % and about 8–19 % of the species collected at each nearfield station, respectively. The contribution of molluscs to species numbers was slightly higher than in 1999.

Diversity—As measured by the Shannon index (H'), diversity among individual nearfield samples collected in 2000 varied from about 2.4 at stations NF24 (Rep 1) to about 4.4 at station NF05 (Table 5-1). Evenness (J') among all nearfield samples ranged from about 0.40 (NF24, rep 1) to 0.74 (NF17, rep 1). Within-station variation was low at all replicated stations except FF10 (Figure 5-1). Log-series alpha varied considerably among nearfield stations, ranging from 8.4 at station FF13 (Rep 1) and NF17 (Rep 3) to 20.6 at station NF05.

Table 5-3. Relative contribution of higher-level taxa to numbers of species among 2000 nearfield samples. Average values are shown.

	Total Species					Percent			
	Annelida	Crustacea	Mollusca	Other	Total	Annelida	Crustacea	Mollusca	Other
FF10	37	18	11	6	73	50.5%	25.2%	15.6%	8.7%
FF12	32	7	4	7	50	64.0%	14.7%	8.0%	13.3%
FF13	34	10	5	5	54	62.7%	19.3%	9.3%	8.7%
NF02	39	10	8	8	65	60.0%	15.4%	12.3%	12.3%
NF04	29	25	10	6	70	41.4%	35.7%	14.3%	8.6%
NF05	37	27	15	8	87	42.5%	31.0%	17.2%	9.2%
NF07	46	17	13	10	86	53.5%	19.8%	15.1%	11.6%
NF08	46	11	7	7	71	64.8%	15.5%	9.9%	9.9%
NF09	46	17	13	7	83	55.4%	20.5%	15.7%	8.4%
NF10	47	17	14	7	85	55.3%	20.0%	16.5%	8.2%
NF12	38	7	11	8	65	58.7%	11.2%	17.3%	12.8%
NF13	40	22	8	6	76	52.6%	28.9%	10.5%	7.9%
NF14	39	17	13	4	73	53.4%	23.3%	17.8%	5.5%
NF15	44	13	10	8	75	58.7%	17.3%	13.3%	10.7%
NF16	38	9	9	6	62	61.3%	14.5%	14.5%	9.7%
NF17	23	18	5	4	50	46.0%	36.0%	9.3%	8.7%
NF18	40	25	13	9	87	46.0%	28.7%	14.9%	10.3%
NF19	39	14	11	7	71	54.9%	19.7%	15.5%	9.9%
NF20	38	15	10	6	69	55.1%	21.7%	14.5%	8.7%
NF21	33	5	10	8	56	58.9%	8.9%	17.9%	14.3%
NF22	33	6	11	7	57	57.9%	10.5%	19.3%	12.3%
NF23	30	20	6	6	62	48.4%	32.3%	9.7%	9.7%
NF24	35	8	11	6	59	59.3%	13.0%	18.1%	9.6%

In contrast with evenness, within-station variation in log-series alpha among replicated stations was relatively high at station NF17 (Figure 5-1).

Most Abundant Species—The 12 most abundant species (Appendix D-5) accounted for about 74–93% of the infaunal abundance at nearfield stations in 2000. Polychaetes predominated at most nearfield stations. Spionid polychaete *Prionospio steenstrupi* was the most abundant species at 16 nearfield stations, one fewer than it was in 1998 and 1999 (Kropp *et al.*, 2000, 2001). Where it was the most common species, *P. steenstrupi* accounted for 22% (NF10) to 56% (NF24) of the infaunal abundance. The numerical dominance of *P. steenstrupi* in the nearfield was further demonstrated by its occurrence among the 12 most numerous species at five of the seven stations where it was not ranked first. *Dipolydora socialis* was the most abundant species at station NF12 and also was among the 12 most abundant taxa at 15 other nearfield stations in 2000. This represented an increase in the numerical importance of *Dipolydora socialis* in the nearfield as compared to 1999. Other polychaete species were the most abundant taxa at three nearfield stations; *Exogone verugera* (NF14), *Mediomastus californiensis* (NF22), and *Exogone hebes* (NF23).

The corophiid amphipod *Crassicorophium crassicorne* was the most abundant species at stations NF04, NF13, and NF17 and was among the top 12 species at 4 other nearfield stations. The amphipod *Unciola inermis*, which was the most abundant species at stations NF13 and NF23 in 1999, ranked only 10th and 4th at those stations, respectively, in 2000. *U. inermis* was among the most abundant species at four additional nearfield stations.

The northern dwarf-cockle *Cerastoderma pinnulatum* and the nutclam *Nucula delphinodonta* were the most abundant molluscs, occurring among the most abundant species at seven and six stations, respectively. Most stations showed relative consistency in the predominant species found in 2000 and 1999. For example, at least 10 of the top 12 most abundant species at stations FF10, NF09, NF12, and NF19 in 1999 were also ranked in the top 12 in 2000. At 15 other stations, at least 8 of the most common species in 1999 were among the 12 most abundant in 2000. The least consistency in numerical dominance between 1999 and 2000 was at station FF13, where only 6 of the top 12 species in 1999 were again ranked among the top 12 in 2000. One nearfield station, NF04, showed considerably different numerically dominant taxa in 1999 than were reported for 1998 (Kropp *et al.*, 2001). At that station only 4 of the 12 most abundant taxa in 1998 were ranked in the top 12 in 1999. However, in 2000, 9 of the top 12 species in 1999 also ranked in the top 12 in 2000.

5.2.3 2000 Farfield Descriptive Community Measures

Abundance—Among individual farfield samples collected in 2000, infaunal abundance varied about eight-fold, ranging from 577 to 4,282 individuals/0.04 m^2 (41,425–107,050/m^2) at stations FF06 (rep 3) and FF07 (rep 3), respectively (Table 5-4). This overall range was lower than that reported for 1999 (1,034–8,563/0.04 m^2). Mean (± sd) abundance among farfield stations ranged from 640 (sd, 99) to 3,754 (sd, 473) individuals/0.04 m^2 at stations FF06 and FF07, respectively (Figure 5-2).

Table 5-4. Summary of ecological variables for samples collected from farfield stations in 2000.

Station	Replicate	Abundance (Total)	(Species[a])	Proportion Identified	Total Species	*H'*	*J'*	Log-series Alpha	Hmax
FF01A	1	2638	2427	92%	69	2.7	0.4	13.2	6.1
FF01A	2	3484	3067	88%	76	2.8	0.5	14.1	6.2
FF01A	3	3581	3432	96%	77	2.6	0.4	14.0	6.3
FF04	1	1363	1178	86%	66	4.4	0.7	15.1	6.0
FF04	2	1226	1125	92%	67	4.5	0.7	15.6	6.1
FF04	3	1222	1143	94%	49	3.9	0.7	10.4	5.6
FF05	1	3053	2620	86%	73	4.3	0.7	13.9	6.2
FF05	2	1870	1519	81%	76	4.4	0.7	16.9	6.2
FF05	3	2634	2337	89%	69	4.3	0.7	13.4	6.1
FF06	1	588	543	92%	40	4.0	0.7	10.0	5.3
FF06	2	754	692	92%	43	3.8	0.7	10.2	5.4
FF06	3	577	541	94%	38	3.7	0.7	9.3	5.2
FF07	1	3608	3496	97%	57	3.5	0.6	9.7	5.8
FF07	2	3371	3309	98%	52	3.0	0.5	8.8	5.7
FF07	3	4282	4176	98%	54	2.8	0.5	8.8	5.8
FF09	1	2498	2193	88%	94	4.2	0.6	20.0	6.6
FF09	2	2444	2169	89%	102	4.2	0.6	22.2	6.7
FF09	3	1760	1554	88%	88	4.4	0.7	20.2	6.5
FF11	1	3037	2887	95%	59	2.7	0.5	10.5	5.9
FF11	2	1829	1741	95%	50	2.3	0.4	9.6	5.6
FF11	3	1908	1807	95%	54	3.2	0.6	10.5	5.8
FF14	1	1497	1309	87%	70	4.5	0.7	15.8	6.1
FF14	2	2147	1770	82%	73	4.6	0.7	15.4	6.2
FF14	3	1638	1347	82%	71	4.7	0.8	16.0	6.2
	Total	53009	48382	91%					

[a]Abundance of individuals identified to species level

Annelid worms were the most abundant major infaunal taxon among the 2000 farfield samples (Table 5-5). Annelids accounted for at least 75 % of the infauna at all but one of the farfield stations, with the highest percentage (95.7 %) at station FF11. At station FF06, annelids accounted for slightly less than half (about 48 %) of the total infaunal abundance. Molluscs typically (6 of 8 stations) were the second highest contributors to infaunal abundance among the major taxa. The highest proportions of molluscs occurred at stations FF09 (16.8 %). Crustaceans were relatively important contributors (34.9 %) to infaunal abundance only at station FF06. At all other stations, crustaceans accounted for less than 6 % of the total infaunal abundance.

Numbers of Species—The total numbers of species per individual farfield sample collected in 2000 varied more than two-fold, ranging from 38 to 102 at station FF06 (rep 3) and FF09 (rep 2), respectively (Table 5-4). Among the farfield stations, mean (sd) numbers of species ranged from 40 (sd, 2.5) to 95 (sd, 7.0) at FF06 and FF09, respectively (Figure 5-2).

Table 5-5. Relative contribution of higher-level taxa to infaunal abundance among 2000 farfield samples. Average values are shown.

	Total Abundance[a]					Percent			
	Annelida	Crustacea	Mollusca	Other	Total	Annelida	Crustacea	Mollusca	Other
FF01A	2655	140	372	67	3234	82.1%	4.3%	11.5%	2.1%
FF04	1069	43	74	85	1270	84.1%	3.4%	5.8%	6.7%
FF05	2123	101	218	76	2519	84.3%	4.0%	8.7%	3.0%
FF06	306	223	83	27	640	47.8%	34.9%	13.0%	4.3%
FF07	3558	98	64	34	3754	94.8%	2.6%	1.7%	0.9%
FF09	1675	126	374	59	2234	75.0%	5.7%	16.8%	2.6%
FF11	2161	14	35	47	2258	95.7%	0.6%	1.6%	2.1%
FF14	1366	41	302	51	1761	77.6%	2.3%	17.2%	2.9%

[a]Abundance of individuals identified to species level.

Among the higher-level taxa, annelid worms contributed the highest percentage of species, accounting for about 51–66 % of the species collected at each farfield station (Table 5-6). Crustaceans (no pycnogonids occurred in the 2000 farfield samples) and molluscs accounted for about 8–23 % and about 10–20 % of the species collected at each farfield station, respectively.

Table 5-6. Relative contribution of higher-level taxa to infaunal abundance among 2000 farfield samples. Average values are shown.

	Total Abundance					Percent			
	Annelida	Crustacea	Mollusca	Other	Total	Annelida	Crustacea	Mollusca	Other
FF01A	39	17	12	6	74	52.3%	23.4%	15.8%	8.6%
FF04	31	11	10	9	61	51.1%	18.1%	15.9%	14.8%
FF05	42	15	8	8	73	57.3%	20.6%	11.0%	11.0%
FF06	21	7	8	5	40	51.2%	17.4%	19.8%	11.6%
FF07	31	10	6	7	54	57.7%	18.4%	10.4%	13.5%
FF09	50	20	14	11	95	52.5%	21.5%	14.4%	11.6%
FF11	36	4	8	6	54	65.6%	8.0%	15.3%	11.0%
FF14	37	12	13	10	71	52.3%	16.4%	17.8%	13.6%

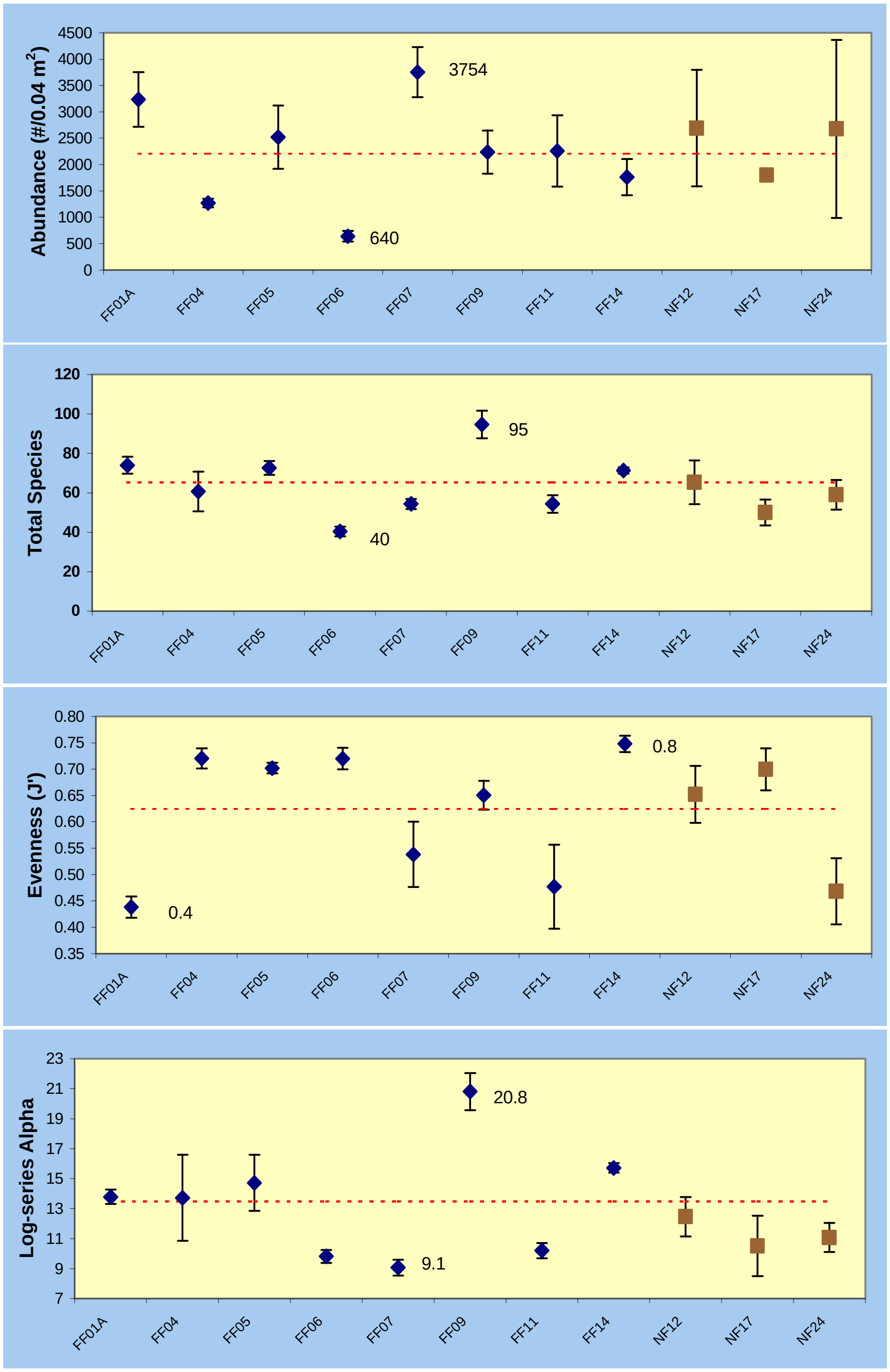


Figure 5-2. Infaunal total abundance, numbers of species, evenness, and log series alpha values for 2000 farfield stations and the three replicated nearfield stations. The maximum and minimum farfield values observed in 2000 are labeled and the farfield yearly mean is indicated by the dashed line.

Diversity—Diversity, as measured by the Shannon Index (*H'*) varied about two-fold across the farfield (Table 5-4), as *H'* values among individual samples ranged from 2.3 (station FF11, rep 2) to 4.7 (station FF14, rep 3). Evenness (*J'*) for individual samples ranged from about 0.4 (3 samples) to 0.7–0.8 (12 samples). Within-station variation was generally small, except for stations FF07 and FF11 (Figure 5-2). Values for log-series alpha ranged from 8.8 (station FF07, reps 2 and 3) to 22.2 (station FF09, rep 2). Within-stations variation was relatively high at three stations (Figure 5-2).

Most Abundant Species—The 12 most abundant species (Appendix D-5) accounted for about 73–93 % of the infaunal abundance at farfield stations in 2000. *Prionospio steenstrupi*, a spionid polychaete was the most abundant species at three stations, FF01A, FF09, and FF11, located in the northern or middle portions of the Bay. *Prionospio steenstrupi* ranked among the 12 most abundant species at all 8 farfield stations, but was generally higher ranked in the northern part of the Bay. *Cossura longocirrata* was the most abundant species at stations FF04, FF06, and FF07. It occurred among the top 12 species at 3 other stations. The sabellid polychaete *Euchone incolor* was the most abundant species at 1 station (FF05) and ranked in the top 12 at 5 others (FF01A, FF04, FF07, FF09, FF11). *Spio limicola* was the top-ranked species at station FF14.

Composition of the 12 most abundant species in 1999 was generally consistent with that found in 1998. At 6 of the 12 farfield stations, at least 9 of the most abundant species found in 2000 also were ranked in 1999. One top-ranked species in 1999 was not among the top 12 species in 2000. At station FF14, *Euchone incolor* was the most abundant species in 1999, but ranked 14th in 2000. The actual abundance of this species dropped from 227.7 (sd = 48.5) individuals per sample in 1999 to 32.7 (sd = 11.7) individuals per sample in 2000.

5.2.4 2000 Nearfield Multivariate Analysis

Cluster analysis of the 2000 nearfield data indicated that station patterns for the infauna were very similar to previous years. Patterns among the 35 grabs, 17 stations with one replicate and six stations with three replicates, indicated that within station similarity was stronger than between stations. At the six-group level (approximately 0.8 CNESS) replicates for a given station were tightly grouped within the same cluster group, except station FF10 (Figure 5-3). Replicate FF10-1 together with NF14 formed cluster group I. Both of these grabs grouped together primarily because they had high abundances of species, for example *Exogone verugera* and *Crassicorophium crassicorne*, which were in low abundance or did not occur in replicates FF10-2 or FF10-3. The other two replicates from FF10 were part of group IIIa. Sediment heterogeneity was likely responsible for the infaunal variation at station FF10. Sediment profile images consistently characterized FF10 as being located in a heterogeneous area with predominantly coarse sediments (Section 3), which was also supported by grain-size analysis that indicated sediments were gravel and medium-sand with 19% fines (Section 4). In addition, group I stations had low abundances of the top numerical dominants *Prionospio steenstrupi* and *Mediomastus californiensis* (Table 5-7). Station group III was the largest and contained all replicates from stations NF12 (IIIb) and NF24 (IIIa). Replicates from station FF12 formed an exclusive group (IV). Station FF13 replicates along with station NF02 formed group V. Replicates from NF17 formed group II along with NF04, NF13, and NF23 (Figure 5-3). Since replicates from a station were closely associated the analysis was simplified by removing the second and third replicate. This is a data reduction stratagem analogous to having only collected one replicate at each station and giving equal weight to each station in defining patterns and associations. At the six-group level (also approximately 0.8 CNESS) station cluster analysis based on the first replicate from each station was very similar to the all-replicate analysis (Figure 5-4).

As in previous years the grouping of stations reflected the influence of sediment type and biogenic activity in structuring nearfield communities. In the one-replicate analysis, the major break in the data was primarily related to sediment type and occurred between coarser sediment stations in groups I and II and the other four station groups with finer sediments (Table 5-8). Group I was composed of two coarse heterogeneous sediment stations, FF10 and NF14, and group II was four low TOC sandy sediment stations, NF04, NF13, NF17, and NF23. The sediment surface at both group I and II stations tended to be dominated by a combination of physical and biogenic processes (Table 5-8, see Sections 3 and 4). Groups III and IV also tended to have coarser sediments, from cobbles to gravels, but significant amounts of fine sediment, 9% to 71%, allowed for many muddy sediment species to occur. The largest station group was V, which was composed of the finer sediment stations with sediment surfaces tending to be dominated by biological processes. Surfaces at group V stations were all dominated by biogenic structures. Subgroups Vb and Vc were both single station groups, NF15 and NF05 respectively. Station NF05 had fine-sand layered over silty sediments and was possibly located in a sedimentary transition area. In 1999, NF05 had similar sedimentological and biological conditions. Station NF15 had heterogeneous sediment that was heavily bioturbated. Group VI was a single station group, NF18, which had physically dominated mixed sediments according to the sediment profile images but coarse-sand according to the grain-size analysis.

Species cluster analysis was based on the 134 species in the reduced data set, which included only the first replicate at a station. Species that occurred at <3 stations and in only the second and third replicates were not included. At about the 0.1 CNESS dissimilarity level six species groups formed with the major break between groups A, B, C and D, E, F (Figure 5-5, Table 5-7). Species groups A, B, and C tended to be associated with station groups III, IV, V, and VI. Groups D and E were primarily associated with station groups I and II, and group F was associated with Vc and VI. Species group A was the largest group with 39 species and contained many of the numerical dominant species that occurred at almost all stations (for example, *Prionospio steenstrupi*, *Euchone incolor*, and *Dipolydora socialis*). Groups B and C each had about ten species with similar distribution patterns as group A species but overall lower abundances. Groups D and E contained the numerically dominant sandy sediment species (for example, *Exogone hebes*, *E. verugera, and Crassicorophium crassicorne*) associated with coarser sediment stations in groups I and II. Many of the species in groups D and E corresponded to those comprising a sand-dwelling fauna identified in previous years (Kropp *et al.*, 2000). Group F tended to be lower abundance species that dominated at stations NF05 and NF18. The exceptions were *Protomedeia fasciata*, *Ericthonius fasciatus*, and *Harpinia propinqua*, which were relatively abundant (Table 5-7).

The data from sediment samples (grain-size, hydrocarbons, heavy metals) and sediment profile images supported the basic pattern of stations and species produced by the cluster analyses (Table 5-8). Addition analysis of the infaunal data with the sediment contaminant data using principle components analysis (PCA) pointed to sediment grain-size (Figure 5-6) as the primary factor determining both community (Figure 5-7) and contaminant patterns (Figure 5-8). No contaminant effects on infaunal communities could be detected above the influence of sediment grain-size.

5.2.5 2000 Farfield Multivariate Analysis

As in previous years, station cluster analysis of the 2000 farfield data with 11 stations and three replicates per station indicated that similarity within a station was stronger than between stations. All three replicates from each of the 11 stations clustered together, except replicate FF10-1 that was different enough from the other replicates to form its own group (Figure 5-9). The reasons for this are related to sediment heterogeneity and explained in the nearfield multivariate analysis section. At the 12 group level, one group for each station plus FF10-1, the CNESS dissimilarity was approximately 0.6. A similar station pattern was produced when the three station replicates were summed (Figure 5-9). At the four-station group level, in the summed analysis, station FF10 associated with FF12 and FF13 to form group IV, which encompassed the area around the outfall and were the stations closest to Boston Harbor. Between station group dissimilarity was high and appeared related to a station's geographic position, sediment grain-size, and depth. Stations FF01A and FF09, the northern most and shallow (36–49 m) stations were group I. Stations FF05 and FF14, primarily eastern stations with 64–75 m water depth, which had the highest station similarity grouped with stations FF04 and FF11, with 89 m depth, to form group II. Cape Cod Bay stations (FF06 and FF07), the shallowest

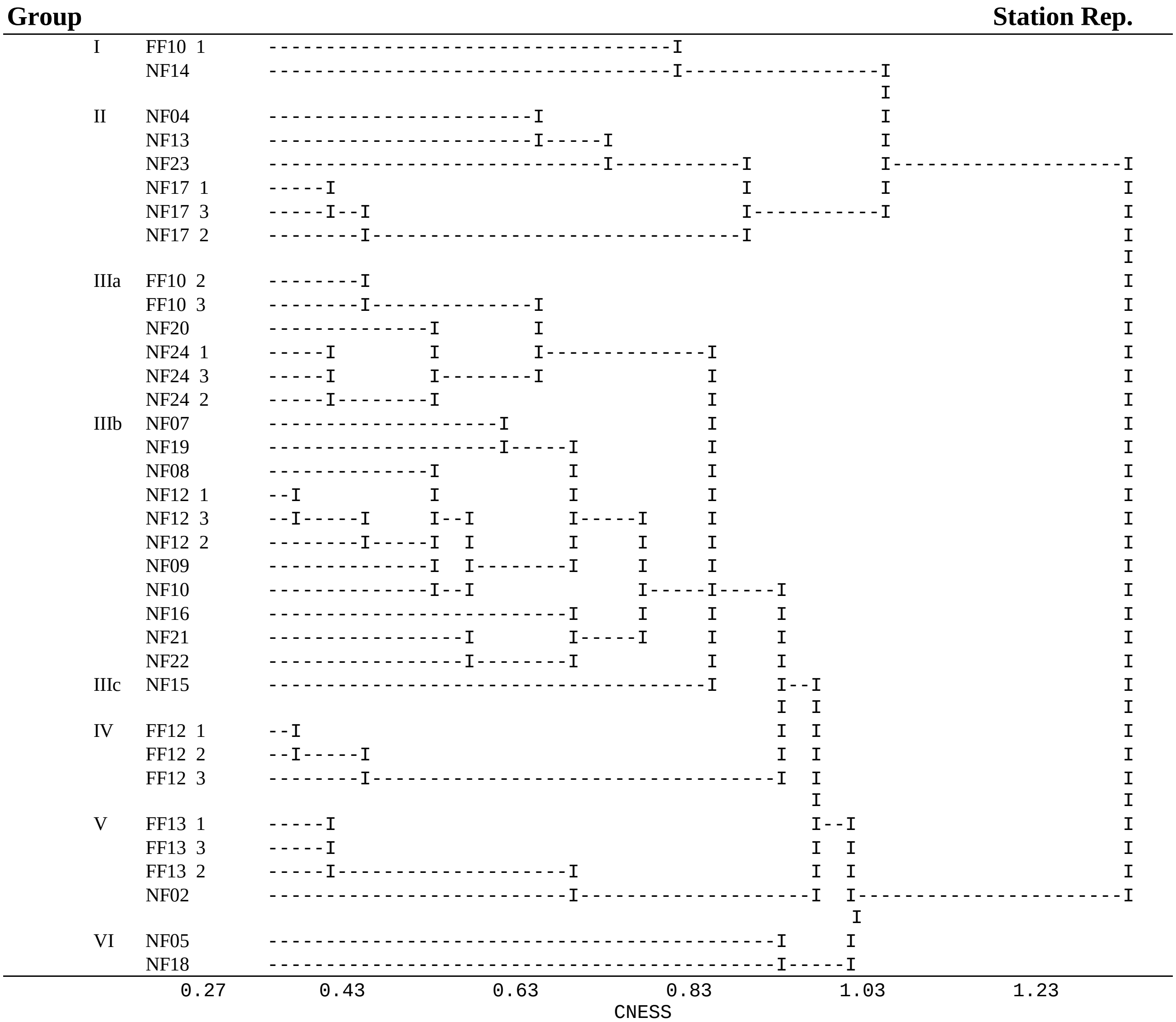


Figure 5-3. Station dendrogram of 2000 nearfield infauna data with all replicates (Gallagher's CNESS dissimilarity [*m* = 15] with group average sorting).

at 33–39 m, formed group III. Group I stations had low TOC and very-fine-sand with highest species richness within the farfield. Groups II and III both had higher TOC and finer sediments (5–7 Phi) with group III having lower taxa richness than group II. Group IV had coarser sediments and overall lowest species richness (Figure 5-9).

Species cluster analysis based on summed replicates used 129 species that occurred at three or more stations. At about the 0.15 CNESS dissimilarity level eight species groups formed (Figure 5-10, Table 5-9). The species groups were divided into two dissimilar sets of groups, A, B, C and D to H.

Each of the species groups contained a few numerical dominants with most of the species occurring in low numbers, <10 individuals/0.12 m^2. Group A contained the top numerically dominant *Prionospio steenstrupi* along with *Nucula delphinodonta* and *Spiophanes bombyx* and was most associated with station group I.

Group B was composed of low abundance species, such as *Pholoe minuta* that occurred at all stations, that were associated with station Groups I and IV. Group C had the numerical dominants *Mediomastus californiensis, Tharyx acutus, Aricidea catherinae,* and *Photis pollex* and was associated with station groups III and IV. Group D contained *Cossura longocirrata*, *Euchone incolor* and Tubificidae sp. 2 and had strongest association with station group III. Group E contained *Aricidea quadrilobata* and *Levinsenia gracilis* and was associated with station groups I and II. Group F was primarily associated with station group II and contained *Chaetozone setosa* and *Tubificoides apectinatus*. Group G was associated with station groups I and II and had four dominants *Spio limicola, Anobothrus gracilis, Dipolydora socialis* and *Thyasira gouldi*. Group H was associated with station group III and had *Ninoe nigripes* and *Harpinia propinqua* as dominants.

5.2.6 Comparison of 2000 Descriptive Community Measures to Previous Years

Nearfield—The nine year period during which the nearfield has been sampled as part of the MWRA monitoring program can be considered in two contrasting periods, an early, five-year period of an infaunal community in substantial flux and a later, four-year period of relative infaunal community consistency. For example, mean infaunal abundance (Figure 5-11a) for the years 1992 through 1996 was relatively low and variable (see text box), whereas the period 1997 through 2000 was characterized by relatively high and consistent infaunal abundance. The number of species per sample and log-series alpha diversity shows patterns somewhat similar to that of abundance (Figure 5-11b, e), albeit with some differences. Species numbers and log-series alpha diversity reached a peak in 1997 and have shown a gradual, but consistent decline since. Nonetheless, separating values for those metrics by the two time periods mentioned above, both show higher, more consistent means for the latter four years than for the earlier five years (see text box below).

	1992–1996 (n=5)			1997–2000 (n=4)		
Metric	**Mean**	**sd**	**CV**	**Mean**	**sd**	**CV**
Abundance [1]	1,918	347	18%	2,652	78	3%
Species [2]	60	8.5	14%	70	3.4	5%
Log-series alpha	12.2	1.6	13%	13.8	0.8	6%
H'	3.71	0.21	6%	3.61	0.14	4%
J'	0.64	0.02	2%	0.59	0.02	3%

[1] individuals per sample
[2] species per sample

Table 5-7. Average abundance of species by cluster group (#/0.04 m^2) for 2000 nearfield infauna. Species with <3 occurrences were not included.

		Station Group							
Species Group	Species	FF10 NF14 I	N04 N13 N23 N17 II	FF13 N02 N20 N24 III	FF12 IV	NF07 NF19 NF09 NF10 NF12 NF08 NF21 NF22 NF16 Va	NF15 Vb	NF05 Vc	NF18 VI
A	*Prionospio steenstrupi*	215	30	1537	1088	780	783	404	617
A	*Mediomastus californiensis*	109	5	302	326	220	208	63	101
A	*Euchone incolor*	7	2	46	26	111	83	9	12
A	*Micrura* spp.	2	2	13	6	13	15	3	4
A	*Ninoe nigripes*	5	0	39	59	82	39	11	52
A	*Levinsenia gracilis*	0	2	52	29	69	13	24	34
A	*Amphiporus angulatus*	0	0	6	3	6	10	2	3
A	*Spio limicola*	0	0	25	5	162	78	18	11
A	*Leitoscoloplos acutus*	0	0	14	6	16	6	1	2
A	*Nephtys incisa*	0	0	1	0	6	0	0	1
A	*Mayerella limicola*	1	1	0	0	11	0	0	0
A	*Eteone longa*	1	2	15	10	10	4	1	1
A	*Dentalium entale*	0	0	5	0	2	0	0	0
A	*Aricidea quadrilobata*	0	0	9	2	9	1	0	0
A	*Praxillella gracilis*	0	0	0	0	2	0	0	0
A	*Terebellides atlantis*	0	0	4	1	3	0	0	0
A	*Cossura longocirrata*	0	0	1	0	2	0	0	0
A	*Yoldia sapotilla*	0	0	2	0	1	0	1	0
A	*Goniada maculata*	0	0	2	1	3	1	3	2
A	*Mya arenaria*	2	0	0	1	1	1	1	0
A	*Phascolion strombi*	0	0	0	0	1	1	0	0
A	*Carinomella lactea*	0	0	0	2	4	0	0	1
A	*Arcteobia anticostiensis*	0	0	0	0	1	0	0	0
A	*Pitar morrhuana*	0	0	0	0	1	0	0	0
A	Tubificidae sp. 2	12	2	15	1	10	0	5	10
A	*Alvania castanea*	3	0	2	0	18	0	0	7
A	*Monticellina dorsobranchialis*	2	7	17	18	11	0	2	13
A	*Parougia caeca*	3	4	9	10	11	13	13	10
A	*Ilyanassa trivittata*	7	3	14	4	10	3	5	5
A	*Dipolydora socialis*	50	67	42	24	175	186	186	1
A	*Aphelochaeta marioni*	5	1	9	0	46	18	78	11
A	*Nucula delphinodonta*	5	0	12	2	86	54	16	12
A	*Capitella capitata* complex	1	0	25	5	11	6	6	2
A	*Campylaspis rubicunda*	1	0	1	0	1	0	1	0
A	*Monticellina baptisteae*	19	7	21	55	57	1	0	16
A	*Thracia conradi*	0	2	2	0	11	1	1	1
A	*Sphaerodoropsis minuta*	1	0	0	0	4	1	1	0
A	*Maldane sarsi*	0	0	2	0	43	0	2	0
A	*Edwardsia elegans*	1	1	2	0	4	0	1	2

Table 5-7. Average abundance of species by cluster group (#/0.04 m^2) for 2000 nearfield infauna. Species with <3 occurrences were not included (continued).

		Station Group							
Group	Species	I	II	III	IV	Va	Vb	Vc	VI
B	*Aricidea catherinae*	47	10	319	2	42	207	19	76
B	*Photis pollex*	1	19	141	11	12	12	2	3
B	*Diplocirrus hirsutus*	1	0	3	2	1	0	0	0
B	*Metopella angusta*	2	0	14	1	7	7	1	0
B	*Pleurogonium rubicundum*	0	0	4	1	4	0	0	0
B	*Tharyx acutus*	19	26	247	121	36	11	38	33
B	*Pectinaria granulata*	2	0	8	0	8	0	0	5
B	*Argissa hamatipes*	0	2	5	1	2	2	1	1
B	*Ampharete finmarchica*	3	2	5	0	1	4	0	0
B	*Pleurogonium inerme*	1	0	3	0	1	0	0	1
C	*Owenia fusiformis*	0	19	10	527	22	202	0	1
C	*Phoronis architecta*	0	1	6	46	10	9	3	0
C	*Scoletoma hebes*	9	0	23	51	5	0	0	0
C	*Edotia montosa*	8	16	17	19	31	66	0	3
C	*Clymenella torquata*	0	0	1	0	4	11	0	0
C	*Nereis procera*	3	0	3	0	3	10	2	0
C	*Pherusa affinis*	0	0	1	0	1	2	0	0
C	*Laonome kroeyeri*	0	0	0	0	2	7	0	0
C	Nemertea sp. 12	19	10	23	49	18	22	4	32
C	*Sphaerodoridium* sp. A	1	1	1	0	3	1	0	0
C	*Stenopleustes inermis*	4	2	3	0	4	2	1	2
C	*Dipolydora quadrilobata*	0	1	0	0	1	1	0	0
D	*Crassicorophium crassicorne*	181	268	1	0	3	0	1	36
D	*Cerastoderma pinnulatum*	88	62	8	0	3	11	15	9
D	*Spio thulini*	21	12	2	1	1	0	1	0
D	*Unciola inermis*	266	59	2	0	0	0	0	15
D	*Exogone hebes*	262	172	15	1	13	186	18	54
D	*Syrrhoe* sp. 1	1	1	0	0	1	2	0	0
D	Enchytraeidae sp. 1	195	117	0	0	0	0	0	0
D	*Tanaissus psammophilus*	0	41	0	0	0	0	0	0
D	*Chiridotea tuftsi*	0	35	0	0	1	0	0	0
D	*Solariella obscura*	0	7	0	0	0	0	0	0
D	*Hippomedon serratus*	0	5	0	0	0	0	0	0
D	*Aglaophamus circinata*	2	12	1	0	0	0	0	0
D	*Politolana polita*	0	12	0	0	0	0	0	0
D	*Galathowenia oculata*	3	5	1	1	4	6	3	1
D	*Phyllodoce mucosa*	15	12	12	1	8	10	3	4
D	*Phoxocephalus holbolli*	14	18	2	0	0	0	0	0
D	*Phyllodoce maculata*	5	9	1	0	5	2	0	1
D	*Echinarachnius parma*	0	16	0	0	0	0	0	0
D	*Rhepoxynius hudsoni*	0	5	0	0	0	0	0	0
D	*Tetrastemma vittatum*	1	5	2	0	2	0	0	1
D	*Chaetozone setosa mb*	2	4	0	0	1	0	0	0
D	*Polycirrus medusa*	1	5	1	0	1	0	0	0
D	*Spiophanes bombyx*	1	69	17	19	5	73	1	0
D	*Polygordius* sp. A	1	70	18	4	6	6	0	1
D	*Clymenura* sp. A	0	2	0	0	0	0	0	0
D	Nemertea sp. 2	0	5	1	1	1	0	0	0
D	*Scalibregma inflatum*	1	2	1	0	1	0	0	0
D	*Cyclocardia borealis*	5	2	1	0	4	0	0	0

Table 5-7. Average abundance of species by cluster group (#/0.04 m^2) for 2000 nearfield infauna. Species with <3 occurrences were not included (continued).

		Station Group							
Group	Species	I	II	III	IV	Va	Vb	Vc	VI
E	*Exogone verugera*	448	85	10	0	31	52	63	44
E	*Exogone longicirris*	7	3	0	0	1	1	0	0
E	*Chone duneri*	2	1	1	0	0	1	0	1
E	*Crenella glandula*	105	8	14	0	20	19	14	16
E	*Euclymene collaris*	48	5	23	0	0	12	0	0
E	*Spio filicornis*	3	0	2	0	3	2	0	2
E	*Astarte undata*	45	5	9	0	12	15	13	54
E	*Hiatella arctica*	47	6	5	0	1	12	2	5
E	*Leptocheirus pinguis*	45	1	1	0	0	0	9	17
E	*Munna* sp. 1	26	0	2	0	0	0	4	3
E	*Musculus niger*	2	0	0	0	1	0	0	1
E	*Tubificoides apectinatus*	15	1	9	1	2	0	0	4
E	*Ceriantheopsis americanus*	8	1	4	1	3	3	1	6
E	*Pholoe minuta*	17	3	9	1	9	13	1	15
E	Cephalothricidae sp. 1	4	5	0	0	2	1	2	1
E	*Cancer borealis*	2	2	0	0	1	0	1	0
E	*Diastylis sculpta*	0	2	3	0	1	0	0	1
F	*Protomedeia fasciata*	66	18	1	0	0	1	18	511
F	*Ericthonius fasciatus*	94	3	5	1	1	0	21	91
F	*Harpinia propinqua*	0	0	0	0	2	0	30	130
F	*Orchomenella minuta*	2	2	2	1	3	1	14	32
F	*Oenopota incisula*	0	0	2	0	1	0	1	3
F	*Gattyana amondseni*	1	0	2	0	2	3	3	4
F	*Scoletoma fragilis*	0	0	2	0	1	0	0	4
F	Euclymeninae sp. 1	1	0	0	0	2	0	0	6
F	*Diastylis quadrispinosa*	0	2	0	0	1	0	0	5
F	*Unciola irrorata*	13	10	1	0	0	0	47	30
F	*Haploops fundiensis*	0	2	0	0	1	0	43	0
F	*Dyopedos monacanthus*	0	1	3	2	1	2	10	2
F	*Sphaerosyllis longicauda*	3	1	0	0	1	0	6	1
F	*Anobothrus gracilis*	1	0	1	2	3	0	13	0
F	*Petalosarsia declivis*	1	1	0	0	2	3	5	0
F	*Arctica islandica*	1	2	3	0	3	4	13	0
F	*Casco bigelowi*	0	0	1	0	1	0	3	1
F	*Lyonsia arenosa*	1	0	1	0	0	0	2	1
F	*Ampelisca macrocephala*	0	2	0	0	3	1	5	1
F	*Thyasira gouldi*	0	0	1	1	8	8	12	3
F	*Onoba pelagica*	0	0	0	0	11	0	13	0
F	*Ptilanthura tenuis*	2	3	0	0	2	1	4	1
F	*Diaphana minuta*	3	3	3	0	0	0	4	1
F	*Ameroculodes* sp. 1	0	1	0	0	1	0	1	1
F	*Apistobranchus typicus*	0	0	4	0	4	0	4	0
F	*Polycirrus phosphoreus*	0	0	2	0	1	0	1	0
F	*Scoloplos armiger*	1	5	1	2	3	3	4	3
F	*Hippomedon propinquus*	0	9	9	0	4	0	1	0

Cluster
Group.. Station

```
I    FF10 --------------------------I
     NF14 --------------------------I---------------I
                                                    I
II   NF04 -------------I                            I
     NF13 -------------I-------I                    I---------------------I
     NF23 ---------------------I----I               I                     I
     NF17 --------------------------I---------------I                     I
                                                                          I
III  FF13 ------------------I                                             I
     NF02 ------------------I-------I                                     I
     NF20 --I                       I---------I                           I
     NF24 --I-----------------------I         I--I                        I
                                              I  I                        I
IV   FF12 ------------------------------------I  I                        I
                                                 I                        I
Va   NF07 ----------I                            I------I                 I
     NF19 ----------I-------I                    I      I                 I
     NF09 -----I            I                    I      I                 I
     NF10 -----I            I----I               I      I                 I
     NF12 -----I------------I    I               I      I                 I
     NF08 -------------I         I-------I       I      I-----------------I
     NF21 -------I     I----I    I       I       I      I
     NF22 -------I-----I    I----I       I--I    I      I
     NF16 ------------------I            I  I----I      I
Vb   NF15 -------------------------------I  I           I
Vc   NF05 ----------------------------------I           I
                                                        I
VI   NF18 ----------------------------------------------I
          0.4        0.5          0.7          0.86         1.0         1.2
```

CNESS

Figure 5-4. Dendrogram of 2000 nearfield infauna data including only the first replicate from each station (Gallagher's CNESS dissimilarity with group average sorting).

Table 5-8. Nearfield 2000 physical and biological parameters averaged by station cluster group. Cluster based on the first replicate grab for each station and Gallagher's CNESS dissimilarity with group average sorting.

Cluster	Station	Abund,	Spp.	SS	OSI	Infauna	Burrow	Oxic Void	Sediment	Phi	Gravel	Fines	Clost,	TOC	Pen.	Relief	RPD	Surface
I	FF10	1619	75	I?					PB–GR	2.1	22	19	1167	2.2	0.0	1.5		BIO/PHY
	NF14	3449	73	II	5.7	0	0	0.7	PB–FSSICL	1.2	36	11	565	2.4	6.0	1.1	>1.9	BIO/PHY
II	NF04	1611	70	I/II	6.3	0	0	0	FS	2.6	0	6	120	0.2	2.8	1.4	>2.8	BIO/PHY
	NF13	1804	76	I/II	6	0	0	0	PB–FSMS	2.2	2	5	90	0.1	2.7	1.2	>2.6	BIO/PHY
	NF23	1200	62	I/II	6	0	0	0	GR, FSMS	1.6	12	5	140	0.1	2.7	1.1	>2.7	BIO/PHY
	NF17	1139	56	I/II	7	0	0	0	PB–FSMS	2.0	0	2	63	0.1	3.2	0.3	>3.4	BIO
III	FF13	3335	50	I/II	5.7	1.7	2.3	0.3	CB–GR, FSSI, SI	5.7	0	71	5960	1.8	2.8	1.8	>2.0	BIO/PHY
	NF02	2454	65	I?	5	0	0	0	CB–GR, MSCS	2.4	3	9	440	0.3	1.1	3.1	>2.2	PHY
	NF20	2259	69	I/II	5	0	1.0	0	PB–GR, SIFS	0.9	39	10	670	3.3	4.6	2.8	2.0	BIO/PHY
	NF24	4481	66	II/III	6.7	12.3	4.3	0.7	FSSICL	4.9	0	54	1373	1.3	9.3	1.9	1.8	BIO
IV	FF12	2556	52	I/II	5.3	3.3	4.0	0	VFS	4.0	3	29	2120	0.5	5.3	1.9	2.0	BIO/PHY
Va	NF07	3174	86	II/III	9.7	7.0	7.7	3.0	SIFS/CL	4.4	0	43	1680	0.9	14.4	0.9	3.8	BIO
	NF19	3320	71	II	6	3.7	3.3	1.0	CB–FSSICL	1.5	38	14	345	0.6	9.0	2.2	1.7	BIO/PHY
	NF09	2724	83	III	9.3	7.7	5.7	2.0	FSSI	4.6	0	39	1000	1	8.4	2.1	2.9	BIO
	NF10	2296	85	III	10	13.0	6.3	1.0	FSSICL	4.9	0	47	1570	1.2	10.0	0.6	3.3	BIO
	NF12	1451	55	III	9.3	5.7	5.3	4.0	FSSICL	5.4	0	65	1820	1.6	17.1	1.1	3.1	BIO
	NF08	1875	71	II	7.3	3.0	2.7	1.3	SIFS	5.4	0	67	2460	1.4	17.5	0.9	3.1	BIO....
	NF21	2124	56	III	10	6.0	5.7	3.3	SIFS	5.2	0	59	2310	1.8	16.2	0.8	3.5	BIO
	NF22	1208	57	II/III	8.7	5.0	5.0	2.3	SIFS	4.3	3	43	1620	1	14.9	1.3	2.9	BIO
	NF16	2101	62	II/III	8	1.3	4.0	1.0	PB–FSSI	3.0	10	26	1380	0.9	7.0	1.4	2.9	BIO/PHY
Vb	NF15	2562	75	II	6	4.0	3.3	0	PB–FSSI	2.8	4	15	350	0.7	4.8	1.2	1.9	BIO/PHY
Vc	NF05	1380	87	II/III	8.3	2.0	4.3	1.0	FS/SICL	4.3	1	40	355	1.2	6.5	1.0	3.1	BIO....
VI	NF18	2242	87	II	6.7	5.7	3.7	0	FSSICL	0.8	48	11	400	1	5.6	1.6	2.5	PHY

```
|-------------I
|             I-------------I
              I             I
|             I             I
|-------------I             I
|                           I
|                           I
                            I
|                           I
|-------I                   I
|       I                   I
|       I--I                I
        I  I                I
--------I  I----I           I
           I    I           I
|          I    I           I
|          I    I           I
|          I    I           I
|          I    I           I
|----I     I    I           I
|    I     I    I-----------I
|    I-I   I    I
|    I I---I    I
|    I I        I
-----I I        I
-------I        I
                I
----------------I
 0.7   0.8   0.9   1.0   1.1   1.2
```

CNESS

```
Species
Group
A      ------------I
                   I
                   I-----I
                   I     I
B      ---------I  I     I
                I  I     I
                I--I     I
C               I        I
       ---------I        I
                         I
D      ------------I     I
                   I     I
                   I-----I
E      ---------I  I
                I  I
                I--I
                I
F      ---------I
            0.1    0.0   -0.1
```

Figure 5-5. Species group dendrogram of 2000 nearfield infaunal data including only the first replicate from each station and species with >3 occurrences (Gallagher's CNESS dissimilarity and UPGMA sorting). See Table 5-7 for species in each group.

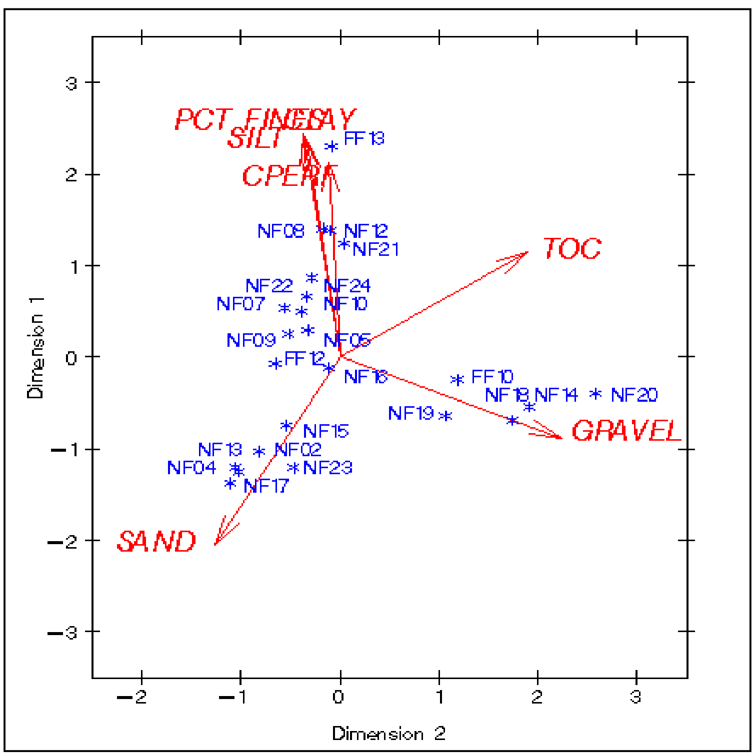


Figure 5-6. Biplot of faunal ordinaton for 2000 nearfield sediment grain-size data. Arrows indicate direction of increase for each parameter.

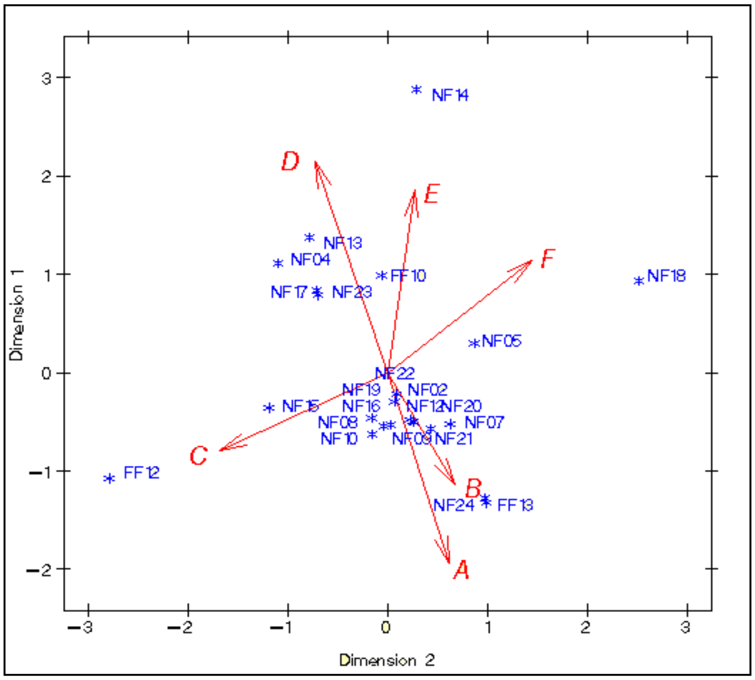


Figure 5-7. Biplot of species cluster groups for 2000 nearfield infauna data. Arrows indicate direction of increase for each species group. Species in each group are listed in Table 5-7.

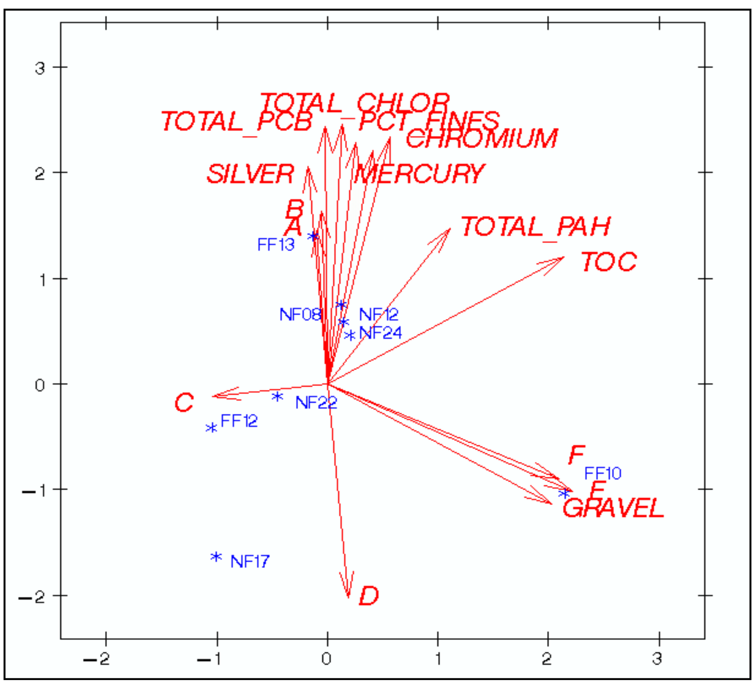


Figure 5-8. Biplot of sediment parameters (grain-size, *Clostridium*, TOC, metals, hydrocarbons) and species cluster groups (A to F) for the eight 2000 nearfield stations that had hydrocarbon data. Arrows indicate direction of increase for each parameter or group.

A

```
Group        Station Rep.
I   FF01A 1  -----I
    FF01A 3  -----I--I
    FF01A 2  --------I--------------------------------I
    FF10 2   --------------I                          I-----------I
    FF10 3   --------------I--------------------------I           I
    FF09 1   --------I                                            I-----I
    FF09 2   -----I  I--------------------------------------------I     I
    FF09 3   -----I--I                                                  I
                                                                        I
II  FF12 1   -----I                                                     I
    FF12 2   -----I-----I                                               I--------I
    FF12 3   -----------I-----------------------------------------I     I        I
    FF13 1   --------I                                            I     I        I
    FF13 3   --------I                                            I-----I        I--I
    FF13 2   --------I--------------------------------------------I              I  I
                                                                                 I  I
III FF10 1   --------------------------------------------------------------------I  I
                                                                                    I
IV  FF04 1   -----------------I                                                     I
    FF04 2   -----------------I--I                                                  I
    FF04 3   --------------------I-----------------------I                          I
    FF05 1   --I                                         I                          I
    FF05 2   --I--I                                      I                          I--I
    FF05 3   -----I-----------------------------I        I                          I  I
    FF14 1   -----------------I                 I--------I--------------------I     I  I
    FF14 2   --------I        I-----------------I        I                    I     I  I
    FF14 3   --------I--------I                          I                    I     I  I
    FF11 1   --I                                         I                    I     I  I
    FF11 3   --I--I                                      I                    I-----I  I
    FF11 2   -----I--------------------------------------I                    I        I
                                                                              I        I
V   FF07 1   --------I                                                        I        I
    FF07 2   --------I-----I                                                  I        I
    FF07 3   --------------I--------------------------------------------------I        I
                                                                                       I
VI  FF06 1   --------I                                                                 I
    FF06 2   --------I--------------------------------I                                I
    FF06 3   -----------------------------------------I--------------------------------I
             0.23        0.38           0.56           0.75          0.93           1.12
```

B

```
Group Stat   Abund.  Spp  Depth  Gravel  Sand  Phi  Clost  TOC
I     FF01A    8926   99     36       1    80  3.5    603  0.4  -------------------I
      FF09     5916  131     49       0    80  3.7    570  0.7  -------------------I---------I
                                                                                             I
II    FF04     3446   82     89       0    10  6.6   1335  2.4  ------------I                I
      FF05     6476  101     64       0    45  5.0    665  1.2  --I         I                I------------I
      FF14     4426   98     75       1    26  5.7   1045  1.5  --I------I  I----------------I            I
      FF11     6435   72     89       0    20  6.2   1185  2.1  ---------I--I                             I---I
                                                                                                          I   I
III   FF06     1776   65     33       0    45  5.2    700  1.0  -----------------------------------I      I   I
      FF07    10981   64     39       0    15  6.2   1040  2.3  -----------------------------------I------I   I
                                                                                                              I
IV    FF10     1619   75     29      22    59  2.1   1167  2.2  ---------------------------------------I      I
      FF12     2556   52     23       3    68  4.0   2120  0.5  ------------------------I              I------I
      FF13     3335   50     23       0    29  5.7   5960  1.8  ------------------------I--------------I
                                                                  0.6     0.7     0.8     0.9     1.0     1.1
```

Figure 5-9. Dendrogram of 2000 farfield station groups with all replicates from each station (A) and replicates summed for each station (B). Both analyses are with Gallagher's CNESS dissimilarity and UMPGA sorting.

```
Species
Group
A      ---------I
                I
                I-----I
                I     I
B      ---------I     I--------I
                      I        I
                      I        I
                      I        I
C      ---------------I        I
                               I
                               I
                               I
D      ------------I           I
                   I           I
                   I           I
                   I           I
E      ---I        I           I
          I        I-----I     I
          I-----I  I     I     I
          I     I  I     I     I
F      ---I     I  I     I     I
                I--I     I     I
                I        I-----I
                I        I
G      ---------I        I
                         I
                         I
                         I
H      ------------------I
              0.2      0.0
```

Figure 5-10. Species group dendrogram of 2000 farfield infaunal data with three replicates for each station summed and including only species with >2 occurrences (Gallagher's CNESS dissimilarity and UPGMA sorting).

Table 5-9. Average abundance of species by cluster group (#/0.12 m^2) for 2000 farfield infauna. Species with <3 occurrences were not included.

		Station Group				
		FF01A FF09	FF04 FF05 FF14 FF11	FF06 FF07	FF10 FF12 FF13	Station Occurrences
Group	Species	I	II	III	IV	(Max. = 11)
A	*Prionospio steenstrupi*	3775	1136	97	805	11
A	*Nucula delphinodonta*	337	77	61	4	10
A	*Spiophanes bombyx*	220	1	0	15	7
A	*Edotia montosa*	113	2	18	6	6
A	*Polygordius* sp. A	41	0	3	3	7
A	*Edwardsia elegans*	33	1	0	0	5
A	*Ptilanthura tenuis*	22	0	1	0	4
A	*Sphaerodoridium* sp. A	9	2	8	1	8
A	*Goniada maculata*	11	4	0	0	7
A	*Petalosarsia declivis*	10	1	0	0	5
A	Euclymeninae sp. 1	11	0	0	0	3
A	*Aeginina longicornis*	10	0	0	0	3
A	*Ampelisca macrocephala*	7	0	0	0	3
A	*Ameroculodes* sp. 1	5	0	1	0	3
B	*Exogone verugera*	39	1	0	71	5
B	*Crenella glandula*	48	19	2	6	5
B	*Pholoe minuta*	30	17	14	10	11
B	*Astarte undata*	60	1	1	15	6
B	*Exogone hebes*	42	0	1	21	6
B	*Cerastoderma pinnulatum*	22	0	1	26	5
B	*Hiatella arctica*	25	1	0	22	6
B	*Spio thulini*	33	1	0	7	7
B	*Ilyanassa trivittata*	3	0	0	10	5
B	*Unciola irrorata*	3	0	0	8	3
B	*Phyllodoce maculata*	5	0	0	1	4
B	*Diaphana minuta*	0	1	2	1	4
B	*Ericthonius fasciatus*	3	0	0	1	4
B	*Nereis procera*	3	0	0	1	3
B	*Pectinaria granulata*	2	0	0	1	3
C	*Mediomastus californiensis*	154	180	471	277	11
C	*Tharyx acutus*	66	1	224	187	9
C	*Aricidea catherinae*	55	0	108	179	8
C	*Photis pollex*	44	20	24	175	11
C	*Owenia fusiformis*	40	8	0	176	6
C	*Eteone longa*	8	18	5	10	9
C	*Monticellina baptisteae*	11	1	4	30	6
C	*Phoronis architecta*	29	1	0	19	7
C	*Scoletoma hebes*	0	0	0	34	3
C	*Capitella capitata* complex	25	6	0	7	8
C	*Phyllodoce mucosa*	19	0	0	10	5
C	*Monticellina dorsobranchialis*	12	0	0	11	4

Table 5-9. Average abundance of species by cluster group (#/0.12 m^2) for 2000 farfield infauna. Species with <3 occurrences were not included (continued).

Group	Species	I	II	III	IV	Station Occurrences
C	*Argissa hamatipes*	7	2	1	2	7
C	*Pleurogonium rubicundum*	5	1	0	3	6
C	*Oenopota incisula*	2	1	0	1	3
C	*Scoloplos armiger*	1	0	0	1	5
D	*Cossura longocirrata*	27	328	2223	0	8
D	*Euchone incolor*	285	508	1032	20	11
D	Tubificidae sp. 2	4	2	677	12	9
D	*Apistobranchus typicus*	14	4	164	0	6
D	*Metopella angusta*	15	14	33	10	11
D	*Diastylis cornuifer*	9	9	16	0	5
D	*Terebellides atlantis*	2	6	20	0	7
D	*Stenopleustes inermis*	5	2	11	1	5
D	*Scoletoma fragilis*	3	2	13	0	7
D	*Stereobalanus canadensis*	1	3	6	0	7
E	*Aricidea quadrilobata*	49	393	183	1	10
E	*Levinsenia gracilis*	224	328	88	11	10
E	*Galathowenia oculata*	35	129	11	1	10
E	*Parougia caeca*	38	70	81	6	11
E	*Sternaspis scutata*	0	65	4	0	6
E	*Yoldia sapotilla*	19	25	7	0	7
E	*Maldane sarsi*	26	6	0	0	3
E	*Heteromastus filiformis*	0	12	0	0	4
E	*Eudorella hispida*	0	11	1	0	5
E	*Tetrastemma vittatum*	5	5	0	1	8
E	*Laonome kroeyeri*	6	4	0	0	4
E	*Praxillella gracilis*	0	6	0	0	4
E	*Spiophanes kroeyeri*	4	2	0	0	5
E	*Scalibregma inflatum*	0	4	0	0	4
E	*Chaetoderma nitidulum canadense*	1	4	0	0	4
E	*Mya arenaria*	0	3	1	1	6
E	*Siliqua costata*	2	2	0	0	3
E	*Prionospio aluta*	1	2	0	0	3
F	*Chaetozone setosa mb*	3	281	8	0	7
F	*Tubificoides apectinatus*	1	158	1	8	10
F	Nemertea sp. 12	35	69	22	31	11
F	*Micrura* spp.	28	41	18	6	11
F	*Aphelochaeta marioni*	29	31	9	6	10
F	*Paramphinome jeffreysii*	0	50	0	0	4
F	*Dentalium entale*	16	27	0	0	6
F	*Leitoscoloplos acutus*	8	19	3	5	9
F	Cephalothricidae sp. 1	4	20	1	1	7
F	*Syllides longocirrata*	0	13	14	0	5
F	*Mayerella limicola*	3	13	0	0	4
F	*Tubulanus pellucidus*	1	13	0	0	5
F	*Bathymedon obtusifrons*	0	9	1	0	5

Table 5-9. Average abundance of species by cluster group (#/0.12 m^2) for 2000 farfield infauna. Species with <3 occurrences were not included (continued).

Group	Species	I	II	III	IV	Station Occurrences
F	*Carinomella lactea*	1	6	3	1	6
F	*Terebellides stroemii*	1	6	0	0	5
F	*Megayoldia thraciaeformis*	0	6	0	0	4
F	Nemertea sp. 2	0	2	3	0	4
F	*Monoculodes packardi*	0	4	0	0	3
F	*Deflexilodes tesselatus*	0	2	1	0	4
F	*Enipo torelli*	1	2	0	0	4
F	*Hartmania moorei*	1	1	0	0	3
G	*Spio limicola*	60	319	33	2	9
G	*Anobothrus gracilis*	120	237	2	1	9
G	*Dipolydora socialis*	391	79	6	21	11
G	*Thyasira gouldi*	145	89	25	0	9
G	*Thracia conradi*	57	51	1	0	7
G	*Proclea graffii*	5	23	9	0	3
G	*Diplocirrus hirsutus*	4	15	0	3	8
G	*Haploops fundiensis*	32	3	0	0	5
G	*Praxillella praetermissa*	3	15	3	0	7
G	*Ctenodiscus crispatus*	6	5	0	0	5
G	*Leptostylis longimana*	1	5	4	0	7
G	*Mystides borealis*	4	3	4	0	6
G	*Eudorella pusilla*	5	1	5	0	6
G	*Phascolion strombi*	11	1	0	0	4
G	*Oenopota* cf. *cancellatus*	8	1	0	0	4
G	*Cylichna gouldi*	3	2	2	0	5
G	*Anonyx liljeborgi*	3	1	2	0	5
G	*Axiothella catenata*	5	0	1	0	4
G	*Sphaerodoropsis minuta*	3	1	0	0	3
G	*Casco bigelowi*	4	0	1	0	3
G	*Trichobranchus roseus*	0	2	0	0	3
G	*Campylaspis rubicunda*	2	1	0	0	4
G	*Sphaerosyllis longicauda*	3	0	0	0	3
G	*Paradulichia typica*	1	0	0	0	3
H	*Ninoe nigripes*	77	18	149	25	11
H	*Harpinia propinqua*	55	18	163	0	8
H	*Onoba pelagica*	1	56	44	0	7
H	*Amphiporus angulatus*	13	4	9	5	10
H	*Orchomenella minuta*	3	0	29	1	5
H	*Nephtys incisa*	5	9	7	1	9
H	*Ophiocten sericeum*	2	0	29	0	4
H	*Aricidea minuta*	1	0	17	0	3
H	*Gattyana amondseni*	4	1	2	0	6
H	*Pleurogonium inerme*	1	0	5	0	3
H	*Priapulus caudatus*	0	1	1	0	3

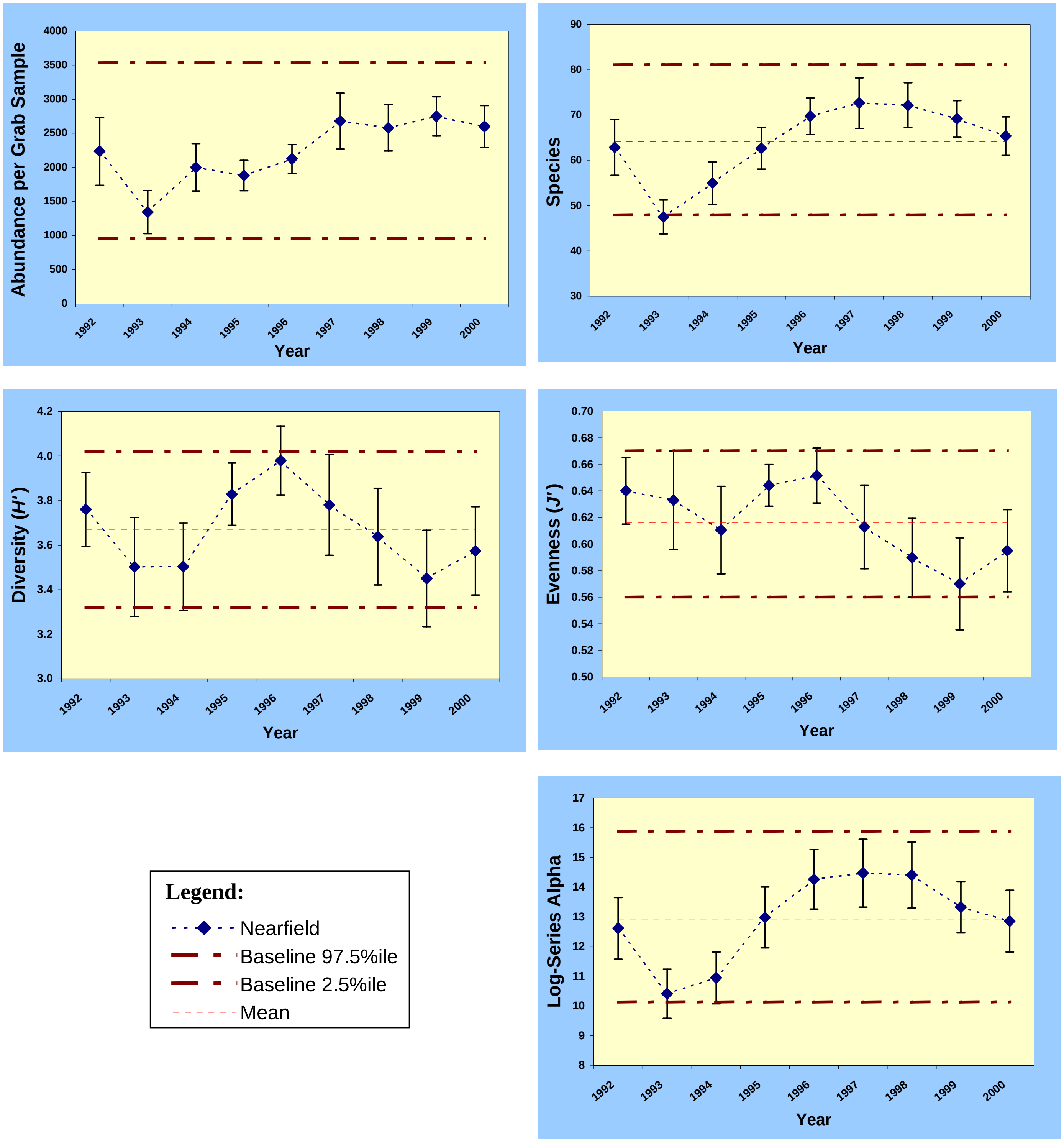


Figure 5-11. Annual mean (± 95% confidence intervals) infaunal numbers of species, Shannon diversity (*H'*), evenness (*J'*), and log-series alpha for nearfield stations sampled from 1992 to 2000.

The more traditional diversity metrics, Shannon's *H'* and Pielou's *J'*, do not show pattern apparent in the other metrics (Figure 5-11c, d). Mean values for both indices were not very different between the 1992–1996 and 1997–2000 time periods (see text box). Variability was low during both periods.

As mentioned previously (Blake *et al.*, 1998, Kropp *et al.*, 2000), the low values describing some aspects of the nearfield infaunal communities in 1993 were attributable to a strong storm that swept the area in late 1992. The storm significantly affected sediments in western Massachusetts Bay (Bothner *et al.*, 1994). The effect of the storm was clearly evident in the marked decrease in the values of the two measured community parameters, abundance and species numbers. The storm's impact was also reflected by one diversity index, log-series alpha. It is noteworthy that the two traditional metrics, *H'* and *J'*, did not clearly record the impact of the storm. Shannon diversity did decline between 1992 and 1993 (Figure 5-11c), but was as low in 1994 as it was in 1993. After increasing in 1995 and 1996, Shannon diversity decreased steadily through 1999. The nadir reached in 1999 was lower (3.45) than the 1993/1994 values (3.50). The pattern evident in the evenness calculations was similar to that seen for Shannon diversity, except that the *J'* calculated for 1994 was lower than that for 1993. Again 1999 had a lower value (0.57) than those for 1993 (0.63) or 1994 (0.61). That these metrics did not detect the largest community changes observed in MWRA's nearfield monitoring suggests that they may not be sensitive to outfall-induced changes if any occurred.

The character of numerical dominance in the nearfield infaunal community changed considerably from the period 1992–1996 to 1997–2000. During the years 1992 and 1994, the spionid polychaete *Spio limicola* was the most abundant species in the nearfield, accounting for 22% and 24% of the infaunal abundance found in those years, respectively. In 1993, the year after the large 1992 storm, the polychaetes *Aricidea catherinae* and *Mediomastus californiensis* were the most numerous taxa. In 1995, the relative abundance of *Spio limicola* decreased and its role as the most abundant taxon was taken by the spionid *Prionospio steenstrupi*. During this early period, the numerical dominance of *Prionospio steenstrupi*, although clearly established by 1995–1996, was not overwhelming (Figure 5-12a). In the early years of the monitoring program, the alternating predominance of *Spio limicola* and another spionid, *Dipolydora socialis*, in 1992–1995 indicated that the prevalence of one species or the other during alternate years might be related to stochastic events related to the timing of larval settlement. However, within the context of the nine-year data set, there is not a pattern of alternating predominance, but rather one of a very strongly predominant species, *Prionospio steenstrupi*, that increased its numerical influence on the nearfield community structure in the years 1995–1999, concomitant with substantially decreased abundances of *Spio limicola* and *Dipolydora socialis* (Figure 5-12a). The relative contribution of *Prionospio steenstrupi* to total infaunal abundance during this later period has been as high as 39%. It is also worth noting that in 2000, the abundance of *Prionospio steenstrupi* decreased markedly (but still accounted for 31% of the total abundance in the nearfield), whereas the abundance of the other two spionids increased slightly over their respective 1999 values. As mentioned in more detail below, the general pattern of a shift in numerical dominance was also seen in the farfield fauna indicating that the phenomenon was very likely Bay-wide, not just restricted to the nearfield and probably not simply a by-product of the 1992 storm that affected primarily the nearfield community.

The polychaete community in the nearfield has shown two other interesting patterns. Some species have shown fairly consistent abundance patterns during the nine years of monitoring. The capitellid *Mediomastus californiensis* has shown alternating peaks and valleys in abundance with the peaks occurring every third year (Figure 5-12b), but its abundance has remained within about 4,000 to 6,000 individuals identified per year. *Aricidea catherinae* reached its highest abundance in 1993, declined rapidly in 1994, and had declined slightly since then (Figure 5-12b). *Tharyx acutus* and *Exogone hebes* have shown relatively consistent abundances over the study period. Several species, in addition to *Spio limicola*, have decreased in numerical importance during the study. *Ampharete acutifrons* and *Dipolydora quadrilobata* were relatively abundant in 1992, decreased substantially in 1993, possibly a

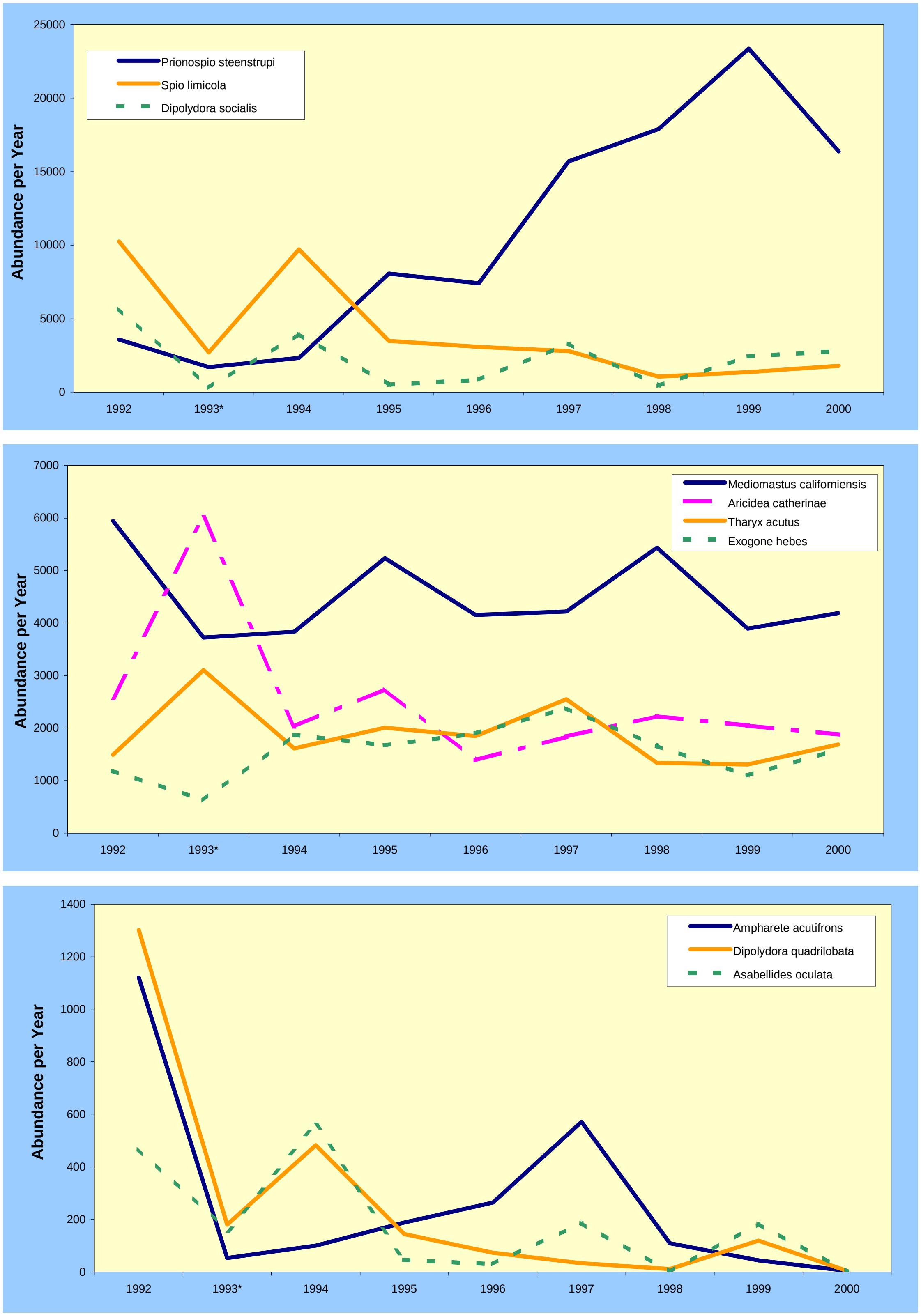


Figure 5-12. Total abundance per year in the nearfield for selected polychaete species. Because fewer samples were collected in 1993, abundance values for that year were corrected to make them equivalent to the other years.

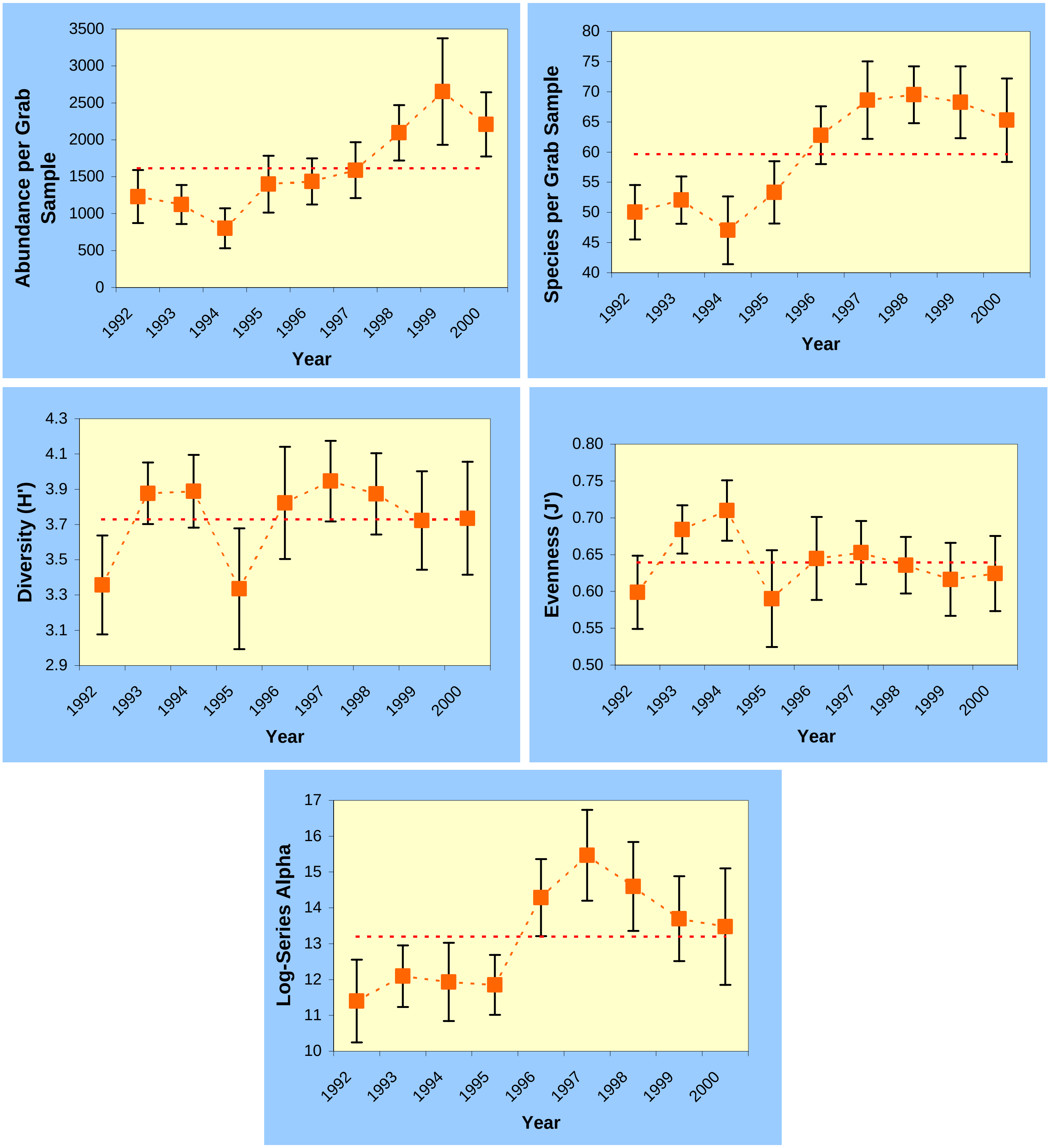


Figure 5-13. Annual mean (± 95% confidence intervals) infaunal numbers of species, Shannon diversity (*H'*), evenness *(J')*, and log-series alpha for farfield stations sampled from 1992 to 2000. The horizontal dashed line indicates the overall mean value for all years.

result of the 1992 storm, and have remained at relatively low numbers most years since (Figure 5-12c). In 2000, both species were extremely rare.

Farfield—Infaunal abundance per sample among the farfield stations (excluding FF10, FF12, FF13) has shown a pattern over the nine-years of sampling somewhat similar to that seen among nearfield stations (Figure 5-13a). Abundances were the lowest early in the study, in particular 1992–1994, increased in the three-year period 1995–1997, then increased further in 1998–2000. The numbers of species occurring among the farfield stations has shown a very striking pattern. During the early years of the program, 1992–1995, species numbers per sample were low (Figure 5-13b), ranging from about 47 to 53 per year (average about 51 species). Since 1996, however, species numbers per sample have ranged from about 63 to 70, averaging about 67, species per year (Figure 5-13b). Species numbers per sample were highest in 1998 and have decreased some since. The pattern shown for species diversity, as measured by log-series alpha, has been similar to that for species numbers; low values for 1992–1995 and high values for 1996–2000 (Figure 5-13e). Shannon diversity (H') and Pielou's evenness (J'), were low only in 1992 and 1995 (Figure 5-13c, d) and fairly consistent most of the other years.

As mentioned earlier, the patterns of predominant species in the farfield has been similar to that for the nearfield, especially with respect to the spionid polychaetes. During the early years, 1992–1994, *Spio limicola* was the predominant species although its abundance decreased steadily during those years (Figure 5-14a). *Prionospio steenstrupi* was much less abundant than *Spio limicola* during that period. In 1995, the abundance of *Spio limicola* continued to decline, whereas that of *Prionospio steenstrupi* more than quadrupled. Although there has been some fluctuation in its abundance, *Prionospio steenstrupi* has been the overwhelmingly predominant species in the farfield since 1995 (Figure 5-14a). Conversely, *Spio limicola* has remained at relatively low abundances since 1995. Another species that showed a remarkable increase in abundance during the most recent years of the monitoring program is *Euchone incolor*, which increased more than five-fold between 1997 and 1998 (Figure 5-14b). *Cossura longocirrata* has increased almost four-fold since 1992 (Figure 5-14b). As in the nearfield, some polychaete species, most notably *Scalibregma inflatum* and *Ampharete acutifrons*, have decreased markedly in abundance since 1992 (Figure 5-14c). Among other major infaunal groups, the nutclam *Nucula delphinodonta*, the isopod *Edotia montosa*, and the amphipod *Harpinia propinqua* have increased in abundance since 1992, but none contributes significantly to total infaunal abundance in the farfield.

5.2.7 Total Species Richness in Massachusetts Bay

The variation in numbers of species per sample described above is a measure of relatively small-scale variation. To determine whether or not this small-scale variation also occurred at a larger, Bay-wide scale, per-sample species data for the nearfield and farfield were pooled. The first step in the analysis determined year-to-year change in the composition of species present in the Massachusetts Bay system. The data presented in Figure 5-15a, show that about 28 to 64 of the species present in any given year may not be present the next year. Conversely, similar numbers of species not found in any given year may be present the following year. Pooling these two sets of numbers, demonstrates that the yearly turnover of species present is about 63 species (1994) and can range as high as about 111 species (1998). The next step in examining the Bay-wide species richness pattern was to determine when species found in 1992 first disappear from the collections and when species not found in 1992 first appear in the collections (Figure 5-15b). This step allows the examination of the changes that would have taken place in the Bay ecosystem if only species appearances or disappearances, rather than both, were occurring. The greatest number of disappearances of 1992 taxa occurred in 1993, most likely related to the strong storm in late 1992 that impacted the Bay's infaunal communities (although not shown in the Figure, the trend was similar when the nearfield and farfield were treated separately). The largest number of appearances of species not found in 1992 occurred in 1995. Both rates have been decreasing since their respective peak years. These two sets of data can be combined in a single, cumulative plot (Figure 5-15c) that also

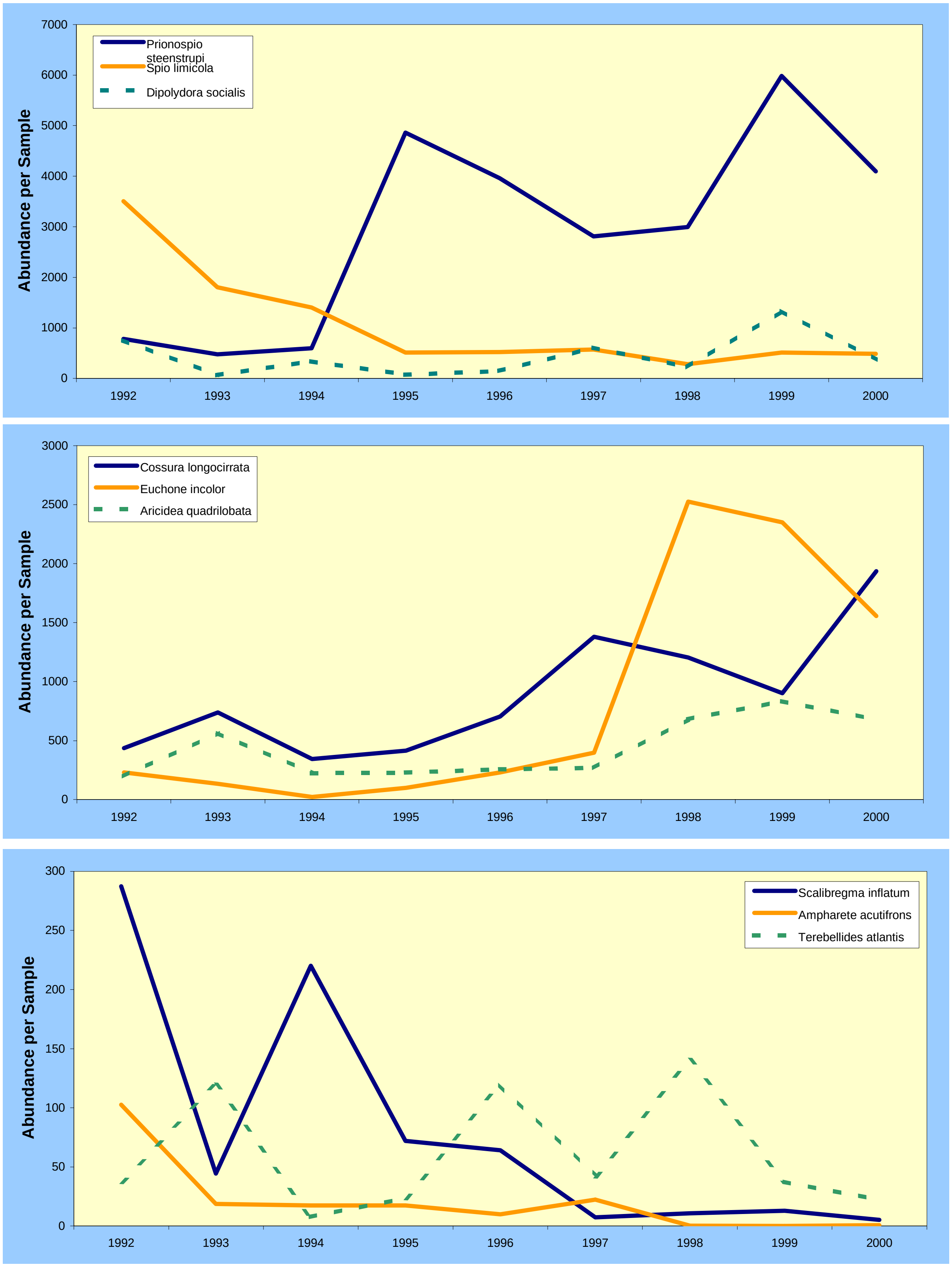


Figure 5-14. Total abundance per year in the farfield for selected poylchaete species.

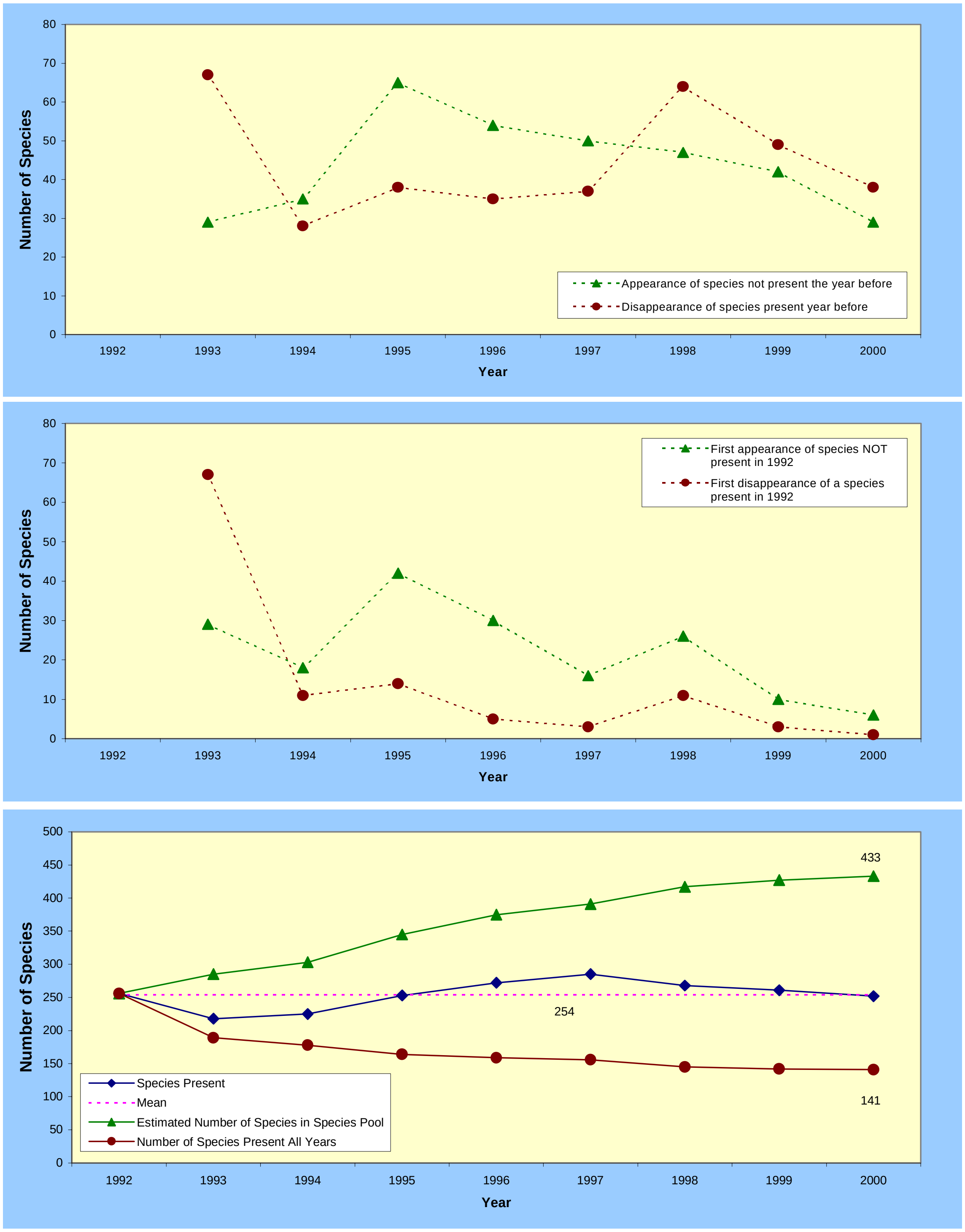


Figure 5-15. Dynamics of infaunal species richness in Massachusetts Bay from 1992 to 2000. (a), The year to year change in species appearances and disappearances; (b), change in species richness relative to the 1992 species list; (c), temporal variation in yearly species richness versus mean richness over the study period and the cumulative first appearances and first disappearances of species relative to the 1992 species list.

includes the mean species found per year, and the number of species found in each year of the program. The mean number of species found in the Bay system per year during the nine years of the program was 254 (standard deviation = 21). Despite the large per-sample changes in species richness discussed above, there has been little variation around this mean value, as indicated by the low coefficient of variation value of about 8%. Sequentially plotting the number of first appearances per year of species not found in 1992 provides a calculated estimate (433 species) of the total species pool present in the Bay system at this point in the study. Sequentially plotting the numbers of first disappearances per year of species found in 1992 reveals the number of species present in every year of the study to date (140 species). This pattern of inherent large-scale consistency in species richness despite considerable small-scale variability and the substantial year-to year change is similar to that reported by Brown *et al.* (2001) for widely disparate taxa (rodent and bird species, plant families) and time scales (tens to thousands of years). Brown *et al.* offer that this consistency indicates that species richness is an ecosystem property and that changes to a system, especially those that alter productivity regimes, should be detectable as changes to species richness patterns such as that shown in Figure 5-15. After nine years of sampling, it appears that rates of appearance of non-1992 taxa and disappearance of 1992 taxa are diminishing such that any substantial change in either rate could indicate that a major change in the Bay ecosystem has occurred.

5.2.8 Comparison of 2000 Multivariate Community Analysis to Previous Years—Nearfield

Station cluster analysis of the 1992 to 2000 nearfield data was done on a reduced set of data. Only the first replicate at a station was used. The second and third replicates were removed to give equal weight to each station in defining patterns and associations through time. A total of 196 station/year combinations and 160 of 365 species were included. Species with 20 or fewer occurrences were dropped from the analysis because over the years the more abundant species were found to be primary contributors to community structure (Blake *et al*., 1998, Kropp *et al*., 2000).

Station clusters from the 1992 to 2000 years analysis exhibited patterns related to both strong and weak within station similarity through time. Strong within station similarity through time was exhibited by stations FF10 and NF05, which formed exclusive groups IV and VIII, respectively (Table 5-10). Group XII was near exclusive for station NF02 with one occurrence of NF24 for 1994. Overall, these three stations tended to be physically dominated through time with heterogeneous sediments. Group XI included all but two year/station combinations for the heterogeneous sediment stations FF12 and FF13. Weak within station similarity was exhibited by stations FF10 and NF07 that were members of four station groups over the nine year period. Temporally, more of the station groups split between 1994 and 1995 than any other two consecutive years. Groups I, IX, and XIII were composed only of stations prior to 1995. Groups V, VI, VII, VIII, and X were all station after 1994, except NF18 in 1994 that was part of group X. Groups II, III, IV, XI, XII, and XIV all contained multi-year station occurrences (Table 5-10). The strongest temporal signal in the data set was in group I, which contained about half of the stations from 1992 and a quarter of stations from 1994, with one 1993 station (NF14). The stations in group I were primarily those with finer sediments. Group XIII was composed of three stations from 1994 that were also primarily finer sediments and were missing many of the numerically dominant species. Groups II, XI, and XIV were multistation groups with a combination of years that reflected a strong within station similarity through time. For example, group II contained all but one year for stations NF09 and NF10.

Overall, the 1992 to 2000 infaunal analysis was not dominated any strong trend. The dendrogram produced by the cluster analysis was heavily concatenated or chained (the tendency of a group to join the dendrogram at the end) and indicated that within group station affinities were stronger than between groups (Table 5-10). Thus the primary feature structuring the 1992 to 2000 infauna was the within station similarity through time. Temporal trends were best represented by the pre and post 1994/1995 collections. At the 14-group level 17 of the 23 stations had the majority of the year/station occurrences within a single cluster group (Table 5-10).

Table 5-10. Station group summary for 1992 to 2000 nearfield infaunal data based on Gallagher's CNESS dissimilarity and group average sorting.

```
Group
Station   199219931994199519961997199819992000
I   FF10 92                                   ------------------I
    NF05 92                                                     I
    NF06 92                                                     I
    NF07 92    94                                               I
    NF09 92                                                     I
    NF13 92                                                     I
    NF14 92 93 94                                               I
    NF15 92    94                                               I
    NF18 92                                                     I
    NF19 92    94                                               I
    NF22       94                                               I
II  NF03 92                                   --I               I
    NF09    93 94 95  96  97  98  99  00        I               I
    NF10 92 93 94 95      97  98  99  00        I               I
    NF12          95  96  97  98  99  00        I               I
    NF21       94 95  96  97  98                I---I           I
III NF08       94 95                          --I   I           I
    NF10              96                            I           I
    NF11 92                                         I           I
    NF12 92 93 94                                   I           I
    NF16 92 93    95                                I           I
    NF20 92       95  96                            I--I        I
IV  FF10   93  94 95  96  97                  ------I  I        I
                                                    I  I--I     I
V   NF07          95                          ------I  I  I     I--I
    NF08              96  97  98  99  00               I  I     I  I
    NF16              96  97  98  99  00               I  I     I  I
    NF21                          99  00               I  I     I  I
    NF22          95  96  97  98  99  00               I  I     I  I
    NF24          95      97  98                       I  I     I  I
VI  FF10                      98              ---------I  I--I  I  I
    FF13                          99                      I  I  I  I
    NF15              96                                  I  I  I  I
    NF20                  97  98  99  00                  I  I  I  I
    NF24                          99  00                  I  I  I  I
VII NF02              96                      ------------I  I--I  I
    NF04                  97                                 I  I  I
    NF07              96      98  99  00                     I  I  I
    NF15          95      97  98  99  00                     I  I  I
    NF19          95  96  97  98  99  00                     I  I  I
    NF24              96                                     I  I  I--I
VIIINF05          95  96  97  98  99  00      ---------------I  I  I  I
                                                                I  I  I
IX  NF02 92    94                             ------------------I  I  I
    NF08 92 93                                                     I  I----I
X   FF10                          99          ---------------------I  I    I
    NF04                      98                                      I    I
    NF14          95  96      98  99                                  I    I
    NF18       94 95  96  97  98  99  00                              I    I
XI  FF12 92 93    95  96  97  98  99  00      ------------------------I    I--I
    FF13 92 93 94 95  96  97  98      00                                   I  I
    NF02          95                  00                                   I  I
XII NF02    93            97  98  99          -----------------------------I  I---I
    NF24       94                                                             I   I
XIIIFF12       94                             --------------------------------I   I
    NF16       94                                                                 I
    NF20       94                                                                 I
XIV NF01 92                                   ------------------------------------I
    NF04 92 93 94 95  96          99  00
    NF05       94
    NF07                  97
    NF13       94
    NF13          95  96  97  98  99  00
    NF14                  97          00
    NF17 92 93 94 95  96  97  98  99  00
    NF23       94 95  96  97  98  99  00
```

Species
Group

```
A     ---I
         I---I
B     ---I   I
             I--I
C     -------I  I
                I--I
D     ----------I  I----I
                   I    I
E     -------------I    I
                        I
F     ----I             I
          I----I        I
G     ----I    I        I
               I        I
H     ---------I--I     I
               I  I     I
I     ---------I  I     I
                  I--I  I
J     -----I      I  I  I
           I------I  I--I
K     -----I         I  I
                     I  I
L     ---------------I  I
                        I
M     ----I             I
          I--I          I
N     ----I  I          I
             I----------I
O     -------I
```

Figure 5-16. Species group dendrogram for 1992–2000 nearfield infauna based on summed replicates for each station, Gallagher's CNESS dissimilarity and group average sorting. See Table 5-11 for species in each group.

At the 15 group level species formed into three distinct clusters A to E, F to L, and M to O (Figure 5-16, Table 5-11). These three clusters matched the general pattern of station groups (Table 5-12). Species groups A to E had strongest representation at all of the station groups, except VIII and XIV, and contained many of the overall dominant and broadly distributed species. Group A included *Prionospio steenstrupi* the overall most abundant species in the nearfield. Species groups F to L were strongly associated with only station groups I, X, and XIV, and groups M to O only with station groups IX, XI, and XII. Groups M, N, and O were composed of species with a preference for sandy sediments, such as *Aricidea catherinae*. Groups F to L formed a super cluster containing species groups found both in muddy and sandy sediments and groups restricted primarily to coarser sediments (Table 5-11 and 5-12).

Canonical correlation was used to analyze the relationship between the matrix composed of sediment, hydrocarbon, and metals by station data (gravel, fines, C. perf., TOC, total PCB, total PAH, total DDT, total LAB, silver, cadmium, mercury) and the species cluster by station (groups A to O) matrix. PCA was used to select the sedimentary variables that were least correlated and represented the greatest spread of variation from 1992 to 2000. The first four canonical variables were significant, indicating that the infaunal patterns were related to the sedimentary variables (Table 5-7). Species occurrence patterns for most of the species groups (10 to 15) could be predicted based on the sedimentary variables (Table 5-7).

Table 5-11. Species groups from combined 1992–2000 cluster analysis of nearfield data. Occurrences are out of 196 station/year combinations and abundance is total individuals for all years.

Group	Species	Occur.	Abund
A	*Prionospio steenstrupi*	190	94693
	Mediomastus californiensis	187	37945
	Euchone incolor	161	8119
	Parougia caeca	166	2107
	Ninoe nigripes	167	12055
	Levinsenia gracilis	159	6203
	Micrura spp.	165	1522
	Monticellina dorsobranchialis	141	1444
	Monticellina baptisteae	141	7792
	Carinomella lactea	73	395
	Leitoscoloplos acutus	153	3791
	Amphiporus angulatus	117	605
B	*Yoldia sapotilla*	69	293
	Stereobalanus canadensis	23	32
	Thracia conradi	64	356
	Aricidea quadrilobata	76	323
	Terebellides atlantis	27	55
	Goniada maculata	59	133
	Arcteobia anticostiensis	36	49
	Mayerella limicola	36	277
	Mya arenaria	93	255
	Dentalium entale	44	213
C	*Spio limicola*	168	34637
	Aphelochaeta marioni	149	8652
	Nucula delphinodonta	157	5802
	Maldane sarsi	56	1776
	Thyasira gouldi	79	594
	Onoba pelagica	31	218
	Anobothrus gracilis	62	215
	Rhodine loveni	27	86
	Trochochaeta multisetosa	53	328
	Enipo torelli	42	70
	Clymenella torquata	41	412
	Periploma papyratium	51	253
	Pitar morrhuana	35	61
D	*Metopella angusta*	140	1271
	Campylaspis rubicunda	42	60
	Cossura longocirrata	46	94
	Deflexilodes intermedius	26	54

Group	Species	Occur.	Abund.
E	Nemertea sp. 5	43	335
	Leitoscoloplos sp. B	47	212
	Cerianthus borealis	24	55
	Chone duneri	51	81
	Pionosyllis sp. A	38	253
	Ameroculodes sp. 1	43	64
	Scoletoma fragilis	74	193
F	*Dipolydora socialis*	149	20459
	Dipolydora quadrilobata	74	2368
	Anonyx liljeborgi	42	74
	Haploops fundiensis	37	469
	Aeginina longicornis	24	162
	Eudorella pusilla	37	77
	Crenella decussata	113	3198
	Nereis grayi	52	201
	Cancer borealis	51	97
	Phascolion strombi	23	33
G	*Exogone verugera*	169	9816
	Crenella glandula	60	1079
	Sphaerosyllis longicauda	85	287
	Exogone longicirris	36	138
	Pleurogonium spinosissimum	24	88
	Astarte undata	135	1667
	Cyclocardia borealis	37	121
	Ptilanthura tenuis	85	518
	Ampelisca macrocephala	85	261
	Euclymene collaris	70	1017
	Euchone elegans	37	645
	Apistobranchus typicus	82	377
	Sphaerodoropsis minuta	37	104
H	*Protomedeia fasciata*	72	2931
	Ericthonius fasciatus	55	1089
	Harpinia propinqua	55	505
	Orchomenella minuta	48	175
	Oenopota incisula	22	29
	Gattyana amondseni	76	167
	Casco bigelowi	25	48
	Stenopleustes inermis	130	764
	Sphaerodoridium sp. A	73	234
	Dulichia tuberculata	36	111
	Paradulichia typica	24	59
	Leptocheirus pinguis	49	459
	Nuculoma tenuis	22	48

Group	Species	Occur.	Abund.
I	*Pholoe minuta*	183	2421
	Eteone longa	151	1252
	Cerebratulus lacteus	81	302
	Diastylis quadrispinosa	39	68
	Scoloplos armiger	90	347
J	*Exogone hebes*	182	13751
	Crassicorophium crassicorne	75	7597
	Aglaophamus circinata	58	803
	Cerastoderma pinnulatum	130	3485
	Tanaissus psammophilus	33	492
	Solariella obscura	21	134
	Unciola inermis	45	4161
	Enchytraeidae sp. 1	21	2879
	Echinarachnius parma	38	439
	Phoxocephalus holbolli	32	158
	Politolana polita	28	115
	Hippomedon serratus	31	86
	Chaetozone setosa mb	58	346
	Spiophanes bombyx	156	4105
	Polygordius sp. A	111	3585
	Phyllodoce mucosa	167	3486
	Phyllodoce maculata	58	305
	Tetrastemma vittatum	28	70
	Spio thulini	47	263
	Galathowenia oculata	110	300
	Petalosarsia declivis	69	200
	Westwoodilla brevicalcar	22	42
K	*Unciola irrorata*	44	478
	Ampharete finmarchica	65	369
	Syrrhoe sp. 1	45	102
	Deflexilodes tuberculatus	24	75
	Cephalothricidae sp. 1	79	314
	Sphaerosyllis brevifrons	27	163
	Munna sp. 1	23	128
	Diaphana minuta	29	48
	Hippomedon propinquus	25	239
L	Nemertea sp. 12	45	733
	Ilyanassa trivittata	85	393
	Nereis procera	23	70
	Ceriantheopsis americanus	68	284
	Lyonsia arenosa	56	274
	Edwardsia elegans	90	264
	Pherusa affinis	41	71

Group	Species	Occur.	Abund.
M	*Aricidea catherinae*	188	19331
	Tharyx acutus	183	15810
	Owenia fusiformis	97	4728
	Scoletoma hebes	62	1264
	Phoronis architecta	142	2156
N	*Photis pollex*	162	2834
	Argissa hamatipes	140	597
	Pleurogonium rubicundum	111	764
	Nephtys incisa	121	818
	Edotia montosa	154	1687
	Arctica islandica	142	981
	Dyopedos monacanthus	91	1403
	Nemertea sp. 2	48	156
	Pythinella cuneata	24	127
	Diastylis sculpta	63	183
	Ensis directus	32	171
	Pleurogonium inerme	48	146
	Tubificidae sp. 2	96	1838
	Heteromastus filiformis	36	68
	Capitella capitata complex	149	1418
	Nephtys cornuta	52	1316
O	*Hiatella arctica*	156	4601
	Actiniaria sp. 2	55	173
	Spio filicornis	51	145
	Pectinaria granulata	29	100
	Gattyana cirrosa	23	40
	Ampharete acutifrons	112	2350
	Scalibregma inflatum	79	604
	Laonome kroeyeri	80	340
	Asabellides oculata	88	1449
	Aphelochaeta monilaris	24	124
	Tubificoides apectinatus	102	679
	Flabelligera spp.	28	70
	Musculus niger	27	48
	Ophelina acuminata	21	28

Table 5-12. Average infauna abundance (#/0.04 m^2) by cluster analysis species and station groups for 1992 to 2000 nearfield infaunal data based on Gallagher's CNESS dissimilarity and group average sorting.

Group	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	Dominant Species
A	498	984	959	613	1499	1985	1425	546	526	1089	1211	620	84	95	*Prionospio steenstrupi*
B	8	26	6	5	27	11	8	8	3	3	2	6	1	1	*Yoldia sapotilla*
C	771	568	321	536	216	78	366	277	162	55	27	264	4	30	*Spio limicola*
D	4	10	7	10	8	8	18	6	1	3	14	10	2	1	*Metopella angusta*
E	4	7	14	8	5	4	8	6	0	19	3	2	0	2	Nemertea sp. 5
F	598	125	11	127	17	25	236	195	13	70	25	219	20	132	*Dipolydora socialis*
G	144	39	22	73	18	44	77	124	2	208	4	9	6	175	*Exogone verugera*
H	11	12	4	8	12	12	24	73	0	203	5	24	1	49	*Protomedeia fasciata*
I	36	19	26	22	23	28	36	10	19	31	18	28	36	9	*Pholoe minuta*
J	106	37	21	37	35	101	201	42	29	348	111	277	8	848	*Exogone hebes*
K	6	4	2	1	5	24	8	26	0	24	3	9	0	18	*Unciola irrorata*
L	2	8	2	6	18	19	17	7	1	18	14	25	2	7	*Ilyanassa trivittata*
M	145	197	246	186	121	328	202	101	1206	124	644	294	96	45	*Aricidea catherinae*
N	71	51	69	65	42	70	98	45	44	56	245	94	67	31	*Photis pollex*
O	128	40	25	35	19	24	50	25	152	101	26	388	46	24	*Hiatella arctica*

Percent fines (silt plus clay) had the largest influence on species group patterns. Standardized regression coefficients for percent fines were the largest, thus having the largest contribution in predicting species group patterns, for groups A, B, and J (Table 5-13). Groups A and B were favored by higher percent fines. The effect on group J, being composed primarily of species that prefer sandy habitats, was opposite. Other variables important in predicting increased abundance for a species group were: gravel for group H, TOC for group K, total PAH for group G, total PCB for group M, and total DDT for group C. Total LAB had a reducing effect on species group E, which means that as total LAB increase group E declines.

5.2.9 Comparison of 2000 Multivariate Community Analysis to Previous Years—Farfield

Since over the years farfield stations consistently had high within station similarity, cluster analysis of the combined 1992 to 2000 data was preformed on sum of the three station replicates. A total of 99 station/year combinations, which included FF10, FF12, and FF13 located among the nearfield stations, and 182 of 338 species were included. Species with fewer 10 or fewer station occurrences for the entire period were dropped.

The primary pattern in the station clusters from the combined 1992 to 2000 analysis was related to the strong within station similarity through time and secondarily to temporal trends. At the five group level farfield stations separated into two distinct clusters. Group I represented the temporal trend cluster and the other four groups were the high within station similarity cluster. Groups II, III, IV, and V were all exclusive station groups (Tables 5-14 and 5-15). Station Group I was composed of four subgroups that tracked temporal changes at the deepest farfield stations FF04, FF05, FF11, and FF14, and station FF01 that was only sampled in 1992 and 1993. Groups Ia and Ib represented 1992 to 1994 collections at these four stations, group Ic represented 1995 to 1997, and group Id represented 1998 and 1999. For 2000, FF04 and FF05 clustered in Id, FF11 was in Ic, and FF14 was in Ib (Table 5-14). Groups II, III, and IV emphasized the strong within station similarity for subsets of stations with the Cape Cod Bay stations FF06 and FF07 being group II, FF01A, FF09 and FF10 being III, and near Boston Harbor stations FF12 and FF13 being IV. Group V was only station FF12 for the year 1994. Overall, the 1992 to 1999 farfield infaunal data was dominated primarily by both strong spatial differences between stations and secondarily by temporal trends. Temporal trends at the deepest stations (FF04, FF05, FF11, and FF14) were more pronounced than spatial differences between these same stations. The reverse was the case at shallower stations located to the north (FF01A and FF09) and in Cape Cod Bay (FF06 and FF07) (Tables 5-8 and 5-9).

Table 5-13. Summary of canonical correlation analysis for 1992–2000 nearfield sedimentary and infauna data. See text for variables used.

A – Canonical Variable and Correlation Statistics:

Canonical Variable Number	Canonical Correlation	Standard Error	Prop.	Cum. Prop.	F	Pr>F
1	0.82	0.031	0.33	0.33	2.85	<.0001
2	0.79	0.035	0.27	0.59	2.35	<.0001
3	0.66	0.053	0.12	0.72	1.82	<.0001
4	0.64	0.057	0.11	0.82	1.56	0.001
5	0.55	0.067	0.07	0.89	1.24	0.09
6	0.43	0.078	0.04	0.93	0.99	0.49
7	0.40	0.079	0.03	0.96	0.88	0.69
8	0.31	0.086	0.02	0.97	0.70	0.89
9	0.23	0.090	0.01	0.98	0.59	0.92
10	0.19	0.091	0.01	0.99	0.60	0.83
11	0.19	0.092	0.01	1.00	0.71	0.61

B – Univariate Multiple Regression Statistics for Predicting Species Groups from Sedimentary Variables:

Species Group	Adjust. R-Square	F	Pr>F
A	0.21	3.71	0.0002
B	0.31	5.44	<.0001
C	0.22	3.85	0.0001
D	-0.04	0.57	0.84
E	0.10	2.07	0.03
F	0.05	1.50	0.14
G	0.21	3.74	0.0002
H	0.12	2.36	0.01
I	0.03	1.36	0.2
J	0.28	4.94	<.0001
K	0.08	1.93	0.04
L	0.07	1.71	0.08
M	0.47	9.82	<.0001
N	0.12	2.41	0.01
O	-0.02	0.76	0.67

C – Standardized Regression Coefficients from Significant Regressions for Predicting Species Groups from Sedimentary Variables:

Spp.Group	Gravel	Fines	C.perf.	TOC	PAH	PCB	DDT	LAB	Silver	Mercury	Cadmium
A	0.11	0.64	-0.11	-0.02	0.26	-0.20	-0.15	0.26	0.11	0.06	-0.56
B	0.03	0.80	-0.22	-0.09	0.25	-0.51	-0.02	0.54	-0.20	0.13	-0.41
C	-0.04	0.41	-0.15	-0.11	0.11	-0.06	0.42	-0.37	-0.12	-0.10	0.07
E	0.22	0.36	-0.08	-0.26	0.12	0.22	-0.32	-0.53	-0.09	0.05	0.50
G	0.11	-0.42	-0.07	0.21	0.59	-0.53	0.06	-0.05	-0.22	0.06	0.24
H	0.43	-0.04	-0.09	-0.32	0.19	-0.01	0.05	-0.04	0.29	0.11	-0.17
J	-0.14	-0.61	-0.20	-0.11	-0.11	-0.03	0.11	-0.03	0.03	0.17	0.16
K	0.01	-0.38	-0.14	0.61	-0.08	-0.18	-0.01	-0.01	-0.25	-0.06	0.16
M	-0.02	-0.12	-0.09	-0.10	-0.09	0.69	0.06	0.44	-0.13	-0.19	0.00
N	-0.02	0.05	0.38	0.10	-0.16	0.22	-0.25	0.03	0.59	-0.19	-0.68

Table 5-14. Average abundance of species by cluster group (#/0.12 m^2) for 1992–2000 farfield infauna. Species with <3 occurrences were not included.

Group	Species	Ia	Ib	Ic	Id	II	III	IV	V	Station Occurrences (Max. = 99)
A	*Prionospio steenstrupi*	33	204	1250	1136	83	2135	799	0	96
A	*Ophelina acuminata*	0	0	1	0	0	2	0	0	32
A	*Laonice cirrata*	0	0	0	0	0	0	0	0	13
A	*Nucula delphinodonta*	19	32	32	89	68	189	1	0	82
A	*Crenella decussata*	16	1	2	8	1	23	0	0	37
A	*Edwardsia elegans*	0	0	0	2	1	17	3	0	47
A	*Ameroculodes* sp. 1	1	0	1	0	1	3	0	0	26
A	*Petalosarsia declivis*	0	0	0	0	0	4	0	0	16
A	*Asabellides oculata*	2	1	1	5	0	13	2	0	34
A	*Praxillella praetermissa*	0	1	5	5	1	11	0	0	38
A	*Ptilanthura tenuis*	0	0	0	0	0	14	0	0	28
A	*Ampelisca macrocephala*	0	0	0	0	0	7	0	0	24
A	*Pholoe minuta*	5	6	10	19	18	33	6	1	95
A	*Paradulichia typica*	1	0	0	0	0	3	0	0	17
A	Nemertea sp. 2	2	0	0	2	2	1	1	0	26
B	*Spiophanes bombyx*	0	0	0	1	0	53	36	5	47
B	*Polygordius* sp. A	0	0	1	4	7	10	4	0	43
B	*Sphaerodoridium* sp. A	0	0	0	2	5	3	0	0	35
B	*Lyonsia arenosa*	0	0	0	0	0	6	1	0	20
B	*Westwoodilla brevicalcar*	0	0	0	0	0	1	0	0	11
B	*Hippomedon propinquus*	0	0	1	1	0	8	0	0	18
B	*Exogone verugera*	1	1	1	1	0	60	0	0	42
B	*Exogone hebes*	2	0	0	0	0	39	1	0	44
B	*Astarte undata*	1	0	1	1	0	28	0	0	39
B	*Cerastoderma pinnulatum*	0	0	1	1	1	45	9	0	41
B	*Hiatella arctica*	1	0	1	1	1	22	10	0	53
B	*Crassicorophium crassicorne*	0	0	1	0	0	7	0	0	11
B	*Euclymene collaris*	0	0	0	0	0	2	0	0	12
B	*Unciola irrorata*	0	0	0	0	0	4	2	0	25
B	*Ceriantheopsis americanus*	0	0	0	0	0	1	1	0	11
B	*Spio thulini*	0	0	0	0	0	5	0	0	18
B	*Diaphana minuta*	0	0	1	2	1	1	0	0	25
B	*Protomedeia fasciata*	0	0	0	0	0	5	0	0	15
B	*Ericthonius fasciatus*	0	0	0	0	0	2	0	0	17
B	*Ampharete finmarchica*	0	0	0	0	0	2	0	0	17
B	*Axiothella catenata*	0	1	1	4	0	1	0	0	25
B	*Crenella glandula*	0	6	1	0	0	9	0	0	11
C	*Aphelochaeta marioni*	20	12	10	31	13	38	3	0	86
C	*Monticellina baptisteae*	4	2	2	2	3	31	38	12	54
C	*Monticellina dorsobranchialis*	0	0	0	0	0	8	5	4	28
C	*Dipolydora quadrilobata*	0	0	0	0	1	25	2	1	30
C	*Ischyrocerus anguipes*	0	0	0	0	0	3	0	0	17
C	*Clymenella torquata*	0	0	0	0	0	4	2	0	16
C	*Pitar morrhuana*	0	0	0	0	0	1	0	0	15

Table 5-14. Average abundance of species by cluster group (#/0.12 m^2) for 1992–2000 farfield infauna. Species with <3 occurrences were not included (continued).

		Station Group								Station
Group	Species	Ia	Ib	Ic	Id	II	III	IV	V	Occurrences
C	*Chone duneri*	0	0	0	0	0	1	0	0	14
C	*Aeginina longicornis*	0	0	0	0	0	4	0	0	13
C	*Campylaspis rubicund*	0	0	0	2	0	1	0	0	27
D	*Dipolydora socialis*	17	15	8	126	90	366	14	7	82
D	*Laonome kroeyeri*	0	0	2	2	0	6	0	0	40
D	*Praxillura ornata*	2	0	0	0	0	11	0	0	15
D	*Casco bigelowi*	0	0	0	0	0	1	0	0	18
D	*Rhodine loveni*	0	0	0	0	1	8	0	0	21
D	*Haploops fundiensis*	2	5	2	4	1	14	0	0	58
D	*Phascolion strombi*	1	1	1	1	0	4	0	0	35
D	*Nereis grayi*	0	1	0	0	0	6	0	1	26
D	*Arcteobia anticostiensis*	0	0	0	0	0	1	0	0	17
D	*Sphaerodoropsis minuta*	1	0	1	2	2	2	0	0	28
D	*Ampharete acutifrons*	0	1	4	0	3	21	1	0	40
D	*Scoloplos armiger*	0	0	0	0	0	4	1	0	25
D	*Gattyana cirrosa*	0	1	0	0	0	1	0	0	15
D	*Diastylis quadrispinosa*	0	0	0	0	0	2	0	0	18
D	*Pleurogonium spinosissimum*	0	0	0	0	1	3	0	0	16
E	*Mediomastus californiensis*	52	121	178	297	540	176	226	6	99
E	*Tharyx acutus*	0	1	2	3	228	84	217	3	73
E	*Aricidea catherinae*	0	0	0	0	207	63	130	88	62
E	*Ninoe nigripes*	27	21	21	19	128	79	45	14	99
E	*Owenia fusiformis*	0	1	1	3	0	23	147	0	41
E	*Phoronis architecta*	0	1	1	2	5	17	30	0	63
E	*Scoletoma hebes*	0	0	0	0	0	9	50	37	35
E	*Leitoscoloplos acutus*	13	41	25	21	3	21	44	5	86
E	*Cerebratulus lacteus*	1	1	0	0	2	1	1	0	41
E	*Photis pollex*	2	2	4	32	25	22	67	22	93
E	*Argissa hamatipes*	0	0	0	1	2	5	8	4	56
E	*Ampelisca abdita*	0	0	0	0	0	0	18	0	17
E	*Dyopedos monacanthus*	0	0	0	0	2	1	35	2	35
E	*Nephtys cornuta*	0	1	5	3	1	1	68	0	30
E	*Phyllodoce mucosa*	1	1	1	3	3	18	34	6	66
E	*Flabelligera* spp.	2	0	0	0	2	0	1	0	19
E	*Diastylis sculpta*	0	0	0	0	0	0	2	0	16
E	*Nephtys ciliata*	1	0	1	0	0	0	1	0	16
E	*Eteone longa*	7	11	6	16	10	13	9	19	89
E	*Pleurogonium rubicundum*	6	1	7	8	2	5	10	47	66
E	*Arctica islandica*	0	0	1	0	4	16	4	29	43
E	*Ilyanassa trivittata*	0	0	0	0	0	3	2	4	24
E	*Edotia montosa*	0	1	0	2	4	30	9	13	61
E	*Capitella capitata*	3	7	3	3	19	12	12	2	83
E	*Microphthalmus pettiboneae*	0	0	0	0	0	0	1	0	12
E	*Pherusa affinis*	0	0	0	0	0	0	1	0	15

Table 5-14. Average abundance of species by cluster group (#/0.12 m^2) for 1992–2000 farfield infauna. Species with <3 occurrences were not included (continued).

Group	Species	Ia	Ib	Ic	Id	II	III	IV	V	Station Occurrences
E	*Mya arenaria*	2	1	1	2	2	1	1	0	52
E	Turbellaria spp.	0	0	0	0	0	0	0	0	13
F	*Spio limicola*	120	680	71	198	289	547	10	0	90
F	*Scalibregma inflatum*	24	60	11	7	4	42	1	0	63
F	*Trochochaeta carica*	4	7	1	0	0	0	0	0	26
F	*Deflexilodes intermedius*	0	1	1	1	1	0	0	0	23
F	*Tetrastemma vittatum*	0	2	3	1	0	1	0	0	27
F	*Levinsenia gracilis*	46	175	268	231	69	102	13	1	95
F	*Aricidea quadrilobata*	79	188	184	444	106	23	0	0	80
F	*Chaetozone setosa*	90	130	142	189	3	5	0	0	64
F	*Tubificoides apectinatus*	87	114	128	127	2	1	6	0	72
F	*Praxillella gracilis*	1	2	4	1	0	0	0	0	25
F	*Chaetoderma nitidulum*	2	1	2	1	0	1	0	0	35
F	*Thyasira gouldi*	64	56	38	53	28	45	0	0	75
F	*Yoldia sapotilla*	44	30	32	36	12	16	0	0	75
F	*Nuculoma tenuis*	7	11	14	1	1	2	0	0	35
F	*Leucon acutirostris*	10	3	4	8	0	0	0	0	29
F	*Maldane sarsi*	83	18	6	2	0	21	0	0	48
F	*Megayoldia thraciaeformis*	12	5	3	2	0	0	0	0	24
F	*Nuculana pernula*	2	0	0	1	0	0	0	0	11
F	*Aphelochaeta monilaris*	4	2	0	0	1	1	0	0	16
F	Nemertea sp. 5	0	3	21	0	4	8	2	0	28
F	*Byblis gaimardi*	1	1	1	0	0	0	0	0	16
F	*Hartmania moorei*	0	0	1	1	0	0	0	0	18
F	*Goniada maculata*	1	3	1	6	0	4	0	0	47
F	*Oenopota incisula*	1	1	1	2	0	1	0	0	29
G	*Euchone incolor*	3	24	74	960	555	81	15	0	87
G	*Parougia caeca*	3	18	28	98	34	15	5	0	94
G	*Anobothrus gracilis*	74	48	44	416	14	31	0	0	81
G	*Dentalium entale*	8	16	17	115	0	4	0	0	51
G	*Melinna cristata*	1	1	0	2	0	0	0	0	20
G	*Spiophanes kroeyeri*	1	1	1	17	0	1	0	0	27
G	*Amphiporus cruentatus*	0	0	0	8	0	0	0	0	11
G	*Micrura* spp.	12	15	10	40	21	16	7	3	97
G	*Sphaerosyllis longicauda*	0	0	0	2	1	2	0	0	30
G	*Mayerella limicola*	1	0	0	13	4	1	0	0	26
G	*Heteromastus filiformis*	20	17	11	22	0	0	0	0	45
G	*Carinomella lactea*	2	3	3	7	5	1	2	0	66
G	*Paramphinome jeffreysii*	0	4	1	35	0	0	0	0	23
G	*Tubulanus pellucidus*	2	3	3	12	0	0	0	0	27
G	*Terebellides stroemii*	1	1	1	4	0	0	0	0	20
H	*Sternaspis scutata*	1	25	54	78	3	0	0	0	54
H	*Priapulus caudatus*	0	1	1	2	1	0	0	0	17
H	*Galathowenia oculata*	2	24	44	66	4	8	1	0	73
H	*Bathymedon obtusifrons*	0	1	7	7	0	0	0	0	22

Table 5-14. Average abundance of species by cluster group (#/0.12 m^2) for 1992–2000 farfield infauna. Species with <3 occurrences were not included (continued).

Group	Species	Ia	Ib	Ic	Id	II	III	IV	V	Station Occurrences
		Station Group								
H	*Monoculodes packardi*	0	1	2	2	0	0	0	0	13
H	*Eudorella hispida*	0	1	10	21	4	0	0	0	32
H	*Leucon fulvus*	0	0	2	2	0	0	0	0	14
H	Cephalothricidae sp. 1	0	1	12	25	2	5	0	0	40
H	*Amphiporus groenlandicus*	0	0	1	4	0	0	0	0	13
H	*Stereobalanus canadensis*	0	0	2	3	4	1	0	0	37
H	*Cylichna gouldi*	3	3	7	11	5	0	0	0	46
H	*Deflexilodes tesselatus*	0	0	0	1	1	0	0	0	18
H	*Trochochaeta multisetosa*	1	2	13	12	1	3	2	0	36
H	*Pythinella cuneata*	0	0	4	7	1	3	1	0	18
H	Nemertea sp. 12	0	5	8	37	7	5	6	0	22
H	*Thracia conradi*	0	4	2	45	0	12	0	0	37
H	*Diplocirrus hirsutus*	1	2	0	14	1	1	0	0	28
H	*Proclea graffii*	0	0	0	11	4	1	0	0	14
H	*Diastylis cornuifer*	0	1	1	4	4	1	0	0	29
H	*Mystides borealis*	1	0	0	4	2	0	0	0	31
H	*Ctenodiscus crispatus*	2	1	1	4	0	1	0	0	28
I	*Cossura longocirrata*	117	55	82	271	1075	4	0	0	73
I	*Syllides longocirrata*	18	10	5	14	36	0	0	0	51
I	Tubificidae sp. 2	0	0	0	1	267	4	12	0	47
I	*Apistobranchus typicus*	9	3	6	47	86	16	0	0	64
I	*Onoba pelagica*	9	18	19	64	79	2	0	0	64
I	*Leptostylis longimana*	0	1	1	4	4	0	0	0	40
I	*Terebellides atlantis*	2	2	3	13	80	1	0	0	54
I	*Nucula annulata*	0	0	0	0	35	0	0	0	20
I	*Ophiura robusta*	6	2	0	0	4	0	0	0	19
I	*Cylichna alba*	1	0	0	0	2	0	0	0	12
I	*Metopella angusta*	10	3	16	32	32	14	11	4	83
I	*Eudorella pusilla*	7	4	1	1	12	6	0	0	63
I	*Periploma papyratium*	4	5	12	0	5	5	1	0	45
I	*Ophiura sarsi*	0	1	3	3	11	1	0	0	34
I	*Scoletoma fragilis*	2	1	2	2	10	2	0	0	63
I	*Anonyx liljeborgi*	1	0	0	1	2	2	0	0	35
I	*Enipo torelli*	5	2	1	2	3	1	0	0	48
I	*Syllides japonica*	3	2	1	0	3	0	0	0	28
I	*Nephtys incisa*	4	2	10	16	36	6	9	15	83
I	*Stenopleustes inermis*	0	0	0	5	13	7	3	1	54
I	*Pleurogonium inerme*	0	0	1	0	8	3	2	0	39
I	*Pusillina harpa*	0	0	0	0	4	0	0	0	11
J	*Harpinia propinqua*	15	16	31	32	55	39	0	0	70
J	*Ophiocten sericeum*	0	0	0	3	6	1	0	0	11
J	*Aricidea minuta*	0	0	0	0	5	0	0	0	13
J	*Brada villosa*	1	0	0	0	1	0	0	0	11
J	*Leptocheirus pinguis*	0	0	0	0	104	2	0	0	22
J	*Orchomenella minuta*	0	0	0	0	15	2	1	3	39

Table 5-14. Average abundance of species by cluster group (#/0.12 m^2) for 1992–2000 farfield infauna. Species with <3 occurrences were not included (continued).

J	*Gattyana amondseni*	0	1	1	1	4	3	0	0	47
J	*Amphiporus angulatus*	4	2	3	4	6	5	3	0	65
J	Actiniaria sp. 2	0	0	0	0	4	1	1	1	22
J	*Retusa obtusa*	0	0	0	1	1	0	0	0	12

Table 5-15. Station group summary for 1992 to 2000 farfield infaunal data based on Gallagher's CNESS dissimilarity and group average sorting.

Cluster Group	Station	Year 1992	1993	1994	1995	1996	1997	1998	1999	2000
Ia	FF01		92	93						
	FF05				94					
Ib	FF04		92	93	94					
	FF05		92	93		95				
	FF11		92	93	94					
	FF14		92	93	94					00
Ic	FF04					95	96			
	FF14					95	96	97		
	FF05						96	97		
	FF11					95	96	97	98	00
Id	FF04						97	98	99	00
	FF05							98	99	00
	FF14							98	99	
	FF11								99	
II	FF06	92	93	94	95	96	97	98	99	00
	FF07	92	93	94	95	96	97	98	99	00
III	FF09	92	93	94	95	96	97	98	99	00
	FF01A			94	95	96	97	98	99	00
	FF10	92	93	94	95	96	97	98	99	00
IV	FF12	92	93		95	96	97	98	99	00
	FF13	92	93	94	95	96	97	98	99	00
V	FF12			94						

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        0.84         1.05         1.26
                     CNESS
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The primary grouping of species in the farfield reflected regional differences among the farfield stations in species distribution and abundance. At the 10 group level, species formed into four distinct clusters, A to D, E, F to H, and I and J (Table 5-16). Group A contained the numerical dominant *Prionospio steenstrupi*, also the top dominant at nearfield stations, which occurred at all but three of the 99 station/year combinations. It was not reported from FF05, FF07, or FF12 in 1994. Group A was most characteristic of station groups I and III. Groups B, C, and D species were most abundant at station group III (Tables 5-15 and 5-16). Group E contained many abundance and occurrence dominant, for example *Mediomastus californiensis, Ninoe nigripes*, and *Photis pollex*, and was broadly distributed across all station groups. Group F was similar in character to group E except that its species did not occur at group IV and V station, which were in the nearfield area close to Boston Harbor, and were most representative of farfield infauna out of the direct influence of the Harbor, for example *Spio limicola, Levinsenia gracilis* and *Aricidea quadrilobata* (Table 5-15). Groups G and H contained species that became most abundant in station group Id for 1998 and 1999. Groups I and J species were most abundant in station group II, which was composed of the Cape Cod Bay stations.

5.2.10 Reconsideration of 2000 Sample Handling Problem

The multivariate analyses carried out in Sections 5.2.4 through 5.2-9 allow a further semi-quantitative evaluation of whether the sample handling discussed in Sections 5.1.1 and 5.2.1 biased those samples' data enough to impact the analyses and suggest those samples should be treated as not fit for use in future reports and analyses.

We found no evidence for such bias. In Figure 5-3, all three replicates from station NF12 clustered together at a low level of dissimilarity before clustering with data from any other station, as did replicates from station NF24. At each of those stations, two of the three replicate samples were identified as problematic. Similarly, in Figure 5-9 all three replicates from FF05 cluster together even though one replicate was problematic. While there are no replicate samples against which to compare the problematic samples from NF15, NF21, or NF22, neither of the latter 2 samples shows up as outliers in the analyses of Figure 5-2. Also, in the station group analyses of Table 5-10, all 3 stations clustered in the same groups in 1999 as they did 2000. Taken together, these results are strong evidence that the sample handling issues identified did not affect the resulting data from those samples enough to warrant treating them as suspect, and they were retained in the analyses in this report and will be used in future multi-year data analyses.

5.3 Nearfield Threshold Comparisons

Diversity Measures—The year 2000 represented the final year of baseline monitoring as effluent discharges through the Massachusetts Bay outfall began in September, a short time after the infaunal sampling occurred. The baseline threshold boundaries (97.5^{th} and 2.5^{th} percentiles), calculated using the data modification specified for this report, are listed in the textbox below. Also, the thresholds are shown in Figure 5-11 to show them in the context of yearly data from the nearfield stations. Evident in the figure (recognizing of course that these values were also included in the determination of the thresholds) is that all of the Year 2000 values for the parameters of concern were well within the threshold boundaries.

Parameter	Percentile	
	2.5^{th}	**97.5^{th}**
Species per Sample	47.95	81.09
Log-series Alpha	10.13	15.88
Shannon Diversity (*H'*)	3.32	4.02
Pielou's Evenness (*J'*)	0.56	0.67

Opportunists—In 2000, the total opportunist contribution to infaunal abundance rose over that found in 1999. The seven selected opportunist taxa accounted for 0.98 % of the total abundance in the nearfield, and for 0.17% in the farfield (Table 5-17). Greater numbers of *Ampelisca abdita*, *Capitella capitata* complex, and *Polydora cornuta* were found in 2000 versus 1999. The total percent composition of the selected opportunist taxa in the nearfield and farfield infaunal communities throughout the baseline period has been < 2 % (Table 5-17). Year-to-year variability during the baseline period, as indicated by the range of yearly values, was small.

Table 5-16. Average infauna abundance (#/0.12 m2) by cluster analysis species and station groups for 1992 to 2000 farfield infaunal data based on Gallagher's CNESS dissimilarity and group average sorting.

	Ia	Ib	Ic	Id	II	III	IV	V	Characteristic Species
A	5	16	87	84	12	164	54	0	*Prionospio steenstrupi*
B	0	0	0	1	1	14	3	0	*Exogone verugera*
C	2	1	1	4	2	12	5	2	*Aphelochaeta marioni*
D	2	2	1	9	7	30	1	1	*Dipolydora socialis*
E	4	8	9	15	43	22	42	11	*Mediomastus californiensis*
F	28	62	39	55	22	34	1	0	*Spio limicola*
G	8	10	13	117	42	10	2	0	*Euchone incolor*
H	0	3	8	17	2	2	1	0	*Galathowenia oculata*
I	9	5	7	22	82	3	2	1	*Cossura longocirrata*
J	2	2	4	4	20	5	1	0	*Harpinia propinqua*

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Table 5-17. Total and percent abundance[1] of selected opportunist species in nearfield and farfield samples collected from Massachusetts Bay, 1992–2000.

Nearfield	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
All *Ampelisca*	75	66	67	105	479	265	118	93	285
Ampelisca abdita	51	33	31	68	445	235	55	41	247
Ampelisca macrocephala	24	33	36	37	34	29	63	51	38
Ampelisca vadorum	0	0	0	0	0	1	0	1	0
Capitella capitata complex	208	196	491	281	120	248	259	204	363
Mulinia lateralis	1	0	0	0	0	0	0	0	0
Polydora cornuta	434	10	0	0	0	0	0	2	241
Streblospio benedicti	1	2	0	0	0	0	0	0	0
Total Opportunist Abundance	719	274	558	386	599	513	377	299	889
Total Infaunal Abundance	64862	48389	70050	65809	74394	93815	90292	96216	91008
Percent Opportunists	1.11%	0.57%	0.80%	0.59%	0.81%	0.55%	0.42%	0.31%	0.98%
Farfield	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
All *Ampelisca*	5	19	27	16	21	24	21	16	14
Ampelisca abdita	0	0	1	1	1	7	0	0	0
Ampelisca macrocephala	5	19	26	15	20	17	21	16	14
Ampelisca vadorum	0	0	0	0	0	0	0	0	0
Capitella capitata complex	44	64	165	39	25	280	31	58	75
Mulinia lateralis	0	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	0
Streblospio benedicti	0	2	0	1	0	0	0	0	0
Total Opportunist Abundance	49	85	192	56	46	304	52	74	89
Total Infaunal Abundance	29541	26960	19223	33579	32529	38134	50293	63681	53009
Percent Opportunists	0.17%	0.32%	1.00%	0.17%	0.14%	0.80%	0.10%	0.12%	0.17%

[1] The actual threshold test will be carried out on the average percent abundance of the "opportunists" in the nearfield samples for a discharge year.

6. 2000 HARDBOTTOM STUDIES

by Barbara Hecker

6.1 Methods

This section contains the results of an analysis of still photographs and videotapes obtained during the nearfield hardbottom survey conducted in June 2000. Twenty-two of the 23 waypoints were surveyed (Table 6-1). Site T2-5 was not surveyed because divers were working at the eastern end of the outfall tunnel. The photographic coverage ranged from 13-27 minutes of video footage and 27-35 still photographs (35-mm slides) at each waypoint. A total of 701 still photographs were used for the following data analysis. Because of ongoing work on the outfall tunnel, the Diffuser #44 site was surveyed by drifting over the diffuser rather than anchoring at the site. As a result, only 13 minutes of video footage were obtained at this site.

Table 6-1. Photographic coverage at locations surveyed during the 2000 nearfield hardbottom survey.

Transect	Waypoint	Location on drumlin	Depth (ft)	Depth (m)	Video (min)	Stills (# frames)
1	1	Top	87	27	27	27
1	2	Top	74	22	22	32
1	3	Top	62	19	26	33
1	4	Top	67	20	22	35
1	5	Flank	87	27	21	33
2	1	Top	85	26	20	30
2	2	Flank	97	29	20	34
2	3	Top	83	26	20	33
2	4	Flank	101	31	22	29
4	1	Flank	100	31	24	34
4	2	Flank	92	28	20	33
4	3	Flank	94	29	22	32
4/6	4	Top	70	21	21	32
6	1	Flank	107	33	21	34
6	2	Flank	98	30	21	28
7	1	Top	82	25	22	33
7	2	Top	79	24	21	32
8	1	Top	83	25	23	32
8	2	Top	80	24	23	30
9	1	Top	83	25	19	31
10	1	Top	81	25	19	32
Diffuser	#44		111	34	13	32

6.1.1 Visual Analysis

Each 35-mm slide was projected and analyzed for sea-floor characteristics (*i.e.*, substratum type and size class, and amount of sediment drape) and biota. The amount of sediment draped on the rock surfaces was assessed in terms of relative thickness, ranging from clean when the entire rock surface was visible to heavy when none of the rock surface was visible. To facilitate comparisons among stations and years, these sediment drape categories were assigned the following numerical codes:

Category	Numerical value
clean to very light	0
light	1
moderately light	2
moderate	3
moderately heavy	4
heavy	5

Most recognizable taxa were counted and recorded. Several very abundant taxa (for which accurate counts were impossible to obtain) were assessed in terms of percent cover or relative abundance. The abundance of encrusting coralline algae was assessed as rough estimates of percent cover. Several other taxa, a filamentous red alga (tentatively identified at *Ptilota serrata*), colonial hydroids, and small barnacles and/or spirorbid polychaetes that were frequently too abundant to count reliably were assessed in terms of relative abundance. The following categories were used to assess abundances of taxa that were not counted on the still photographs:

Category	Percent cover	Numerical value assigned for analysis
rare	1-5	1
few	6-10	2
common	11-50	5
abundant	51-90	15
very abundant	>90	20

Organisms were identified to the lowest possible taxonomic level, about half of them to species, with the aid of pictorial keys of the local flora and fauna (Martinez and Harlow 1994, Weiss 1995). Many of the encrusting species could not be identified to species. Most of these were assigned to descriptive categories (*e.g.*, "orange-tan encrusting"); however, each of these descriptive categories possibly includes several species. Additionally, some species might be split between two similar descriptive categories (*e.g.*, "orange encrusting" and "orange lumpy encrusting"), as a result of differences in viewing angles and lighting. Because of high relief in many of the habitats surveyed, all reported abundances should be considered to be extremely conservative. In many areas, only part of the surfaces of large boulders was visible; thus, actual faunal abundances in these areas were undoubtedly much higher than the counts indicated. A summary of the 2000 slide analysis is included in Appendix E-1.

The videotapes were viewed to provide additional information about uniformity of the habitat at each of the sites. Notes on habitat relief, substrate size classes, and relative amount of sediment drape were recorded. Rare, large, and clearly identifiable organisms were enumerated. With the exception of the cunner *Tautogolabrus adspersus* (which was frequently very abundant), all fish were enumerated. Counts of abundant motile organisms, cryptic organisms, and all encrusting organisms were not attempted because of the large amount of time that accurate counts would require and the general lack of resolution of the video footage. A summary of the 2000 video analyses is included in Appendix E-2.

6.1.2 Data analysis

Data for the analyses from all slides taken at each waypoint were pooled. To facilitate comparisons among waypoints, species counts were normalized to mean number of individuals per slide to normalize for differences in the number of slides collected at each site. Hydroids and small barnacles and/or spirorbids were omitted from the data analysis because they consisted of several species, could not be accurately assessed, and it was impossible to tell if they were alive. General taxonomic categories (*i.e*., fish, sponge, etc.) were included in estimates of total faunal abundances, but were omitted from community analysis. Only taxa with an abundance of ten or more individuals in the entire data set were retained for community analysis. This process resulted in 41 out of the original 65 taxa being retained for community analysis. Juvenile and adult *Asterias vulgaris* (northern sea stars) and white and pink color-morphs of *Halocynthia pyriformis* (sea peach tunicates) were pooled.

Hierarchical classification was used to examine the data obtained from the still photographs. This analysis consisted of a pair-wise comparison of the species composition of all waypoints using the percent similarity coefficient. This coefficient was chosen because it relies on the relative proportion that each species contributes to the faunal composition, and as a result is least sensitive to differences in sampling effort among locations. Unweighted pair-group clustering was used to group samples with similar species composition (Sokal and Sneath 1963). This strategy has the advantage of being relatively conservative in clustering intensity, while avoiding excessive chaining.

6.2 Results and Discussion

Habitat characterizations and dominant taxa that were determined separately from video images and still photographs were similar, indicating that the still photographs were representative of the areas surveyed. Differences between the two types of coverage were mainly related to a higher occurrence of some sparsely distributed larger taxa observed in the greater geographic coverage afforded by the videotapes, and the higher occurrence of encrusting taxa afforded by the superior resolution of the still photographs.

Visibility was generally quite poor, due to a high amount of suspended particulate material in the water column, when compared to previous years. The suspended material caused a substantial increase in the back-scatter of light which frequently resulted in slight blurring of the images. The slight blurring of the images made it harder to see and identify smaller and/or cryptic taxa. The back-scatter also resulted in reduced areal coverage, since less area was visible on each of the images. Examples of the high amount of suspended material can be seen in Appendix F, particularly Plate 1.

6.2.1 Distribution of Habitat Types

The sea floor on the tops of the drumlins usually consisted of a mix of glacial erratics in the boulder and cobble size categories. These areas frequently consisted of numerous boulders interspersed with cobbles, and were generally characterized by moderate to high relief. Several exceptions to this pattern of moderate to high relief on the tops of drumlins were noted. The sea floor at three sites in the middle of the drumlin directly north of the diffuser (T1-1, T1-2 and T2-1) mainly consisted of a mix of cobbles, small boulders and gravel and had moderately low to moderate relief. Two reference sites located southwest of the diffuser (T8-1 and T8-2) also had moderately low relief, consisting of a cobble pavement occasionally interrupted by smaller boulders. In contrast, the sea floor at the other southwestern reference site (T10-1) consisted mostly of large boulders and was characterized by high relief. The tops of drumlins had quite variable amounts of sediment drape, ranging from mostly clean rock surfaces (T1-2, T1-3, T1-4, and T4/6-4) to a heavy sediment drape (T10-1). The sea floor on the flanks of the drumlins usually consisted of a moderately low to moderate relief mix of cobbles, boulders, and gravel. Sediment drape on the flanks ranged from a moderate drape (T4-2 and T6-2) to a heavy mat-like cover (T2-4 and T6-1). Habitat relief and sediment drape frequently were quite variable within many of the sites surveyed. Most moderate to high relief areas also contained small patches of low relief cobbles and gravel, and some of the low relief areas contained occasional small patches of boulders. Additionally, in areas of moderate to heavy sediment drape, occasional bare rock surfaces neighbored heavily draped ones.

Sediment drape tended to increase with increasing water depth. The relationship between depth, sediment drape, and topography is shown on Figure 6-1. Shallow drumlin tops (<23 meters) had the least amount of sediment drape, with rock surfaces that ranged from clean to having a light dusting of sediment. Sediment drape on the deeper drumlin tops (23 -27 meters) was quite variable, ranging from a moderately light dusting to a heavy sediment mat. Sediment drape on the rock surfaces on the flanks of the drumlins (>27 meters) ranged from a moderate layer of sediment to a heavy mat.

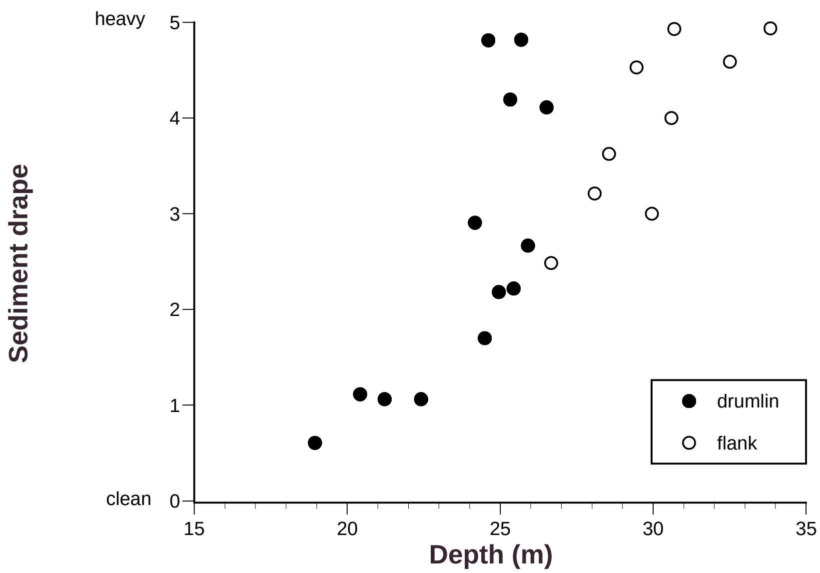

Figure 6-1. Depth, sediment drape, and topographic location of the sites from the 2000 nearfield hardbottom survey.

6.2.2 Distribution and Abundance of Epibenthic Biota

Sixty-five taxa were seen during the visual analyses of the 2000 nearfield hardbottom survey still photographs and videotapes (Table 6-2). Sixty of these taxa were seen on the still photographs. Taxonomic counts or estimates of abundances included 6,519 algae, 16,571 invertebrates, and 856 fish (Table 6-3). Coralline algae was the most abundant taxon observed during the survey, with an estimated abundance of 4,610 individuals. This taxon consists of at least 5 different species that had been identified as *Lithothamnion* spp. in previous surveys. Five species of corallines, *Leptophytum laevae*, *Leptophytum foecundum*, *Phymatolithon lamii*, *Phymatolithon laevigatum*, and *Lithothamnion glaciale*, were identified from voucher specimens collected during September 2000. Differences between these species cannot be discerned on the basis of photographs, so all pink encrusting coralline algae were lumped into one taxon called coralline algae. Two other algae commonly seen were dulse (*Rhodymenia palmata*) and a red filamentous alga *Ptilota serrata*, with abundances of 1,082 and 711 individuals, respectively. The red filamentous alga had previously been identified as *Asparagopsis hamifera*, but a voucher specimen collected at T7-1 was identified as *Ptilota serrata.* Another alga, the shotgun kelp *Agarum cribosum*, also was seen during this survey. This large alga was most abundant at T7-2, where more than half of the individuals seen were being overgrown by an encrusting organism that appears to be a species of the

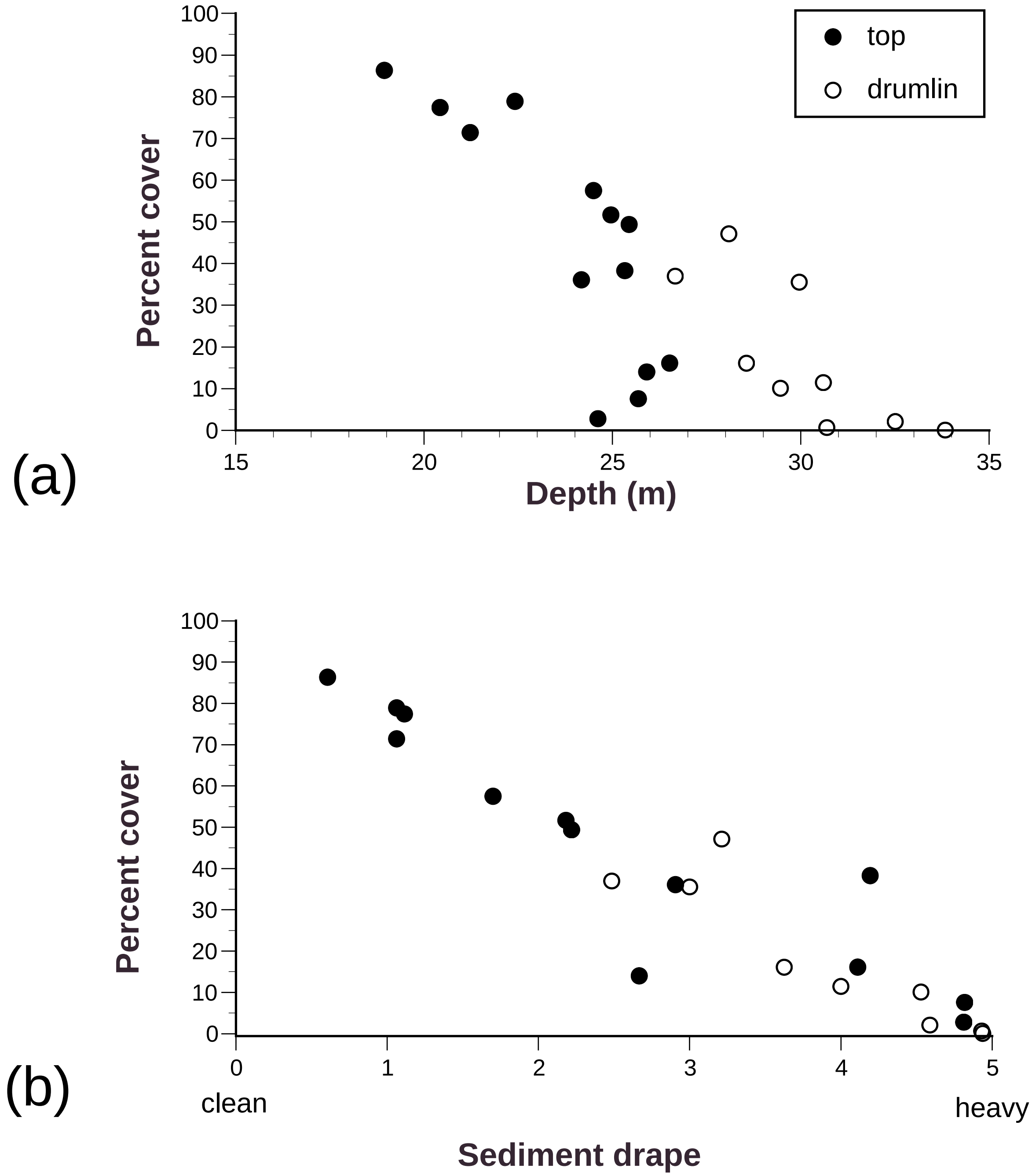

Figure 6-2. Percent cover of coralline algae in relation to topography, depth (a) and sediment drape (b) from the 2000 nearfield hardbottom survey.

lacey bryozoan *Membranipora* (Plates 2 and 3, Appendix F). *Agarum cribosum* was also seen at 4 other stations, but none of those seen at the other stations was being encrusted by the bryozoan.

The most abundant invertebrates observed on the still photographs were the northern sea star *Asterias vulgaris* (3,103 juveniles and 292 adults), an unidentified orange/tan sponge (1,425 individuals), the horse mussel *Modiolus modiolus* (1,193 individuals), the drop of blood tunicate *Dendrodoa carnea* (1,092 individuals), the sea pork tunicate *Aplidium* spp. (982 individuals), the flat slipper limpet *Crepidula plana* (917 individuals), and the frilled anemone *Metridium senile* (824 individuals). Other common invertebrate inhabitants of the drumlins included the northern white crust tunicate *Didemnum albidum* (729 individuals), the brachiopod *Terebratulina septentrionalis* (634 individuals), the blood sea star *Henrecia sanguinolenta* (559 individuals, and many sponges and encrusting organisms. The most abundant fish observed in the still photographs was the cunner *Tautogolabrus adspersus* (833 individuals).

Coralline algae was the most abundant and widely distributed taxon encountered during the survey. This encrusting alga was seen at all waypoints except Diffuser #44. Its mean areal coverage ranged from 1% at T2-4 to 86% at T1-3. Figure 6-2 shows the relationship between percent cover of coralline algae, depth, sediment drape, and topography. Corallines were most abundant in drumlin top areas that had minimal sediment drape on the rock surfaces and least abundant in areas that had heavy sediment cover. An example of high percent cover of coralline algae can be seen in representative photographs from T1-2 and T8-2 (Plates 4 and 5, Appendix F). In contrast, two upright algae, *Ptilota serrata* and dulse had much more restricted distributions. These algae dominated in areas characterized by high relief and a moderate to heavy sediment drape (Plates 2 and 3, Appendix F). The reduced percent cover of coralline algae in areas supporting high abundances of upright algae appeared to be related to fine particles being trapped by the holdfasts of the upright algae and blanketing the rock surfaces. In areas with heterogeneous substrate characteristics, *Ptilota* and dulse frequently dominated on the tops of boulders, while corallines dominated on the cobbles and smaller boulders in between.

Several of the commonly seen invertebrates also exhibited wide distributional patterns. The northern sea star *Asterias vulgaris* was found at all of the sites. Juvenile *Asterias* were usually much more abundant than adults and were most abundant on the top of drumlins. In contrast, adult *Asterias* were most abundant on the flank of drumlins and at the Diffuser #44 site. The highest abundances of juvenile *A. vulgaris* were found at T1-3, T4/6-4, and T7-2, and the lowest abundances were found at T2-4 and T8-1. The horse mussel *Modiolus modiolus* was also very widely distributed, being found at all but one site (Diffuser #44). This mussel was most abundant on the top of drumlins, where large numbers frequently were observed nestled among cobbles and at the bases of boulders (T1-3, T1-4 and T7-2). Because of the mussel's cryptic nature of being nestled in among rocks and frequently being almost totally buried, the observed abundances should be considered very conservative. The number of mussels definitely would be underestimated in areas of high relief, because the bases of larger boulders frequently were not visible in the images. Three species of tunicates also were widely distributed. The drop of blood tunicate *Dendrodoa carnea* was found at all of the sites and was most abundant at T1-2 and T1-3. The sea pork tunicate *Aplidium* spp. was found at all but three of the sites and was most abundant at 1-5, T6-2, and T8-2. The northern white crust tunicate *Didemnum albidum* was found at 19 of the sites surveyed. The blood sea star *Henrecia sanguinolenta* was observed at all of the sites, and was most abundant on boulders in areas of high relief (T10-1 and T7-2).

Several other abundant invertebrates exhibited much more restricted distributions. Three of these species appeared to be primarily restricted to large boulders. The brachiopod *Terebratulina septentrionalis* was found at 12 of the sites, but was only seen in high abundances at 4 of them (T7-2, T2-4, T4-1, and T10-1). This species appeared to be restricted to the sides of large boulders where it might be protected from heavy sediment loading. Another species that was markedly more abundant on large boulders was the frilled anemone *Metridium senile*. This anemone was found at 12 sites, but was abundant at only 3 of them. It was very abundant on the head of Diffuser #44 and on several large boulders at T4/6-4. This anemone usually was seen on the tops of large boulders. Another species that appeared to be restricted to large boulders was the soft coral *Gersemia rubiformis*, which had an exceptionally restricted distribution. It was seen only at T10-1, where it dominated the fauna attached to the large boulders characteristic of this site.

Table 6-2. Taxa observed during the 2000 nearfield hardbottom survey.

	Taxon	Common Name		Taxon	Common Name
	Algae		*	*Coryphella* sp.	red-gilled nudibranch
	Coralline algae	encrusting alga	*	bivalve	
	Ptilota serrata	filamentous red alga		*Modiolus modiolus*	horse mussel
	Rhodymenia palmata	dulse		*Placopecten magellanicus*	sea scallop
	Agarum cribrosum	shotgun kelp	*	*Arctica islandica*	ocean quahog
	Fauna			Crustaceans	
	Sponges			*Balanus* spp.	acorn barnacle
	sponge			*Homarus americanus*	American lobster
*	*Aplysilla sulfurea*	yellow sponge		*Cancer* spp.	rock crab
	Halichondria panicea	crumb-of-bread sponge	**	hermit crab	
	Haliclona spp.	finger sponge		Echinoderms	
	Melonanchora elliptica	warty sponge		*Strongylocentrotus droebachiensis*	green sea urchin
	Phakellia spp.	chalice sponge	*	starfish	
	Polymastia?	siphon sponge?		juvenile *Asterias*	small white sea star
	Suberites spp.	fig sponge		*Asterias vulgaris*	northern sea star
	white divided	sponge on brachiopod		*Henricia sanguinolenta*	blood sea star
*	orange/tan encrusting			*Crossaster papposus*	spiny sun star
*	orange encrusting		**	*Porania insignis*	badge star
*	gold encrusting			*Pteraster militaria*	winged sea star
*	tan encrusting			*Psolus fabricii*	scarlet holothurian
*	pink fuzzy encrusting			Tunicates	
*	dark red/brown encrusting		*	tunicate	
*	white translucent			*Aplidium* spp.	sea pork tunicate
*	cream encrusting			*Boltenia ovifera*	stalked tunicate
*	rust-cream encrusting			*Dendrodoa carnea*	drop of blood tunicate
*	General encrusting organism			*Didemnum albidum*	northern white crust
	Cnidarians			*Halocynthia pyriformis*	sea peach tunicate
	hydroid		*	clear globular tunicate	
	Campanularia sp.	wine-glass hydroids		Bryozoans	
*	*Corymorpha pendula*	solitary hydroid	*	bryozoan	
	Obelia geniculata	zig-zag hydroid	*	?*Bugula* spp.	spiral tufted bryozoan
*	anemone			*Membranipora* spp.	sea lace bryozoan
	Metridium senile	frilly anemone	*	red crust bryozoan	
	Urticina felina	northern red anemone		Miscellaneous	
	Cerianthus borealis	northern cerianthid		*Myxicola infundibulum*	slime worm
	Gersemia rubiformis	red soft coral		spirorbid and serpulid polychaetes	
	Mollusks			*Terebratulina septentrionalis*	northern lamp shell
	gastropod			Fish	
*	*Tonicella marmorea*	mottled red chiton	*	fish	
	Crepidula plana	flat slipper limpet	**	*Gadus morhua*	cod
	Buccinum undatum	waved whelk		*Macrozoarces americanus*	ocean pout
*	*Neptunea decemcostata*	ten-ridged whelk		*Myoxocephalus spp.*	sculpin
*	*Ilyanassa trivittata*	dog whelk		*Pseudopleuronectes americanus*	winter flounder
*	nudibranch			*Tautogolabrus adspersus*	cunner

* Only seen on still photographs
** Only seen on video

Table 6-3. List of taxa seen on still photographs taken during the 2000 nearfield hardbottom survey, arranged in order of abundance.

Taxon	Count	Taxon	Count
Algae		*Melonanchora elliptica*	22
Coralline algae	4610[1]	*Cancer* spp.	20
Rhodymenia palmata	1082	*Arctica islandica*	19
Ptilota serrata	711[1]	*Campanularia* sp.	11
Agarum cribrosum	116	tan encrusting sponge	10
Total algae	**6519**	rust-cream encrusting sponge	9
		Polymastia?	9
Invertebrates		*Placopecten magellanicus*	8
juvenile *Asterias*	3103	*Haliclona* spp.	7
orange/tan encrusting sponge	1425	*Urticina felina*	6
Modiolus modiolus	1193	*Buccinum undatum*	6
Dendrodoa carnea	1092	nudibranch	5
Aplidium spp.	982	*Homarus americanus*	5
Crepidula plana	917	dark red/brown encrusting sponge	4
Metridium senile	824	*Crossaster papposus*	4
white translucent sponge	753	*Boltenia ovifera*	4
orange encrusting sponge	736	*Cerianthus borealis*	3
Didemnum albidum	729	*Pteraster militaria*	2
Terebratulina septentrionalis	634	clear globular tunicate	2
Henricia sanguinolenta	559	gold encrusting sponge	1
general encrusting organism	391	*Phakellia* spp.	1
?*Bugula* spp.	330	*Corymorpha pendula*	1
Asterias vulgaris	292	gastropod	1
pink fuzzy encrusting sponge	285	*Coryphella* sp.	1
Suberites spp.	246	bivalve	1
cream encrusting sponge	185	starfish	1
Myxicola infundibulum	185	tunicate	1
Aplysilla sulfurea	176	bryozoan	1
white *Halocynthia pyriformis*	165	hydroids	*
Gersemia rubiformis	159	spirorbid/barnacle complex	*
Strongylocentrotus droebachiensis	159	**Total invertebrates**	**16571**
white divided sponge on brachiopod	144		
Halocynthia pyriformis	125	**Fish**	
Balanus spp.	114	*Tautogolabrus adspersus*	833
Psolus fabricii	112	*Myoxocephalus* spp.	13
red crust bryozoan	96	*Macrozoarces americanus*	3
Halichondria panicea	86	*Pseudopleuronectes americanus*	3
anemone	77	fish	4
Membranipora spp.	43	**Total fish**	**856**
Obelia geniculata	40		
Tonicella marmorea	26		
sponge	23		

* Not counted
[1] Estimated

The distribution of the green sea urchin *Strongylocentrotus droebachiensis* appeared to be related to food availability rather than specific substrate characteristics. This urchin was widely distributed, but was only found in high abundances in regions that had high cover of coralline algae (T1-2, T1-3, and T4/6-4), on which it grazes (Sebens, 1986). The red holothurian *Psolus fabricii* also was widely distributed. This holothurian was found at 12 sites, but was abundant at only 5 of them (T1-3, T1-5, T6-2, T8-1, and T8-2). Reasons for its high abundance at some sites, and not at others, were not readily apparent.

Encrusting invertebrate taxa generally were most abundant in moderate to high relief areas that had light to moderate sediment drape on the rock surfaces. This is not surprising because most juveniles of attached taxa require sediment-free surfaces for settlement. Additionally, clean rock surfaces are indicative of strong currents that could provide adequate food supplies for suspension-feeding organisms. Boulders and large cobbles also provide a physically more stable environment than smaller cobbles as they are more resistant to mechanical disturbance.

The fish fauna was dominated by the cunner *Tautogolabrus adspersus*, which was observed at all 22 waypoints. This fish was most abundant in moderate to high relief areas, where it tended to congregate among large boulders (T1-2, T1-3, T2-3, T4-2, T7-1, and T7-2). In areas of heterogeneous relief, *T. adspersus* frequently was seen only in the vicinity of boulders. Four other fish species, sculpin (*Myoxocephalus* spp.), winter flounder (*Pseudopleuronectes americanus*), ocean pout (*Macrozoarces americanus*) and cod (*Gadus morhua*) also were seen. The sculpin and flounder were usually in areas of low relief, while cod were only observed in the vicinity of large boulders. The cod were observed only on the video footage, since they appeared to actively avoid the ROV.

6.2.3 Community Structure

Classification of the 22 waypoints and 41 taxa (retained for analysis) defined three clusters of stations and two outlier areas (Figure 6-3). The first two clusters further divided into slightly more cohesive subgroups. The first cluster consisted of mostly moderate to high-relief drumlin top areas that had relatively heavy sediment drape. These included the three northern reference sites (T7-1, T7-2, and T9), one site on the drumlin north of the outfall (T2-3), and a reference site southwest of the outfall (T10-1). The second cluster consisted of drumlin top and flank areas that had variable relief and sediment drape. These included the two southernmost reference sites (T8-1 and T8-2), as well as sites on the drumlins north and south of the outfall. The third cluster consisted of 2 drumlin flank areas that had moderately low relief and moderate to heavy sediment drape (T1-5 and T2-2). The first outlier consisted of a drumlin flank site with moderate relief and heavy sediment drape (T2-4), while the second outlier consisted of a diffuser head and the area immediately surrounding it (Diffuser #44). The clustering structure appeared to be determined by a combination of drumlin topography, habitat relief, sediment drape, and geographic location. Neighboring waypoints with similar habitat characteristics tended to cluster together. Habitat characteristics and range of abundances of dominant taxa for each of the cluster groups are presented in Table 6-4.

Encrusting coralline algae were common inhabitants of most of the areas comprising the first two cluster groups. Differences among the areas in these two cluster groups were mainly related to the relative proportion of encrusting and upright algae at each of the sites. The areas in Cluster 1 were dominated by upright algae, *Ptilota serrata* and *Rhodymenia palmata*, whereas the areas in Cluster 2 were dominated by coralline algae. This is not surprising because the sea floor of all areas in Cluster 1 had moderate to high relief, and upright algae appeared to be more common on the tops of boulders. Cluster 1 divided into one subgroup and two individual sites, This division reflected slight shifts in the composition of the communities inhabiting these areas, as well as differences in the abundances of their biotic inhabitants. The areas in Subgroup 1a (the three northern reference sites) supported numerous upright algae, moderate coralline algae (36-52 percent cover), and numerous *Modiolus modiolus*, while the two other areas in this

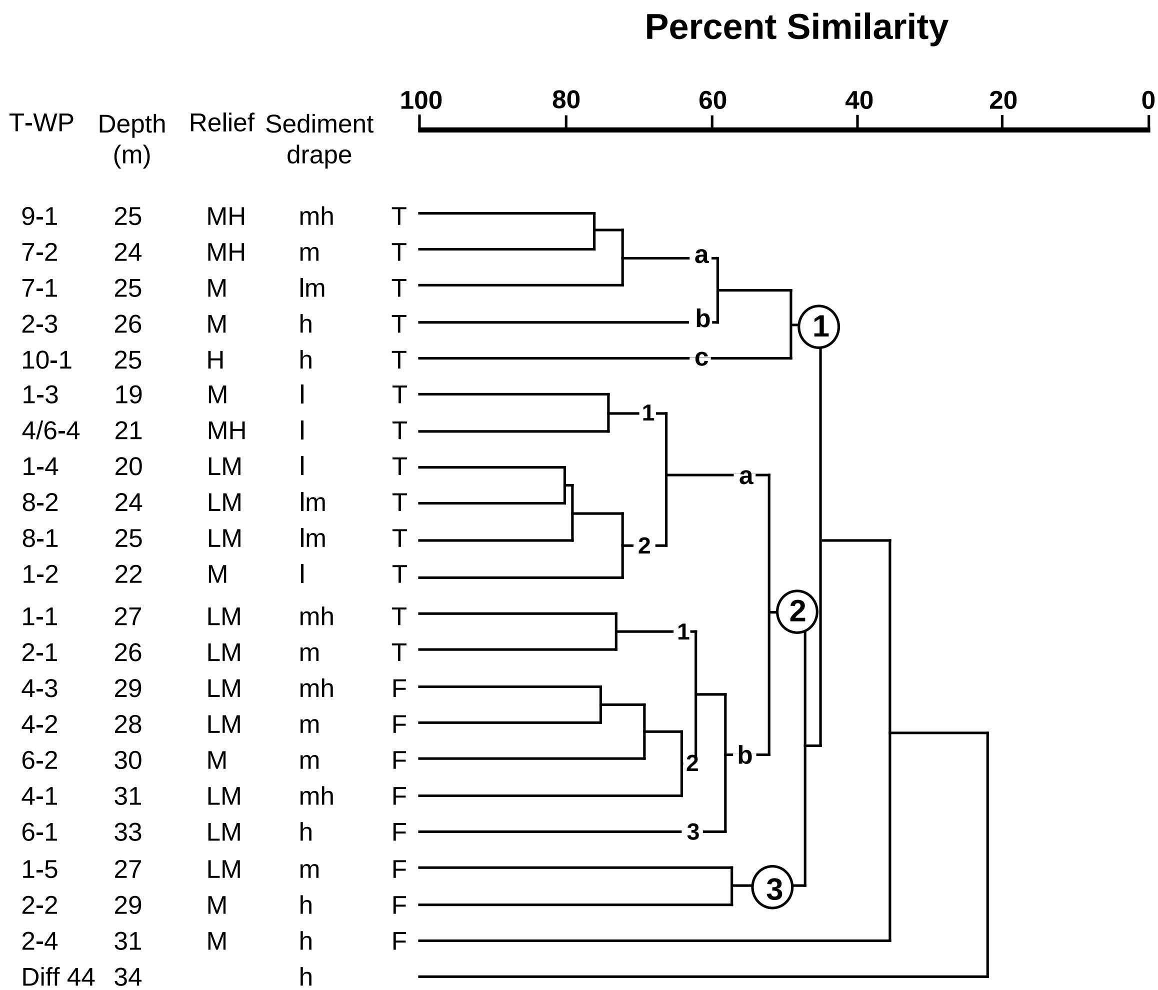

Figure 6-3. Cluster analysis of data collected from still photographs taken during the 2000 nearfield hardbottom survey.

cluster (T2-3 and T10-1) supported far fewer upright and coralline algae (8 and 3 percent cover, respectively). The northern reference sites (Subgroup 1a) supported high numbers of algae and invertebrates, while the other two sites supported mainly invertebrates. The large boulders at T10-1 supported numerous soft corals *Gersemia rubiformis* (which were not seen anywhere else) and many *Asterias vulgaris.* All but two of the sites in this cluster (T9-1 and T10-1) supported relatively high abundances of the cunner, *Tautogolabus adspersus.* Representative photographs of the sites in Cluster 1 can be seen in Appendix F (Plates 2, 3, and 6).

The thirteen areas in Cluster 2 were characterized by either less or more variable habitat relief and generally less sediment drape than the areas in Cluster 1. The benthic communities at all of the areas in Cluster 2 were dominated by either coralline algae or invertebrates, but never by upright algae. The areas in this cluster further divided into 2 subgroups. The six sites in subgroup 2a consisted of drumlin top sites, including the two southernmost reference sites (T8-1 and T8-2). Coralline algae were dominant components of the benthic communities found at all six of these sites, with the two reference sites having 49 and 58 percent cover and the other four sites having ≥71 percent cover. Additionally, the two-drumlin top sites in subgroup $2a_1$ supported numerous *Asterias vulgaris, Modiolus modiolus,* and *Metridium*

Table 6-4. Habitat characteristics and range of abundance (number per picture) of selected taxa in the clusters defined by classification analysis. Numbers in bold highlight major differences among clusters and subgroups.

Cluster	**1**			**2**					**3**		
	a	**T2-3**	**T10-1**	**a_1**	**a_2**	**b_1**	**b_2**	**T6-1**		**2-4**	**Diff #44**
Depth (meters)	24-25	26	25	19-21	20-25	26-27	28-31	33	27-29	31	34
Habitat relief[a]	M-MH	M	H	M-MH	LM-M	LM	LM-M	LM	LM-M	M	
Sediment drape[b]	lm-mh	h	h	l	l-lm	m-mh	m-mh	h	m-h	h	h
Location[c]	T	T	T	T	T	T	F	F	F	F	
Ptilota serrata	**2.7-11.1**	**2.4**	-	0.0-0.1	-	-	-	-	-	-	-
Rhodymenia palmata	**4.6-9.5**	**4.7**	1.9	0.0-0.1	-	0.6-4.1	0.0-0.1	-	-	-	-
Coralline algae	**7.1-9.7**	1.7	0.7	**13.0-15.9**	9.4-14.9	3.0-3.5	2.6-8.6	0.8	2.7-6.8	0.2	-
Coralline (percent cover)	36-52	8	3	71-86	49-79	14-16	11-47	2	10-37	<1	-
Asterias vulgaris	4.6-9.3	2.5	8.1	8.1-8.5	1.2-4.7	2.3-4.2	3.5-7.9	3.7	2.9-3.6	1.6	**5.3**
Modiolus modiolus	**3.2-7.2**	0.3	2.4	**2.1-6.3**	0.7-4.5	0. 1-0.5	0.1-1.3	0.3	0.4-0.6	-	-
Aplidium spp.	0.0-1.5	0.3	0.3	0.0-0.5	1.3-4.7	1.7-2.0	0.1-5.3	1.6	1.4-3.9	0.3	-
Strongylocentrotus droebachiensis	0.1-0.2	-	0.1	0.8-0.9	0.0-0.9	-	0.0-0.5	0.1	0.1-0.4	-	0.1
Gersemia rubiformis	-	-	**5.0**	-	-	-	-	-	-	-	-
Terebratulina septentrionalis	0.1-10.2	0.4	2.2	0.0-0.5	-	-	0.0-2.0	-	0.0-0.2	3.3	-
Crepidula plana	0.0-0.9	-	-	0.0-0.4	0.0-1.0	-	0.0-0.8	-	**7.6-15.3**	1.0	-
Metridium senile	0.0-0.2	-	0.3	**1.9-8.8**	0.0-0.6	0.0-0.1	0.0-0.1	-	0.0-0.1	-	**13.3**
Halocynthia pyriformis	0.0-0.3	0.1	0.4	0.1-0.2	-	0.0-0.1	0.0-0.1	-	-	-	**7.5**
Tautogolabrus adspersus	0.4-4.8	3.0	0.9	0.7-2.5	0.1-2.8	0.7	0.3-3.2	0.1	0.3-0.4	0.1	0.2
Algae	**18.6-30.0**	9.0	2.8	**13.1-16.0**	9.4-14.9	3.6-7.6	2.6-8.7	0.8	2.7-6.8	0.2	0.1
Invertebrates	22.1-50.6	17.5	**36.9**	**29.7-30.3**	13.9-17.9	9.9-15.7	12.2-24.9	15.5	**28.1-37.0**	16.9	**36.5**
Fish	0.4-4.8	3.0	0.9	0.8-2.5	0.1-2.9	0.7	0.4-3.2	0.1	0.4-0.5	0.1	0.2
Total	**41.1-84.1**	29.6	**40.6**	**43.6-48.8**	23.4-34.5	14.2-24.1	16.1-36.7	16.4	35.4-40.0	17.1	36.8

Key:

[a]Habitat relief: L = low, LM = moderately low, M = moderate, MH = moderately high, H = high
[b]Sediment drape: l = light, lm = moderately light, m = moderate, mh = moderately light, h = heavy
[c]Location: T = drumlin top, F = drumlin flank

senile. The benthic communities inhabiting the remaining seven sites in this cluster (Subgroup 2b) varied considerably, but they were all dominated by invertebrates. All but two of these sites were located on the flanks of drumlins. The two-drumlin top areas in this subgroup ($2b_1$) supported moderately low abundances of coralline algae (14 and 16 percent cover) and a few dulse. The flank areas in the 2b subgroup supported more invertebrates than algae. Representative photographs of sites in this cluster can be seen in Appendix F (Plates 1, 4, 5, and 7).

The two-drumlin flank areas in Cluster 3 supported benthic communities that were similar to those found in the sites in Cluster 2. The Cluster 3 areas differed in that they both had high abundances of the flat slipper limpet *Crepidula plana*. The distribution of this limpet is extremely patchy, and large numbers of these limpets were seen in only several pictures at each site (Plate 8, Appendix F).

The two outlier areas supported markedly different communities. The benthic community at T2-4 was not dominated by one particular species, but rather consisted of low to moderate abundances of a number of invertebrates. In contrast, the hard substrate provided by the diffuser head at Diffuser #44 provided suitable attachment sites for numerous *Metridium senile* and *Halocynthia pyriformis*. Numerous *Asterias vulgaris* were also seen on the diffuser head. Representative photographs of the diffuser head can be seen in Appendix F (Plates 9 and 10).

6.3 Spatial and Temporal Trends in the Nearfield Hardbottom Benthos

Baseline studies of the nearfield hardbottom communities in the vicinity of the outfall have been conducted for the last seven years. These studies have provided a database that has allowed characterization of the habitats and benthic communities on the hardbottom drumlins in the vicinity of the outfall. During this time period the sampling design and approach have evolved to maximize the probability of detecting potential impacts of future outfall operations. The original survey conducted in 1994 consisted of videotapes taken along a series of transects of hardbottom areas adjacent to the outfall (Coats *et al.*, 1995). Starting in 1995 the sampling protocol was changed to surveying discrete stations (waypoints) on the drumlins immediately north and south of the outfall, and at several reference sites on drumlins further away (Figure 6-4). The 1995 sampling plan consisted of 19 waypoints, 17 near the outfall (on Transects 1, 2, 4 and 6) and one at each of two reference sites (Transects 7 and 8). In 1996, one additional waypoint was added at each of the reference sites and T6-3 was dropped because it was found to be exceptionally depauperate. Two new reference sites (Transects 9 and 10), and the head of Diffuser #44, were added during the 1997 survey. Diffuser #44 was added to the survey protocol because it is not scheduled to go online. Because it is less than 40m from adjacent diffusers that are to be activated, and it like other diffusers, has been densely colonized, it represents a worst-case scenario of potential impact. This general sampling protocol was repeated from 1998 to 2000, with the omission of the two waypoints on or near the diffuser (T2-5 and Diffuser #44) from the 1999 survey (because of concurrent work being conducted in the outfall tunnel) and the omission of T2-5 from the 2000 survey (a dive platform barge was anchored at the eastern end of the outfall).

In addition to a sampling plan that evolved to address specific issues, the emphasis on data products also has evolved during this time period. The 1994 and 1995 data sets relied mainly on an analysis of video footage. During the 1995 survey a few still photographs also were taken at each of the sites. Analysis of these photographs showed that the resolution afforded by the still photographs was far superior to that of the video images, and hence subsequent emphasis has been shifted to analysis of still photographs. The video images cover a much broader area than the still photographs, and are primarily used to assess habitat relief and heterogeneity and the occurrence of rarer fauna. The still photographs are used to provide detailed data on habitat characteristics (substrate size classes and amount of sediment drape), estimated percent cover of encrusting algae, estimated relative abundances of upright algae, and faunal composition of the benthic communities.

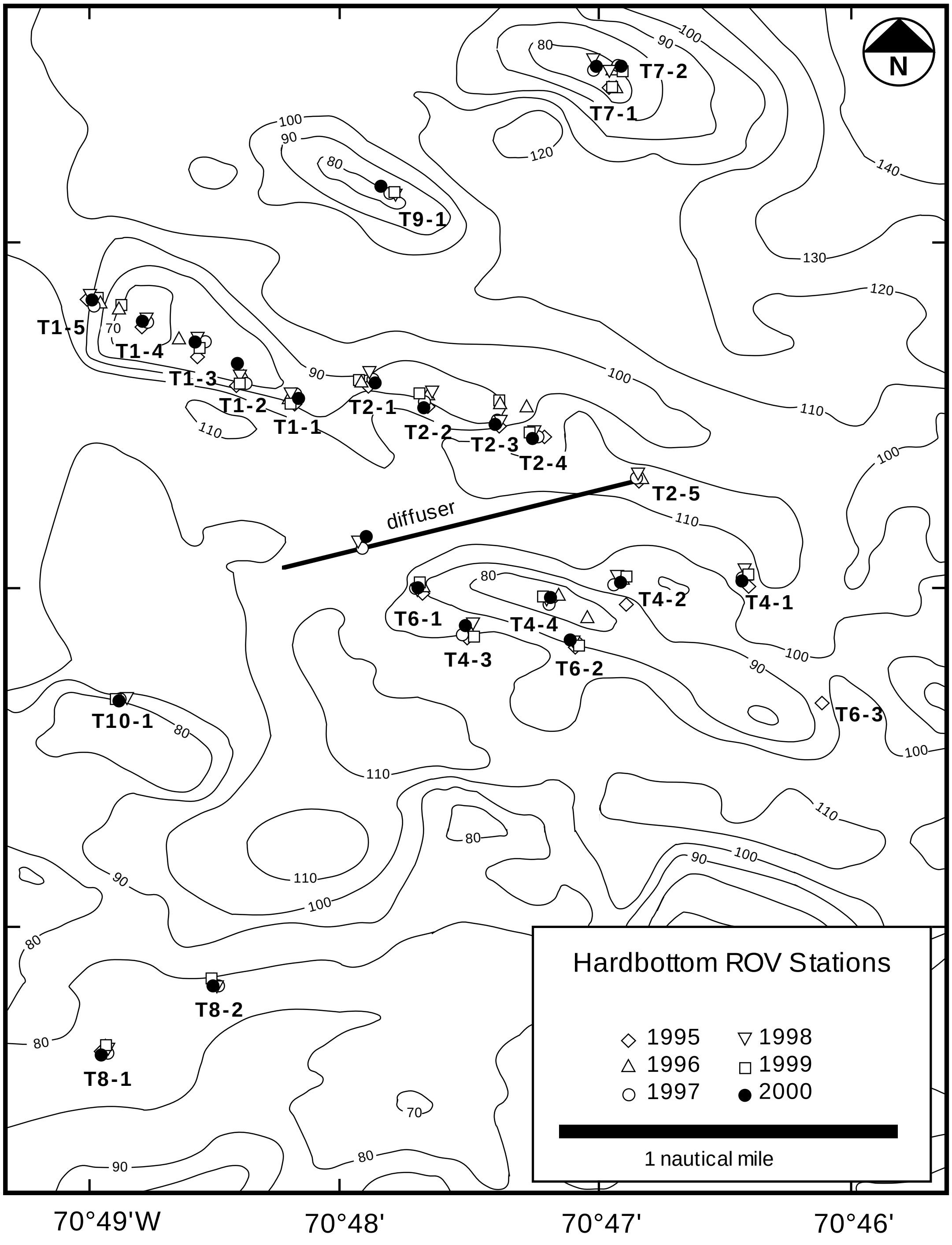

Figure 6-4. Nearfield hardbottom stations surveyed from 1995 to 2000. Note: T4/6-4 is abbreviated as T4-4 on all maps.

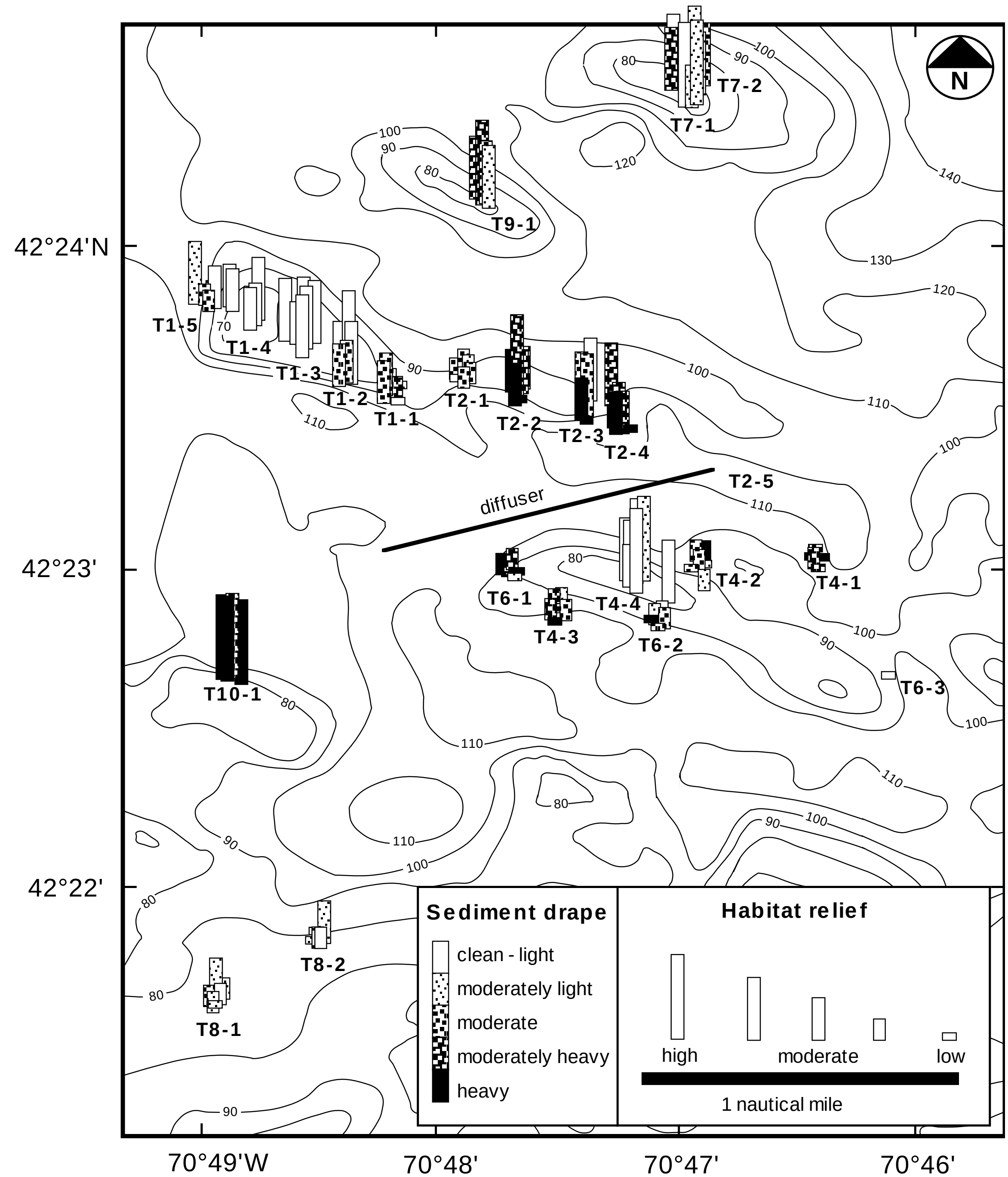

Figure 6-5. Sea floor characteristics, habitat relief and sediment drape determined from the 1995 to 2000 nearfield hardbottom surveys.

Analysis of the last six years of video and 35-mm still photographs showed a temporally stable pattern in the structure of benthic communities inhabiting the hardbottom areas in the vicinity of the outfall. The hardbottom habitats are spatially quite variable, but have shown several consistent trends during the study period. Figure 6-5 shows the habitat characteristics observed during the 1995 to 2000 surveys. Location on the drumlins appeared to be a primary factor in determining habitat relief. The sea floor on the tops of drumlins usually consisted of a mix of boulders and cobbles. Habitat relief on the tops of drumlins varied from moderately high-to-high in areas dominated by boulders (T1-2, T1-3, T2-2, T2-3, T4/6-4, T7, T9, and T10) to moderate to low in areas that consisted of a mix of cobbles and boulders (T1-4 and T8).

Sediment drape on the tops of drumlins ranged from light (T1-3, T1-4, T4/6-4 and T8) to moderate (T2-1 and T2-3) at most locations, to moderately heavy or heavy at others (T2-2, and T9, T10). The sea floor on the flanks of drumlins was quite variable, but usually consisted of a cobble pavement interspersed with patches of sand, gravel and occasional boulders. Habitat relief on the flanks ranged from low to moderate, depending on how many boulders were present. Sediment drape in the flank areas usually ranged from moderate to heavy. The tops of the drumlins frequently were relatively homogeneous, so lateral shifts in position frequently did not result in different habitat characteristics (T1-3, T1-4, T4/6-4, T8, T9 and T10). In contrast, small lateral shifts in position near the edges of the drumlin tops or on the flanks frequently resulted in substantially different habitat characteristics (*i.e.*, T1-1, T1-2, T2-2 and T2-3).

The benthic communities inhabiting the hardbottom areas showed a temporally consistent trend during the 1995 to 2000 time period. Algae usually dominated on the tops of drumlins, while invertebrates (mostly encrusting or attached forms) were increasingly dominant on the flanks. Encrusting coralline algae was the most abundant and widely distributed taxon encountered during this study. The distribution and areal coverage of coralline algae were temporally quite stable during the six years of this study. Figure 6-6 shows the percent cover of coralline algae estimated from the 35-mm images taken during the 1995 to 2000 surveys. Coralline algae were generally most abundant on the top of drumlins and least abundant on the flanks. Table 6-5 shows the estimated percent cover of coralline algae for the five years (1996-2000) in which comparable data was collected. The percent cover of corallines was most variable near the edges of the tops of drumlins or on the flanks, where small lateral shifts in location frequently resulted in a very different habitat.

Analysis of the year 2000 data showed that while there was a general trend of fewer coralline algae with increasing depth, depth *per se* did not appear to explain much of the observed variation in percent cover of coralline algae. It is unlikely that light attenuation with depth is a limiting factor for coralline algae, within the range of depths covered during this survey. Vadas and Steneck (1988) reported coralline algal cover of up to 80% at depths >50 m on Ammen Rock Pinnacle in the Gulf of Maine and Sears and Cooper (1978) reported finding coralline algae at depths of 47 m on offshore ledges in the Gulf of Maine. Additionally, numerous coralline algae have been observed at a depth of 34 m at a hardbottom site in Massachusetts Bay near Scituate (B. Hecker, personal observation). Sediment drape on the rock surfaces also tended to increase with depth. A plot of percent cover of coralline algae versus sediment drape shows that the abundance of corallines appears to be strongly related to sediment drape; percent cover was highest in areas that had little drape and lowest in areas with moderate to heavy drape (Figure 6-7). This is not surprising, because the encrusting growth form of coralline algae would make them susceptible to smothering by fine particles. The relationship between coralline algal abundance and sediment drape can also be seen in the variation within stations, where percent cover of corallines usually varied with the amount of sediment drape (Figure 6-8).

In contrast, the abundance and distribution of three upright algae, the filamentous red alga *Ptilota serrata* (previously called *Asparagopsis hamifera*), the dulse *Rhodymenia palmata*, and the shotgun kelp *Agarum cribosum*, appeared to be mainly controlled by habitat relief. These algae were patchily distributed and only abundant on the top of boulders in areas of moderate to high relief. Figure 6-9 shows the relationship between relative abundance of *P. serrata* and habitat relief. The abundance of *P. serrata* increased with increasing habitat relief. Sediment drape in areas supporting high abundances of upright algae ranged from moderate to high. The numerous holdfasts of the algae appeared to actively trap sediment, thereby possibly excluding encrusting coralline algae. Additionally, invertebrates and fish (mainly the cunner, *Tautogolabrus adspersus*) generally were more abundant in areas of moderate to high relief and less abundant in areas of low relief.

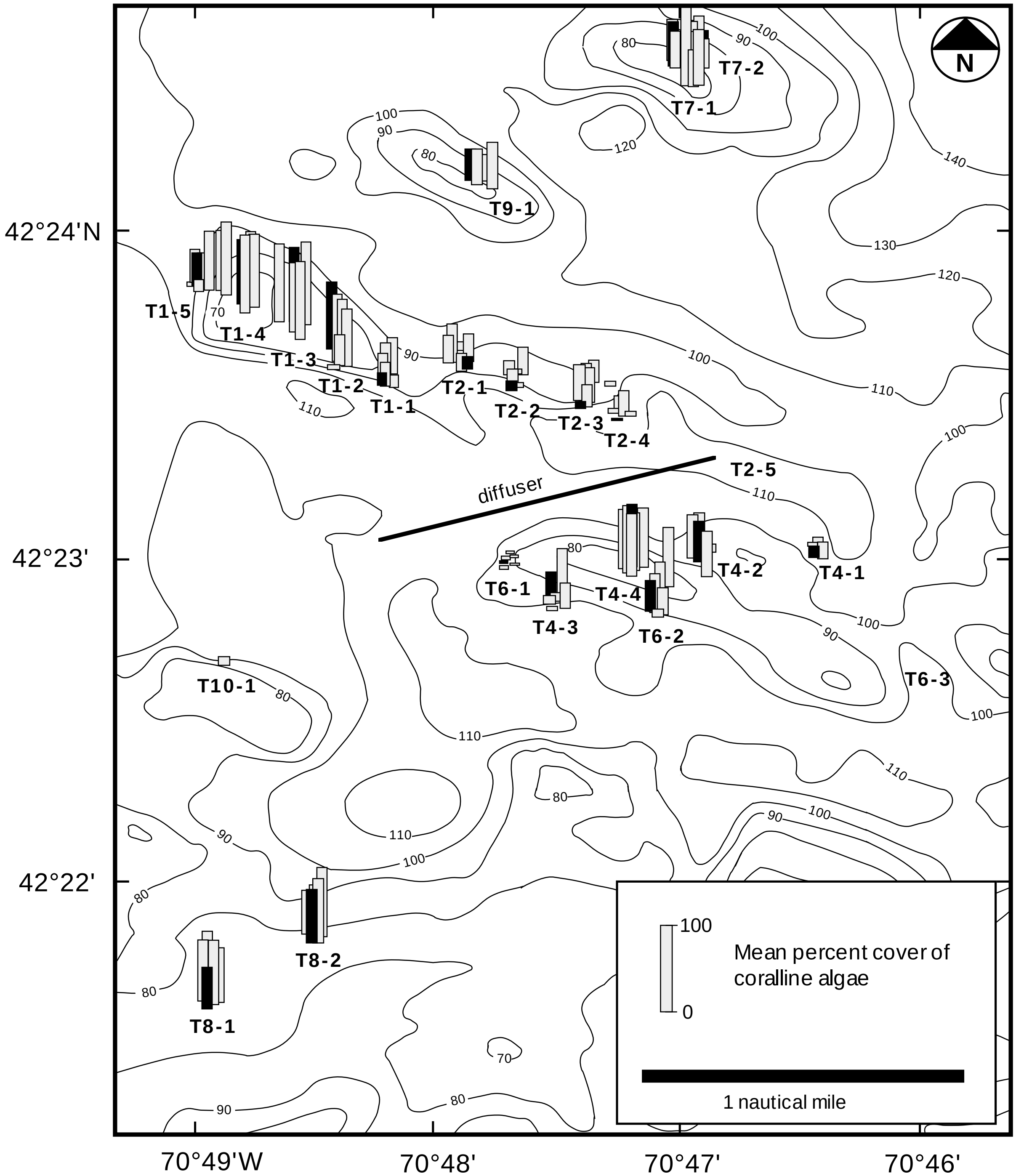

Figure 6-6. Percent cover of coralline algae determined from the 1995 to 2000 nearfield hardbottom surveys. Black bars are values from the 2000 survey.

Table 6-5. Estimated percent cover of coralline algae from 1996 to 2000. Large differences are highlighted by borders. Asterisks mark differences that appear to be related to shifts in position of the areas surveyed.

Transect	Waypoint	1996	1997	1998	1999	2000
1	1	35	42	37	26	16*
	2	71	72	79	36*	79
	3	90	96	80	83	86
	4	87	83	82	70	77
	5	68*	12	39	37	37
2	1	45	33	9*	35	14*
	2	5	13	33*	13	10
	3	27	41	39	21	8*
	4	7	27	18	4	1
	5	<1	<1	<1		
4	1		16	<1	0	11
	2	41	53	9*	8*	47
	3	12	12	56*	25	16
	4	72	67	77	72	71
6	1	2	4	5	2	2
	2	69*	55	45	29*	36
7	1	65	43	49	47	52
	2	53	54	45	36	36
8	1		73	74	69	49
	2	82	75	65	51*	58
9	1		40	54	28	38
10	1		12	<1	2	3
Diffuser	44		<1	<1		<1

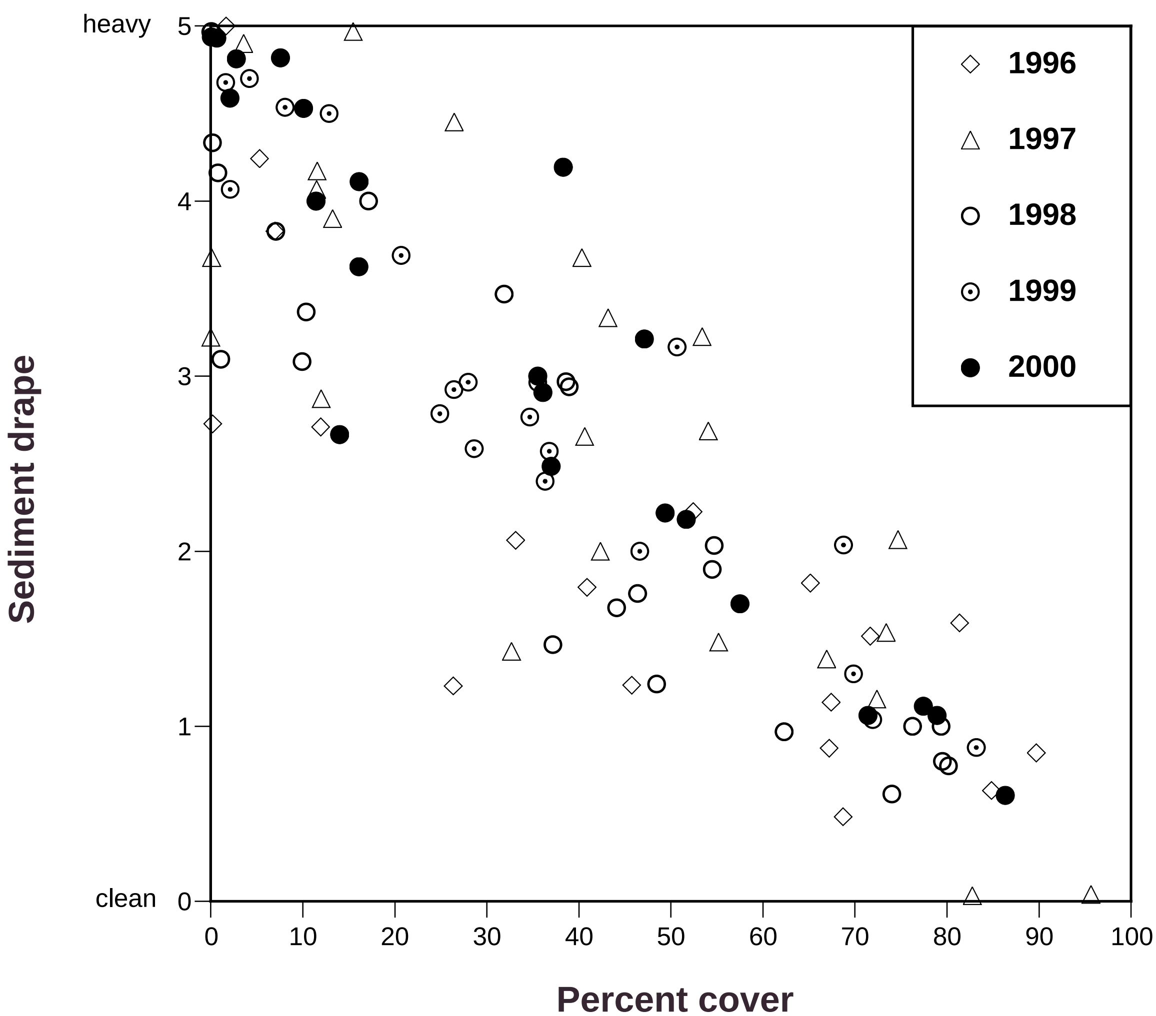

Figure 6-7. Percent cover of coralline algae versus sediment drape from the 35-mm images taken at each waypoint during the 1996 to 2000 nearfield hardbottom surveys.

The pattern of benthic community structure in the hardbottom areas was remarkably consistent during the 1996-2000 time period. Figure 6-10 shows the distribution of benthic communities defined by hierarchical classification analysis. The dendrograms were remarkably similar among the four years (see Blake *et al.*, 1997, Blake *et al.*, 1998, Kropp *et al*,. 2000, Kropp *et al.*, 2001, for the 1996, 1997, 1998, and 1999 dendrograms). The communities at many of the sites remained the same during the four-year period. Good examples of this can be seen at the northern reference sites (T7 and T9), the southernmost reference sites (T8), and the top of the drumlin north of the outfall (T1-3, T1-4, T2-2, and T2-3). Frequently instances of waypoints differing in their cluster designation among the years appeared to reflect slight lateral shifts in relation to drumlin topography (Table 6-6). This was quite noticeable at T1-5 where in 1996 and 1999 the community was dominated by coralline algae (Cluster 1) and in 1997, 1998, and 2000 it was not (Cluster 3). A close examination of the map reveals that the areas surveyed at this site in 1996 and 1999 were nearer to the top of the drumlin. Another example of this can be seen at T2-1 where the community surveyed in 1998 (Cluster 3) differed from that found in the other four years (Cluster 2). The area surveyed at this site in 1998 was located slightly down the flank of the drumlin and was not dominated by algae. The remaining instances of differences in cluster group designation among years appeared to be related to the generally patchy nature of the hardbottom habitats.

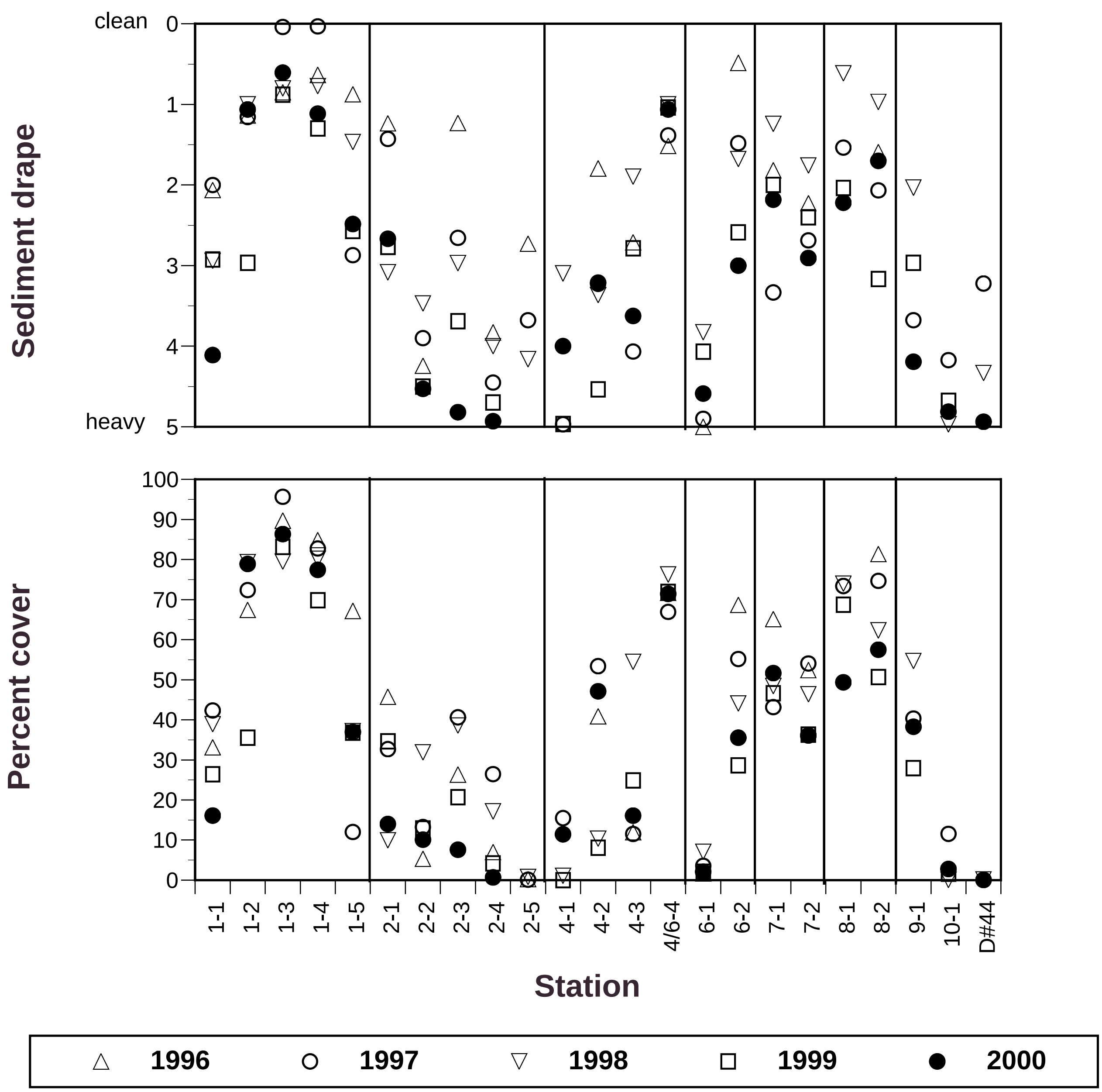

Figure 6-8. Sediment drape and percent cover of coralline algae at each nearfield site determined from the 35-mm slides taken during the 1996 to 2000 hardbottom surveys.

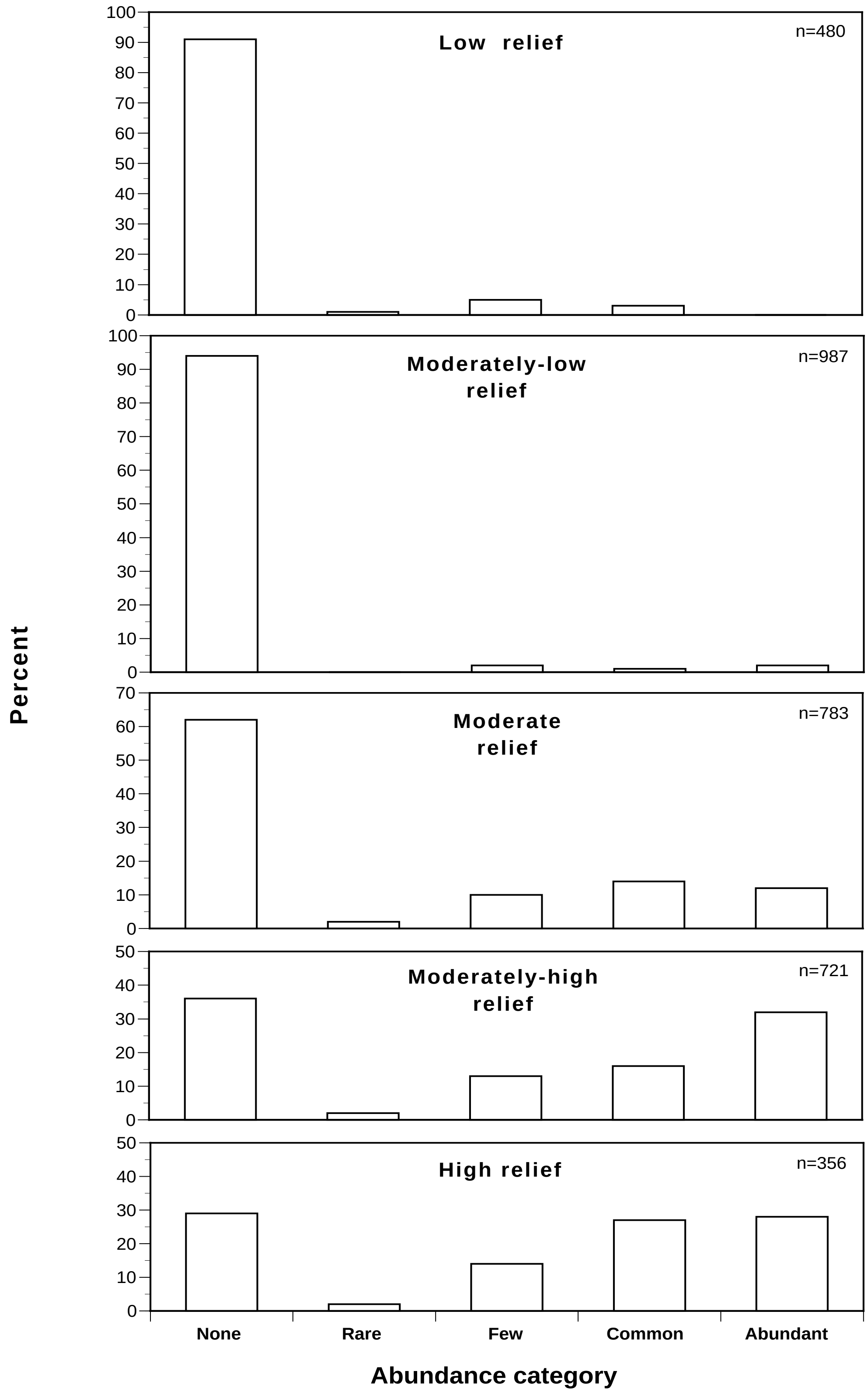

Figure 6-9. Relative abundance of the filamentous red alga *Ptilota serrata* in relation to habitat relief. Based on individual 35-mm images taken during the 1995 to 2000 nearfield hardbottom surveys. n=number of slides taken within each habitat relief category.

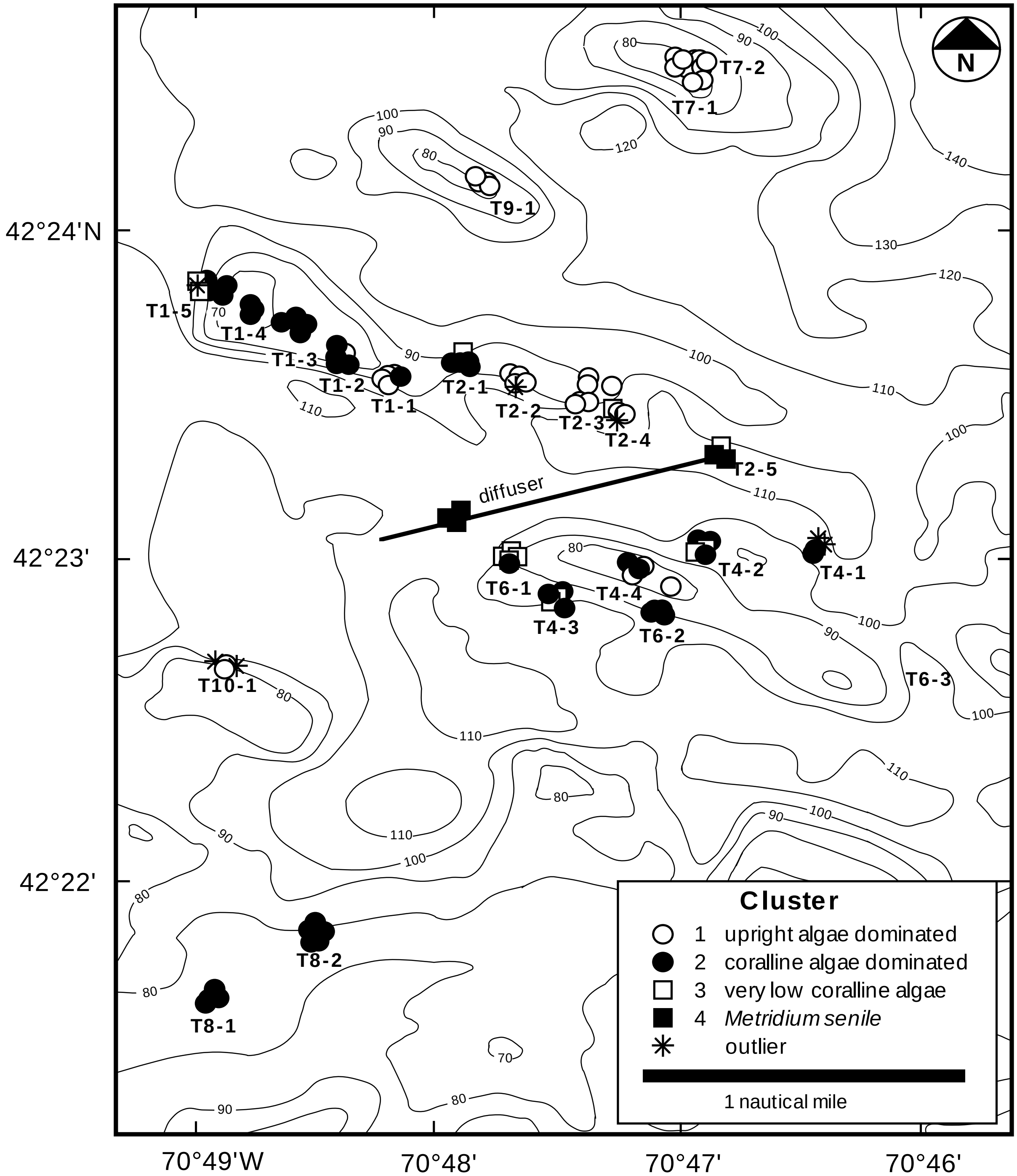

Figure 6-10. Map of benthic communities defined from classification of the 35-mm images taken during the 1995 to 2000 nearfield hardbottom surveys.

Table 6-6. Cluster group designations defined by classification analysis of the waypoints surveyed from 1996 to 2000. Differences are highlighted by borders. Asterisks show differences explained by shifts in location.

Transect	Waypoint	1996	1997	1998	1999	2000
1	1	1	1	1	1	2
	2	1*	2	2	2	2
	3	2	2	2	2	2
	4	2	2	2	2	2
	5	2*	3	3	2*	3
2	1	2	2	3*	2	2
	2	1	1	1	1	3*
	3	1	1	1	1	1
	4	1	1	1	3	outlier
	5	4	4	3*		
4	1		2	outlier	outlier	2
	2	2	2	3*	3*	2
	3	3	3	2	2	2
	4	1	1	2	2	2
6	1	3	3	3	3	2
	2	1*	2	2	2	2
7	1	1	1	1	1	1
	2	1	1	1	1	1
8	1		2	2	2	2
	2	2	2	2	2	2
9	1		1	1	1	1
10	1		1	outlier	outlier	1
Diff	44		4	4		outlier

Communities dominated by upright algae were found on the tops of drumlins on either side of the diffuser (T1-1, T2-2, T2-3, T2-4 and T4/6-4) and at all three of the northern reference sites (T7-1, T7-2 and T9-1). In contrast, coralline algae dominated the benthic communities on top of a drumlin located northwest of the diffuser (T1-2, T1-3 and T1-4), at 2 of the southwestern reference sites (T8-1 and T8-2), and at some of the drumlin flank sites. Two of the flank sites located just south of the diffuser (T4-3 and T6-1) had exceptionally low abundances of coralline algae and were relatively depauperate when compared to the other sites. The diffuser heads that were surveyed were colonized by *Metridium senile* and *Asterias vulgaris* (T2-5 and Diffuser #44). Some of the outlier areas represented the most extreme habitats that were surveyed, flat sand and cobble pavement at T4-1 (in 1998 and 1999) and very large boulders with heavy sediment drape at T10-1. These patterns also generally agreed with the results obtained in 1995.

No attempt at a direct community analysis comparison with the 1995 data was made, because of the limited number and non-random collection of the 35-mm images taken during that year.

Our results are generally similar to those reported by Coats *et al.* (1995) from the video survey conducted in 1994. Four of the eight transects covered in this report (Transects 1, 2, 4 and 6) were the same as those included in the 1994 survey. The 1994 survey consisted of near continuous video coverage along the transects, while the present design focuses on topographically selected points (waypoints) along the transects that include representative drumlin top and flank locations. The 1995-2000 surveys respectively identified 76, 72, 100, 84, 78, and 65 taxa, compared to 37 identified from the 1994 survey. Rather than indicating changes in the benthic communities, the greater number of taxa identified from the post-1994 surveys appear to be related to the enhanced visual resolution of the still photographs. Many of the additional taxa identified in the last six surveys are encrusting forms that would be difficult to resolve on video images. Additionally, the ROV has been kept much closer to the sea floor in the post-1994 surveys (right on the bottom as opposed to an altitude of 1 to 3 meters). Differences in taxonomic designations also exist between the 1994 and post-1994 surveys. Coats *et al.* identified an abundant pinnate red alga as *Rhodymenia* sp A, this appears to be the filamentous red alga that we have designated as *Ptilata serrata* based on collection of a voucher specimen (identified as *Asparagopsis hamifera* in the 1995 to 1999 surveys). Additionally, their Porifera sp. A was an orange encrusting sponge, which is probably the orange/tan sponge commonly seen during the present study.

Another video survey of the area west of the outfall identified 23 taxa (Etter *et al.*, 1987). The lower number of species seen in that survey was probably related to habitat differences between the areas surveyed. The 1987 survey mostly covered depositional sediment areas, whereas the present study concentrated on erosional hard substratum areas (drumlins). At any given depth, sediment generally supports fewer epifaunal species per unit area than does hard substrate (B. Hecker, personal observation). This may be related to the generally more limited availability of hard substrates in subtidal environments. Even in much deeper water, occasional hard surfaces *(i.e.* boulders, ship wrecks, airplane wrecks, and nuclear-waste drums) are almost always heavily colonized by a variety of attached taxa (B. Hecker, personal observation).

General faunal distribution patterns were similar among the 1994-2000 surveys. All surveys found algae to be most abundant on the tops of drumlins. Coats *et al.* reported that *Rhodymenia palmata*, *Rhodymenia* sp. A (a pinnate red alga), and *Agarum cribosum* were found together on hard substrata at shallower depths. In the later surveys (1995-2000), coralline algae were found to dominate on cobbles and smaller boulders, while *Ptilata serrata*, *R. palmata*, and *A. cribosum* were found to dominate on the tops of larger boulders. While Coats *et al.* estimated percent cover of *Lithothamnion*, they did not discuss its distribution. All three sets of surveys (1987, 1994, and 1995-2000) also found that the anemone *Metridium senile* and the cunner *Tautogolabrus adspersus* were most abundant near large boulders. Coats *et al.* reported that the distribution of the green sea urchin *Strongylocentrotus droebachiensis* was depth related, with the urchins being most abundant at shallower depths. A similar pattern was found in the 1995-2000 surveys, with the highest abundance of urchins being found on the top of drumlins, but the distribution of the urchin was attributed to availability of their primary food source, coralline algae (Sebens 1986). Because of the different overall focus of the Coats *et al.* (1995) report, more detailed comparisons of community structure and factors that control it cannot be made.

The baseline surveys show that the hardbottom benthic communities near the outfall were relatively stable over the 1995 to 2000 time period, and apparently back to 1994 as well. The remarkable similarities among the 1996 to 2000 surveys indicate that substantial departures from baseline conditions should be detectable. The expanded emphasis on 35-mm images has enabled better resolution of factors controlling the distribution of several of the dominant taxa. Larger boulders appeared to be the predominant substrate for upright algae and a number of attached invertebrate taxa. This is not surprising since larger rocks would be less susceptible to mechanical disturbance. Boulders were frequently the dominant size class observed on the top of drumlins. In contrast, the distribution of encrusting coralline algae appeared to be primarily related to degree of sediment drape. Not surprisingly, sediment loading also appeared to restrict many other encrusting and sessile taxa, which frequently were restricted to the sides and underhangs of boulders. Sediment drape was frequently heaviest on the flanks of drumlins.

The amount of sediment drape on rocks frequently varied widely within sites, with totally clean rocks adjacent to rocks heavily covered with sediment. This resulted in substantial small-scale within-site heterogeneity in the distribution of many of the taxa. The coralline algae taxon appears to hold the greatest promise as an indicator species for detecting habitat degradation as a result of the outfall coming on line. This species group was the most predictable taxon encountered in terms of abundance, distributional pattern, and habitat requirements. It was the least patchily distributed taxon, and appeared to dominate in all areas that were shallower than 33 m and had little sediment drape. Additionally, it was common in areas of high and low relief. By focusing on coralline algae as an indicator, it is likely that major changes in the benthic communities inhabiting the hardbottom areas near the outfall could be detected.

Potential outfall related impacts might include changes in the amount of particulate material reaching the sea floor. A marked decrease in the percent coverage of coralline algae likely would result if materials discharged from the outfall were to accumulate in the vicinity of the drumlins. Changes might be expected in the depth distribution of corallines if discharges from the outfall alter properties of the water column that affect light penetration. If water clarity were reduced it is expected that the lower depth limit of high coralline algal coverage would be reduced. Conversely, if water clarity were increased, then it is expected that high coralline algal coverage would extend into some of the deeper areas.

7. CONCLUSION

7.1 Sediment Profile Image (SPI) Analyses

- Quick Look analysis of sediment redox potential discontinuity (RPD) depth was highly comparable to that resulting from the detailed image analysis.
  - The difference between the two analyses averaged 0.4 cm; only one station (NF10) showed a difference of > 1 cm.
  - The Quick Look analysis has sufficient resolution to evaluate the MWRA RPD trigger.
- Detailed analyses showed that the grand average RPD value for 2000 (2.6 cm) was statistically the same as it was for 1999.
  - Overall, the average RPD layer depth in 1992 and 1995 was deeper, by about 1 cm, relative to 1997 and 1998 and that in 1999 and 2000 RPD layer depth had increased and was the same as 1992 and 1995.
  - The shallowing in RPD after 1995 and 1999 rebound was likely linked to the interaction of physical and biological process at work in structuring bottom communities.
- Stage II communities dominated in the nearfield in 1998, 1999, and 2000, whereas pioneering successional Stage I communities prevailed in 1992 to 1997.
- The overall 2000 nearfield average Organism-Sediment Index was statistically the same as those calculated in 1992, 1995, 1998, and 1999, but was higher than the 1997 value. The low 1997 values might have reflected a seasonal change stress as SPI sampling was done in October rather than August.
- The 2000 SPI data showed that biological processes continued to increase in importance as a structuring mechanism of the nearfield communities, a trend that likely began in 1995.

7.2 Sediment Geochemistry and Contaminants

- The principal component analysis (PCA), the *Clostridium perfringens* regional analysis, and the correlation analyses identify multiple regions in physical and chemical terms.
  - In the nearfield, with Massachusetts Bay, there is a series of stations with heterogeneous sediments in relatively close proximity to the historic leading source of contaminants (*i.e.*, Boston Harbor).
  - The farfield stations were generally less physically heterogeneous in terms of sediments but were substantially more spatially dispersed.
- Within each of these distinct regions, the spatial distribution of bulk sediment properties and contaminant parameters in 2000 was not substantially different from previous years (1992-1999).
- With the exception of *Clostridium perfringens* and total LAB, the temporal response of bulk sediment properties and contaminants was not substantially different over time.

- *Clostridium perfringens* abundances decreased in 1998–2000 (total LAB also decreased since 1994) for stations located closer to the Harbor (20-km of Deer Island Light), suggesting that the documented reductions in effluent solids loading during the 1990s (Werme and Hunt, 2001) also reflect a reduction in *Clostridium* spore loads that is being seen in nearby sediments.
- Baseline mean values for organic and metal contaminants in the nearfield were well below the MWRA thresholds

7.3 Infaunal Communities

- Values for infaunal abundance, species numbers, diversity, and evenness generally were similar to those estimated for the previous two years
- The most abundant species also were generally the same as found in 1997–1999. *Prionospio steenstrupi* continued to be the predominant infaunal organism in the Bay. The abundance and overall importance of crustaceans also appeared to be slightly less in 2000 than in 1999.
- Cluster analysis of the 2000 nearfield data indicated that station patterns for the infauna were very similar to previous years. Patterns among the 35 grabs, 17 stations with one replicate and six stations with three replicates, indicated that within station similarity was stronger than between stations. As in previous years the grouping of stations reflected the influence of sediment type and biogenic activity in structuring nearfield communities.
  - In the one-replicate analysis, the major break in the data was primarily related to sediment type and occurred between coarser sediment stations in groups I and II and the other four station groups with finer sediments.
- Station cluster analysis of the 2000 farfield data with 11 stations and three replicates per station indicated that similarity within a station was stronger than between stations.
- A set of diversity measures (numbers of species, Shannon diversity, Pielou's evenness, and log-series alpha) and the proportion of seven opportunistic taxa (*Ampelisca abdita*, *Ampelisca vadorum*, *Ampelisca macrocephela*, *Capitella capitata* complex, *Polydora cornuta*, *Mulinia lateralis*, and *Streblospio benedicti*) were evaluated as potential nearfield thresholds.
  - Analysis of nearfield data through 2000 showed that all yearly mean values were within the estimated threshold values (the 2.5^{th} and 97.5^{th} percentiles of a normal distribution fitted to the data).
  - The total percent composition of the selected opportunist taxa in the nearfield and farfield infaunal communities throughout the baseline period has been < 2 % and the year-to-year variability during the baseline period, as indicated by the range of yearly values, has been small.

7.4 Hardbottom Communities

- The hardbottom communities near the outfall have been studied consistently for the past six years. During this time, especially from 1996 to 2000, the communities, although spatially variable, have shown reasonable temporal stability.

- Classification analysis of the 2000 hardbottom data showed that the community could be separated into three clusters of stations and two outlier areas.
  - The first cluster consisted of mostly moderate to high-relief drumlin top areas that had relatively heavy sediment drape. These included the three northern reference sites (T7-1, T7-2, and T9), one site on the drumlin north of the outfall (T2-3), and a reference site southwest of the outfall (T10-1).
  - The second cluster consisted of drumlin top and flank areas that had variable relief and sediment drape. These included the two southernmost reference sites (T8-1 and T8-2), as well as sites on the drumlins north and south of the outfall.
  - The third cluster consisted of 2 drumlin flank areas that had moderately low relief and moderate to heavy sediment drape (T1-5 and T2-2).
  - The first outlier consisted of a drumlin flank site with moderate relief and heavy sediment drape (T2-4), while the second outlier consisted of a diffuser head and the area immediately surrounding it (Diffuser #44).
- The clustering structure appeared to be determined by a combination of drumlin topography, habitat relief, sediment drape, and geographic location. Neighboring waypoints with similar habitat characteristics tended to cluster together.
- The identification of several voucher specimens clarified some of the taxonomic difficulties typically associated with "remote" data collection. Significantly, the taxon previously called *Lithothamnion* spp. was found to consist of at least five coralline algal species, none of which can be identified solely by studying photographs or videotape. Therefore, this taxon has been renamed "coralline algae" and all pink encrusting coralline species treated as one. Also, a red filamentous alga that was previously known as *Asparagopsis hamifera* was reidentified as *Ptilota serrata*.

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APPENDICES

APPENDIX A

Sampling Coordinates, Grab Samples

BN001/BF001/BC002

Sample ID	Survey ID	Station ID	Longitude	Latitude	Sample Date and Time
BF001008	BF001	FF06	-70.4033	41.8983	8/22/00 9:18
BF00100C	BF001	FF06	-70.4033	41.8983	8/22/00 9:27
BF00100E	BF001	FF06	-70.4034	41.8983	8/22/00 9:36
BF001011	BF001	FF06	-70.4034	41.8983	8/22/00 9:56
BF001013	BF001	FF06	-70.4034	41.8983	8/22/00 10:11
BF001016	BF001	FF07	-70.2668	41.9582	8/22/00 11:10
BF001018	BF001	FF07	-70.2666	41.9583	8/22/00 11:16
BF001019	BF001	FF07	-70.2666	41.9584	8/22/00 11:24
BF00101D	BF001	FF07	-70.2666	41.9583	8/22/00 11:51
BF00101E	BF001	FF07	-70.2667	41.9583	8/22/00 11:59
BF001022	BF001	FF05	-70.4224	42.1333	8/22/00 13:20
BF001023	BF001	FF05	-70.4224	42.1333	8/22/00 13:29
BF001025	BF001	FF05	-70.4223	42.1332	8/22/00 13:45
BF001026	BF001	FF05	-70.4225	42.1334	8/22/00 13:55
BF001027	BF001	FF05	-70.4225	42.1333	8/22/00 14:06
BF00102A	BF001	FF04	-70.4250	42.2881	8/22/00 15:06
BF00102B	BF001	FF04	-70.4249	42.2882	8/22/00 15:17
BF00102F	BF001	FF04	-70.4249	42.2882	8/22/00 15:56
BF001030	BF001	FF04	-70.4252	42.2882	8/22/00 16:09
BF001031	BF001	FF04	-70.4247	42.2883	8/22/00 16:23
BF001039	BF001	FF09	-70.6567	42.3125	8/22/00 17:26
BF00103A	BF001	FF09	-70.6568	42.3125	8/22/00 17:35
BF00103B	BF001	FF09	-70.6567	42.3126	8/22/00 17:42
BF00103C	BF001	FF09	-70.6567	42.3126	8/22/00 17:52
BF00103E	BF001	FF09	-70.6567	42.3125	8/22/00 18:07
BF001043	BF001	FF13	-70.8228	42.3200	8/23/00 8:17
BF001045	BF001	FF13	-70.8229	42.3199	8/23/00 8:30
BF001046	BF001	FF13	-70.8231	42.3200	8/23/00 8:35
BF001049	BF001	FF13	-70.8228	42.3199	8/23/00 8:57
BF00104A	BF001	FF13	-70.8230	42.3199	8/23/00 9:07
BF00104F	BF001	NF22	-70.8149	42.3478	8/23/00 9:29
BF001050	BF001	NF22	-70.8150	42.3478	8/23/00 9:43
BF001051	BF001	NF22	-70.8150	42.3480	8/23/00 9:53
BF001052	BF001	NF22	-70.8150	42.3478	8/23/00 10:10
BF001055	BF001	NF02	-70.8282	42.3385	8/23/00 10:26
BF001057	BF001	NF02	-70.8283	42.3385	8/23/00 10:37
BF00105A	BF001	NF20	-70.8448	42.3780	8/23/00 10:59
BF00105B	BF001	NF20	-70.8448	42.3782	8/23/00 11:06
BF00105E	BF001	NF16	-70.8378	42.3783	8/23/00 11:19
BF001061	BF001	NF16	-70.8377	42.3783	8/23/00 11:35
BF001065	BF001	NF15	-70.8279	42.3822	8/23/00 11:53
BF001066	BF001	NF15	-70.8278	42.3822	8/23/00 12:02
BF001069	BF001	NF19	-70.8050	42.3718	8/23/00 12:38
BF00106C	BF001	NF19	-70.8050	42.3718	8/23/00 12:57
BF00107C	BF001	FF01A	-70.6759	42.5641	8/25/00 9:40

Sample ID	Survey ID	Station ID	Longitude	Latitude	Sample Date and Time
BF00107D	BF001	FF01A	-70.6759	42.5641	8/25/00 9:47
BF00107E	BF001	FF01A	-70.6759	42.5639	8/25/00 9:53
BF00107F	BF001	FF01A	-70.6758	42.5640	8/25/00 9:59
BF001080	BF001	FF01A	-70.6759	42.5640	8/25/00 10:09
BF001087	BF001	FF11	-70.4999	42.6584	8/25/00 11:14
BF00108A	BF001	FF11	-70.4999	42.6583	8/25/00 11:42
BF00108B	BF001	FF11	-70.5000	42.6583	8/25/00 11:52
BF00108C	BF001	FF11	-70.4999	42.6584	8/25/00 12:03
BF00108D	BF001	FF11	-70.4999	42.6583	8/25/00 12:13
BF001090	BF001	FF14	-70.6549	42.4168	8/25/00 13:44
BF001091	BF001	FF14	-70.6550	42.4166	8/25/00 13:57
BF001092	BF001	FF14	-70.6549	42.4169	8/25/00 14:07
BF001093	BF001	FF14	-70.6548	42.4169	8/25/00 14:16
BF001094	BF001	FF14	-70.6547	42.4168	8/25/00 14:26
BF001097	BF001	NF23	-70.8018	42.3978	8/25/00 15:07
BF001099	BF001	NF23	-70.8018	42.3977	8/25/00 15:18
BF00109C	BF001	NF24	-70.8018	42.3804	8/25/00 15:36
BF00109D	BF001	NF24	-70.8018	42.3805	8/25/00 15:45
BF00109F	BF001	NF24	-70.8017	42.3805	8/25/00 15:58
BF0010A0	BF001	NF24	-70.8017	42.3806	8/25/00 16:13
BF0010A3	BF001	NF24	-70.8017	42.3804	8/25/00 16:37
BF0010A5	BF001	NF24	-70.8022	42.3805	8/25/00 16:53
BF0010AA	BF001	NF17	-70.8149	42.3812	8/25/00 17:10
BF0010AB	BF001	NF17	-70.8152	42.3815	8/25/00 17:13
BF0010AC	BF001	NF17	-70.8148	42.3814	8/25/00 17:24
BF0010AD	BF001	NF17	-70.8151	42.3814	8/25/00 17:30
BF0010AE	BF001	NF17	-70.8149	42.3816	8/25/00 17:34
BF0010BB	BF001	NF20	-70.8448	42.3781	8/26/00 9:44
BF0010BE	BF001	NF16	-70.8377	42.3785	8/26/00 9:56
BF0010C4	BF001	NF15	-70.8278	42.3822	8/26/00 10:04
BF0010C8	BF001	NF19	-70.8050	42.3717	8/26/00 10:25
BF0010CB	BF001	NF22	-70.8150	42.3479	8/26/00 10:40
BF0010D4	BF001	NF02	-70.8285	42.3384	8/26/00 11:24
BF0010D8	BF001	FF13	-70.8226	42.3198	8/26/00 11:41
BF0010D9	BF001	FF13	-70.8230	42.3198	8/26/00 11:49
BF0010DA	BF001	FF13	-70.8229	42.3199	8/26/00 11:56
BF0010DF	BF001	FF09	-70.6568	42.3127	8/26/00 12:59
BF0010E0	BF001	FF09	-70.6569	42.3126	8/26/00 13:05
BF0010E1	BF001	FF09	-70.6567	42.3126	8/26/00 13:12
BF0010EC	BF001	FF04	-70.4251	42.2884	8/26/00 14:28
BF0010EF	BF001	FF04	-70.4251	42.2883	8/26/00 14:53
BF0010F0	BF001	FF04	-70.4251	42.2884	8/26/00 15:05
BF0010F7	BF001	FF05	-70.4224	42.1334	8/26/00 16:13
BF0010F8	BF001	FF05	-70.4224	42.1334	8/26/00 16:24
BF0010F9	BF001	FF05	-70.4223	42.1333	8/26/00 16:32
BF0010FC	BF001	FF07	-70.2668	41.9584	8/26/00 17:53

Sample ID	Survey ID	Station ID	Longitude	Latitude	Sample Date and Time
BF0010FE	BF001	FF07	-70.2667	41.9583	8/26/00 18:04
BF0010FF	BF001	FF07	-70.2668	41.9582	8/26/00 18:11
BF00110B	BF001	FF06	-70.4034	41.8985	8/27/00 13:27
BF00110C	BF001	FF06	-70.4032	41.8985	8/27/00 13:36
BF00110D	BF001	FF06	-70.4032	41.8984	8/27/00 13:47
BF001121	BF001	FF12	-70.8996	42.3900	8/28/00 12:00
BF001122	BF001	FF12	-70.8998	42.3899	8/28/00 12:10
BF001123	BF001	FF12	-70.8998	42.3901	8/28/00 12:16
BF001124	BF001	FF12	-70.9000	42.3899	8/28/00 12:32
BF001127	BF001	FF12	-70.8997	42.3899	8/28/00 12:59
BF001134	BF001	FF10	-70.8786	42.4141	8/31/00 8:37
BF001135	BF001	FF10	-70.8787	42.4140	8/31/00 8:42
BF001136	BF001	FF10	-70.8788	42.4140	8/31/00 8:47
BF001139	BF001	FF10	-70.8786	42.4140	8/31/00 9:10
BF00113B	BF001	FF10	-70.8789	42.4140	8/31/00 9:26
BF00113D	BF001	FF10	-70.8790	42.4138	8/31/00 9:38
BF00113F	BF001	NF08	-70.8635	42.4000	8/31/00 9:58
BF001141	BF001	NF08	-70.8640	42.4000	8/31/00 10:08
BF001142	BF001	NF08	-70.8638	42.3998	8/31/00 10:17
BF001144	BF001	NF08	-70.8635	42.4000	8/31/00 10:29
BF001147	BF001	NF09	-70.8448	42.3998	8/31/00 10:48
BF001148	BF001	NF09	-70.8448	42.3998	8/31/00 10:56
BF00114B	BF001	NF21	-70.8366	42.4027	8/31/00 11:08
BF00114C	BF001	NF21	-70.8364	42.4025	8/31/00 11:15
BF00114F	BF001	NF05	-70.8338	42.4271	8/31/00 11:29
BF001150	BF001	NF05	-70.8339	42.4269	8/31/00 11:37
BF001153	BF001	NF04	-70.8066	42.4155	8/31/00 11:55
BF001155	BF001	NF04	-70.8066	42.4156	8/31/00 12:07
BF001158	BF001	NF07	-70.8147	42.4100	8/31/00 12:16
BF001159	BF001	NF07	-70.8147	42.4101	8/31/00 12:25
BF00115D	BF001	NF18	-70.8219	42.3967	8/31/00 12:43
BF00115E	BF001	NF18	-70.8218	42.3966	8/31/00 12:49
BF001162	BF001	NF10	-70.8383	42.3928	8/31/00 13:04
BF001163	BF001	NF10	-70.8381	42.3929	8/31/00 13:12
BF001166	BF001	NF12	-70.8305	42.3900	8/31/00 13:23
BF001167	BF001	NF12	-70.8304	42.3902	8/31/00 13:30
BF001168	BF001	NF12	-70.8306	42.3900	8/31/00 13:36
BF001169	BF001	NF12	-70.8305	42.3900	8/31/00 13:44
BF00116A	BF001	NF12	-70.8306	42.3901	8/31/00 13:54
BF00116D	BF001	NF14	-70.8225	42.3866	8/31/00 14:03
BF00116E	BF001	NF14	-70.8228	42.3867	8/31/00 14:12
BF001172	BF001	NF13	-70.8224	42.3900	8/31/00 14:28
BF001177	BF001	NF13	-70.8225	42.3900	8/31/00 14:49

BC003

SampleID	Survey ID	Station ID	Longitude	Latitude	SampleDateTime
BC003031	BC003	NF22	-70.8151	42.3478	11/28/00 9:43
BC003033	BC003	NF22	-70.8151	42.3478	11/28/00 10:05
BC003034	BC003	NF22	-70.8150	42.3478	11/28/00 10:14
BC003038	BC003	NF24	-70.8017	42.3805	11/28/00 10:47
BC003039	BC003	NF24	-70.8017	42.3805	11/28/00 11:00
BC00303A	BC003	NF24	-70.8017	42.3804	11/28/00 11:13
BC00303F	BC003	NF08	-70.8635	42.4000	11/28/00 11:45
BC003040	BC003	NF08	-70.8635	42.4000	11/28/00 11:55
BC003043	BC003	NF08	-70.8635	42.4000	11/28/00 12:09
BC003049	BC003	FF10	-70.8788	42.4142	11/28/00 12:39
BC00304B	BC003	FF10	-70.8788	42.4142	11/28/00 12:54
BC00304D	BC003	FF10	-70.8786	42.4142	11/28/00 13:08

APPENDIX B

Sampling Coordinates, SPI Images

HR001 Nearfield SPI

Station ID	Date	Time	Latitude	Longitude
FF13	8/22/00	8:36	042°19.183'N	070°49.423'W
FF13	8/22/00	8:38	042°19.180'N	070°49.412'W
FF13	8/22/00	8:38	042°19.178'N	070°49.404'W
FF13	8/22/00	8:39	042°19.176'N	070°49.397'W
NF02	8/22/00	8:55	042°20.319'N	070°49.669'W
NF02	8/22/00	9:00	042°20.319'N	070°49.681'W
NF02	8/22/00	9:01	042°20.323'N	070°49.668'W
NF02	8/22/00	9:05	042°20.317'N	070°49.693'W
NF22	8/22/00	9:20	042°20.872'N	070°48.887'W
NF22	8/22/00	9:25	042°20.883'N	070°48.897'W
NF22	8/22/00	9:30	042°20.872'N	070°48.906'W
NF19	8/22/00	9:46	042°22.234'N	070°48.364'W
NF19	8/22/00	9:47	042°22.240'N	070°48.362'W
NF19	8/22/00	9:48	042°22.245'N	070°48.361'W
NF19	8/22/00	9:49	042°22.248'N	070°48.360'W
NF24	8/22/00	9:57	042°22.813'N	070°48.133'W
NF24	8/22/00	9:58	042°22.819'N	070°48.132'W
NF24	8/22/00	9:59	042°22.822'N	070°48.131'W
NF24	8/22/00	9:59	042°22.826'N	070°48.132'W
NF23	8/22/00	10:12	042°23.875'N	070°48.094'W
NF23	8/22/00	10:18	042°23.856'N	070°48.096'W
NF23	8/22/00	10:19	042°23.862'N	070°48.095'W
NF23	8/22/00	10:19	042°23.865'N	070°48.094'W
NF07	8/22/00	10:30	042°24.611'N	070°48.890'W
NF07	8/22/00	10:34	042°24.595'N	070°48.891'W
NF07	8/22/00	10:35	042°24.600'N	070°48.885'W
NF04	8/22/00	10:48	042°24.931'N	070°48.383'W
NF04	8/22/00	10:48	042°24.937'N	070°48.379'W
NF04	8/22/00	10:52	042°24.933'N	070°48.396'W
NF04	8/22/00	10:53	042°24.939'N	070°48.391'W
NF05	8/22/00	11:08	042°25.618'N	070°50.034'W
NF05	8/22/00	11:09	042°25.620'N	070°50.034'W
NF05	8/22/00	11:10	042°25.621'N	070°50.033'W
NF05	8/22/00	11:11	042°25.622'N	070°50.033'W
FF10	8/22/00	11:31	042°24.836'N	070°52.721'W
FF10	8/22/00	11:33	042°24.838'N	070°52.723'W
FF10	8/22/00	11:34	042°24.839'N	070°52.724'W
FF10	8/22/00	11:34	042°24.841'N	070°52.725'W
FF12	8/22/00	11:51	042°23.397'N	070°53.983'W
FF12	8/22/00	11:52	042°23.399'N	070°53.986'W
FF12	8/22/00	11:53	042°23.401'N	070°53.988'W
FF12	8/22/00	11:54	042°23.403'N	070°53.990'W
NF08	8/22/00	12:11	042°23.998'N	070°51.807'W
NF08	8/22/00	12:13	042°23.999'N	070°51.812'W
NF08	8/22/00	12:15	042°23.999'N	070°51.821'W

Station ID	Date	Time	Latitude	Longitude
NF09	8/22/00	12:26	042°23.994'N	070°50.700'W
NF09	8/22/00	12:31	042°23.987'N	070°50.681'W
NF09	8/22/00	12:31	042°23.988'N	070°50.687'W
NF09	8/22/00	12:32	042°23.989'N	070°50.692'W
NF13	8/22/00	15:49	042°23.400'N	070°49.361'W
NF13	8/22/00	15:50	042°23.409'N	070°49.365'W
NF13	8/22/00	15:53	042°23.400'N	070°49.352'W
NF13	8/22/00	15:54	042°23.410'N	070°49.359'W
NF14	8/22/00	16:01	042°23.204'N	070°49.365'W
NF14	8/22/00	16:06	042°23.204'N	070°49.361'W
NF14	8/22/00	16:07	042°23.212'N	070°49.368'W
NF14	8/22/00	16:11	042°23.199'N	070°49.362'W
NF17	8/22/00	16:19	042°22.879'N	070°48.896'W
NF17	8/22/00	16:20	042°22.885'N	070°48.901'W
NF17	8/22/00	16:24	042°22.876'N	070°48.883'W
NF17	8/22/00	16:25	042°22.887'N	070°48.891'W
NF15	8/22/00	16:32	042°22.933'N	070°49.666'W
NF15	8/22/00	16:33	042°22.943'N	070°49.670'W
NF15	8/22/00	16:37	042°22.924'N	070°49.671'W
NF15	8/22/00	16:38	042°22.934'N	070°49.683'W
NF16	8/22/00	16:45	042°22.697'N	070°50.256'W
NF16	8/22/00	16:46	042°22.708'N	070°50.262'W
NF16	8/22/00	16:49	042°22.686'N	070°50.251'W
NF16	8/22/00	16:51	042°22.695'N	070°50.268'W
NF16	8/22/00	16:51	042°22.706'N	070°50.273'W
NF20	8/22/00	16:58	042°22.686'N	070°50.690'W
NF20	8/22/00	16:59	042°22.695'N	070°50.697'W
NF20	8/22/00	17:03	042°22.682'N	070°50.684'W
NF20	8/22/00	17:04	042°22.696'N	070°50.694'W
*NF21	8/22/00	12:39	not available	not available
*NF18	8/22/00	13:41	not available	not available
*NF10	8/22/00	13:57	not available	not available
NF12	8/22/00	15:39	040°23.431'N	070°49.846'W
NF12	8/22/00	15:41	042°23.435'N	070°49.848'W
NF12	8/22/00	15:41	042°023.437'N	070°49.848'W

*Due to file corruption, positional data for stations NF21, NF18 and NF10 on 8/22/01 were lost. Target locations were reported in the database.

APPENDIX C-1

Station Mean Values (dry weight basis) for Bulk Sediment Properties and *Clostridium perfringens* Determined in August 2000.

Station	Gravel PCT	Sand PCT	Gravel + Sand PCT	Silt PCT	Clay PCT	Fines PCT	Mean Phi PCT	TOC PCT	*Clostridium Perfringens* #/GDW
Farfield									
FF01A	0.65	79.80	80.45	12.95	6.60	19.55	3.48	0.45	602.50
FF04	0.00	9.80	9.80	56.85	33.35	90.20	6.65	2.38	1335.00
FF05	0.15	45.00	45.15	39.90	14.95	54.85	5.04	1.25	665.00
FF06	0.00	45.30	45.30	38.70	16.05	54.75	5.23	0.97	700.00
FF07	0.00	15.25	15.25	58.05	26.65	84.70	6.24	2.31	1040.00
FF09	0.20	80.30	80.50	10.90	8.60	19.50	3.70	0.70	570.00
FF11	0.00	20.00	20.00	53.10	26.85	79.95	6.21	2.11	1185.00
FF14	1.30	26.35	27.65	52.30	20.05	72.35	5.66	1.45	1045.00
NF12	0.00	34.90	34.90	47.80	17.25	65.05	5.38	1.55	1820.00
NF17	0.00	98.05	98.05	0.75	1.25	2.00	1.98	0.10	63.00
NF24	0.20	45.90	46.10	39.57	14.30	53.87	4.85	1.27	1373.33
Nearfield									
NF02	3.10	88.30	91.40	5.10	3.40	8.50	2.38	0.33	440.00
NF04	0.20	94.00	94.20	2.80	3.00	5.80	2.61	0.15	120.00
NF05	1.10	59.50	60.60	24.20	15.30	39.50	4.31	1.24	355.00
NF07	0.30	56.80	57.10	28.10	14.80	42.90	4.40	0.89	1680.00
NF08	0.08	33.40	33.48	53.30	13.23	66.53	5.35	1.37	2460.00
NF09	0.10	61.40	61.50	26.20	12.30	38.50	4.60	0.97	1000.00
NF10	0.30	52.40	52.70	34.10	13.20	47.30	4.86	1.23	1570.00
NF12	0.00	34.90	34.90	47.80	17.25	65.05	5.38	1.55	1820.00
NF13	1.87	93.50	95.37	1.90	2.73	4.63	2.22	0.08	90.00
NF14	35.70	53.10	88.80	7.20	4.00	11.20	1.15	2.35	565.00
NF15	3.90	81.00	84.90	9.70	5.40	15.10	2.79	0.70	350.00
NF16	10.20	64.10	74.30	16.20	9.50	25.70	2.99	0.91	1380.00
NF17	0.00	98.05	98.05	0.75	1.25	2.00	1.98	0.10	63.00
NF18	47.50	41.30	88.80	7.30	3.90	11.20	0.83	0.98	400.00
NF19	38.30	47.83	86.13	7.27	6.60	13.87	1.49	0.59	345.00
NF20	38.60	51.10	89.70	5.70	4.70	10.40	0.86	3.32	670.00
NF21	0.40	40.70	41.10	44.20	14.70	58.90	5.17	1.83	2310.00
NF22	2.63	54.50	57.13	30.10	12.77	42.87	4.28	0.96	1620.00
NF23	12.40	82.70	95.10	2.70	2.10	4.80	1.64	0.14	140.00
NF24	0.20	45.90	46.10	39.57	14.30	53.87	4.85	1.27	1373.33
FF10	22.47	58.67	81.13	13.17	5.70	18.87	2.06	2.17	1166.67
FF12	2.95	68.35	71.30	22.30	6.40	28.70	3.98	0.54	2120.00
FF13	0.00	29.25	29.25	48.45	22.30	70.75	5.73	1.76	5960.00

APPENDIX C-2

Station Mean Values (dry weight basis) for Organic Contaminant Parameters Determined in August 2000. Note that 2000 Represents a Reduced Sampling Year for Contaminant Analyses.

Station	Total PAH ng/g	Total PCB ng/g	Total Pesticide ng/g	Total DDT ng/g	Total Chlordane ng/g	Total LAB ng/g
Farfield						
NF12	10868.36	21.87	0.73	3.42	0.36	157.76
NF17	86.42	0.32	0.07	0.01	ND	ND
NF24	6583.43	15.18	0.32	2.67	0.27	131.33
Nearfield						
FF10	5439.80	5.43	0.31	1.20	0.18	54.11
FF12	3076.73	11.26	0.23	1.60	0.19	115.10
FF13	4094.10	31.04	0.81	4.10	0.76	288.37
NF08	7847.56	25.47	0.66	3.89	0.50	167.76
NF12	10868.36	21.87	0.73	3.42	0.36	157.76
NF17	86.42	0.32	0.07	0.01	ND	ND
NF22	3564.74	12.82	0.43	1.88	0.25	142.27
NF24	6583.43	15.18	0.32	2.67	0.27	131.33

ND, Not detected.

APPENDIX C-3

Station Mean Values (dry weight basis) for Metal Contaminant Parameters Determined in August 2000. Note that 2000 Represents a Reduced Sampling Year for Contaminant Analyses.

Station	Al %	Cd µg/g	Cr µg/g	Cu µg/g	Fe %	Pb µg/g	Hg µg/g	Ni µg/g	Ag µg/g	Zn µg/g
Farfield										
NF12	5.98	0.10	97.38	33.00	2.79	58.95	0.34	27.13	0.46	77.33
NF17	3.37	0.00	20.30	6.63	1.23	27.28	0.02	7.30	0.03	24.20
NF24	5.72	0.10	80.40	28.57	2.48	53.07	0.51	23.10	0.37	135.57
Nearfield										
FF10	5.26	0.08	62.90	13.90	2.53	29.50	0.14	22.73	0.16	57.20
FF12	5.13	0.11	64.73	15.45	1.86	33.90	0.12	12.13	0.39	43.85
FF13	5.56	0.30	103.28	47.18	3.22	57.48	0.41	30.33	1.80	97.68
NF08	5.47	0.22	107.97	35.03	2.64	52.03	0.35	24.20	0.92	78.40
NF12	5.98	0.10	97.38	33.00	2.79	58.95	0.34	27.13	0.46	77.33
NF17	3.37	0.00	20.30	6.63	1.23	27.28	0.02	7.30	0.03	24.20
NF22	5.25	0.12	73.10	24.70	2.63	44.73	0.24	25.50	0.50	64.80
NF24	5.72	0.10	80.40	28.57	2.48	53.07	0.51	23.10	0.37	135.57

APPENDIX D-1

Taxonomic Responsibilities for the 2000 Outfall Benthic Analyses

List of Taxa Identified by Each Taxonomist
August 2000 Nearfield Macrobenthic Samples

Taxonomist	Groups Identified
Suzanne L. Arcuri (Cove Corporation)	• Polychaeta: Capitellidae, Cossuridae, Goniadidae, Lumbrineridae, Nephtyidae, Opheliidae, Pectinariidae, Pholoidae, Polygordiidae, Scalibregmatidae, Sphaerodoridae, Sternaspidae, and Trochochaetidae
C. Timothy Morris (Cove Corporation)	• Anthozoa • Arthropoda • Ascidiacea • Echinodermata • Echiura • Enteropneusta • Nemertinea • Phoronida • Polychaeta: Amphinomidae, Aphroditidae, Chrysopetalidae, Dorvilleidae, Glyceridae, Hesionidae, Nereididae, Oenonidae, Orbiniidae, Paraonidae, Pilargidae, and Spionidae • Sipuncula • Turbellaria
Nancy K. Mountford (Cove Corporation)	• Mollusca • Polychaeta: Ampharetidae, Apistobranchidae, Capitellidae, Cossuridae, Flabelligeridae, Goniadidae, Opheliidae, Oweniidae, Pectinariidae, Pholoidae, Phyllodocidae, Polygordiidae, Scalibregmatidae, Sphaerodoridae, Sternaspidae, and Syllidae
C. Anthony Phillips (Environmental Monitoring Division)	• Polychaeta: Cirratulidae
R. Eugene Ruff (Ruff Systematics)	• Polychaeta: Maldanidae, Polynoidae, Sabellidae, Sigalionidae, Terebellidae, and Trichobranchidae
Russell D. Winchell (Ocean's Taxonomic Services)	• Oligochaeta

List of Taxa Identified by Each Taxonomist
August 2000 Farfield Macrobenthic Samples

Taxonomist	Groups Identified
Suzanne L. Arcuri (Cove Corporation)	• Polychaeta: Capitellidae, Cossuridae, Goniadidae, Lumbrineridae, Nephtyidae, Opheliidae, Pectinariidae, Pholoidae, Polygordiidae, Scalibregmatidae, Sphaerodoridae, Sternaspidae, and Trochochaetidae
C. Timothy Morris (Cove Corporation)	• Anthozoa • Arthropoda • Ascidiacea • Echiura • Enteropneusta • Nemertinea • Phoronida • Polychaeta: Amphinomidae, Aphroditidae, Chrysopetalidae, Dorvilleidae, Glyceridae, Hesionidae, Nereididae, Oenonidae, Orbiniidae, Paraonidae, Pilargidae, and Spionidae • Sipuncula • Turbellaria
Nancy K. Mountford (Cove Corporation)	• Mollusca • Echinodermata • Polychaeta: Ampharetidae, Apistobranchidae, Capitellidae, Cossuridae, Flabelligeridae, Goniadidae, Opheliidae, Oweniidae, Pectinariidae, Pholoidae, Phyllodocidae, Polygordiidae, Scalibregmatidae, Sphaerodoridae, Sternaspidae, and Syllidae
C. Anthony Phillips (Environmental Monitoring Division)	• Polychaeta: Cirratulidae
R. Eugene Ruff (Ruff Systematics)	• Polychaeta: Maldanidae, Polynoidae, Sabellidae, Sigalionidae, Terebellidae, and Trichobranchidae
Russell D. Winchell (Ocean's Taxonomic Services)	• Oligochaeta

APPENDIX D-2

Preliminary Data Treatments

Changes to BMBSOFT Database

1. Several provisional taxa were "described" early in the program based on few numbers of individuals, but are not supported by voucher specimens. It is unlikely that we will never know the true identity of these taxa. Also, Turbellaria are no longer identified to species level. Therefore, the following changes to the BMBSOFT database were made.

FROM_CODE	(FROM_DESCR)	N	TO_CODE	(TO_DESCR)	Comment
3758SP01	Actiniaria sp. 1	1	3758SPP	Actiniaria spp.	1992
3758SP03	Actiniaria sp. 3	1	3758SPP	Actiniaria spp.	1992
3901SP01	Turbellaria sp. 1	2	3901SPP	Turbellaria spp.	1993, 1994
3901SP02	Turbellaria sp. 2	1	3901SPP	Turbellaria spp.	1994
43SP04	Nemertea sp. D	1	43SPP	Nemertea spp.	1993
500143SP01	Spionidae sp. A	1	500143SPP	Spionidae spp.	1993
50015003SP02	Tharyx sp. A	9	50015003SPP	Tharyx spp.	1992
50090103PAST	Grania postclitello longiducta	All	5009010301LONG	Grania postclitellochaeta longiducta	name correction
500901SP01	Enchytraeidae sp. 1	761	5009010301LONG	Grania postclitellochaeta longiducta	2000; code error?
51032001SP02	Alvania sp. 2	6	??	Alvania spp.	1995
51SP02	Gastropoda sp. 2	1	51SPP	Gastropoda spp.	1993
61631201SP02	Munna sp. 2	11	61631201SPP	Munna spp.	1992
616937SP03	Oedicerotidae sp. A	1	616937SPP	Oedicerotidae spp.	1993

2. The following corrections to the BMBSOFT database for BF001 only was made:

FROM_CODE	(FROM_DESCR)	COUNT	TO_CODE	(TO_DESCR)	Data sets affected	Comment
5106020601	Propebela turricula	1	5106020426	Oenopota incisula	**BF001 only**	Reidentification, NKM

1. The May 1992 (S9202) data were excluded from the analyses.
2. Station FF08 data were excluded from the analyses.
3. Stations FF10, FF12, and FF13 were included in the Nearfield analyses, but were not included in the Farfield analyses.
4. The following taxa were excluded from the analyses:

36SPP	Porifera spp.
3701SPP	Hydrozoa spp.
3703250104	Corymorpha pendula
5103640204	Crepidula fornicata
51036402SPP	Crepidula spp.
53SPP	Polyplacophora spp.
5507010101	Mytilus edulis
55070101SPP	Mytilus spp.
5507010601	Modiolus modiolus
6134020104	Balanus crenatus
61340201SPP	Balanus spp.
6151SPP	Mysidacea spp.
6153011401	Mysis mixta
6153011508	Neomysis americana
6153012301	Erythrops erythrophthalma
6161050101	Limnoria lignorum
6179160408	Eualus pusiolus
6179180301	Dichelopandalus leptocerus
6179220103	Crangon septemspinosa
6179SPP	Caridea spp.
6183060226	Pagurus acadianus
61830602SPP	Pagurus spp.

5. The following taxa were merged for these analyses only

Merge This		With This	
CODE	DESCR	CODE	DESCR
50010601SPP	Pholoe spp.	5001060101	Pholoe minuta
50010601TECT	Pholoe tecta	5001060101	Pholoe minuta
50013614SP01	Parougia sp. 1	50013614CAEC	Parougia caeca
50013614SP02	Parougia sp. 2	50013614CAEC	Parougia caeca
5001420101	Apistobranchus tullbergi	5001420103	Apistobranchus typicus
5001540202	Flabelligera affinis	50015402 SPP	Flabelligera spp.
5001630302	Maldane glebifex	5001630301	Maldane sarsi
5001631102CF	Euclymene cf. collaris	5001631102	Euclymene collaris
5001631202	Clymenura polaris	50016312SP01	Clymenura sp. A
50016817SP01	Proclea sp. 1	5001681702	Proclea graffii
5103760402CF	Polinices cf. pallidus	5103760402	Polinices pallidus
54SPP	Aplacophora spp.	5402010102	Chaetoderma nitidulum canadense
5502040220CF	Nuculana nr. messanensis	5502040220	Nuculana messanensis
56SPP	Scaphopoda spp.	5601010201	Dentalium entale
6175SP01	Decapoda sp. 1	6175SPP	Decapoda spp.

6. The following taxa were treated as species-level taxa for these analyses:

CODE	DESCR
3901SPP	Turbellaria spp.
43030205SPP	Micrura spp.
50015402 SPP	Flabelligera spp.
51050103SPP	Urosalpinx spp.
51050508SPP	Neptunea spp.

7. Total abundance for each 2000 and 1992–2000 sample, was calculated including all infaunal taxa identified
8. Dominance per station was calculated for 2000 data only and included only taxa identified to or treated as species-level taxa. For replicated stations, the mean and standard deviation abundance per sample were calculated.
9. The abundance (all taxa) and number of species (good species) of major taxa for 2000 data only were calculated according to the following categories—Annelida (MWRA codes 50*), Arthropoda (MWRA codes 60* and 61*), Mollusca (MWRA codes 51*, 54*, 55*, and 56*), Other (MWRA codes 37*, 39*, 43*, 72*, 73*, 74*, 77*, 81*, 82*, and 84*)
10. A list of all taxa included in the analyses, including the MWRA code, Taxon Name, Higher Taxon, Family, and Species? [whether the taxon was included in (Yes) or excluded from (No) species-level calculations] was prepared.

Appendix D-3

Massachusetts Bay Outfall Monitoring Program Species List
1992 – 2000

MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
6168SPP	AMPHIPODA SPP.	AMP		No
6169020101	AMPELISCA MACROCEPHALA	AMP	Ampeliscidae	Yes
6169020108	AMPELISCA ABDITA	AMP	Ampeliscidae	Yes
6169020109	AMPELISCA VADORUM	AMP	Ampeliscidae	Yes
61690201SPP	AMPELISCA SPP.	AMP	Ampeliscidae	No
6169020202	BYBLIS GAIMARDI	AMP	Ampeliscidae	Yes
6169020202CF	BYBLIS CF. GAIMARDI	AMP	Ampeliscidae	Yes
61690202SPP	BYBLIS SPP.	AMP	Ampeliscidae	No
6169020306	HAPLOOPS FUNDIENSIS	AMP	Ampeliscidae	Yes
616902SPP	AMPELISCIDAE SPP.	AMP	Ampeliscidae	No
6169030403	GITANOPSIS ARCTICA	AMP	Amphilocidae	Yes
6169040101	AMPITHOE RUBRICATA	AMP	Amphilochidae	Yes
6169060402	MICRODEUTOPUS ANOMALUS	AMP	Aoridae	Yes
6169060702	LEPTOCHEIRUS PINGUIS	AMP	Aoridae	Yes
6169070101	ARGISSA HAMATIPES	AMP	Argissidae	Yes
6169150201	MONOCOROPHIUM ACHERUSICUM	AMP	Corophiidae	Yes
6169150203	CRASSICOROPHIUM CRASSICORNE	AMP	Corophiidae	Yes
6169150207	MONOCOROPHIUM TUBERCULATUM	AMP	Corophiidae	Yes
6169150211	MONOCOROPHIUM INSIDIOSUM	AMP	Corophiidae	Yes
6169150308	ERICTHONIUS FASCIATUS	AMP	Corophiidae	Yes
6169150702	UNCIOLA INERMIS	AMP	Corophiidae	Yes
6169150703	UNCIOLA IRRORATA	AMP	Corophiidae	Yes
61691507SPP	UNCIOLA SPP.	AMP	Corophiidae	No
6169150801	PSEUDUNCIOLA OBLIQUUA	AMP	Corophiidae	Yes
616915SPP	COROPHIIDAE SPP.	AMP	Corophiidae	No
6169201203	PONTOGENEIA INERMIS	AMP	Eusiridae	Yes
6169210602	GAMMARELLUS ANGULOSUS	AMP	Gammaridae	Yes
61692107SPP	GAMMARUS SPP.	AMP	Gammaridae	No
6169210802	MAERA LOVENI	AMP	Melitidae	Yes
6169211003	MELITA DENTATA	AMP	Melitidae	Yes
61692110SP01	MELITA SP. 1	AMP	Melitidae	Yes
6169211601	CASCO BIGELOWI	AMP	Melitidae	Yes
616921MESP01	MELITIDAE SP. 1	AMP	Melitidae	Yes
616921MESPP	MELITIDAE SPP.	AMP	Melitidae	No
6169220602	ACANTHOHAUSTORIUS MILLSI	AMP	Haustoriidae	Yes
6169221301	PSEUDOHAUSTORIUS BOREALIS	AMP	Haustoriidae	Yes
6169260202	PHOTIS REINHARDI	AMP	Isaeidae	Yes
6169260217	PHOTIS POLLEX	AMP	Isaeidae	Yes
6169260301	PROTOMEDEIA FASCIATA	AMP	Isaeidae	Yes
6169270202	ISCHYROCERUS ANGUIPES	AMP	Ischyroceridae	Yes
6169270303	JASSA MARMORATA	AMP	Ischyroceridae	Yes
6169340303	ANONYX LILJEBORGI	AMP	Lysianassidae	Yes
6169341405	HIPPOMEDON PROPINQUUS	AMP	Lysianassidae	Yes
6169341408	HIPPOMEDON SERRATUS	AMP	Lysianassidae	Yes

MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
61693414SPP	HIPPOMEDON SPP.	AMP	Lysianassidae	No
6169345201	ORCHOMENELLA MINUTA	AMP	Lysianassidae	Yes
61693452SPP	ORCHOMENELLA SPP.	AMP	Lysianassidae	No
616934SPP	LYSIANASSIDAE SPP.	AMP	Lysianassidae	No
61693501SPP	MELPHIDIPPA SPP.	AMP	Melphidippidae	No
6169370505	BATHYMEDON OBTUSIFRONS	AMP	Oedicerotidae	Yes
6169370810	MONOCULODES PACKARDI	AMP	Oedicerotidae	Yes
6169370815	DEFLEXILODES TUBERCULATUS	AMP	Oedicerotidae	Yes
6169370817	DEFLEXILODES INTERMEDIUS	AMP	Oedicerotidae	Yes
6169370821	DEFLEXILODES TESSELATUS	AMP	Oedicerotidae	Yes
61693708DESPP	DEFLEXILODES SPP.	AMP	Oedicerotidae	No
61693708SPP	MONOCULODES SPP.	AMP	Oedicerotidae	No
6169371505	WESTWOODILLA BREVICALCAR	AMP	Oedicerotidae	Yes
616937AMSP01	AMEROCULODES SP. 1	AMP	Oedicerotidae	Yes
616937SPP	OEDICEROTIDAE SPP.	AMP	Oedicerotidae	No
6169420116	HARPINIA PROPINQUA	AMP	Phoxocephalidae	Yes
61694202SP01	HARPINIOPSIS SP. 1	AMP	Phoxocephalidae	Yes
6169420702	PHOXOCEPHALUS HOLBOLLI	AMP	Phoxocephalidae	Yes
6169421502	RHEPOXYNIUS HUDSONI	AMP	Phoxocephalidae	Yes
6169421901	EOBROLGUS SPINOSUS	AMP	Phoxocephalidae	Yes
616942SPP	PHOXOCEPHALIDAE SPP.	AMP	Phoxocephalidae	No
6169430305	PARAPLEUSTES GRACILIS	AMP	Pleustidae	Yes
6169430405	PLEUSTES PANOPLUS	AMP	Pleustidae	Yes
6169430503	PLEUSYMTES GLABER	AMP	Pleustidae	Yes
6169430610	STENOPLEUSTES INERMIS	AMP	Pleustidae	Yes
616943SPP	PLEUSTIDAE SPP.	AMP	Pleustidae	No
6169440104	DYOPEDOS MONACANTHUS	AMP	Podoceridae	Yes
6169440110	DULICHIA TUBERCULATA	AMP	Podoceridae	Yes
6169440302	PARADULICHIA TYPICA	AMP	Podoceridae	Yes
616944SPP	PODOCERIDAE SPP.	AMP	Podoceridae	No
6169480306	METOPELLA ANGUSTA	AMP	Stenothoidae	Yes
6169480801	PROBOLOIDES HOLMESI	AMP	Stenothoidae	Yes
616948SPP	STENOTHOIDAE SPP.	AMP	Stenothoidae	No
61695003SP01	SYRRHOE SP. 1	AMP	Synopiidae	Yes
6171010302	MAYERELLA LIMICOLA	AMP	Caprellidae	Yes
6171010703	CAPRELLA LINEARIS	AMP	Caprellidae	Yes
61710107SPP	CAPRELLA SPP.	AMP	Caprellidae	No
6171010801	AEGININA LONGICORNIS	AMP	Caprellidae	Yes
6171010901	PARACAPRELLA TENUIS	AMP	Caprellidae	Yes
617101SPP	CAPRELLIDAE SPP.	AMP	Caprellidae	No
5402010102	CHAETODERMA NITIDULUM CANADENSE	APL	Chaetodermatidae	Yes
5502020201	NUCULOMA TENUIS	BIV	Nuculidae	Yes
5502020205	NUCULA ANNULATA	BIV	Nuculidae	Yes
5502020206	NUCULA DELPHINODONTA	BIV	Nuculidae	Yes
5502020216	NUCULOMA GRANULOSA	BIV	Nuculidae	Yes

MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
55020202SPP	NUCULA SPP.	BIV	Nuculidae	No
550202SPP	NUCULIDAE SPP.	BIV	Nuculidae	No
5502040201	NUCULANA PERNULA	BIV	Nuculanidae	Yes
5502040220	NUCULANA MESSANENSIS	BIV	Nuculanidae	Yes
55020402SP01	NUCULANA SP. 1	BIV	Nuculanidae	Yes
55020402SPP	NUCULANA SPP.	BIV	Nuculanidae	No
5502040507	MEGAYOLDIA THRACIAEFORMIS	BIV	Nuculanidae	Yes
5502040513	YOLDIA SAPOTILLA	BIV	Nuculanidae	Yes
55020405SPP	YOLDIA SPP.	BIV	Nuculanidae	No
5502040611	YOLDIELLA LUCIDA	BIV	Nuculanidae	Yes
550204SPP	NUCULANIDAE SPP.	BIV	Nuculanidae	No
550601SPP	ARCIDAE SPP.	BIV	Arcidae	No
5507010201	CRENELLA DECUSSATA	BIV	Mytilidae	Yes
5507010203	CRENELLA GLANDULA	BIV	Mytilidae	Yes
55070102SPP	CRENELLA SPP.	BIV	Mytilidae	No
5507010401	MUSCULUS NIGER	BIV	Mytilidae	Yes
5507010402	MUSCULUS DISCORS	BIV	Mytilidae	Yes
55070104SPP	MUSCULUS SPP.	BIV	Mytilidae	No
550701SPP	MYTILIDAE SPP.	BIV	Mytilidae	No
5509050901	PLACOPECTEN MAGELLANICUS	BIV	Pectinidae	Yes
550905SPP	PECTINIDAE SPP.	BIV	Pectinidae	No
5509090202	ANOMIA SIMPLEX	BIV	Anomiidae	Yes
5509090203	ANOMIA SQUAMULA	BIV	Anomiidae	Yes
55090902SPP	ANOMIA SPP.	BIV	Anomiidae	No
5515020301	THYASIRA FLEXUOSA	BIV	Thyasiridae	Yes
5515020325	THYASIRA GOULDI	BIV	Thyasiridae	Yes
55150203MICF	THYASIRA NR. MINUTUS	BIV	Thyasiridae	Yes
55150203SPP	THYASIRA SPP.	BIV	Thyasiridae	No
551502SPP	THYASIRIDAE SPP.	BIV	Thyasiridae	No
5515090301	PYTHINELLA CUNEATA	BIV	Montacutidae	Yes
5515170106	CYCLOCARDIA BOREALIS	BIV	Carditidae	Yes
5515190101	ASTARTE BOREALIS	BIV	Astartidae	Yes
5515190113	ASTARTE UNDATA	BIV	Astartidae	Yes
55151901SPP	ASTARTE SPP.	BIV	Astartidae	No
5515220601	CERASTODERMA PINNULATUM	BIV	Cardiidae	Yes
5515250102	SPISULA SOLIDISSIMA	BIV	Mactridae	Yes
5515250301	MULINIA LATERALIS	BIV	Mactridae	Yes
5515290105	SILIQUA COSTATA	BIV	Solenidae	Yes
5515290301	ENSIS DIRECTUS	BIV	Solenidae	Yes
55152903SPP	ENSIS SPP.	BIV	Solenidae	No
5515310116	MACOMA BALTHICA	BIV	Tellinidae	Yes
5515310205	TELLINA AGILIS	BIV	Tellinidae	Yes
55153102SPP	TELLINA SPP.	BIV	Tellinidae	No
5515390101	ARCTICA ISLANDICA	BIV	Arcticidae	Yes
5515471201	PITAR MORRHUANA	BIV	Veneridae	Yes

MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
5517010201	MYA ARENARIA	BIV	Myidae	Yes
5517060102	CRYTODARIA SILIQUA	BIV	Hiatellidae	Yes
5517060201	HIATELLA ARCTICA	BIV	Hiatellidae	Yes
5520020101	PANDORA GLACIALIS	BIV	Pandoridae	Yes
5520020107	PANDORA GOULDIANA	BIV	Pandoridae	Yes
5520020109CF	PANDORA NR. INFLATA	BIV	Pandoridae	Yes
55200201SPP	PANDORA SPP.	BIV	Pandoridae	No
5520050201	LYONSIA ARENOSA	BIV	Lyonsiidae	Yes
55200502SPP	LYONSIA SPP.	BIV	Lyonsiidae	No
552005SPP	LYONSIIDAE SPP.	BIV	Lyonsiidae	No
5520070102	PERIPLOMA FRAGILE	BIV	Periplomatidae	Yes
5520070104	PERIPLOMA PAPYRATIUM	BIV	Periplomatidae	Yes
55200701SPP	PERIPLOMA SPP.	BIV	Periplomatidae	No
5520080102	ASTHENOTHAERUS HEMPHILLI	BIV	Thraciidae	Yes
5520080209	THRACIA CONRADI	BIV	Thraciidae	Yes
552008SPP	THRACIIDAE SPP.	BIV	Thraciidae	No
55SP02	BIVALVIA SP. A	BIV		Yes
55SPP	BIVALVIA SPP.	BIV		No
3740SPP	ANTHOZOA SPP.	CNI		No
3743010102	CERIANTHUS BOREALIS	CNI	Cerianthidae	Yes
3743010201	CERIANTHEOPSIS AMERICANUS	CNI	Cerianthidae	Yes
374301SPP	CERIANTHIDAE SPP.	CNI	Cerianthidae	No
3758SP02	ACTINIARIA SP. 2	CNI		Yes
3758SP04	ACTINIARIA SP. 4	CNI		Yes
3758SP05	ACTINIARIA SP. 5	CNI		Yes
3758SP06	ACTINIARIA SP. 6	CNI		Yes
3758SPP	ACTINIARIA SPP.	CNI		No
3759010101	EDWARDSIA ELEGANS	CNI	Edwardsiidae	Yes
3759040102	HALCAMPA DUODECIMCIRRATA	CNI	Halcampidae	Yes
6154010105	LAMPROPS QUADRIPLICATA	CUM	Lampropidae	Yes
6154040104	LEUCON FULVUS	CUM	Leuconidae	Yes
6154040106	LEUCON ACUTIROSTRIS	CUM	Leuconidae	Yes
61540401SP01	LEUCON SP. 1	CUM	Leuconidae	Yes
61540401SPP	LEUCON SPP.	CUM	Leuconidae	No
6154040208	EUDORELLA HISPIDA	CUM	Leuconidae	Yes
6154040211	EUDORELLA PUSILLA	CUM	Leuconidae	Yes
61540402HIRS	EUDORELLA HIRSUTA	CUM	Leuconidae	Yes
61540402SPP	EUDORELLA SPP.	CUM	Leuconidae	No
6154040304	EUDORELLOPSIS DEFORMIS	CUM	Leuconidae	Yes
6154050121	DIASTYLIS POLITA	CUM	Diastylidae	Yes
6154050126	DIASTYLIS QUADRISPINOSA	CUM	Diastylidae	Yes
6154050127	DIASTYLIS SCULPTA	CUM	Diastylidae	Yes
6154050129	DIASTYLIS ABBREVIATA	CUM	Diastylidae	Yes
6154050130	DIASTYLIS CORNUIFER	CUM	Diastylidae	Yes
61540501SPP	DIASTYLIS SPP.	CUM	Diastylidae	No

MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
6154050403CF	LEPTOSTYLIS CF. AMPULLACEA	CUM	Diastylidae	Yes
6154050404	LEPTOSTYLIS LONGIMANA	CUM	Diastylidae	Yes
61540504SPP	LEPTOSTYLIS SPP.	CUM	Diastylidae	No
615405SPP	DIASTYLIDAE SPP.	CUM	Diastylidae	No
6154060101	PETALOSARSIA DECLIVIS	CUM	Pseudocumidae	Yes
6154070103	CAMPYLASPIS RUBICUNDA	CUM	Nannastacidae	Yes
61540701SPP	CAMPYLASPIS SPP.	CUM	Nannastacidae	No
61540701SUCF	CAMPYLASPIS NR. SULCATA	CUM	Nannastacidae	Yes
6154090301	PSEUDOLEPTOCUMA MINOR	CUM	Bodotriidae	Yes
6154SPP	CUMACEAN SPP.	CUM		No
6175SPP	DECAPODA SPP.	DEC		No
6183020301	AXIUS SERRATUS	DEC	Axiidae	Yes
6188030107	CANCER BOREALIS	DEC	Cancridae	Yes
8104SPP	ASTEROIDEA SPP.	ECH		No
8107020101	CTENODISCUS CRISPATUS	ECH	Porcellanasteridae	Yes
8114040111	HENRICIA SANGUINOLENTA	ECH	Echinasteridae	Yes
8120SPP	OPHIUROIDEA SPP.	ECH		No
8127010401	OPHIOCTEN SERICEUM	ECH	Ophiuridae	Yes
8127010610	OPHIURA SARSI	ECH	Ophiuridae	Yes
8127010611	OPHIURA ROBUSTA	ECH	Ophiuridae	Yes
81270106SP02	OPHIURA SP. A	ECH	Ophiuridae	Yes
81270106SPP	OPHIURA SPP.	ECH		No
8129030202	AXIOGNATHUS SQUAMATUS	ECH	Amphiuridae	Yes
8129040102	OPHIOTHRIX ANGULATA	ECH	Ophiotrichidae	Yes
8136SPP	ECHINOIDEA SPP.	ECH		No
8155020101	ECHINARACHNIUS PARMA	ECH	Echinarachniidae	Yes
8170SPP	HOLOTHUROIDEA SPP.	ECH		No
8179010102	MOLPADIA OOLITICA	ECH	Molpadiidae	Yes
7301020201	ECHIURUS ECHIURUS	ECI	Echiuridae	Yes
73SPP	ECHIURIDA SPP.	ECI	Echiuridae	No
5102100402	SOLARIELLA OBSCURA	GAS	Trochidae	Yes
51021004SPP	SOLARIELLA SPP.	GAS	Trochidae	No
510210SPP	TROCHIDAE SPP.	GAS	Trochidae	No
5102120202	MOELLERIA COSTULATA	GAS	Turbinidae	Yes
5103090305	LACUNA VINCTA	GAS	Lacunidae	Yes
5103200108	ALVANIA CASTANEA	GAS	Rissoidae	Yes
5103200127	PUSILLINA HARPA	GAS	Rissoidae	Yes
51032001SPP	ALVANIA SPP.	GAS	Rissoidae	No
5103202113	ONOBA PELAGICA	GAS	Rissoidae	Yes
5103202115	ONOBA MIGHELSI	GAS	Rissoidae	Yes
5103202301	PUSILLINA PSEUDOAREOLATA	GAS	Rissoidae	Yes
510320SP01	RISSOIDAE SP. A	GAS	Rissoidae	Yes
5103240102	SKENEOPSIS PLANORBIS	GAS	Skeneopsidae	Yes
5103500102GR	EPITONIUM GREENLANDICUM	GAS	Epitoniidae	Yes
5103760402	POLINICES PALLIDUS	GAS	Naticidae	Yes

MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
5103760408	EUSPIRA IMMACULATA	GAS	Naticidae	Yes
5103761201	EUSPIRA HEROS	GAS	Naticidae	Yes
510376SPP	NATICIDAE SPP.	GAS	Naticidae	No
51050103SPP	UROSALPINX SPP.	GAS	Muricidae	Yes
510504SPP	BUCCINIDAE SPP.	GAS	Buccinidae	No
5105050326	COLUS PUBESCENS	GAS	Buccinidae	Yes
5105050328	COLUS PYGMAEUS	GAS	Buccinidae	Yes
5105050335	COLUS PARVUS	GAS	Buccinidae	Yes
51050503SP01	COLUS SP. A	GAS	Buccinidae	Yes
51050503SPP	COLUS SPP.	GAS	Buccinidae	No
51050508SPP	NEPTUNEA SPP.	GAS	Buccinidae	Yes
5105080202	ILYANASSA TRIVITTATA	GAS	Nassariidae	Yes
5106020409	OENOPOTA HARPULARIA	GAS	Turridae	Yes
5106020410	OENOPOTA PYRIMIDALIS	GAS	Turridae	Yes
5106020426	OENOPOTA INCISULA	GAS	Turridae	Yes
5106020443CF	OENOPOTA CF. CANCELLATUS	GAS	Turridae	Yes
51060204SPP	OENOPOTA SPP.	GAS	Turridae	No
5106020601	PROPEBELA TURRICULA	GAS	Turridae	Yes
5106020603	PROPEBELA EXARATA	GAS	Turridae	Yes
51060206SPP	PROPEBELA SPP.	GAS	Turridae	No
510602SP01	TURRIDAE SP. A	GAS	Turridae	Yes
510602SPP	TURRIDAE SPP.	GAS	Turridae	No
5108010133	ODOSTOMIA SULCOSA	GAS	Pyramidellidae	Yes
5108011402	BOONEA IMPRESSA	GAS	Pyramidellidae	Yes
5108011504	ODOSTOMIA GIBBOSA	GAS	Pyramidellidae	Yes
5110040103	ACTEOCINA CANALICULATA	GAS	Acteocinidae	Yes
5110040203	CYLICHNA ALBA	GAS	Cylichnidae	Yes
5110040206	CYLICHNA GOULDI	GAS	Cylichnidae	Yes
51100402SPP	CYLICHNA SPP.	GAS	Cylichnidae	No
5110090101	DIAPHANA MINUTA	GAS	Diaphanidae	Yes
5110130101	RETUSA OBTUSA	GAS	Retusidae	Yes
5110SPP	CEPHALASPIDEA SPP.	GAS		No
5127SPP	NUDIBRANCHIA SPP.	GAS		No
5131070201	DORIDELLA OBSCURA	GAS	Corambidae	Yes
51310702SPP	DORIDELLA SPP.	GAS	Corambidae	No
5181SPP	OPISTHOBRANCHIA SPP.	GAS		No
51SP01	GASTROPODA SP. A	GAS		Yes
51SPP	GASTROPODA SPP.	GAS		No
8201010201	STEREOBALANUS CANADENSIS	HEM	Harrimaniidae	Yes
8201SPP	ENTEROPNEUSTA SPP.	HEM		No
6159010111	GNATHIA CERINA	ISO	Gnathiidae	Yes
6160010301	PTILANTHURA TENUIS	ISO	Anthuridae	Yes
6161011203	POLITOLANA POLITA	ISO	Cirolanidae	Yes
6162020308	IDOTEA BALTHICA	ISO	Idoteidae	Yes
6162020503	CHIRIDOTEA TUFTSI	ISO	Chaetiliidae	Yes

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6162020701	EDOTIA MONTOSA	ISO	Idoteidae	Yes
6162020703	EDOTIA TRILOBA	ISO	Idoteidae	Yes
61631201SP01	MUNNA SP. 1	ISO	Munnidae	Yes
61631201SPP	MUNNA SPP.	ISO	Munnidae	No
6163120201	PLEUROGONIUM SPINOSISSIMUM	ISO	Paramunnidae	Yes
6163120202	PLEUROGONIUM RUBICUNDUM	ISO	Paramunnidae	Yes
6163120204	PLEUROGONIUM INERME	ISO	Paramunnidae	Yes
61631202SPP	PLEUROGONIUM SPP.	ISO	Paramunnidae	No
616312SPP	MUNNIDAE SPP.	ISO	Munnidae	No
6163170702	BAEONECTES MUTICUS	ISO	Eurycopidae	Yes
4302010104	TUBULANUS PELLUCIDUS	NEM	Tubulanidae	Yes
4302010201	CARINOMELLA LACTEA	NEM	Carinomidae	Yes
430203SP01	CEPHALOTHRICIDAE SP. 1	NEM	Cephalothricidae	Yes
4303020209	CEREBRATULUS LACTEUS	NEM	Lineidae	Yes
4303020405	LINEUS PALLIDUS	NEM	Lineidae	Yes
43030205SPP	MICRURA SPP.	NEM	Lineidae	Yes
4306050101	AMPHIPORUS ANGULATUS	NEM	Amphiporidae	Yes
4306050115	AMPHIPORUS CRUENTATUS	NEM	Amphiporidae	Yes
4306050124	AMPHIPORUS GROENLANDICUS	NEM	Amphiporidae	Yes
43060501SPP	AMPHIPORUS SPP.	NEM	Amphiporidae	No
4306060216	TETRASTEMMA VITTATUM	NEM	Tetrastemmatidae	Yes
43060602SPP	TETRASTEMMA SPP.	NEM	Tetrastemmatidae	No
43SP02	NEMERTEA SP. 2	NEM		Yes
43SP05	NEMERTEA SP. 5	NEM		Yes
43SP07	NEMERTEA SP. 7	NEM		Yes
43SP12	NEMERTEA SP. 12	NEM		Yes
43SP13	NEMERTEA SP. 13	NEM		Yes
43SP14	NEMERTEA SP. 14	NEM		Yes
43SPP	NEMERTEA SPP.	NEM		No
5003SPP	OLIGOCHAETA SPP.	OLI		No
5009010301LONG	GRANIA POSTCLITELLOCHAETA LONGIDUCTA	OLI	Enchytraeidae	Yes
500901SP01	ENCHYTRAEIDAE SP. 1	OLI	Enchytraeidae	Yes
500901SP02	ENCHYTRAEIDAE SP. 2	OLI	Enchytraeidae	Yes
500901SP03	ENCHYTRAEIDAE SP. 3	OLI	Enchytraeidae	Yes
5009020403	TUBIFICOIDES NR. PSEUDOGASTER	OLI	Tubificidae	Yes
5009020906	TUBIFICOIDES APECTINATUS	OLI	Tubificidae	Yes
50090209SP01	TUBIFICOIDES SP. 1	OLI	Tubificidae	Yes
50090209SP03	TUBIFICOIDES SP. 3	OLI	Tubificidae	Yes
50090209SPP	TUBIFICOIDES SPP.	OLI	Tubificidae	No
50090210SP01	ADELODRILUS SP. 1	OLI	Tubificidae	Yes
50090210SP02	ADELODRILUS SP. 2	OLI	Tubificidae	Yes
500902SP02	TUBIFICIDAE SP. 2	OLI	Tubificidae	Yes
500902SP04	TUBIFICIDAE SP. 4	OLI	Tubificidae	Yes
500902SPP	TUBIFICIDAE SPP.	OLI	Tubificidae	No
7700010203	PHORONIS ARCHITECTA	PHO	Phoronidae	Yes

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3901SPP	TURBELLARIA SPP.	PLA		Yes
5001010104	APHRODITA HASTATA	POL	Aphroditidae	Yes
50010101SPP	APHRODITA SPP.	POL	Aphroditidae	No
5001020301	ARCTEOBIA ANTICOSTIENSIS	POL	Polynoidae	Yes
5001020601	GATTYANA AMONDSENI	POL	Polynoidae	Yes
5001020603	GATTYANA CIRROSA	POL	Polynoidae	Yes
50010206SPP	GATTYANA SPP.	POL	Polynoidae	No
5001020803	HARMOTHOE EXTENUATA	POL	Polynoidae	Yes
5001020806	HARMOTHOE IMBRICATA	POL	Polynoidae	Yes
50010208SPP	HARMOTHOE SPP.	POL	Polynoidae	No
5001021502	ENIPO GRACILIS	POL	Polynoidae	Yes
5001022001	HARTMANIA MOOREI	POL	Polynoidae	Yes
5001022103	ENIPO TORELLI	POL	Polynoidae	Yes
5001022401	AUSTROLAENILLA MOLLIS	POL	Polynoidae	Yes
5001025501	BYLGIDES ELEGANS	POL	Polynoidae	Yes
50010255GROE	BYLGIDES GROENLANDICUS	POL	Polynoidae	Yes
50010255SARS	BYLGIDES SARSI	POL	Polynoidae	Yes
50010255SPP	BYLGIDES SPP.	POL	Polynoidae	No
500102HARSPP	HARMOTHOINAE SPP.	POL	Polynoidae	No
500102SPP	POLYNOIDAE SPP.	POL	Polynoidae	No
5001060101	PHOLOE MINUTA	POL	Pholoidae	Yes
5001060303	STHENELAIS LIMICOLA	POL	Sigalionidae	Yes
50010603SPP	STHENELAIS SPP.	POL	Sigalionidae	No
5001080201	DYSPONETUS PYGMAEUS	POL	Chrysopetalidae	Yes
5001100401	PARAMPHINOME JEFFREYSII	POL	Amphinomidae	Yes
5001130102	PHYLLODOCE GROENLANDICA	POL	Phyllodocidae	Yes
5001130104	PHYLLODOCE MUCOSA	POL	Phyllodocidae	Yes
5001130106	PHYLLODOCE MACULATA	POL	Phyllodocidae	Yes
5001130202	ETEONE SPETSBERGENSIS	POL	Phyllodocidae	Yes
5001130204	ETEONE FLAVA	POL	Phyllodocidae	Yes
5001130205	ETEONE LONGA	POL	Phyllodocidae	Yes
5001130207	ETEONE HETEROPODA	POL	Phyllodocidae	Yes
5001130211	ETEONE FOLIOSA	POL	Phyllodocidae	Yes
50011302SPP	ETEONE SPP.	POL	Phyllodocidae	No
5001130301	EULALIA VIRIDIS	POL	Phyllodocidae	Yes
5001130304	EULALIA BILINEATA	POL	Phyllodocidae	Yes
50011303SPP	EULALIA SPP.	POL	Phyllodocidae	No
5001130501	MYSTIDES BOREALIS	POL	Phyllodocidae	Yes
5001130801	PARANAITIS SPECIOSA	POL	Phyllodocidae	Yes
50011308SPP	PARANAITIS SPP.	POL	Phyllodocidae	No
5001131101	EUMIDA SANGUINEA	POL	Phyllodocidae	Yes
5001131410	PHYLLODOCE ARENAE	POL	Phyllodocidae	Yes
50011314SPP	PHYLLODOCE SPP.	POL	Phyllodocidae	No
500113SPP	PHYLLODOCIDAE SPP.	POL	Phyllodocidae	No
5001210103	GYPTIS CF. VITTATA	POL	Hesionidae	Yes

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5001210203	MICROPHTHALMUS LISTENSIS	POL	Hesionidae	Yes
50012102PETT	MICROPHTHALMUS PETTIBONEAE	POL	Hesionidae	Yes
50012102SPP	MICROPHTHALMUS SPP.	POL	Hesionidae	No
5001220104	ANCISTROSYLLIS GROENLANDICA	POL	Pilargiidae	Yes
50012201SPP	ANCISTROSYLLIS SPP.	POL	Pilargiidae	No
5001220501	SYNELMIS KLATTI	POL	Pilargiidae	Yes
5001230101	PROCERAEA CORNUTA	POL	Syllidae	Yes
50012302SP01	PIONOSYLLIS SP. A	POL	Syllidae	Yes
50012302SPP	PIONOSYLLIS SPP.	POL	Syllidae	No
5001230306	SYLLIS CORNUTA	POL	Syllidae	Yes
50012303SPP	SYLLIS SPP.	POL	Syllidae	No
5001230501	TYPOSYLLIS ALTERNATA	POL	Syllidae	Yes
50012305SP01	TYPOSYLLIS SP. 1	POL	Syllidae	Yes
50012305SPP	TYPOSYLLIS SPP.	POL	Syllidae	No
5001230706	EXOGONE VERUGERA	POL	Syllidae	Yes
5001230707	EXOGONE HEBES	POL	Syllidae	Yes
5001230711	EXOGONE LONGICIRRIS	POL	Syllidae	Yes
50012307SP01	EXOGONE SP. A	POL	Syllidae	Yes
50012307SPP	EXOGONE SPP.	POL	Syllidae	No
5001230801	SPHAEROSYLLIS BREVIFRONS	POL	Syllidae	Yes
5001230817	SPHAEROSYLLIS LONGICAUDA	POL	Syllidae	Yes
50012308SPP	SPHAEROSYLLIS SPP.	POL	Syllidae	No
5001231501	SYLLIDES JAPONICA	POL	Syllidae	Yes
5001231503	SYLLIDES LONGOCIRRATA	POL	Syllidae	Yes
5001231503CON	SYLLIDES CONVOLUTA	POL	Syllidae	Yes
50012315SPP	SYLLIDES SPP.	POL	Syllidae	No
5001231605CF	STREPTOSYLLIS CF. PETTIBONEAE	POL	Syllidae	Yes
5001231701	PARAPIONOSYLLIS LONGICIRRATA	POL	Syllidae	Yes
500123AUSPP	AUTOLYTINAE SPP.	POL	Syllidae	No
500123SPP	SYLLIDAE SPP.	POL	Syllidae	No
5001240302	NEANTHES VIRENS	POL	Nereidae	Yes
5001240404	NEREIS PROCERA	POL	Nereidae	Yes
5001240406	NEREIS ZONATA	POL	Nereidae	Yes
5001240409	NEREIS GRAYI	POL	Nereidae	Yes
50012404SPP	NEREIS SPP.	POL	Nereidae	No
5001241001	WEBSTERINEREIS TRIDENTATA	POL	Nereidae	Yes
500124SPP	NEREIDIDAE SPP.	POL	Nereidae	No
5001250102	NEPHTYS CILIATA	POL	Nephtyidae	Yes
5001250103	NEPHTYS CAECA	POL	Nephtyidae	Yes
5001250104	NEPHTYS CORNUTA	POL	Nephtyidae	Yes
5001250108	NEPHTYS DISCORS	POL	Nephtyidae	Yes
5001250110	NEPHTYS PARADOXA	POL	Nephtyidae	Yes
5001250115	NEPHTYS INCISA	POL	Nephtyidae	Yes
50012501SPP	NEPHTYS SPP.	POL	Nephtyidae	No
5001250304	AGLAOPHAMUS CIRCINATA	POL	Nephtyidae	Yes

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500125SPP	NEPHTYIDAE SPP.	POL	Nephtyidae	No
5001260201	SPHAERODOROPSIS MINUTA	POL	Sphaerodoridae	Yes
5001260401	SPHAERODORIDIUM CLAPAREDII	POL	Sphaerodoridae	Yes
50012604SP01	SPHAERODORIDIUM SP. A	POL	Sphaerodoridae	Yes
500126SPP	SPHAERODORIDAE SPP.	POL	Sphaerodoridae	No
5001270101	GLYCERA CAPITATA	POL	Glyceridae	Yes
5001270105	GLYCERA DIBRANCHIATA	POL	Glyceridae	Yes
50012701SPP	GLYCERA SPP.	POL	Glyceridae	No
500127SPP	GLYCERIDAE SPP.	POL	Glyceridae	No
5001280202	GONIADA MACULATA	POL	Goniadidae	Yes
50012802SPP	GONIADA SPP.	POL	Goniadidae	No
500128SPP	GONIADIDAE SPP.	POL	Goniadidae	No
5001290108	ONUPHIS OPALINA	POL	Onuphidae	Yes
500129SPP	ONUPHIDAE SPP.	POL	Onuphidae	No
5001310102	SCOLETOMA FRAGILIS	POL	Lumbrineridae	Yes
5001310113	LUMBRINERIS TENUIS	POL	Lumbrineridae	Yes
5001310115	SCOLETOMA IMPATIENS	POL	Lumbrineridae	Yes
5001310140	SCOLETOMA HEBES	POL	Lumbrineridae	Yes
50013101SPP	SCOLETOMA SPP.	POL	Lumbrineridae	No
5001310203	PARANINOE BREVIPES	POL	Lumbrineridae	Yes
5001310204	NINOE NIGRIPES	POL	Lumbrineridae	Yes
500131ERASPP	ERANNO SPP.	POL	Lumbrineridae	No
500131SPP	LUMBRINERIDAE SPP.	POL	Lumbrineridae	No
500131WINS	ABYSSONINOE WINSNESAE	POL	Lumbrineridae	Yes
5001330101	DRILONEREIS FILUM	POL	Arabellidae	Yes
5001330103	DRILONEREIS LONGA	POL	Arabellidae	Yes
5001330105	DRILONEREIS MAGNA	POL	Arabellidae	Yes
50013301SPP	DRILONEREIS SPP.	POL	Arabellidae	No
5001330901	LABROROSTRATUS PARASITICUS	POL	Arabellidae	Yes
500133SPP	ARABELLIDAE SPP.	POL	Arabellidae	No
5001360108	DORVILLEA SOCIABILIS	POL	Dorvilleidae	Yes
5001360402CF	OPHRYOTROCHA CF. LABRONICA	POL	Dorvilleidae	Yes
5001360413	OPHRYOTROCHA BIFIDA	POL	Dorvilleidae	Yes
50013604SP01	OPHRYOTROCHA SP. 1	POL	Dorvilleidae	Yes
50013604SP02	OPHRYOTROCHA SP. 2	POL	Dorvilleidae	Yes
50013604SPP	OPHRYOTROCHA SPP.	POL	Dorvilleidae	No
5001360601	MEIODORVILLEA MINUTA	POL	Dorvilleidae	Yes
50013614CAEC	PAROUGIA CAECA	POL	Dorvilleidae	Yes
500136SPP	DORVILLEIDAE SPP.	POL	Dorvilleidae	No
5001400301	SCOLOPLOS ARMIGER	POL	Orbiniidae	Yes
5001400305	LEITOSCOLOPLOS ACUTUS	POL	Orbiniidae	Yes
5001400307CF	SCOLOPLOS (LEODAMAS) ?RUBRA	POL	Orbiniidae	Yes
5001400311	SCOLOPLOS ACMECEPS	POL	Orbiniidae	Yes
50014003SPP	SCOLOPLOS SPP.	POL	Orbiniidae	No
5001400502	ORBINIA SWANI	POL	Orbiniidae	Yes

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50014005SPP	ORBINIA SPP.	POL	Orbiniidae	No
50014016SP01	LEITOSCOLOPLOS SP. B	POL	Orbiniidae	Yes
50014016SPP	LEITOSCOLOPLOS SPP.	POL	Orbiniidae	No
500140SPP	ORBINIIDAE SPP.	POL	Orbiniidae	No
5001410208	ARICIDEA CATHERINAE	POL	Paraonidae	Yes
5001410217	ARICIDEA QUADRILOBATA	POL	Paraonidae	Yes
5001410220	ARICIDEA MINUTA	POL	Paraonidae	Yes
50014102CERR	ARICIDEA CERRUTII	POL	Paraonidae	Yes
50014102SPP	ARICIDEA SPP.	POL	Paraonidae	No
5001410606	CIRROPHORUS FURCATUS	POL	Paraonidae	Yes
5001410801	LEVINSENIA GRACILIS	POL	Paraonidae	Yes
50014108SPP	LEVINSENIA SPP.	POL	Paraonidae	No
5001411201	PARADONEIS LYRA	POL	Paraonidae	Yes
5001411204	PARADONEIS ARMATUS	POL	Paraonidae	Yes
5001411205	PARADONEIS ELIASONI	POL	Paraonidae	Yes
500141SPP	PARAONIDAE SPP.	POL	Paraonidae	No
5001420103	APISTOBRANCHUS TYPICUS	POL	Apistobranchidae	Yes
50014201SPP	APISTOBRANCHUS SPP.	POL	Apistobranchidae	No
5001430201	LAONICE CIRRATA	POL	Spionidae	Yes
50014302SP01	LAONICE SP. 1	POL	Spionidae	Yes
50014302SPP	LAONICE SPP.	POL	Spionidae	No
5001430402	DIPOLYDORA SOCIALIS	POL	Spionidae	Yes
5001430404	DIPOLYDORA CAULLERYI	POL	Spionidae	Yes
5001430408	DIPOLYDORA QUADRILOBATA	POL	Spionidae	Yes
5001430412	POLYDORA WEBSTERI	POL	Spionidae	Yes
5001430414	DIPOLYDORA CONCHARUM	POL	Spionidae	Yes
5001430438	POLYDORA AGGREGATA	POL	Spionidae	Yes
5001430448	POLYDORA CORNUTA	POL	Spionidae	Yes
50014304SPP	POLYDORA SPP.	POL	Spionidae	No
5001430506	PRIONOSPIO STEENSTRUPI	POL	Spionidae	Yes
5001430520	PRIONOSPIO ALUTA	POL	Spionidae	Yes
50014305CIRR	PRIONOSPIO CIRRIFERA	POL	Spionidae	Yes
5001430701	SPIO FILICORNIS	POL	Spionidae	Yes
5001430704	SPIO SETOSA	POL	Spionidae	Yes
5001430707	SPIO LIMICOLA	POL	Spionidae	Yes
5001430709	SPIO THULINI	POL	Spionidae	Yes
50014307SPP	SPIO SPP.	POL	Spionidae	No
5001431001	SPIOPHANES BOMBYX	POL	Spionidae	Yes
5001431002	SPIOPHANES KROEYERI	POL	Spionidae	Yes
5001431302	PYGOSPIO ELEGANS	POL	Spionidae	Yes
5001431801	STREBLOSPIO BENEDICTI	POL	Spionidae	Yes
5001432001	SCOLELEPIS SQUAMATA	POL	Spionidae	Yes
5001432006	SCOLELEPIS TEXANA	POL	Spionidae	Yes
5001432007	SCOLELEPIS FOLIOSA	POL	Spionidae	Yes
500143DISPP	DIPOLYDORA SPP.	POL	Spionidae	No

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500143SPP	SPIONIDAE SPP.	POL	Spionidae	No
5001450201	TROCHOCHAETA CARICA	POL	Trochochaetidae	Yes
5001450202	TROCHOCHAETA WATSONI	POL	Trochochaetidae	Yes
5001450203	TROCHOCHAETA MULTISETOSA	POL	Trochochaetidae	Yes
50014502PETT	TROCHOCHAETA PETTIBONEAE	POL	Trochochaetidae	Yes
50014502SPP	TROCHOCHAETA SPP.	POL	Trochochaetidae	No
5001480101	PSAMMODRILUS BALANOGLOSSOIDES	POL	Psammodrilidae	Yes
5001490303	SPIOCHAETOPTERUS OCULATUS	POL	Chaetopteridae	Yes
5001500101	CIRRATULUS CIRRATUS	POL	Cirratulidae	Yes
50015002SP02	CAULLERIELLA SP. B	POL	Cirratulidae	Yes
50015002SP03	CAULLERIELLA SP. C	POL	Cirratulidae	Yes
5001500301	APHELOCHAETA MONILARIS	POL	Cirratulidae	Yes
5001500305	THARYX ACUTUS	POL	Cirratulidae	Yes
5001500307	APHELOCHAETA MARIONI	POL	Cirratulidae	Yes
5001500310	MONTICELLINA DORSOBRANCHIALIS	POL	Cirratulidae	Yes
50015003ASP01	APHELOCHAETA SP. 1	POL	Cirratulidae	Yes
50015003ASPP	APHELOCHAETA SPP.	POL	Cirratulidae	No
50015003BAPT	MONTICELLINA BAPTISTEAE	POL	Cirratulidae	Yes
50015003KIRK	THARYX KIRKEGAARDI	POL	Cirratulidae	Yes
50015003MSPP	MONTICELLINA SPP.	POL	Cirratulidae	No
50015003SPP	THARYX SPP.	POL	Cirratulidae	No
500150043SP04	CHAETOZONE SP. 4	POL	Cirratulidae	Yes
50015004MB	CHAETOZONE SETOSA MB	POL	Cirratulidae	Yes
50015004SP05	CHAETOZONE SP. 5	POL	Cirratulidae	Yes
50015004SPP	CHAETOZONE SPP.	POL	Cirratulidae	No
50015004VIVI	CHAETOZONE VIVIPARA	POL	Cirratulidae	Yes
500150SPP	CIRRATULIDAE SPP.	POL	Cirratulidae	No
5001520101	COSSURA LONGOCIRRATA	POL	Cossuridae	Yes
500152SPP	COSSURIDAE SPP.	POL	Cossuridae	No
5001540102	BRADA VILLOSA	POL	Flabelligeridae	Yes
5001540107	BRADA INCRUSTATA	POL	Flabelligeridae	Yes
50015401SPP	BRADA SPP.	POL	Flabelligeridae	No
50015402SPP	FLABELLIGERA SPP.	POL	Flabelligeridae	Yes
5001540302	PHERUSA PLUMOSA	POL	Flabelligeridae	Yes
5001540304	PHERUSA AFFINIS	POL	Flabelligeridae	Yes
50015403SPP	PHERUSA SPP.	POL	Flabelligeridae	No
5001540401	DIPLOCIRRUS LONGISETOSUS	POL	Flabelligeridae	Yes
5001540402	DIPLOCIRRUS HIRSUTUS	POL	Flabelligeridae	Yes
50015404SPP	DIPLOCIRRUS SPP.	POL	Flabelligeridae	No
5001570101	SCALIBREGMA INFLATUM	POL	Scalibregmatidae	Yes
500157SPP	SCALIBREGMATIDAE SPP.	POL	Scalibregmatidae	No
5001580404	TRAVISIA CARNEA	POL	Ophellidae	Yes
5001580601	OPHELINA ABRANCHIATA	POL	Ophellidae	Yes
5001580607	OPHELINA ACUMINATA	POL	Ophellidae	Yes
500158SPP	OPHELIIDAE SPP.	POL	Ophellidae	No

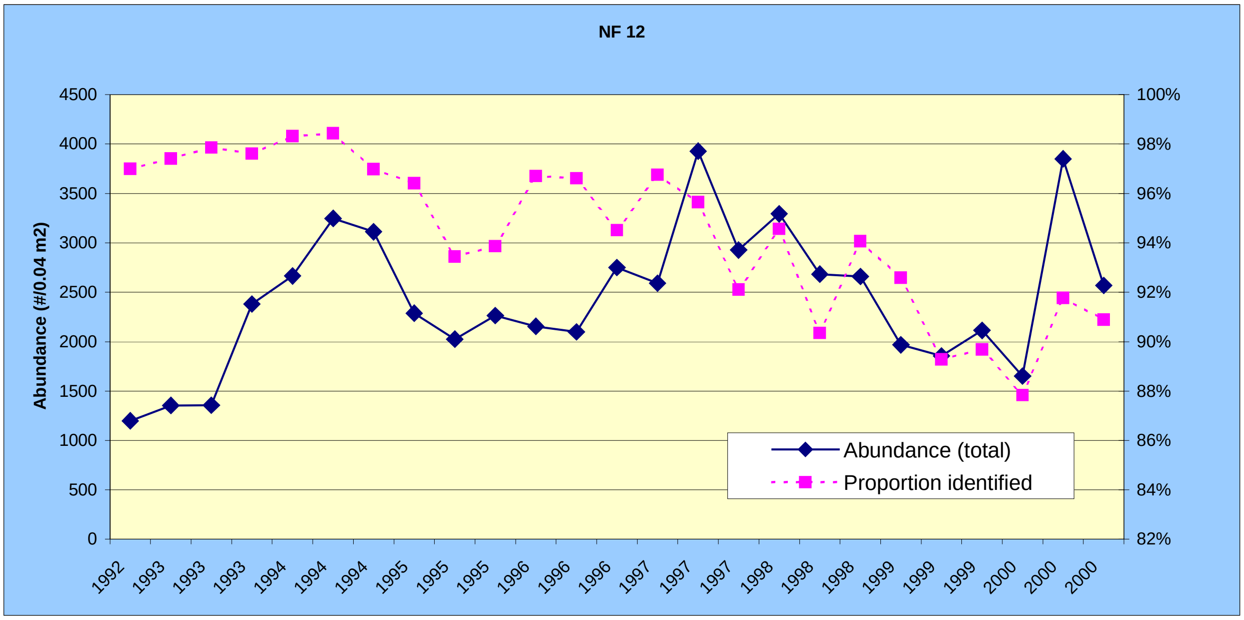
MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
5001590101	STERNASPIS SCUTATA	POL	Sternaspidae	Yes
5001600101	CAPITELLA CAPITATA COMPLEX	POL	Capitellidae	Yes
5001600201	HETEROMASTUS FILIFORMIS	POL	Capitellidae	Yes
50016003SPP	NOTOMASTUS SPP.	POL	Capitellidae	No
5001600402	MEDIOMASTUS CALIFORNIENSIS	POL	Capitellidae	Yes
5001600601	BARANTOLLA AMERICANA	POL	Capitellidae	Yes
50016006SP01	BARANTOLLA SP. A	POL	Capitellidae	Yes
500160SPP	CAPITELLIDAE SPP.	POL	Capitellidae	No
5001630202	CLYMENELLA TORQUATA	POL	Maldanidae	Yes
5001630301	MALDANE SARSI	POL	Maldanidae	Yes
50016303SPP	MALDANE SPP.	POL	Maldanidae	No
5001630701	PETALOPROCTUS TENUIS	POL	Maldanidae	Yes
5001630801	AXIOTHELLA CATENATA	POL	Maldanidae	Yes
5001630901	PRAXILLELLA GRACILIS	POL	Maldanidae	Yes
5001630902	PRAXILLELLA PRAETERMISSA	POL	Maldanidae	Yes
5001630903	PRAXILLELLA AFFINIS	POL	Maldanidae	Yes
50016309SPP	PRAXILLELLA SPP.	POL	Maldanidae	No
5001631001	RHODINE BITORQUATA	POL	Maldanidae	Yes
5001631003	RHODINE LOVENI	POL	Maldanidae	Yes
5001631102	EUCLYMENE COLLARIS	POL	Maldanidae	Yes
50016312SP01	CLYMENURA SP. A	POL	Maldanidae	Yes
50016312SPP	CLYMENURA SPP.	POL	Maldanidae	No
50016317SPP	MICROCLYMENE SPP.	POL	Maldanidae	No
5001631803	PRAXILLURA ORNATA	POL	Maldanidae	Yes
500163EUSP01	EUCLYMENINAE SP. 1	POL	Maldanidae	Yes
500163EUSPP	EUCLYMENINAE SPP.	POL	Maldanidae	No
500163NISPP	NICHOMACHINAE SPP.	POL	Maldanidae	No
500163SPP	MALDANIDAE SPP.	POL	Maldanidae	No
5001640102	OWENIA FUSIFORMIS	POL	Oweniidae	Yes
5001640201	MYRIOCHELE HEERI	POL	Oweniidae	Yes
50016402SPP	MYRIOCHELE SPP.	POL	Oweniidae	No
5001640402	GALATHOWENIA OCULATA	POL	Oweniidae	Yes
500164SPP	OWENIIDAE SPP.	POL	Oweniidae	No
5001660302	PECTINARIA GOULDI	POL	Pectinariidae	Yes
5001660303	PECTINARIA GRANULATA	POL	Pectinariidae	Yes
50016603SPP	PECTINARIA SPP.	POL	Pectinariidae	No
5001670208	AMPHARETE ACUTIFRONS	POL	Ampharetidae	Yes
5001670213	AMPHARETE LINDSTROEMI	POL	Ampharetidae	Yes
5001670214	AMPHARETE FINMARCHICA	POL	Ampharetidae	Yes
50016702SPP	AMPHARETE SPP.	POL	Ampharetidae	No
5001670303	AMPHICTEIS GUNNERI	POL	Ampharetidae	Yes
5001670501	MELINNA CRISTATA	POL	Ampharetidae	Yes
50016705SPP	MELINNA SPP.	POL	Ampharetidae	No
5001670701	ANOBOTHRUS GRACILIS	POL	Ampharetidae	Yes
5001670802	ASABELLIDES OCULATA	POL	Ampharetidae	Yes

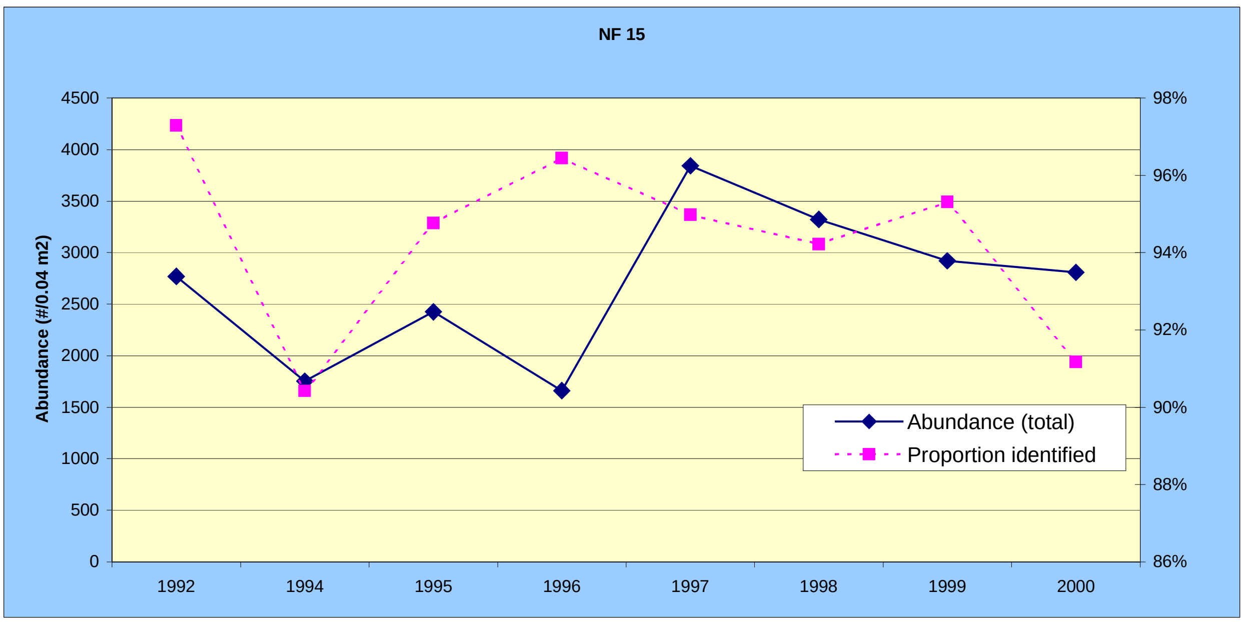
MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
500167SPP	AMPHARETIDAE SPP.	POL	Ampharetidae	No
5001680101	AMPHITRITE CIRRATA	POL	Terebellidae	Yes
50016801SPP	AMPHITRITINAE SPP.	POL	Terebellidae	No
5001680602	NICOLEA ZOSTERICOLA	POL	Terebellidae	Yes
5001680701	PISTA CRISTATA	POL	Terebellidae	Yes
5001680802	POLYCIRRUS MEDUSA	POL	Terebellidae	Yes
5001680804	POLYCIRRUS EXIMIUS	POL	Terebellidae	Yes
5001680805	POLYCIRRUS CF. HAEMATODES	POL	Terebellidae	Yes
5001680807	POLYCIRRUS PHOSPHOREUS	POL	Terebellidae	Yes
50016808SPP	POLYCIRRUS SPP.	POL	Terebellidae	No
500168130201	LANASSA VENUSTA VENUSTA	POL	Terebellidae	Yes
5001681702	PROCLEA GRAFFII	POL	Terebellidae	Yes
500168SPP	TEREBELLIDAE SPP.	POL	Terebellidae	No
5001690101	TEREBELLIDES STROEMII	POL	Trichobranchidae	Yes
5001690105	TEREBELLIDES ATLANTIS	POL	Trichobranchidae	Yes
50016901SPP	TEREBELLIDES SPP.	POL	Trichobranchidae	No
5001690201	TRICHOBRANCHUS GLACIALIS	POL	Trichobranchidae	Yes
5001690202	TRICHOBRANCHUS ROSEUS	POL	Trichobranchidae	Yes
5001700102	CHONE INFUNDIBULIFORMIS	POL	Sabellidae	Yes
5001700104	CHONE DUNERI	POL	Sabellidae	Yes
5001700106	CHONE CF. MAGNA	POL	Sabellidae	Yes
50017001SPP	CHONE SPP.	POL	Sabellidae	No
5001700202	EUCHONE PAPILLOSA	POL	Sabellidae	Yes
5001700204	EUCHONE INCOLOR	POL	Sabellidae	Yes
5001700205	EUCHONE ELEGANS	POL	Sabellidae	Yes
50017002SPP	EUCHONE SPP.	POL	Sabellidae	No
5001700502	MYXICOLA INFUNDIBULUM	POL	Sabellidae	Yes
5001700601	POTAMILLA NEGLECTA	POL	Sabellidae	Yes
5001700609	POTAMILLA RENIFORMIS	POL	Sabellidae	Yes
5001701401	LAONOME KROEYERI	POL	Sabellidae	Yes
50017022SP01	POTAMETHUS SP. 1	POL	Sabellidae	Yes
500170SPP	SABELLIDAE SPP.	POL	Sabellidae	No
50020501SP01	POLYGORDIUS SP. A	POL	Polygordiidae	Yes
7400010101	PRIAPULUS CAUDATUS	PRI	Priapulidae	Yes
74SPP	PRIAPULIDA SPP.	PRI		No
6001010101	NYMPHON GROSSIPES	PYC	Nymphonidae	Yes
60SPP	PYCNOGONIDA SPP.	PYC		No
5601010201	DENTALIUM ENTALE	SCA	Dentaliidae	Yes
7200020305	NEPHASOMA DIAPHANES	SIP	Golfingiidae	Yes
7200020401	PHASCOLION STROMBI	SIP	Golfingiidae	Yes
72SPP	SIPUNCULA SPP.	SIP		No
6157000101	ANARTHRURA CF. SIMPLEX	TAN	Anarthruridae	Yes
6157020402	TANAISSUS PSAMMOPHILUS	TAN	Nototanaidae	Yes
8401SPP	ASCIDIACEA SPP.	URO		No
8406010303	CNEMIDOCARPA MOLLIS	URO	Molgulidae	Yes

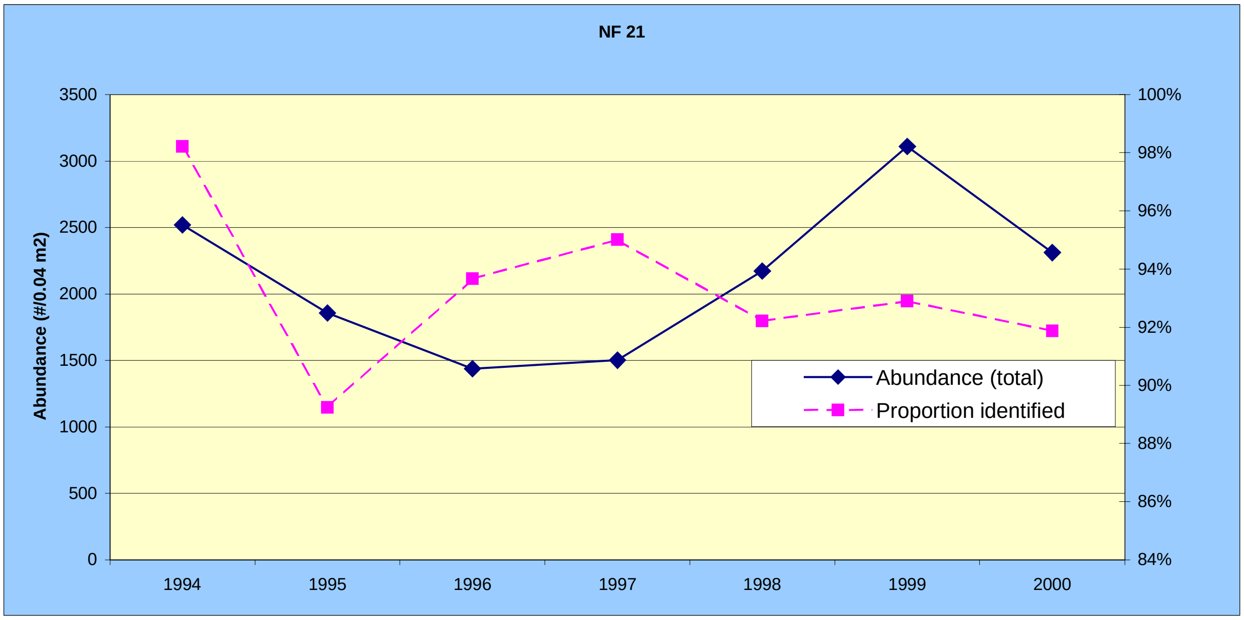
MWRA Code	Taxon Name	Higher Taxon	Family	Species ?
8406030108	MOLGULA MANHATTENSIS	URO	Molgulidae	Yes
84060301SPP	MOLGULA SPP.	URO	Molgulidae	No
8406030501	BOSTRICHOBRANCHUS PILULARIS	URO	Molgulidae	Yes
Key:				
AMP	Amphipoda			
APL	Aplacophora			
BIV	Bivalvia			
CNI	Cnidaria			
CUM	Cumacea			
DEC	Decapoda			
ECH	Echinodermata			
ECI	Echiura			
GAS	Gastropoda			
HEM	Hemichordata			
ISO	Isopoda			
NEM	Nemertea			
OLI	Oligochaeta			
PHO	Phoronida			
PLA	Platyhelminthes			
POL	Polychaeta			
PYC	Pycnogonida			
SIP	Sipuncula			
TAN	Tanaidacea			
URO	Urochordata			
Species ? = Was taxon included in (Yes) or excluded from (No) species level calculations?				

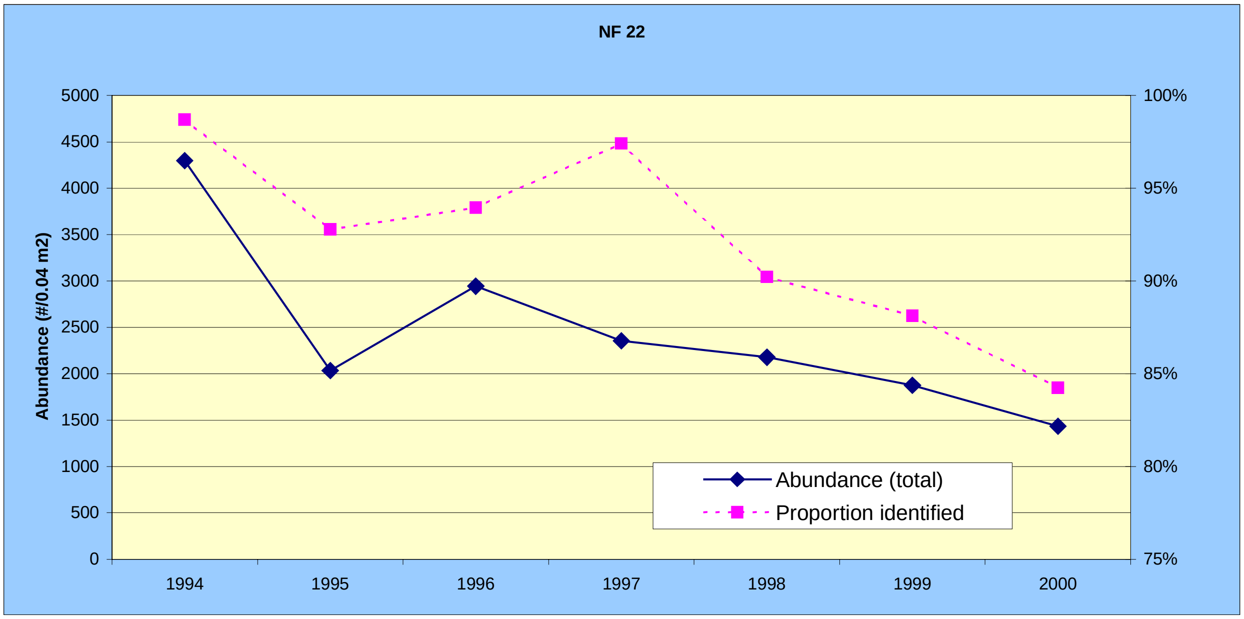
Appendix D-4

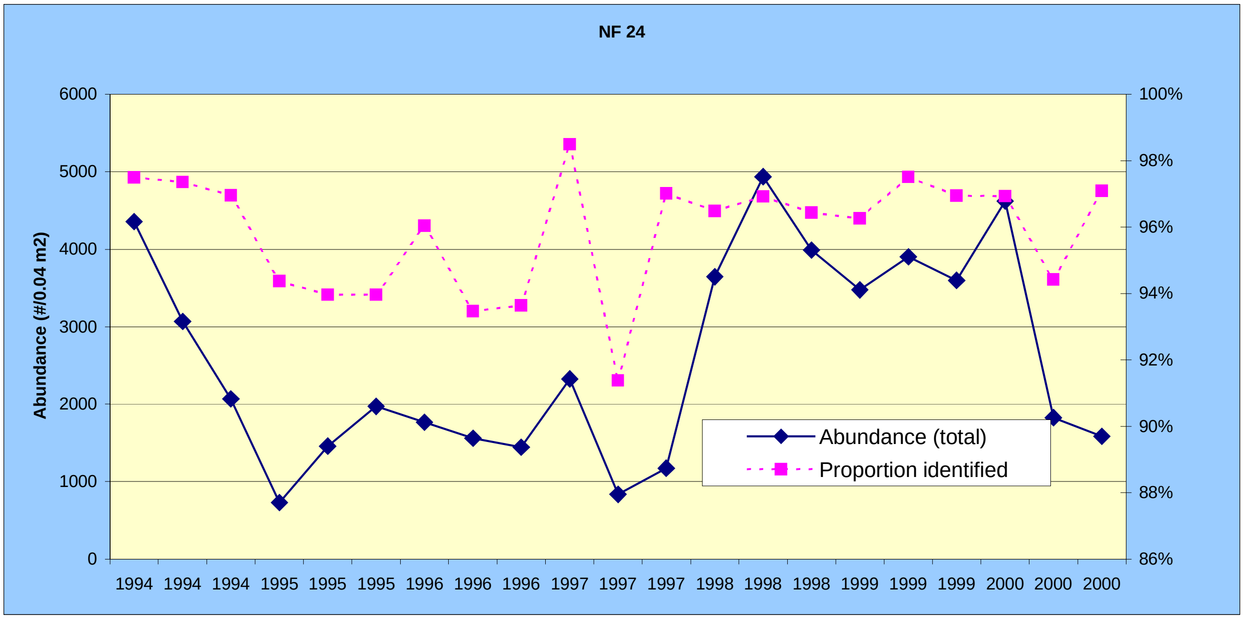
Total Infaunal Abundance and Proportion Identified to Species Level at the Nearfield Stations for which there was a Sample Handling Problem


NF 12
Abundance (#/0.04 m2)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
100%
98%
96%
94%
92%
90%
88%
86%
84%
82%
1992
1993
1993
1993
1994
1994
1994
1995
1995
1995
1996
1996
1996
1997
1997
1997
1998
1998
1998
1999
1999
1999
2000
2000
2000
Abundance (total)
Proportion identified


NF 15
Abundance (#/0.04 m2)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
98%
96%
94%
92%
90%
88%
86%
1992
1994
1995
1996
1997
1998
1999
2000
Abundance (total)
Proportion identified


NF 21
Abundance (#/0.04 m2)
3500
3000
2500
2000
1500
1000
500
0
100%
98%
96%
94%
92%
90%
88%
86%
84%
1994
1995
1996
1997
1998
1999
2000
Abundance (total)
Proportion identified


NF 22
Abundance (#/0.04 m2)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
100%
95%
90%
85%
80%
75%
1994
1995
1996
1997
1998
1999
2000
Abundance (total)
Proportion identified


NF 24
Abundance (#/0.04 m2)
6000
5000
4000
3000
2000
1000
0
100%
98%
96%
94%
92%
90%
88%
86%
1994 1994 1994 1995 1995 1995 1996 1996 1996 1997 1997 1997 1998 1998 1998 1999 1999 1999 2000 2000 2000
Abundance (total)
Proportion identified

Appendix D-5

Twelve Most Abundant Taxa at Each Station
2000

NF

Station		Species	Mean	StDev	%	Cum %	1999 Rank
FF10	5001430506	PRIONOSPIO STEENSTRUPI	825	478.8	43.4%	43.4%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	132	13.1	6.9%	50.3%	4
	5001410208	ARICIDEA CATHERINAE	119	47.5	6.2%	56.6%	2
	5001230706	EXOGONE VERUGERA	77	117.5	4.1%	60.6%	6
	5502020206	NUCULA DELPHINODONTA	69	70.1	3.6%	64.3%	9
	5001310204	NINOE NIGRIPES	53	41.2	2.8%	67.1%	8
	50015003BAPT	MONTICELLINA BAPTISTEAE	53	31.0	2.8%	69.8%	12
	6169150702	UNCIOLA INERMIS	51	88.0	2.7%	72.5%	10
	6169150203	CRASSICOROPHIUM CRASSICORNE	44	76.2	2.3%	74.8%	11
	5515190113	ASTARTE UNDATA	41	17.8	2.2%	77.0%	
	5515220601	CERASTODERMA PINNULATUM	30	40.6	1.6%	78.6%	3
	5001230707	EXOGONE HEBES	25	33.0	1.3%	79.9%	7
			1,900				
FF12	5001430506	PRIONOSPIO STEENSTRUPI	1,021	122.5	42.1%	42.1%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	342	19.9	14.1%	56.2%	3
	5001640102	OWENIA FUSIFORMIS	337	175.6	13.9%	70.1%	2
	5001500305	THARYX ACUTUS	131	72.5	5.4%	75.5%	4
	5001310204	NINOE NIGRIPES	75	23.3	3.1%	78.7%	6
	50015003BAPT	MONTICELLINA BAPTISTEAE	74	32.6	3.1%	81.7%	9
	5001310140	SCOLETOMA HEBES	68	15.6	2.8%	84.5%	7
	5001430402	DIPOLYDORA SOCIALIS	50	26.0	2.1%	86.6%	
	5001410801	LEVINSENIA GRACILIS	36	13.6	1.5%	88.1%	
	5001500310	MONTICELLINA DORSOBRANCHIALIS	35	14.7	1.4%	89.5%	
	7700010203	PHORONIS ARCHITECTA	31	14.5	1.3%	90.8%	10
	5001431001	SPIOPHANES BOMBYX	28	8.5	1.2%	92.0%	8
			2,423				
FF13	5001430506	PRIONOSPIO STEENSTRUPI	1,492	411.3	38.8%	38.8%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	507	252.4	13.2%	52.0%	3
	5001500305	THARYX ACUTUS	462	121.2	12.0%	64.1%	7
	6169260217	PHOTIS POLLEX	394	108.8	10.2%	74.3%	4
	5001410208	ARICIDEA CATHERINAE	358	129.4	9.3%	83.7%	2
	6169020108	AMPELISCA ABDITA	82	73.8	2.1%	85.8%	
	5001430448	POLYDORA CORNUTA	80	70.3	2.1%	87.9%	
	5001700204	EUCHONE INCOLOR	45	14.8	1.2%	89.0%	
	43SP12	NEMERTEA SP. 12	38	4.0	1.0%	90.0%	
	5001430402	DIPOLYDORA SOCIALIS	34	5.5	0.9%	90.9%	
	5001130104	PHYLLODOCE MUCOSA	33	25.3	0.9%	91.8%	
	50015003BAPT	MONTICELLINA BAPTISTEAE	26	22.4	0.7%	92.4%	
	5001310140	SCOLETOMA HEBES	26	16.5	0.7%	93.1%	5
			3,841				
NF02	5001430506	PRIONOSPIO STEENSTRUPI	1,242		50.6%	50.6%	1
	5001500305	THARYX ACUTUS	418		17.0%	67.6%	3
	5001600402	MEDIOMASTUS CALIFORNIENSIS	150		6.1%	73.8%	9
NF02	5001430402	DIPOLYDORA SOCIALIS	88		3.6%	77.3%	7
	5001410208	ARICIDEA CATHERINAE	63		2.6%	79.9%	4

Station		Species	Mean	StDev	%	Cum %	1999 Rank
	5001600101	CAPITELLA CAPITATA COMPLEX	55		2.2%	82.2%	
	50020501SP01	POLYGORDIUS SP. A	49		2.0%	84.1%	5
	5001631102	EUCLYMENE COLLARIS	38		1.5%	85.7%	
	6169260217	PHOTIS POLLEX	35		1.4%	87.1%	
	5001431001	SPIOPHANES BOMBYX	29		1.2%	88.3%	8
	5515220601	CERASTODERMA PINNULATUM	21		0.9%	89.2%	10
	5001230707	EXOGONE HEBES	18		0.7%	89.9%	
			2,454				
NF04	6169150203	CRASSICOROPHIUM CRASSICORNE	359		22.3%	22.3%	7
	5001230707	EXOGONE HEBES	220		13.7%	35.9%	2
	500901SP01	ENCHYTRAEIDAE SP. 1	127		7.9%	43.8%	3 [1]
	5001230706	EXOGONE VERUGERA	89		5.5%	49.3%	8
	5515220601	CERASTODERMA PINNULATUM	77		4.8%	54.1%	5
	5001430402	DIPOLYDORA SOCIALIS	73		4.5%	58.7%	1
	6169150702	UNCIOLA INERMIS	69		4.3%	62.9%	4
	5001640102	OWENIA FUSIFORMIS	64		4.0%	66.9%	9
	6162020503	CHIRIDOTEA TUFTSI	61		3.8%	70.7%	
	5001431001	SPIOPHANES BOMBYX	57		3.5%	74.2%	
	6169260301	PROTOMEDEIA FASCIATA	37		2.3%	76.5%	11
	6169260217	PHOTIS POLLEX	34		2.1%	78.6%	
			1,611				
NF05	5001430506	PRIONOSPIO STEENSTRUPI	404		29.3%	29.3%	2
	5001430402	DIPOLYDORA SOCIALIS	186		13.5%	42.8%	1
	5001500307	APHELOCHAETA MARIONI	78		5.7%	48.4%	5
	5001230706	EXOGONE VERUGERA	63		4.6%	53.0%	
	5001600402	MEDIOMASTUS CALIFORNIENSIS	63		4.6%	57.5%	4
	6169150703	UNCIOLA IRRORATA	47		3.4%	60.9%	
	6169020306	HAPLOOPS FUNDIENSIS	43		3.1%	64.1%	3
	5001500305	THARYX ACUTUS	38		2.8%	66.8%	9
	6169420116	HARPINIA PROPINQUA	30		2.2%	69.0%	10
	5001410801	LEVINSENIA GRACILIS	24		1.7%	70.7%	7
	6169150308	ERICTHONIUS FASCIATUS	21		1.5%	72.2%	
	5001410208	ARICIDEA CATHERINAE	19		1.4%	73.6%	
			1,380				
NF07	5001430506	PRIONOSPIO STEENSTRUPI	1,494		47.1%	47.1%	1
	5001430707	SPIO LIMICOLA	277		8.7%	55.8%	3
	5001430402	DIPOLYDORA SOCIALIS	191		6.0%	61.8%	2
	5001600402	MEDIOMASTUS CALIFORNIENSIS	183		5.8%	67.6%	4
	5001700204	EUCHONE INCOLOR	161		5.1%	72.7%	5
	5502020206	NUCULA DELPHINODONTA	159		5.0%	77.7%	10
	5001310204	NINOE NIGRIPES	94		3.0%	80.6%	
NF07	5001230706	EXOGONE VERUGERA	61		1.9%	82.5%	11
	5001410801	LEVINSENIA GRACILIS	55		1.7%	84.3%	
	5001500307	APHELOCHAETA MARIONI	52		1.6%	85.9%	
	5507010203	CRENELLA GLANDULA	48		1.5%	87.4%	
	5001060101	PHOLOE MINUTA	32		1.0%	88.4%	8

Station		Species	Mean	StDev	%	Cum %	1999 Rank
	5001500305	THARYX ACUTUS	32		1.0%	89.4%	
			3,174				
NF08	5001430506	PRIONOSPIO STEENSTRUPI	681		36.3%	36.3%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	237		12.6%	49.0%	2
	5001430402	DIPOLYDORA SOCIALIS	167		8.9%	57.9%	
	5001700204	EUCHONE INCOLOR	109		5.8%	63.7%	3
	5001430707	SPIO LIMICOLA	101		5.4%	69.1%	
	43SP12	NEMERTEA SP. 12	71		3.8%	72.9%	
	5001410801	LEVINSENIA GRACILIS	71		3.8%	76.6%	5
	5001310204	NINOE NIGRIPES	51		2.7%	79.4%	4
	50015003BAPT	MONTICELLINA BAPTISTEAE	44		2.3%	81.7%	7
	5001400305	LEITOSCOLOPLOS ACUTUS	39		2.1%	83.8%	10
	5001500305	THARYX ACUTUS	35		1.9%	85.7%	8
	6171010302	MAYERELLA LIMICOLA	34		1.8%	87.5%	
			1,875				
NF09	5001430506	PRIONOSPIO STEENSTRUPI	633		23.2%	23.2%	1
	5001430402	DIPOLYDORA SOCIALIS	377		13.8%	37.1%	10
	5001430707	SPIO LIMICOLA	339		12.4%	49.5%	4
	5001600402	MEDIOMASTUS CALIFORNIENSIS	201		7.4%	56.9%	2
	50015003BAPT	MONTICELLINA BAPTISTEAE	112		4.1%	61.0%	12
	5502020206	NUCULA DELPHINODONTA	103		3.8%	64.8%	5
	5001630301	MALDANE SARSI	97		3.6%	68.4%	7
	5001310204	NINOE NIGRIPES	91		3.3%	71.7%	3
	5001410801	LEVINSENIA GRACILIS	75		2.8%	74.4%	11
	5001700204	EUCHONE INCOLOR	62		2.3%	76.7%	8
	5001410208	ARICIDEA CATHERINAE	58		2.1%	78.9%	5
	5001230706	EXOGONE VERUGERA	56		2.1%	80.9%	
	5507010203	CRENELLA GLANDULA	56		2.1%	83.0%	
			2,724				
NF10	5001430506	PRIONOSPIO STEENSTRUPI	510		22.2%	22.2%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	235		10.2%	32.4%	3
	5001410208	ARICIDEA CATHERINAE	183		8.0%	40.4%	5
	5001430707	SPIO LIMICOLA	156		6.8%	47.2%	4
	5001430402	DIPOLYDORA SOCIALIS	149		6.5%	53.7%	2
	5001310204	NINOE NIGRIPES	121		5.3%	59.0%	6
	50015003BAPT	MONTICELLINA BAPTISTEAE	113		4.9%	63.9%	9
	5001500307	APHELOCHAETA MARIONI	95		4.1%	68.0%	7
	6162020701	EDOTIA MONTOSA	88		3.8%	71.9%	
NF10	5001630301	MALDANE SARSI	87		3.8%	75.7%	
	5001700204	EUCHONE INCOLOR	86		3.7%	79.4%	11
	5001410801	LEVINSENIA GRACILIS	65		2.8%	82.2%	
			2,296				
NF12	5001430402	DIPOLYDORA SOCIALIS	519	440.4	21.3%	21.3%	3
	5001430506	PRIONOSPIO STEENSTRUPI	441	160.0	18.1%	39.4%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	275	100.2	11.3%	50.6%	2
	5001430707	SPIO LIMICOLA	264	171.5	10.8%	61.5%	5

Station		Species	Mean	StDev	%	Cum %	1999 Rank
	5001700204	EUCHONE INCOLOR	120	111.4	4.9%	66.4%	4
	50015003BAPT	MONTICELLINA BAPTISTEAE	92	19.1	3.8%	70.2%	9
	5001410208	ARICIDEA CATHERINAE	84	15.2	3.5%	73.6%	6
	5001410801	LEVINSENIA GRACILIS	81	18.6	3.3%	77.0%	10
	5001500305	THARYX ACUTUS	65	43.0	2.7%	79.6%	12
	5001500307	APHELOCHAETA MARIONI	54	5.6	2.2%	81.8%	8
	5001310204	NINOE NIGRIPES	45	7.5	1.9%	83.7%	7
	5001600101	CAPITELLA CAPITATA COMPLEX	44	10.0	1.8%	85.5%	
			2,440				
NF13	6169150203	CRASSICOROPHIUM CRASSICORNE	402		22.3%	22.3%	3
	500901SP01	ENCHYTRAEIDAE SP. 1	274		15.2%	37.5%	7 [1]
	5001230706	EXOGONE VERUGERA	197		10.9%	48.4%	10
	5001230707	EXOGONE HEBES	168		9.3%	57.7%	9
	6157020402	TANAISSUS PSAMMOPHILUS	101		5.6%	63.3%	
	50020501SP01	POLYGORDIUS SP. A	77		4.3%	67.6%	2
	5001430506	PRIONOSPIO STEENSTRUPI	63		3.5%	71.1%	4
	5001430402	DIPOLYDORA SOCIALIS	61		3.4%	74.4%	5
	5515220601	CERASTODERMA PINNULATUM	52		2.9%	77.3%	6
	6169150702	UNCIOLA INERMIS	36		2.0%	79.3%	1
	50090210SP01	ADELODRILUS SP. 1	34		1.9%	81.2%	
	6169260217	PHOTIS POLLEX	28		1.6%	82.8%	
			1,804				
NF14	5001230706	EXOGONE VERUGERA	683		19.8%	19.8%	6
	5001230707	EXOGONE HEBES	461		13.4%	33.2%	10
	6169150702	UNCIOLA INERMIS	379		11.0%	44.2%	8
	6169150203	CRASSICOROPHIUM CRASSICORNE	230		6.7%	50.8%	
	500901SP01	ENCHYTRAEIDAE SP. 1	195		5.7%	56.5%	
	5507010203	CRENELLA GLANDULA	192		5.6%	62.0%	
	6169150308	ERICTHONIUS FASCIATUS	187		5.4%	67.5%	
	5001430506	PRIONOSPIO STEENSTRUPI	130		3.8%	71.2%	1
	6169260301	PROTOMEDEIA FASCIATA	122		3.5%	74.8%	9
	5001700205	EUCHONE ELEGANS	110		3.2%	78.0%	
	5001600402	MEDIOMASTUS CALIFORNIENSIS	101		2.9%	80.9%	2
	5515220601	CERASTODERMA PINNULATUM	99		2.9%	83.8%	4
			3,449				
NF15	5001430506	PRIONOSPIO STEENSTRUPI	783		30.6%	30.6%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	208		8.1%	38.7%	2
	5001410208	ARICIDEA CATHERINAE	207		8.1%	46.8%	4
	5001640102	OWENIA FUSIFORMIS	202		7.9%	54.6%	3
	5001230707	EXOGONE HEBES	186		7.3%	61.9%	6
	5001430402	DIPOLYDORA SOCIALIS	186		7.3%	69.2%	
	5001700204	EUCHONE INCOLOR	83		3.2%	72.4%	5
	5001430707	SPIO LIMICOLA	78		3.0%	75.4%	9
	5001431001	SPIOPHANES BOMBYX	73		2.8%	78.3%	8
	6162020701	EDOTIA MONTOSA	66		2.6%	80.9%	
	5502020206	NUCULA DELPHINODONTA	54		2.1%	83.0%	

Station		Species	Mean	StDev	%	Cum %	1999 Rank
	5001230706	EXOGONE VERUGERA	52		2.0%	85.0%	
			2,562				
NF16	5001430506	PRIONOSPIO STEENSTRUPI	1,152		54.8%	54.8%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	217		10.3%	65.2%	2
	5001410801	LEVINSENIA GRACILIS	105		5.0%	70.2%	5
	5001310204	NINOE NIGRIPES	103		4.9%	75.1%	3
	5001700204	EUCHONE INCOLOR	102		4.9%	79.9%	4
	5001500305	THARYX ACUTUS	57		2.7%	82.6%	10
	43SP12	NEMERTEA SP. 12	44		2.1%	84.7%	
	5001500310	MONTICELLINA DORSOBRANCHIALIS	35		1.7%	86.4%	8
	50015003BAPT	MONTICELLINA BAPTISTEAE	31		1.5%	87.9%	
	5105080202	ILYANASSA TRIVITTATA	28		1.3%	89.2%	
	50013614CAEC	PAROUGIA CAECA	27		1.3%	90.5%	6
	5502020206	NUCULA DELPHINODONTA	19		0.9%	91.4%	
			2,101				
NF17	6169150203	CRASSICOROPHIUM CRASSICORNE	298	119.7	23.7%	23.7%	1
	6169150801	PSEUDUNCIOLA OBLIQUUA	200	57.6	15.9%	39.7%	2
	5001230707	EXOGONE HEBES	96	37.7	7.7%	47.3%	11
	5001430402	DIPOLYDORA SOCIALIS	85	37.0	6.8%	54.1%	
	5515220601	CERASTODERMA PINNULATUM	81	21.3	6.5%	60.6%	6
	50020501SP01	POLYGORDIUS SP. A	70	19.5	5.6%	66.2%	3
	5001431001	SPIOPHANES BOMBYX	61	22.6	4.9%	71.1%	10
	6162020503	CHIRIDOTEA TUFTSI	49	33.5	3.9%	75.0%	
	500901SP01	ENCHYTRAEIDAE SP. 1	38	18.5	3.1%	78.0%	
	6169420702	PHOXOCEPHALUS HOLBOLLI	36	11.4	2.9%	80.9%	
	8155020101	ECHINARACHNIUS PARMA	32	10.2	2.6%	83.5%	7
	6157020402	TANAISSUS PSAMMOPHILUS	16	4.2	1.3%	84.8%	
			1,254				
NF18	5001430506	PRIONOSPIO STEENSTRUPI	617		27.5%	27.5%	1
	6169260301	PROTOMEDEIA FASCIATA	511		22.8%	50.3%	2
	6169420116	HARPINIA PROPINQUA	130		5.8%	56.1%	
	5001600402	MEDIOMASTUS CALIFORNIENSIS	101		4.5%	60.6%	3
NF18	6169150308	ERICTHONIUS FASCIATUS	91		4.1%	64.7%	
	5001410208	ARICIDEA CATHERINAE	76		3.4%	68.1%	4
	5001230707	EXOGONE HEBES	54		2.4%	70.5%	6
	5515190113	ASTARTE UNDATA	54		2.4%	72.9%	
	5001310204	NINOE NIGRIPES	52		2.3%	75.2%	5
	5001230706	EXOGONE VERUGERA	44		2.0%	77.2%	7
	6169150203	CRASSICOROPHIUM CRASSICORNE	36		1.6%	78.8%	
	5001410801	LEVINSENIA GRACILIS	34		1.5%	80.3%	
			2,242				
NF19	5001430506	PRIONOSPIO STEENSTRUPI	1,373		41.4%	41.4%	1
	5001430402	DIPOLYDORA SOCIALIS	414		12.5%	53.8%	3
	5502020206	NUCULA DELPHINODONTA	330		9.9%	63.8%	6
	5001600402	MEDIOMASTUS CALIFORNIENSIS	174		5.2%	69.0%	2
	5001700204	EUCHONE INCOLOR	158		4.8%	73.8%	4

Station		Species	Mean	StDev	%	Cum %	1999 Rank
	5001500307	APHELOCHAETA MARIONI	110		3.3%	77.1%	11
	5001230706	EXOGONE VERUGERA	87		2.6%	79.7%	12
	5001230707	EXOGONE HEBES	70		2.1%	81.8%	7
	5001310204	NINOE NIGRIPES	55		1.7%	83.5%	9
	5001640102	OWENIA FUSIFORMIS	53		1.6%	85.1%	
	6162020701	EDOTIA MONTOSA	46		1.4%	86.4%	8
	5515190113	ASTARTE UNDATA	44		1.3%	87.8%	
			3,320				
NF20	5001430506	PRIONOSPIO STEENSTRUPI	1,110		49.1%	49.1%	1
	5001410208	ARICIDEA CATHERINAE	355		15.7%	64.9%	2
	5001600402	MEDIOMASTUS CALIFORNIENSIS	202		8.9%	73.8%	3
	5001310204	NINOE NIGRIPES	83		3.7%	77.5%	4
	5001410801	LEVINSENIA GRACILIS	46		2.0%	79.5%	6
	5001500305	THARYX ACUTUS	39		1.7%	81.2%	9
	43SP12	NEMERTEA SP. 12	27		1.2%	82.4%	
	50015003BAPT	MONTICELLINA BAPTISTEAE	27		1.2%	83.6%	7
	5507010203	CRENELLA GLANDULA	26		1.2%	84.8%	
	5001230706	EXOGONE VERUGERA	22		1.0%	85.7%	
	5001310140	SCOLETOMA HEBES	21		0.9%	86.7%	
	5001230707	EXOGONE HEBES	20		0.9%	87.6%	11
			2,259				
NF21	5001430506	PRIONOSPIO STEENSTRUPI	836		39.4%	39.4%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	302		14.2%	53.6%	3
	5001430707	SPIO LIMICOLA	297		14.0%	67.6%	2
	5001700204	EUCHONE INCOLOR	153		7.2%	74.8%	4
	5001310204	NINOE NIGRIPES	86		4.0%	78.8%	5
	5001410801	LEVINSENIA GRACILIS	67		3.2%	82.0%	8
	50015003BAPT	MONTICELLINA BAPTISTEAE	47		2.2%	84.2%	6
	5502020206	NUCULA DELPHINODONTA	36		1.7%	85.9%	9
NF21	5001400305	LEITOSCOLOPLOS ACUTUS	29		1.4%	87.2%	
	5001500305	THARYX ACUTUS	26		1.2%	88.5%	
	5001630301	MALDANE SARSI	20		0.9%	89.4%	
	5001410217	ARICIDEA QUADRILOBATA	18		0.8%	90.3%	
	5103200108	ALVANIA CASTANEA	18		0.8%	91.1%	
			2,124				
NF22	5001600402	MEDIOMASTUS CALIFORNIENSIS	235		19.5%	19.5%	2
	5001700204	EUCHONE INCOLOR	137		11.3%	30.8%	1
	5001430707	SPIO LIMICOLA	127		10.5%	41.3%	6
	5001410801	LEVINSENIA GRACILIS	109		9.0%	50.3%	4
	5001310204	NINOE NIGRIPES	93		7.7%	58.0%	5
	5001430506	PRIONOSPIO STEENSTRUPI	86		7.1%	65.1%	3
	5001500305	THARYX ACUTUS	78		6.5%	71.6%	8
	5001430402	DIPOLYDORA SOCIALIS	46		3.8%	75.4%	
	5001410217	ARICIDEA QUADRILOBATA	41		3.4%	78.8%	
	50015003BAPT	MONTICELLINA BAPTISTEAE	38		3.1%	82.0%	10
	5001500310	MONTICELLINA DORSOBRANCHIALIS	24		2.0%	83.9%	

Station		Species	Mean	StDev	%	Cum %	1999 Rank
	5001500307	APHELOCHAETA MARIONI	20		1.7%	85.6%	7
			1,208				
NF23	5001230707	EXOGONE HEBES	209		17.4%	17.4%	4
	5001431001	SPIOPHANES BOMBYX	137		11.4%	28.8%	12
	6169150203	CRASSICOROPHIUM CRASSICORNE	126		10.5%	39.3%	8
	6169150702	UNCIOLA INERMIS	118		9.8%	49.2%	1
	50020501SP01	POLYGORDIUS SP. A	107		8.9%	58.1%	
	5001500305	THARYX ACUTUS	75		6.3%	64.3%	
	500901SP01	ENCHYTRAEIDAE SP. 1	50		4.2%	68.5%	5 [2]
	5001430402	DIPOLYDORA SOCIALIS	49		4.1%	72.6%	2
	5515220601	CERASTODERMA PINNULATUM	34		2.8%	75.4%	7
	5001230706	EXOGONE VERUGERA	33		2.8%	78.2%	6
	5001430506	PRIONOSPIO STEENSTRUPI	23		1.9%	80.1%	3
	6157020402	TANAISSUS PSAMMOPHILUS	17		1.4%	81.5%	
			1,200				
NF24	5001430506	PRIONOSPIO STEENSTRUPI	1,436	1,157.4	55.6%	55.6%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	314	132.8	12.2%	67.8%	2
	5001410208	ARICIDEA CATHERINAE	245	145.1	9.5%	77.3%	4
	5001410801	LEVINSENIA GRACILIS	110	17.6	4.3%	81.6%	5
	5001700204	EUCHONE INCOLOR	72	51.2	2.8%	84.4%	3
	5001430707	SPIO LIMICOLA	54	26.5	2.1%	86.5%	9
	5001500305	THARYX ACUTUS	50	42.5	1.9%	88.4%	6
	5001310204	NINOE NIGRIPES	42	12.1	1.6%	90.1%	8
NF24	6162020701	EDOTIA MONTOSA	17	15.0	0.7%	90.7%	
	5001130205	ETEONE LONGA	16	13.0	0.6%	91.3%	
	50015003BAPT	MONTICELLINA BAPTISTEAE	16	8.4	0.6%	92.0%	
	5502020206	NUCULA DELPHINODONTA	16	11.9	0.6%	92.6%	
			2,581				

[1] Listed as *GRANIA POSCLITELLO LONGIDUCTA* in 1999.
[2] Listed as *ADELODRILUS* SP. 2 in 1999.

Station		Species	Mean	StDev	%	Cum %	1999 Rank
FF01A	5001430506	PRIONOSPIO STEENSTRUPI	1,889	346.5	63.5%	63.5%	1
	5001431001	SPIOPHANES BOMBYX	147	21.4	4.9%	68.4%	3
	5502020206	NUCULA DELPHINODONTA	144	36.5	4.8%	73.2%	6
	6162020701	EDOTIA MONTOSA	67	14.5	2.2%	75.5%	
	5001410801	LEVINSENIA GRACILIS	65	25.2	2.2%	77.7%	8
	5001700204	EUCHONE INCOLOR	56	10.3	1.9%	79.6%	5
	5001600402	MEDIOMASTUS CALIFORNIENSIS	54	1.5	1.8%	81.4%	12
	5001310204	NINOE NIGRIPES	39	9.0	1.3%	82.7%	
	5001500305	THARYX ACUTUS	37	26.4	1.3%	83.9%	10
	5001410208	ARICIDEA CATHERINAE	36	9.6	1.2%	85.1	
	5515020325	THYASIRA GOULDI	22	12.2	1.1%	86.2	
	50020501SP01	POLYGORDIUS SP. A	27	23.6	0.9%	87.1	
			2,975				
FF04	5001520101	COSSURA LONGOCIRRATA	255	40.1	22.2%	22.2%	2
	50015004MB	CHAETOZONE SETOSA MB	131	56.9	11.4%	33.6%	4
	5001410801	LEVINSENIA GRACILIS	85	8.4	7.4%	41.0%	5
	5001410217	ARICIDEA QUADRILOBATA	71	13.5	6.2%	47.2%	3
	5001600402	MEDIOMASTUS CALIFORNIENSIS	62	26.7	5.4%	52.6%	7
	5001700204	EUCHONE INCOLOR	59	39.1	5.1%	57.7%	1
	5001100401	PARAMPHINOME JEFFREYSII	57	74.7	5.0%	62.7%	8
	5009020906	TUBIFICOIDES APECTINATUS	56	15.8	4.8%	67.5%	
	5001670701	ANOBOTHRUS GRACILIS	48	24.2	4.2%	71.7%	5
	5001430506	PRIONOSPIO STEENSTRUPI	29	3.2	2.5%	74.2%	9
	43SP12	NEMERTEA SP. 12	24	6.4	2.1%	76.3%	
	5515020325	THYASIRA GOULDI	22	9.5	1.9%	78.3%	
			1,149				
FF05	5001700204	EUCHONE INCOLOR	489	158.0	22.7%	22.7%	1
	5001430707	SPIO LIMICOLA	189	37.2	8.7%	31.4%	4
	5001670701	ANOBOTHRUS GRACILIS	179	76.6	8.3%	39.7%	5
	5001430506	PRIONOSPIO STEENSTRUPI	167	82.3	7.7%	47.4%	3
	5001410217	ARICIDEA QUADRILOBATA	156	35.7	7.2%	54.6%	6
	5001600402	MEDIOMASTUS CALIFORNIENSIS	110	24.2	5.1%	59.7%	7
	50015004MB	CHAETOZONE SETOSA MB	96	26.3	4.5%	64.2%	
	5001430402	DIPOLYDORA SOCIALIS	79	40.2	3.7%	67.9%	2
	5001410801	LEVINSENIA GRACILIS	73	17.4	3.4%	71.2%	9
	5515020325	THYASIRA GOULDI	62	10.8	2.9%	74.1%	8 [3]
	5001520101	COSSURA LONGOCIRRATA	60	32.4	2.8%	76.9%	10
	5520080209	THRACIA CONRADI	44	11.5	2.0%	78.9%	
			2,159				
FF06	5001520101	COSSURA LONGOCIRRATA	114	53.9	19.3%	19.3%	2
	6169420116	HARPINIA PROPINQUA	108	28.6	18.3%	37.6%	3
	6169060702	LEPTOCHEIRUS PINGUIS	62	57.2	10.4%	48.0%	1
	5001600402	MEDIOMASTUS CALIFORNIENSIS	57	18.5	9.6%	57.5%	4
FF06	5001410801	LEVINSENIA GRACILIS	35	2.5	6.0%	63.5%	10
	5103202113	ONOBA PELAGICA	19	9.5	3.2%	66.7%	9

Station		Species	Mean	StDev	%	Cum %	1999 Rank
	5502020205	NUCULA ANNULATA	18	3.0	3.0%	69.8%	
	6169345201	ORCHOMENELLA MINUTA	18	14.7	3.0%	72.7%	6
	5001310204	NINOE NIGRIPES	15	5.5	2.6%	75.3%	7
	5502020206	NUCULA DELPHINODONTA	14	10.0	2.3%	77.6%	11
	5001430506	PRIONOSPIO STEENSTRUPI	13	8.5	2.3%	79.9%	
	5001410208	ARICIDEA CATHERINAE	12	14.8	2.0%	81.9%	8
			592				
FF07	5001520101	COSSURA LONGOCIRRATA	1,368	477.8	37.4%	37.4%	2
	5001700204	EUCHONE INCOLOR	687	328.8	18.8%	56.1%	1
	500902SP02	TUBIFICIDAE SP. 2	440	319.4	12.0%	68.2%	4
	5001600402	MEDIOMASTUS CALIFORNIENSIS	257	28.6	7.0%	75.2%	3
	5001500305	THARYX ACUTUS	145	6.6	4.0%	79.1%	9
	5001410217	ARICIDEA QUADRILOBATA	122	53.3	3.3%	82.5%	5
	5001420103	APISTOBRANCHUS TYPICUS	109	53.1	3.0%	85.4%	
	5001310204	NINOE NIGRIPES	84	10.8	2.3%	87.7%	7
	5001410208	ARICIDEA CATHERINAE	60	74.9	1.6%	89.4%	6
	5001430506	PRIONOSPIO STEENSTRUPI	51	6.1	1.4%	90.8%	8
	50013614 CAEC	PAROUGIA CAECA	49	14.5	1.3%	92.1%	
	5502020206	NUCULA DELPHINODONTA	27	10.4	0.7%	92.8%	
			3,660				
FF09	5001430506	PRIONOSPIO STEENSTRUPI	628	211.9	31.8%	31.8%	2
	5001430402	DIPOLYDORA SOCIALIS	248	40.2	12.6%	44.4%	1
	5001700204	EUCHONE INCOLOR	133	55.1	6.8%	51.2%	3
	5001410801	LEVINSENIA GRACILIS	84	9.5	4.3%	55.4%	4
	5502020206	NUCULA DELPHINODONTA	81	27.2	4.1%	59.5%	9
	5001670701	ANOBOTHRUS GRACILIS	73	24.3	3.7%	63.2%	8
	5515020325	THYASIRA GOULDI	64	4.0	3.3%	66.5%	5 [3]
	5001600402	MEDIOMASTUS CALIFORNIENSIS	49	3.5	2.5%	69.0%	7
	6169420116	HARPINIA PROPINQUA	34	5.9	1.7%	70.7%	10
	5520080209	THRACIA CONRADI	29	3.6	1.5%	72.2%	
	5001410217	ARICIDEA QUADRILOBATA	27	12.1	1.4%	73.6%	
	5515190113	ASTARTE UNDATA	26	9.0	1.3%	74.9%	
			1,972				
FF11	5001430506	PRIONOSPIO STEENSTRUPI	1,179	424.0	55.0%	55.0%	1
	5001410801	LEVINSENIA GRACILIS	206	91.5	9.6%	64.6%	5
	5001410217	ARICIDEA QUADRILOBATA	185	110.0	8.6%	73.2%	2
	5001700204	EUCHONE INCOLOR	97	31.8	4.5%	77.7%	3
	5001520101	COSSURA LONGOCIRRATA	75	33.2	3.5%	81.2%	
	5009020906	TUBIFICOIDES APECTINATUS	56	19.0	2.6%	83.8%	8
	50015004MB	CHAETOZONE SETOSA MB	38	16.2	1.8%	85.6%	
	50013614CAEC	PAROUGIA CAECA	37	21.5	1.7%	87.3%	6
	5001640402	GALATHOWENIA OCULATA	35	6.4	1.6%	89.0%	10
	5001670701	ANOBOTHRUS GRACILIS	32	17.0	1.5%	90.5%	4
	5001430707	SPIO LIMICOLA	21	11.6	1.0%	91.5%	
FF11	5001600402	MEDIOMASTUS CALIFORNIENSIS	21	6.7	1.0%	92.5%	
			2,145				

Station		Species	Mean	StDev	%	Cum %	1999 Rank
FF14	5001430707	SPIO LIMICOLA	200	93.9	13.6%	13.6%	2
	5001430506	PRIONOSPIO STEENSTRUPI	140	105.5	9.5%	23.1%	3
	5001410217	ARICIDEA QUADRILOBATA	112	27.0	7.6%	30.6%	4
	50015004MB	CHAETOZONE SETOSA MB	110	21.2	7.5%	38.1%	12
	5001640402	GALATHOWENIA OCULATA	91	21.6	6.2%	44.3%	
	5009020906	TUBIFICOIDES APECTINATUS	88	29.9	6.0%	50.3%	6
	5001410801	LEVINSENIA GRACILIS	73	10.5	4.9%	55.2%	8
	5001670701	ANOBOTHRUS GRACILIS	56	35.2	3.8%	59.0%	9
	5001590101	STERNASPIS SCUTATA	55	21.6	3.7%	62.7%	9
	5502020206	NUCULA DELPHINODONTA	51	20.8	3.4%	66.2%	
	5001600402	MEDIOMASTUS CALIFORNIENSIS	47	25.5	3.2%	69.3%	5
	5001520101	COSSURA LONGOCIRRATA	46	18.0	3.1%	72.5%	7
			1,475				

[3] Listed as *THYASIRA FLEXUOSA* in 1999.

APPENDIX E-1

Hardbottom 2000 – Stills Summary

Transect	1	1	1	1	1	2	2	2	2	4	4	4	4	6	6	7	7	8	8	9	10	Diff #44	Total
Waypoint	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	1	2	1	2	1	1		
# Frames	27	32	33	35	33	30	34	33	29	34	33	32	32	34	28	33	32	32	30	31	32	32	701
Depth (meters)	27	22	19	20	27	26	29	26	31	31	28	29	21	33	30	25	24	25	24	25	25	34	
Substrate	b+mx	b+c	b+c	b+mx	mx	mx	mx+b	b+mx	mx	cp+mx	mx	c+mx	b	mx	mx	b+c	b+mx	mx	mx	b+mx	b	d+rr	
Sediment drape	mh	l	vl	l	m	m	h	h	h	mh	m	mh	l	h	m	lm	m	lm	lm	mh	h	h	
Coralline algae (average% cover)	16	79	86	77	37	14	10	8	1	11	47	16	71	2	36	52	36	49	58	38	3	0	
Ptilota serrata			0-r					f-c								0-a	c-a			c			
Hydroids	f-a	f-c	f-c	f-c	f-c	r-a	c	c-a	f-c	r-a	f-c	f-c	f-c	f-a	f-c	c	f-c	f-c	f-c	c-a	c-a	a	
Spirorbid/barnacle complex	f-c	f-c	f-c	f	f-c	f-c	f-c	f-c	r-c	f-c	c	f-c	r-c	f	f-c	f-a	c	f-c	f-c	f-c	0-a	0-f	
Rhodymenia palmata	110		1			19		155			2	1	3			284	303			143	61		1082
Agarum cribrosum			1					7								14	74			15	5		116
sponge	1	2		1						2	1	1	1			4		2	7	1			23
Aplysilla sulfurea		3	2			5	5	8	3	14	27	35	2	13	15	11				3	30		176
Halichondria panicea	7	2	1		5		2	1	5	2	5	2	8	3	7	4	8			5	19		86
Haliclona spp.									5			1										1	7
Suberites spp.	5	4	4		7	6	54	2	40	11	37	19		34	19				1	3			246
white divided sponge on brachiopod						1	2		37	19	5			1		2	48			9	20		144
orange/tan encrusting sponge	46	25	30	11	43	31	130	128	73	85	120	66	36	30	71	50	87	42	35	75	194	17	1425
orange encrusting sponge	37	19	38	25	137	26	36	40	13	41	17	12	23	17	16	64	75	21	6	59	13	1	736
gold encrusting sponge				1																			1
tan encrusting sponge		4	1	2			2		1														10
pink fuzzy encrusting sponge			34	10	17		4		7	1	3	27	5	66	4	33	25	25	17	7			285
dark red/brown encrusting sponge	1				1				2														4
white translucent sponge	7	2	5	8	25	10	128	146	78	78	53	6	8	11	10	27	25	16	24	20	51	15	753
cream encrusting sponge	3	5	3	17	15	7	8	4	6	1	11	3	1	13	11	23	4	18	7	7		18	185
Phakellia spp.									1														1
rust-cream encrusting sponge				2														7					9
Melonanchora elliptica	1			1			12		2		1				1					2		2	22
general encrusting organism	3	6	3	1	1	10	42	17	9	26	14	15	8	37	35	23	14	19	15	23	63	7	391
Obelia geniculata								5								7	24			2	2		40
Corymorpha pendula														1									1
anemone	1	3	8	2	4		6			6	16	1		3	14		4	4	5				77

Metridium senile	2	20	64	2			3		1				282		3	8	7				8	424	824
Urticina felina		1	1		1		1								1	1							6
Cerianthus borealis										3													3
Gersemia rubiformis																					159		159
Campanularia sp.													11										11
gastropod										1													1
Tonicella marmorea		4	17										2				1		2				26
Crepidula plana					250		520		30			24	12		20	30		31					917
Coryphella sp.														1									1
Buccinum undatum						1								1		2				1	1		6
nudibranch			1																			4	5
bivalve															1								1
Modiolus modiolus	14	22	208	157	13	4	21	9	1	2	10	2	67	10	37	120	231	54	36	98	77		1193
Placopecten magellanicus						2				5				1									8
Arctica islandica							2			2	3	1		7	1					3			19
Polymastia?	7									2													9
Balanus spp.	3	22	12		14	9	7	1			3	1	15	6	4	1		1	12	3			114
Homarus americanus			2				1										1	1					5
Cancer spp.				1	1		2			1	2	5		3	1			2			1	1	20
Strongylocentrotus droebachiensis	1	28	26	10	13		2	1			3	2	29	2	13	5	2	1	14	2	3	2	159
starfish																	1						1
juvenile Asterias	111	86	261	162	88	67	110	78	46	134	237	88	265	89	164	173	292	30	117	140	245	120	3103
Asterias vulgaris	2	13	5	3	9	3	11	3	1	34	24	25	6	36	6	28	5	8	6	2	14	48	292
Henricia sanguinolenta	12	33	43	18	13	15	31	47	14	21	21	8	36	9	13	25	63	11	14	31	58	23	559
Crossaster papposus										1	1					2							4
Pteraster militaria															1						1		2
Psolus fabricii		2	20	8	16		3	1			1		2	2	21			15	21				112
tunicate				1																			1
Aplidium spp.	45	43		84	129	59	47	9	10	34	37	2	15	55	149	3		64	142	45	10		982
Dendrodoa carnea	3	149	132	75	89	9	17	39	4	3	90	35	74	13	32	58	85	61	45	36	34	9	1092
Didemnum albidum	83	24	50	21	28	23	6			3	14		18	36	4	66	149	12	2	81	61	48	729
Halocynthia pyriformis	1	1	4					2			2				1	6	2			1	14	91	125
Boltenia ovifera	1											1					2						4
clear globular tunicate											2												2
white Halocynthia pyriformis			1		1	3							3			1	6					150	165
bryozoan	1																						1

Membranipora spp.																	43						43
?*Bugula* spp.	3		16		1		16	10		6	9		3			28	78				6	154	330
red crust bryozoan	13	1	1								32		1	16								32	96
Myxicola infundibulum	11	11	7	2	7	6	19	15	3	14	8	9	2	10	7		11	1	9	5	26	2	185
Terebratulina septentrionalis						1	7	13	97	68	12		16		1	3	325			21	70		634
fish		1					1					1						1					4
Tautogolabrus adspersus	20	90	81	11	13	21	9	99	3	14	104	9	23	2	12	157	112	2	4	11	29	7	833
Myoxocephalus spp.		1		1	3		1			1		3			1			1	1				13
Macrozoarces americanus								1					2										3
Pseudopleuronectes americanus							1							1	1								3
Total	555	627	1083	637	944	338	1269	841	492	635	927	405	979	529	697	1263	2107	450	542	854	1275	1176	

APPENDIX E-2

Hardbottom 2000 – Video Summary

Table E-2.

Transect	1	1	1	1	1	2	2	2	2	4	4	4	4/6	6	6	6	7	7	8	8	9	10	Diffuser	
Waypoint	1	2	3	4	5	1	2	3	4	1	2	3	4	1 (rep1)	1 (rep2)	2	1	2	1	2	1	1	#44	
Start time	9:18	10:55	11:48	12:39	13:28	14:18	15:05	15:48	16:29	9:44,10:11	10:38	12:14	11:30	13:34,14:11	9:51	10:50	8:03	8:47	7:47	8:49	17:28	18:28	12:17	
End time	9:55	11:17	12:14	13:01	13:49	14:38	15:25	16:08	16:51	10:05,10:14	10:58	12:36	11:51	13:38,14:28	10:12	11:11	8:25	9:08	8:10	9:12	17:47	18:51	12:30	
Minutes	27	22	26	22	21	20	20	20	22	24	20	22	21	21	21	21	22	21	23	23	19	19	13	
Start depth (ft)	87	77	66	73	94	87	105	86	104	109	98	96	75	102,104	110	101	86	84	86	84	88	79	111	
End depth (ft)	87	74	61	63	82	84	99	83	101	97	90	96	69	100,89	106	100	80	80	80	80	85	82	111	
Primary substrate	mix	b+c	b+c	c+b	c+ob	mix	c+b	b+c	mix	mix	mix	c+ob	b+c	mix	cp+mix	mix	mix	b+c	mix	mix	b+c	b+c	d+rr	
Sediment drape	m	l	l	l	m	l-mh	h	h	h	h	m	mh	l	h	h	m	m	m	lm	lm	h	h	h	
Relief	lm	m	m	lm	lm	lm	m	m	m	lm	lm	lm	mh	lm	l	m	m	mh	lm	lm	mh	h	m	
Coralline algae	25	80	90	80	20-60	20	15	10		15	50	25	80	1	2	35	20-80	50	50	60	40			
Ptilota serrata								f-c									c	c-a			c-a			
hydroids	c	f-c	f-c	f-c	c	f-c	c	c-a	c-a	r-c	f-c	c	f-c	c-a	c	c	c	c	c	f-c	c-a	a	a	
spirorbids/small barnacles	f	f-c	f	f	c	c	c	f-c	f	f	c	f-c	f-c	f	f	c	f-c	c	f-c	f-c	f-c	a	r	
Rhodymenia palmata	f-c		r			r		c					r				c-a	c			a	c		
Agarum cribrosum	2		1					27									a	a			26	12		
Sponge	3									1														4
Halichondria panicea	7	3	1		3	2	3	1	4		5	6	9	4		1	7	13		1		17		87
Haliclona spp.	4								5			1		3	3					1			1	18
sponge? (*Polymastia*?)	11									1														12
Suberites spp.	f	f			f	f	c	f	c	r-c	c-a	c		f-c	f-c	c					f			
Melonanchora elliptica	3					2	6	2	1		1					2	1	1			1	2	1	23
Phakellia sp.									1															1
white divided sponge									a	0-a	f							a			c	c		
Campanularia sp.													c											
Obelia geniculata								c									a					c		
Metridium senile	2	9	c	2	3				1	f			a				7	a			1	c	a	25
Urticina felina			1	1	5	2	5	2	2	1	3	1		2	2	6			1					34
Cerianthus borealis									1	5														6
Gersemia rubiformis																						a		
Crepidula plana							a																	
Gastropod															1									1
Buccinum undatum	1														1				1					3

Neptunea decemcostata													1								1			2
Ilyanassa trivittata														1										1
Modiolus modiolus	f	f-c	a	c-a	f	f	f	c	f				a	f-c			c	a	f	c	a	a		
Placopecten magellanicus					1	6			1	7	2	3		7	14				2	2		1	3	49
Balanus spp.		c			c																			
Homarus americanus		1	2				2	3					2	1			1	1	3	1		1		18
Cancer spp.	2	1		2	2	2	4	1	1	1	3	12		23	16	2		1	4	6	1	1	20	105
hermit crab																							1	1
Strongylocentrotus droebachiensis		c		f-c	c	r	f	f			f	f	c	r	r	c	c	r	f	c	f	f		
juvenile *Asterias*	c	c	a	c-a	c	c	f-c	c	c	c	c	c	a	f-c	c	a	c	a	f	f	a	a	c	
Asterias vulgaris	f	c	r	r	f	f	f-c	r	f	c	a	c	f	c	c	c	c	f	f	f	f	c	c	
Henricia sanguinolenta	f	c	c	f	c	f-c	c	c	c	f	c	f	c	r	f	f	c	c	f	f	c	c	r	
Crossaster papposus										2	1													3
Porania insignis	1											2												3
Pteraster militaris																1								1
Psolus fabricii		f	c	f	c	r	f								f	c			f	c				
Aplidium spp.	c	c		c	a	f	f	r		r-c	c		f	c	f-c	c			c	c	f	f		
Halocynthia pyriformis	6	8	6		2		3	6					c			1	3	9	1		c*	c	a	45
Boltenia ovifera	2							1									1	3			1			8
Membranipora sp.																		a						
Myxicola infundibulum	f-c	f			f	f	c	c	c	r		f		c				c			f	c		
Terebratulina septentrionalis									a	0-a	f							a			c	c		
Tautogolabrus adspersus	c	c-a	a	f	f	r-c	f-c	a	f	f-c	c-a	f	a	r	f	c	a	a	f	f	c	a	c	
Myoxocephalus spp.	4	1		4	4	3	2		4	2	2	5	1	4	5	3			1	4	2	1		52
Macrozoarces americanus		1						1			1													3
Psuedopleuronectes americanus			2				1						2	1	2	1			1				1	11
Gadus morhua	1		7							1			1				1	1						12
whelk egg case		1		4	2		1										5	3			3	1		20

APPENDIX F

Selected Plates from Survey BH001 Hardbottom

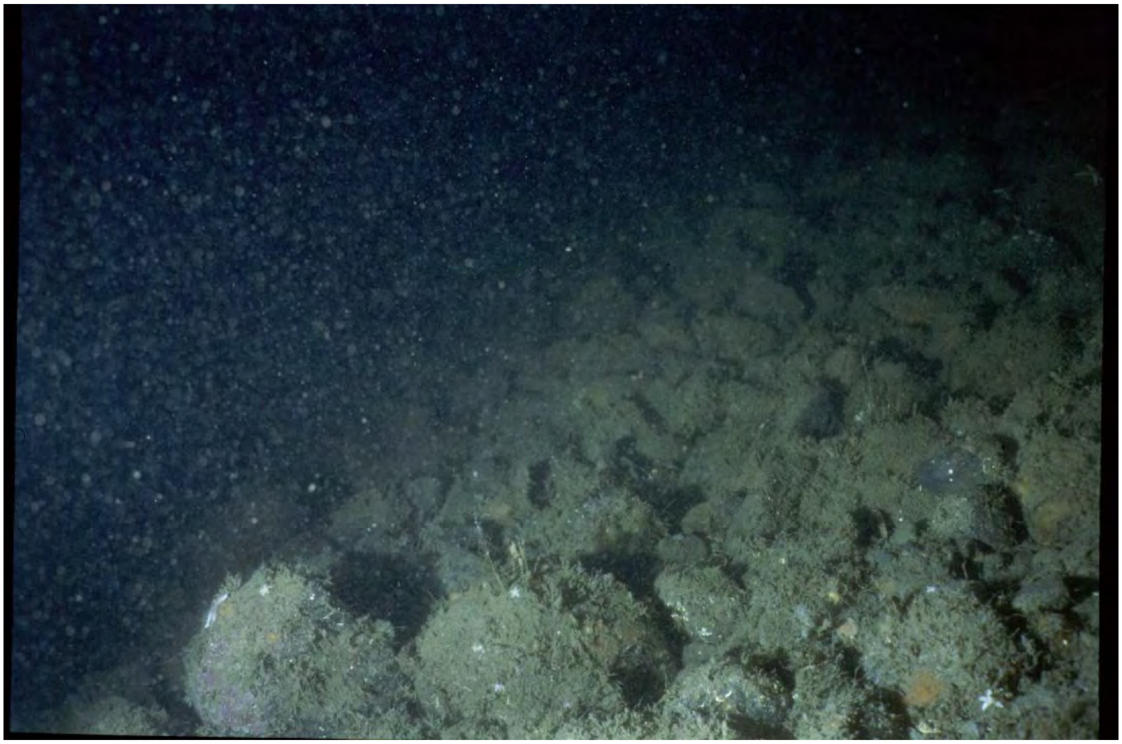


Plate 1. Transect 6 – Waypoint 1, Frame #27; Cobble pavement with heavy sediment drape, high amount of suspended material, and several juvenile and adult *Asterias*.

Plate 2. Transect 7 – Waypoint 2, Frame #30; Boulder with moderate sediment drape, 20% coralline algal cover, numerous *Ptilota serrata*, shotgun kelp *Agarum cribosum* being overgrown by the lacy bryozoan *Membranipora*, two stalked tunicates *Boltenia ovifera*, and several cunner *Tautogolabrus adspersus*.

Plate 3. Transect 7 – Waypoint 2, Frame #13; Boulders and cobbles with moderate sediment drape, 30% coralline algal cover, numerous *Ptilota serrata*, shotgun kelp *Agarum cribosum* being overgrown by the lacy bryozoan *Membranipora*, and several cunner *Tautogolabrus adspersus*.

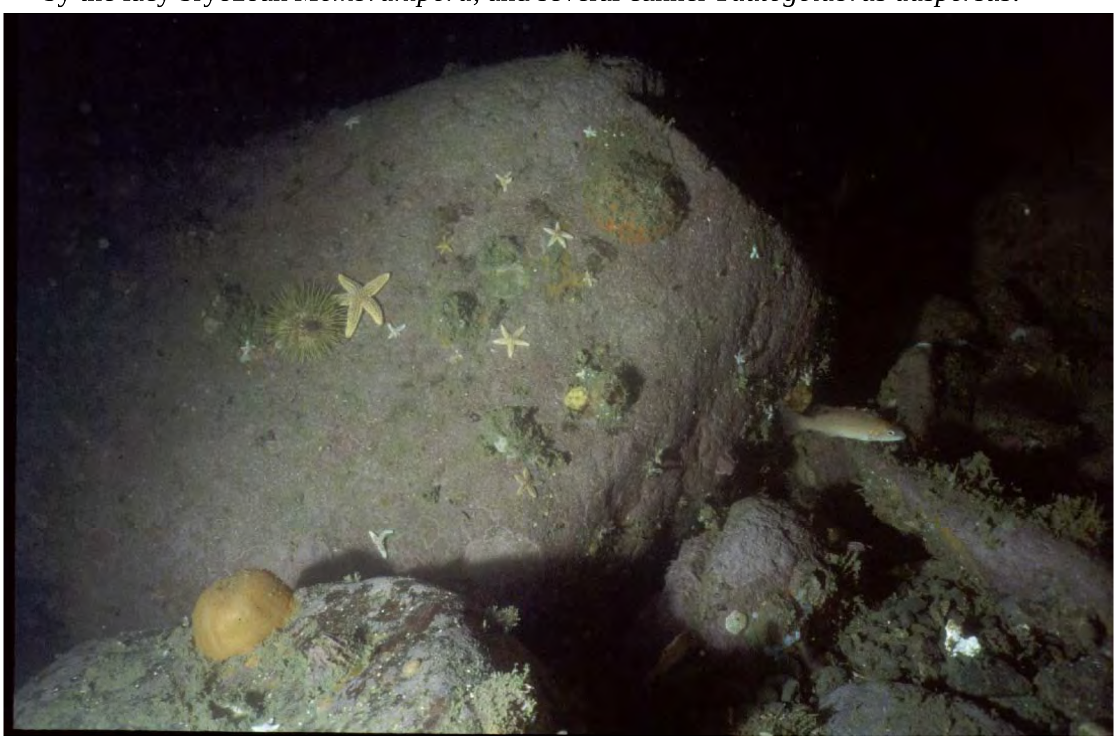


Plate 4. Transect 1 – Waypoint 2, Frame #3; Boulder and cobbles with very light sediment dusting, 80% coralline algal cover, a green sea urchin *Strongylocentrotus droebachiensis*, juvenile and adult *Asterias*, a retracted frilled anemone *Metridium senile*, a scarlet holothurian *Psolus fabricii*, several barnacles, and a cunner *Tautogolabrus adspersus*.

F-3

Plate 5 Transect 8 – Waypoint 2, Frame #15; Boulder and cobbles with moderately light sediment dusting, 70% coralline algal cover, several green sea urchins *Strongylocentrotus droebachiensis*, juvenile *Asterias*, and sea pork *Aplidium* spp.

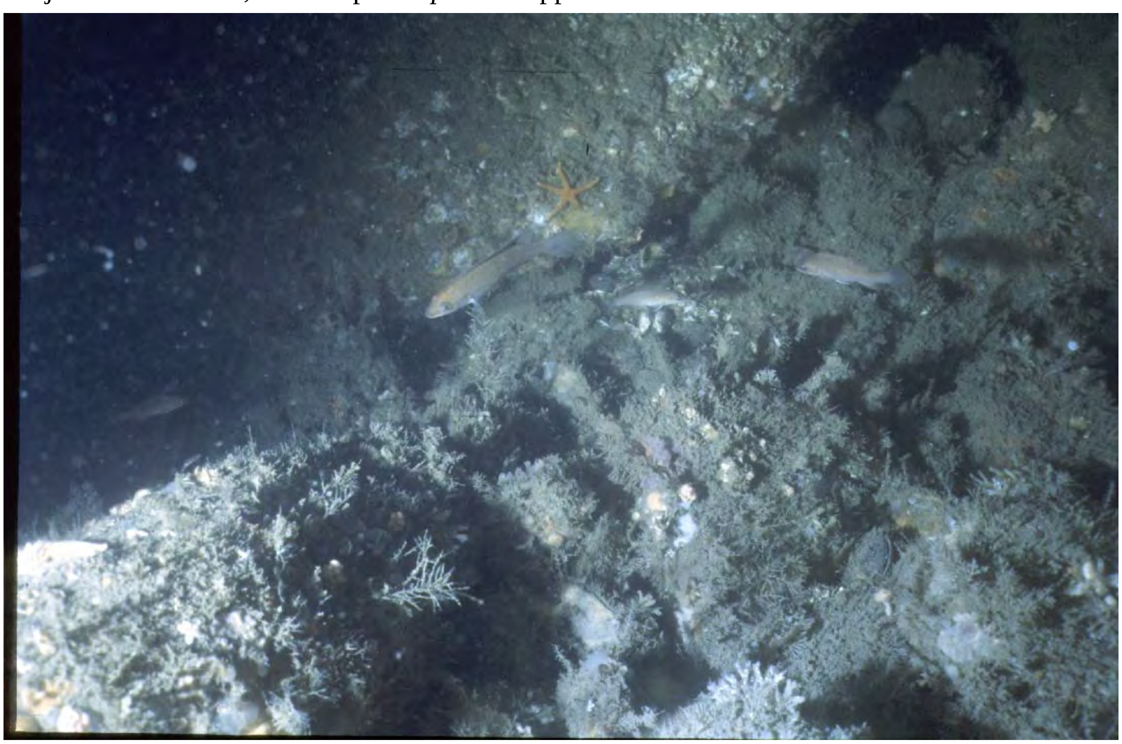


Plate 6. Transect 10 – Waypoint 1, Frame #29; Boulders and cobbles with a heavy, matted sediment drape, numerous hydroids and barnacle, a blood star *Henricia sanguinolenta*, several juvenile *Asterias*, the mussel *Modiolus modiolus*, and several cunner *Tautogolabrus adspersus*.

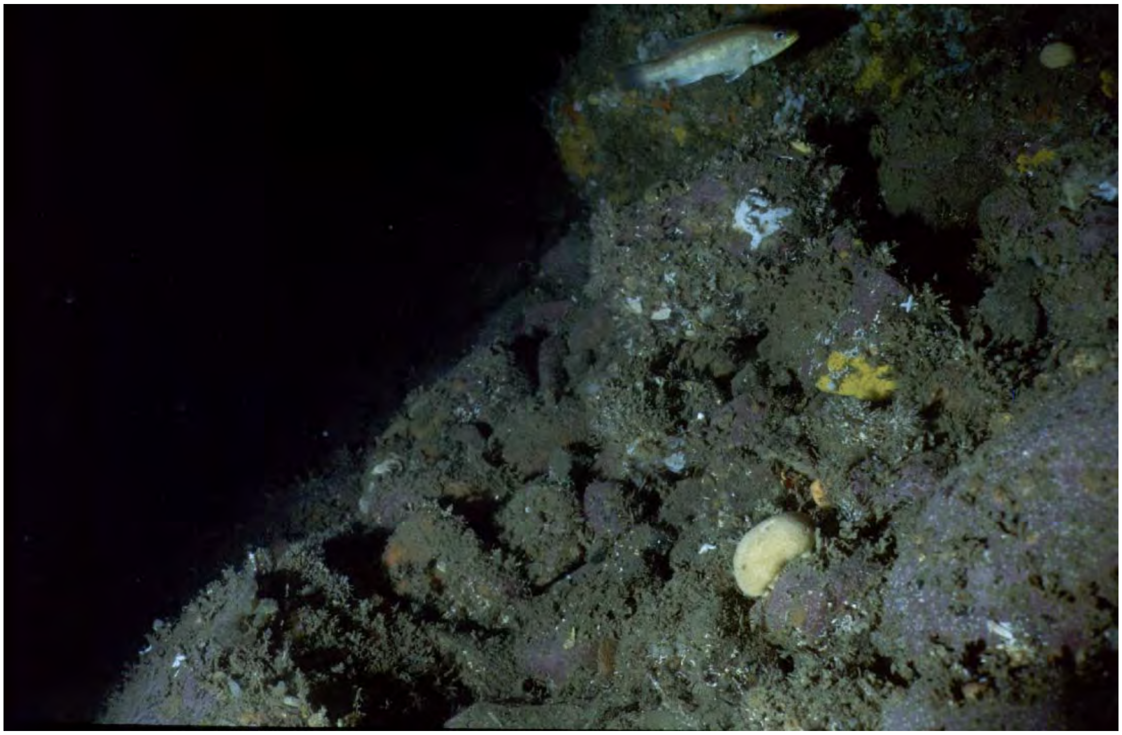


Plate 7. Transect 4 – Waypoint 2, Frame #26; Boulders and cobbles with a moderately heavy sediment drape, 40% coralline algal cover, several juvenile *Asterias*, a fig sponge *Suberites* spp., numerous encrusting organisms, and a cunner *Tautogolabrus adspersus*.

Plate 8. Transect 2 – Waypoint 2, Frame #3; Boulders and cobbles with a moderately heavy sediment drape, high suspended material, two adult *Asterias*, a blood star *Henricia sanguinolenta*, numerous flat slipper limpets *Crepidula plana*, some encrusting organisms, and a cunner *Tautogolabrus adspersus*.

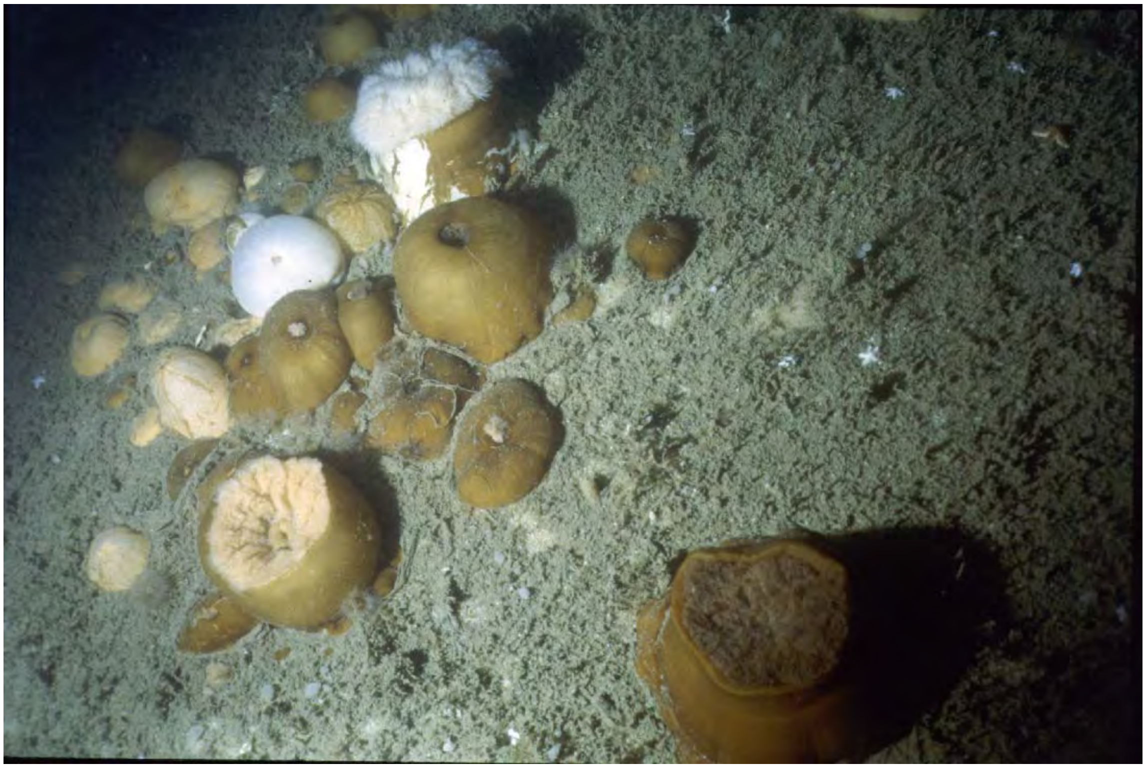


Plate 9. Diffuser #44, Frame #4; Side of the top of the diffuser with heavy sediment, numerous frilled anemones *Metridium senile*, and several juvenile *Asterias*.

Plate 10. Diffuser #44, Frame #11; Side of the diffuser with a heavy sediment drape, a finger sponge *Haliclona* sp., a number of sea peach tunicates *Halocynthia pyriformis*, and a cunner *Tautogolabrus adspersus* behind the sponge.

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