Outfall Benthic Monitoring Report: 2013 Results

Massachusetts Water Resources Authority

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2013 Results

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EXECUTIVE SUMMARY

Benthic monitoring during 2013 included soft-bottom sampling for sediment conditions and infauna at 14 nearfield and farfield stations, and sediment profile imaging (SPI) at 23 nearfield stations.

Sediment conditions were characterized based on spore counts of the anaerobic bacterium, *Clostridium perfringens*, and analyses of sediment grain size composition and total organic carbon (TOC). As in past years during the post-diversion period, *C. perfringens* concentrations during 2013 were highest at sites closest to the discharge. These *C. perfringens* results provide evidence of solids from the effluent at sites in close proximity (within 2 km) to the outfall. No such evidence of the wastewater discharge was evident in the monitoring results for sediment grain size or TOC during 2013. These findings are consistent with prior monitoring results (Nestler et al. 2013a, Maciolek et al. 2008).

There were threshold exceedances in 2013 for two infaunal diversity measures: (1) Shannon-Wiener Diversity (H′) and (2) Pielou’s Evenness (J′). No exceedances were reported for other infaunal diversity measures or for the percent opportunistic species. Exceedances of H′ and J' have been reported each year since 2010. During these past four years, annual Nearfield averages for H′ and J' have been higher than during the baseline period, resulting in exceedances of the upper threshold limits. In response to these exceedances, an in-depth evaluation of whether increased H′ and J' reflect an influence of the wastewater discharge on infaunal communities has been conducted (Appendix A). The findings from this evaluation were consistent with those presented in the 2010, 2011, and 2012 Outfall Benthic Monitoring Reports (Nestler et al. 2013, Nestler et al. 2012, Maciolek et al. 2011), concluding that there is no evidence that the threshold exceedances resulted from an impact of the outfall discharge on infaunal communities. Recent increases in H′and J′ appear to be a region-wide occurrence, strongly influenced by relatively low abundance in a few dominant species, and unrelated to the discharge. The polychaetes *Prionospio steenstrupi*, *Spio limicola,* and *Mediomastus californiensis* were identified as the species that were most influential in the threshold exceedances. Although these species have remained among the numerical dominants in recent years, their annual abundances have been lower than previously reported. Infaunal data in 2013 continue to suggest that the macrobenthic communities at sampling stations near the outfall have not been adversely impacted by the wastewater discharge.

The results of the threshold exceedance evaluation in this report suggest it may be appropriate to revisit the need for upper diversity triggers for MWRA’s infaunal Contingency Plan thresholds.

The 2013 SPI survey found no indication that the wastewater discharge has resulted in low levels of dissolved oxygen in nearfield sediments. The average thickness of the sediment oxic layer in 2013 was greater than during the baseline period, and the highest reported during post-discharge years. These results support previous findings that organic loading and the associated decrease in oxygen levels have not been a problem at the nearfield benthic monitoring stations (Nestler et al. 2013a, Maciolek et al. 2008).

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1. INTRODUCTION

The Massachusetts Water Resource Authority (MWRA) has conducted long-term monitoring since 1992 in Massachusetts Bay and Cape Cod Bay to evaluate the potential effects of discharging secondarily treated effluent 15 kilometers (km) offshore in Massachusetts Bay. Relocation of the outfall from Boston Harbor to Massachusetts Bay in September 2000, raised concerns about potential effects of the discharge on the offshore benthic (bottom) environment. These concerns focused on three issues: (1) eutrophication and related low levels of dissolved oxygen; (2) accumulation of toxic contaminants in depositional areas; and (3) smothering of animals by particulate matter.

Under its Ambient Monitoring Plan (MWRA 1991, 1997, 2001, 2004, 2010) the MWRA has collected extensive information over a nine-year baseline period (1992–2000) and a thirteen-year post-diversion period (2001–2013). These studies include surveys of sediments and soft-bottom communities using traditional grab sampling and sediment profile imaging (SPI); and surveys of hard-bottom communities using a remotely operated vehicle (ROV). Data collected by this program allow for a more complete understanding of the bay system and provide a basis to explain any changes in benthic conditions and to address the question of whether MWRA's discharge has contributed to any such changes. A comprehensive presentation of methods and evaluation of the long-term sediment monitoring data collected from 1992 to 2007 is provided in the Outfall Benthic Interpretive Report: 1992–2007 Results (Maciolek et al. 2008).

Benthic monitoring during 2013 was conducted following the current version of the Ambient Monitoring Plan (MWRA 2010). Under this plan, annual monitoring includes soft-bottom sampling for sediment conditions and infauna at 14 nearfield and farfield stations, and Sediment Profile Imaging (SPI) at 23 nearfield stations. Every third year, hard-bottom surveys are conducted (at 23 nearfield stations) and sediment contaminants are evaluated (at the same 14 stations where infauna and sediment condition samples are collected). The most recent sediment contaminant monitoring and hard-bottom surveys were conducted in 2011 (next sampling will be in 2014). Sediment contaminant monitoring in 2011 found no indication that toxic contaminants from the wastewater discharge are accumulating in depositional areas surrounding the outfall (Nestler et al. 2012). Monitoring results for 2011 also indicated that hard-bottom benthic communities near the outfall have not changed substantially during the post-diversion period as compared to the baseline period (Nestler et al. 2012).

The purpose of this report is to summarize key findings from the 2013 benthic surveys, with a focus on the most noteworthy observations relevant to understanding the potential effects of the discharge on the offshore benthic environment. There were Contingency Plan threshold exceedances for two infaunal diversity measures in 2013: (1) Shannon-Wiener Diversity (H′) and (2) Pielou's Evenness (J′). Exceedances have been reported for these two parameters each year since 2010 (Nestler et al. 2013a). An in-depth evaluation of these exceedances is presented in Appendix A. Results of 2013 benthic monitoring were presented at MWRA's Annual Technical Workshop on March 11, 2014. PowerPoint presentations from this workshop are provided in Appendix B.

2. METHODS

Methods used to collect, analyze, and evaluate all sample types remain largely consistent with those reported for previous monitoring years (Nestler et al. 2012, Maciolek et al. 2008). Detailed descriptions of the methods are contained in the Quality Assurance Project Plan (QAPP) for Benthic Monitoring (Nestler et al. 2013b). A brief overview of methods, focused on information that is not included in the QAPP, is provided in Sections 2.1 to 2.3.

2.1 Field Methods

Sediment and infauna sampling was conducted at 14 stations on August 7 and 8, 2013 (Figure 2-1):

- Transition area station FF12, located between Boston Harbor and the offshore outfall
- Nearfield stations NF13, NF14, NF17, and NF24, located in close proximity (<2 km) to the offshore outfall
- Nearfield stations NF04, NF10, NF12, NF20, NF21, and NF22, located in Massachusetts Bay but farther than 2 km from the offshore outfall
- Farfield reference stations FF01A, FF04, and FF09, located in Massachusetts Bay (Figure 2-1 inset)

Sampling effort at these stations has varied somewhat during the monitoring program. In particular, from 2004-2010 some stations were sampled only during even years (NF22, FF04 and FF09), Stations NF17 and NF12 were sampled each year, and the remaining stations were sampled only during odd years.

Sampling at Station FF04 within the Stellwagen Bank National Marine Sanctuary was conducted in accordance with Research permit SBNMS-2010-001.

Soft-bottom stations were sampled for grain size composition, total organic carbon (TOC), the sewage tracer *Clostridium perfringens*, and benthic infauna. Infauna samples were collected using a 0.04-m^2 Ted Young-modified van Veen grab, and were rinsed with filtered seawater through a 300-µm-mesh sieve.

Sediment Profile Imaging (SPI) samples were collected in triplicate at 23 nearfield stations on August 12, 2013 (Figure 2-2).

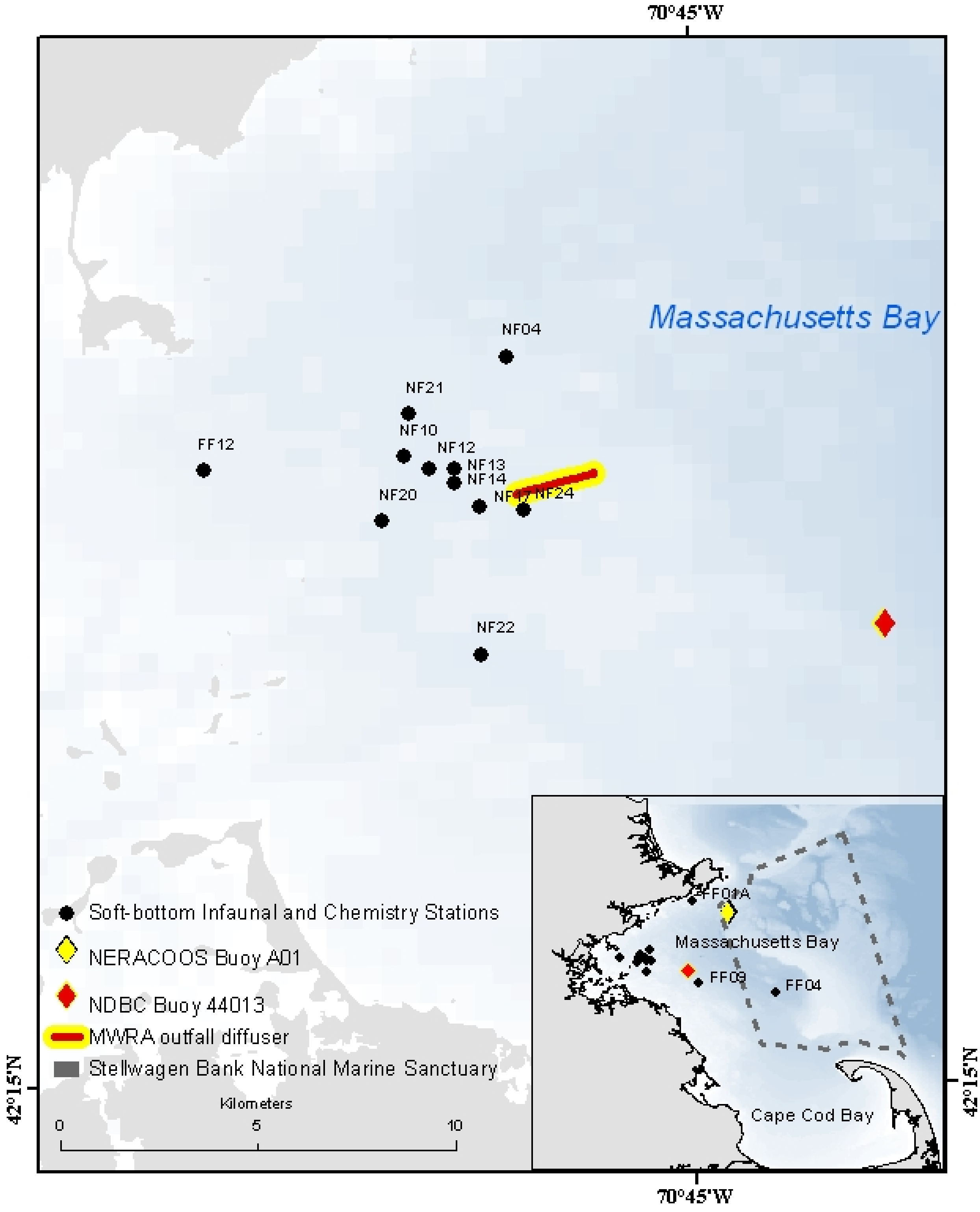


Figure 2-1. **Locations of soft-bottom sampling stations for 2013.**

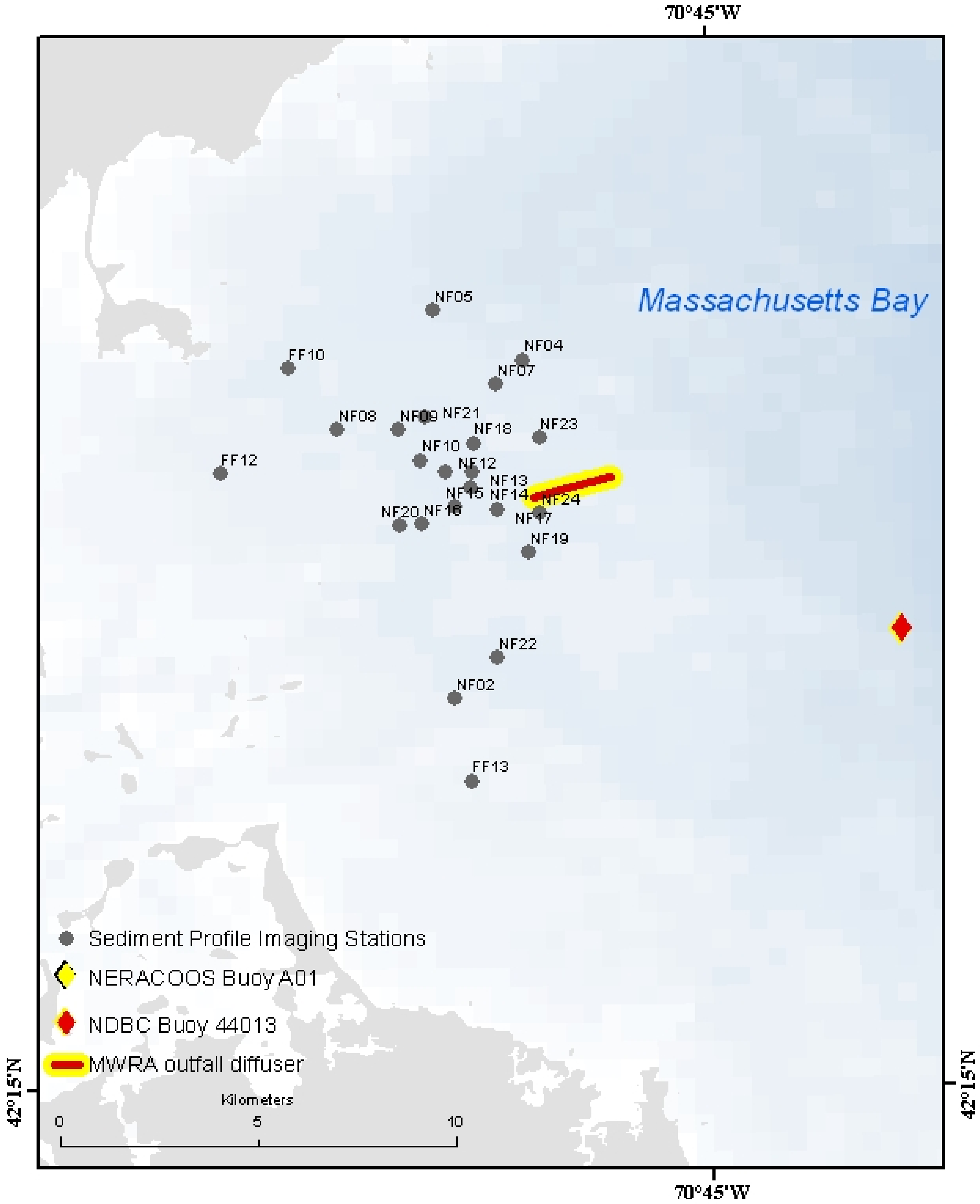


Figure 2-2. **Locations of sediment profile imaging stations for 2013.**

2.2 Laboratory Methods

All sample processing, including sorting, identification, and enumeration of organisms, was done following methods consistent with the QAPP (Nestler et al. 2013b).

2.3 Data Handling, Reduction, and Analysis

All benthic data were extracted directly from the HOM database and imported into Excel. Data handling, reduction, graphical presentations and statistical analyses were performed as described in the QAPP (Nestler et al. 2013b) or by Maciolek et al. (2008).

3. RESULTS AND DISCUSSION

3.1 Sediment Conditions

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

Sediment conditions were characterized by three parameters measured during 2013 at each of the 14 sampling stations: (1) *Clostridium perfringens*, (2) grain size (gravel, sand, silt, and clay), and (3) total organic carbon (Table 3-1).

Spores of the anaerobic bacterium *Clostridium perfringens* provide a sensitive tracer of effluent solids. Temporal analyses of *C. perfringens* at the 14 sampling sites demonstrated that a sharp increase occurred coincident with diversion of effluent to the offshore outfall at sites within two kilometers from the diffuser (Figure 3-1). *C. perfringens* concentrations have declined or remained comparable to the baseline at all other locations during the post-diversion period. *C. perfringens* counts (reported as colony forming units per gram dry weight, normalized to percent fines) in samples collected during 2013 were highest at stations NF14, NF24, NF17, and NF13 (Table 3-1); the four stations located within two kilometers from the outfall (Figure 3-2).

Sediment texture varied considerably among the 14 stations, ranging from predominantly sand (e.g., NF13, NF17, NF04, and FF01A) to almost entirely silt and clay (i.e., FF04 and NF21), with most stations having mixed sediments (Table 3-1, Figure 3-3). Although sediment texture has remained generally consistent over time at most stations, the 2013 results indicated larger than average changes from previous years in the percent fine sediments at a number of stations (Figures 3-4 and 3-5). These changes in sediment texture are most likely the result of strong storms in February and March 2013 (R. Geyer, personal communication). Bothner et al. (2002) reported that sediment transport at water depths less than 50 meters near the outfall site in Massachusetts Bay occurs largely as a result of wave-driven currents during strong northeast storm events.

Concentrations of total organic carbon (TOC) in 2013 also remained similar to values reported in prior years at most stations (Figure 3-6). Concentrations of TOC track closely to percent fine sediments (i.e., silt + clay), with higher TOC values generally associated with higher percent fines (Maciolek et al. 2008). This pattern is evident in comparisons of Figures 3-4 and 3-6.

As in past years during the post-diversion period, *Clostridium perfringens* concentrations during 2013 continue to indicate a footprint of the effluent plume, but only at sites closest to the discharge. Although *C. perfingens* counts continue to provide evidence of effluent solids depositing near the outfall, there is no indication that the wastewater discharge has resulted in changes to the sediment grain size composition at the Massachusetts Bay sampling stations, and there is no indication of organic enrichment. TOC concentrations remain comparable to, or lower than, values reported during the baseline period, even at sites closest to the outfall. These findings are consistent with prior year monitoring results (Nestler et al. 2013a, Maciolek et al. 2008).

Table 3-1. 2013 monitoring results for sediment condition parameters.

Location	Station	*Clostridium perfringens* (cfu/g dry/%fines)	Total Organic Carbon (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Percent Fines (Silt + Clay)
Transition Area	FF12	43	0.41	1.5	72.8	22.6	3.1	25.8
Nearfield (<2 km from outfall)	NF13	122	0.13	1.6	95.8	0.8	1.8	2.6
	NF14	245	0.40	16.2	78.5	3.8	1.5	5.3
	NF17	157	0.17	1.5	96.8	1.3	0.4	1.7
	NF24	227	1.77	0.0	29.4	40.0	30.6	70.6
Nearfield (>2 km from outfall)	NF04	84	0.20	3.1	90.3	4.7	2.0	6.7
	NF10	70	0.39	3.4	72.4	18.6	5.6	24.2
	NF12	58	1.29	0.0	23.8	58.9	17.4	76.2
	NF20	76	0.15	6.5	89.5	2.1	1.8	4.0
	NF21	38	0.86	0.0	11.2	62.5	26.4	88.8
	NF22	75	0.72	0.0	31.6	48.9	19.5	68.4
Farfield	FF01A	16	0.18	0.7	93.8	3.4	2.1	5.6
	FF04	16	1.82	0.0	7.0	59.0	34.1	93.1
	FF09	33	0.39	0.9	85.7	7.3	6.2	13.4

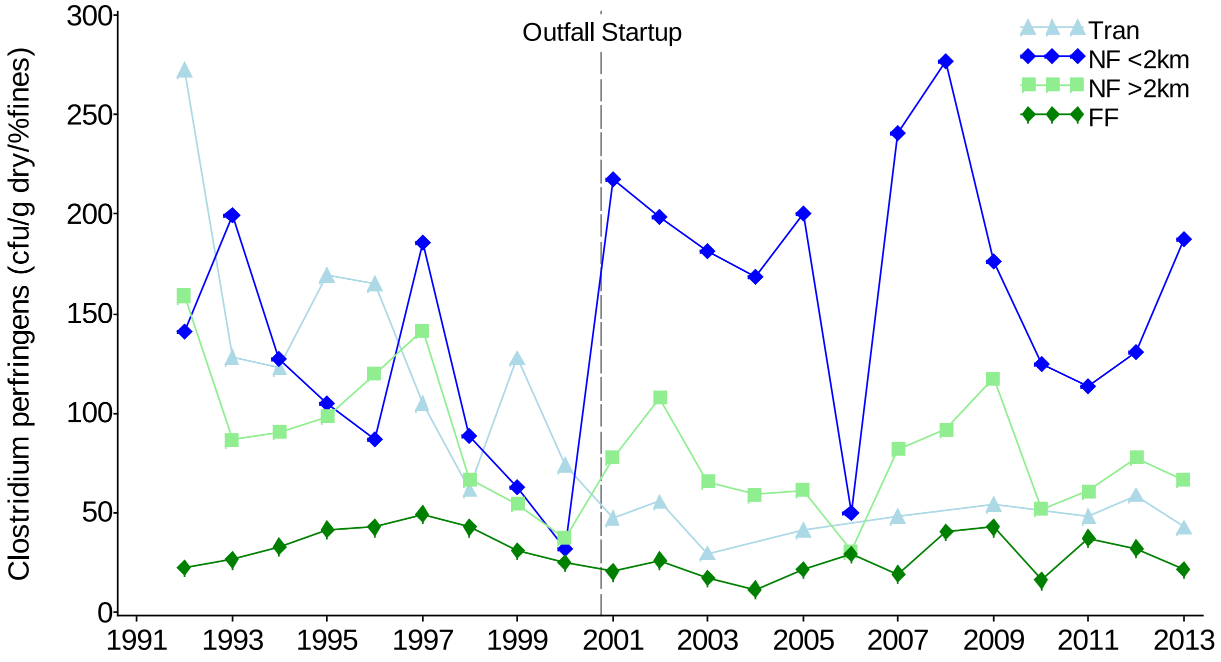


Figure 3-1. Mean concentrations of *Clostridium perfringens* in four areas of Massachusetts Bay, 1992 to 2013. Tran=Transition area; NF<2km=nearfield, less than two kilometers from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield.

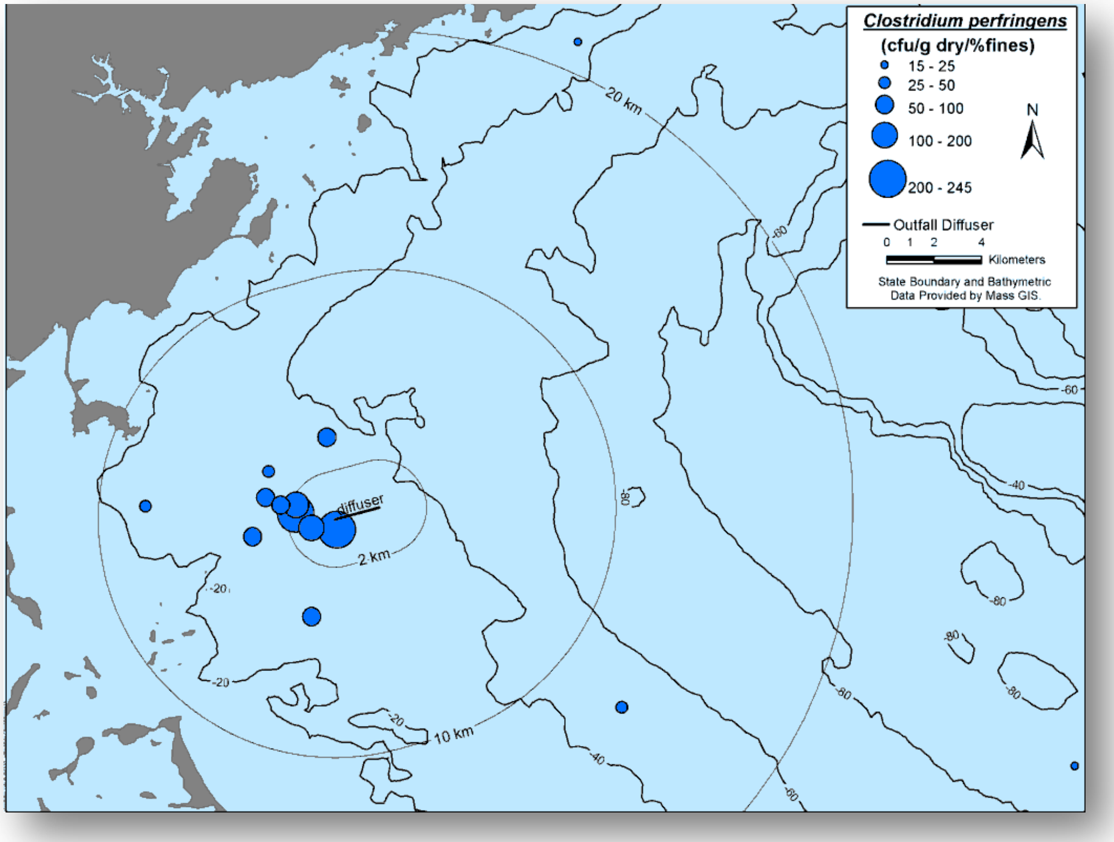


Figure 3-2. **2013 monitoring results for *Clostridium perfringens*.**

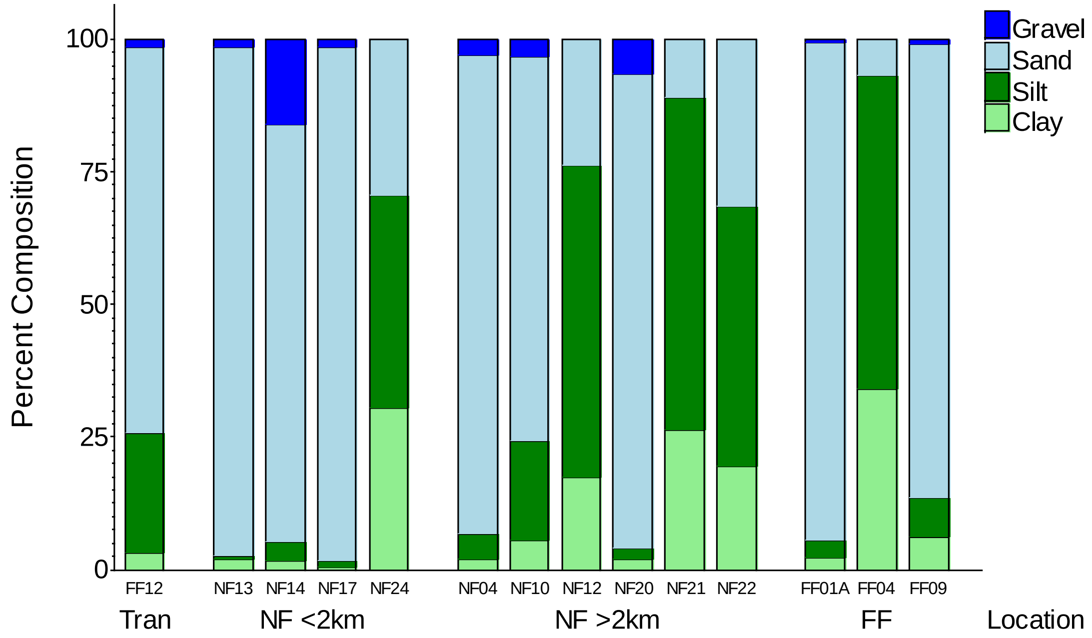


Figure 3-3. **2013 monitoring results for sediment grain size.**

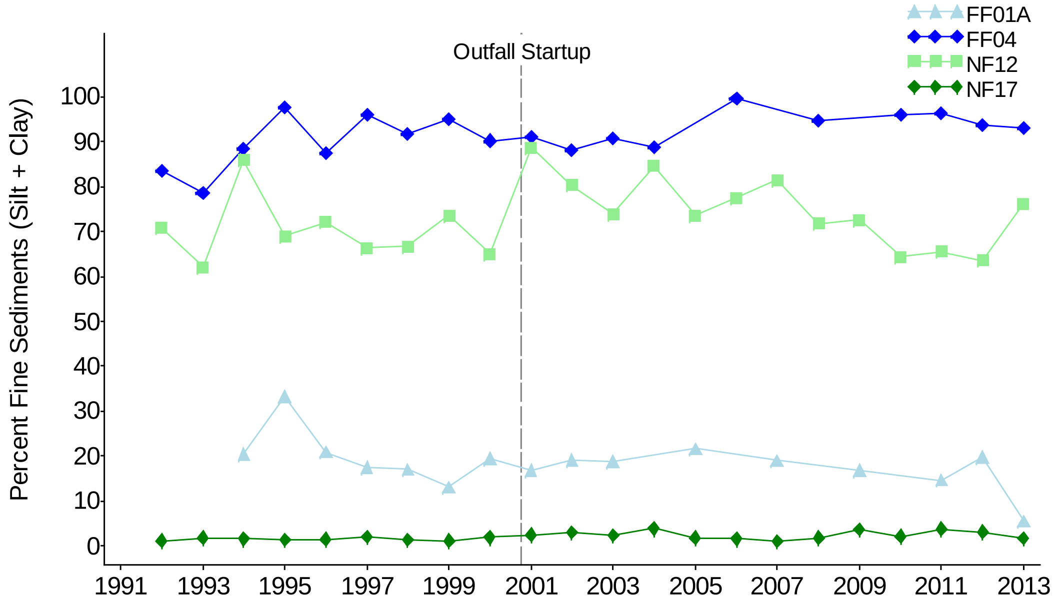


Figure 3-4. **Mean percent fine sediments at FF01A, FF04, NF12 and NF17; 1992 to 2013.**

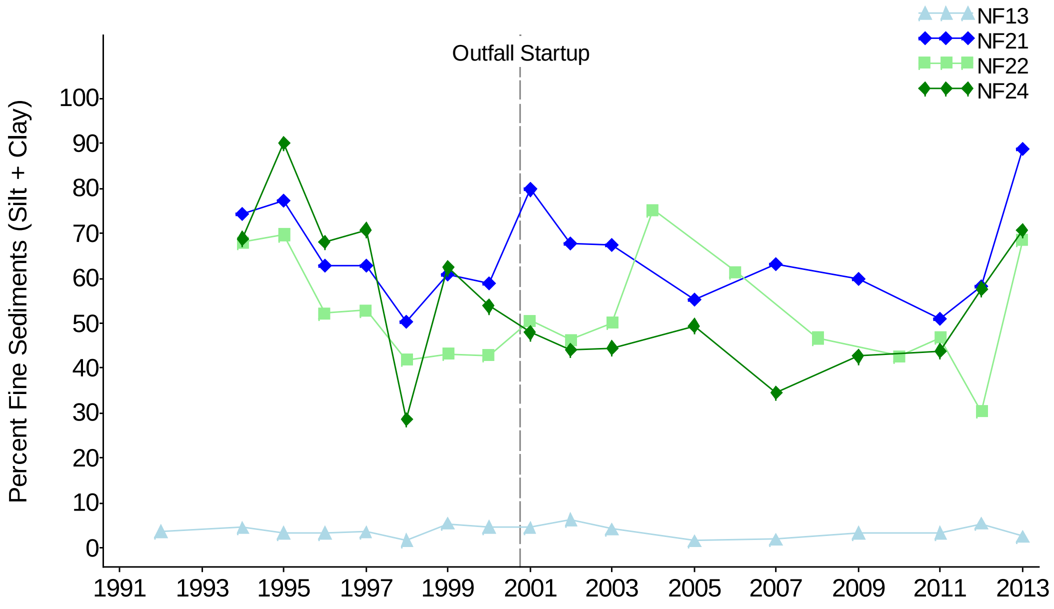


Figure 3-5. **Mean percent fine sediments at NF13, NF21, NF22 and NF24; 1992 to 2013.**

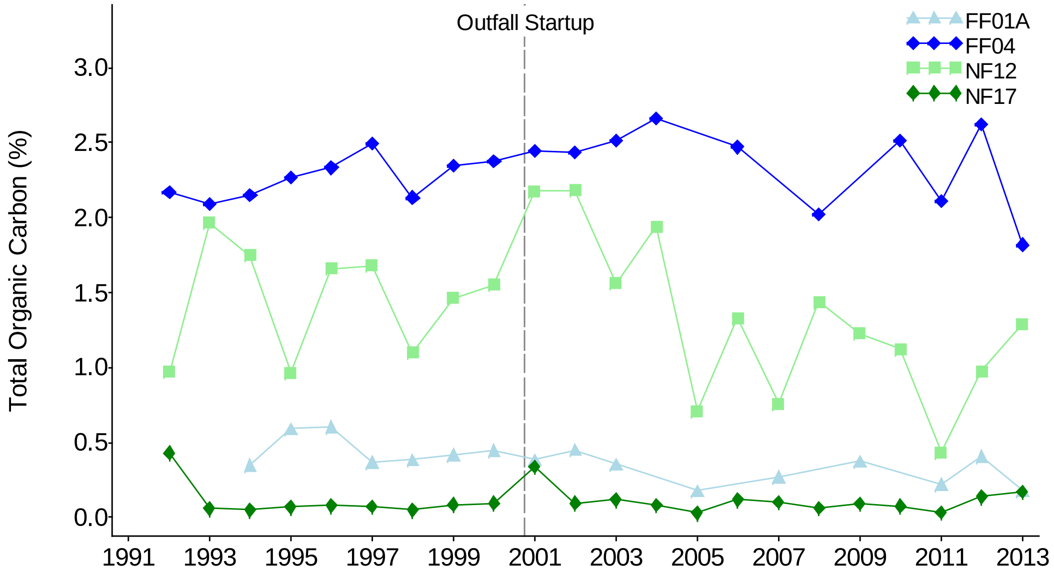


Figure 3-6. **Mean concentrations of TOC at four stations in Massachusetts Bay, 1992 to 2013.**

3.2 Benthic Infauna

3.2.1 Community Parameters

A total of 14,522 infaunal organisms were counted from the 14 samples in 2013. Organisms were classified into 207 discrete taxa; 183 of those taxa were species-level identifications. Abundance values reported herein reflect the total counts from both species and higher taxonomic groups, while diversity measures are based on the species-level identifications only (Table 3-2).

Abundance values reported for 2013 were lower than the previous year at all four locations (i.e., spatial groups of stations classified by distance from the outfall) in Massachusetts Bay, and comparable to values reported in 2011 (Figure 3-7). The numbers of species per sample were also generally lower than the previous year, but within the range of historic variability reported for most locations (Figure 3-8). Note that sampling of different stations during even and odd years from 2004 to 2010 has likely influenced year to year variability in community parameters averaged by location during that time period (e.g. Figures 3-7 and 3-8; see Section 2.1).

There were threshold exceedances in 2013 for Shannon-Wiener Diversity (H′) and Pielou’s Evenness (J′); no exceedances were reported for other diversity measures or for the percent opportunistic species (Table 3-3). Contingency Plan threshold exceedances for these same two parameters have been reported each year since 2010 (Nestler et al. 2013a). During these past four years, annual Nearfield averages for H′ and J' have been higher than during the baseline period, resulting in exceedances of the upper threshold limits. In response to these exceedances, an in-depth evaluation of whether increased H′ and J' reflect an influence of the wastewater discharge on infaunal communities has been conducted and is presented in Appendix A.

Evaluations in Appendix A conclude that changes in faunal communities that resulted in threshold exceedances appear to be region-wide and unrelated to the discharge. Both analyses of spatial and temporal patterns in community parameters and multivariate analyses, found no evidence of impacts to infaunal communities from the wastewater discharge in Massachusetts Bay.

Table 3-2. 2013 monitoring results for infaunal community parameters.

Location	Station	Total Abundance (per grab)	Number of Species (per grab)	Log-series alpha	Shannon-Wiener Diversity (H′)	Pielou's Evenness (J')
Transition Area	**FF12**	924	38	8.00	3.99	0.76
Nearfield (<2 km from outfall)	**NF13**	835	64	16.28	4.07	0.68
	NF14	1164	66	15.34	4.16	0.69
	NF17	570	49	12.88	4.54	0.81
	NF24	424	32	8.23	3.83	0.77
Nearfield (>2 km from outfall)	**NF04**	973	67	16.37	4.25	0.70
	NF10	1495	61	13.04	4.19	0.71
	NF12	1765	62	12.78	3.95	0.66
	NF20	697	68	19.62	4.47	0.73
	NF21	828	46	10.56	3.64	0.66
	NF22	1990	58	11.41	3.81	0.65
Farfield	**FF01A**	678	70	19.83	4.60	0.75
	FF04	813	38	8.33	3.44	0.66
	FF09	1366	85	20.63	4.88	0.76

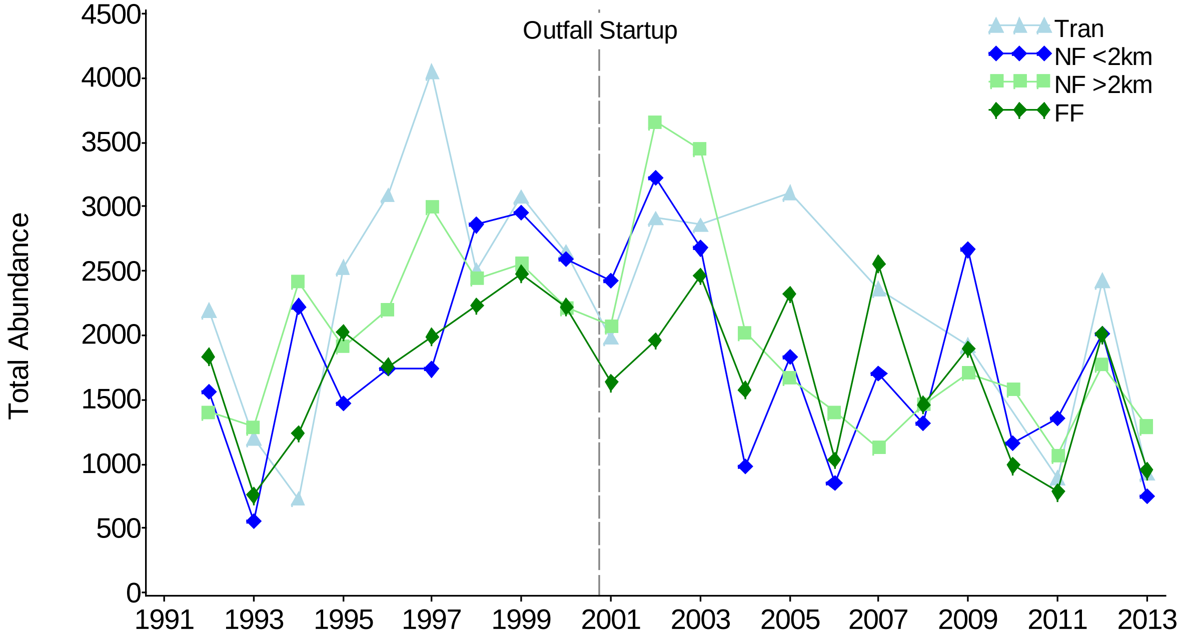


Figure 3-7. Mean infaunal abundance per sample at four areas of Massachusetts Bay, 1992 to 2013. Tran=Transition area; NF<2km=nearfield, less than two kilometers from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield.

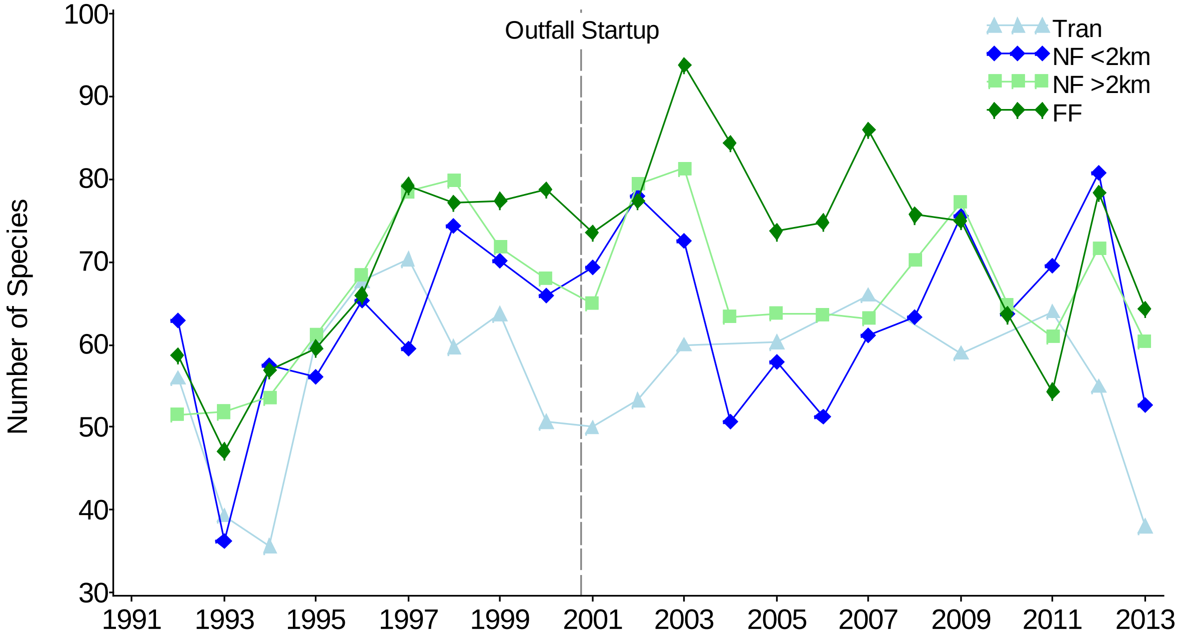


Figure 3-8. Mean number of species per sample at four areas of Massachusetts Bay, 1992 to 2013. Tran=Transition area; NF<2km=nearfield, less than two kilometers from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield.

Table 3-3. Infaunal monitoring threshold results, August 2013 samples.

Parameter	Threshold range		Result	Exceedance?
	Low	High		
Total species	43.0	81.9	55.55	No
Log-series Alpha	9.42	15.8	13.14	No
Shannon-Weiner H′	3.37	3.99	4.08	Yes, Caution Level
Pielou’s J'	0.57	0.67	0.71	Yes, Caution Level
Apparent RPD	1.18	NA	3.76	No
Percent opportunists	10% (Caution) 25% (Warning)		0.47%	No

3.3 Sediment Profile Imaging

As with the previous years, in 2013 there was little change in any of the sediment profile image parameters at the 23 nearfield monitoring stations. At sandy and silty bottom areas around the outfall, benthic habitat conditions in 2013 were similar to the previous eleven years. When baseline conditions (1992 to 2000) are compared with post outfall (2001 to 2013) operational conditions there is no evidence of an outfall effect based on SPI (Table 3-4). The grand average apparent color redox-potential discontinuity layer (aRPD) for 2013 was the highest of all the post outfall years. Sediments at many stations continued to be heterogeneous, ranging from sandy-silt-clay to cobble. Overall, the sediment surface appeared to be structured primarily by physical processes and secondarily by biological processes.

Being the highest annual average for post outfall monitoring, the grand mean of the thickness of the aRPD layer in 2013 did not exceed the threshold of a 50% decrease from the baseline conditions. If only measured values are considered the thickness of the aRPD for 2013 would be 5.4 cm (SD = 1.70 cm, 10 stations in mean). At 13 of the 23 stations, the aRPD was deeper than prism penetration due to coarse grain size and high sediment compaction that limited penetration. If all stations are included in the aRPD calculation the mean for 2013 was 3.8 cm (SD = 1.92 cm). From the start of annual SPI sampling in 1997, the aRPD has never been observed at stations N04, NF13, and N17. Overall, post-baseline period aRPD remained deeper than during the baseline period (Table 3-4). Since 2001, the thickness of the annual grand mean aRPD, for all stations and for only those stations with measured values, has been variable but since 2010 it has tended deeper and increased in 2013 to the highest average over the 23 years of monitoring (Figures 3-9 and 3-10), which is an indication of continued high quality benthic habitat conditions. High diversity of benthos also confirms the presence of high quality benthic habitat (see infaunal discussion of diversity exceedence in 2013, Appendix A).

The higher average aRPD in 2013 occurred despite a decline in average prism penetration (Figures 3-9 and 3-10). The 2013 average aRPD layer depth for the 10 stations with measured aRPDs was actually deeper than the average penetration depth for all 23 stations (Figure 3-10). Prism penetration is hampered by coarse grained sediments and shell at many stations. From 2004 to 2010 annual average penetration declined from about 7 cm to 3 cm and then increased to about 5 cm in 2012 and back to 4 cm in 2013 (Figure 3-9). Prism penetration is primarily a function of sediment parameters of grain-size and porosity, landing on obstacles such as shell, and weight added to the camera frame. Changes in prism penetration do not appear to be related to the camera system or weight added to the frame. Between 1992 and 2013 three different SPI camera systems were used to sample the nearfield stations with no correspondence to penetration. From 1992 to 2001 a film camera in a stainless steel housing was used, from 2002 to 2009 a digital camera in a stainless steel housing was used, and from 2010 to 2013 a digital camera in an aluminum housing was used. The camera frame and weight added were about the same for all years being 125 to 150 lbs. But at many stations grain-size and porosity between 1993 and 2013 were variable with much of it related to within station spatial heterogeneity (Table 3-5). For example, at station NF16 sediment type for the three SPI replicates ranged from fine-grained to coarse pebbles (Figure 3-11). Sediment grain-size analysis from benthic grabs indicated NF16 was heterogeneous and varied between silty-sand and sandy-silt (Figure 3-12). Porosity at NF22, measured as part of the nutrient flux studies (flux station MB03, Tucker et al. 2009) varied between about 0.55 to 0.85 g water/ml sediment (Figure 3-

13). Higher porosity indicates sediments that should be easier for the SPI prism to penetrate as there would be more water and/or pore space within sediments.

Changes in penetration by just a few cm did affect the aRPD data. At 11 of the 23 stations, prism penetration has declined to a point where the aRPD was no longer visible in the images. Due to shallowing prism penetration, the aRPD layer was last observed at station NF20 in 2005, at NF15 and NF19 in 2006, NF17 and NF18 in 2007, FF10, FF13 and NF14 in 2010, NF05 and NF23 in 2011, and NF24 in 2012. NF18 is a good example of this trend (Figures 3-14 and 3-15). At station FF12 the aRPD was observed in all of the base-line years but only twice post base-line (Figure 3-16). The aRPD was observed all years at stations NF07, NF08, NF10, NF12, NF21, and NF22 (Figure 3-17). Sediments at NF22 were primarily fine-sand-silt-clay with some increase in medium-sand in 2006, 2008, and 2012 (Figure 3-18). The aRPD was observed all years except one at station NF09 (2010) (Figure 3-19) and station NF24 (2013).

While not statistically tested, there appeared to be long-term trends in prism penetration and aRPD depth. Even though penetration tended to decline, aRPD tended to increase at nine stations (NF05, NF07, NF08, NF09, NF10, NF12, NF21, and NF22 (Figure 3-17). Prism penetration tended to decline and aRPD depth tended to remain the same at stations FF10 (Figure 3-20), FF13, NF14, and NF16. Sediments at FF10 were primarily gravel and sand, primarily very-fine and fine-sands, medium-sands increased starting in 2006 (Figure 3-21). At stations NF02, NF23, and NF24 (Figure 3-22), both prism penetration and aRPD depth have remained the same throughout the study. Changes in penetration are likely related to variations in sediment grain-size, in particular, to variation in Phi class (Table 3-5).

There was also no indication of organic carbon accumulation in sediments for any of the pre- or post-baseline years. Image sequences from the mixed sand-silt-clay sediment stations, which had the finest sediments sampled in the nearfield, do not show a darkening of surface sediment that is typical for higher organic content sediments. For example the long-term average for NF24 (Figure 3-23), located within a half km of the outfall and the closest sediment station to the outfall, was about 1.3% total organic carbon (TOC) and fine grained mixed sand-silt-clay sediments with about 55% fines (silt plus clay). In 2013, NF24 had 1.8% TOC and 71% fines. Sediment at five other stations averaged >50% fines (silt plus clay) over the years with no indication of increases in organic carbon content through time (NF08, NF12, NF16, NF21, NF22; Maciolek et al. 2011, Nestler et al. 2013). The operation of the outfall did not appear to negatively affect benthic habitat quality for infauna.

Based on the generally light color of sediments observed in the SPI from all stations the true RPD layer was beyond prism penetration at all stations. Eh profiles measured by Tucker et al. (2009) in fine-sand-silt-clay sediments were positive to sediment depths of 18 cm. The light color of sediments in the SPI indicated low organic content and oxidized geochemical conditions with the aRPD measured from the SPI likely being an estimate of where sediment geochemistry shifts from oxic to suboxic processes (Fenchel and Riedl 1974, Seitzenger 1988). Reduced sediments are darker in color (mostly Fe and Mn sulfides) and a function of organic carbon content and geochemistry (Vismann 1991). Thus, the measurements of aRPD within the nearfield area relate more to the depth at which sediments shift from oxic to suboxic verses suboxic to anoxic (Seitzenger 1988). In higher organic content sediments, aRPD measurements are highly correlated with Eh profiles and the RPD layer depth (Rosenberg et al. 2001). The most important factors controlling aRPD throughout the nearfield appeared to be hydrodynamics at sandy stations and bioturbating infauna at finer grained stations.

From 1995 to 2013, changes and trends in SPI variables appeared to be related to broader regional forcing factors. The dominance of hydrodynamic and physical factors (Butman et al. 2008), such as tidal and storm currents, turbulence, and sediment transport, is the principal reason that benthic habitat quality remains high in the nearfield area. The high-energy environment in the region of the outfall disperses effluents quickly and prevents degradation of soft bottom benthic infaunal habitat.

The lack of accumulation of organic matter in the sediments is the principle reason for lack of benthic impacts in the nearfield. Pearson and Rosenberg (1978) generalized the response of benthic communities to organic loading, which appears to be similar in all marine systems. They found that as organic matter loading increases the benthic habitat conditions decline. The break point for benthos appears to be around 3% total organic carbon (Hyland et al. 1999). The only stations to have >3% TOC were NF08 in 1992 with 3.2% and NF14 in 2002 with 3.1% (Maciolek et al. 2011). Station NF08 is the westernmost Massachusetts Bay station that is reliably greater than 50% silt+clay and the most depositional station between Boston Harbor and the rest of the nearfield. The spike of higher TOC could have resulted from the October 1991 Halloween Nor'easter (Sebastian Junger's Perfect Storm) that transported material from inshore to fine-grain stations like NF08 and NF12 (Bothner and Butman 2007, Keay, personal communication). The spike in TOC at NF14, a coarser grained station, was not apparent in any SPI image. SPI did not indicate high TOC levels in the sediments for any year (Figure 3-24). If >3% TOC persisted at these stations, it is likely that changes would occur in benthic community structure. The grand average for nearfield station is <1% TOC. It is likely that benthic habitat quality in the nearfield will remain high as the strong influence of hydrodynamics and bioturbation keeps sediment organic content low.

Table 3-4. Summary of SPI parameters pre- and post-baseline years for all nearfield stations.

	Baseline Years 1992-2000 9-Year Interval	**Post-Baseline Years 2001-2013 13-Year Interval**
SS	Advanced from I to II-III	Bimodal: I-II and II-III
OSI - Low	4.8 (1997)	5.8 (2003)
OSI - High	7.2 (2000)	8.7 (2012)
aRPD - Low	1.8 cm (1997 and 1998)	2.1 cm (2003)
aRPD -High	3.0 cm (1995)	3.8 cm (2013)
Annual Mean aRPD Measured	2.2 (0.49 SD) cm	3.3 (0.92 SD) cm
Annual Mean aRPD All Values	2.4 (0.47 SD) cm	2.8 (0.50 SD) cm

Table 3-5. General trends in sediment grain-size, and SPI penetration and aRPD at nearfield stations. Between 2004 and 2010, stations other than NF12 and NF17 were sampled every other year, according to whether they were in the "Odd" or "Even" year bins. Stations retained in the infaunal and sediment sampling after 2010 are in bold and underlined. Sediment classes are clay (CL, >8 Phi). silt (SI, 7 to 5 Phi), very-fine-sand (VFS, 4 to 3 Phi), fine-sand (FS, 3 to 2 Phi), medium-sand (MS, 2 to 1 Phi), coarse-sand (CS, 1 to 0 Phi), very-coarse-sand (VCS, 0 to -1 Phi), gravel (GR, -1 to -2 Phi). Solids is percent dry weight of sediment.

Stat.	Year	Sediment Observations	SPI Observations
FF10	Even	Except for 1997 to 2000, gravel/sand fraction was 55 to 70%, 1998-2001 made up over 80%. FS to VFS predominated, but MS increased 2006-2010. No trend in solids.	Penetration variable, shallowest from 2009-2013. Deepest in 2004. 2010 last year aRPD was observed.
<u>FF12</u>	Odd	Consistently silty-sand. No trend in solids. VFS predominates most years, increase in FS in recent years, MS spiked in 2009.	Deepest penetration in 1999-2000 and 2013. Other years were consistently shallow. aRPD was observed twice form 2002-2013.
FF13	Even	Very heterogeneous, GR 40% in 1992, 0% in 1993. Other classes almost as variable. Solids may have increased between 1999-2000 and later years. MS spiked to ~40% in 2006 and 2008, ~10% other years. VFS decreased after 1997 until 2008, increased slightly in 2010.	Penetration variable, deepest 1998, 2001, and 2004, uniformly shallow form 2005-2013. Last year for measured aRPD was 2010.
NF02	Odd	Very temporally heterogeneous, 80% SICL in 1992, 95% sand in 1993. FS and MS predominant in sandy years.	Penetration variable, deepest 2004-2005, uniformly shallow all other years. aRPD was observed twice form 2007-2013.
<u>NF04</u>	Odd	GR abundant only in 1992 (>35%), all other years >95% sand. No trend in solids. FS generally decreases 1994-2013, especially since 2006, replaced by MS.	Penetration shallow and variable, deepest 1999-2000 and 2004-2008, uniformly shallow all other years. aRPD was observed once form 1997 to 2013.
NF05	Even	Consistently sandy w/ ~20-40% SICL. Possible increase in solids between 2002 and 2008, FS predominated, usually 40-60%. Might be decreasing since 2004. MS increased since 2004; spiked to 35% in 2006.	Penetration tended to increase 1997-2006 and declined form 2007-2013. aRPD was consistently observed from 1997-2009 and tended to deepen. aRPD was observed once 2010-2013.
NF07	Even	Consistently ~65% sand, 25% SI, 10%CL, little GR. Solids might increase slightly after 2002. FS and VFS predominate except in 2006, MS and CS then increased.	Penetration tended to increase 1997-2000 and declined in 2001 and consistent to 2007, then declined again 2008 and remained uniformly shallow to 2013. aRPD was consistently observed from 1997-2013 with slight deepening trend.

Stat.	Year	Sediment Observations	SPI Observations
NF08	Even	Fines decrease fairly consistently over 1992-2010. Sand increased. Solids might increase after 2004. VFS decreases, mirror amounts of SI, FS and MS increase.	Penetration was deep, tended to increase 1997-1999 and slowly declined 2000-2013. aRPD was consistently observed from 1997-2013 with slight deepening trend.
NF09	Even	Consistently ~60% sand, 30% SI, 10% CL. Solids might increase after 2003. Sands mostly VFS and FS, MS spiked in 2008.	Penetration deepest 1998-1999, uniform form 2001-2013 with shallowest penetration in 2010. aRPD was observed all year except 2010 and had a deepening trend.
NF10	Odd	Broadly similar to NF09 and fairly stable. Solids might increase 1999-2013. Mostly VFS and FS, MS spiked in 2009.	Penetration and aRPD pattern similar to NF09 but slightly deeper.
NF12	All	65-90% SICL through time. Possible slight increase in solids 2007-2013. Mostly VFS and FS, except FS ~15% in 2009, 2010, and 2012.	Penetration variable, deepest 1998-2000, 2004. Less variable other years form 2001-2013. aRPD was observed all years with slight deepening trend.
NF13	Odd	All sand all years, 20% GR in 1996. No change in solids. General decrease in FS from 1994 to 2013, increase in MS, especially since 2007.	Penetration shallow and variable all years. aRPD was never observed from 1997 to 2013.
NF14	Odd	Consistently gravel-sand thru time, proportion of gravel and sand fluctuates widely. No trend in solids. Years without high GR, FS predominates, MS higher in 2012 and 2013.	Penetration variable with slight shallowing trend from 1999-2013. aRPD was last observed in 2010.
NF15	Odd	Solids unchanged post 1998. Mostly sandy sediments. FS decreasing after 1994, 60% to 10%. MS about 30% 1995-2007, 10% in 2009. GR and CS spike in 2009.	Penetration and aRPD pattern similar to NF14 but aRPD was last observed in 2006.
NF16	Even	Little change in solids post 1999, ~65%. Wide swings between ~50+% SICL (1992, 1995, 1998, 2004) and 60+% sand (1994, 1996, 1999). Most sand is FS until 2002, but proportion decreasing. After 2004, MS increases.	Penetration variable, deepest 1998, 1999, 2002, 2005. Shallower and less variable other years. aRPD was observed all years except 2003, when penetration was zero, and 2008.
NF17	All	Nearly 100% sand throughout, 80% solids unchanging. Varies between FSMS and MS as the dominant proportion, with some years having 10-20% contribution from CS and VCS. From 2006, proportion of FS decreases almost monotonically, from >65% to <10%, while MS increases to nearly 85% by 2013.	Penetration shallow and variable all years. aRPD was never observed from 1997 to 2013.

Stat.	Year	Sediment Observations	SPI Observations
NF18	Even	Alternates between 40+% GR (1994, 1995, 1997, 2001-2004) and 50+% sand (1992, 1996, 1998). 10-20% fines throughout. High sand years tend to be a mixture of MS, FS, and sometimes VFS, 10-25% each. Solids 70-80%, maybe trending up from 2004-2010.	Penetration variable, deepest 1999, 2007. Less variable other years with slight shallowing trend 2000-2010. aRPD was last observed 2007.
NF19	Even	Mostly (80+%) sand except 2000 and 2003. SICL less than 10% each. Most years sands dominated by FS, but decreasing after 2003 with increased proportions of MS after 2004. Little change in solids.	Penetration variable, deepest 2000. Less variable other years. aRPD was last observed 2006.
NF20	Odd	>50% SICL in 1992, decreasing thereafter, not above 30% after 1997. >50% sand after 1995, gravel sometimes >30% (1994, 2000, 2007, 2012). Solids 65-85%. Sands heterogeneous, FS dominant many years but not strikingly so, MS increases since 2007.	Penetration variable but deepest 1998-2005. Shallower and less variable 2006-2013. aRPD was last observed 2005.
NF21	Odd	>50% SICL throughout, spiking to 80%+ in 2001, 2013. Appreciable GR only in 1996. Solids generally increase between 1999 and 2011-2012, dropped markedly in 2013. Sands mostly VFS and FS.	Penetration deepest 1998-2007, shallower 2008-2011, deepened 2012-2013. aRPD was observed all years and deepened 2012-2013.
NF22	Even	Primarily fine sediments, always >10% CL, 30-55% SI all years but 2012 (~22%), 30-65% sand all years but 2004 (~25%), little GR. Solids seems to correlate with %CL. VFS dominant class until 2004, MS in 2006 and 2008, variable thereafter.	Penetration variable but deep with shallowing trend from 2000-2013. aRPD was observed all years with slight deepening trend.
NF23	Even	Always >65% sand sometimes ~95%. 20-30% GR some years (e.g. 1994, 1999, 2006). Little SICL. Little change in solids. MS and FS make up most of the sands, FS showing a general decrease since 1994, to <10% since 2006. MS variable but increases to most of sands by 2004.	Penetration shallow and variable, deepest 2006, shallow all other years. aRPD was not consistently observed, seven years from 1997-2013.
NF24	Odd	Homogenous fine sediments, with highest proportions of CL observed in nearfield (70% in 1995). GR never abundant, SICL dominant 1994-1997, FS spiked in 1998. Sand and SICL roughly equal 1999-2005, sand ~60% 2007-2011. SICL 55-70% in 2012-2013. Sands mixture of FS and VFS with some MS, MS made up most of the sands only in 2012.	Penetration variable but uniformly deep 1997-2012. Shallower 1998, 2009-2011. Shallowest in 2013. aRPD was observed all years except 2013.

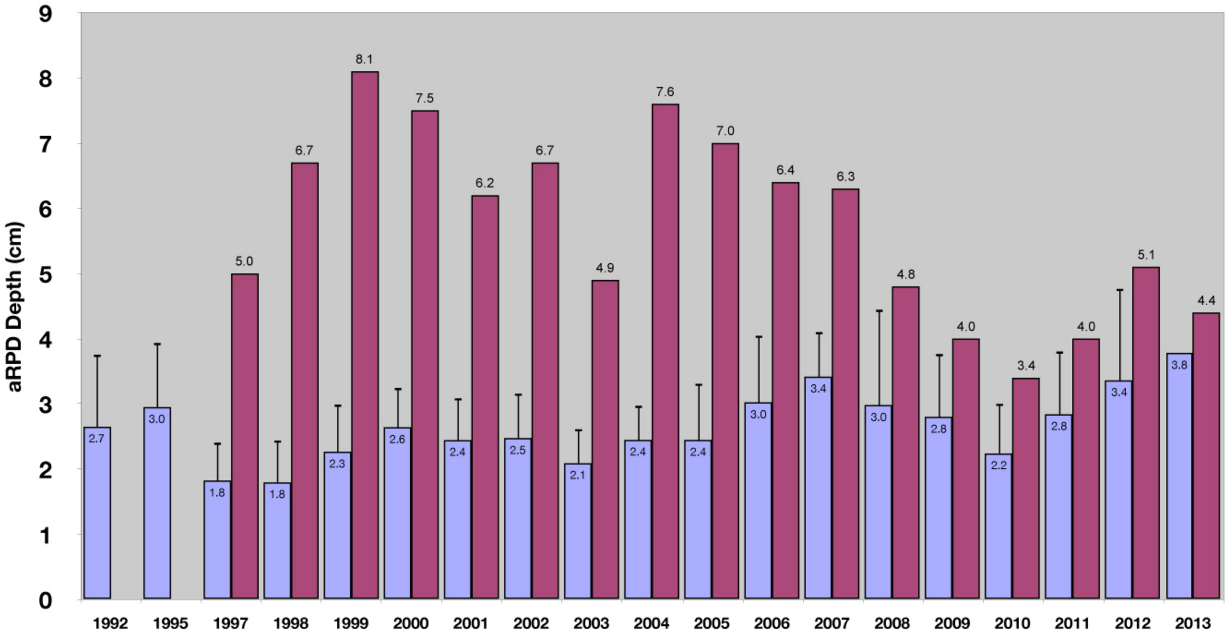


Figure 3-9. **Annual average aRPD layer depth (blue bars) at nearfield stations by year for all 23 stations. Annual average prism penetration is shown as red bars.**

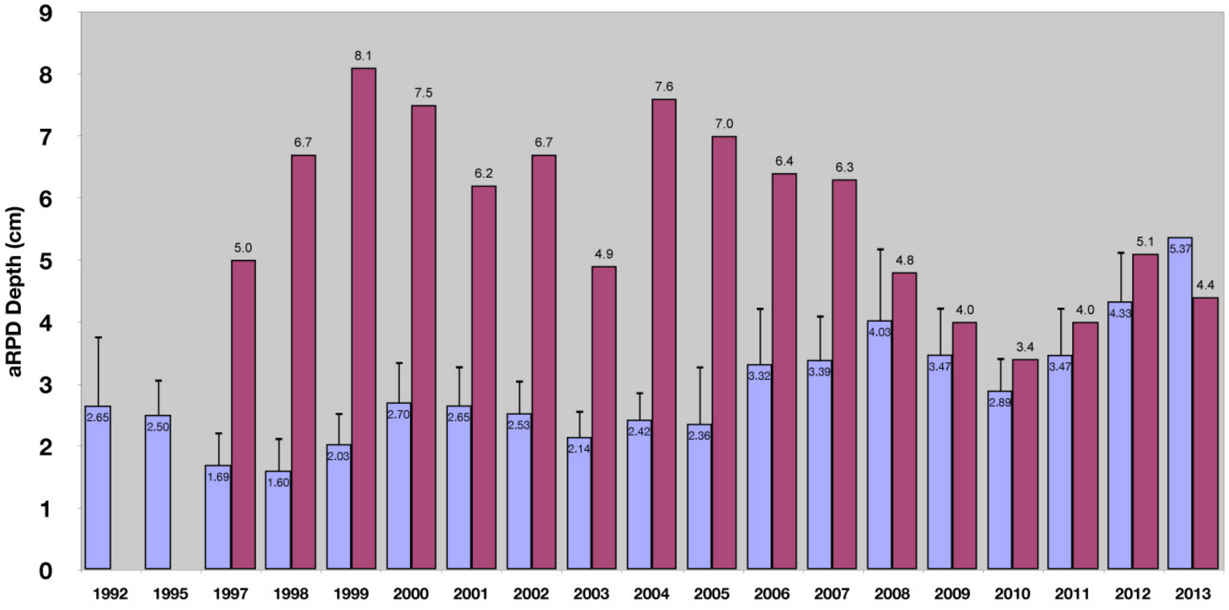


Figure 3-10. **Annual average aRPD layer depth (blue bars) at nearfield stations by year for only stations with measured aRPD layers. Annual average prism penetration is shown as red bars.**

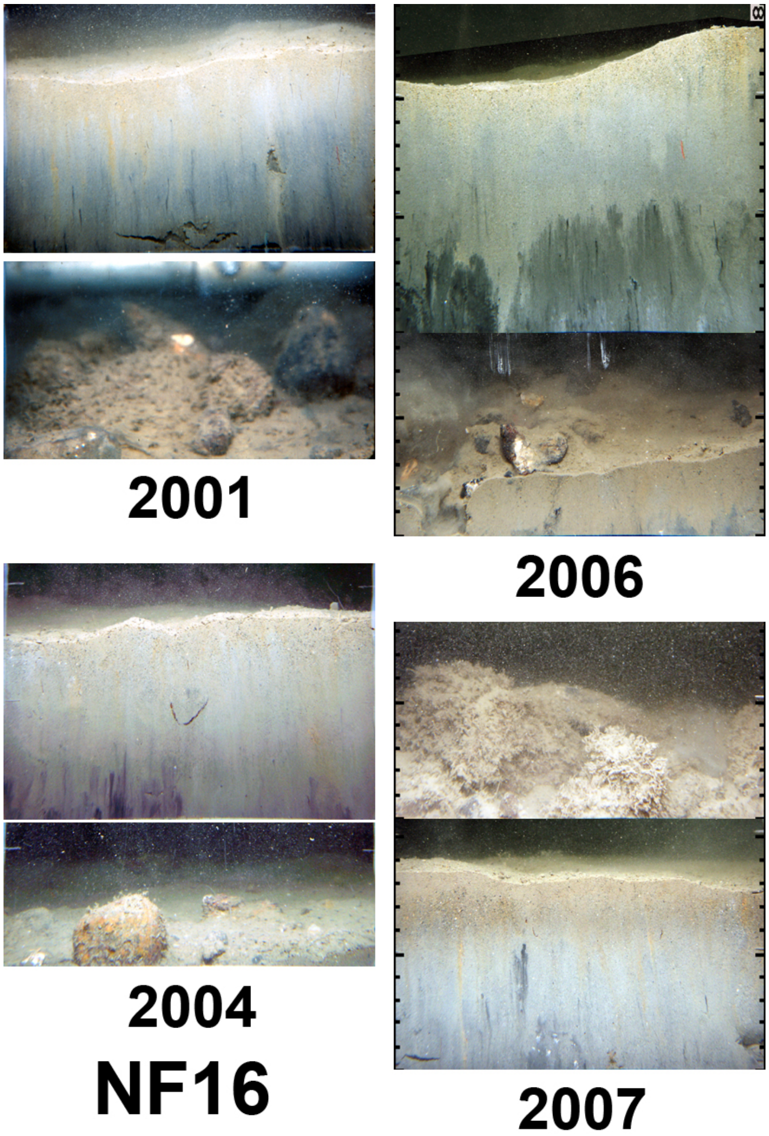


Figure 3-11. Within station sediment variation at station NF16. For four of the 18 years of SPI monitoring, sediments at NF16 ranged from fine-sand-silt-clay to pebble. Scale in images is in cm(not visible in all images).

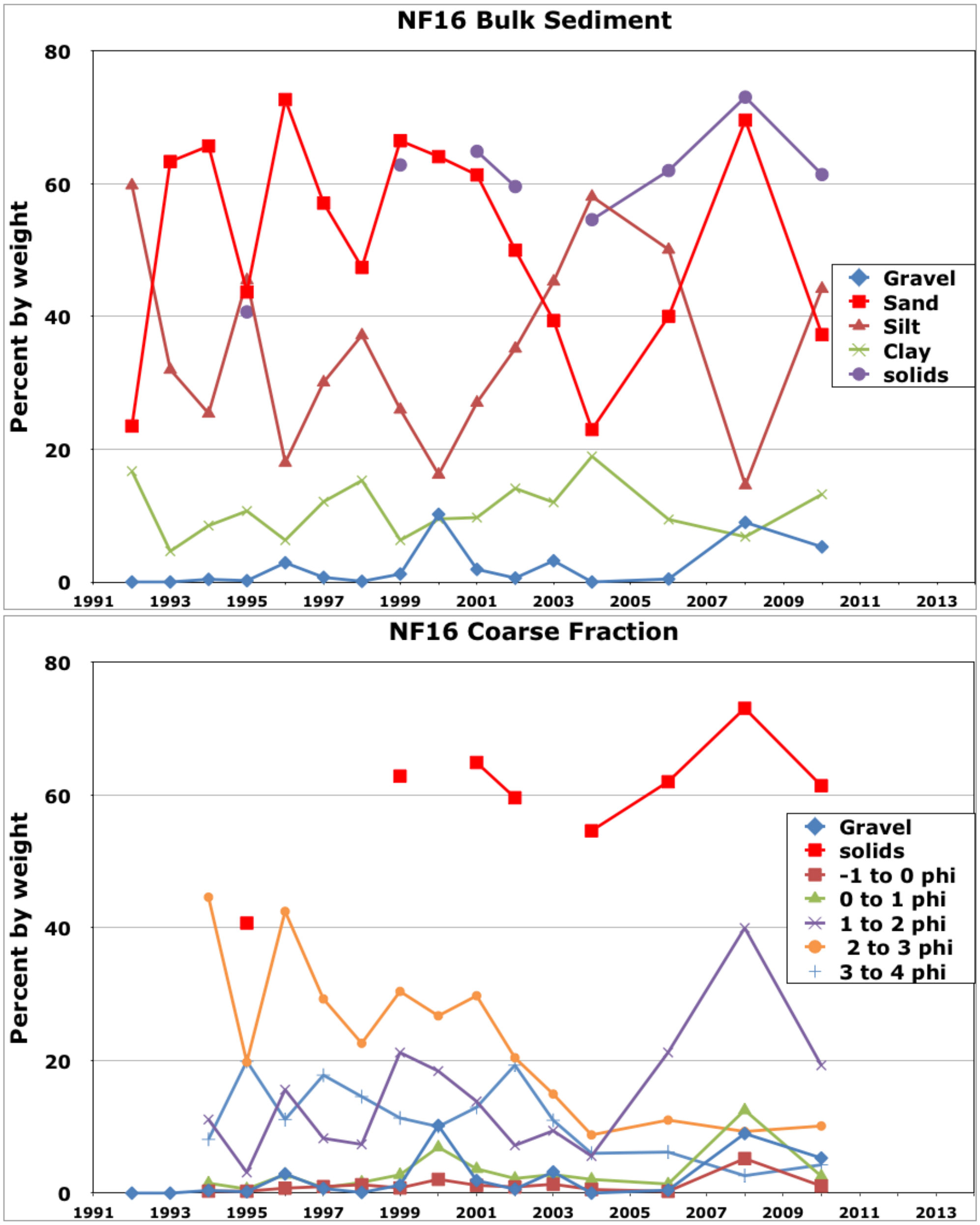


Figure 3-12. Within station variation in sediment grain-size at station NF16. Bulk sediment parameters are percent gravel, sand, silt, clay, and solids. Solids is the percent dry weight of bulk sediment.

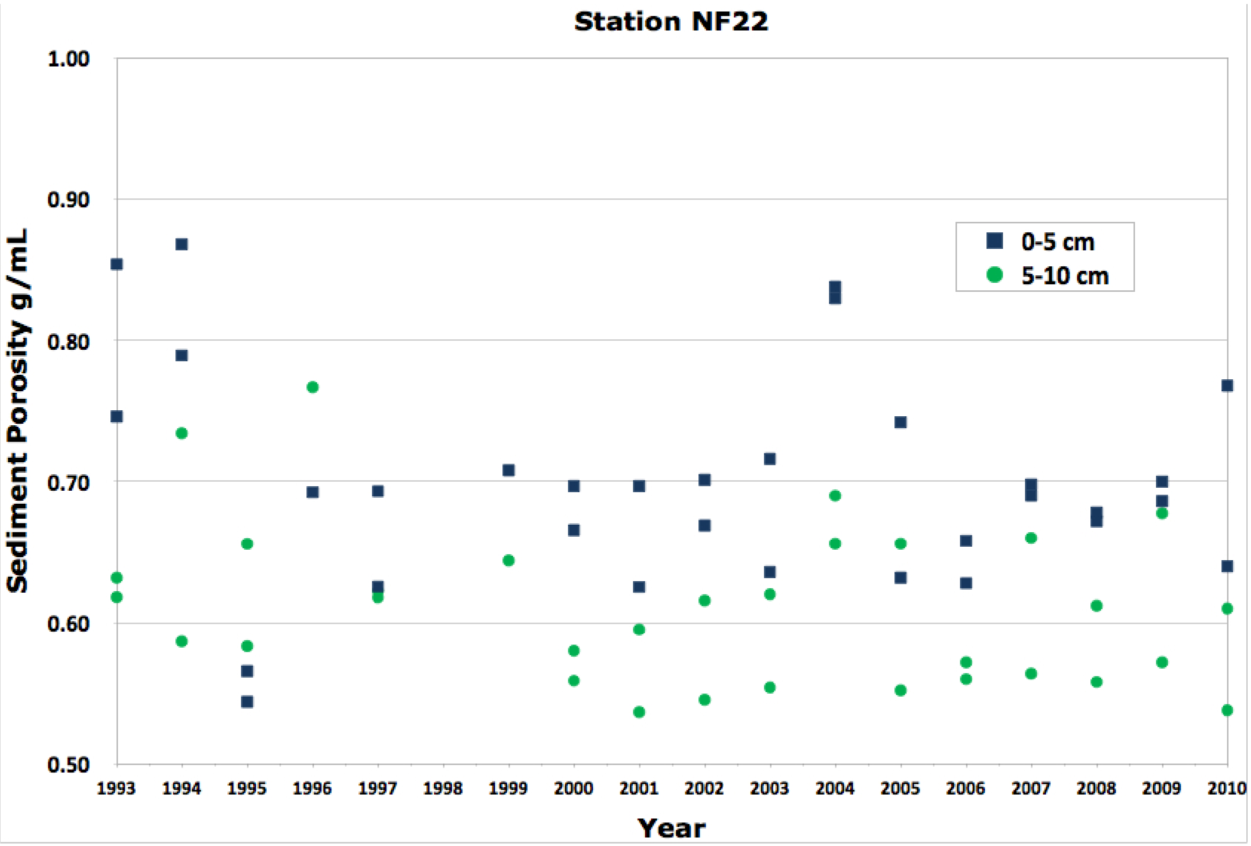


Figure 3-13. Within station variation in sediment porosity at station NF16. Higher porosity indicates softer sediments. Data from two sediment cores each sectioned into surface (0-5 cm) and subsurface (5-10 cm) layers. Subsurface sediments are consistently harder than surficial sediments.

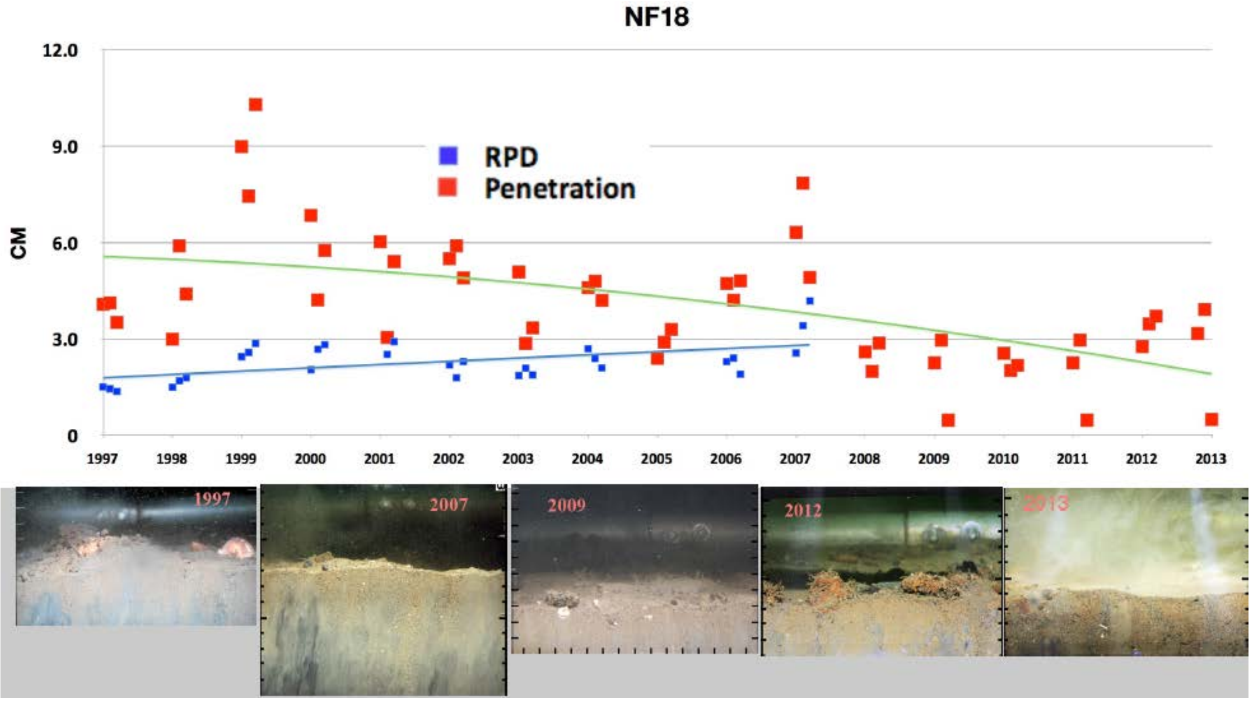


Figure 3-14. Comparison of prism penetration and aRPD layer depth at station NF18 by year for only stations with measured aRPD layers. aRPD was last observed in 2007. Thumbnail images are shown for selected years. Scale in images is in cm.

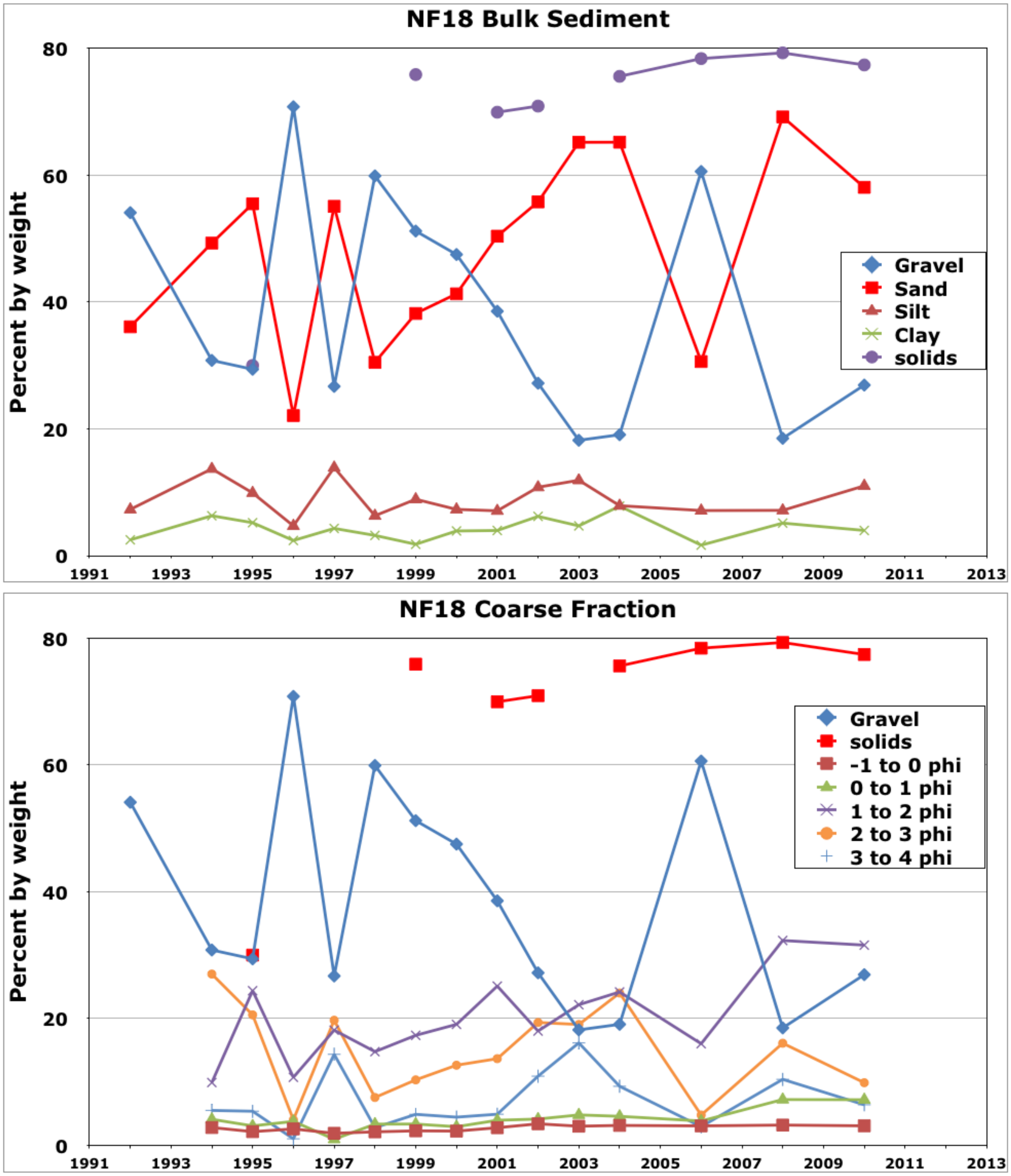


Figure 3-15. Within station variation in sediment grain-size at station NF18. Bulk sediment parameters are percent gravel, sand, silt, clay, and solids. Solids is the percent dry weight of bulk sediment.

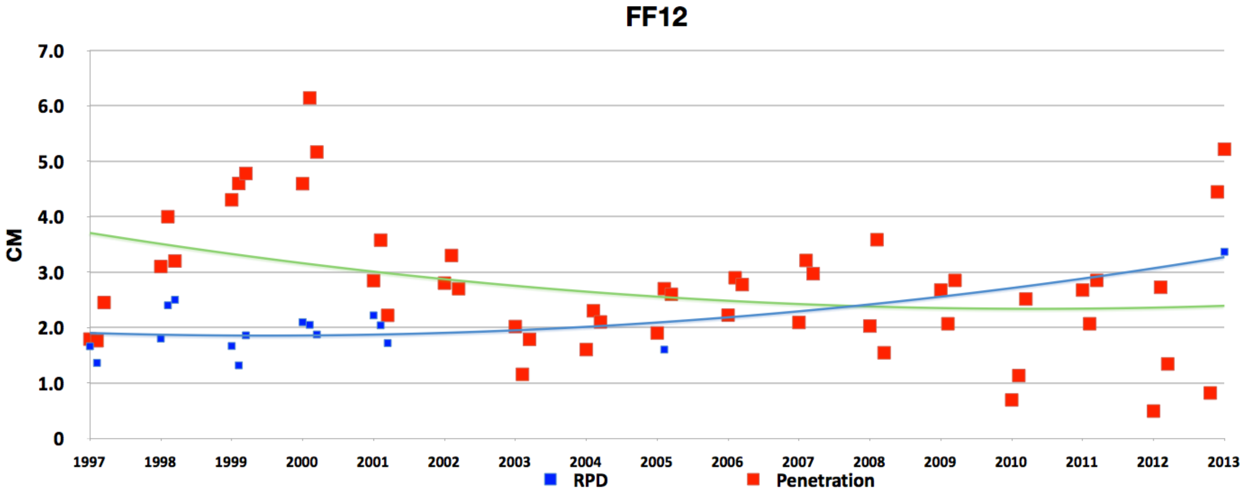


Figure 3-16. Comparison of prism penetration and aRPD layer depth at station FF12 by year for only stations with measured aRPD layers. Post base-line, aRPD was observed in 2005 and 2013.

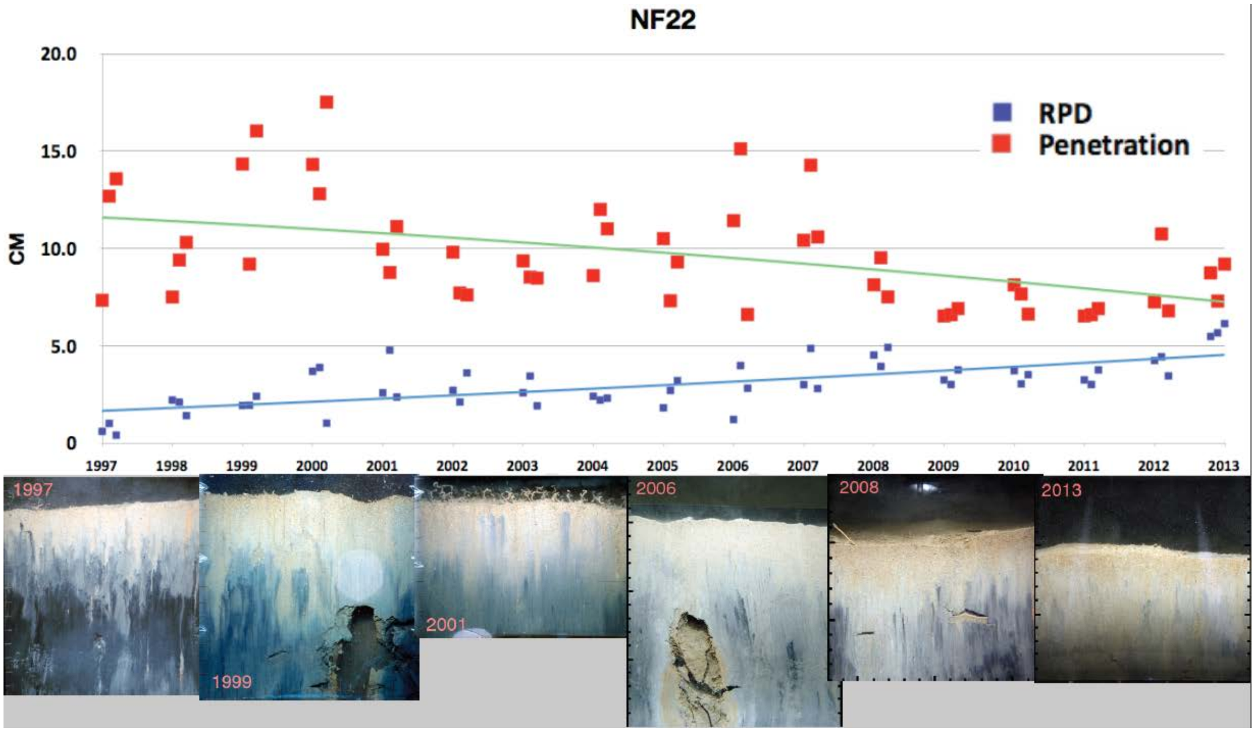


Figure 3-17. Comparison of prism penetration and aRPD layer depth at station NF22 by year for only measured aRPD layers. Thumbnail images are show for selected years. Scale in images is in cm.

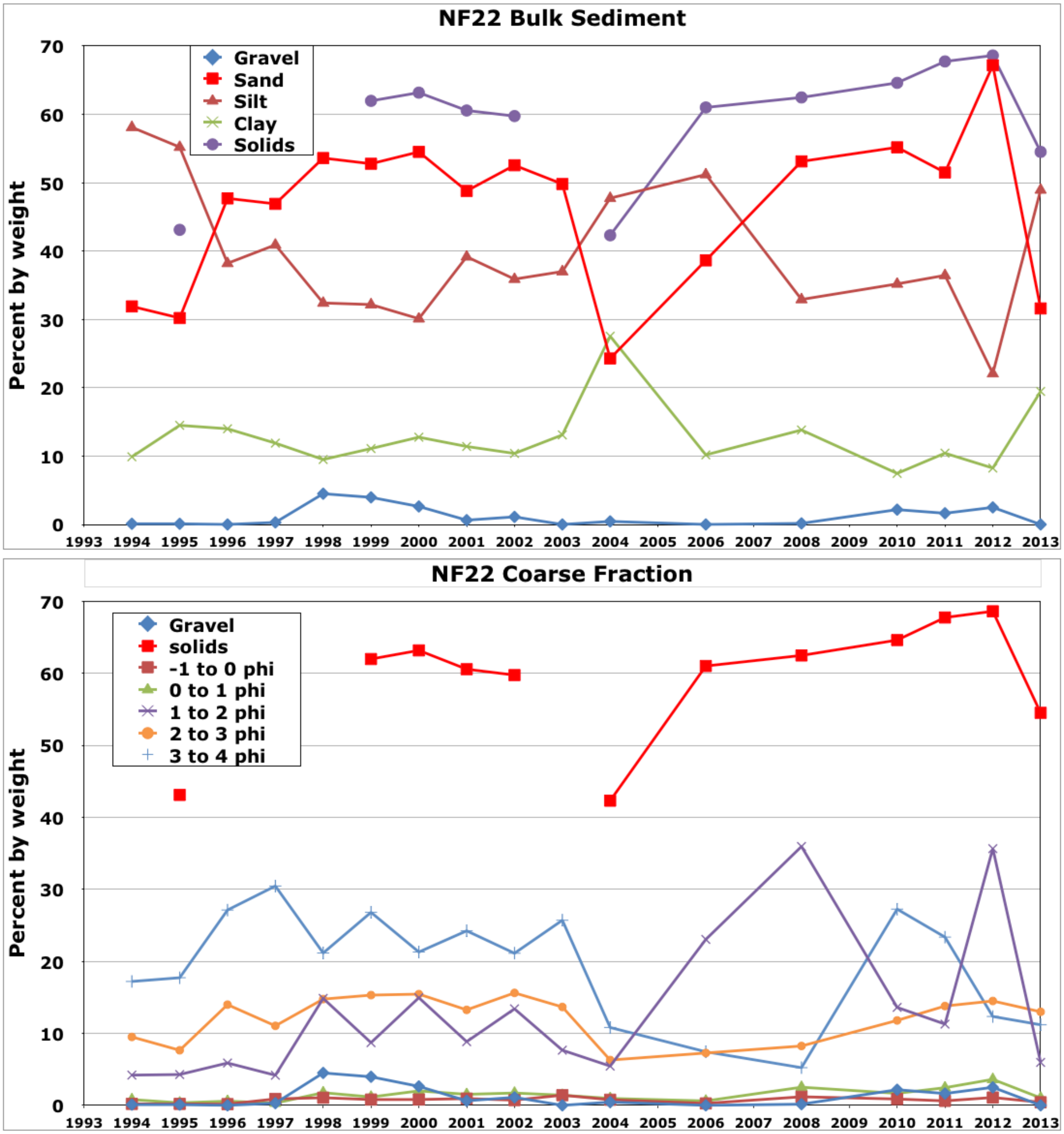


Figure 3-18. Within station variation in sediment grain-size at station NF22. Bulk sediment parameters are percent gravel, sand, silt, clay, and solids. "Solids" is the percent dry weight of bulk sediment.

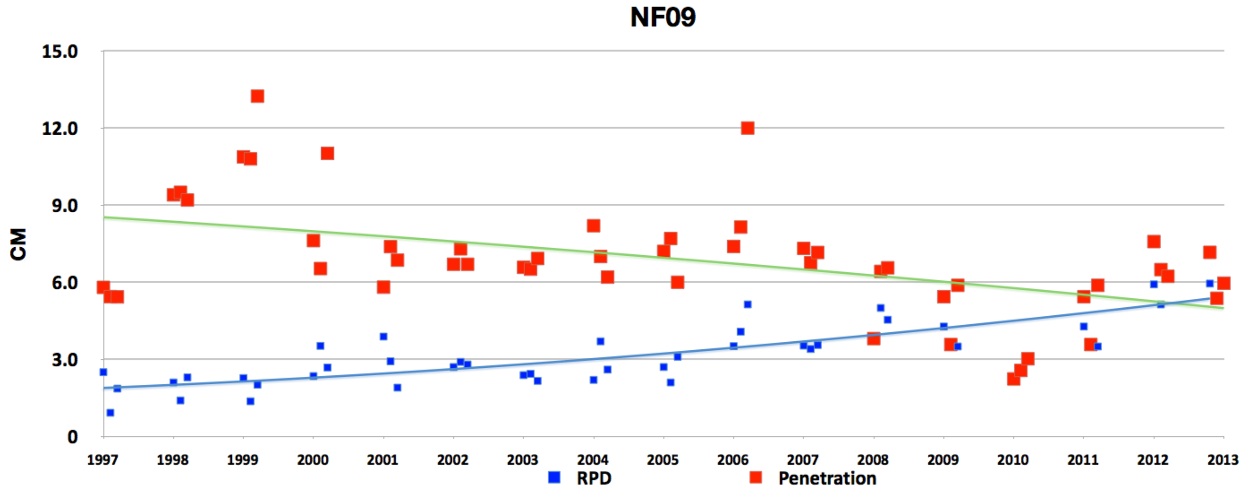


Figure 3-19. Comparison of prism penetration and aRPD layer depth at station NF09 by year for only measured aRPD layers. aRPD was not observed in 2010. Overall trend was for prism penetration to decline and aRPD to increase through time.

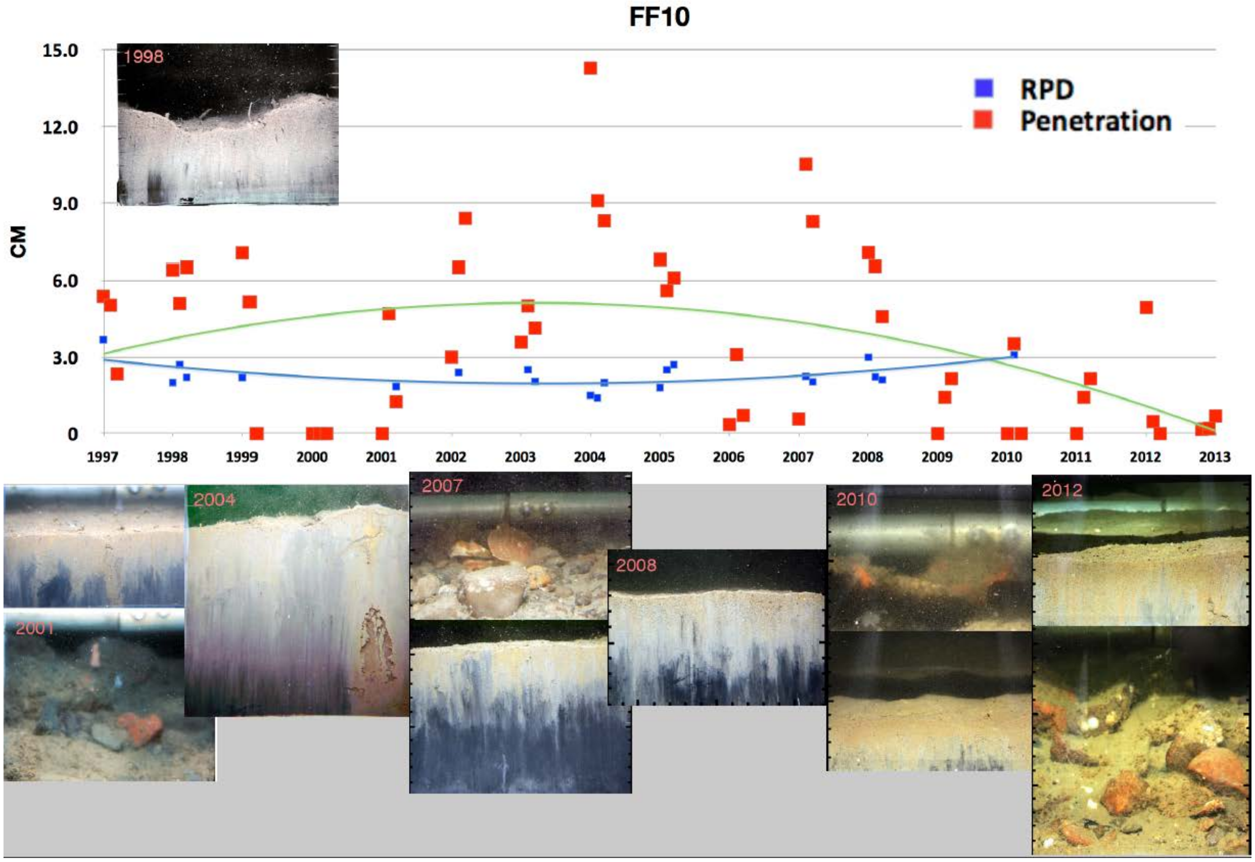


Figure 3-20. Comparison of prism penetration and aRPD layer depth at station FF10 by year for only measured aRPD layers. aRPD was last observed in 2010. Overall trend was for prism penetration to decrease and aRPD to remain the same. Heterogeneity of the sediments can be seen in the thumbnail images for selected years. Scale in images is in cm.

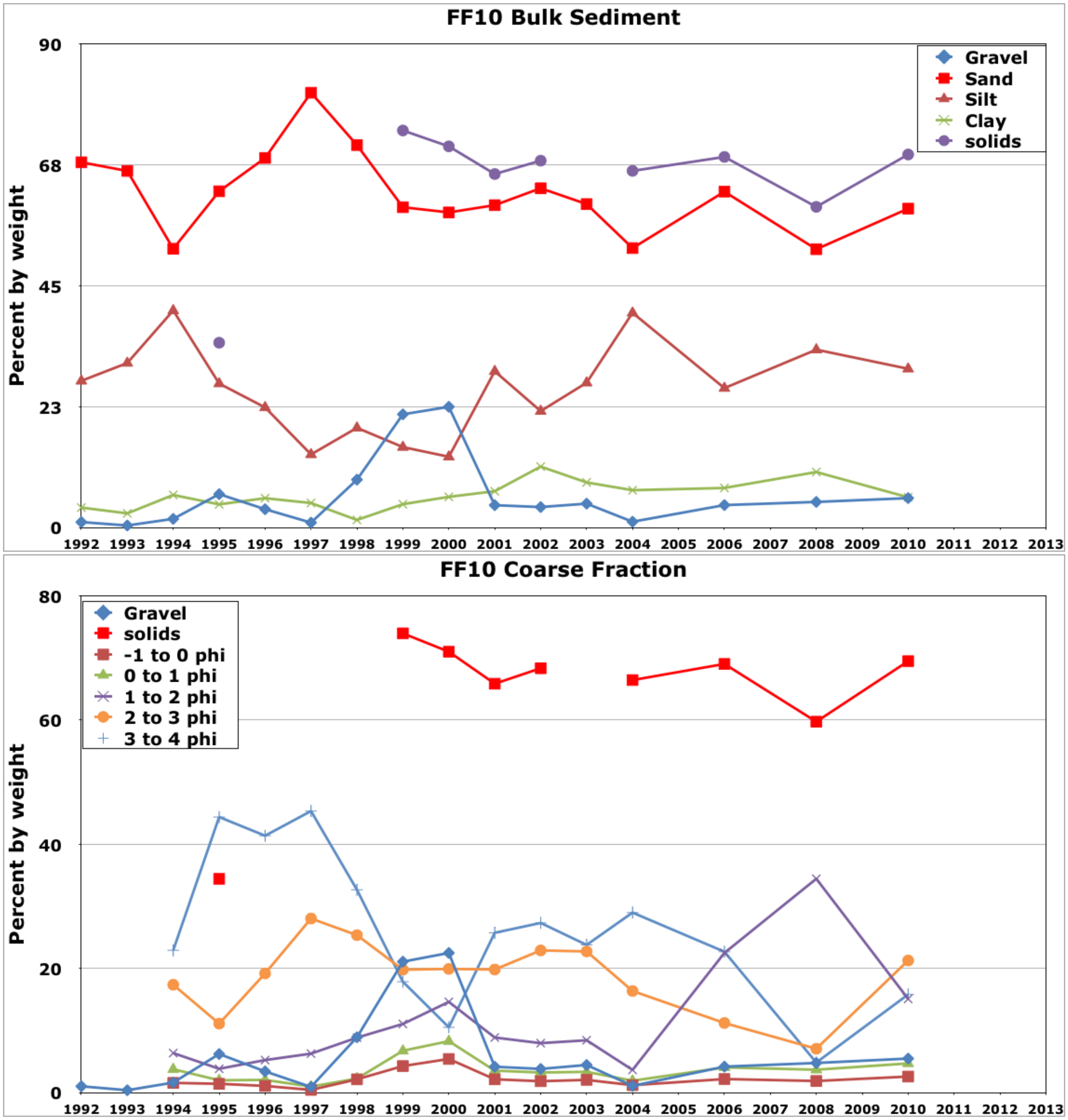


Figure 3-21. Within station variation in sediment grain-size at station FF10. Bulk sediment parameters are percent gravel, sand, silt, clay, and solids. "Solids" is the percent dry weight of bulk sediment.

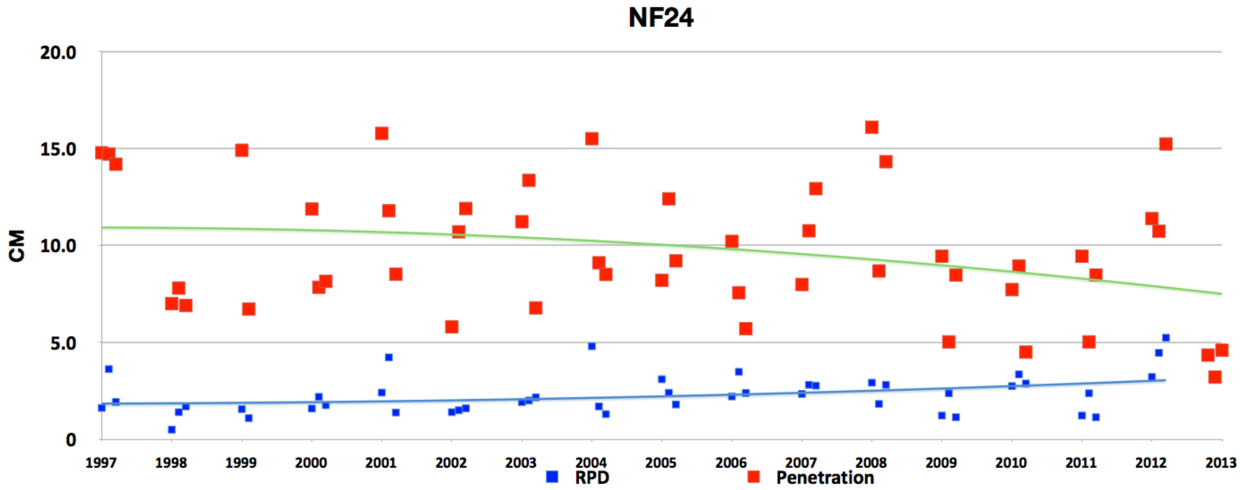
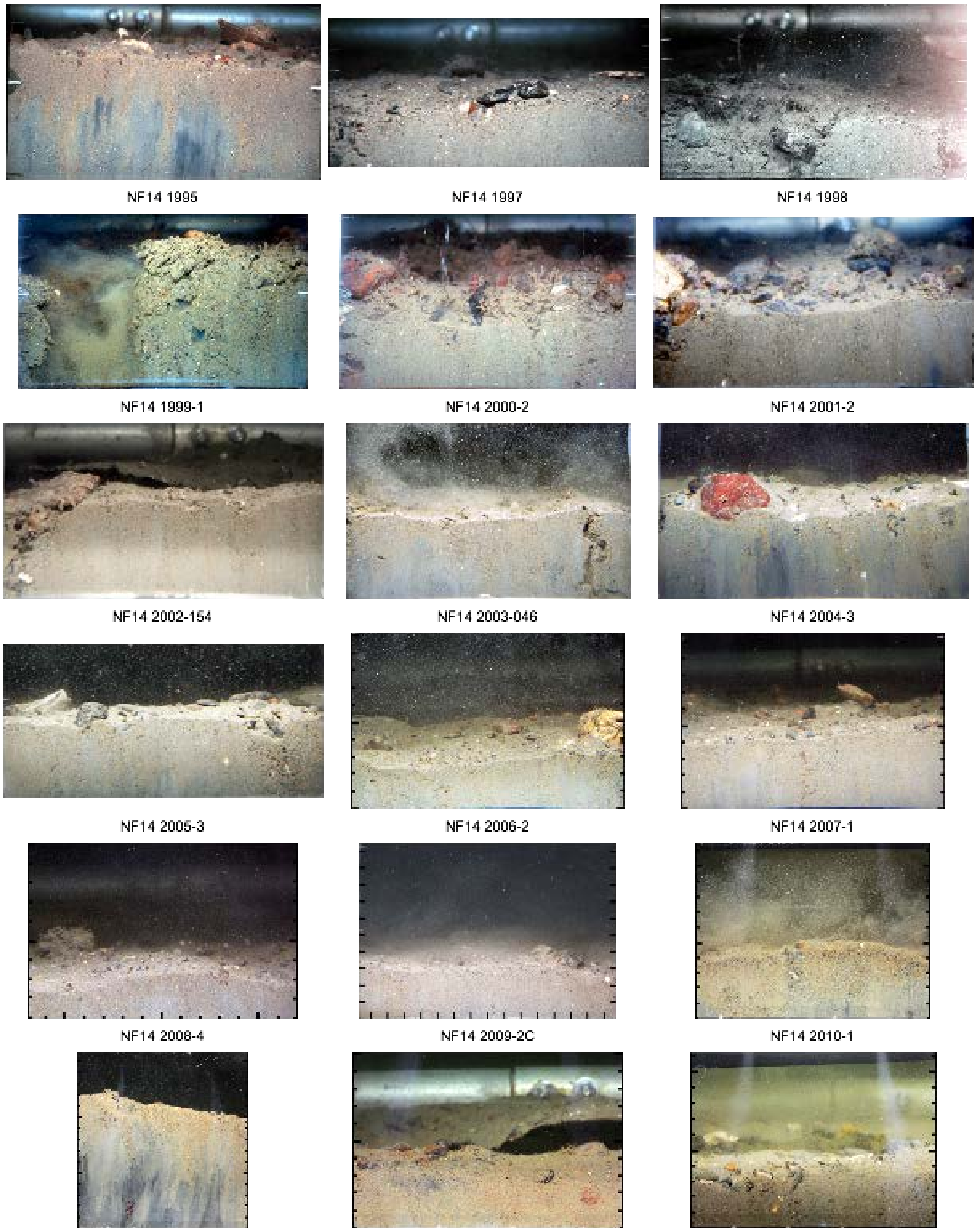


Figure 3-22. Comparison of prism penetration and aRPD layer depth at station NF24 by year for only measured aRPD layers. aRPD was not observed in 2013. Both prism penetration and aRPD depth remained about the same through time.

Figure 3-23. **Mosaic of SPI from station NF24 for all years. Baseline years are up to 2000. Post-baseline years are from 2001. Sediment grain-size at NF24, within a half km of the outfall, is finest of all nearfield stations. Surface sediments are consistently light in color indicating there has been no accumulation of organic matter post-baseline. Scale along the side of each image is in cm.**



NF14 1995
NF14 1997
NF14 1998
NF14 1999-1
NF14 2000-2
NF14 2001-2
NF14 2002-154
NF14 2003-046
NF14 2004-3
NF14 2005-3
NF14 2006-2
NF14 2007-1
NF14 2008-4
NF14 2009-2C
NF14 2010-1
NF14 2011-1
NF14 2012-1
NF14 2013-1

Figure 3-24. Mosaic of SPI from station NF14 for all years. Baseline years are up to 2000. Post-baseline years are from 2001. Sediment grain-size at NF14 is heterogeneous and tends to have <10% fines and <1% TOC. In 2002, TOC at NF14 was 3.2% based on data from grab samples, but in SPI there is little evidence of TOC being >1%. Surface sediments are consistently light in color indicating low organic matter concentrations. Scale along the side of each image is in cm (in some images scales are not visible; in others (e.g. 1995) only the 5 cm scale-marks are visible

4. SUMMARY OF RELEVANCE TO MONITORING OBJECTIVES

Benthic monitoring for MWRA's offshore ocean outfall is focused on addressing three primary concerns regarding potential impacts to the benthos from the wastewater discharge: (1) eutrophication and related low levels of dissolved oxygen; (2) accumulation of toxic contaminants in depositional areas; and (3) smothering of animals by particulate matter.

The 2013 SPI survey found no indication that the wastewater discharge has resulted in low levels of dissolved oxygen in nearfield sediments. The average thickness of the sediment oxic layer in 2013 was greater than reported during the baseline period. The numbers of opportunistic species remained negligible in 2013. These results support previous findings that eutrophication and the associated decrease in oxygen levels have not been a problem at the nearfield benthic monitoring stations (Nestler et al. 2013a, Maciolek et al. 2008).

Sediment contaminant loads were last monitored in 2011 when testing found no indication that toxic contaminants from the wastewater discharge are accumulating in depositional areas surrounding the outfall (Nestler et al. 2012). No Contingency Plan threshold exceedances for sediment contaminants have occurred to date, including in 2011. Patterns in the spatial distribution of higher contaminant concentrations primarily reflect both the percentage of fine particles in the sediment, and the proximity to historic sources of contaminants in Boston Harbor (Nestler et al. 2012). The hard-bottom community was also last monitored in 2011. Although some modest changes in this community (e.g., coralline algae and upright algae cover) have been observed, comparisons between the post-diversion and baseline periods indicate that these changes are not substantial. Factors driving changes in the algal cover are unclear, but, since declines in upright algae started in the late 1990s (prior to wastewater diversion to the outfall), it is unlikely that the decrease was attributable to diversion of the outfall (Nestler et al. 2012).

Surveys of soft-bottom benthic communities continue to suggest that animals near the outfall have not been smothered by particulate matter from the wastewater discharge. As there were in each of the previous three years, there were threshold exceedances in 2013 for two infaunal diversity measures: (1) Shannon-Wiener Diversity (H′) and (2) Pielou’s Evenness (J′). Previous analyses of these parameters suggest that recent increases in H′ and J′ have been largely driven by relatively lower abundance in a small number of dominant species. In-depth analyses of these exceedances are provided in Appendix A. Changes in faunal communities that resulted in threshold exceedances appear to be region-wide and unrelated to the discharge. Both analyses of spatial and temporal patterns in community parameters and multivariate analyses, found no evidence of impacts to infaunal communities from the wastewater discharge in Massachusetts Bay.

The results of the threshold exceedance evaluation in this report suggest it may be appropriate to revisit the need for upper diversity triggers for MWRA’s infaunal Contingency Plan thresholds.

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Appendix A Evaluation of Infaunal Threshold Exceedances for H′ and J′

Appendix A

Evaluation of Infaunal Threshold Exceedances for H′ and J′

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1. INTRODUCTION

Shannon-Wiener Diversity (H′) and Pielou's Evenness (J′) values at MWRA's nearfield stations exceeded the Contingency Plan thresholds in 2013 for the fourth consecutive year. This evaluation has been prepared in response to these exceedances. The goal of this evaluation was to investigate two related questions: (1) what factors have contributed to the threshold exceedances (see Section 4.2); and (2) are the threshold exceedances an indication of outfall impacts (see Section 4.3)?

This evaluation included a combination of targeted data analyses and a review of the literature on response in species diversity to anthropogenic impacts. Factors that have been most influential to threshold exceedances are identified and discussed. The contributions of individual species to the threshold exceedances are evaluated. Results of MWRA's infaunal monitoring in Massachusetts Bay are considered in the context of historically observed responses of diversity in marine soft-bottom communities exposed to impacts such as those associated with wastewater discharges.

2. BACKGROUND

The MWRA's Contingency Plan defines thresholds for key monitoring parameters (MWRA 1997, 2001). These thresholds provide benchmark values that were designed to trigger actions such as further evaluation of potential outfall effects, or modifications to wastewater treatment processes. Shannon-Wiener diversity (H′) and Pielou's evenness (J′) are among the seven infaunal biodiversity measures that are tracked by MWRA as Contingency Plan thresholds. The Contingency Plan includes both upper and lower threshold limits for H′ and J′ on the basis that "appreciable change" in these parameters, measured as either an increase or decrease, may provide an indication of outfall impacts (MWRA 1997, 2001). Change is assessed by annual comparisons of the baseline period (1992–2000) to the current year. Upper and lower diversity thresholds are tested by comparing whether the annual nearfield station means fall within the central 95th percentiles (plus or minus) of the baseline means (see Appendix A, MWRA SOP-04 in Nestler et al. 2013a). The nearfield stations included in this comparison are defined within MWRA's Ambient Monitoring Plan, which has been revised periodically over the years since monitoring began (MWRA 1991, 1997, 2001, 2004, 2010). Current infauna sampling is conducted at 11 nearfield stations (FF12, NF13, NF14, NF17, NF24, NF04, NF10, NF12, NF20, NF21, and NF22) and 3 farfield stations (FF01A, FF04, and FF09) during August (Figure 1). All analyses in this evaluation have been done using the stations that are sampled under the current monitoring plan. Due to changes over time in the monitoring plan, sampling effort at these stations has varied somewhat during the monitoring program. In particular, from 2004-2010 some stations were sampled only during even years (NF22, FF04 and FF09), Stations NF17 and NF12 were sampled each year, and the remaining stations were sampled only during odd years.

Diversity (H′) and eveness (J′) of the nearfield benthic community were above the upper threshold limits in August 2010 through 2013, triggering caution level exceedances (Table 1). Benthic monitoring during 2010 was conducted following the 2004 revision to the Ambient Monitoring Plan (MWRA 2004), while monitoring during 2011 to 2013 was conducted following the 2010 revision to the Plan (MWRA 2010). Annual mean values for H′ and J′ at the nearfield stations, along with threshold limits under the current monitoring plan, are shown in Figures 2 and 3. Results for H′ in 2008 and 2009 did not exceed the thresholds for the station sets that were sampled in those years and the threshold ranges then in effect.

Threshold exceedances for H′ and J′ have been reported to regulators and the public each year (MWRA 2013, MWRA 2012, MWRA 2011a, MWRA 2011b), and evaluations of the exceedances were conducted. Previous evaluations of the threshold exceedances have included spatial and temporal analyses of H′ and J′ and of patterns in the abundance of dominant species (Nestler et al. 2013b and 2012, Maciolek et al. 2011). To date there has been no evidence found that the threshold exceedances resulted from an impact of the outfall discharge on infaunal communities. Changes over time in H′ and J′ values have been attributed to natural variability in the benthic communities monitored in the vicinity of MWRA’s outfall. Unanswered questions about the specific factors driving the exceedances, and the implications of the exceedances to understanding potential outfall impacts are the impetus for this current evaluation.

Table 1. Caution level threshold exceedances for H′ and J′ in 2010 to 2013.

	Shannon-Wiener Diversity (H′)			Pielou’s Evenness (J')		
	Threshold range			Threshold range		
Year	Low	High	Result	Low	High	Result
2010[1]	3.37	4.14	4.23	0.58	0.68	0.70
2011	3.37	3.99	4.15	0.57	0.67	0.69
2012	3.37	3.99	4.36	0.57	0.67	0.70
2013	3.37	3.99	4.08	0.57	0.67	0.71

[1] 2010 threshold ranges and results based on data collection under the 2004 revision to the Ambient Monitoring Plan (MWRA 2004).

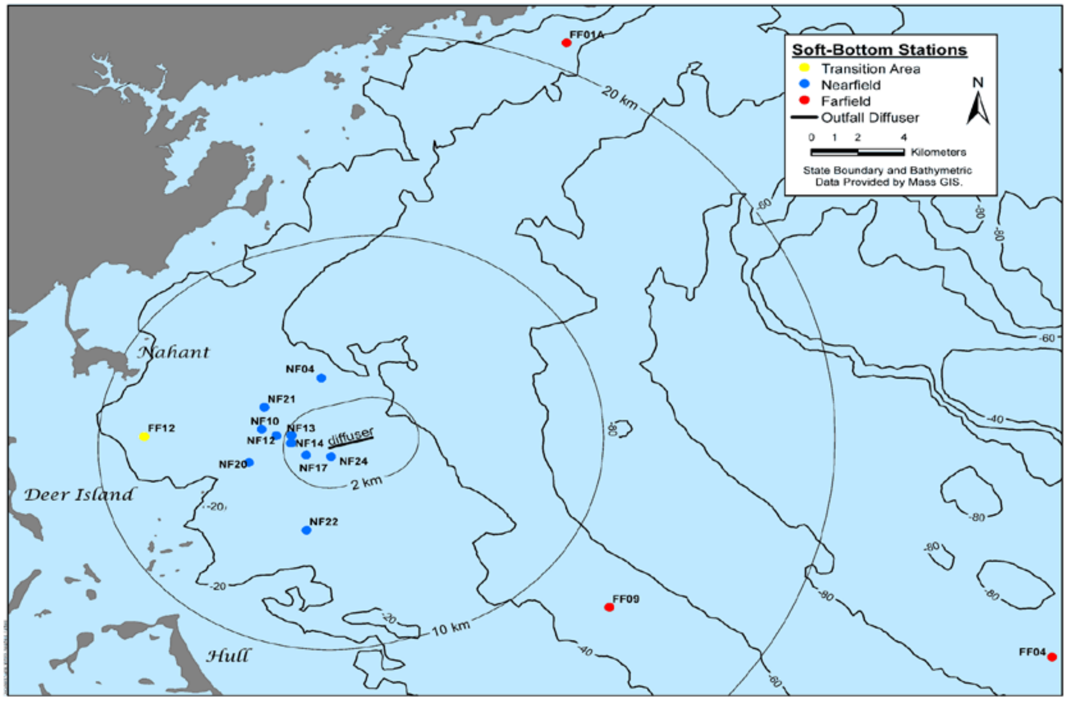


Figure 1. Sampling stations for sediments and infauna in Massachusetts Bay

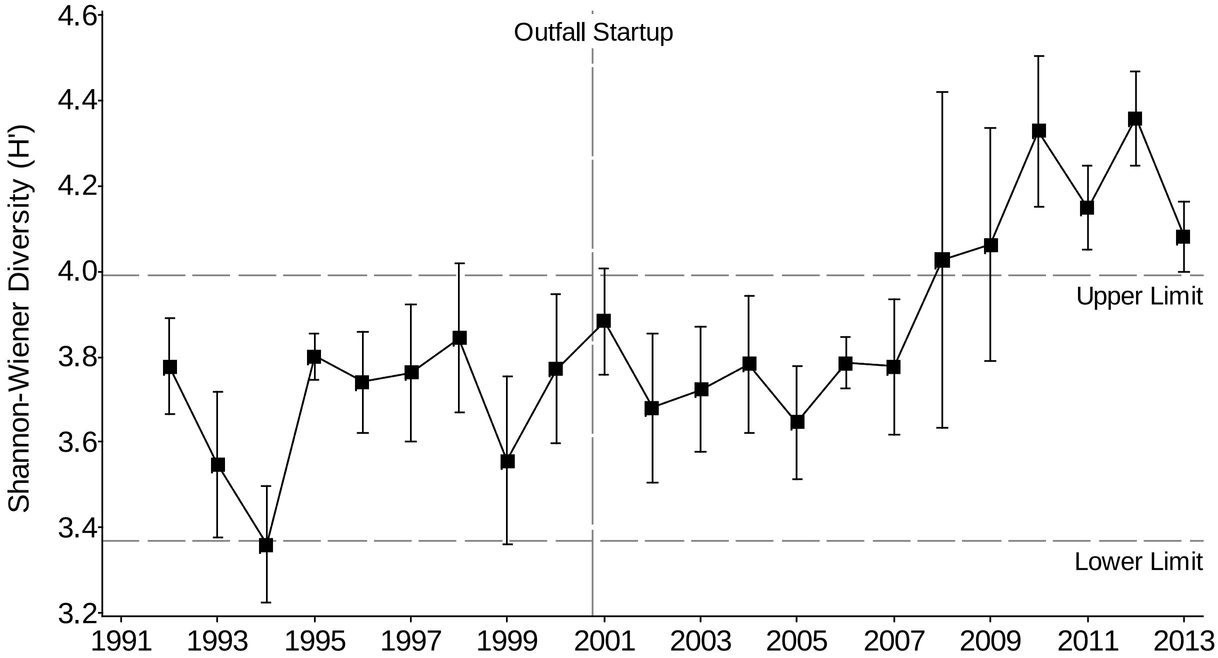


Figure 2. Mean Shannon-Wiener Diversity (H′) at nearfield stations in comparison to threshold limits, 1992 to 2013.

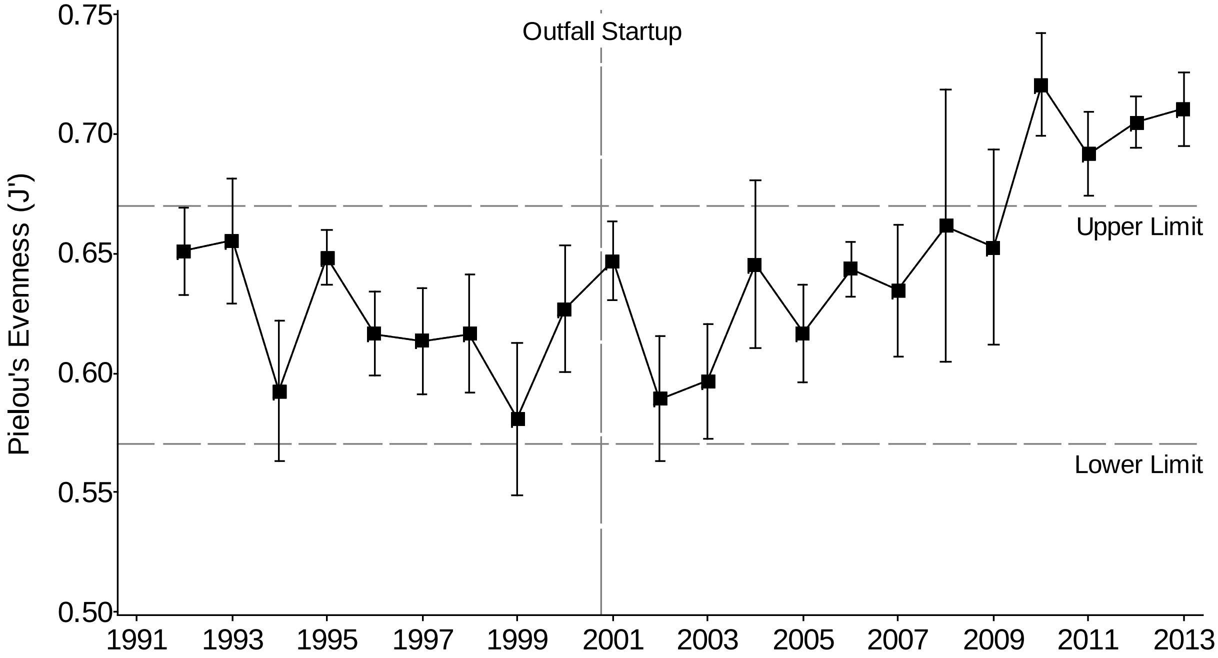


Figure 3. Mean Pielou's Evenness (J′) at nearfield stations in comparison to threshold limits, 1992 to 2013.

3. METHODS

Field, laboratory, and analytical methods for the Outfall Benthic Monitoring Program are described in Section 2 (main body of report). The overall approach to this evaluation and the additional analytical methods that were used are described in the sections below.

3.1 Structure of the Threshold Exceedance Evaluations

This evaluation began with a review of previous analyses that investigated infaunal threshold exceedances in 2010 to 2012 (Nestler et al. 2013b and 2012, Maciolek et al. 2011). The review was done as part of an overall assessment to identify analytical approaches that would be most useful for determining whether exceedances have been related to the outfall. Based on this assessment it was evident that no one analytical approach could reliably answer the question of whether or not the exceedances were related to the discharge. Instead it was determined that a weight of evidence approach, pursuing several complimentary methods in greater detail than previous evaluations, was the best option.

The selected evaluation approach targeted two related questions: (1) what factors have contributed to the threshold exceedances; and (2) are the threshold exceedances an indication of outfall impacts? The first question focused on identifying specific factors that contributed to the exceedances. The rationale for this reductionist approach was to identify driving factors behind the exceedances, so that those individual factors (e.g., individual species) could then be evaluated for evidence of causal relationships with the wastewater discharge. This evaluation of driving factors was done through the following steps:

- Detailed review of Diversity (H′) and Evenness (J′) computations and the data properties that influence these indices (Section 4.1).
- Community-level assessment of changes that resulted in exceedances (Section 4.2.1). This was done to assess the relative importance of dominance versus species richness to the H′ exceedances.
- Species-level assessment of changes that resulted in exceedances (Section 4.2.2). This was done to identify which of the 419 species collected at the current nearfield stations were most influential to the threshold exceedances.

Once the driving factors behind threshold exceedances had been identified, the second question (whether exceedances indicate outfall impacts), could then be addressed using the best available evidence and a multi-faceted weight of evidence approach. The rationale for a broad weight of evidence approach was that impacts to the nearfield infaunal community that resulted in changes to H′ and J′ would likely also be evident in other measures of the species and community-level patterns in faunal distribution. Spatial and temporal patterns suggesting exceedances caused by outfall impacts should match spatial (distance from outfall) and temporal (co-occurrence with outfall startup or changes to wastewater treatment) patterns related to the outfall. Such patterns would likely also be evident in sediment parameters such as *Clostridium perfringens*, total organic carbon, or sediment texture. The evidence for outfall impacts was investigated through the following analyses:

- Spatial and temporal analyses of H′ and J′ (Section 4.3.1).
- Spatial and temporal analyses of species that influenced exceedances (Section 4.3.1).
- Spatial analyses of infaunal communities in 2013 using multivariate techniques (Section 4.3.2.1).
- Temporal analyses of infaunal communities using multivariate techniques (Section 4.3.2.2).

- Evaluation of evidence for impacts based on analytical results (Section 4.4).

3.2 Evaluation of Species-level Influences on Diversity Measures

Exploratory analyses were conducted to identify the individual species that contributed most to threshold exceedances. An index of "influence" was calculated by comparing baseline versus exceedance period (years with exceedances) differences for mean values calculated using the full project data set to the same values for a data set from which one species had been excluded. First, the difference between the baseline (1992 to 2000) and exceedance (2010 to 2013) period mean values (for H′ and J′) was calculated by subtracting the baseline mean from the exceedance period mean, using the full project database with all species. Next, a species was removed from the project database and the baseline versus exceedance period difference was re-calculated. The re-calculated difference was then subtracted from the original difference to calculate the influence of each individual species.

Thus, influence was calculated using the following equation:

Influence = Difference_All – Difference_Sp

where,

Difference_All = the difference between the baseline (1992 to 2000) and exceedance (2010 to 2013) period mean values for H′ and J′; calculated by subtracting the baseline mean from the exceedance period mean using the full project database with all species.

Difference_Sp = the difference between the baseline (1992 to 2000) and exceedance (2010 to 2013) period mean values for H′ and J′; calculated by subtracting the baseline mean from the exceedance period mean using a data set from which one species was removed.

Through an iterative process, an "influence" value was calculated for each species by excluding that species from the project database and running these calculations. This process of calculating an influence index value for each species was done separately for H′ and J′. All computations were done using SAS system software (version 9.3) and a data set that included all currently sampled nearfield stations. Once influence was calculated for each species, the species were ranked in order of their relative contributions to threshold exceedances.

3.3 Multivariate Analyses

Multivariate techniques were used to evaluate spatial and temporal patterns in faunal communities. Multivariate analyses were performed using PRIMER v6 (Plymouth Routines in Multivariate Ecological Research) software to examine spatial patterns in the overall similarity of benthic assemblages in the survey area (Clarke 1993, Warwick 1993, Clarke and Green 1988). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group average linking and ordination by non-metric multidimensional scaling (MDS). Bray-Curtis similarity was used as the basis for both classification and ordination. Prior to analyses, infaunal abundance data were fourth-root transformed to ensure that all taxa, not just the numerical dominants, would contribute to similarity measures.

Cluster analysis and MDS ordination. Cluster analysis produces a dendrogram that represents discrete groupings of samples along a scale of similarity. This representation is most useful when delineating among sites with distinct community structure. MDS ordination produces a plot or “map” in which the distance between samples represents their rank ordered similarities, with closer proximity in the plot representing higher similarity. Ordination provides a more useful representation of patterns in community structure when assemblages vary along a steady gradation of differences among sites. Stress provides a measure of adequacy of the representation of similarities in the MDS ordination plot (Clarke 1993). Stress levels less than 0.05 indicate an excellent representation of relative similarities among samples with no prospect of misinterpretation. Stress less than 0.1 corresponds to a good ordination with no real prospect of a misleading interpretation. Stress less than 0.2 still provides a potentially useful two-dimensional picture, while stress greater than 0.3 indicates that points on the plot are close to being arbitrarily placed. Together, cluster analysis and MDS ordination provide a highly informative representation of patterns of community-level similarity among samples.

SIMPROF (“similarity profile test”). The SIMPROF analysis was used to provide statistical support for the identification of faunal assemblages (i.e., selection of cluster groups). SIMPROF is a permutation test of the null hypothesis that the groups identified by cluster analysis (samples included under each node in the dendrogram) do not differ from each other in multivariate structure.

SIMPER (“similarity percentages”). The SIMPER analysis was used to determine the contribution of each individual species to the average Bray-Curtis dissimilarity between assemblages that occurred at nearfield stations during the baseline period compared to years with exceedances. SIMPER was also used to identify species that accounted for differences between the major infaunal assemblages identified as groups from the dendrograms.

ANOSIM (“analysis of similarities”). Spatial and temporal differences in multivariate time-series data were assessed by using the ANOSIM procedure (a multivariate analysis of similarities; see Clarke 1993). Tests for differences between treatment main effects, period and location, were assessed by a two-way ANOSIM (Clarke and Warwick 2001). According to the before-after-control-impact (BACI) design (Stewart-Oaten et al. 1986), potential outfall impacts appear as an interaction between treatment main effects. Using ANOSIM to test for differences, an interaction between main effects can be determined indirectly by comparing the baseline period to the post-diversion period (separately for each habitat type, based on sediment grain size and water depth) using a one-way test, provided that there were no differences between locations in the baseline period (Clarke 1993). Therefore, the interaction of the main effects must be tested using a two-stage procedure. First, the baseline period must be tested for location differences using a one-way ANOSIM. If there are no significant differences between locations in the baseline period, then each location can be tested for differences between periods using one-way ANOSIM. If there are significant differences between locations in the baseline period, this test for an interaction of the main effects is not valid.

4. EVALUATION OF THRESHOLD EXCEEDANCES

4.1 Definitions of Diversity (H′) and Evenness (J′)

The term "diversity" has been used for a wide range of concepts in ecology to describe various aspects of community composition (Tuomisto 2011, 2010). Numerous diversity indices and models have been designed to quantify these concepts (Magurran 1988). Each of these indices quantifies different, specific attributes of assemblage composition and structure. Thus, an intuitive understanding of the concept of diversity is not necessarily sufficient for interpreting what factors may have contributed most to the threshold exceedances. Evaluation of the threshold exceedances requires an understanding of how H′ and J′ are calculated, and the attributes of infaunal samples that are quantified by each of these indices.

The Shannon-Wiener Diversity Index (H′) is calculated using the following equation:

$$H' = -$$

Where,

S = total number of species in the sample
N = total number of individuals in the sample
n_i = total number of individuals in *i*th species

Pielou's Evenness (J') is calculated as the ratio of observed diversity to maximum diversity:

$$J' = H'/H_{max}$$

Where $H_{max} = \log_2(S)$

Both H′ and J′ are indices based on the proportional abundances of species (Magurran 1988). Evenness (J′) is entirely a function of proportional abundance; J′ values are unaffected by the number of species in a sample. Values for J' can range between 0 and 1, with J' = 1 when all species in a sample have equal abundances (i.e., $H_{max}/H_{max} = 1$). Diversity (H′) is a function of both proportional abundance and the number of species in the sample. The quantity in the H′ equation is the proportion of individuals found in the *i*th species. The maximum possible H′ diversity (H_{max}) for a given number of species occurs where all species have equal abundances [i.e., $\log_2(S)$]. Any log base can be used in the H′ equation; $\log_2$, as shown in the equations above (and used for MWRA calculations), is among the most common. H′ values calculated using different log bases are not comparable and must be converted to a common base prior to comparison. J' values are not affected by log base.

Shannon-Wiener Diversity (H′) is the most commonly cited measure of species diversity for marine benthic communities (Oliver et al. 2011, Johnston and Roberts 2009). Tuomisto (2010) explains that the Shannon-Wiener Diversity Index (H′) is more appropriately conceptualized as a measure of entropy (uncertainty) than of 'true diversity'. H′ quantifies the uncertainty in predicting the species identity of an individual organism selected randomly from a sample (Tuomisto 2010). For this reason, H′ is sometimes referred to as ‘Shannon’s Entropy’ as opposed to ‘Shannon’s Diversity’ (e.g., Hill 1973). Thus, H′ (the uncertainty of predicting a species’ identity) increases both with increasing numbers of species, and with increasingly even distributions of the total abundance among those species.

4.2 Infaunal Community Changes that led to Exceedances

4.2.1 Influence of Dominance and Species Richness

The H′ and J' exceedances of the upper threshold limits resulted from higher annual values at the nearfield stations during 2010 to 2013 than during the baseline period (Figures 4 and 5). Both H′ and J' are sensitive to dominance, whereas there have not been threshold exceedances for the two community parameters that are most sensitive to species richness (number of species and log-series alpha). Since exceedances occurred for both evenness and diversity, and evenness is entirely a function of proportional abundances, it was clear that changes in the dominance structure of the community were an important factor to evaluate. One measure of the dominance structure is provided by the Schwartz Dominance Index (SDI), which represents the number of species composing 75% of total abundance in a sample (Schwartz 1978). Comparisons of SDI at the nearfield stations over time illustrate that average dominance during 2010 to 2013 was higher than both the baseline period (1992 to 2000) and the post-diversion period through 2009 (Figure 6). SDI results compared across time periods show similar temporal patterns to H′ and J′, reflecting the importance of the dominant species to proportional abundances. Dominance plots, or ‘ranked species abundance curves’, provide an additional approach to evaluate proportional abundances. These plots are prepared by ranking species according to decreasing abundance, then plotting the species abundance as a percentage of total abundance against the species rank (plotted on a log scale). Analyses of the ranked species abundance at the nearfield stations further demonstrated that the dominance structure during the past four years differed considerably from most years up through 2009 (Figure 7). Both of these approaches documented that dominant species made up a smaller proportion of total abundance in recent years than was the case previously; that is, evenness in the communities increased.

In contrast to evenness, H′ is a function of both proportional abundance and the number of species in a sample (species richness). To evaluate the role of species richness in the H′ exceedances, comparisons of the mean numbers of species per sample for each time period were also made (Figure 8). These comparisons suggested that the numbers of species have not changed enough to explain the exceedances. Nonetheless, the influence of species richness on H′ values may be illustrated by comparing the 2013 results to those from 2010 to 2012 in Figures 4, 5, and 8. The slightly lower H′ in 2013 (Figure 4) may reflect lower species richness (Figure 8), while J′ in 2013 is no lower than in 2010 to 2012 (Figure 5). Although higher species richness may have contributed marginally to H′ exceedances in some years (e.g., 2012; Nestler et al. 2013b), lower dominance during 2010 to 2013 than during the baseline period appears to be the main factor behind threshold exceedances.

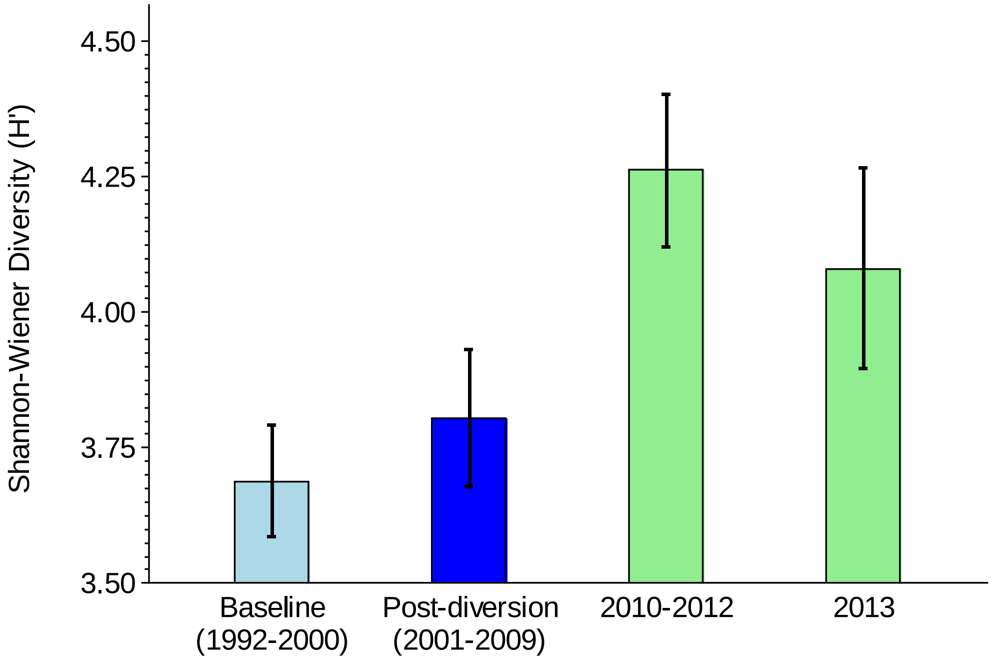


Figure 4. **Mean H′ per sample at nearfield stations in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2009) periods compared to 2010 to 2012 and 2013.**

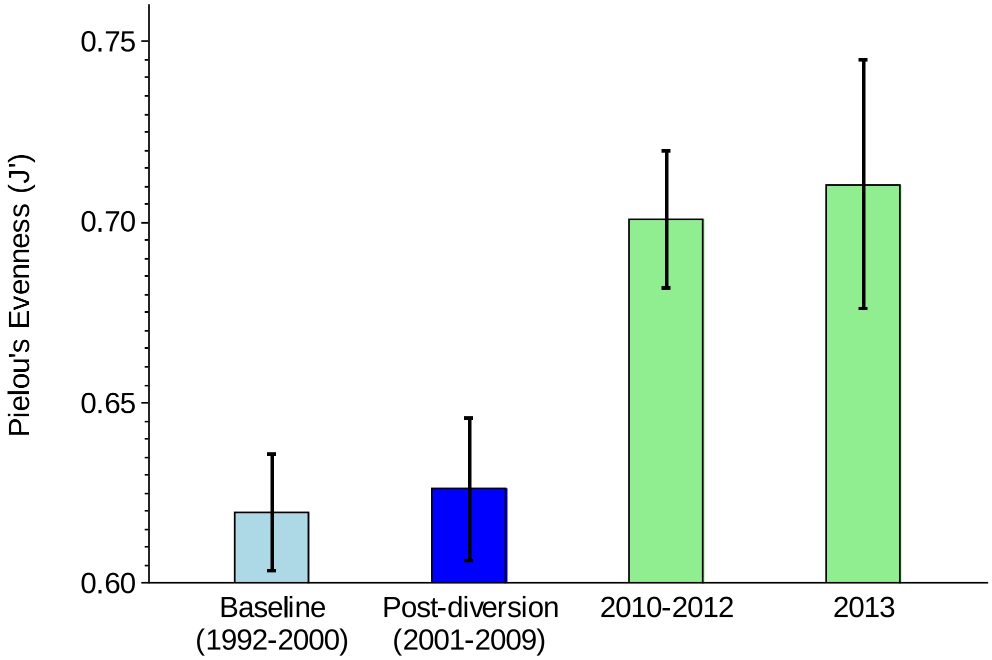


Figure 5. **Mean J′ per sample at nearfield stations in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2009) periods compared to 2010 to 2012 and 2013.**

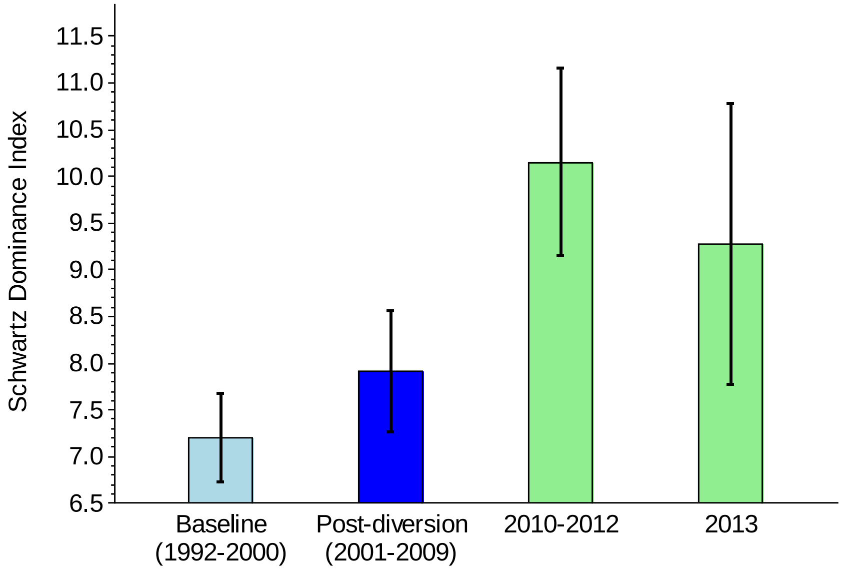


Figure 6. Mean Schwartz Dominance Index (minimum number of species composing 75% of the total abundance) per sample at nearfield stations in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2009) periods compared to 2010 to 2012 and 2013.

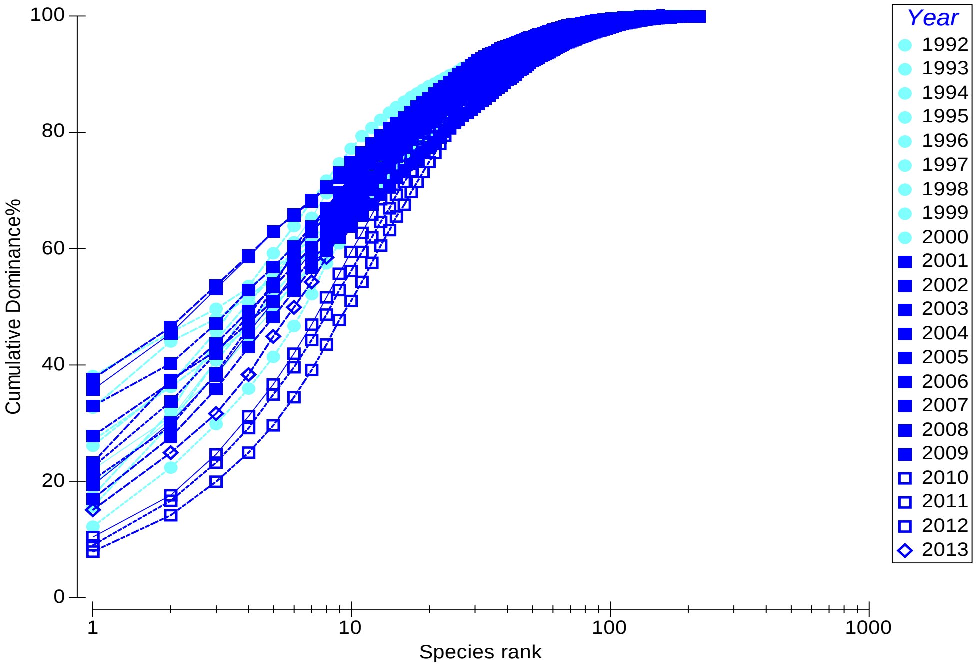


Figure 7 Ranked species abundance plot (dominance plot) comparing the cumulative percent contribution to total abundance for each species plotted against the species ranked from most to least dominant using species mean abundance across all nearfield stations for each year.

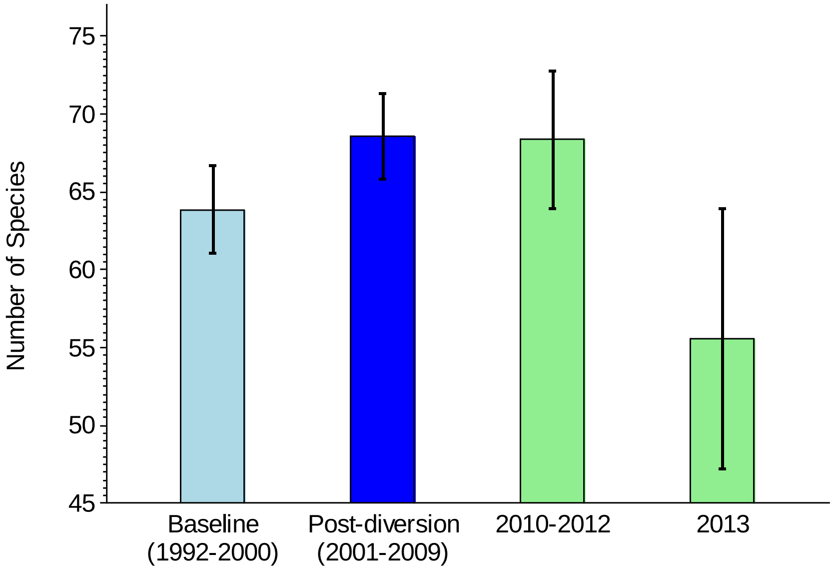


Figure 8. Mean number of species per sample at nearfield stations in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2009) periods compared to 2010 to 2012 and 2013.

4.2.2 Influence of Individual Species

Dominance is largely driven by fluctuations in abundance over time in a relatively small number of numerically important species. The analyses presented in Figures 4 to 8 demonstrated that changes to the distribution of total abundance among species in the nearfield samples (i.e., dominance or evenness) have been the most important driver of threshold exceedances. These findings raised the question of which individual species have been most influential in the observed changes that led to exceedances.

Previous evaluations. Maciolek et al. (2011) and Nestler et al. (2012) identified region-wide declines in the abundance of the spionid polychaete, *Prionospio steenstrupi*, as a likely factor influencing the H′ and J′ exceedances. Nestler et al. (2013b) looked further into the role of dominant species in the threshold exceedances and demonstrated that the removal of five species (*P. steenstrupi*, *Spio limicola*, *Mediomastus californiensis*, *Tharyx acutus*, and *Molgula manhattensis*) from the project database resulted in substantial increases to both H′ and J′ during the baseline period. These five numerically dominant species were selected on the basis that each contributed at least 5% to total abundance during either the baseline period or the post-diversion period through 2009. The influence of these five species was demonstrated by excluding them from the project database, then re-calculating the H′ and J′ values for the baseline and post-diversion periods. Comparisons of Figures 4 and 5 to Figures 9 and 10 illustrate the result of removing these species from the database.

New evaluations. Previous evaluations of individual species suggested that *P. steenstrupi* and several other numerical dominants had an important influence on H′ and J′ over time. However, the relative influence of each of these dominant species, and their individual contributions to threshold exceedances, were unclear. It was also unclear if other species may also have been influential in the threshold exceedances. To address these questions, further exploratory analyses were conducted to investigate the influence of individual species on the threshold exceedances. The contributions of individual species to exceedances were quantified by calculating an index of “influence” for each species, as described in Section 3.2. Once influence was calculated for each species, the species were ranked in order of their relative contributions to threshold exceedances.

During the baseline and exceedance periods, 419 species were collected at the current nearfield stations. The influence of each of these species on the relative differences in H′ and J′ values between periods is provided in Appendix I. The top numerical dominants were found to be the most influential species (Table 2). The 25 species listed on Table 2 accounted for 75% of the total abundance at nearfield stations during either the baseline (1992 to 2000) or the exceedance (2010 to 2013) periods. Half of these 25 dominant species had a positive influence on the threshold exceedances (i.e., influence value > 0 = differential between baseline and exceedance periods decreases with species removal), and half had a negative influence (i.e., influence value > 0 = differential between baseline and exceedance periods increases with species removal).

It is important to note that the influence values and ranking (Appendix I and Table 2) reflect the results of removing only a single species from the dataset (each of 419 species, one at a time). These results do not necessarily help to answer the question of *which group of species, in combination*, may have been most influential to the threshold exceedances. The reason for this is that the “influence” of each species on H′ and J′ is affected by the abundances of co-occurring species in each sample. The relative influences of sub-dominant species are strongly affected by dominant species in a sample. These results demonstrate that *P. steenstrupi* was by far the most influential species, accounting for about 36% of the difference in H′ and about 37% of the difference in J′ between baseline and exceedance periods (compare Figures 11 and 12 to 4 and 5). However, the influence values and ranking of other species were strongly influenced by *P. steenstrupi* abundances. The procedure, therefore, is most useful for identifying only the most influential species in the data set.

In order to identify which species was the next most influential after *P. steenstrupi*, the process of identifying and ranking influential species was repeated using a data set from which *P. steenstrupi* had been removed. *S. limicola* was confirmed as the next most influential species and then a third iteration of the process was repeated with both *P. steenstrupi* and *S. limicola* excluded from the dataset. This third iteration identified *M. californiensis* as the third most influential species. Through this process, *P. steenstrupi*, *S. limicola*, and *M. californiensis* were identified as the three most influential species. The finding that *M. californiensis* was the third most influential species may seem unlikely since it was one of the least influential of the 419 nearfield species evaluated when each was considered individually (Table 2). This illustrates (as described above) how the influence of each species is dependent upon the abundances of co-occurring species. *M. californiensis* was consistently among the top dominants during baseline years, with relatively small inter-annual differences in abundance, and peak abundance values below the levels of the the dominant spionid polychaetes (Figure 13). By contrast, *S. limicola* was most abundant in years when *P. steenstrupi* was least abundant and vice versa (e.g., 1994, 1998, and 1999). Nonetheless, *M. californiensis* remained one of the dominant species in nearfield samples when the dominant spionid polychaetes were not particularly abundant (e.g., 1992; Figure 13). Thus, the influence of *P. steenstrupi* on dominance was amplified by excluding *M. californiensis* (by itself) from the database, and the influence of *M. californiensis* is only apparent when both of the other top dominants were excluded. During 2010 to 2013, all three species were less dominant than they were in most baseline years. These three species in combination, accounted for about 64% of the difference in H′ and about 68% of the difference in J′ between baseline and exceedance periods. This exercise confirmed that the top dominant species from the baseline period (Table 2) were most influential, with *P. steenstrupi* having had the greatest effect on the H′ and J′ exceedances. Lower abundances of these three species during the exceedance period than during the baseline period resulted in a benthic community with no overwhelming dominants (Table 2, Figure 13).

Mean H′ and J′ values for the baseline and exceedance periods represent reductions of the multi-dimensional relationship of species abundances across samples. To account for this high dimensionality, the multivariate SIMPER routine (PRIMER software) was used to confirm species-level differences in nearfield infaunal communities between the baseline and exceedance periods. The SIMPER routine identifies species that contribute most to the dissimilarity among assemblages. The routine does this by decomposing the average Bray-Curtis similarities from all pairs of samples in each group into the percentage contributions from each species. While SIMPER cannot identify which species were most influential to changes in H′ or J′, it can identify the role of individual species in contributing to differences between infaunal assemblages at the nearfield stations during the baseline and exceedance periods. SIMPER was run on a data set of nearfield stations that included annual mean abundances for each species. This analysis identified *P. steenstrupi*, *S. limicola*, and *M. californiensis* as the three species that contributed most to the dissimilarity among assemblages between the baseline and exceedance periods. *P. steenstrupi* was the highest contributor to dissimilarity (20.3%), followed by *S. limicola* (7.4%) and *M. californiensis* (5.3%). SIMPER analysis helped to confirm that although many species contributed marginally to the threshold exceedances, none were more influential than these three.

Table 2. Mean abundance per sample of dominant[1] species along with Influence[2] and Rank Influence[3] of each species on H′ and J' exceedances based on the 11 nearfield stations in Massachusetts Bay during the baseline period (1992 to 2000), the post-diversion period from 2001 to 2009, and the years with exceedances (2010 to 2013).

Taxon		Mean abundance per sample			Influence on exceedances		Rank influence	
Phylum: Higher Taxon, Family	Species	Baseline (1992-2000)	Post-diversion (2001-2009)	2010-2013	H′	J'	H′	J'
Annelida: Polychaeta, Spionidae	*Prionospio steenstrupi*	425.8	615.2	66.1	0.19765	0.031793	1	1
Annelida: Polychaeta, Spionidae	*Spio limicola*	170.2	87.8	60.7	0.04533	0.007520	2	2
Annelida: Polychaeta, Cirratulidae	*Monticellina cf. dorsobranchialis*	6.6	15.2	26.0	0.03240	0.004906	3	4
Arthropoda: Amphipoda, Corophiidae	*Crassicorophium crassicorne*	69.9	58.3	30.3	0.02184	0.005116	4	3

(continued)

Table 2. (Continued)

Taxon		Mean abundance per sample			Influence on exceedances		Rank influence	
Phylum: Higher Taxon, Family	**Species**	**Baseline (1992-2000)**	**Post-diversion (2001-2009)**	**2010-2013**	**H′**	**J'**	**H′**	**J'**
Annelida: Polychaeta, Scalibregmatidae	*Scalibregma inflatum*	1.4	0.7	22.4	0.01869	0.001503	5	7
Annelida: Polychaeta, Dorvilleidae	*Parougia caeca*	11.0	22.8	14.5	0.01216	0.001486	8	8
Annelida: Polychaeta, Sabellidae	*Euchone incolor*	48.4	25.1	46.1	0.00889	0.001008	14	11
Mollusca: Bivalvia, Nuculidae	*Nucula delphinodonta*	14.5	16.6	25.4	0.00719	0.000648	17	16
Annelida: Polychaeta, Spionidae	*Spiophanes bombyx*	27.3	24.3	17.6	0.00523	0.000891	23	12
Annelida: Polychaeta, Orbiniidae	*Leitoscoloplos acutus*	28.3	39.5	25.9	0.00431	0.000188	27	41
Annelida: Polychaeta, Cirratulidae	*Monticellina baptisteae*	54.0	33.6	56.3	0.00415	0.000098	28	66
Annelida: Polychaeta, Cirratulidae	*Aphelochaeta cf. marioni*	49.5	37.1	25.5	0.00374	0.000349	31	26
Annelida: Polychaeta, Maldanidae	*Euclymene collaris*	6.1	4.3	14.5	0.00027	-0.000015	115	288
Annelida: Polychaeta, Lumbrineridae	*Scoletoma hebes*	13.5	16.7	21.5	-0.00209	-0.001244	377	406
Annelida: Polychaeta, Oweniidae	*Owenia fusiformis*	49.1	80.5	12.6	-0.00638	-0.001744	397	409
Annelida: Polychaeta, Syllidae	*Exogone hebes*	57.6	54.4	56.0	-0.00656	-0.001012	399	401
Annelida: Polychaeta, Lumbrineridae	*Ninoe nigripes*	64.0	51.8	43.6	-0.00980	-0.002116	408	410
Chordata: Urochordata, Molgulidae	*Molgula manhattensis*	8.1	138.2	22.4	-0.01658	-0.002807	411	412
Annelida: Polychaeta, Paraonidae	*Levinsenia gracilis*	39.9	59.7	75.6	-0.01669	-0.003603	412	416
Annelida: Polychaeta, Cirratulidae	*Tharyx acutus*	88.7	151.1	96.0	-0.01745	-0.003392	414	415
Annelida: Polychaeta, Syllidae	*Exogone verugera*	35.7	20.9	12.6	-0.01871	-0.003322	415	414
Annelida: Polychaeta, Spionidae	*Dipolydora socialis*	77.6	14.1	1.5	-0.02116	-0.002831	416	413
Annelida: Polychaeta, Polygordiidae	*Polygordius jouinae*	23.1	7.9	53.8	-0.02381	-0.004741	417	417
Annelida: Polychaeta, Capitellidae	*Mediomastus californiensis*	215.3	195.9	143.4	-0.03724	-0.006689	418	419
Annelida: Polychaeta, Paraonidae	*Aricidea catherinae*	91.7	95.7	69.8	-0.03833	-0.005894	419	418

[1] Dominants identified as taxa composing 75% of the total abundance in either the baseline period (1992 to 2000) or during years with exceedances (2010 to 2013).

[2] Influence = Influence of a species on H′ or J' exceedances based on removal of a single species from the project database. Higher Influence values indicate that the species contributed more to exceedances - values above zero indicate that the species contributed to exceedances; values below zero indicate that the species did not contribute to exceedances.

[3] Rank = Rank order of species from highest (1) to lowest (419) influence.

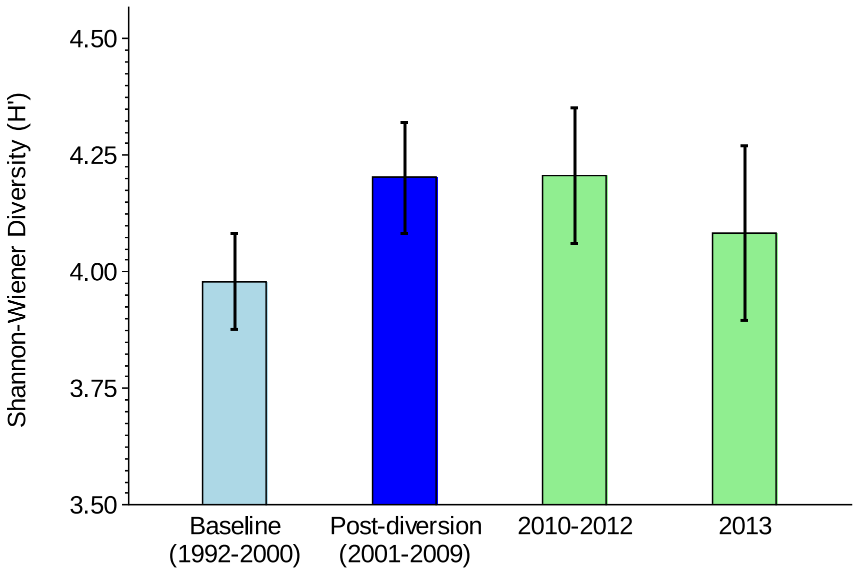


Figure 9. **Mean H′ per sample after excluding five dominant species from the data set at the nearfield stations in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2009) periods compared to 2010 to 2012 and 2013.**

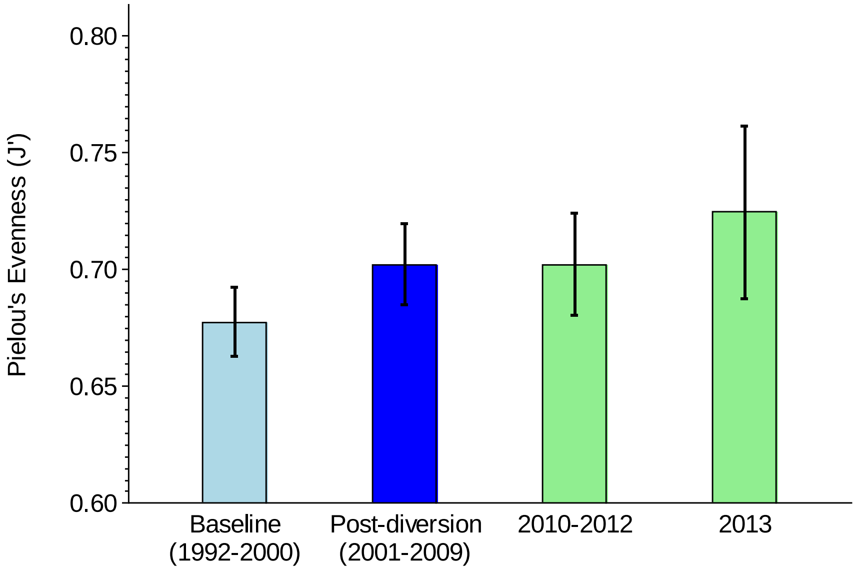


Figure 10. **Mean J′ per sample after excluding five dominant species from the data set at the nearfield stations in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2009) periods compared to 2010 to 2012 and 2013.**

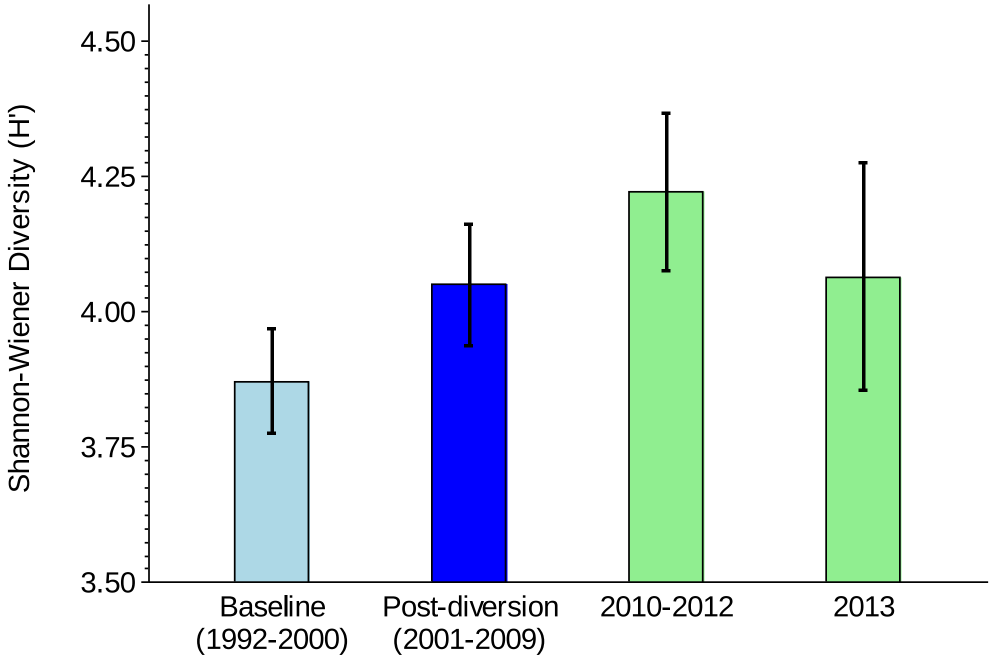


Figure 11. **Mean H′ per sample after excluding *Prionospio steenstrupi* from the data set at the nearfield stations in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2009) periods compared to 2010 to 2012 and 2013.**

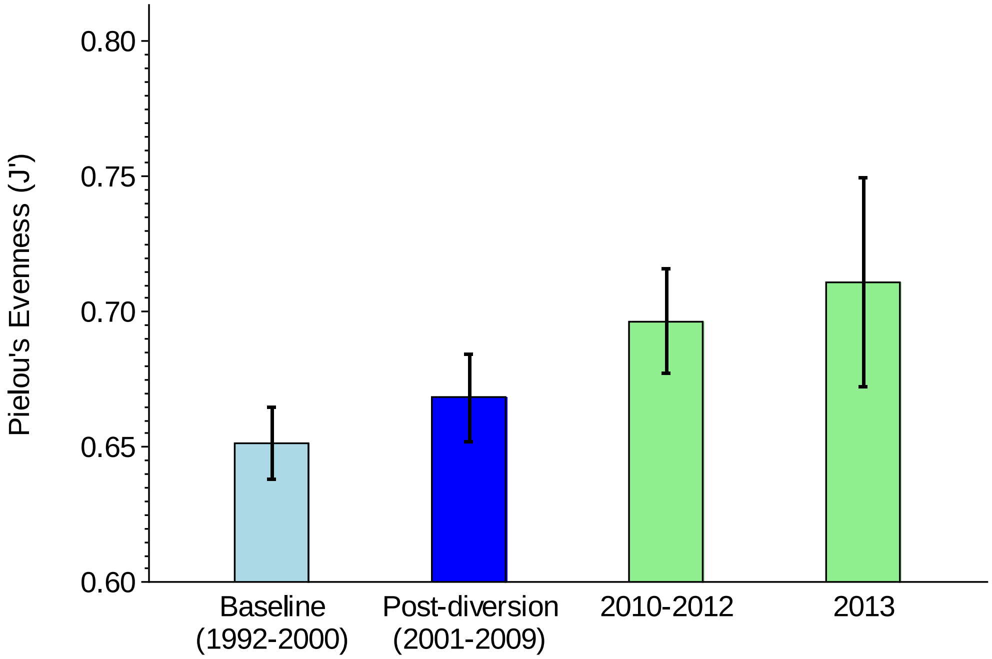


Figure 12. **Mean J′ per sample after excluding *Prionospio steenstrupi* from the data set at thenearfield stations in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2009) periods compared to 2010 to 2012 and 2013.**

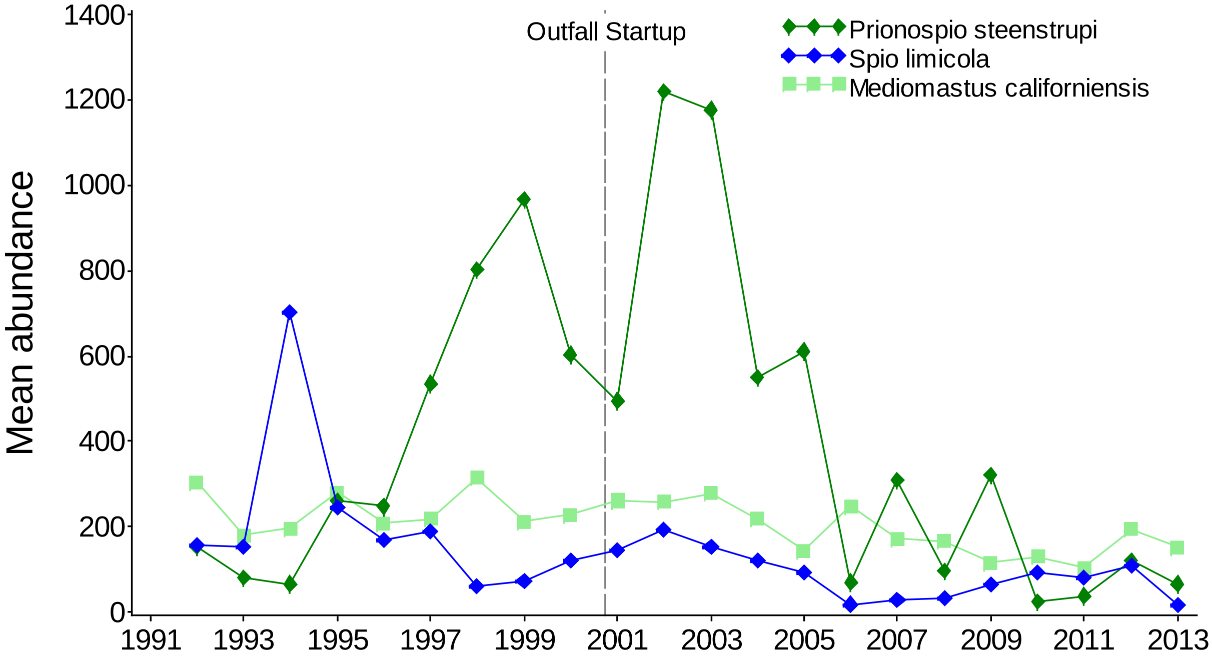


Figure 13. **Mean abundance per sample of three species that were most influential in H′ and J′ exceedances at the nearfield stations in Massachusetts Bay, 1992 to 2013.**

4.3 Spatial and Temporal Patterns in Benthic Infaunal Distributions

4.3.1 Community Parameters and Individual Species

To answer the question of whether the exceedances are related to the discharge, spatial and temporal patterns in H′, J′, and in species that most strongly influenced these parameters, were compared to the patterns expected if the discharge were influencing diversity and evenness. The most likely pattern of change for infaunal communities impacted by the discharge would be one that is coincident in time with the start of the post-diversion period, having the highest magnitude response at stations closest to the outfall. *Clostridium perfringens* spore counts show such a pattern (Figures 3-1 and 3-2 of main report). This pattern of increased *C. perfringens* counts at stations closest to the outfall as a result of effluent discharge has long been recognized (e.g., Kropp et al. 2002).

There was considerable spatial variability in both H′ and J' across the 14 stations sampled in Massachusetts Bay during 2013 (Figures 14 and 15). Spatial patterns in these parameters do not suggest an association between high diversity or evenness values (or low values) and proximity to the outfall diffuser. Similar patterns of spatial variability in H′ and J′ have been reported in previous years, with no apparent gradients in these parameters relative to the discharge (Nestler et al. 2013b).

At stations closest to the outfall (i.e., NF<2km = NF24, NF17, NF14, and NF13), there was no indication that H′ and J′ values increased more than at other locations in the post-diversion period as compared to the baseline (Figures 16 and 17). H′ and J′ have increased in both nearfield and farfield locations, suggesting region-wide changes, unrelated to the discharge.

The purpose of the species-level influence and SIMPER analyses (Section 4.2.2) was to identify which species contributed most to the threshold exceedances so that the distributional patterns of those species could be evaluated for evidence of outfall impacts. No species influenced the threshold exceedances more than the spionid polychaete, *P. steenstrupi*. This species was the numerical dominant in the Massachusetts Bay samples from the mid 1990’s to the mid 2000’s, with relatively low abundances in recent years (Figure 13). The relative distribution of *P. steenstrupi* among the 11 nearfield stations has remained largely consistent in the post-diversion period compared to the baseline period (Figure 18). Although the spatial distribution remained consistent, abundances of *P. steenstrupi* increased at several nearfield stations in the post-diversion years 2001 to 2009, compared to the baseline period. The greatest increase in numbers occurred at Station NF24, the station closest to the discharge. Nonetheless, the annual patterns of *P. steenstrupi* abundances across the nearfield stations suggest a gradual increase in densities that occurred at most stations beginning in the mid 1990’s, peaking in 2002, and declining through the mid 2000’s (Figures 19 to 21). This pattern of increasing abundances beginning about five years prior to the diversion of wastewater to the offshore outfall, and occurring fairly consistently across the nearfield stations, does not suggest a response related to the discharge.

Results for other species that were identified as influential to threshold exceedances were similar to those of *P. steenstrupi*. The spionid polychaete *S. limicola* and the capitellid polychaete *M. californiensis* also had spatial distributions among the nearfield stations that were consistent over time (Figures 22 and 23). As with *P. steenstrupi*, the spatial and temporal patterns in the abundance distributions of these species were not consistent with an outfall impact.

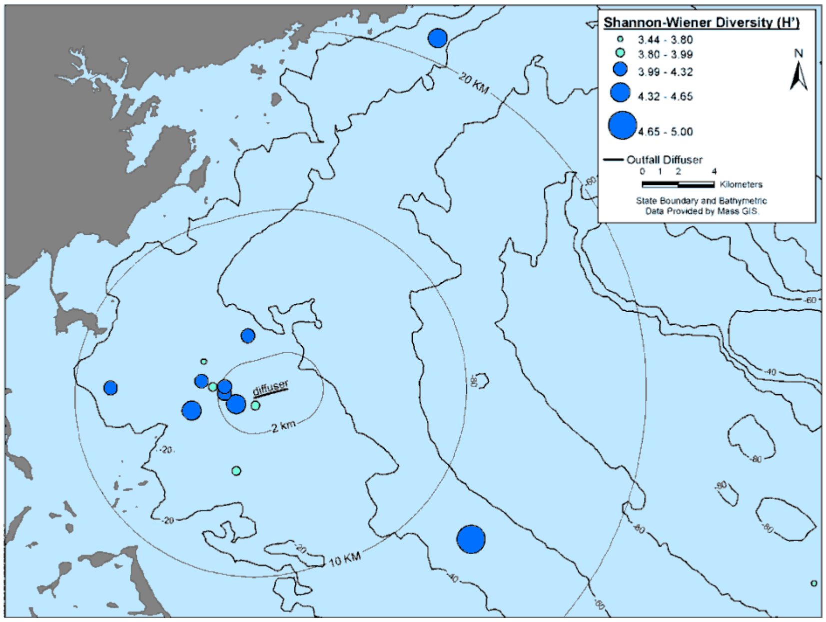


Figure 14. Shannon Weiner (H′) diversity in 2013; light = below threshold; dark = above threshold.

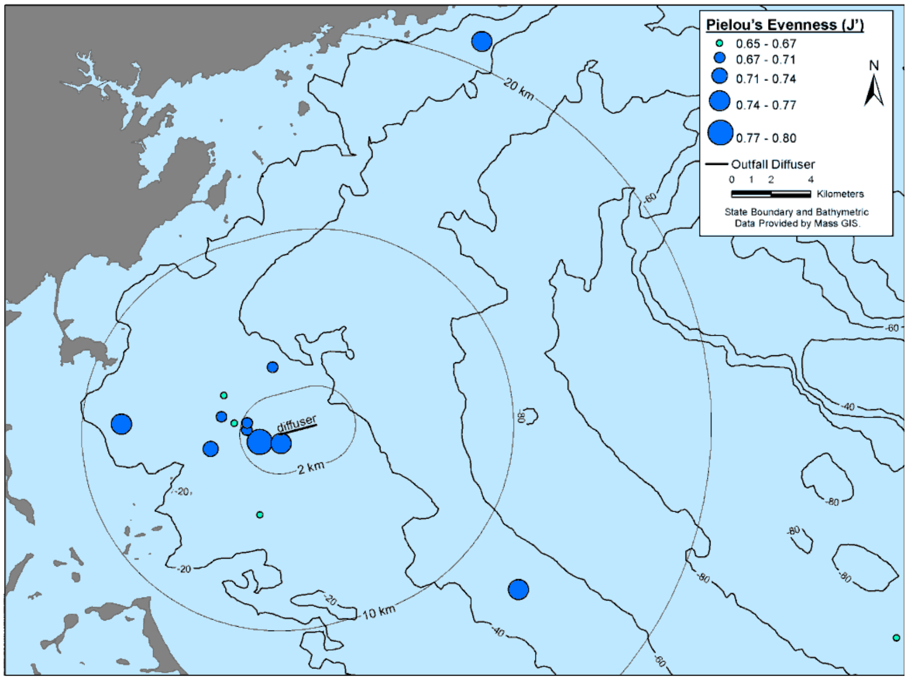


Figure 15. **Pielou's evenness (J′) in 2013; light = below threshold; dark = above threshold.**

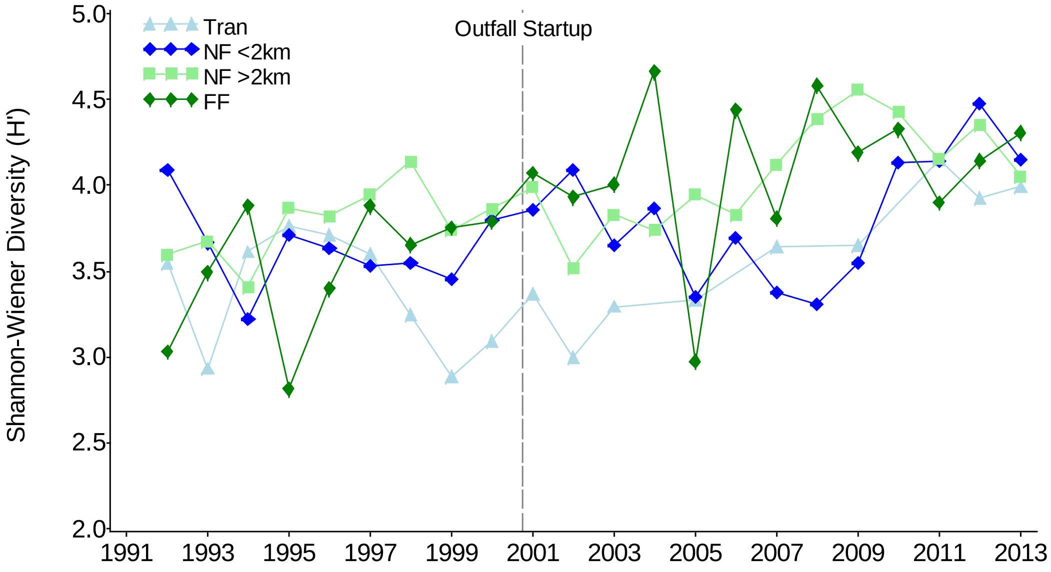


Figure 16. **Mean H′ per sample at four areas (Tran=Transition area; NF<2km=nearfield, less than two kilometers of from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield) of Massachusetts Bay, 1992 to 2013.**

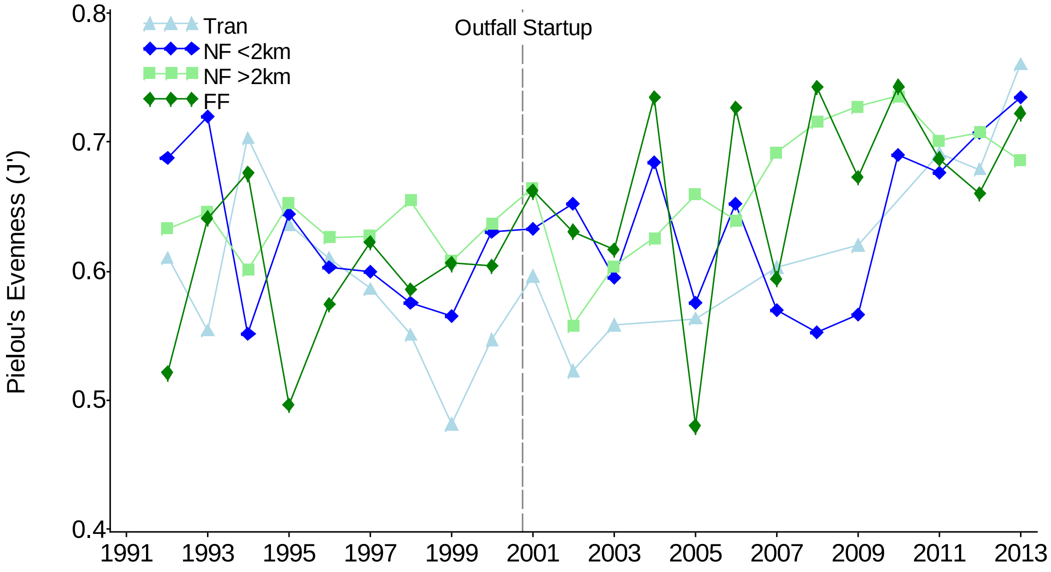


Figure 17. Mean J′ per sample at four areas (Tran=Transition area; NF<2km=nearfield, less than two kilometers of from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield) of Massachusetts Bay, 1992 to 2013.

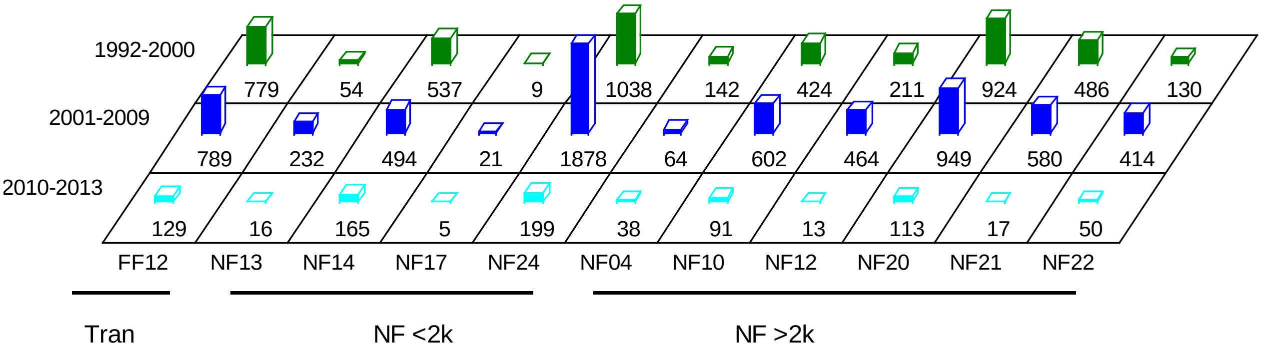


Figure 18. Mean abundance per sample of *Prionospio steenstrupi* in Massachusetts Bay during the baseline period (1992 to 2000), the post-diversion period from 2001 to 2009, and the years with exceedances (2010 to 2013) by region in the nearfield (Tran = transition area; NF<2km = nearfield, less than two kilometers of from the outfall; NF>2km = nearfield, more than two kilometers from the outfall).

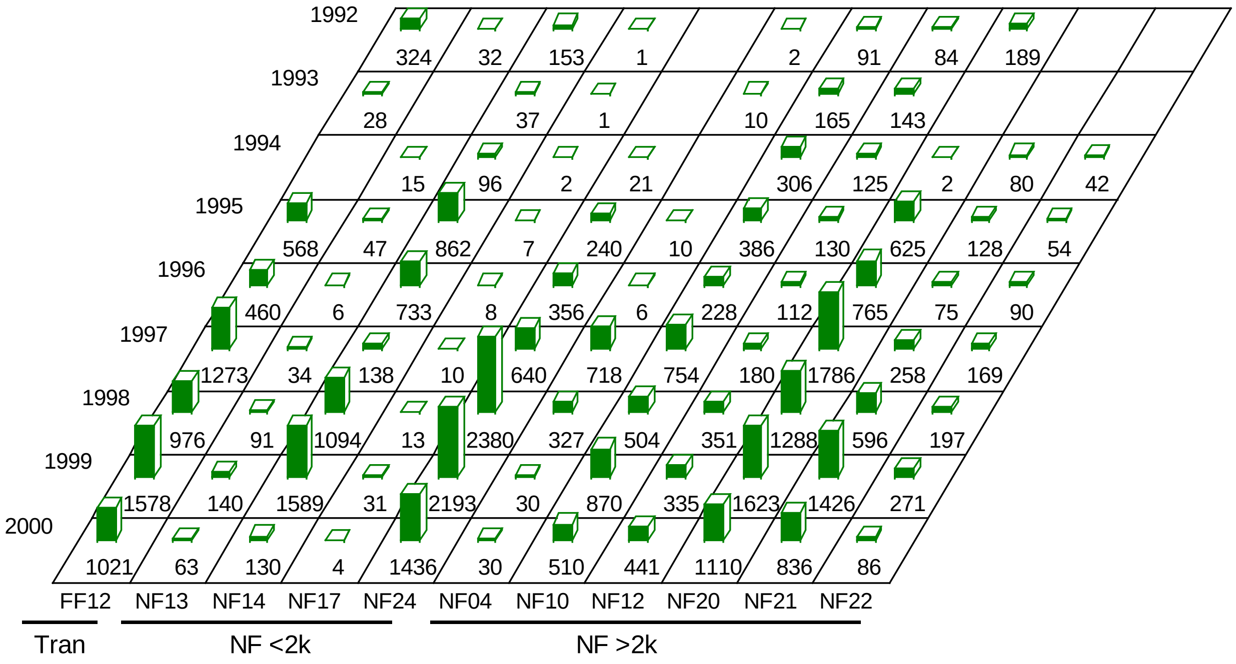


Figure 19. Mean abundance per sample of *Prionospio steenstrupi* at nearfield stations (grouped by location) in Massachusetts Bay during the baseline period (1992 to 2000).

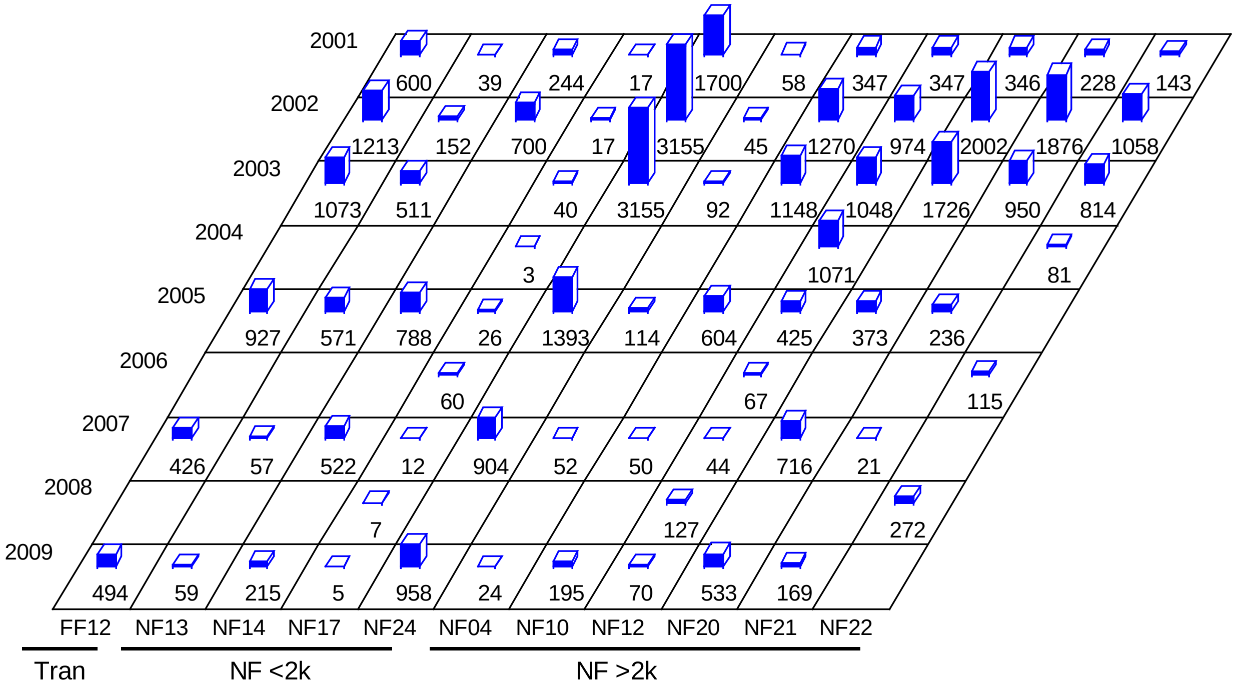


Figure 20. Mean abundance per sample of *Prionospio steenstrupi* at nearfield stations (grouped by location) in Massachusetts Bay during the post-diversion period from 2001 to 2009.

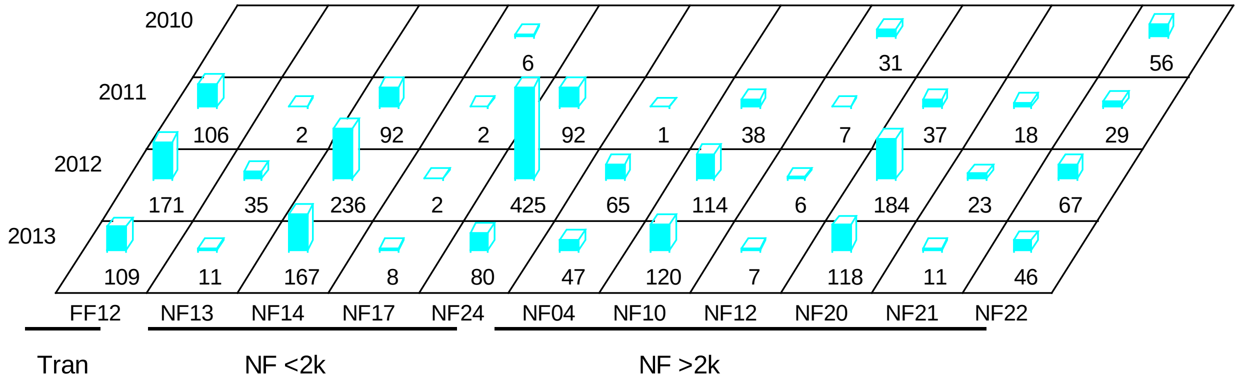


Figure 21. Mean abundance per sample of *Prionospio steenstrupi* at nearfield stations (grouped by location) in Massachusetts Bay during the years with exceedances (2010 to 2013).

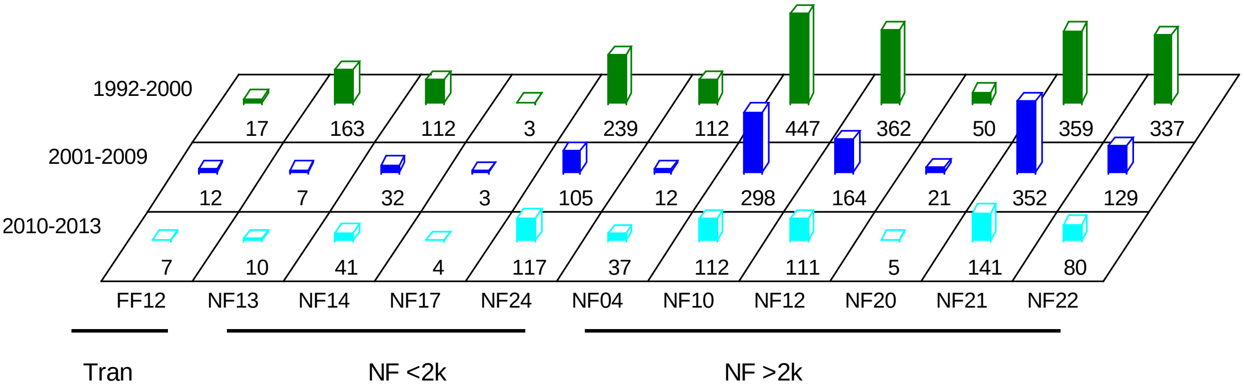


Figure 22. Mean abundance per sample of *Spio limicola* at nearfield stations (grouped by location) in Massachusetts Bay during the baseline period (1992 to 2000), the post-diversion period from 2001 to 2009, and the years with exceedances (2010 to 2013).

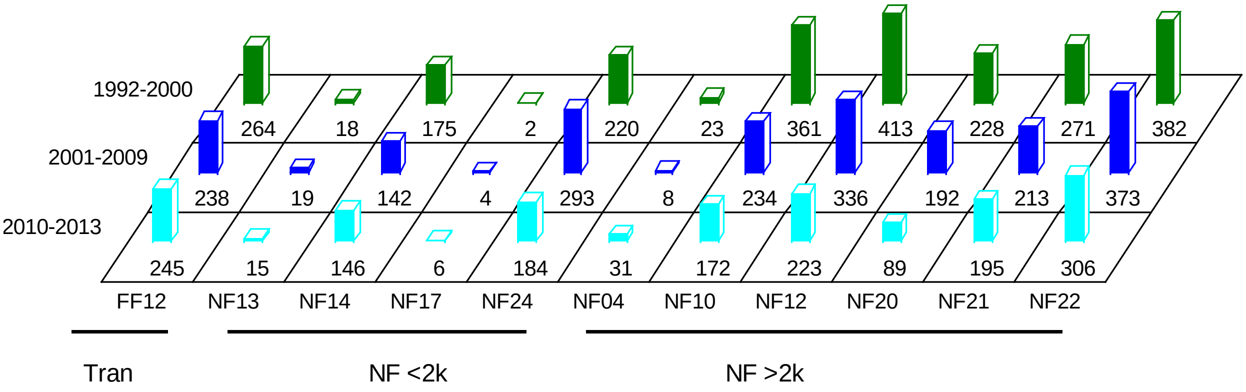


Figure 23. Mean abundance per sample of *Mediomastus californiensis* at nearfield stations (grouped by location) in Massachusetts Bay during the baseline period (1992 to 2000), the post-diversion period from 2001 to 2009, and the years with exceedances (2010 to 2013).

4.3.2 Infaunal Assemblages

Multivariate methods have proven more sensitive to subtle changes in marine soft-bottom communities than univariate methods (Warwick and Clarke 1991, 1993). To further assess whether the threshold exceedances may be indicative of an outfall impact, multivariate analyses based on Bray-Curtis Similarity were used to assess spatial and temporal patterns in the faunal assemblages at the Massachusetts Bay sampling stations.

4.3.2.1 Spatial Distribution of Assemblages

Spatial patterns in the faunal assemblages at the Massachusetts Bay sampling stations were evaluated using the samples collected in August 2013. Two main assemblages (with an outlier assemblage at Station FF04) were identified in a cluster analysis of the 14 samples (Figure 24). Each of the main assemblages contained sub-assemblages that could be differentiated by species composition. Assemblages varied considerably in species composition, but were mostly dominated by polychaetes (Table 3). Different assemblages occurred at each of the four stations within two kilometers of the discharge; and assemblages similar to those nearest the discharge were found at stations more than two kilometers from the discharge (Figure 24). An example of this is Group IIA, which contains Station NF14, less than 2 km from the outfall, Station FF12, a transitional station between the outfall and Boston Harbor, and Station FF01A, a farfield reference station off Gloucester. Thus, stations closest to the discharge are not characterized by a unique faunal assemblage reflecting effluent impacts.

Comparisons of faunal distribution to habitat conditions indicated that stations with similar sediment types supported similar faunal assemblages (Figures 25 and 26). Figure 25 illustrates that much of the spatial pattern of association between faunal assemblages and sediment texture can be demonstrated by looking only at the percent fine (i.e., silt and clay) fraction of the sediments. Nonetheless, the full composition of the sediments may help to further explain associations between benthic habitat and the infaunal community, which are not explained by percent fines alone (Figure 26). Multivariate analyses of the 2013 data found no evidence of impacts from the offshore outfall on infaunal communities in Massachusetts Bay.

Spatial patterns in the faunal assemblages collected during 2013 are consistent with those identified through previous sampling. Nestler et al. (2013b) identified two distinct assemblages (each composed of sub-assemblages), associated with different sediment textures at the nearfield stations. These assemblages have largely remained stable over time (Nestler et al. 2012, Maciolek et al. 2011, 2008; Hilbig and Blake 2000). The three species that were identified as the most influential to threshold exceedances, *P. steenstrupi*, *S. limicola*, and *M. californiensis*, have all been more abundant in the assemblage that occurs in mixed sediments (i.e., Group II in Figure 24, stations where sediments have a higher percentage of fines; Table 3, Figures 18 to 23, 26) than in the one occurring at sandy stations (i.e., Group I in Figure 24, e.g., NF13, NF17, NF04).

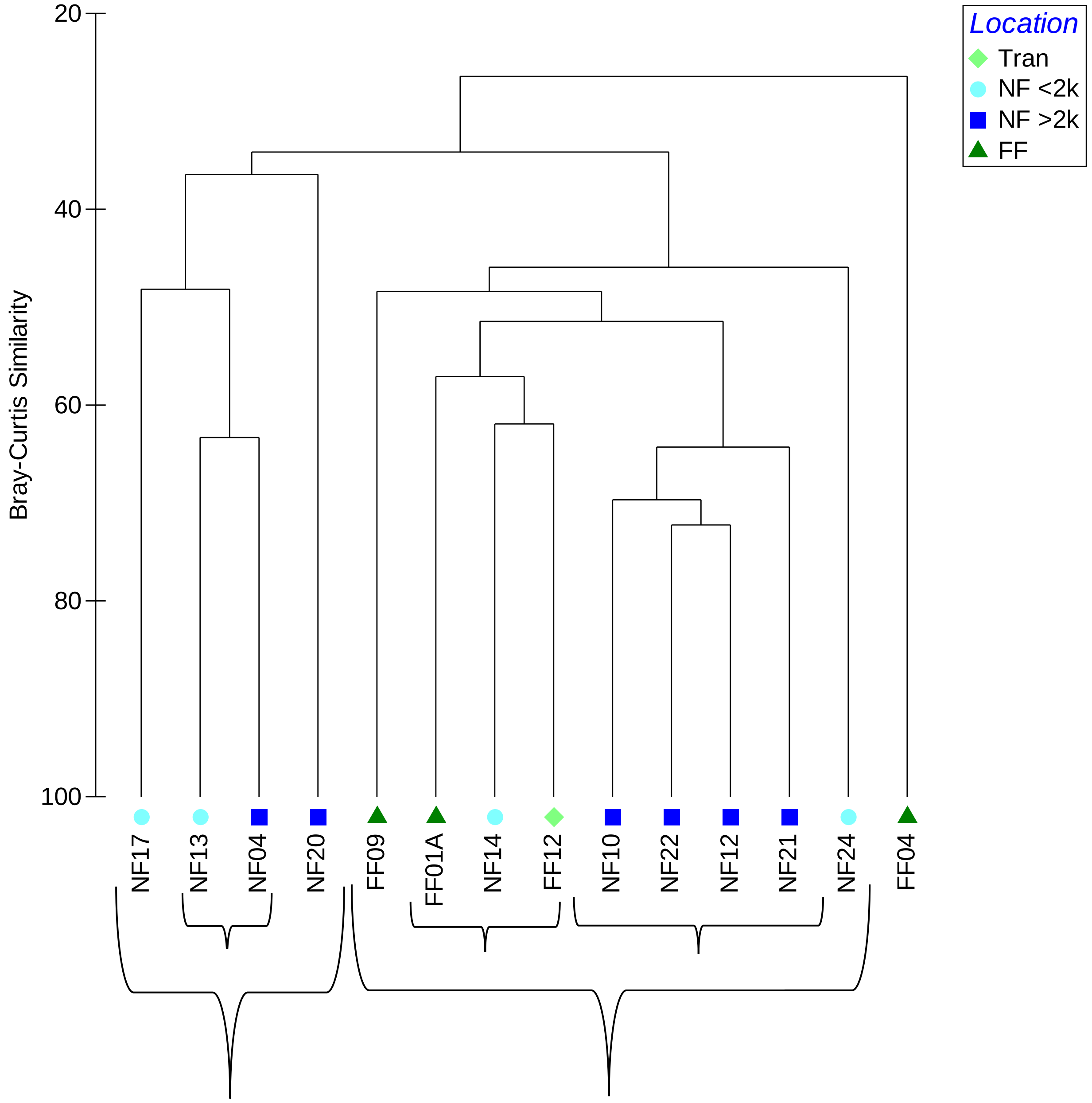


Figure 24. Results of cluster analysis of the 2013 infauna samples collected from nearfield and farfield stations in Massachusetts Bay.

Table 3. Abundance (mean # per grab) of numerically dominant taxa (10 most abundant per group) composing infaunal assemblages identified by cluster analysis of the 2013 samples.

		Group I			Group II				
Family	**Species**	**NF17**	**NF13&04**	**NF20**	**IIA (n=3)**	**IIB (n=4)**	**FF09**	**NF24**	**FF04**
Platyhelminthes (Turbellaria)									
	Turbellaria sp. 12	45.0	-	5.0	0.3	0.3	-	-	-
Cephalothricidae	Cephalothricidae sp. 1	-	-	5.0	-	0.3	-	-	14.0
Mollusca (Bivalvia)									
Hiatellidae	*Hiatella arctica*	-	0.5	26.0	0.3	-	-	-	-
Mytilidae	*Crenella decussata*	-	2.0	11.0	0.7	0.5	36.0	-	-
Nuculidae	*Nucula delphinodonta*	-	18.0	3.0	10.3	7.8	72.0	-	1.0
Annelida (Polychaeta)									
Ampharetidae	*Anobothrus gracilis*	-	-	-	0.3	0.5	94.0	-	91.0
Capitellidae	*Mediomastus californiensis*	1.0	12.5	43.0	115.7	323.8	58.0	17.0	20.0
Cirratulidae	*Aphelochaeta* cf. *marioni*	-	8.0	1.0	4.0	92.3	6.0	49.0	5.0
	Chaetozone anasimus	1.0	10.0	-	1.3	4.3	2.0	-	116.0
	Monticellina baptisteae	-	5.0	-	42.7	105.5	5.0	23.0	1.0
	Monticellina cf. *dorsobranchialis*	-	6.5	3.0	36.0	56.3	1.0	26.0	-
	Tharyx acutus	5.0	44.5	3.0	44.3	204.3	45.0	54.0	-
Cossuridae	*Cossura longocirrata*	-	-	-	-	3.3	4.0	-	104.0
Flabelligeridae	*Flabelligera affinis*	-	0.5	21.0	13.7	1.0	-	3.0	-
Lumbrineridae	*Ninoe nigripes*	-	2.0	3.0	23.3	52.3	28.0	1.0	28.0
Nephtyidae	*Aglaophamus circinata*	21.0	28.5	1.0	9.0	0.3	2.0	-	-
	Nephtys incisa	-	-	-	0.7	6.8	3.0	14.0	9.0
Orbiniidae	*Leitoscoloplos acutus*	-	1.5	5.0	12.0	38.5	23.0	5.0	10.0
Paraonidae	*Aricidea catherinae*	68.0	149.5	7.0	97.7	13.0	-	32.0	-
	Aricidea quadrilobata	-	-	-	-	6.8	70.0	4.0	62.0
	Levinsenia gracilis	1.0	1.5	2.0	29.7	164.0	86.0	2.0	234.0
Phyllodocidae	*Phyllodoce mucosa*	6.0	12.0	18.0	10.0	1.0	1.0	12.0	-
Polygordiidae	*Polygordius jouinae*	13.0	57.5	2.0	2.7	1.5	1.0	-	-
Sabellidae	*Euchone incolor*	-	2.0	6.0	13.3	30.0	189.0	29.0	24.0
Scalibregmatidae	*Scalibregma inflatum*	34.0	26.5	126.0	69.0	13.3	6.0	6.0	-
Spionidae	*Prionospio steenstrupi*	8.0	29.0	118.0	136.7	46.0	89.0	80.0	-
	Spio limicola	-	19.5	1.0	4.7	21.8	85.0	1.0	-
	Spio thulini	2.0	3.0	17.0	1.7	-	4.0	-	-
	Spiophanes bombyx	41.0	81.5	1.0	54.3	11.5	12.0	6.0	-
Syllidae	*Exogone hebes*	61.0	192.5	4.0	7.0	3.0	17.0	-	1.0
	Exogone verugera	1.0	16.0	20.0	5.0	10.8	15.0	2.0	-
Terebellidae	*Polycirrus phosphoreus*	2.0	3.0	28.0	0.3	0.3	-	-	-
Annelida (Oligochaeta)									
Tubificidae	*Limnodriloides medioporus*	-	0.5	7.0	5.0	32.3	-	1.0	-
Arthropoda (Isopoda)									
Chaetiliidae	*Chiridotea tuftsi*	15.0	-	-	0.7	-	-	-	-
Idoteidae	*Edotia montosa*	17.0	4.0	-	7.7	1.0	4.0	1.0	-
Arthropoda (Tanaidacea)									
Nototanaidae	*Tanaissus psammophilus*	72.0	8.5	-	-	0.3	1.0	-	-
Phorona (Phoronida)									
	Phoronis muelleri	-	21.5	-	14.7	17.8	9.0	-	-

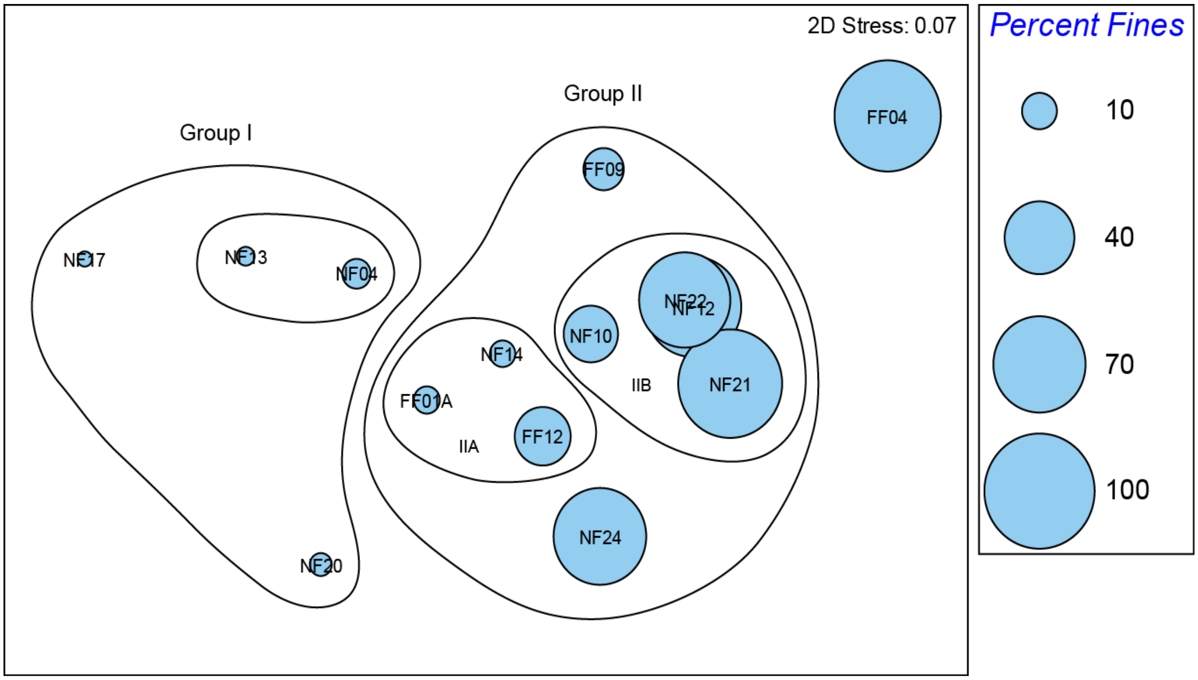


Figure 25. Percent fine sediments superimposed on nMDS ordination plot of the 2013 infauna samples. Each point on the plot represents one of the 14 samples; similarity of species composition is indicated by proximity of points on the plot. Faunal assemblages (Groups I-II, and sub-groups) identified by cluster analysis are circled on the plot. The ordination and cluster analysis are both based on Bray-Curtis Similarity.

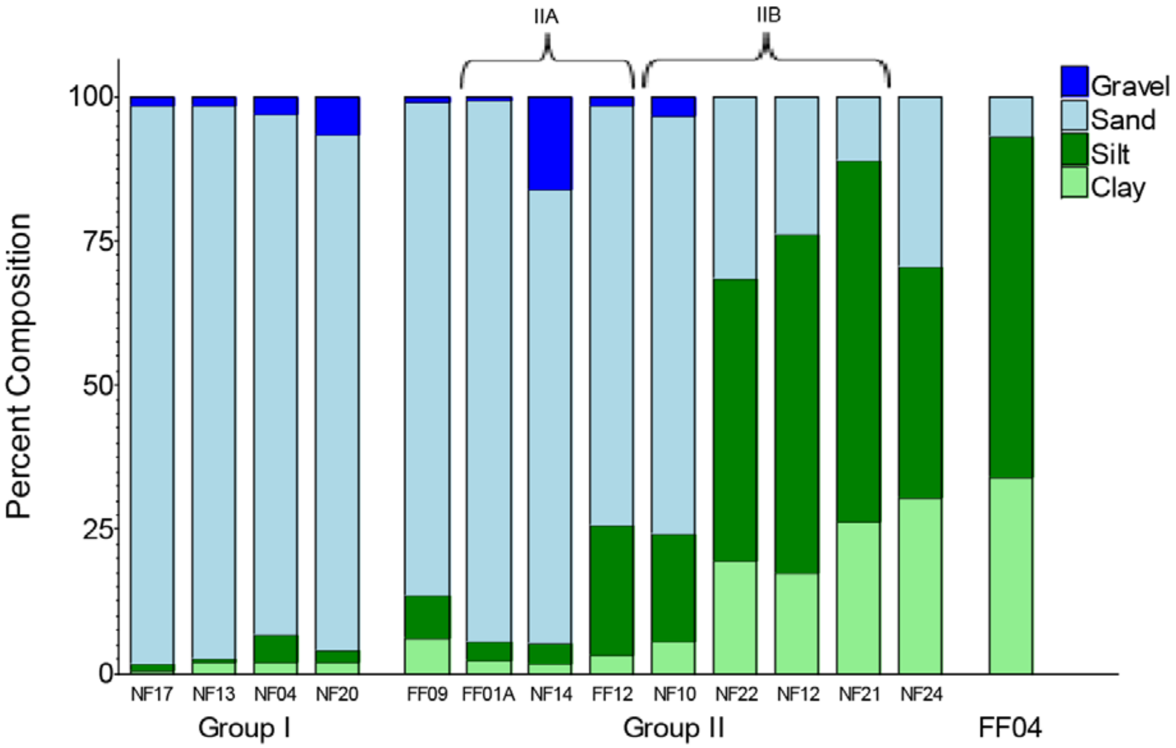


Figure 26. Monitoring results for sediment grain size with stations grouped by infaunal assemblages identified by cluster analysis of the 2013 samples.

4.3.2.2 Temporal Patterns in Assemblages

Multivariate analyses were used to assess temporal patterns in faunal communities at nearfield stations closest to the outfall. Stations were selected based on habitat conditions (grain size) and evidence of solids deposition from the wastewater plume (*Clostridium perfringens* spores). The objective of these analyses was to determine whether measurable, albeit subtle, outfall-related changes had occurred.

The presence of the sewage tracer *C. perfringens* provides a tracer of solids deposition at the nearfield stations (Figure 27). The highest percent increase in *C. perfringens* concentrations between the baseline and post-diversion periods occurred at Stations NF17 (112%) and NF24 (88%), the two stations closest to the discharge. Distribution and species composition of infaunal assemblages in Massachusetts Bay have remained relatively stable over time, associated with particular habitat types that can be differentiated largely by sediment texture. To provide comparisons among comparable assemblages along a gradient of potential outfall effects, Stations NF17 and NF24 were each paired for analyses with stations that were most similar based on habitat, while having lower levels of solids deposition from the discharge. Based on prior analyses (see Section 4.3.2.1) and sediment texture (Figure 28), NF17 was paired with NF04, and NF24 was paired with NF22. Bottom depths are similar at all four stations (NF17 = 31 m, NF04 = 34 m; NF24 = 37 m, NF22 = 30 m). The percent increase in *C. perfringens* concentrations between the baseline and post-diversion periods at NF04 was 23%, while at NF22, concentrations decreased by 30% (Figure 27).

The analyses were structured according to the before-after-control-impact (BACI) design (Stewart-Oaten et al. 1986) to allow for both pattern analyses (i.e., cluster analysis, non-metric multidimensional scaling, and SIMPROF), and ANOSIM (“analysis of similarities”); all using the PRIMER v6 software (see Clarke 1993, Warwick 1993). Using a two-way ANOSIM to test for differences, potential outfall impacts would appear as an interaction between treatment main effects (station and period; Clarke and Warwick 2001). Stations with the highest *C. perfringens* signal (NF17 and NF24) were considered the potential “Impact” stations, while the stations with similar habitat (NF04 and NF22) and lower *C. perfringens* were considered the “Control” locations. Based on prior analyses it was evident that no farfield stations have habitat/assemblages that are similar enough to NF17 or NF24 to be used in the ANOSIM analysis.

Cluster analysis and ordination indicated that assemblages at NF17 and NF04 have been measurably different throughout the baseline and post-diversion periods (Figure 29) despite having similar habitat. Each station had one sample (NF17=1993; NF04=1997) that was an independent outlier and an additional group of three stations (NF17=1996, 2002, 2011; NF04=1992, 1993, 1994) that clustered together as an outlier group. All other samples indicated very low levels of dissimilarity in the assemblages collected at these stations over time (Figure 29). Assemblages at NF17 and NF04 included typical dominants for Massachusetts Bay sand communities, with top numerical dominants including the corophiid amphipod *Crassicorophium crassicorne*, the syllid polychaete *Exogone hebes*, and the urochordate *Molgula manhattensis* (Table 4). The corophiid amphipod *Pseudunciola obliquua* occurred in relatively high numbers at NF17, but was not reported at NF04.

Results of cluster analysis and ordination for NF24 and NF22 indicated high levels of consistency in assemblages at each station over time (Figure 30). Although assemblages at these stations were more similar to one another than were the assemblages at NF17 and NF04, differences were still apparent. Most samples clustered together within the Group I assemblage, including four of the samples from NF24 and all except one sample from NF22. Both samples from 1994 (NF24 and NF22) formed an outlier group, and a second outlier group was formed by two samples from NF24 (1995 and 2013). Two other samples from NF24 (1996 and 2005) were independent outliers. The remaining six samples from NF24 formed Group II. Typical of mixed sediment habitats at the Massachusetts Bay stations, all assemblages at NF24 and NF22 were heavily dominated by polychaetes, with some molluscs included among the dominants (Table 5). The top numerical dominants were the spionid *Prionospio steenstrupi*, the capitellid *Mediomastus californiensis*, and the cirratulid *Tharyx acutus*.

Significant differences between both pairs of stations during the baseline period prevented the use of ANOSIM to test for the interaction of main effects (Table 6). This reflects the high level of small-scale spatial heterogeneity in these infaunal assemblages. Significant differences were also found between period (with stations considered together) and station (with periods considered together) in tests of both sandy (NF17 and NF04) and mixed sediment (NF24 and NF22) stations (Table 6).

Although assemblages at each station remained highly consistent over time in terms of overall species composition, some level of temporal change was apparent at all stations. For example, some separation of baseline from post-diversion samples is apparent at NF17 (Figure 29). To further evaluate the changes in assemblages over time, SIMPER analysis was used to determine which species accounted for most of the dissimilarity between samples collected at NF17 during the baseline and post-diversion periods. The top contributor to dissimilarity among the periods was *Pseudunciola obliquua*, followed by *Molgula manhattensis* and *Crassicorophium crassicorne* (Table 7). SIMPER analysis was also used to assess changes in the assemblages at NF24 between the baseline and post-diversion periods (Table 8). *P. steenstrupi* accounted for more dissimilarity between periods than any other species. As discussed in Section 4.3.1, changes over time in the abundance of *P. steenstrupi* do not appear to reflect an outfall influence because they were widespread (Figures 19 to 21). The opportunistic species that are tracked by MWRA as a Contingency Plan threshold for infaunal communities (*Polydora cornuta*, *Capitella capitata* complex, *Capitella* spp., *Streblospio benedicti*, *Mulinia lateralis*, *Ampelisca macrocephala*, *Ampelisca abdita*, and *Ampelisca vadorum*) were notably absent among the species accounting for most of the temporal differences at both NF17 and NF24. Figure 31 illustrates that the level of change in assemblages at FF04, the station located farthest from the outfall, has been similar to the change observed at stations closest to the discharge. These changes over time do not appear to be related to the discharge and likely reflect a wide range of biological and physical mechanisms that are influencing these communities.

Table 4. Abundance (mean # per grab) of numerically dominant taxa (10 most abundant per group) composing infaunal assemblages identified by cluster analysis of samples collected at NF17 and NF04, 1992 to 2013.

		NF17			NF04		
Family	**Species**	**Main group (n=18)**	**Outlier group ('96, '02, '11)**	**1993**	**Main group (n=14)**	**Outlier group ('92, '93, '94)**	**1997**
Mollusca (Bivalvia)							
Cardiidae	*Parvicardium pinnulatum*	31.7	36.0	4.0	52.0	2.7	18.0
Mytilidae	*Crenella decussata*	0.1	1.7	-	0.7	22.7	38.0
	Crenella glandula	0.3	25.0	-	4.1	0.3	-
Nuculidae	*Nucula delphinodonta*	0.6	1.0	-	5.4	1.0	79.0
Annelida (Polychaeta)							
Ampharetidae	*Ampharete acutifrons*	0.1	1.0	-	0.1	-	219.0
Capitellidae	*Mediomastus californiensis*	1.8	6.3	-	14.1	4.0	123.0
Cirratulidae	*Aphelochaeta cf. marioni*	0.1	0.7	-	15.8	1.3	111.0
	Tharyx acutus	1.5	21.3	-	27.4	1.0	18.0
Dorvilleidae	*Parougia caeca*	1.7	26.3	-	3.8	-	16.0
Lumbrineridae	*Ninoe nigripes*	1.4	0.3	-	2.6	2.7	90.0
Maldanidae	*Euclymene collaris*	5.1	116.0	-	7.0	18.7	-
Nephtyidae	*Aglaophamus circinata*	12.1	7.0	6.0	20.9	20.3	-
Paraonidae	*Aricidea catherinae*	11.7	7.0	4.0	54.2	14.3	-
	Paradoneis lyra	-	19.7	-	-	-	-
Phyllodocidae	*Phyllodoce mucosa*	28.3	3.0	1.0	15.2	7.3	10.0
Polygordiidae	*Polygordius jouinae*	58.8	336.3	-	33.0	-	1.0
Sabellidae	*Euchone incolor*	0.6	-	-	13.0	-	67.0
Spionidae	*Dipolydora quadrilobata*	4.9	-	-	1.3	36.3	2.0
	Dipolydora socialis	25.3	9.7	-	63.4	166.3	668.0
	Prionospio steenstrupi	9.3	16.0	1.0	64.4	0.7	718.0
	Spio limicola	0.6	-	-	13.6	12.7	575.0
	Spiophanes bombyx	70.9	9.7	9.0	36.5	1.0	10.0
Syllidae	*Exogone hebes*	48.7	14.0	6.0	305.0	194.7	20.0
	Exogone verugera	4.7	16.0	-	77.4	86.0	56.0
Annelida (Oligochaeta)							
Enchytraeidae	*Marionina welchi*	3.6	13.7	-	48.7	-	-
Arthropoda (Amphipoda)							
Aoridae	*Unciola inermis*	9.5	110.3	-	20.4	20.7	-
	Unciola irrorata	1.5	23.0	-	4.5	-	-
Corophiidae	*Crassicorophium crassicorne*	246.5	6.7	48.0	172.6	129.3	-
	Pseudunciola obliquua	56.3	-	6.0	-	-	-
Haustoriidae	*Acanthohaustorius millsi*	3.1	1.0	7.0	-	-	-
Isaeidae	*Photis pollex*	1.7	0.3	-	10.9	3.7	59.0
Phoxocephalidae	*Rhepoxynius hudsoni*	7.2	-	10.0	1.2	-	-
Arthropoda (Isopoda)							
Anthuridae	*Ptilanthura tenuis*	1.5	0.3	1.0	10.1	24.7	9.0
Chaetiliidae	*Chiridotea tuftsi*	14.7	-	5.0	7.5	-	-
Cirolanidae	*Politolana polita*	4.7	0.3	7.0	3.6	3.7	-
Echinodermata							
Echinarachniidae	*Echinarachnius parma*	26.5	3.3	6.0	9.4	3.0	-
Chordata (Urochordata)							
Molgulidae	*Molgula manhattensis*	264.1	40.3	-	95.6	1.3	-

Table 5. Abundance (mean # per grab) of numerically dominant taxa (10 most abundant per group) composing infaunal assemblages identified by cluster analysis of samples collected at NF24 and NF22, 1992 to 2013.

		NF24 & NF22		NF24			
Family	**Species**	**Group I (n=21)**	**Outlier group (1994)**	**Group II (n=6)**	**Outlier group ('95, '13)**	**1996**	**2005**
Mollusca (Bivalvia)							
Arcticidae	*Arctica islandica*	5.0	28.5	10.3	1.0	26.0	76.0
Astartidae	*Astarte undata*	7.1	0.5	8.5	-	60.0	-
Hiatellidae	*Hiatella arctica*	0.3	183.0	1.5	-	6.0	-
Nuculidae	*Nucula delphinodonta*	21.1	14.0	12.3	-	32.0	9.0
Annelida (Polychaeta)							
Capitellidae	*Mediomastus californiensis*	336.6	269.0	408.3	30.5	91.0	140.0
Cirratulidae	*Aphelochaeta* cf. *marioni*	61.4	228.0	159.0	53.5	348.0	102.0
	Monticellina baptisteae	48.1	610.5	26.7	13.5	-	16.0
	Monticellina cf. *dorsobranchialis*	27.5	4.0	17.2	18.5	3.0	17.0
	Tharyx acutus	254.2	403.0	331.2	49.5	28.0	77.0
Lumbrineridae	*Ninoe nigripes*	126.4	30.0	43.7	10.0	27.0	62.0
Nephtyidae	*Nephtys incisa*	14.1	15.0	4.5	13.5	-	62.0
Orbiniidae	*Leitoscoloplos acutus*	52.9	21.0	75.2	6.0	29.0	4.0
Paraonidae	*Aricidea catherinae*	27.5	43.5	310.8	16.5	5.0	34.0
	Levinsenia gracilis	153.6	39.0	94.5	30.5	10.0	120.0
Pholoidae	*Pholoe minuta*	6.5	37.5	22.0	14.5	16.0	41.0
Sabellidae	*Euchone incolor*	113.6	20.5	106.3	25.5	55.0	40.0
Spionidae	*Dipolydora socialis*	3.4	788.5	52.0	-	59.0	-
	Prionospio steenstrupi	374.1	27.5	2277.5	117.5	504.0	1625.0
	Spio limicola	138.9	1142.0	95.5	68.5	160.0	31.0
Syllidae	*Exogone verugera*	7.2	53.0	39.5	2.5	8.0	-

Table 6. Results of ANOSIM test for spatial and temporal differences among infaunal assemblages at four sampling stations in Massachusetts Bay during the baseline period (1992 to 2000) and the post-diversion period (2001 to 2013).

Assemblage	**Comparison**	**R**	**p (%)[1]**
Sand (NF17, NF04)	Period[2]	0.21	0.3*
	Station[2]	0.54	0.1*
	NF17 Baseline vs. NF04 Baseline[3]	0.4	0.1*
	Interaction of Main Effects		Not testable
Mixed Sediments (NF24, NF22)	Period[2]	0.18	0.3*
	Station[2]	0.42	0.1*
	NF24 Baseline vs. NF22 Baseline[3]	0.24	0.3*
	Interaction of Main Effects		Not testable

[1] p = significance level of test statistic R.

[2] Two-way ANOSIM.

[3] One-way ANOSIM.

***indicates significant differences, p<5.0%.**

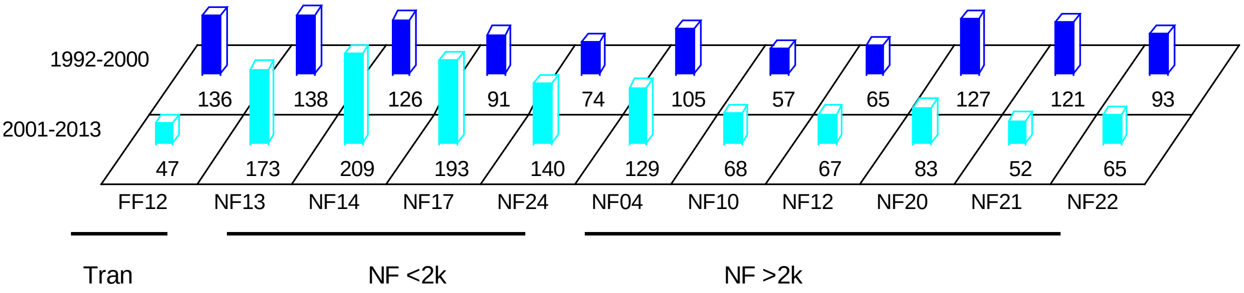
Table 7. Species contributing more than 1% to the average dissimilarity between infaunal assemblages at NF17 during the baseline and post-diversion periods based on SIMPER analysis.

Species	Mean Abundance at NF17		Contribution to Dissimilarity (%)
	Baseline (1994 to 2000)	Post-diversion (2001 to 2013)	
Pseudunciola obliquua	2.64	0.27	2.91
Molgula manhattensis	1.42	2.91	2.79
Crassicorophium crassicorne	3.36	2.92	1.73
Unciola inermis	1.84	0.86	1.64
Polygordius jouinae	2.72	2.48	1.58
Dipolydora socialis	1.27	0.61	1.48
Ensis directus	0.24	1.31	1.45
Euclymene collaris	1.52	1.14	1.35
Phyllodoce mucosa	1.60	1.85	1.29
Parvicardium pinnulatum	2.01	1.85	1.27
Diastylis sculpta	0.55	1.42	1.22
Edotia montosa	0.44	1.23	1.21
Hiatella arctica	1.32	1.30	1.19
Tanaissus psammophilus	1.31	2.16	1.18
Ampharete finmarchica	1.05	0.09	1.14
Clymenura sp. A	1.03	0.18	1.07
Tharyx acutus	0.24	0.95	1.05
Spiophanes bombyx	2.49	2.42	1.04
Acanthohaustorius millsi	0.88	0.75	1.03
Marionina welchi	0.38	0.80	1.01
Ampharete lindstroemi	0.33	0.88	1.01
Phyllodoce maculata	0.76	0.68	1.00
Solariella obscura	1.03	0.68	1.00

Table 8. Species contributing more than 1% to the average dissimilarity between infaunal assemblages at NF24 during the baseline and post-diversion periods based on SIMPER analysis.

Species	Mean Abundance at NF24		Contribution to Dissimilarity (%)
	Baseline (1994 to 2000)	Post-diversion (2001 to 2013)	
Prionospio steenstrupi	5.19	5.49	2.07
Dipolydora socialis	1.18	1.36	1.83
Aricidea catherinae	2.26	3.44	1.72
Aphelochaeta cf. marioni	2.77	2.57	1.45
Monticellina baptisteae	1.92	2.22	1.41
Flabelligera affinis	0.14	1.42	1.36
Amphiporus caecus	0.8	1.68	1.3
Hiatella arctica	1.3	0.29	1.28
Gattyana amondseni	1.34	0.32	1.2
Nemertea sp. 12	0.9	1.74	1.2
Spio limicola	3.52	2.89	1.19
Astarte undata	1.66	1.26	1.08
Mediomastus californiensis	3.73	3.82	1.08
Phoronis muelleri	1.17	1.55	1.05
Pleurogonium rubicundum	1.05	0.11	1.02
Nephtys incisa	1.24	1.24	1.02

A. Nearfield stations



B. Farfield stations.

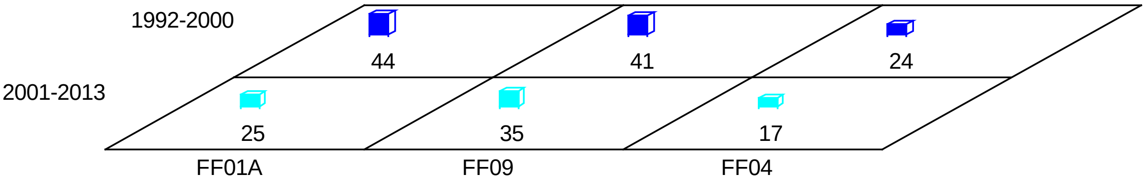
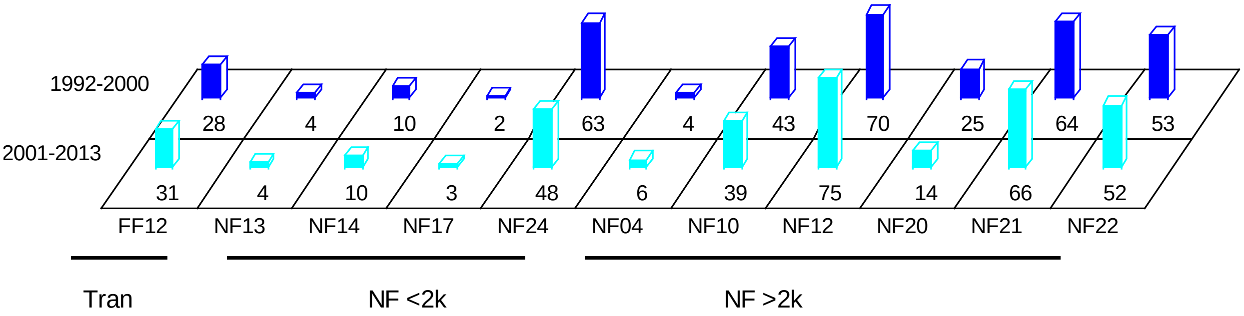


Figure 27. **Mean concentrations of *Clostridium perfringens* (cfu/g dry/%fines) at Massachusetts Bay nearfield (A) and farfield (B) stations during the baseline period (1992 to 2000) compared to the post-diversion period (2001 to 2013).**

A. Nearfield stations



B. Farfield stations.

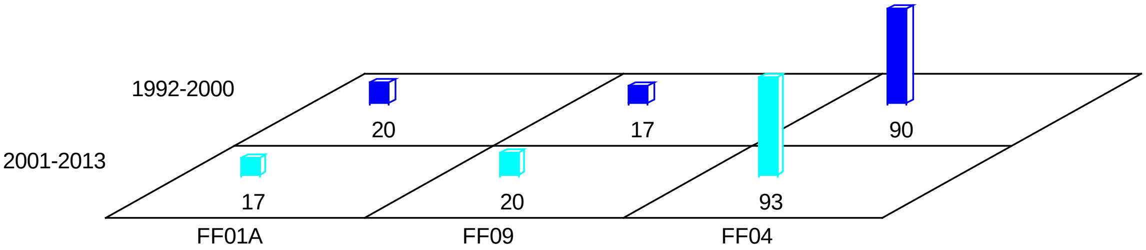


Figure 28. Mean percent fine sediments at Massachusetts Bay nearfield (A) and farfield (B) stations during the baseline period (1992 to 2000) compared to the post-diversion period (2001 to 2013).

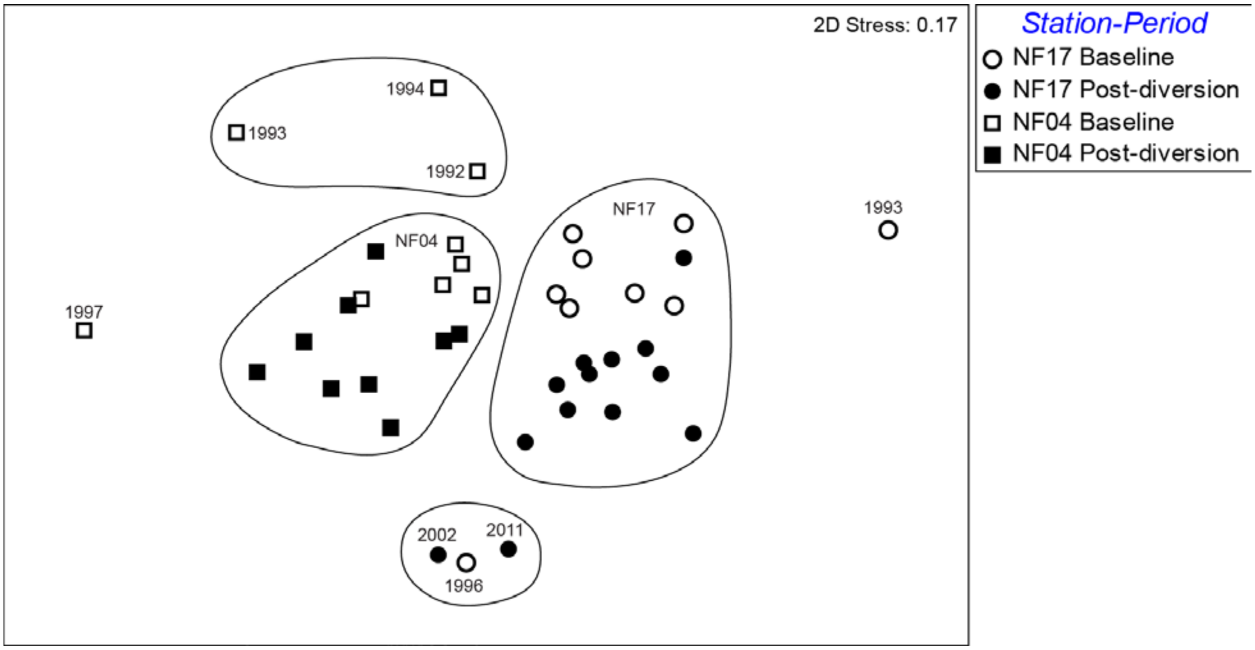


Figure 29. Results of nMDS ordination of infauna samples from Stations NF17 and NF04, 1992 to 2013. Each point on the plot represents one sample; similarity of species composition is indicated by proximity of points on the plot. Groups identified using cluster analysis are circled and labeled on the plot. The ordination and cluster analysis are both based on Bray-Curtis Similarity.

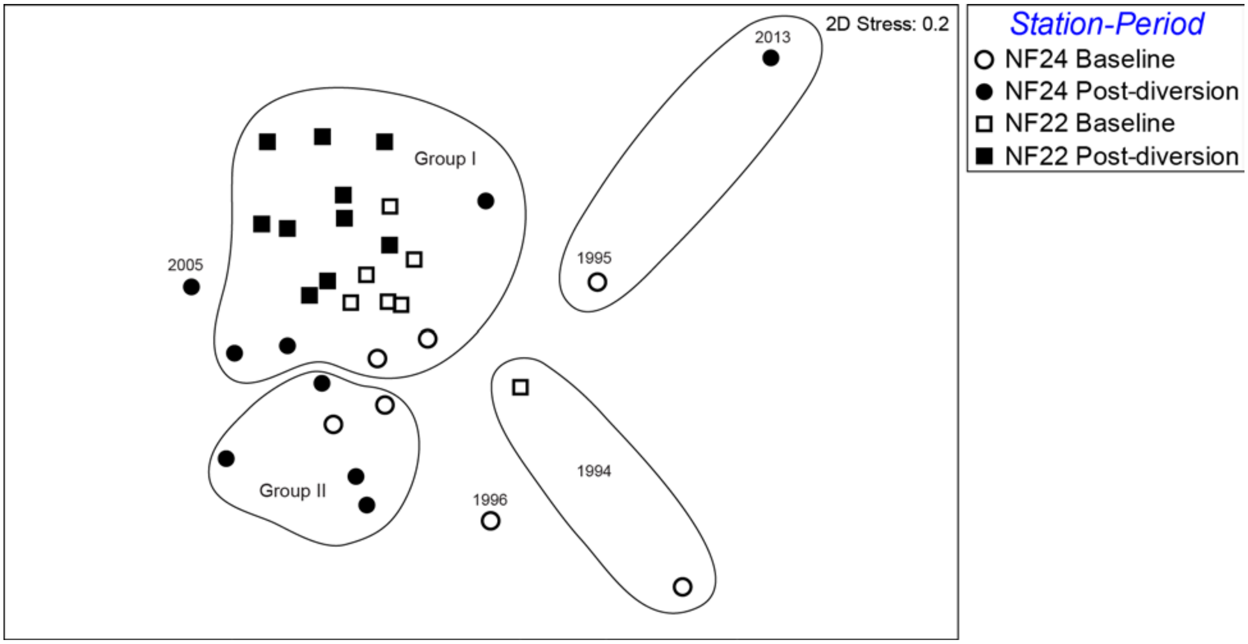


Figure 30. Results of nMDS ordination of infauna samples from Stations NF24 and NF22, 1992 to 2013. Each point on the plot represents one sample; similarity of species composition is indicated by proximity of points on the plot. Groups identified using cluster analysis are circled and labeled on the plot. The ordination and cluster analysis are both based on Bray-Curtis Similarity.

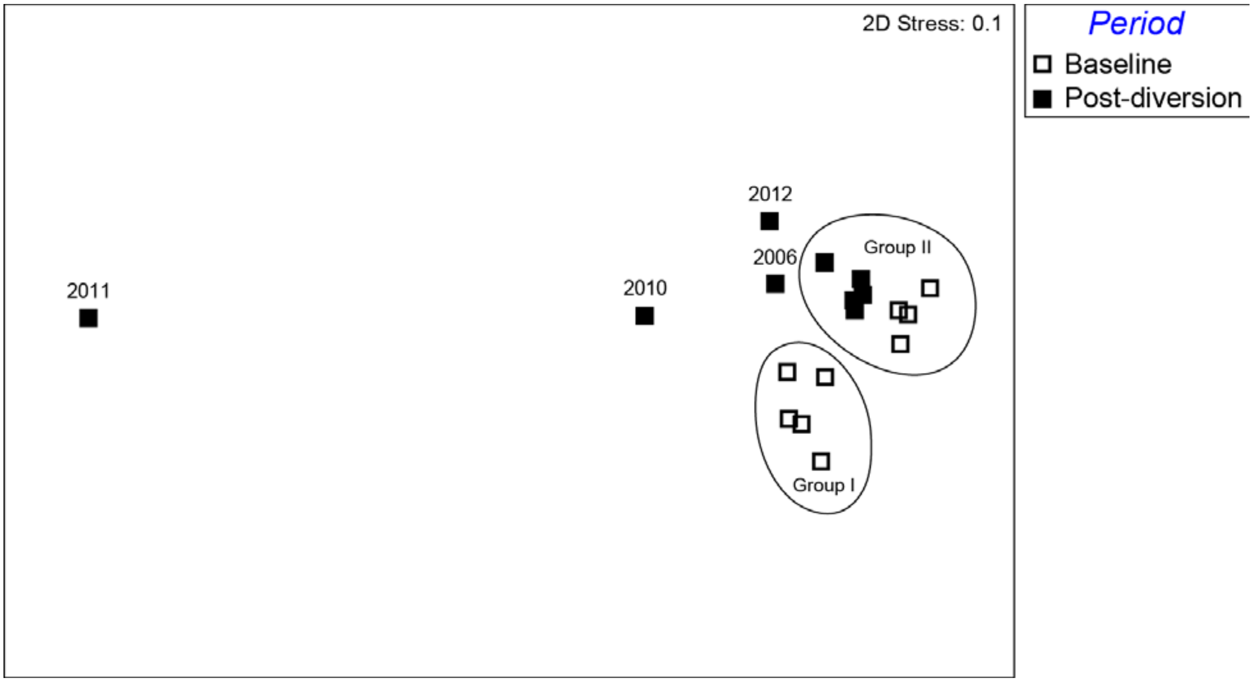


Figure 31. Results of nMDS ordination of infauna samples from Station FF04, 1992 to 2012. Each point on the plot represents one sample; similarity of species composition is indicated by proximity of points on the plot. Groups identified using cluster analysis are circled on the plot (Group I: 1992 to 1996; Group II: 1997 to 2004 and 2008). The ordination and cluster analysis are both based on Bray-Curtis Similarity.

4.4 Discussion of Threshold Exceedances and Evidence for Outfall Impacts

High diversity is widely recognized as an indication of healthy ecosystems (Magurran 1988). Low diversity has been linked to sediment contamination from both nutrient loading (Pearson and Rosenberg 1978) and from chemical contaminants (Hyland et al. 2003). Johnston and Roberts (2009) reviewed the literature and conducted a meta-analysis that quantified the reported responses of marine communities to pollution. The majority (138) of the 216 studies focused on soft-sediment habitats; 49 studies evaluated impacts related to sewage. The authors found that species richness, Shannon-Wiener diversity (H′) and Pielou's evenness (J') were the most commonly reported measures of diversity in the literature reviewed. Across all habitats and pollution types that were studied, anthropogenic contamination was strongly associated with lower diversity (Johnston and Roberts 2009). Although these results exemplify the widely understood interpretation of diversity response to impact, this interpretation is an over-simplification of the relation between impact and diversity for marine macrobenthos. A more realistic interpretation is that the response of diversity to impact falls along a gradient of impact magnitude over either space or time. At the high impact end of that gradient is low diversity, at the pristine end is higher diversity; but the diversity response along that gradient is not necessarily linear (Pearson and Rosenberg 1978, Swartz et al. 1986). In the review by Johnston and Roberts (2009), the authors used comparisons between the sites closest to a contaminant source and those furthest from the contaminant source, to calculate effect. This method provided results focused on the extremes, but downplaying conditions in between.

Pearson and Rosenberg (1978) demonstrated that the highest diversity along an impact gradient may occur at a point outside the area (or time period) of highest impacts, but away from the end of the gradient where conditions are pristine. At least two hypotheses provide potential explanations for the observed peaks in diversity along pollution impact gradients. The first suggests that higher levels of stress (e.g., from pollution) can reduce competition, allowing for increased diversity at intermediate levels of disturbance (Connell 1978, Huston 1979). The second is more specific to gradients of organic loading. This hypothesis suggests that the addition of nutrients to a nutrient-limited environment allows for higher levels of productivity and higher diversity (Hall et al. 2000). Above a certain threshold, higher levels of organic loading result in decreased diversity. Hyland et al. (2005) found that macrobenthic communities are adversely impacted above around 3% total organic carbon. Regardless of the mechanisms at work, the Pearson and Rosenberg (1978) model demonstrates that higher levels of diversity can occur along an impact gradient. Thus, changes in diversity can only be assessed by comparisons among samples collected along gradients in space or time.

Considering whether the higher H′ and J′ values reported during 2010 to 2013 might represent a peak along a plausible impact gradient is key to understanding the implications of these exceedances. Relocation of the outfall from Boston Harbor to Massachusetts Bay in September 2000, raised three main concerns about potential effects of the discharge on the macrobenthos: (1) organic loading and related low levels of dissolved oxygen; (2) accumulation of toxic contaminants in depositional areas; and (3) smothering of animals by particulate matter. These three concerns involve a direct impact to benthic communities from precipitation of suspended solids out of the wastewater plume. The footprint of this type of impact would most likely be outlined by monitoring parameters such as TOC and the sewage tracer *C. perfringens*. The magnitude of impact would be defined along a gradient of distance to the outfall, with the highest impact levels occurring at sites closest to the discharge. The timing of such an impact would be linked to the diversion of the wastewater to the offshore outfall (or to changes in wastewater treatment). This is the impact scenario that has been considered most carefully in this evaluation of threshold exceedances. A potential indirect impact to the macrobenthos is also possible through loading of dissolved nutrients in the water column, leading to eutrophication and, ultimately, organic loading of the benthos. Measurable impacts to the benthos through an indirect pathway would most likely also be measureable in TOC concentrations, which would increase with organic loading. Spatial and temporal analyses have found no evidence to suggest that the higher H′ and J′ occurred at distances from the outfall or points in time that suggest these values represent diversity peaks along an impact gradient. Thus, MWRA’s monitoring data do not fit a pattern that suggests outfall impacts, and that can be explained by ecological theories for peaks in diversity along impact gradients.

This evaluation of the H′ and J′ exceedances found no clear evidence of impacts to the macrobenthos from the wastewater discharge. Prior studies have also found no evidence of outfall impacts to the infauna of Massachusetts Bay (Nestler et al. 2013b, 2012; Maciolek et al 2011, 2008). The exceedances appear to have been driven by reduced abundances of a small number of dominant species during 2010 to 2013 in comparison to the baseline years. Change in the abundances of *P. steenstrupi*, the numerical dominant during baseline years, was clearly a factor in the exceedances. Large fluctuations in abundance of dominant infaunal organisms are typical for marine benthic communities. Vitaliano et al. (2007) reported that *P. steenstrupi* at ~30 meters depth in the New York Bight were highly variable at both annual and monthly time scales. During three years of sampling, two years of relatively low abundance (>50 per $0.1m^2$), were followed by a year of relatively high abundance (500+ per $0.1m^2$) at three sampling locations separated by distances as far as around 10 km. During the year when abundances were higher, counts varied dramatically month over month, peaking in late summer. While lower abundances of dominant taxa at MWRA's sampling stations may reflect natural fluctuations in the densities of infaunal organisms at multi-year time scales, it is also possible that temperature-related shifts in the timing of annual peak abundances relative to the annual August sampling could explain the lower abundances of some dominant organisms. While benthic sampling has been conducted each year in August throughout the history of the monitoring program, August bottom water temperatures in Massachusetts Bay during recent years have been elevated in comparison to historical averages (Libby et al. 2013, 2012, 2011).

5. SUMMARY

The goal of this evaluation was to investigate two related questions: (1) what factors have contributed to the threshold exceedances; and (2) are the threshold exceedances an indication of outfall impacts?

A general answer to the first question is that threshold exceedances were driven by changes in dominance levels within nearfield infaunal assemblages. Lower dominance during 2010 to 2013 than during the baseline period was the main factor behind threshold exceedances. Higher species richness (more species per sample, on average) may have contributed marginally to H′ exceedances in some years (e.g., 2012). At the species level, the spionid polychaete *Prionospio steenstrupi* stands out among all others as the single taxon that contributed most to threshold exceedances. *P. steenstrupi* was the numerically dominant taxon in the Massachusetts Bay samples from the mid 1990’s to the mid 2000’s. During years in which *P. steenstrupi* numbers were relatively low, other dominants were often abundant (e.g., *Spio limicola* in 1994). Two sub-dominant species, *Spio limicola* and *Mediomastus californiensis*, also contributed to threshold exceedances. Relatively low abundance has been reported for all dominant species during the past four years (these three and other sub-dominant species). This reduced abundance of dominant species in comparison to the baseline has been the driving factor behind threshold exceedances.

The question of whether threshold exceedances for H′ and J′ are indicative of outfall impacts was investigated through multiple approaches. Spatial and temporal analyses of H′ and J′ found no patterns suggesting outfall influence on nearfield infaunal communities. None of the species that were most influential in the threshold exceedences are commonly recognized as either sensitive species, or opportunistic/tolerant species, whose changing distributions or abundances at the nearfield stations are likely indicative of a response to the wastewater discharge. And the spatial distribution of these species showed no patterns relative to the outfall or changes over time that would suggest an outfall impact. Multivariate analyses of spatial and temporal patterns in assemblages at the Massachusetts Bay stations also found no evidence of impact. These analyses indicated that the distribution and species composition of assemblages have remained relatively stable over time, associated with particular habitat types that can be differentiated largely by sediment texture. Even at stations closest to the outfall where *C. perfringens* concentrations indicate some level of solids deposition from wastewater, multivariate analyses found no evidence of impacts from the offshore outfall on infaunal communities.

No evidence was found to suggest that the threshold exceedances for H′ and J′ occurred in response to the MWRA’s wastewater discharge. These exceedances likely reflect natural fluctuations in the abundances of dominant species.

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Appendix I Influence of each species on H′ and J' exceedances

Appendix Table 1. Influence[1] and Rank Influence[2] of each species on H′ exceedances based on all data from the 11 nearfield stations in Massachusetts Bay during the baseline period (1992 to 2000) and the years with exceedances (2010 to 2013).

Species	Species code	Baseline H′[3]	Exceedance H′[4]	Difference_ Sp[5]	Difference_ All[6]	Influence	Influence rank
Prionospio steenstrupi	5001430506	3.84641	4.19311	0.34669	0.54434	0.19765	1
Spio limicola	5001430707	3.70163	4.20065	0.49901	0.54434	0.04533	2
Monticellina cf. *dorsobranchialis*	5001500310CF	3.66991	4.18185	0.51194	0.54434	0.03240	3
Crassicorophium crassicorne	6169150203	3.72392	4.24642	0.52250	0.54434	0.02184	4
Scalibregma inflatum	5001570101	3.68009	4.20574	0.52565	0.54434	0.01869	5
Limnodriloides medioporus	5009020701	3.67037	4.19939	0.52902	0.54434	0.01532	6
Aricidea quadrilobata	5001410217	3.67796	4.20901	0.53105	0.54434	0.01329	7
Parougia caeca	50013614CAEC	3.66087	4.19305	0.53218	0.54434	0.01216	8
Apistobranchus typicus	5001420103	3.67916	4.21184	0.53268	0.54434	0.01166	9
Periploma papyratium	5520070104	3.68135	4.21415	0.53280	0.54434	0.01154	10
Ampharete lindstroemi	5001670213	3.68417	4.21711	0.53294	0.54434	0.01140	11
Nemertea sp. 12	43SP12	3.67522	4.20852	0.53330	0.54434	0.01104	12
Nephtys incisa	5001250115	3.67518	4.20965	0.53447	0.54434	0.00987	13
Euchone incolor	5001700204	3.64475	4.18020	0.53545	0.54434	0.00889	14
Flabelligera affinis	5001540202	3.68373	4.22033	0.53659	0.54434	0.00775	15
Terebellides atlantis	5001690105	3.68352	4.22046	0.53694	0.54434	0.00740	16
Nucula delphinodonta	5502020206	3.65813	4.19528	0.53715	0.54434	0.00719	17
Diastylis sculpta	6154050127	3.68131	4.21950	0.53820	0.54434	0.00614	18
Ilyanassa trivittata	5105080202	3.68013	4.21877	0.53864	0.54434	0.00570	19
Ensis directus	5515290301	3.68156	4.22042	0.53886	0.54434	0.00548	20
Thyasira gouldi	5515020325	3.68113	4.22005	0.53892	0.54434	0.00542	21
Trochochaeta multisetosa	5001450203	3.67995	4.21893	0.53898	0.54434	0.00536	22
Spiophanes bombyx	5001431001	3.66430	4.20341	0.53911	0.54434	0.00523	23
Phyllodoce mucosa	5001130104	3.65912	4.19840	0.53928	0.54434	0.00506	24
Cnemidocarpa mollis	8406010303	3.68463	4.22421	0.53958	0.54434	0.00476	25
Tanaissus psammophilus	6157020402	3.67796	4.21798	0.54002	0.54434	0.00432	26
Leitoscoloplos acutus	5001400305	3.64210	4.18213	0.54003	0.54434	0.00431	27
Monticellina baptisteae	50015003BAPT	3.63646	4.17665	0.54019	0.54434	0.00415	28
Chaetozone anasimus	50015004AN	3.67451	4.21504	0.54053	0.54434	0.00381	29
Polycirrus phosphoreus	5001680807	3.68369	4.22426	0.54057	0.54434	0.00377	30
Aphelochaeta cf. marioni	5001500307CF	3.65435	4.19495	0.54060	0.54434	0.00374	31
Cossura longocirrata	5001520101	3.68252	4.22323	0.54071	0.54434	0.00363	32
Galathowenia oculata	5001640402	3.67988	4.22073	0.54085	0.54434	0.00349	33
Praxillella gracilis	5001630901	3.68404	4.22496	0.54092	0.54434	0.00342	34
Turbellaria spp.	3901SPP	3.68427	4.22534	0.54107	0.54434	0.00327	35
Eudorella pusilla	6154040211	3.68385	4.22497	0.54112	0.54434	0.00322	36
Spio thulini	5001430709	3.68083	4.22208	0.54124	0.54434	0.00310	37
Sternaspis scutata	5001590101	3.68459	4.22587	0.54127	0.54434	0.00307	38
Sthenelais limicola	5001060303	3.68473	4.22618	0.54146	0.54434	0.00288	39
Nemertea sp. 17	43SP17	3.68475	4.22627	0.54152	0.54434	0.00282	40
Spio filicornis	5001430701	3.68260	4.22414	0.54155	0.54434	0.00279	41
Cephalothricidae sp. 1	430203SP01	3.67897	4.22070	0.54173	0.54434	0.00261	42
Clymenella torquata	5001630202	3.68220	4.22399	0.54179	0.54434	0.00255	43
Arctica islandica	5515390101	3.67103	4.21299	0.54195	0.54434	0.00239	44
Scoloplos sp. A	50014003SP01	3.68475	4.22671	0.54196	0.54434	0.00238	45
Pythinella cuneata	5515090301	3.68368	4.22566	0.54198	0.54434	0.00236	46
Goniada maculata	5001280202	3.68310	4.22513	0.54203	0.54434	0.00231	47

Species	Species code	Baseline H′[3]	Exceedance H′[4]	Difference_ Sp[5]	Difference_ All[6]	Influence	Influence rank
Onoba pelagica	5103202113	3.68337	4.22545	0.54209	0.54434	0.00225	48
Philine sp. 1	51100501SP1	3.68475	4.22686	0.54211	0.54434	0.00223	49
Turbellaria sp. 12	3901SP12	3.68443	4.22665	0.54221	0.54434	0.00213	50
Ophelina acuminata	5001580607	3.68443	4.22664	0.54221	0.54434	0.00213	51
Turbellaria sp. 11	3901SP11	3.68254	4.22483	0.54229	0.54434	0.00205	52
Pherusa plumosa	5001540302	3.68475	4.22708	0.54232	0.54434	0.00202	53
Turbellaria sp. 14	3901SP14	3.68475	4.22711	0.54236	0.54434	0.00198	54
Praxillella praetermissa	5001630902	3.68463	4.22699	0.54236	0.54434	0.00198	55
Cerebratulus spp.	43030202SPP	3.67969	4.22212	0.54242	0.54434	0.00192	56
Stereobalanus canadensis	8201010201	3.68418	4.22663	0.54245	0.54434	0.00189	57
Syllides convoluta	5001231503CON	3.68419	4.22669	0.54250	0.54434	0.00184	58
Eudorellopsis deformis	6154040304	3.68329	4.22585	0.54255	0.54434	0.00179	59
Amphiporus caecus	4306050111	3.67583	4.21847	0.54263	0.54434	0.00171	60
Lyonsia arenosa	5520050201	3.68263	4.22540	0.54277	0.54434	0.00157	61
Chaetozone cf. *vivipara*	50015004VIVICF	3.68467	4.22758	0.54291	0.54434	0.00143	62
Polydora cornuta	5001430448	3.68472	4.22764	0.54292	0.54434	0.00142	63
Pleurogonium inerme	6163120204	3.68395	4.22690	0.54295	0.54434	0.00139	64
Tubificoides apectinatus	5009020906	3.68475	4.22772	0.54297	0.54434	0.00137	65
Pitar morrhuanus	5515471201	3.68368	4.22670	0.54302	0.54434	0.00132	66
Periploma leanum	5520070103	3.68345	4.22653	0.54307	0.54434	0.00127	67
Eusyllis sp. A	50012302SP01	3.68328	4.22636	0.54308	0.54434	0.00126	68
Harmothoe extenuata	5001020803	3.68466	4.22777	0.54311	0.54434	0.00123	69
Unciola inermis	6169150702	3.67526	4.21840	0.54313	0.54434	0.00121	70
Eusyllis sp. 2	50012302SP02	3.68475	4.22789	0.54314	0.54434	0.00120	71
Turbellaria sp. 15	3901SP15	3.68475	4.22796	0.54321	0.54434	0.00113	72
Paradoneis lyra	5001411201	3.68439	4.22761	0.54322	0.54434	0.00112	73
Hippomedon propinquus	6169341405	3.68341	4.22665	0.54325	0.54434	0.00109	74
Dulichia tuberculata	6169440110	3.68401	4.22728	0.54327	0.54434	0.00107	75
Caulleriella venefica	50015002VE	3.68466	4.22801	0.54335	0.54434	0.00099	76
Pherusa affinis	5001540304	3.68383	4.22719	0.54336	0.54434	0.00098	77
Rhepoxynius hudsoni	6169421502	3.68054	4.22392	0.54338	0.54434	0.00096	78
Phoxocephalus holbolli	6169420702	3.68027	4.22366	0.54339	0.54434	0.00095	79
Stylochus ellipticus	3906030101	3.68475	4.22815	0.54340	0.54434	0.00094	80
Syllides sp. 1	50012315SP01	3.68475	4.22815	0.54340	0.54434	0.00094	81
Ampharete finmarchica	5001670214	3.67974	4.22317	0.54343	0.54434	0.00091	82
Tubulanus pellucidus	4302010104	3.68475	4.22821	0.54345	0.54434	0.00089	83
Nephtys cornuta	5001250104	3.68124	4.22471	0.54347	0.54434	0.00087	84
Brada villosa	5001540102	3.68444	4.22796	0.54352	0.54434	0.00082	85
Yoldia sapotilla	5502040513	3.67980	4.22336	0.54356	0.54434	0.00078	86
Pontogeneia inermis	6169201203	3.68472	4.22831	0.54359	0.54434	0.00075	87
Microclymene sp.1	50016317SP1	3.68475	4.22835	0.54360	0.54434	0.00074	88
Megamoera dentata	616921MEGDENT	3.68470	4.22831	0.54362	0.54434	0.00072	89
Grania longiducta	5009010301LONG	3.68408	4.22773	0.54365	0.54434	0.00069	90
Harpinia propinqua	6169420116	3.68366	4.22731	0.54365	0.54434	0.00069	91
Hartmania moorei	5001022001	3.68470	4.22840	0.54370	0.54434	0.00064	92
Polydora sp. 1	50014304SP01	3.68475	4.22846	0.54371	0.54434	0.00063	93
Naididae sp. 5	500903SP05	3.68463	4.22837	0.54374	0.54434	0.00060	94
Nephtys ciliata	5001250102	3.68433	4.22808	0.54375	0.54434	0.00059	95
Angulus agilis	5515310205	3.68475	4.22851	0.54376	0.54434	0.00058	96
Rhodine loveni	5001631003	3.68440	4.22818	0.54378	0.54434	0.00056	97

Species	Species code	Baseline H′[3]	Exceedance H′[4]	Difference_ Sp[5]	Difference_ All[6]	Influence	Influence rank
Grania sp. 3	50090103SP03	3.68475	4.22858	0.54383	0.54434	0.00051	98
Nereis grayi	5001240409	3.68081	4.22465	0.54384	0.54434	0.00050	99
Euphysa aurata	3703031201	3.68472	4.22858	0.54385	0.54434	0.00049	100
Pectinaria granulata	5001660303	3.68439	4.22825	0.54387	0.54434	0.00047	101
Tetrastemma elegans	4306060205	3.68475	4.22862	0.54387	0.54434	0.00047	102
Axiothella catenata	5001630801	3.68462	4.22849	0.54387	0.54434	0.00047	103
Prionospio cirrifera	50014305CIRR	3.68475	4.22867	0.54391	0.54434	0.00043	104
Cylichna alba	5110040203	3.68455	4.22846	0.54392	0.54434	0.00042	105
Diastylis quadrispinosa	6154050126	3.68346	4.22740	0.54394	0.54434	0.00040	106
Scoloplos sp. B	50014003SP02	3.68475	4.22872	0.54397	0.54434	0.00037	107
Astarte undata	5515190113	3.67156	4.21554	0.54398	0.54434	0.00036	108
Mystides borealis	5001130501	3.68467	4.22867	0.54399	0.54434	0.00035	109
Phascolion strombi	7200020401	3.68453	4.22852	0.54400	0.54434	0.00034	110
Psammodrilus balanoglossoides	5001480101	3.68466	4.22866	0.54400	0.54434	0.00034	111
Eudorella hispida	6154040208	3.68472	4.22873	0.54400	0.54434	0.00034	112
Pusillina pseudoareolata	5103202301	3.68475	4.22877	0.54402	0.54434	0.00032	113
Pentamera calcigera	8172060302	3.68475	4.22880	0.54405	0.54434	0.00029	114
Euclymene collaris	5001631102	3.67144	4.21551	0.54407	0.54434	0.00027	115
Spiochaetopterus costarum oculatus	5001490303	3.68474	4.22882	0.54408	0.54434	0.00026	116
Amacrodorum bipapillatum	500126AMACBIPA	3.68475	4.22884	0.54409	0.54434	0.00025	117
Spisula solidissima	5515250102	3.68447	4.22857	0.54410	0.54434	0.00024	118
Ophiura sp. 2	81270106SP02	3.68466	4.22878	0.54412	0.54434	0.00022	119
Diplocirrus hirsutus	5001540402	3.68456	4.22870	0.54414	0.54434	0.00020	120
Acanthohaustorius spinosus	6169220603	3.68451	4.22866	0.54415	0.54434	0.00019	121
Ameroculodes edwardsi	6169370820	3.68344	4.22760	0.54416	0.54434	0.00018	122
Deflexilodes tuberculatus	6169370815	3.68386	4.22802	0.54416	0.54434	0.00018	123
Hypereteone foliosa	5001130211	3.68475	4.22892	0.54416	0.54434	0.00018	124
Amphiporus bioculatus	4306050110	3.68475	4.22892	0.54417	0.54434	0.00017	125
Eobrolgus spinosus	6169421901	3.68473	4.22890	0.54417	0.54434	0.00017	126
Munna sp. 1	61631201SP01	3.68428	4.22846	0.54417	0.54434	0.00017	127
Scolelepis bousfieldi	5001432002	3.68472	4.22892	0.54420	0.54434	0.00014	128
Diastylis cornuifer	6154050130	3.68461	4.22881	0.54420	0.54434	0.00014	129
Neomysis americana	6153011508	3.68471	4.22892	0.54421	0.54434	0.00013	130
Moelleria costulata	5102120202	3.68475	4.22897	0.54421	0.54434	0.00013	131
Erichsonella filiformis	6162020602	3.68475	4.22897	0.54422	0.54434	0.00012	132
Retusa obtusa	5110130101	3.68472	4.22895	0.54423	0.54434	0.00011	133
Lamprops quadriplicata	6154010105	3.68408	4.22831	0.54424	0.54434	0.00010	134
Chone cf. *magna*	5001700106	3.68474	4.22897	0.54424	0.54434	0.00010	135
Enipo torelli	5001022103	3.68336	4.22760	0.54424	0.54434	0.00010	136
Prionospio aluta	5001430520	3.68475	4.22901	0.54425	0.54434	0.00009	137
Melinna cristata	5001670501	3.68470	4.22897	0.54426	0.54434	0.00008	138
Musculus niger	5507010401	3.68441	4.22868	0.54427	0.54434	0.00007	139
Peosidrilus coeloprostatus	5009021102	3.68408	4.22837	0.54429	0.54434	0.00005	140
Paranaitis speciosa	5001130801	3.68449	4.22880	0.54431	0.54434	0.00003	141
Terebellides stroemii	5001690101	3.68466	4.22897	0.54431	0.54434	0.00003	142
Polycirrus eximius	5001680804	3.68437	4.22869	0.54432	0.54434	0.00002	143
Priapulus caudatus	7400010101	3.68464	4.22898	0.54434	0.54434	0.00000	144
Acaulis primarius	3703270101	3.68475	4.22910	0.54434	0.54434	0.00000	145
Aphrodita hastata	5001010104	3.68475	4.22910	0.54434	0.54434	0.00000	146
Gattyana nutti	5001020607	3.68475	4.22910	0.54434	0.54434	0.00000	147
Bylgides elegans	5001025501	3.68475	4.22910	0.54434	0.54434	0.00000	148

Species	**Species code**	**Baseline H′[3]**	**Exceedance H′[4]**	**Difference_ Sp[5]**	**Difference_ All[6]**	**Influence**	**Influence rank**
Bylgides sarsi	50010255SARS	3.68475	4.22910	0.54434	0.54434	0.00000	149
Dysponetus pygmaeus	5001080201	3.68475	4.22910	0.54434	0.54434	0.00000	150
Eteone trilineata	5001130209	3.68475	4.22910	0.54434	0.54434	0.00000	151
Typosyllis alternata	5001230501	3.68475	4.22910	0.54434	0.54434	0.00000	152
Exogone sp. A	50012307SP01	3.68475	4.22910	0.54434	0.54434	0.00000	153
Sphaerosyllis sp. 1	50012308SP01	3.68475	4.22910	0.54434	0.54434	0.00000	154
Streptosyllis cf. *pettiboneae*	5001231605CF	3.68475	4.22910	0.54434	0.54434	0.00000	155
Websterinereis tridentata	5001241001	3.68475	4.22910	0.54434	0.54434	0.00000	156
Sphaerodoropsis cf. *longipalpa*	50012602LONGCF	3.68475	4.22910	0.54434	0.54434	0.00000	157
Glycera dibranchiata	5001270105	3.68475	4.22910	0.54434	0.54434	0.00000	158
Nothria conchylega	5001290301	3.68475	4.22910	0.54434	0.54434	0.00000	159
Nothria sp. 1	50012903SP01	3.68475	4.22910	0.54434	0.54434	0.00000	160
Lumbrinerides acuta	5001310301	3.68475	4.22910	0.54434	0.54434	0.00000	161
Abyssoninoe winsnesae	500131WINS	3.68475	4.22910	0.54434	0.54434	0.00000	162
Drilonereis longa	5001330103	3.68475	4.22910	0.54434	0.54434	0.00000	163
Ophryotrocha sp. 2	50013604SP02	3.68475	4.22910	0.54434	0.54434	0.00000	164
Ougia tenuidentis	50013612TENU	3.68475	4.22910	0.54434	0.54434	0.00000	165
Spio setosa	5001430704	3.68475	4.22910	0.54434	0.54434	0.00000	166
Malacoceros sp. 1	50014314SP01	3.68475	4.22910	0.54434	0.54434	0.00000	167
Streblospio benedicti	5001431801	3.68475	4.22910	0.54434	0.54434	0.00000	168
Scolelepis foliosa	5001432007	3.68475	4.22910	0.54434	0.54434	0.00000	169
Trochochaeta carica	5001450201	3.68475	4.22910	0.54434	0.54434	0.00000	170
Aphelochaeta sp. 3	50015003ASP03	3.68475	4.22910	0.54434	0.54434	0.00000	171
Brada incrustata	5001540107	3.68475	4.22910	0.54434	0.54434	0.00000	172
Capitellidae sp. 2	500160SP02	3.68475	4.22910	0.54434	0.54434	0.00000	173
Petaloproctus tenuis	5001630701	3.68475	4.22910	0.54434	0.54434	0.00000	174
Praxillura ornata	5001631803	3.68475	4.22910	0.54434	0.54434	0.00000	175
Myriochele heeri	5001640201	3.68475	4.22910	0.54434	0.54434	0.00000	176
Pectinaria hyperborea	50016603HYPE	3.68475	4.22910	0.54434	0.54434	0.00000	177
Amphicteis gunneri	5001670303	3.68475	4.22910	0.54434	0.54434	0.00000	178
Amphitrite cirrata	5001680101	3.68475	4.22910	0.54434	0.54434	0.00000	179
Nicolea zostericola	5001680602	3.68475	4.22910	0.54434	0.54434	0.00000	180
Pista cristata	5001680701	3.68475	4.22910	0.54434	0.54434	0.00000	181
Streblosoma spiralis	5001682501	3.68475	4.22910	0.54434	0.54434	0.00000	182
Trichobranchus roseus	5001690202	3.68475	4.22910	0.54434	0.54434	0.00000	183
Euchone papillosa	5001700202	3.68475	4.22910	0.54434	0.54434	0.00000	184
Myxicola infundibulum	5001700502	3.68475	4.22910	0.54434	0.54434	0.00000	185
Tubificoides sp. 2	50090209SP02	3.68475	4.22910	0.54434	0.54434	0.00000	186
Pusillina harpa	5103200127	3.68475	4.22910	0.54434	0.54434	0.00000	187
Epitonium greenlandicum	5103500102GR	3.68475	4.22910	0.54434	0.54434	0.00000	188
Couthouyella striatula	5103501201	3.68475	4.22910	0.54434	0.54434	0.00000	189
Euspira pallida	5103760402	3.68475	4.22910	0.54434	0.54434	0.00000	190
Euspira triseriata	5103761205	3.68475	4.22910	0.54434	0.54434	0.00000	191
Colus pubescens	5105050326	3.68475	4.22910	0.54434	0.54434	0.00000	192
Colus pygmaeus	5105050328	3.68475	4.22910	0.54434	0.54434	0.00000	193
Oenopota cf. *cancellatus*	5106020443CF	3.68475	4.22910	0.54434	0.54434	0.00000	194
Onchidoris bilamellata	5131050507	3.68475	4.22910	0.54434	0.54434	0.00000	195
Nucula annulata	5502020205	3.68475	4.22910	0.54434	0.54434	0.00000	196
Nuculana pernula	5502040201	3.68475	4.22910	0.54434	0.54434	0.00000	197
Nuculana messanensis	5502040220	3.68475	4.22910	0.54434	0.54434	0.00000	198
Yoldiella lucida	5502040611	3.68475	4.22910	0.54434	0.54434	0.00000	199
Solemya velum	5504010101	3.68475	4.22910	0.54434	0.54434	0.00000	200
Thyasira nr. *minutus*	55150203MICF	3.68475	4.22910	0.54434	0.54434	0.00000	201

Species	**Species code**	**Baseline H′[3]**	**Exceedance H′[4]**	**Difference_ Sp[5]**	**Difference_ All[6]**	**Influence**	**Influence rank**
Macoma calcarea	5515310101	3.68475	4.22910	0.54434	0.54434	0.00000	202
Cyrtodaria siliqua	5517060102	3.68475	4.22910	0.54434	0.54434	0.00000	203
Pandora nr. *inflata*	5520020109CF	3.68475	4.22910	0.54434	0.54434	0.00000	204
Lyonsia hyalina	5520050206	3.68475	4.22910	0.54434	0.54434	0.00000	205
Mysis mixta	6153011401	3.68475	4.22910	0.54434	0.54434	0.00000	206
Erythrops erythrophthalma	6153012301	3.68475	4.22910	0.54434	0.54434	0.00000	207
Leucon fulvus	6154040104	3.68475	4.22910	0.54434	0.54434	0.00000	208
Leucon acutirostris	6154040106	3.68475	4.22910	0.54434	0.54434	0.00000	209
Campylaspis nr. *sulcata*	61540701SUCF	3.68475	4.22910	0.54434	0.54434	0.00000	210
Pseudoleptocuma minor	6154090301	3.68475	4.22910	0.54434	0.54434	0.00000	211
Gnathia cerina	6159010111	3.68475	4.22910	0.54434	0.54434	0.00000	212
Baeonectes muticus	6163170702	3.68475	4.22910	0.54434	0.54434	0.00000	213
Joeropsis bifasciatus	61632201BIFA	3.68475	4.22910	0.54434	0.54434	0.00000	214
Byblis gaimardi	6169020202	3.68475	4.22910	0.54434	0.54434	0.00000	215
Microdeutopus anomalus	6169060402	3.68475	4.22910	0.54434	0.54434	0.00000	216
Crassicorophium bonellii	6169150202	3.68475	4.22910	0.54434	0.54434	0.00000	217
Monocorophium sextonae	6169150217	3.68475	4.22910	0.54434	0.54434	0.00000	218
Ericthonius brasiliensis	6169150302	3.68475	4.22910	0.54434	0.54434	0.00000	219
Pseudohaustorius borealis	6169221301	3.68475	4.22910	0.54434	0.54434	0.00000	220
Photis reinhardi	6169260202	3.68475	4.22910	0.54434	0.54434	0.00000	221
Anonyx sarsi	6169340314	3.68475	4.22910	0.54434	0.54434	0.00000	222
Bathymedon obtusifrons	6169370505	3.68475	4.22910	0.54434	0.54434	0.00000	223
Oedicerotidae sp. 2	616937SP02	3.68475	4.22910	0.54434	0.54434	0.00000	224
Henricia sanguinolenta	8114040111	3.68475	4.22910	0.54434	0.54434	0.00000	225
Leptasterias tenera	8117030414	3.68475	4.22910	0.54434	0.54434	0.00000	226
Ophiopholis aculeata	8129020101	3.68475	4.22910	0.54434	0.54434	0.00000	227
Havelockia scabra	8172040201	3.68475	4.22910	0.54434	0.54434	0.00000	228
Harmothoe imbricata	5001020806	3.68452	4.22886	0.54435	0.54434	-0.00001	229
Ischyrocerus anguipes	6169270202	3.68448	4.22882	0.54435	0.54434	-0.00001	230
Ampelisca abdita	6169020108	3.68457	4.22892	0.54435	0.54434	-0.00001	231
Siliqua costata	5515290105	3.68475	4.22910	0.54435	0.54434	-0.00001	232
Pandora glacialis	5520020101	3.68474	4.22910	0.54435	0.54434	-0.00001	233
Pandora gouldiana	5520020107	3.68474	4.22910	0.54435	0.54434	-0.00001	234
Chone infundibuliformis	5001700102	3.68474	4.22910	0.54435	0.54434	-0.00001	235
Ampelisca vadorum	6169020109	3.68474	4.22910	0.54436	0.54434	-0.00002	236
Eteone heteropoda	5001130207	3.68473	4.22910	0.54436	0.54434	-0.00002	237
Megayoldia thraciaeformis	5502040507	3.68473	4.22910	0.54436	0.54434	-0.00002	238
Paradoneis armatus	5001411204	3.68473	4.22910	0.54436	0.54434	-0.00002	239
Hippomedon serratus	6169341408	3.68045	4.22482	0.54437	0.54434	-0.00003	240
Monocorophium tuberculatum	6169150207	3.68473	4.22910	0.54437	0.54434	-0.00003	241
Austrolaenilla mollis	5001022401	3.68472	4.22910	0.54437	0.54434	-0.00003	242
Monoculodes packardi	6169370810	3.68472	4.22910	0.54437	0.54434	-0.00003	243
Aricidea cf. minuta	5001410220CF	3.68455	4.22892	0.54438	0.54434	-0.00004	244
Paramphinome jeffreysii	5001100401	3.68472	4.22910	0.54438	0.54434	-0.00004	245
Eteone flava	5001130204	3.68472	4.22910	0.54438	0.54434	-0.00004	246
Propebela turricula	5106020601	3.68472	4.22910	0.54438	0.54434	-0.00004	247
Eulalia bilineata	5001130304	3.68472	4.22910	0.54438	0.54434	-0.00004	248
Eumida sanguinea	5001131101	3.68472	4.22910	0.54438	0.54434	-0.00004	249
Musculus discors	5507010402	3.68472	4.22910	0.54438	0.54434	-0.00004	250
Parapionosyllis longicirrata	5001231701	3.68472	4.22910	0.54438	0.54434	-0.00004	251
Proboloides holmesi	6169480801	3.68472	4.22910	0.54438	0.54434	-0.00004	252
Oenopota incisula	5106020426	3.68446	4.22884	0.54438	0.54434	-0.00004	253
Propebela exarata	5106020603	3.68471	4.22910	0.54438	0.54434	-0.00004	254

Species	**Species code**	**Baseline H′[3]**	**Exceedance H′[4]**	**Difference_ Sp[5]**	**Difference_ All[6]**	**Influence**	**Influence rank**
Gitanopsis arctica	6169030403	3.68471	4.22910	0.54438	0.54434	-0.00004	255
Ophiura sarsi	8127010610	3.68471	4.22910	0.54439	0.54434	-0.00005	256
Proceraea cornuta	5001230101	3.68471	4.22910	0.54439	0.54434	-0.00005	257
Travisia carnea	5001580404	3.68471	4.22910	0.54439	0.54434	-0.00005	258
Capitella capitata complex	5001600101	3.67181	4.21620	0.54439	0.54434	-0.00005	259
Gammarellus angulosus	6169210602	3.68471	4.22910	0.54439	0.54434	-0.00005	260
Solariella obscura	5102100402	3.68141	4.22580	0.54439	0.54434	-0.00005	261
Pectinaria gouldi	5001660302	3.68470	4.22910	0.54439	0.54434	-0.00005	262
Pleustes panoplus	6169430405	3.68470	4.22910	0.54439	0.54434	-0.00005	263
Monocorophium insidiosum	6169150211	3.68470	4.22910	0.54439	0.54434	-0.00005	264
Amphipholis squamatus	8129030202	3.68470	4.22910	0.54439	0.54434	-0.00005	265
Scolelepis texana	5001432006	3.68470	4.22910	0.54440	0.54434	-0.00006	266
Odostomia sulcosa	5108010133	3.68470	4.22910	0.54440	0.54434	-0.00006	267
Oenopota pyrimidalis	5106020410	3.68470	4.22910	0.54440	0.54434	-0.00006	268
Ctenodiscus crispatus	8107020101	3.68470	4.22910	0.54440	0.54434	-0.00006	269
Amphiporus cruentatus	4306050115	3.68428	4.22868	0.54440	0.54434	-0.00006	270
Proclea graffii	5001681702	3.68455	4.22895	0.54440	0.54434	-0.00006	271
Molpadia oolitica	8179010102	3.68469	4.22910	0.54440	0.54434	-0.00006	272
Macoma balthica	5515310116	3.68469	4.22910	0.54440	0.54434	-0.00006	273
Axius serratus	6183020301	3.68469	4.22910	0.54440	0.54434	-0.00006	274
Oenopota harpularia	5106020409	3.68469	4.22910	0.54440	0.54434	-0.00006	275
Crangon septemspinosa	6179220103	3.68409	4.22849	0.54441	0.54434	-0.00007	276
Corambe obscura	5131070201	3.68469	4.22910	0.54441	0.54434	-0.00007	277
Ancistrosyllis groenlandica	5001220104	3.68469	4.22910	0.54441	0.54434	-0.00007	278
Boonea impressa	5108011402	3.68469	4.22910	0.54441	0.54434	-0.00007	279
Jassa marmorata	6169270303	3.68469	4.22910	0.54441	0.54434	-0.00007	280
Chaetoderma nitidulum canadense	5402010102	3.68469	4.22910	0.54441	0.54434	-0.00007	281
Halcampa duodecimcirrata	3759040102	3.68469	4.22910	0.54441	0.54434	-0.00007	282
Euspira heros	5103761201	3.68445	4.22887	0.54442	0.54434	-0.00008	283
Paraonis fulgens	5001410302	3.68467	4.22910	0.54443	0.54434	-0.00009	284
Euspira immaculata	5103760408	3.68467	4.22910	0.54443	0.54434	-0.00009	285
Pleusymtes glaber	6169430503	3.68466	4.22910	0.54444	0.54434	-0.00010	286
Tubulanus sp. 1	43020101SP01	3.67894	4.22338	0.54444	0.54434	-0.00010	287
Colus parvus	5105050335	3.68466	4.22910	0.54444	0.54434	-0.00010	288
Nephtys discors	5001250108	3.68465	4.22910	0.54445	0.54434	-0.00011	289
Typosyllis cornuta	5001230517	3.68465	4.22910	0.54445	0.54434	-0.00011	290
Ophryotrocha sp. 1	50013604SP01	3.68465	4.22910	0.54445	0.54434	-0.00011	291
Monocorophium acherusicum	6169150201	3.68464	4.22910	0.54445	0.54434	-0.00011	292
Lanassa venusta venusta	5.00168E+11	3.68457	4.22903	0.54445	0.54434	-0.00011	293
Drilonereis filum	5001330101	3.68463	4.22910	0.54446	0.54434	-0.00012	294
Astarte borealis	5515190101	3.68463	4.22910	0.54446	0.54434	-0.00012	295
Drilonereis magna	5001330105	3.68463	4.22910	0.54447	0.54434	-0.00013	296
Pagurus acadianus	6183060226	3.68462	4.22910	0.54447	0.54434	-0.00013	297
Nereis zonata	5001240406	3.68462	4.22910	0.54448	0.54434	-0.00014	298
Melitidae sp. 1	616921MESP01	3.68462	4.22910	0.54448	0.54434	-0.00014	299
Nephasoma diaphanes	7200020305	3.68462	4.22910	0.54448	0.54434	-0.00014	300
Ophryotrocha cf. *labronica*	5001360402CF	3.68461	4.22910	0.54448	0.54434	-0.00014	301
Microphthalmus pettiboneae	50012102PETT	3.68444	4.22892	0.54448	0.54434	-0.00014	302
Placopecten magellanicus	5509050901	3.68461	4.22910	0.54449	0.54434	-0.00015	303
Neanthes virens	5001240302	3.68461	4.22910	0.54449	0.54434	-0.00015	304
Dorvillea sociabilis	5001360108	3.68444	4.22892	0.54449	0.54434	-0.00015	305
Casco bigelowi	6169211601	3.68386	4.22836	0.54450	0.54434	-0.00016	306

Species	**Species code**	**Baseline H′^{3}**	**Exceedance H′^{4}**	**Difference_ Sp^{5}**	**Difference_ All^{6}**	**Influence**	**Influence rank**
Cirratulus cirratus	5001500101	3.68460	4.22910	0.54450	0.54434	-0.00016	307
Marionina welchi	5009010201	3.68050	4.22501	0.54451	0.54434	-0.00017	308
Parapleustes gracilis	6169430305	3.68458	4.22910	0.54452	0.54434	-0.00018	309
Paradulichia typica	6169440302	3.68437	4.22889	0.54452	0.54434	-0.00018	310
Exogone longicirris	5001230711	3.68345	4.22799	0.54454	0.54434	-0.00020	311
Microphthalmus nahantensis	50012102NAHA	3.68456	4.22910	0.54454	0.54434	-0.00020	312
Spiophanes kroeyeri	5001431002	3.68447	4.22903	0.54455	0.54434	-0.00021	313
Diastylis polita	6154050121	3.68453	4.22910	0.54457	0.54434	-0.00023	314
Pleurogonium spinosissimum	6163120201	3.68436	4.22892	0.54457	0.54434	-0.00023	315
Syllis hyalina	5001230511	3.68449	4.22910	0.54461	0.54434	-0.00027	316
Diaphana minuta	5110090101	3.68397	4.22861	0.54463	0.54434	-0.00029	317
Syllides longocirratus	5001231503	3.68432	4.22899	0.54467	0.54434	-0.00033	318
Campylaspis rubicunda	6154070103	3.68365	4.22832	0.54467	0.54434	-0.00033	319
Dipolydora caulleryi	5001430404	3.68441	4.22910	0.54469	0.54434	-0.00035	320
Cyclocardia borealis	5515170106	3.68266	4.22735	0.54469	0.54434	-0.00035	321
Phyllodoce arenae	5001131410	3.68411	4.22884	0.54473	0.54434	-0.00039	322
Euclymeninae sp. 1	500163EUSP01	3.68437	4.22910	0.54473	0.54434	-0.00039	323
Scoletoma impatiens	5001310115	3.68437	4.22910	0.54473	0.54434	-0.00039	324
Praxillella affinis	5001630903	3.68436	4.22910	0.54474	0.54434	-0.00040	325
Polycirrus medusa	5001680802	3.68427	4.22901	0.54474	0.54434	-0.00040	326
Phyllodoce groenlandica	5001130102	3.68435	4.22910	0.54475	0.54434	-0.00041	327
Scoloplos acmeceps	5001400311	3.68416	4.22893	0.54477	0.54434	-0.00043	328
Westwoodilla megalops	6169371504	3.68398	4.22877	0.54479	0.54434	-0.00045	329
Leptostylis longimana	6154050404	3.68430	4.22910	0.54480	0.54434	-0.00046	330
Orbinia swani	5001400502	3.68393	4.22873	0.54480	0.54434	-0.00046	331
Laonice cirrata	5001430201	3.68397	4.22879	0.54481	0.54434	-0.00047	332
Phyllodoce maculata	5001130106	3.68171	4.22652	0.54481	0.54434	-0.00047	333
Turbellaria sp. 13	3901SP13	3.68428	4.22910	0.54482	0.54434	-0.00048	334
Unciola irrorata	6169150703	3.68134	4.22618	0.54483	0.54434	-0.00049	335
Deflexilodes tesselatus	6169370821	3.68286	4.22771	0.54485	0.54434	-0.00051	336
Arcteobia anticostiensis	5001020301	3.68391	4.22876	0.54485	0.54434	-0.00051	337
Polydora aggregata	5001430438	3.68423	4.22910	0.54486	0.54434	-0.00052	338
Orchomenella minuta	6169345201	3.68362	4.22848	0.54487	0.54434	-0.00053	339
Onoba mighelsi	5103202115	3.68414	4.22901	0.54487	0.54434	-0.00053	340
Nuculoma tenuis	5502020201	3.68386	4.22878	0.54493	0.54434	-0.00059	341
Ophiura robusta	8127010611	3.68414	4.22910	0.54496	0.54434	-0.00062	342
Glycera capitata	5001270101	3.68413	4.22910	0.54497	0.54434	-0.00063	343
Sphaerosyllis erinaceus	5001230801	3.68160	4.22657	0.54497	0.54434	-0.00063	344
Cylichna gouldi	5110040206	3.68411	4.22910	0.54499	0.54434	-0.00065	345
Anonyx liljeborgi	6169340303	3.68372	4.22872	0.54500	0.54434	-0.00066	346
Lacuna vincta	5103090305	3.68406	4.22910	0.54504	0.54434	-0.00070	347
Nephtys caeca	5001250103	3.68392	4.22901	0.54508	0.54434	-0.00074	348
Cancer spp.	61880301SPP	3.68308	4.22818	0.54510	0.54434	-0.00076	349
Sphaerodoropsis sp. 1	50012602SP01	3.68319	4.22832	0.54512	0.54434	-0.00078	350
Leptocheirus pinguis	6169060702	3.68130	4.22643	0.54513	0.54434	-0.00079	351
Haploops fundiensis	6169020306	3.68390	4.22910	0.54520	0.54434	-0.00086	352
Heteromastus filiformis	5001600201	3.68383	4.22910	0.54527	0.54434	-0.00093	353
Chone duneri	5001700104	3.68366	4.22901	0.54535	0.54434	-0.00101	354
Micrura spp.	43030205SPP	3.66440	4.20976	0.54536	0.54434	-0.00102	355
	8406030501	3.68374	4.22910	0.54536	0.54434	-0.00102	356
Laonome kroeyeri	5001701401	3.68215	4.22752	0.54537	0.54434	-0.00103	357
Cyanophthalma cordiceps	4306060216	3.68334	4.22876	0.54543	0.54434	-0.00109	358
Thracia conradi	5520080209	3.67998	4.22541	0.54543	0.54434	-0.00109	359

Species	**Species code**	**Baseline H′[3]**	**Exceedance H′[4]**	**Difference_ Sp[5]**	**Difference_ All[6]**	**Influence**	**Influence rank**
Gattyana amondseni	5001020601	3.68212	4.22755	0.54543	0.54434	-0.00109	360
Edwardsia elegans	3759010101	3.68090	4.22635	0.54544	0.54434	-0.00110	361
Gattyana cirrosa	5001020603	3.68338	4.22884	0.54546	0.54434	-0.00112	362
Sphaerodoridium sp. A	50012604SP01	3.68200	4.22752	0.54552	0.54434	-0.00118	363
Phoronis muelleri	7700010207	3.66643	4.21199	0.54556	0.54434	-0.00122	364
Scoletoma fragilis	5001310102	3.68176	4.22736	0.54559	0.54434	-0.00125	365
Syrrhoe sp. 1	61695003SP01	3.68305	4.22871	0.54566	0.54434	-0.00132	366
Sphaerosyllis brevifrons	50012308BRE	3.68198	4.22765	0.54567	0.54434	-0.00133	367
Acanthohaustorius millsi	6169220602	3.68185	4.22754	0.54569	0.54434	-0.00135	368
Petalosarsia declivis	6154060101	3.68065	4.22638	0.54573	0.54434	-0.00139	369
Aphelochaeta cf. monilaris	5001500301CF	3.68318	4.22894	0.54577	0.54434	-0.00143	370
Mya arenaria	5517010201	3.67994	4.22584	0.54590	0.54434	-0.00156	371
Anobothrus gracilis	5001670701	3.68213	4.22809	0.54595	0.54434	-0.00161	372
Adelodrilus anisosetosus	5009021001	3.68216	4.22828	0.54612	0.54434	-0.00178	373
Argissa hamatipes	6169070101	3.67548	4.22178	0.54630	0.54434	-0.00196	374
Pygospio elegans	5001431302	3.68276	4.22910	0.54634	0.54434	-0.00200	375
Clymenura sp. A	50016312SP01	3.68221	4.22856	0.54635	0.54434	-0.00201	376
Scoletoma hebes	5001310140	3.67182	4.21824	0.54643	0.54434	-0.00209	377
Edotia montosa	6162020701	3.67021	4.21690	0.54669	0.54434	-0.00235	378
Scoloplos armiger	5001400301	3.67852	4.22525	0.54673	0.54434	-0.00239	379
Aglaophamus circinata	5001250304	3.66910	4.21597	0.54687	0.54434	-0.00253	380
Politolana polita	6161011203	3.67830	4.22537	0.54707	0.54434	-0.00273	381
Ericthonius fasciatus	6169150308	3.67878	4.22595	0.54717	0.54434	-0.00283	382
Chiridotea tuftsi	6162020503	3.67582	4.22299	0.54717	0.54434	-0.00283	383
Tubificoides intermedius	5009020903	3.67759	4.22497	0.54738	0.54434	-0.00304	384
Ampharete acutifrons	5001670208	3.67073	4.21815	0.54743	0.54434	-0.00309	385
Dentalium entale	5601010201	3.68103	4.22861	0.54758	0.54434	-0.00324	386
Crenella glandula	5507010203	3.67734	4.22538	0.54804	0.54434	-0.00370	387
Ceriantheopsis americanus	3743010201	3.67797	4.22609	0.54811	0.54434	-0.00377	388
Pseudunciola obliquua	6169150801	3.68007	4.22820	0.54813	0.54434	-0.00379	389
Ampelisca macrocephala	6169020101	3.67942	4.22769	0.54827	0.54434	-0.00393	390
Mayerella limicola	6171010302	3.68037	4.22910	0.54872	0.54434	-0.00438	391
Ptilanthura tenuis	6160010301	3.67743	4.22616	0.54872	0.54434	-0.00438	392
Echinarachnius parma	8155020101	3.67406	4.22350	0.54944	0.54434	-0.00510	393
Pleurogonium rubicundum	6163120202	3.67799	4.22756	0.54957	0.54434	-0.00523	394
Euchone elegans	5001700205	3.67866	4.22855	0.54989	0.54434	-0.00555	395
Stenopleustes inermis	6169430610	3.67622	4.22653	0.55031	0.54434	-0.00597	396
Owenia fusiformis	5001640102	3.66893	4.21965	0.55072	0.54434	-0.00638	397
Dyopedos monacanthus	6169440104	3.67743	4.22821	0.55078	0.54434	-0.00644	398
Exogone hebes	5001230707	3.67270	4.22360	0.55090	0.54434	-0.00656	399
Asabellides oculata	5001670802	3.67443	4.22621	0.55178	0.54434	-0.00744	400
Dipolydora quadrilobata	5001430408	3.67725	4.22910	0.55184	0.54434	-0.00750	401
Hiatella arctica	5517060201	3.66773	4.21983	0.55210	0.54434	-0.00776	402
Parvicardium pinnulatum	5515220601	3.65814	4.21032	0.55217	0.54434	-0.00783	403
Protomedeia fasciata	6169260301	3.67308	4.22599	0.55290	0.54434	-0.00856	404
Eteone longa	5001130205	3.66909	4.22206	0.55296	0.54434	-0.00862	405
Crenella decussata	5507010201	3.66513	4.21878	0.55365	0.54434	-0.00931	406
Maldane sarsi	5001630301	3.67342	4.22731	0.55389	0.54434	-0.00955	407
Ninoe nigripes	5001310204	3.62200	4.17613	0.55414	0.54434	-0.00980	408
Metopella angusta	6169480306	3.67251	4.22673	0.55422	0.54434	-0.00988	409
Photis pollex	6169260217	3.66720	4.22254	0.55534	0.54434	-0.01100	410
Molgula manhattensis	8406030108	3.67838	4.23930	0.56092	0.54434	-0.01658	411
Levinsenia gracilis	5001410801	3.63698	4.19801	0.56103	0.54434	-0.01669	412

Species	Species code	Baseline H′[3]	Exceedance H′[4]	Difference_ Sp[5]	Difference_ All[6]	Influence	Influence rank
Pholoe minuta	5001060101	3.66158	4.22303	0.56144	0.54434	-0.01710	413
Tharyx acutus	5001500305	3.62855	4.19034	0.56179	0.54434	-0.01745	414
Exogone verugera	5001230706	3.64201	4.20507	0.56305	0.54434	-0.01871	415
Dipolydora socialis	5001430402	3.65850	4.22400	0.56550	0.54434	-0.02116	416
Polygordius jouinae	50020501JO	3.67119	4.23934	0.56815	0.54434	-0.02381	417
Mediomastus californiensis	5001600402	3.65384	4.23542	0.58158	0.54434	-0.03724	418
Aricidea catherinae	5001410208	3.63637	4.21904	0.58267	0.54434	-0.03833	419

[1] Influence = Influence of a species on H′ or J' exceedances. Higher Influence values indicate that the species contributed more to exceedances - values above zero indicate that the species contributed to exceedances; values below zero indicate that the species did not contribute to exceedances. Influence values based on removal of a single species from the project data set.

[2] Rank Influence = Rank order of species from highest (1) to lowest (419) influence for 419 species.

[3] Baseline H′ = Mean H′at Nearfield stations during baseline years (1992 to 2000) with species excluded.

[4] Exceedance H′ = Mean H′at Nearfield stations during years with threshold exceedances (2010 to 2013) with species excluded.

[5] Difference_Sp = Difference between Exceedance H′ and Baseline H′ for the data set with species excluded (i.e., Difference = Exceedance H′ - Baseline H′).

[6] Difference_All = Difference between mean H′ in exceedance and baseline periods for the data set with all species.

Appendix Table 2. Influence[1] and Rank Influence[2] of each species on J' exceedances. Data are from the 11 nearfield stations in Massachusetts Bay during the baseline period (1992 to 2000) and the years with exceedances (2010 to 2013).

Species	Species code	Baseline J'	Exceedance J'	Difference _Sp	Difference _All	Influence	Influence rank
Prionospio steenstrupi	5001430506	0.650829	0.703553	0.052724	0.084517	0.031793	1
Spio limicola	5001430707	0.627253	0.704249	0.076997	0.084517	0.007520	2
Crassicorophium crassicorne	6169150203	0.630885	0.710286	0.079401	0.084517	0.005116	3
Monticellina cf. *dorsobranchialis*	5001500310CF	0.621438	0.701048	0.079611	0.084517	0.004906	4
Limnodriloides medioporus	5009020701	0.620877	0.703740	0.082863	0.084517	0.001654	5
Aricidea quadrilobata	5001410217	0.622119	0.705024	0.082905	0.084517	0.001612	6
Scalibregma inflatum	5001570101	0.622366	0.705380	0.083014	0.084517	0.001503	7
Parougia caeca	50013614CAEC	0.620332	0.703363	0.083031	0.084517	0.001486	8
Nephtys incisa	5001250115	0.622045	0.705235	0.083190	0.084517	0.001327	9
Apistobranchus typicus	5001420103	0.622209	0.705585	0.083376	0.084517	0.001141	10
Euchone incolor	5001700204	0.617455	0.700964	0.083509	0.084517	0.001008	11
Spiophanes bombyx	5001431001	0.620919	0.704545	0.083626	0.084517	0.000891	12
Periploma papyratium	5520070104	0.622302	0.705946	0.083644	0.084517	0.000873	13
Ensis directus	5515290301	0.622168	0.705881	0.083712	0.084517	0.000805	14
Trochochaeta multisetosa	5001450203	0.622217	0.706063	0.083846	0.084517	0.000671	15
Nucula delphinodonta	5502020206	0.619621	0.703490	0.083869	0.084517	0.000648	16
Nemertea sp. 12	43SP12	0.621592	0.705532	0.083940	0.084517	0.000577	17
Ampharete lindstroemi	5001670213	0.622279	0.706233	0.083954	0.084517	0.000563	18
Thyasira gouldi	5515020325	0.622599	0.706570	0.083971	0.084517	0.000546	19
Phyllodoce mucosa	5001130104	0.620046	0.704022	0.083976	0.084517	0.000541	20
Cnemidocarpa mollis	8406010303	0.622278	0.706264	0.083986	0.084517	0.000531	21
Tanaissus psammophilus	6157020402	0.621723	0.705727	0.084004	0.084517	0.000513	22
Diastylis sculpta	6154050127	0.622429	0.706455	0.084027	0.084517	0.000490	23
Ampharete finmarchica	5001670214	0.622214	0.706290	0.084076	0.084517	0.000441	24
Unciola inermis	6169150702	0.621499	0.705598	0.084099	0.084517	0.000418	25
Aphelochaeta cf. *marioni*	5001500307CF	0.618956	0.703124	0.084168	0.084517	0.000349	26
Galathowenia oculata	5001640402	0.622668	0.706864	0.084196	0.084517	0.000321	27
Eudorellopsis deformis	6154040304	0.622314	0.706525	0.084210	0.084517	0.000307	28
Flabelligera affinis	5001540202	0.622373	0.706591	0.084218	0.084517	0.000299	29
Spio filicornis	5001430701	0.622435	0.706662	0.084227	0.084517	0.000290	30
Chaetozone anasimus	50015004AN	0.621479	0.705711	0.084232	0.084517	0.000285	31
Pythinella cuneata	5515090301	0.622254	0.706494	0.084239	0.084517	0.000278	32
Chone duneri	5001700104	0.622553	0.706802	0.084249	0.084517	0.000268	33
Spio thulini	5001430709	0.622217	0.706491	0.084273	0.084517	0.000244	34
Phoxocephalus holbolli	6169420702	0.622121	0.706398	0.084277	0.084517	0.000240	35
Nereis grayi	5001240409	0.622525	0.706819	0.084294	0.084517	0.000223	36
Heteromastus filiformis	5001600201	0.622474	0.706779	0.084304	0.084517	0.000213	37
Leptocheirus pinguis	6169060702	0.622220	0.706546	0.084326	0.084517	0.000191	38
Tubificoides intermedius	5009020903	0.622294	0.706620	0.084326	0.084517	0.000191	39
Laonice cirrata	5001430201	0.622507	0.706835	0.084328	0.084517	0.000189	40
Leitoscoloplos acutus	5001400305	0.616839	0.701168	0.084329	0.084517	0.000188	41
Syrrhoe sp. 1	61695003SP01	0.622429	0.706761	0.084332	0.084517	0.000185	42
Enipo torelli	5001022103	0.622571	0.706906	0.084334	0.084517	0.000183	43
Eusyllis sp. A	50012302SP01	0.622368	0.706703	0.084335	0.084517	0.000182	44
Periploma leanum	5520070103	0.622282	0.706626	0.084343	0.084517	0.000174	45
Cancer spp.	61880301SPP	0.622528	0.706873	0.084345	0.084517	0.000172	46
Pleurogonium inerme	6163120204	0.622449	0.706803	0.084354	0.084517	0.000163	47
Anonyx liljeborgi	6169340303	0.622514	0.706868	0.084355	0.084517	0.000162	48
Hippomedon propinquus	6169341405	0.622344	0.706701	0.084357	0.084517	0.000160	49
Chaetozone cf. *vivipara*	50015004VIVICF	0.622272	0.706634	0.084362	0.084517	0.000155	50
Paradoneis lyra	5001411201	0.622218	0.706581	0.084363	0.084517	0.000154	51
Haploops fundiensis	6169020306	0.622407	0.706779	0.084372	0.084517	0.000145	52
Phyllodoce maculata	5001130106	0.622338	0.706718	0.084380	0.084517	0.000137	53
Arctica islandica	5515390101	0.621778	0.706161	0.084383	0.084517	0.000134	54

Species	Species code	Baseline J'	Exceedance J'	Difference _Sp	Difference _All	Influence	Influence rank
Ilyanassa trivittata	5105080202	0.622454	0.706840	0.084386	0.084517	0.000131	55
Arcteobia anticostiensis	5001020301	0.622514	0.706901	0.084388	0.084517	0.000129	56
Rhodine loveni	5001631003	0.622369	0.706759	0.084390	0.084517	0.000127	57
Eusyllis sp. 2	50012302SP02	0.622262	0.706653	0.084391	0.084517	0.000126	58
Polycirrus phosphoreus	5001680807	0.622298	0.706693	0.084394	0.084517	0.000123	59
Sphaerodoropsis sp. 1	50012602SP01	0.622359	0.706755	0.084397	0.084517	0.000120	60
Campylaspis rubicunda	6154070103	0.622584	0.706990	0.084406	0.084517	0.000111	61
Laonome kroeyeri	5001701401	0.622668	0.707080	0.084412	0.084517	0.000105	62
Ophiura robusta	8127010611	0.622367	0.706779	0.084412	0.084517	0.000105	63
Pherusa plumosa	5001540302	0.622262	0.706678	0.084416	0.084517	0.000101	64
Nephtys caeca	5001250103	0.622384	0.706802	0.084418	0.084517	0.000099	65
Monticellina baptisteae	50015003BAPT	0.615896	0.700315	0.084419	0.084517	0.000098	66
Diastylis quadrispinosa	6154050126	0.622512	0.706935	0.084423	0.084517	0.000094	67
Nemertea sp. 17	43SP17	0.622262	0.706685	0.084423	0.084517	0.000094	68
Turbellaria sp. 12	3901SP12	0.622317	0.706742	0.084425	0.084517	0.000092	69
Onoba pelagica	5103202113	0.622208	0.706646	0.084439	0.084517	0.000078	70
Musculus niger	5507010401	0.622347	0.706789	0.084441	0.084517	0.000076	71
Westwoodilla megalops	6169371504	0.622382	0.706829	0.084447	0.084517	0.000070	72
Deflexilodes tuberculatus	6169370815	0.622335	0.706784	0.084448	0.084517	0.000069	73
Edwardsia elegans	3759010101	0.622644	0.707092	0.084449	0.084517	0.000068	74
Caulleriella venefica	50015002VE	0.622275	0.706725	0.084450	0.084517	0.000067	75
Gattyana cirrosa	5001020603	0.622437	0.706887	0.084451	0.084517	0.000066	76
Phyllodoce arenae	5001131410	0.622341	0.706793	0.084452	0.084517	0.000065	77
Orchomenella minuta	6169345201	0.622441	0.706894	0.084453	0.084517	0.000064	78
Glycera capitata	5001270101	0.622321	0.706779	0.084458	0.084517	0.000059	79
Grania longiducta	5009010301LONG	0.622221	0.706679	0.084458	0.084517	0.000059	80
Diastylis polita	6154050121	0.622319	0.706779	0.084460	0.084517	0.000057	81
Placopecten magellanicus	5509050901	0.622317	0.706779	0.084462	0.084517	0.000055	82
Euclymeninae sp. 1	500163EUSP01	0.622317	0.706779	0.084462	0.084517	0.000055	83
Dipolydora caulleryi	5001430404	0.622314	0.706779	0.084465	0.084517	0.000052	84
Pagurus acadianus	6183060226	0.622313	0.706779	0.084466	0.084517	0.000051	85
Polycirrus eximius	5001680804	0.622291	0.706758	0.084467	0.084517	0.000050	86
Nephtys ciliata	5001250102	0.622339	0.706806	0.084467	0.084517	0.000050	87
Naididae sp. 5	500903SP05	0.622264	0.706734	0.084470	0.084517	0.000047	88
Ophryotrocha cf. labronica	5001360402CF	0.622309	0.706779	0.084470	0.084517	0.000047	89
Spiophanes kroeyeri	5001431002	0.622346	0.706816	0.084470	0.084517	0.000047	90
Polydora sp. 1	50014304SP01	0.622262	0.706733	0.084471	0.084517	0.000046	91
Syllis hyalina	5001230511	0.622306	0.706779	0.084473	0.084517	0.000044	92
Crangon septemspinosa	6179220103	0.622425	0.706898	0.084473	0.084517	0.000044	93
Syllides sp. 1	50012315SP01	0.622262	0.706735	0.084473	0.084517	0.000044	94
Dorvillea sociabilis	5001360108	0.622324	0.706799	0.084475	0.084517	0.000042	95
Lamprops quadriplicata	6154010105	0.622387	0.706863	0.084476	0.084517	0.000041	96
Harmothoe extenuata	5001020803	0.622294	0.706770	0.084476	0.084517	0.000041	97
Neanthes virens	5001240302	0.622302	0.706779	0.084476	0.084517	0.000041	98
Cyanophthalma cordiceps	4306060216	0.622395	0.706872	0.084477	0.084517	0.000040	99
Nephtys discors	5001250108	0.622301	0.706779	0.084478	0.084517	0.000039	100
Dulichia tuberculata	6169440110	0.622320	0.706798	0.084479	0.084517	0.000038	101
Lacuna vincta	5103090305	0.622300	0.706779	0.084479	0.084517	0.000038	102
Ameroculodes edwardsi	6169370820	0.622544	0.707024	0.084479	0.084517	0.000038	103
Drilonereis magna	5001330105	0.622299	0.706779	0.084480	0.084517	0.000037	104
Marionina welchi	5009010201	0.621886	0.706366	0.084480	0.084517	0.000037	105
Harmothoe imbricata	5001020806	0.622317	0.706799	0.084483	0.084517	0.000034	106
Paranaitis speciosa	5001130801	0.622356	0.706839	0.084484	0.084517	0.000033	107
Monocorophium acherusicum	6169150201	0.622295	0.706779	0.084484	0.084517	0.000033	108
Nereis zonata	5001240406	0.622293	0.706779	0.084486	0.084517	0.000031	109
Polycirrus medusa	5001680802	0.622330	0.706817	0.084487	0.084517	0.000030	110
Diaphana minuta	5110090101	0.622397	0.706884	0.084487	0.084517	0.000030	111
Colus parvus	5105050335	0.622292	0.706779	0.084487	0.084517	0.000030	112

Species	**Species code**	**Baseline J'**	**Exceedance J'**	**Difference _Sp**	**Difference _All**	**Influence**	**Influence rank**
Euphysa aurata	3703031201	0.622264	0.706752	0.084488	0.084517	0.000029	113
Astarte borealis	5515190101	0.622290	0.706779	0.084489	0.084517	0.000028	114
Pleusymtes glaber	6169430503	0.622288	0.706779	0.084491	0.084517	0.000026	115
Tubulanus pellucidus	4302010104	0.622262	0.706752	0.084491	0.084517	0.000026	116
Phyllodoce groenlandica	5001130102	0.622288	0.706779	0.084491	0.084517	0.000026	117
Melitidae sp. 1	616921MESP01	0.622288	0.706779	0.084491	0.084517	0.000026	118
Nephasoma diaphanes	7200020305	0.622287	0.706779	0.084491	0.084517	0.000026	119
Jassa marmorata	6169270303	0.622287	0.706779	0.084492	0.084517	0.000025	120
Turbellaria sp. 13	3901SP13	0.622286	0.706779	0.084493	0.084517	0.000024	121
Chaetoderma nitidulum canadense	5402010102	0.622286	0.706779	0.084493	0.084517	0.000024	122
Ancistrosyllis groenlandica	5001220104	0.622286	0.706779	0.084493	0.084517	0.000024	123
Halcampa duodecimcirrata	3759040102	0.622285	0.706779	0.084494	0.084517	0.000023	124
Scoloplos acmeceps	5001400311	0.622314	0.706808	0.084494	0.084517	0.000023	125
Megamoera dentata	616921MEGDENT	0.622268	0.706762	0.084494	0.084517	0.000023	126
Cylichna gouldi	5110040206	0.622284	0.706779	0.084495	0.084517	0.000022	127
Cirratulus cirratus	5001500101	0.622284	0.706779	0.084495	0.084517	0.000022	128
Oenopota pyrimidalis	5106020410	0.622283	0.706779	0.084496	0.084517	0.000021	129
Euspira heros	5103761201	0.622292	0.706788	0.084496	0.084517	0.000021	130
Pleustes panoplus	6169430405	0.622282	0.706779	0.084496	0.084517	0.000021	131
Oenopota harpularia	5106020409	0.622282	0.706779	0.084497	0.084517	0.000020	132
Amphiporus cruentatus	4306050115	0.622337	0.706833	0.084497	0.084517	0.000020	133
Terebellides atlantis	5001690105	0.622353	0.706850	0.084497	0.084517	0.000020	134
Axius serratus	6183020301	0.622282	0.706779	0.084497	0.084517	0.000020	135
Lanassa venusta venusta	5.00168E+11	0.622319	0.706816	0.084497	0.084517	0.000020	136
Typosyllis cornuta	5001230517	0.622281	0.706779	0.084498	0.084517	0.000019	137
Microphthalmus pettiboneae	50012102PETT	0.622329	0.706827	0.084498	0.084517	0.000019	138
Parapleustes gracilis	6169430305	0.622280	0.706779	0.084499	0.084517	0.000018	139
Hippomedon serratus	6169341408	0.622174	0.706673	0.084499	0.084517	0.000018	140
Monocorophium insidiosum	6169150211	0.622279	0.706779	0.084500	0.084517	0.000017	141
Cossura longocirrata	5001520101	0.622431	0.706931	0.084500	0.084517	0.000017	142
Pectinaria gouldi	5001660302	0.622279	0.706779	0.084500	0.084517	0.000017	143
Drilonereis filum	5001330101	0.622278	0.706779	0.084501	0.084517	0.000016	144
Praxillella affinis	5001630903	0.622278	0.706779	0.084501	0.084517	0.000016	145
Ctenodiscus crispatus	8107020101	0.622277	0.706779	0.084502	0.084517	0.000015	146
Oenopota incisula	5106020426	0.622343	0.706846	0.084503	0.084517	0.000014	147
Proboloides holmesi	6169480801	0.622276	0.706779	0.084503	0.084517	0.000014	148
Proceraea cornuta	5001230101	0.622275	0.706779	0.084504	0.084517	0.000013	149
Travisia carnea	5001580404	0.622275	0.706779	0.084504	0.084517	0.000013	150
Scolelepis texana	5001432006	0.622275	0.706779	0.084504	0.084517	0.000013	151
Acanthohaustorius spinosus	6169220603	0.622267	0.706771	0.084504	0.084517	0.000013	152
Macoma balthica	5515310116	0.622274	0.706779	0.084505	0.084517	0.000012	153
Odostomia sulcosa	5108010133	0.622274	0.706779	0.084505	0.084517	0.000012	154
Propebela exarata	5106020603	0.622274	0.706779	0.084505	0.084517	0.000012	155
Gitanopsis arctica	6169030403	0.622274	0.706779	0.084505	0.084517	0.000012	156
Anobothrus gracilis	5001670701	0.622457	0.706962	0.084505	0.084517	0.000012	157
Ampelisca abdita	6169020108	0.622303	0.706808	0.084505	0.084517	0.000012	158
Eulalia bilineata	5001130304	0.622273	0.706779	0.084505	0.084517	0.000012	159
Eumida sanguinea	5001131101	0.622273	0.706779	0.084505	0.084517	0.000012	160
Musculus discors	5507010402	0.622273	0.706779	0.084505	0.084517	0.000012	161
Boonea impressa	5108011402	0.622273	0.706779	0.084506	0.084517	0.000011	162
Ophiura sarsi	8127010610	0.622273	0.706779	0.084506	0.084517	0.000011	163
Austrolaenilla mollis	5001022401	0.622273	0.706779	0.084506	0.084517	0.000011	164
Clymenura sp. A	50016312SP01	0.622322	0.706829	0.084506	0.084517	0.000011	165
Paramphinome jeffreysii	5001100401	0.622272	0.706779	0.084507	0.084517	0.000010	166
Argissa hamatipes	6169070101	0.622412	0.706919	0.084507	0.084517	0.000010	167
Propebela turricula	5106020601	0.622271	0.706779	0.084508	0.084517	0.000009	168
Parapionosyllis longicirrata	5001231701	0.622271	0.706779	0.084508	0.084517	0.000009	169
Euspira immaculata	5103760408	0.622271	0.706779	0.084508	0.084517	0.000009	170

Species	Species code	Baseline J'	Exceedance J'	Difference _Sp	Difference _All	Influence	Influence rank
Eteone flava	5001130204	0.622270	0.706779	0.084509	0.084517	0.000008	171
Paradoneis armatus	5001411204	0.622270	0.706779	0.084509	0.084517	0.000008	172
Gammarellus angulosus	6169210602	0.622269	0.706779	0.084510	0.084517	0.000007	173
Corambe obscura	5131070201	0.622269	0.706779	0.084510	0.084517	0.000007	174
Paraonis fulgens	5001410302	0.622269	0.706779	0.084510	0.084517	0.000007	175
Exogone longicirris	5001230711	0.622411	0.706921	0.084510	0.084517	0.000007	176
Proclea graffii	5001681702	0.622293	0.706804	0.084511	0.084517	0.000006	177
Chone infundibuliformis	5001700102	0.622268	0.706779	0.084511	0.084517	0.000006	178
Paradulichia typica	6169440302	0.622345	0.706856	0.084511	0.084517	0.000006	179
Ischyrocerus anguipes	6169270202	0.622325	0.706836	0.084511	0.084517	0.000006	180
Ampelisca vadorum	6169020109	0.622268	0.706779	0.084511	0.084517	0.000006	181
Siliqua costata	5515290105	0.622267	0.706779	0.084511	0.084517	0.000006	182
Monoculodes packardi	6169370810	0.622267	0.706779	0.084512	0.084517	0.000005	183
Pleurogonium spinosissimum	6163120201	0.622315	0.706827	0.084512	0.084517	0.000005	184
Pandora glacialis	5520020101	0.622267	0.706779	0.084512	0.084517	0.000005	185
Psammodrilus balanoglossoides	5001480101	0.622258	0.706771	0.084512	0.084517	0.000005	186
Pandora gouldiana	5520020107	0.622266	0.706779	0.084513	0.084517	0.000004	187
Eteone heteropoda	5001130207	0.622266	0.706779	0.084513	0.084517	0.000004	188
Megayoldia thraciaeformis	5502040507	0.622266	0.706779	0.084513	0.084517	0.000004	189
Monocorophium tuberculatum	6169150207	0.622265	0.706779	0.084513	0.084517	0.000004	190
Ophryotrocha sp. 1	50013604SP01	0.622264	0.706779	0.084515	0.084517	0.000002	191
Molpadia oolitica	8179010102	0.622263	0.706779	0.084516	0.084517	0.000001	192
Microclymene sp.1	50016317SP1	0.622262	0.706779	0.084517	0.084517	0.000000	193
Nuculoma tenuis	5502020201	0.622321	0.706838	0.084517	0.084517	0.000000	194
Acaulis primarius	3703270101	0.622262	0.706779	0.084517	0.084517	0.000000	195
Aphrodita hastata	5001010104	0.622262	0.706779	0.084517	0.084517	0.000000	196
Gattyana nutti	5001020607	0.622262	0.706779	0.084517	0.084517	0.000000	197
Bylgides elegans	5001025501	0.622262	0.706779	0.084517	0.084517	0.000000	198
Bylgides sarsi	50010255SARS	0.622262	0.706779	0.084517	0.084517	0.000000	199
Dysponetus pygmaeus	5001080201	0.622262	0.706779	0.084517	0.084517	0.000000	200
Eteone trilineata	5001130209	0.622262	0.706779	0.084517	0.084517	0.000000	201
Typosyllis alternata	5001230501	0.622262	0.706779	0.084517	0.084517	0.000000	202
Exogone sp. A	50012307SP01	0.622262	0.706779	0.084517	0.084517	0.000000	203
Sphaerosyllis sp. 1	50012308SP01	0.622262	0.706779	0.084517	0.084517	0.000000	204
Streptosyllis cf. *pettiboneae*	5001231605CF	0.622262	0.706779	0.084517	0.084517	0.000000	205
Websterinereis tridentata	5001241001	0.622262	0.706779	0.084517	0.084517	0.000000	206
Sphaerodoropsis cf. *longipalpa*	50012602LONGCF	0.622262	0.706779	0.084517	0.084517	0.000000	207
Glycera dibranchiata	5001270105	0.622262	0.706779	0.084517	0.084517	0.000000	208
Nothria conchylega	5001290301	0.622262	0.706779	0.084517	0.084517	0.000000	209
Nothria sp. 1	50012903SP01	0.622262	0.706779	0.084517	0.084517	0.000000	210
Lumbrinerides acuta	5001310301	0.622262	0.706779	0.084517	0.084517	0.000000	211
Abyssoninoe winsnesae	500131WINS	0.622262	0.706779	0.084517	0.084517	0.000000	212
Drilonereis longa	5001330103	0.622262	0.706779	0.084517	0.084517	0.000000	213
Ophryotrocha sp. 2	50013604SP02	0.622262	0.706779	0.084517	0.084517	0.000000	214
Ougia tenuidentis	50013612TENU	0.622262	0.706779	0.084517	0.084517	0.000000	215
Spio setosa	5001430704	0.622262	0.706779	0.084517	0.084517	0.000000	216
Malacoceros sp. 1	50014314SP01	0.622262	0.706779	0.084517	0.084517	0.000000	217
Streblospio benedicti	5001431801	0.622262	0.706779	0.084517	0.084517	0.000000	218
Scolelepis foliosa	5001432007	0.622262	0.706779	0.084517	0.084517	0.000000	219
Trochochaeta carica	5001450201	0.622262	0.706779	0.084517	0.084517	0.000000	220
Aphelochaeta sp. 3	50015003ASP03	0.622262	0.706779	0.084517	0.084517	0.000000	221
Brada incrustata	5001540107	0.622262	0.706779	0.084517	0.084517	0.000000	222
Capitellidae sp. 2	500160SP02	0.622262	0.706779	0.084517	0.084517	0.000000	223
Petaloproctus tenuis	5001630701	0.622262	0.706779	0.084517	0.084517	0.000000	224
Praxillura ornata	5001631803	0.622262	0.706779	0.084517	0.084517	0.000000	225
Myriochele heeri	5001640201	0.622262	0.706779	0.084517	0.084517	0.000000	226
Pectinaria hyperborea	50016603HYPE	0.622262	0.706779	0.084517	0.084517	0.000000	227
Amphicteis gunneri	5001670303	0.622262	0.706779	0.084517	0.084517	0.000000	228

Species	**Species code**	**Baseline J'**	**Exceedance J'**	**Difference _Sp**	**Difference _All**	**Influence**	**Influence rank**
Amphitrite cirrata	5001680101	0.622262	0.706779	0.084517	0.084517	0.000000	229
Nicolea zostericola	5001680602	0.622262	0.706779	0.084517	0.084517	0.000000	230
Pista cristata	5001680701	0.622262	0.706779	0.084517	0.084517	0.000000	231
Streblosoma spiralis	5001682501	0.622262	0.706779	0.084517	0.084517	0.000000	232
Trichobranchus roseus	5001690202	0.622262	0.706779	0.084517	0.084517	0.000000	233
Euchone papillosa	5001700202	0.622262	0.706779	0.084517	0.084517	0.000000	234
Myxicola infundibulum	5001700502	0.622262	0.706779	0.084517	0.084517	0.000000	235
Tubificoides sp. 2	50090209SP02	0.622262	0.706779	0.084517	0.084517	0.000000	236
Pusillina harpa	5103200127	0.622262	0.706779	0.084517	0.084517	0.000000	237
Epitonium greenlandicum	5103500102GR	0.622262	0.706779	0.084517	0.084517	0.000000	238
Couthouyella striatula	5103501201	0.622262	0.706779	0.084517	0.084517	0.000000	239
Euspira pallida	5103760402	0.622262	0.706779	0.084517	0.084517	0.000000	240
Euspira triseriata	5103761205	0.622262	0.706779	0.084517	0.084517	0.000000	241
Colus pubescens	5105050326	0.622262	0.706779	0.084517	0.084517	0.000000	242
Colus pygmaeus	5105050328	0.622262	0.706779	0.084517	0.084517	0.000000	243
Oenopota cf. *cancellatus*	5106020443CF	0.622262	0.706779	0.084517	0.084517	0.000000	244
Onchidoris bilamellata	5131050507	0.622262	0.706779	0.084517	0.084517	0.000000	245
Nucula annulata	5502020205	0.622262	0.706779	0.084517	0.084517	0.000000	246
Nuculana pernula	5502040201	0.622262	0.706779	0.084517	0.084517	0.000000	247
Nuculana messanensis	5502040220	0.622262	0.706779	0.084517	0.084517	0.000000	248
Yoldiella lucida	5502040611	0.622262	0.706779	0.084517	0.084517	0.000000	249
Solemya velum	5504010101	0.622262	0.706779	0.084517	0.084517	0.000000	250
Thyasira nr. *minutus*	55150203MICF	0.622262	0.706779	0.084517	0.084517	0.000000	251
Macoma calcarea	5515310101	0.622262	0.706779	0.084517	0.084517	0.000000	252
Cyrtodaria siliqua	5517060102	0.622262	0.706779	0.084517	0.084517	0.000000	253
Pandora nr. inflata	5520020109CF	0.622262	0.706779	0.084517	0.084517	0.000000	254
Lyonsia hyalina	5520050206	0.622262	0.706779	0.084517	0.084517	0.000000	255
Mysis mixta	6153011401	0.622262	0.706779	0.084517	0.084517	0.000000	256
Erythrops erythrophthalma	6153012301	0.622262	0.706779	0.084517	0.084517	0.000000	257
Leucon fulvus	6154040104	0.622262	0.706779	0.084517	0.084517	0.000000	258
Leucon acutirostris	6154040106	0.622262	0.706779	0.084517	0.084517	0.000000	259
Campylaspis nr. *sulcata*	61540701SUCF	0.622262	0.706779	0.084517	0.084517	0.000000	260
Pseudoleptocuma minor	6154090301	0.622262	0.706779	0.084517	0.084517	0.000000	261
Gnathia cerina	6159010111	0.622262	0.706779	0.084517	0.084517	0.000000	262
Baeonectes muticus	6163170702	0.622262	0.706779	0.084517	0.084517	0.000000	263
Joeropsis bifasciatus	61632201BIFA	0.622262	0.706779	0.084517	0.084517	0.000000	264
Byblis gaimardi	6169020202	0.622262	0.706779	0.084517	0.084517	0.000000	265
Microdeutopus anomalus	6169060402	0.622262	0.706779	0.084517	0.084517	0.000000	266
Crassicorophium bonellii	6169150202	0.622262	0.706779	0.084517	0.084517	0.000000	267
Monocorophium sextonae	6169150217	0.622262	0.706779	0.084517	0.084517	0.000000	268
Ericthonius brasiliensis	6169150302	0.622262	0.706779	0.084517	0.084517	0.000000	269
Pseudohaustorius borealis	6169221301	0.622262	0.706779	0.084517	0.084517	0.000000	270
Photis reinhardi	6169260202	0.622262	0.706779	0.084517	0.084517	0.000000	271
Anonyx sarsi	6169340314	0.622262	0.706779	0.084517	0.084517	0.000000	272
Bathymedon obtusifrons	6169370505	0.622262	0.706779	0.084517	0.084517	0.000000	273
Oedicerotidae sp. 2	616937SP02	0.622262	0.706779	0.084517	0.084517	0.000000	274
Henricia sanguinolenta	8114040111	0.622262	0.706779	0.084517	0.084517	0.000000	275
Leptasterias tenera	8117030414	0.622262	0.706779	0.084517	0.084517	0.000000	276
Ophiopholis aculeata	8129020101	0.622262	0.706779	0.084517	0.084517	0.000000	277
Havelockia scabra	8172040201	0.622262	0.706779	0.084517	0.084517	0.000000	278
Amphipholis squamatus	8129030202	0.622260	0.706779	0.084519	0.084517	-0.000002	279
Cephalothricidae sp. 1	430203SP01	0.622090	0.706613	0.084523	0.084517	-0.000006	280
Angulus agilis	5515310205	0.622262	0.706787	0.084525	0.084517	-0.000008	281
Pherusa affinis	5001540304	0.622421	0.706947	0.084526	0.084517	-0.000009	282
Priapulus caudatus	7400010101	0.622292	0.706819	0.084527	0.084517	-0.000010	283
Pectinaria granulata	5001660303	0.622336	0.706864	0.084528	0.084517	-0.000011	284
Microphthalmus nahantensis	50012102NAHA	0.622248	0.706779	0.084531	0.084517	-0.000014	285
Eudorella pusilla	6154040211	0.622429	0.706960	0.084531	0.084517	-0.000014	286

Species	Species code	Baseline J'	Exceedance J'	Difference _Sp	Difference _All	Influence	Influence rank
Ceriantheopsis americanus	3743010201	0.622747	0.707278	0.084532	0.084517	-0.000015	287
Euclymene collaris	5001631102	0.621084	0.705616	0.084532	0.084517	-0.000015	288
Scolelepis bousfieldi	5001432002	0.622276	0.706808	0.084532	0.084517	-0.000015	289
Peosidrilus coeloprostatus	5009021102	0.622175	0.706708	0.084534	0.084517	-0.000017	290
Polydora cornuta	5001430448	0.622278	0.706812	0.084534	0.084517	-0.000017	291
Mystides borealis	5001130501	0.622290	0.706825	0.084535	0.084517	-0.000018	292
Neomysis americana	6153011508	0.622271	0.706808	0.084537	0.084517	-0.000020	293
Eobrolgus spinosus	6169421901	0.622265	0.706804	0.084539	0.084517	-0.000022	294
Munna sp. 1	61631201SP01	0.622325	0.706865	0.084540	0.084517	-0.000023	295
Prionospio aluta	5001430520	0.622262	0.706802	0.084540	0.084517	-0.000023	296
Sphaerodoridium sp. A	50012604SP01	0.622434	0.706975	0.084540	0.084517	-0.000023	297
Syllides longocirratus	5001231503	0.622284	0.706824	0.084540	0.084517	-0.000023	298
Scoletoma impatiens	5001310115	0.622238	0.706779	0.084541	0.084517	-0.000024	299
Moelleria costulata	5102120202	0.622262	0.706804	0.084542	0.084517	-0.000025	300
Amphiporus bioculatus	4306050110	0.622262	0.706804	0.084542	0.084517	-0.000025	301
Turbellaria sp. 15	3901SP15	0.622262	0.706804	0.084542	0.084517	-0.000025	302
Lyonsia arenosa	5520050201	0.622269	0.706812	0.084543	0.084517	-0.000026	303
Retusa obtusa	5110130101	0.622277	0.706820	0.084543	0.084517	-0.000026	304
Aricidea cf. *minuta*	5001410220CF	0.622256	0.706799	0.084543	0.084517	-0.000026	305
Diplocirrus hirsutus	5001540402	0.622302	0.706847	0.084545	0.084517	-0.000028	306
Terebellides stroemii	5001690101	0.622280	0.706827	0.084548	0.084517	-0.000031	307
Scoloplos sp. B	50014003SP02	0.622262	0.706814	0.084552	0.084517	-0.000035	308
Diastylis cornuifer	6154050130	0.622309	0.706862	0.084553	0.084517	-0.000036	309
Erichsonella filiformis	6162020602	0.622262	0.706817	0.084555	0.084517	-0.000038	310
Chone cf. *magna*	5001700106	0.622272	0.706827	0.084555	0.084517	-0.000038	311
Leptostylis longimana	6154050404	0.622223	0.706779	0.084556	0.084517	-0.000039	312
Onoba mighelsi	5103202115	0.622257	0.706817	0.084560	0.084517	-0.000043	313
Goniada maculata	5001280202	0.622496	0.707056	0.084560	0.084517	-0.000043	314
Melinna cristata	5001670501	0.622278	0.706839	0.084561	0.084517	-0.000044	315
Spisula solidissima	5515250102	0.622280	0.706844	0.084563	0.084517	-0.000046	316
Amphiporus caecus	4306050111	0.622100	0.706664	0.084564	0.084517	-0.000047	317
Harpinia propinqua	6169420116	0.622398	0.706964	0.084566	0.084517	-0.000049	318
Ophiura sp. 2	81270106SP02	0.622271	0.706840	0.084569	0.084517	-0.000052	319
Stylochus ellipticus	3906030101	0.622262	0.706833	0.084571	0.084517	-0.000054	320
Clymenella torquata	5001630202	0.622307	0.706878	0.084571	0.084517	-0.000054	321
Cylichna alba	5110040203	0.622279	0.706850	0.084571	0.084517	-0.000054	322
Amacrodorum bipapillatum	500126AMACBIPA	0.622262	0.706833	0.084571	0.084517	-0.000054	323
Grania sp. 3	50090103SP03	0.622262	0.706836	0.084574	0.084517	-0.000057	324
Pentamera calcigera	8172060302	0.622262	0.706842	0.084580	0.084517	-0.000063	325
Polydora aggregata	5001430438	0.622195	0.706779	0.084584	0.084517	-0.000067	326
Aphelochaeta cf. *monilaris*	5001500301CF	0.622261	0.706845	0.084584	0.084517	-0.000067	327
Phascolion strombi	7200020401	0.622342	0.706927	0.084585	0.084517	-0.000068	328
Orbinia swani	5001400502	0.622287	0.706873	0.084586	0.084517	-0.000069	329
Pusillina pseudoareolata	5103202301	0.622262	0.706850	0.084588	0.084517	-0.000071	330
Cyclocardia borealis	5515170106	0.622340	0.706928	0.084588	0.084517	-0.000071	331
Sthenelais limicola	5001060303	0.622267	0.706865	0.084599	0.084517	-0.000082	332
Spiochaetopterus costarum oculatus	5001490303	0.622266	0.706865	0.084599	0.084517	-0.000082	333
Petalosarsia declivis	6154060101	0.622372	0.706972	0.084600	0.084517	-0.000083	334
Eudorella hispida	6154040208	0.622264	0.706864	0.084601	0.084517	-0.000084	335
Tubificoides apectinatus	5009020906	0.622262	0.706864	0.084602	0.084517	-0.000085	336
Sphaerosyllis erinaceus	5001230801	0.622581	0.707186	0.084605	0.084517	-0.000088	337
Casco bigelowi	6169211601	0.622406	0.707011	0.084606	0.084517	-0.000089	338
Scoletoma fragilis	5001310102	0.622619	0.707226	0.084606	0.084517	-0.000089	339
Solariella obscura	5102100402	0.622144	0.706750	0.084607	0.084517	-0.000090	340
Hypereteone foliosa	5001130211	0.622262	0.706872	0.084610	0.084517	-0.000093	341
Rhepoxynius hudsoni	6169421502	0.621910	0.706523	0.084614	0.084517	-0.000097	342
	8406030501	0.622160	0.706779	0.084618	0.084517	-0.000101	343
Prionospio cirrifera	50014305CIRR	0.622262	0.706881	0.084619	0.084517	-0.000102	344

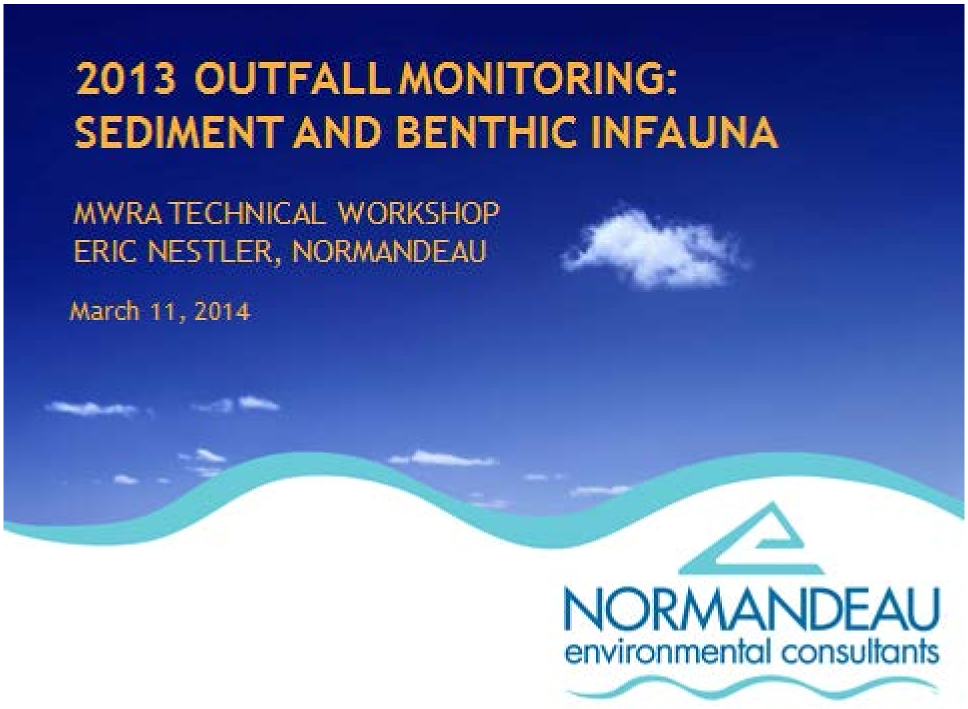
Species	Species code	Baseline J'	Exceedance J'	Difference _Sp	Difference _All	Influence	Influence rank
Tetrastemma elegans	4306060205	0.622262	0.706885	0.084624	0.084517	-0.000107	345
Sphaerosyllis brevifrons	50012308BRE	0.622193	0.706823	0.084630	0.084517	-0.000113	346
Scoloplos sp. A	50014003SP01	0.622262	0.706899	0.084637	0.084517	-0.000120	347
Axiothella catenata	5001630801	0.622294	0.706934	0.084640	0.084517	-0.000123	348
Syllides convoluta	5001231503CON	0.622291	0.706941	0.084650	0.084517	-0.000133	349
Praxillella gracilis	5001630901	0.622391	0.707048	0.084657	0.084517	-0.000140	350
Pygospio elegans	5001431302	0.622114	0.706779	0.084665	0.084517	-0.000148	351
Ampelisca macrocephala	6169020101	0.622328	0.706999	0.084671	0.084517	-0.000154	352
Adelodrilus anisosetosus	5009021001	0.622055	0.706732	0.084677	0.084517	-0.000160	353
Unciola irrorata	6169150703	0.622076	0.706757	0.084681	0.084517	-0.000164	354
Gattyana amondseni	5001020601	0.622569	0.707253	0.084684	0.084517	-0.000167	355
Philine sp. 1	51100501SP1	0.622262	0.706948	0.084687	0.084517	-0.000170	356
Astarte undata	5515190113	0.621607	0.706295	0.084688	0.084517	-0.000171	357
Acanthohaustorius millsi	6169220602	0.622015	0.706706	0.084691	0.084517	-0.000174	358
Pitar morrhuanus	5515471201	0.622509	0.707203	0.084694	0.084517	-0.000177	359
Brada villosa	5001540102	0.622328	0.707028	0.084700	0.084517	-0.000183	360
Pontogeneia inermis	6169201203	0.622269	0.706971	0.084702	0.084517	-0.000185	361
Dentalium entale	5601010201	0.622256	0.706964	0.084708	0.084517	-0.000191	362
Thracia conradi	5520080209	0.622149	0.706864	0.084715	0.084517	-0.000198	363
Turbellaria spp.	3901SPP	0.622325	0.707046	0.084721	0.084517	-0.000204	364
Deflexilodes tesselatus	6169370821	0.622423	0.707144	0.084721	0.084517	-0.000204	365
Praxillella praetermissa	5001630902	0.622310	0.707034	0.084724	0.084517	-0.000207	366
Mayerella limicola	6171010302	0.622038	0.706779	0.084740	0.084517	-0.000223	367
Nephtys cornuta	5001250104	0.622388	0.707128	0.084741	0.084517	-0.000224	368
Hartmania moorei	5001022001	0.622291	0.707035	0.084745	0.084517	-0.000228	369
Ericthonius fasciatus	6169150308	0.621893	0.706640	0.084748	0.084517	-0.000231	370
Ampharete acutifrons	5001670208	0.621142	0.705894	0.084752	0.084517	-0.000235	371
Stenopleustes inermis	6169430610	0.622337	0.707098	0.084761	0.084517	-0.000244	372
Turbellaria sp. 14	3901SP14	0.622262	0.707030	0.084768	0.084517	-0.000251	373
Cerebratulus spp.	43030202SPP	0.622470	0.707246	0.084776	0.084517	-0.000259	374
Capitella capitata complex	5001600101	0.621802	0.706590	0.084788	0.084517	-0.000271	375
Sternaspis scutata	5001590101	0.622298	0.707094	0.084796	0.084517	-0.000279	376
Edotia montosa	6162020701	0.621627	0.706429	0.084801	0.084517	-0.000284	377
Scoloplos armiger	5001400301	0.622363	0.707187	0.084825	0.084517	-0.000308	378
Micrura spp.	43030205SPP	0.620793	0.705653	0.084861	0.084517	-0.000344	379
Yoldia sapotilla	5502040513	0.622251	0.707116	0.084865	0.084517	-0.000348	380
Pleurogonium rubicundum	6163120202	0.622177	0.707055	0.084879	0.084517	-0.000362	381
Hiatella arctica	5517060201	0.621330	0.706209	0.084880	0.084517	-0.000363	382
Politolana polita	6161011203	0.621852	0.706732	0.084880	0.084517	-0.000363	383
Stereobalanus canadensis	8201010201	0.622364	0.707263	0.084898	0.084517	-0.000381	384
Mya arenaria	5517010201	0.622552	0.707458	0.084906	0.084517	-0.000389	385
Dipolydora quadrilobata	5001430408	0.621852	0.706779	0.084927	0.084517	-0.000410	386
Pseudunciola obliquua	6169150801	0.621824	0.706764	0.084941	0.084517	-0.000424	387
Crenella glandula	5507010203	0.621716	0.706666	0.084950	0.084517	-0.000433	388
Ophelina acuminata	5001580607	0.622361	0.707314	0.084953	0.084517	-0.000436	389
Dyopedos monacanthus	6169440104	0.621972	0.706929	0.084957	0.084517	-0.000440	390
Turbellaria sp. 11	3901SP11	0.622430	0.707415	0.084985	0.084517	-0.000468	391
Ptilanthura tenuis	6160010301	0.621987	0.707016	0.085029	0.084517	-0.000512	392
Euchone elegans	5001700205	0.621856	0.706894	0.085039	0.084517	-0.000522	393
Tubulanus sp. 1	43020101SP01	0.622252	0.707334	0.085082	0.084517	-0.000565	394
Chiridotea tuftsi	6162020503	0.621111	0.706207	0.085096	0.084517	-0.000579	395
Phoronis muelleri	7700010207	0.620708	0.705844	0.085136	0.084517	-0.000619	396
Echinarachnius parma	8155020101	0.621111	0.706293	0.085181	0.084517	-0.000664	397
Aglaophamus circinata	5001250304	0.620549	0.705890	0.085340	0.084517	-0.000823	398
Metopella angusta	6169480306	0.621808	0.707226	0.085418	0.084517	-0.000901	399
Asabellides oculata	5001670802	0.621589	0.707053	0.085464	0.084517	-0.000947	400
Exogone hebes	5001230707	0.622751	0.708280	0.085529	0.084517	-0.001012	401
Photis pollex	6169260217	0.621229	0.706787	0.085558	0.084517	-0.001041	402

Species	Species code	Baseline J'	Exceedance J'	Difference _Sp	Difference _All	Influence	Influence rank
Protomedeia fasciata	6169260301	0.621131	0.706737	0.085606	0.084517	-0.001089	403
Eteone longa	5001130205	0.621347	0.706981	0.085634	0.084517	-0.001117	404
Parvicardium pinnulatum	5515220601	0.619301	0.704972	0.085671	0.084517	-0.001154	405
Scoletoma hebes	5001310140	0.620784	0.706545	0.085761	0.084517	-0.001244	406
Maldane sarsi	5001630301	0.621016	0.706848	0.085832	0.084517	-0.001315	407
Crenella decussata	5507010201	0.620321	0.706223	0.085901	0.084517	-0.001384	408
Owenia fusiformis	5001640102	0.620620	0.706881	0.086261	0.084517	-0.001744	409
Ninoe nigripes	5001310204	0.613596	0.700230	0.086633	0.084517	-0.002116	410
Pholoe minuta	5001060101	0.620768	0.707469	0.086700	0.084517	-0.002183	411
Molgula manhattensis	8406030108	0.621776	0.709100	0.087324	0.084517	-0.002807	412
Dipolydora socialis	5001430402	0.619590	0.706938	0.087348	0.084517	-0.002831	413
Exogone verugera	5001230706	0.617236	0.705074	0.087839	0.084517	-0.003322	414
Tharyx acutus	5001500305	0.614995	0.702904	0.087909	0.084517	-0.003392	415
Levinsenia gracilis	5001410801	0.616050	0.704171	0.088120	0.084517	-0.003603	416
Polygordius jouinae	50020501JO	0.621298	0.710556	0.089258	0.084517	-0.004741	417
Aricidea catherinae	5001410208	0.617006	0.707417	0.090411	0.084517	-0.005894	418
Mediomastus californiensis	5001600402	0.619561	0.710766	0.091206	0.084517	-0.006689	419

[1] Influence = Influence of a species on H′ or J' exceedances. Higher Influence values indicate that the species contributed more to exceedances - values above zero indicate that the species contributed to exceedances; values below zero indicate that the species did not contribute to exceedances. Influence values based on removal of a single species from the project data set.
[2] Rank Influence = Rank order of species from highest (1) to lowest (419) influence for 419 species.
[3] Baseline J' = Mean J'at Nearfield stations during baseline years (1992 to 2000) with species excluded.
[4] Exceedance J' = Mean J'at Nearfield stations during years with threshold exceedances (2010 to 2013) with species excluded.
[5] Difference_Sp = Difference between Exceedance J' and Baseline J' for the data set with species excluded (i.e., Difference = Exceedance J' - Baseline J').
[6] Difference_All = Difference between mean J' in exceedance and baseline periods for the data set with all species.

Appendix B Annual Technical Meeting Presentations for Outfall Benthic Monitoring in 2013

Appendix B1. 2013 Outfall Monitoring: Sediment and Benthic Infauna

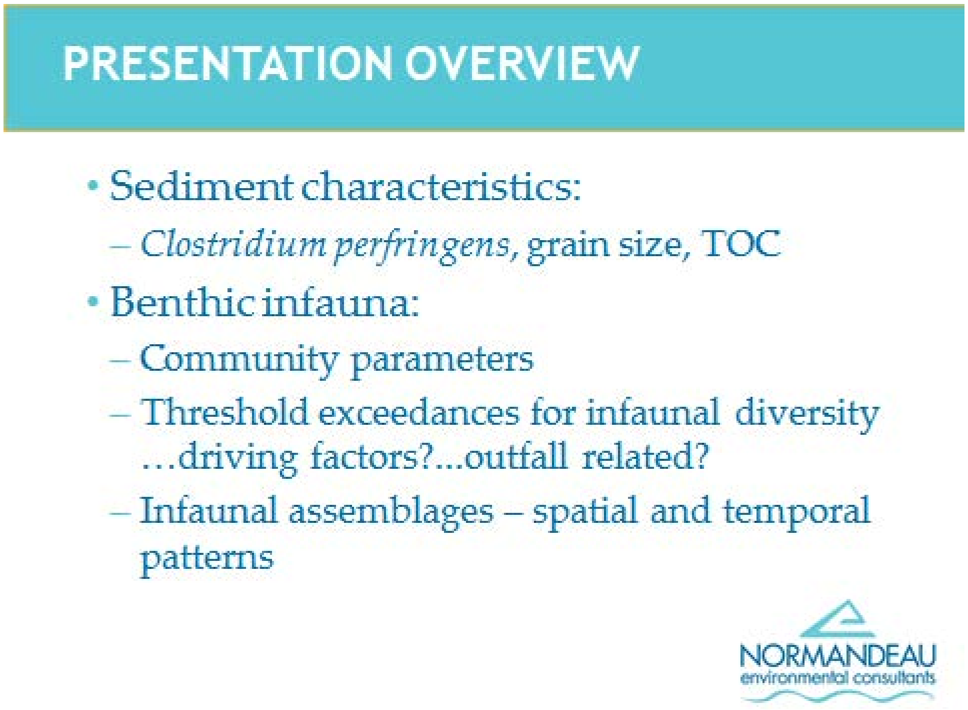


2013 OUTFALL MONITORING: SEDIMENT AND BENTHIC INFAUNA

MWRA TECHNICAL WORKSHOP
ERIC NESTLER, NORMANDEAU

March 11, 2014

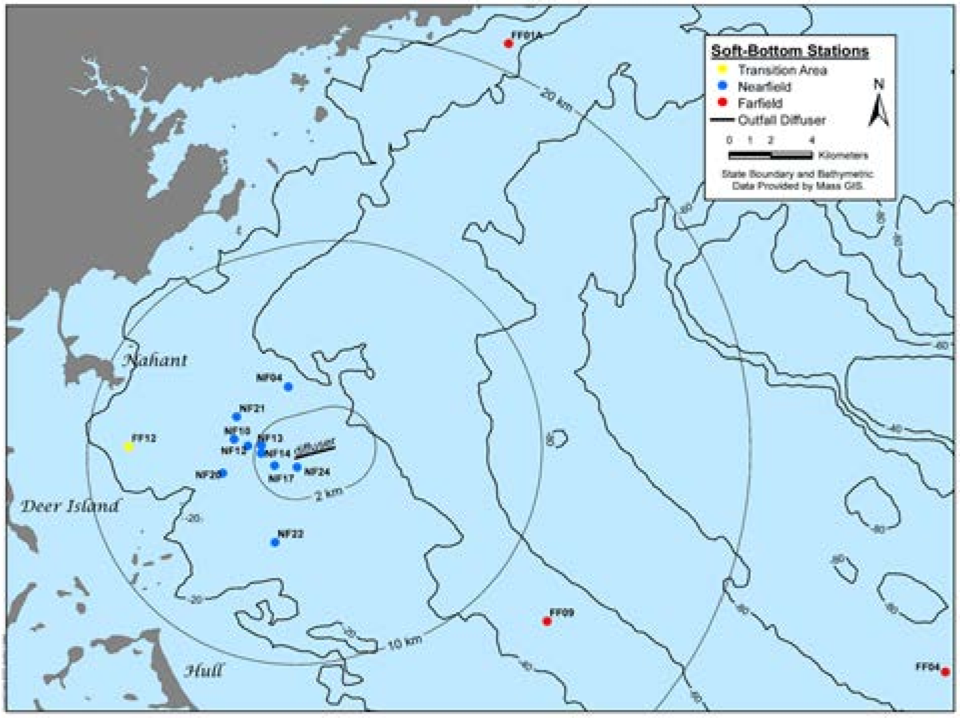
NORMANDEAU
environmental consultants

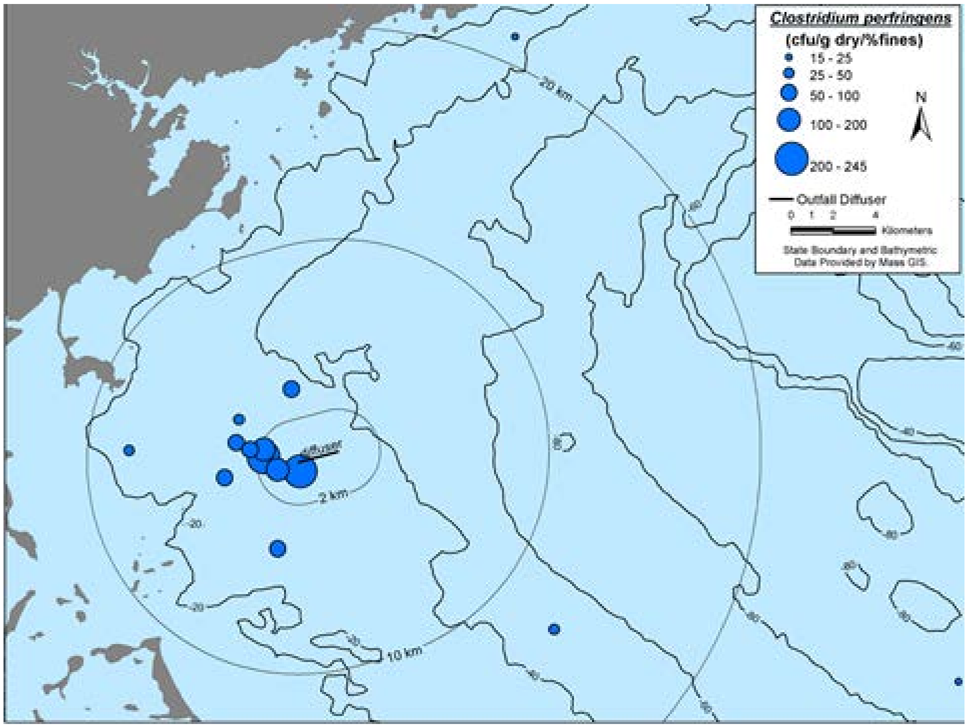


PRESENTATION OVERVIEW

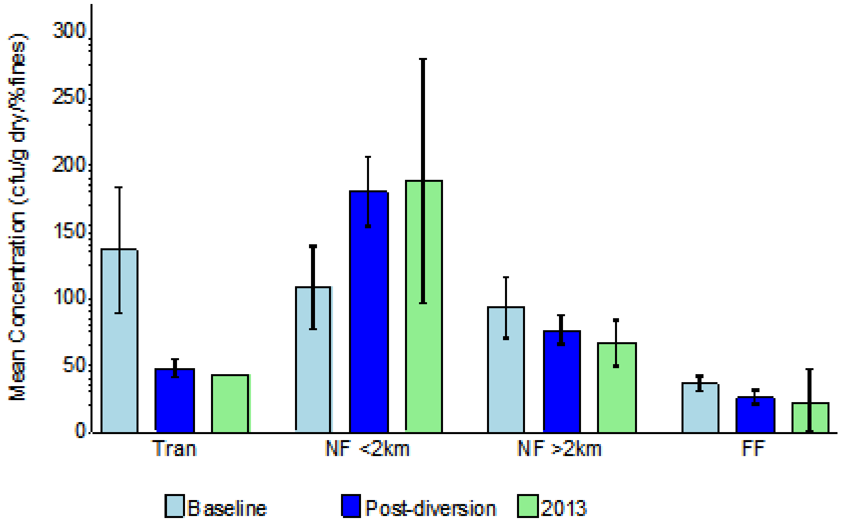
- Sediment characteristics:
  - *Clostridium perfringens*, grain size, TOC
- Benthic infauna:
  - Community parameters
  - Threshold exceedances for infaunal diversity …driving factors?...outfall related?
  - Infaunal assemblages – spatial and temporal patterns

NORMANDEAU
environmental consultants

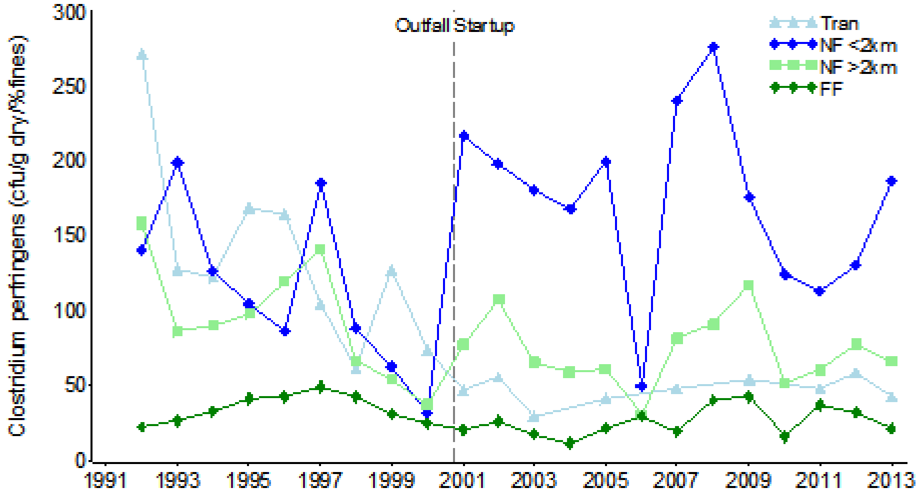

Soft-Bottom Stations
Transition Area
Nearfield
Farfield
Outfall Diffuser
0 1 2 4 Kilometers
State Boundary and Bathymetric Data Provided by Mass GIS.
N
FF01A
20 km
10 km
2 km
Nahant
Deer Island
Hull
FF12
NF04
NF21
NF10
NF12
NF13
NF14
NF17
NF24
NF20
NF22
FF09
FF04
diffuser
-20
-40
-60
-80


Clostridium perfringens
(cfu/g dry/%fines)
15 - 25
25 - 50
50 - 100
100 - 200
200 - 245
N
Outfall Diffuser
0 1 2 4 Kilometers
State Boundary and Bathymetric Data Provided by Mass GIS.
20 km
10 km
2 km
diffuser
-20
-40
-60
-80

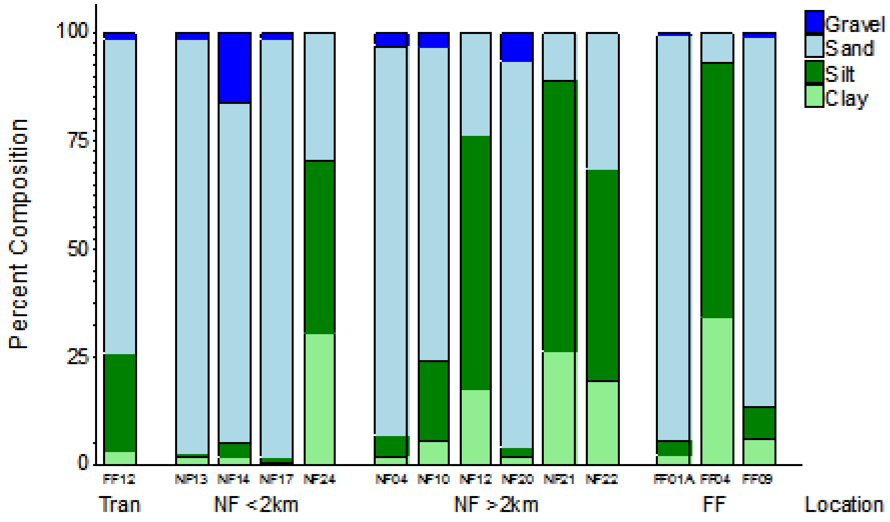
Clostridium perfringens



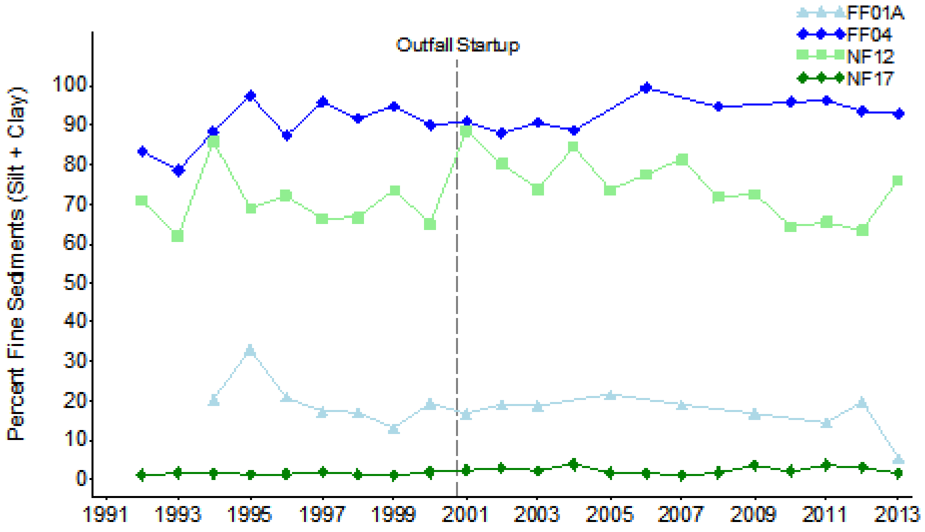
Clostridium perfringens



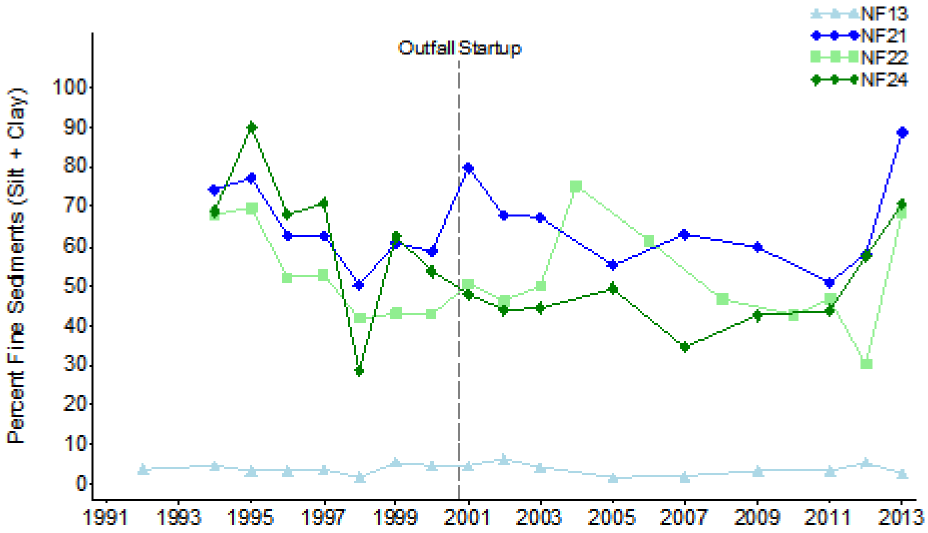
2013 SEDIMENT GRAIN SIZE



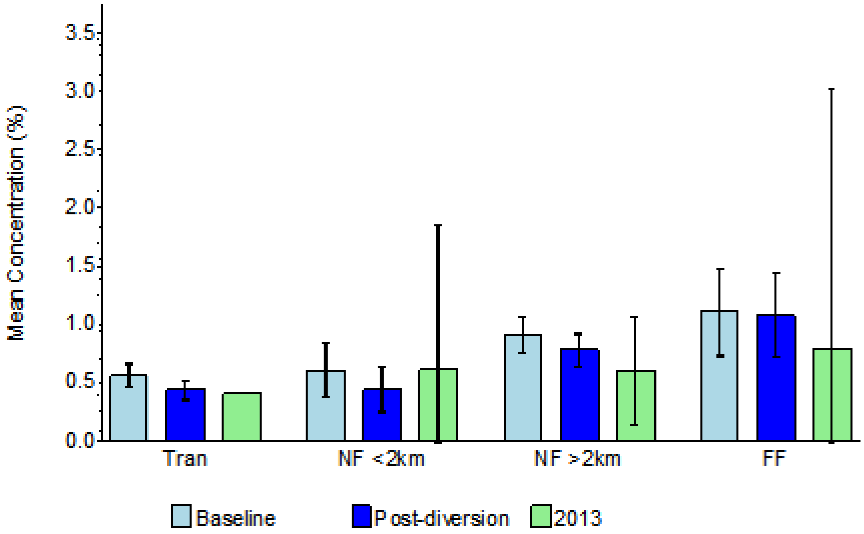
SEDIMENT GRAIN SIZE



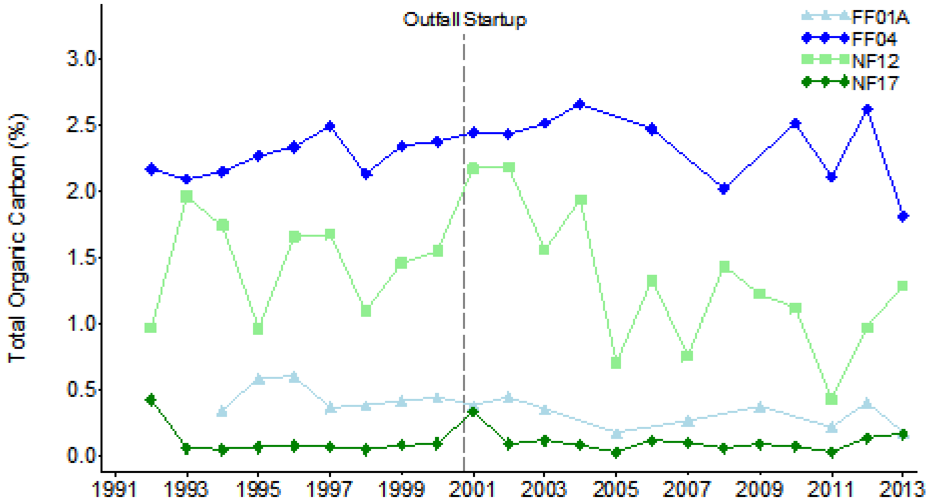
SEDIMENT GRAIN SIZE



TOTAL ORGANIC CARBON



TOTAL ORGANIC CARBON



SEDIMENT SUMMARY:

- Plume footprint indicated by *Clostridium perfringens*; only at stations closest to the outfall.
- No evidence of change in grain size from the discharge.
- No evidence of change in TOC from the discharge.

BENTHIC INFAUNA

- Summary for 14 samples in 2013:
  - 14,522 individual organisms (27,114 in 2012)
  - 207 taxa identified; 183 species and 24 higher taxonomic groups (240 taxa total, and 210 species in 2012)
  - All counts used for abundance
  - Only species-level counts used for diversity measures and multivariate analyses

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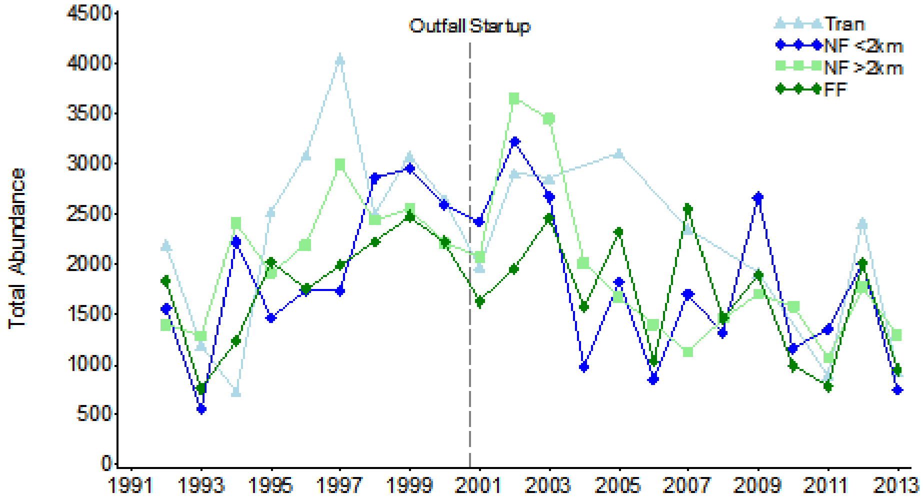
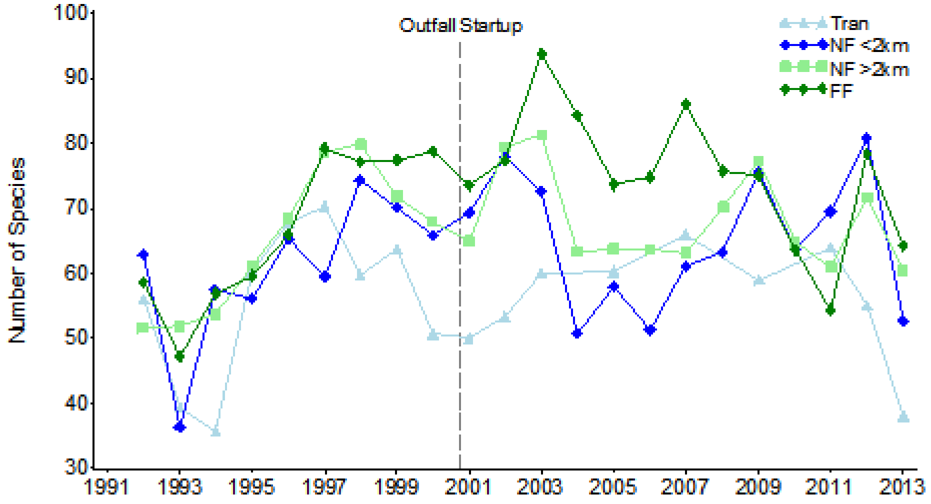
TOTAL ABUNDANCE



NUMBER OF SPECIES

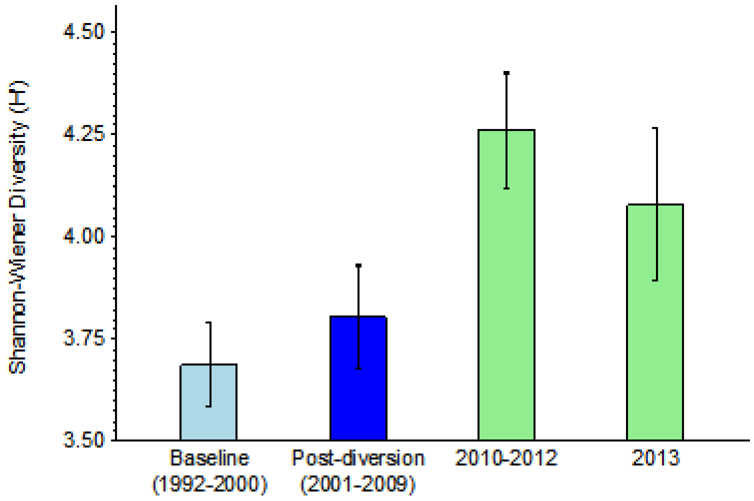


2013 THRESHOLD EXCEEDANCES

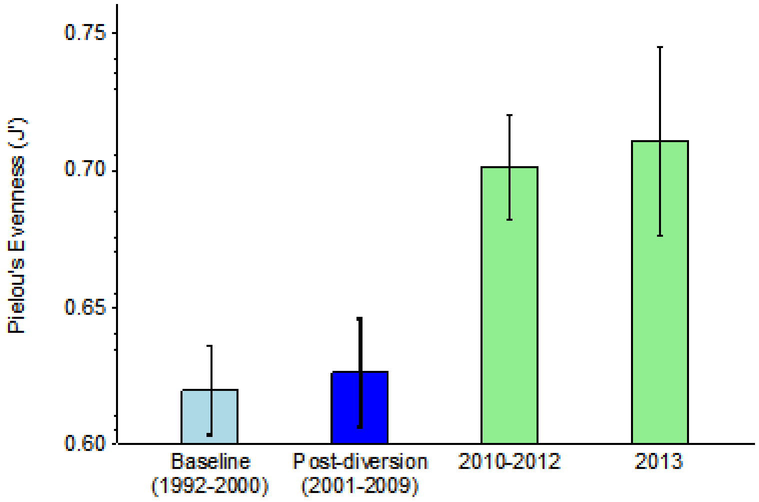
- Contingency Plan threshold exceedances for: Shannon-Wiener Diversity (H′) and Pielou's Evenness (J′).
- Threshold exceedances for H′ and J′ have been reported each year since 2010.
- No exceedances for: Total species, log-series alpha, or percent opportunists.

	Threshold range		2013 Result	
Parameter	Low	High		Exceedance?
Shannon-Weiner (H')	3.37	3.99	4.08	Yes, Caution Level
Pielou's (J')	0.57	0.67	0.71	Yes, Caution Level

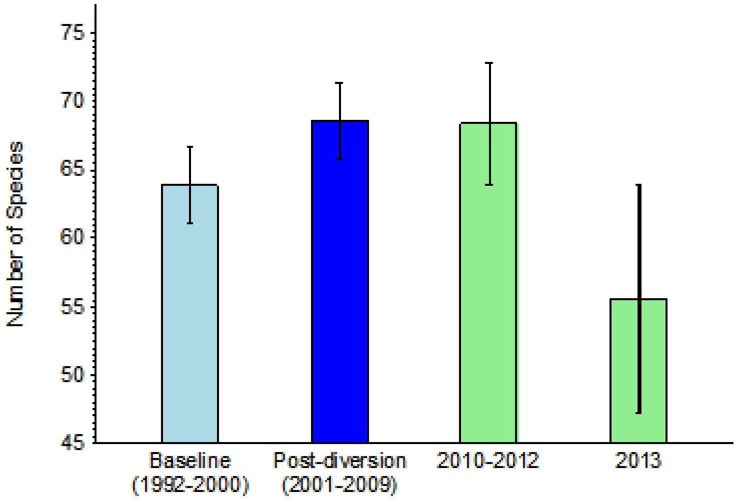
DIVERSITY (H'): NF STATIONS ONLY



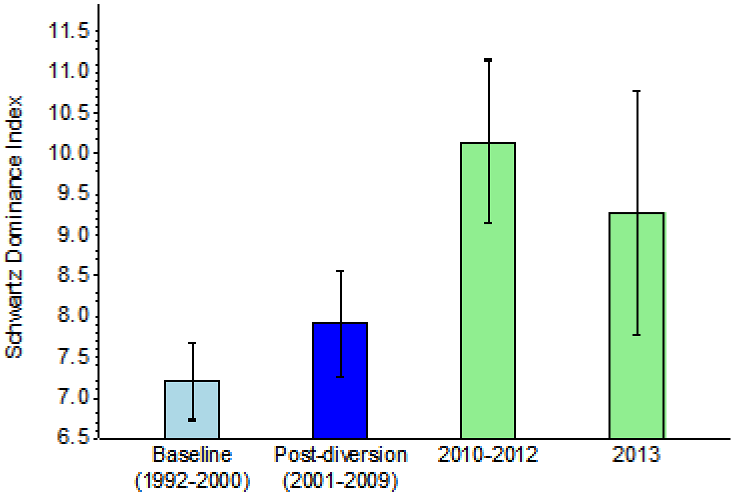
EVENNESS (J'): NF STATIONS ONLY



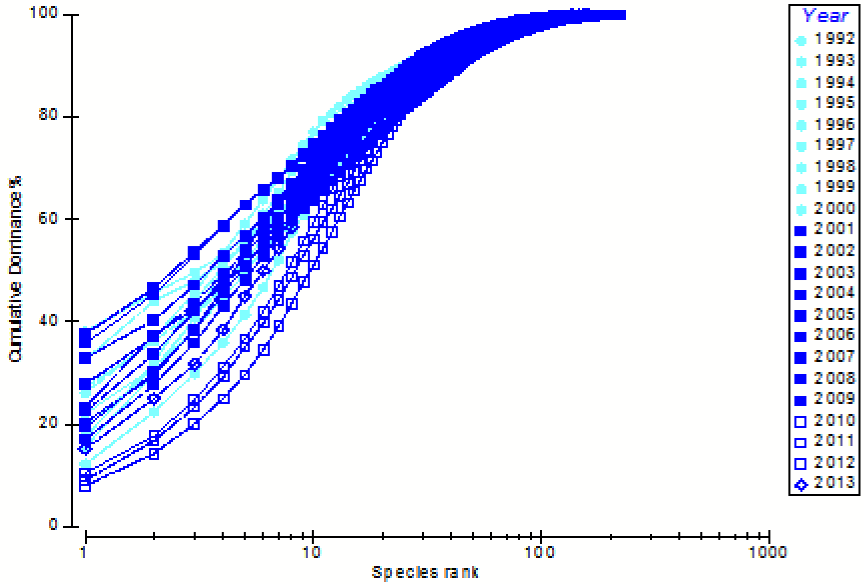
SPECIES RICHNESS: NF ONLY



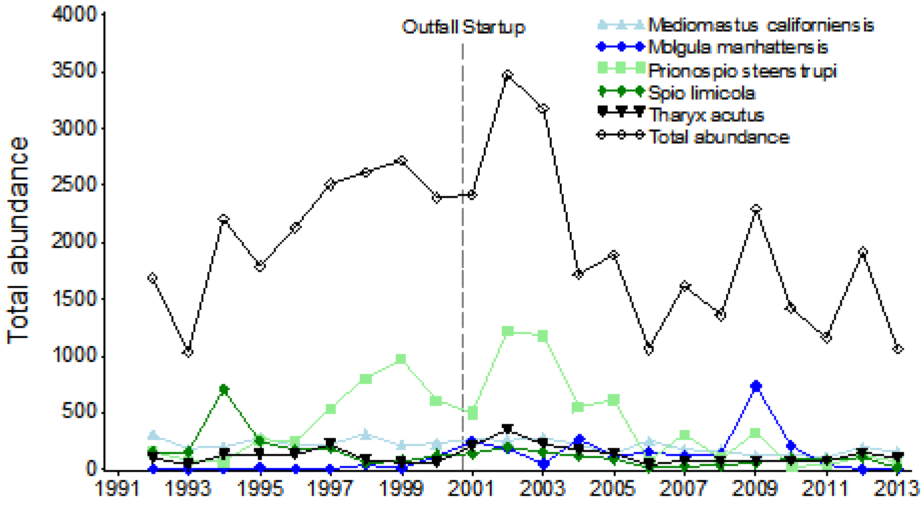
DOMINANCE: NF STATIONS ONLY



DOMINANCE PLOT: NF ONLY

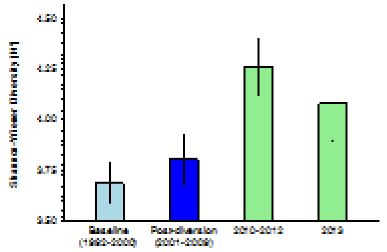


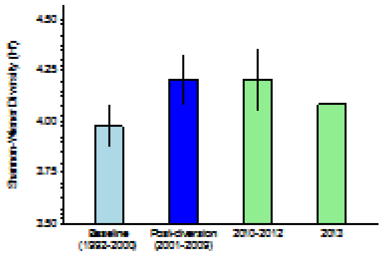
DOMINANT SPECIES: NF ONLY

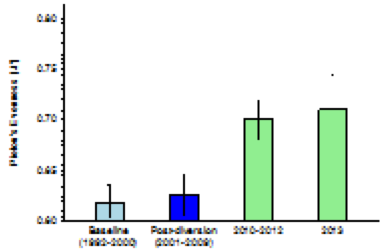


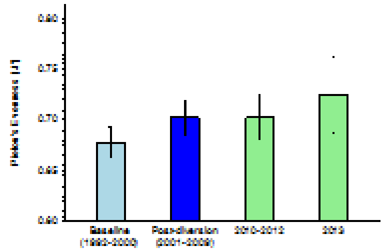
FULL SPECIES LIST

FIVE DOMINANT SPECIES REMOVED

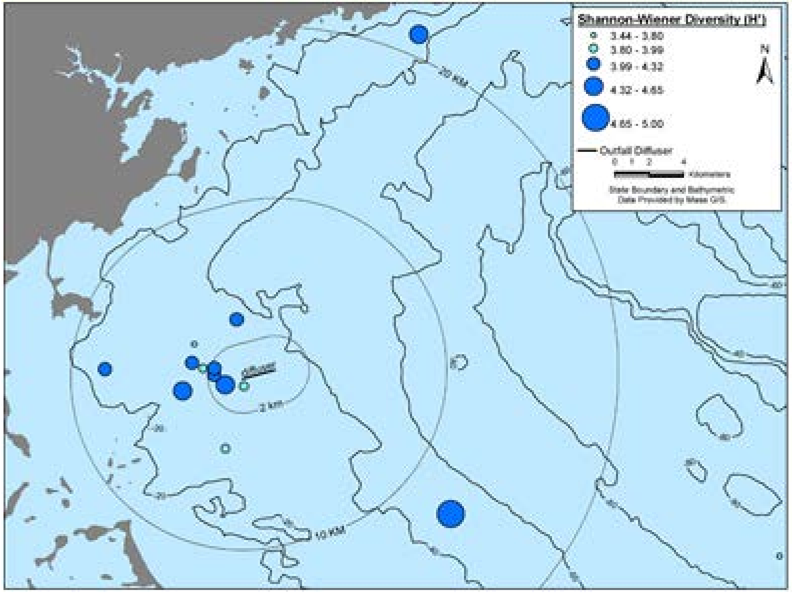








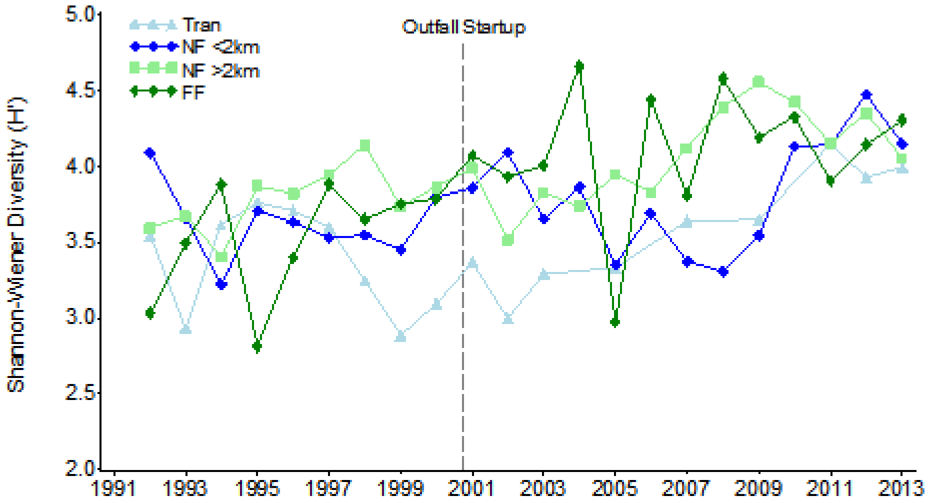
2013 DIVERSITY (H')



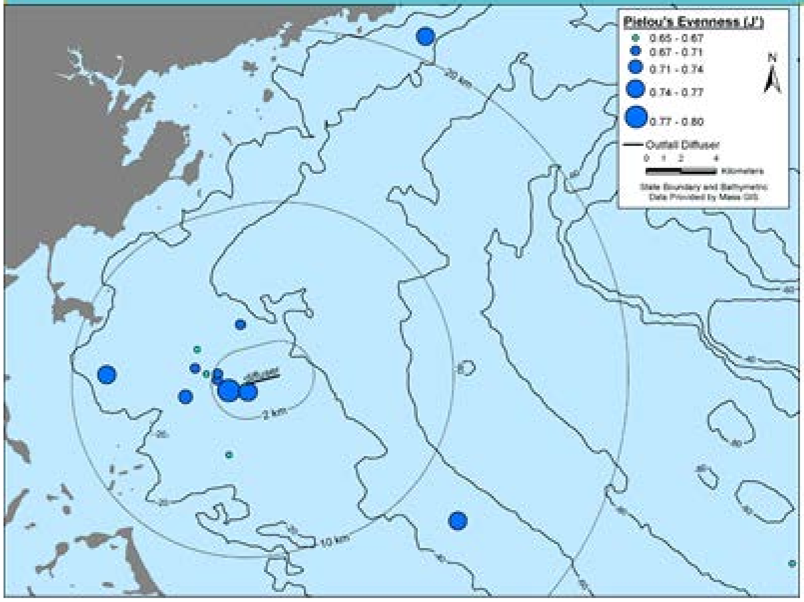
Light = below threshold

Dark = above threshold

DIVERSITY (H')



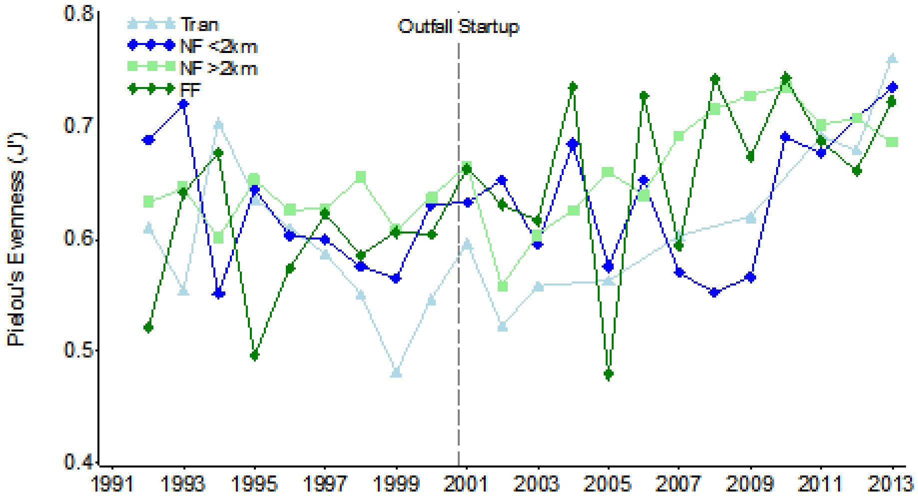
2013 EVENNESS (J')



Light = below threshold

Dark = above threshold

EVENNESS (J')



INFAUNAL ASSEMBLAGES

- Spatial Patterns:
  - Multivariate analyses to assess patterns in the distribution of faunal assemblages
  - 2013 Samples
  - Bray-Curtis Similarity
  - Cluster Analysis
  - nMDS Ordination Plots

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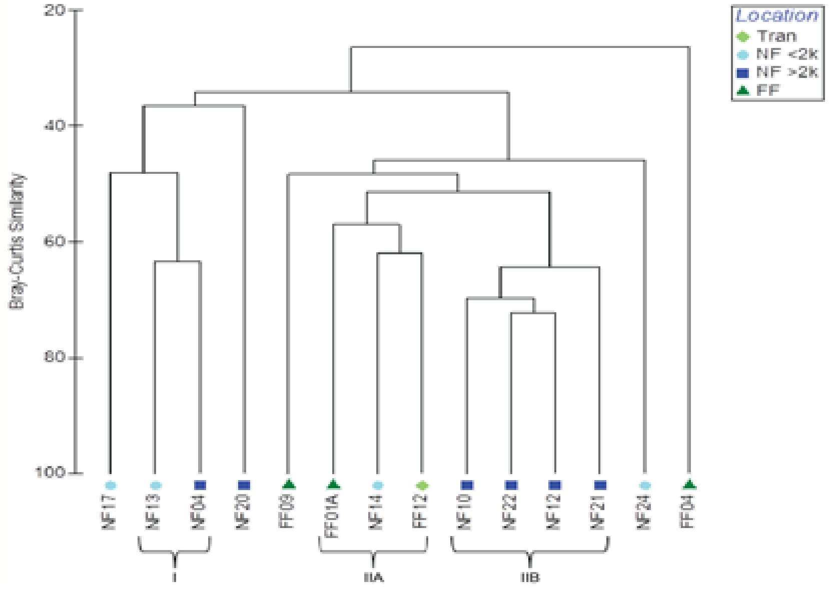
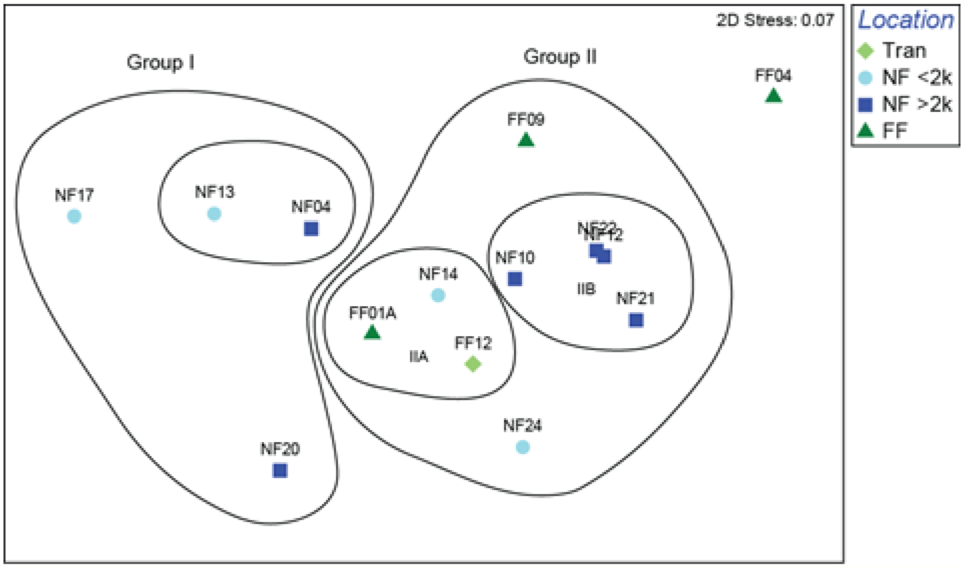
CLUSTER ANALYSIS: 2013 SAMPLES



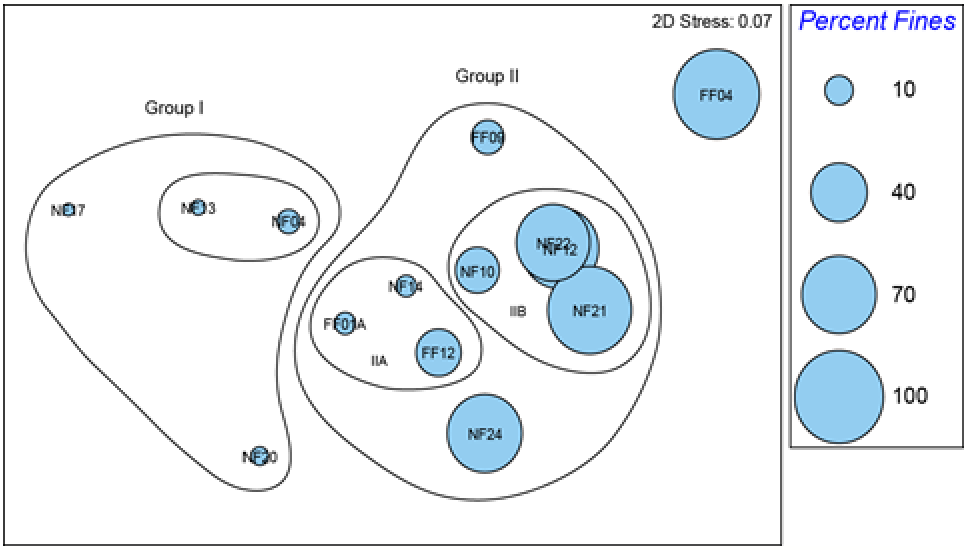
ORDINATION PLOT: 2013 SAMPLES LOCATION OVERLAY



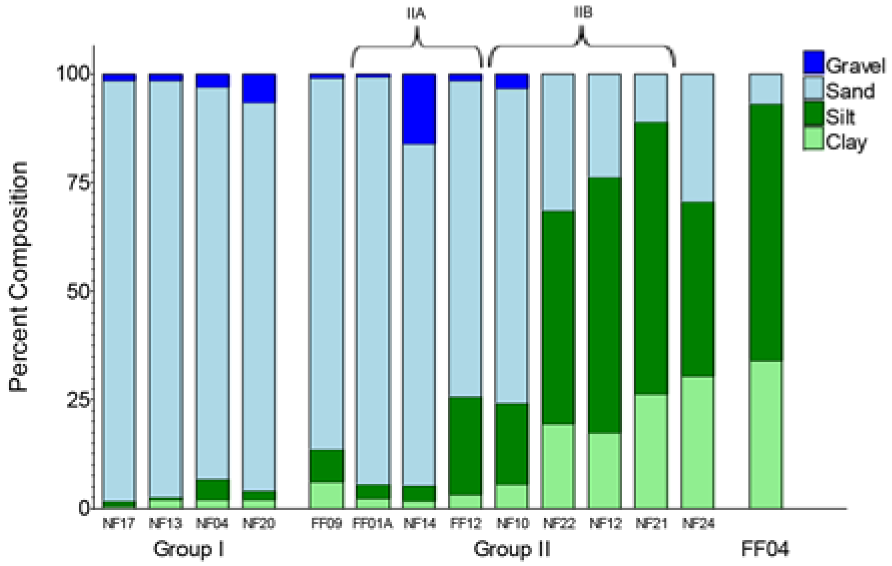
INFAUNAL ASSEMBLAGES

- Group I, NF17, NF20 (sand)
  - *Exogone hebes, Aricidea catherinae, Tanaissus psammophilus, Scalibregma inflatum*
- Group IIA (sand with fines, some gravel)
  - *Prionospio steenstrupi, Mediomastus californiensis, Aricidea catherinae*
- FF09 (sand with fines)
  - *Euchone incolor, Anobothrus gracilis, Spio limicola*
- Group IIB, NF24 (fines with sand)
  - *Mediomastus californiensis, Tharyx acutus, Levinsenia gracilis, Prionospio steenstrupi*
- FF04 (fines)
  - *Levinsenia gracilis, Chaetozone anasimus, Cossura longocirrata*

ORDINATION PLOT: 2013 SAMPLES PERCENT FINES OVERLAY



SEDIMENT GRAIN SIZE COMPOSITION BY CLUSTER GROUP



INFAUNAL ASSEMBLAGES

- Temporal Patterns:
  - Multivariate analyses to assess changes in faunal assemblages over time
  - Selected Stations: NF14, FF01A
  - 1992-2013, Rep 1 only

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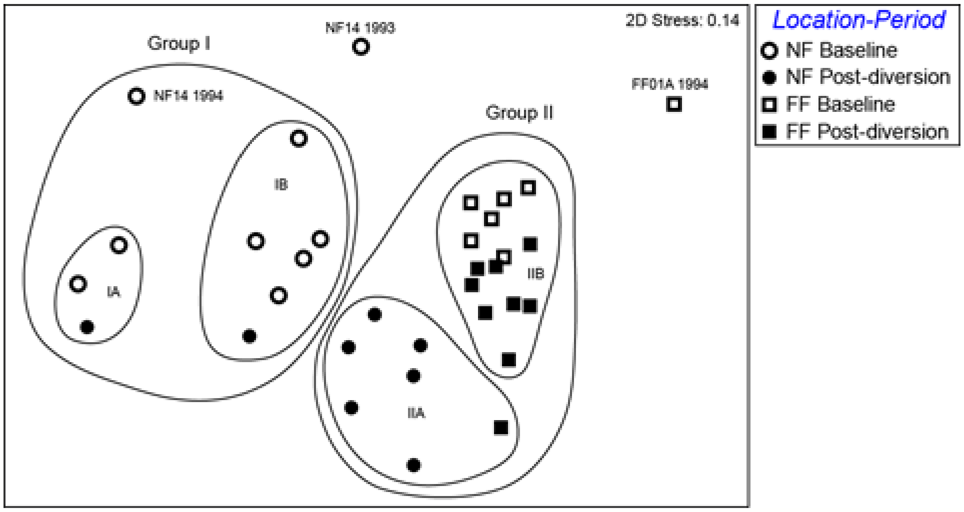
ORDINATION PLOT: NF14 and FF01A, 1992-2013, PERIOD OVERLAY



INFAUNA SUMMARY

- Increased Diversity (H′) and Evenness (J′) reflect reductions in numbers of dominant species; not related to the discharge.
- Faunal distributions reflect habitat. Patterns in the spatial distribution of infauna are consistent with patterns in the spatial distribution of sediment types (grain size).
- No evidence of impacts to infauna from the discharge.

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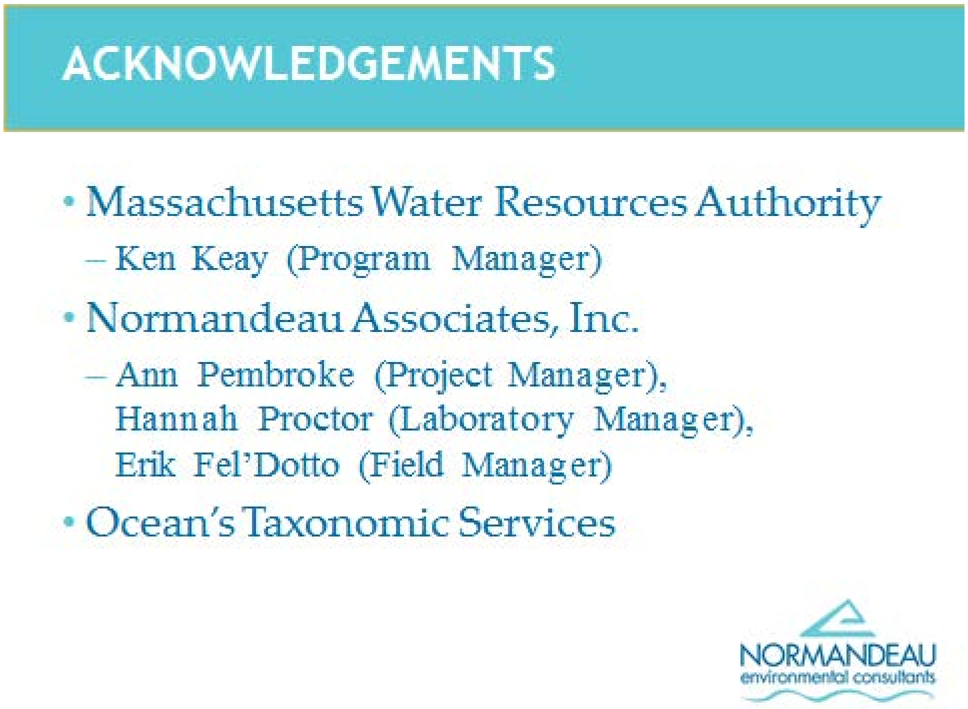

ACKNOWLEDGEMENTS

- Massachusetts Water Resources Authority
  - Ken Keay (Program Manager)
- Normandeau Associates, Inc.
  - Ann Pembroke (Project Manager),
    Hannah Proctor (Laboratory Manager),
    Erik Fel'Dotto (Field Manager)
- Ocean's Taxonomic Services

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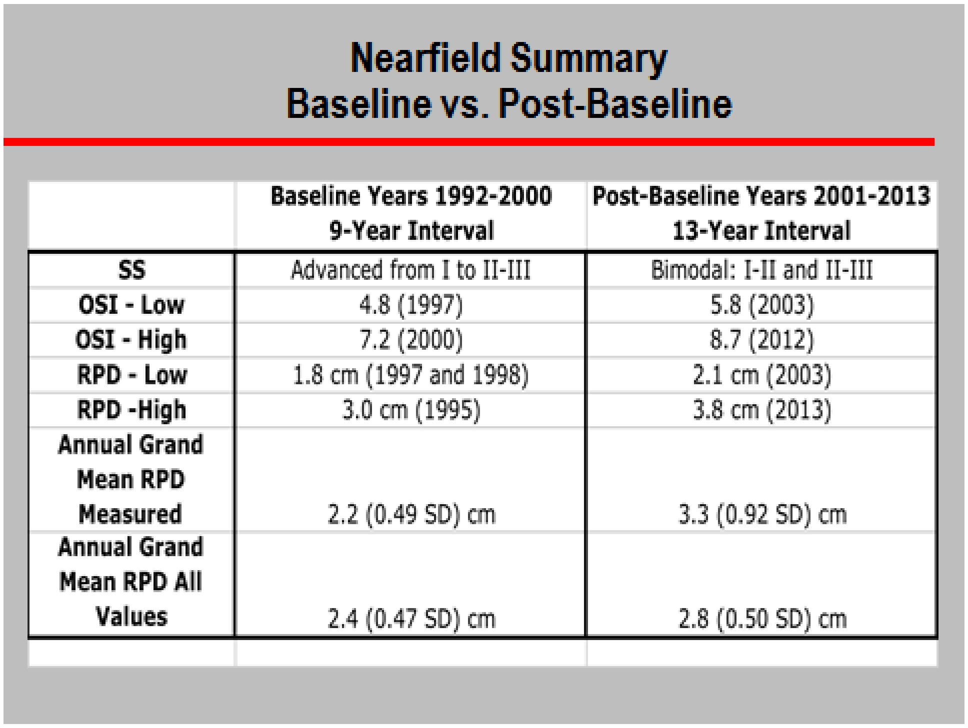
Appendix B2. 2013 Harbor and Bay Sediment Profile Imaging

2013 Harbor and Bay Sediment Profile Imaging

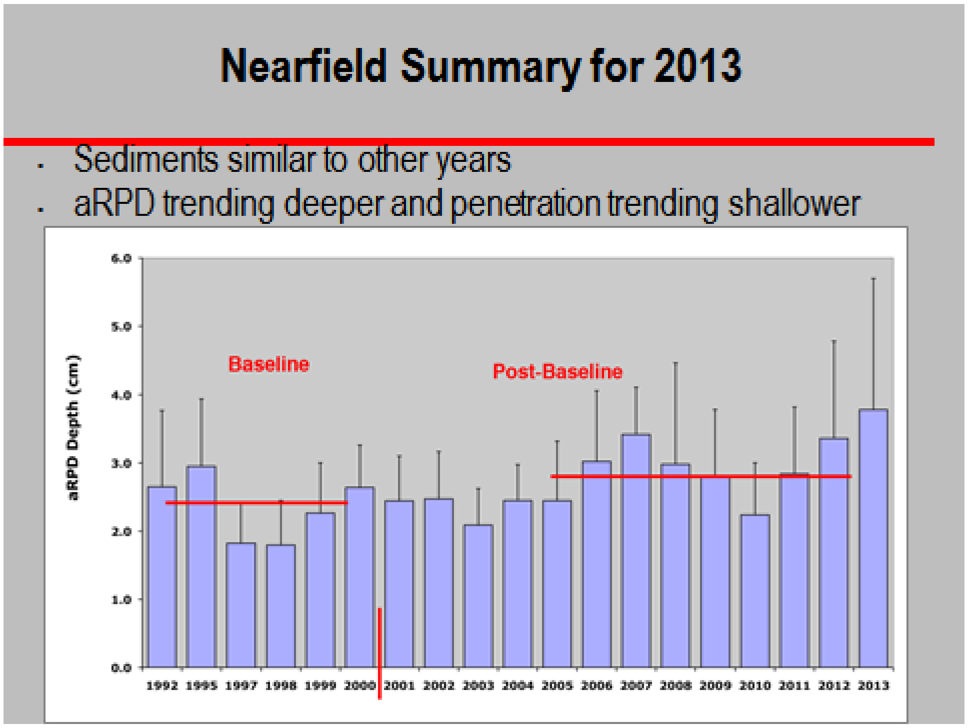
Robert Diaz et al.
R.J. Diaz & Daughters

R02 2013



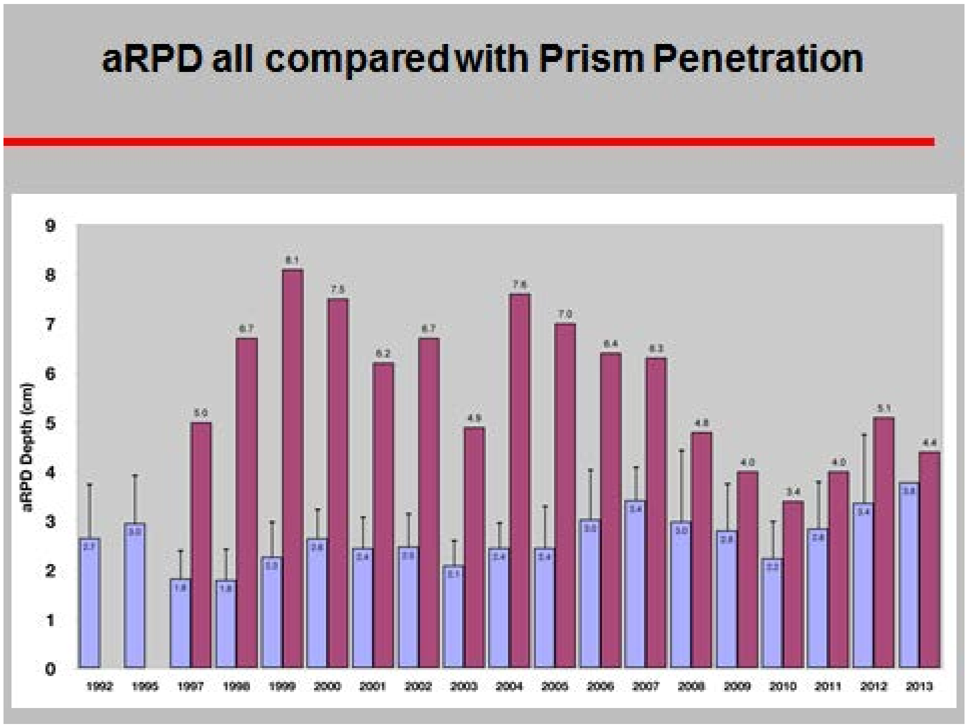
Nearfield Summary
Baseline vs. Post-Baseline

	Baseline Years 1992-2000 9-Year Interval	Post-Baseline Years 2001-2013 13-Year Interval
SS	Advanced from I to II-III	Bimodal: I-II and II-III
OSI - Low	4.8 (1997)	5.8 (2003)
OSI - High	7.2 (2000)	8.7 (2012)
RPD - Low	1.8 cm (1997 and 1998)	2.1 cm (2003)
RPD -High	3.0 cm (1995)	3.8 cm (2013)
Annual Grand Mean RPD Measured	2.2 (0.49 SD) cm	3.3 (0.92 SD) cm
Annual Grand Mean RPD All Values	2.4 (0.47 SD) cm	2.8 (0.50 SD) cm

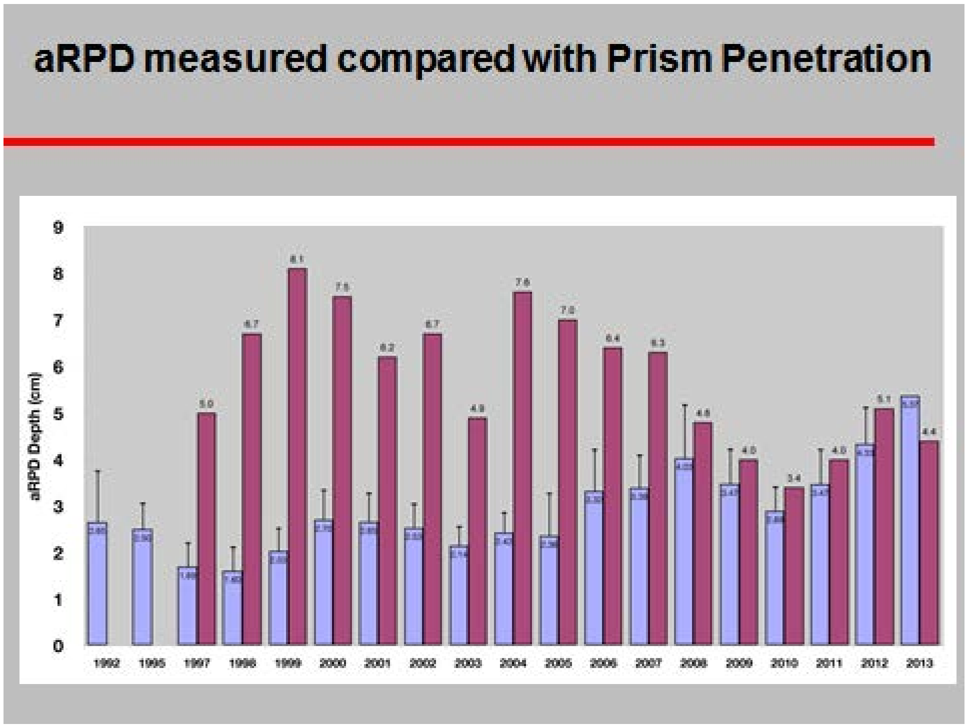


Nearfield Summary for 2013

- Sediments similar to other years
- aRPD trending deeper and penetration trending shallower



aRPD all compared with Prism Penetration



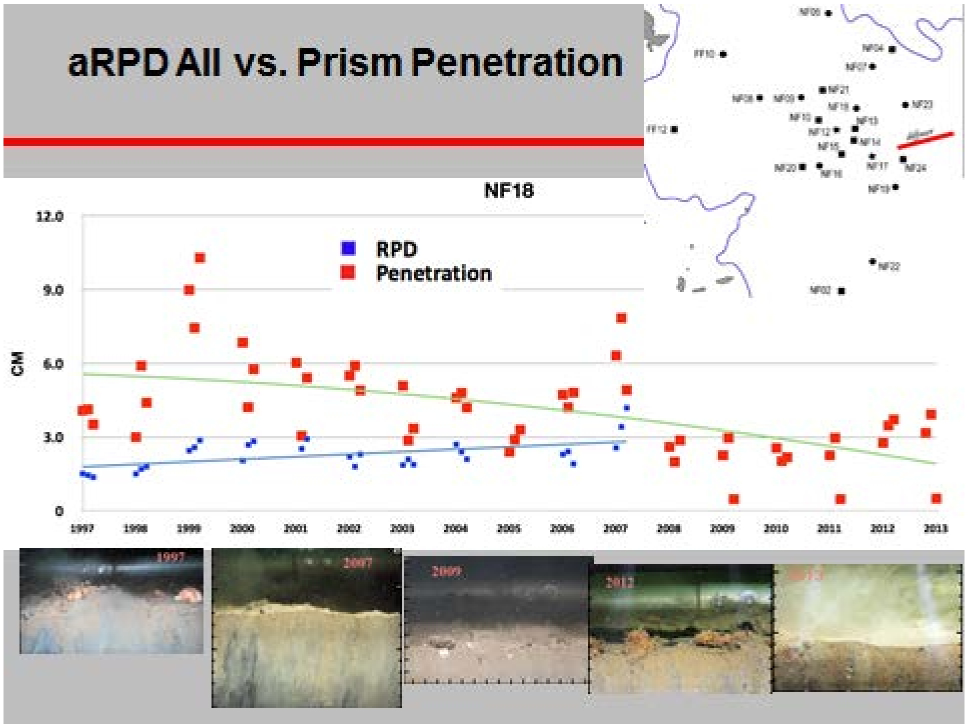
aRPD measured compared with Prism Penetration

aRPD compared with Prism Penetration

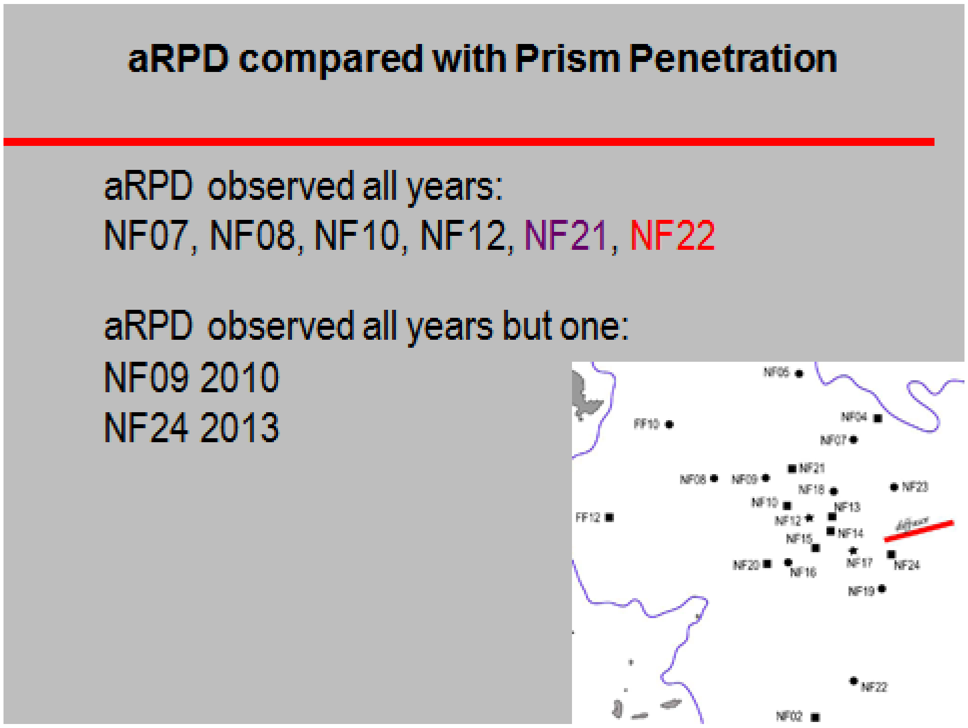
No aRPD observed: NF04, NF13, NF17

Penetration declined below aRPD depth:

- NF20 last in 2005
- NF15 and NF19 last in 2006
- NF17 and NF18 last in 2007
- FF10, FF13, and NF14 last in 2010
- NF05 and NF23 last in 2011
- NF24 last in 2012



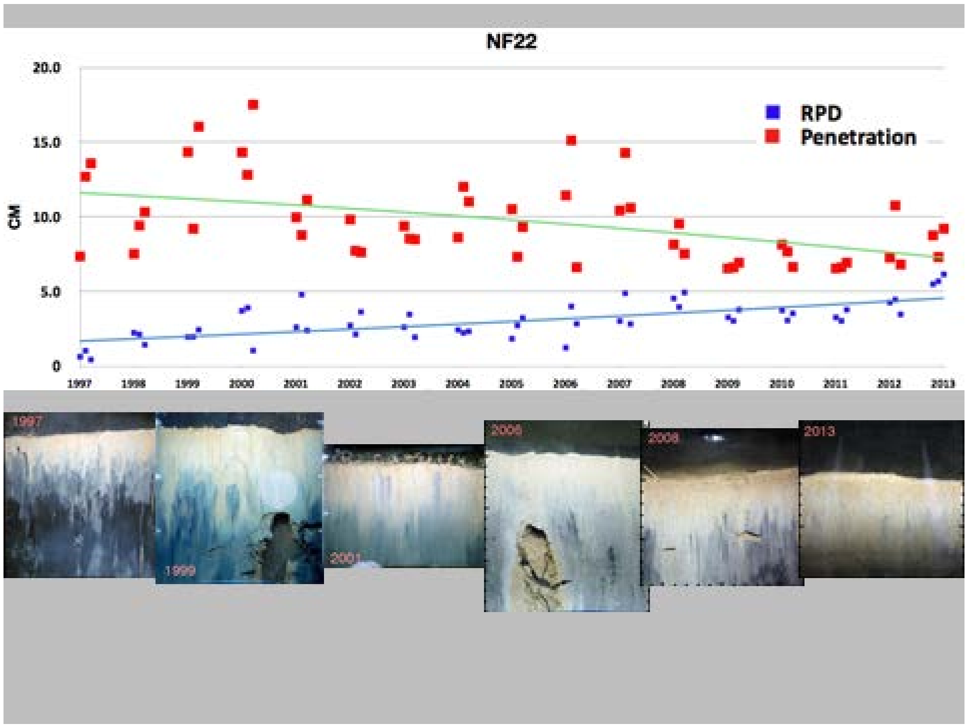
aRPD All vs. Prism Penetration



aRPD compared with Prism Penetration

aRPD observed all years:
NF07, NF08, NF10, NF12, NF21, NF22

aRPD observed all years but one:
NF09 2010
NF24 2013

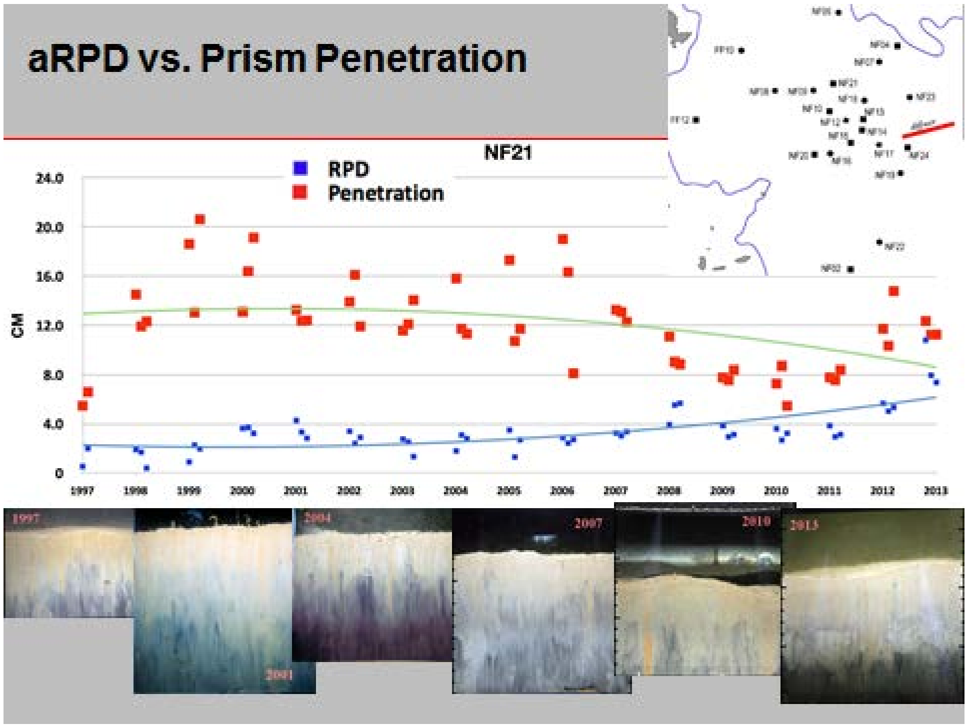


aRPD compared with Prism Penetration

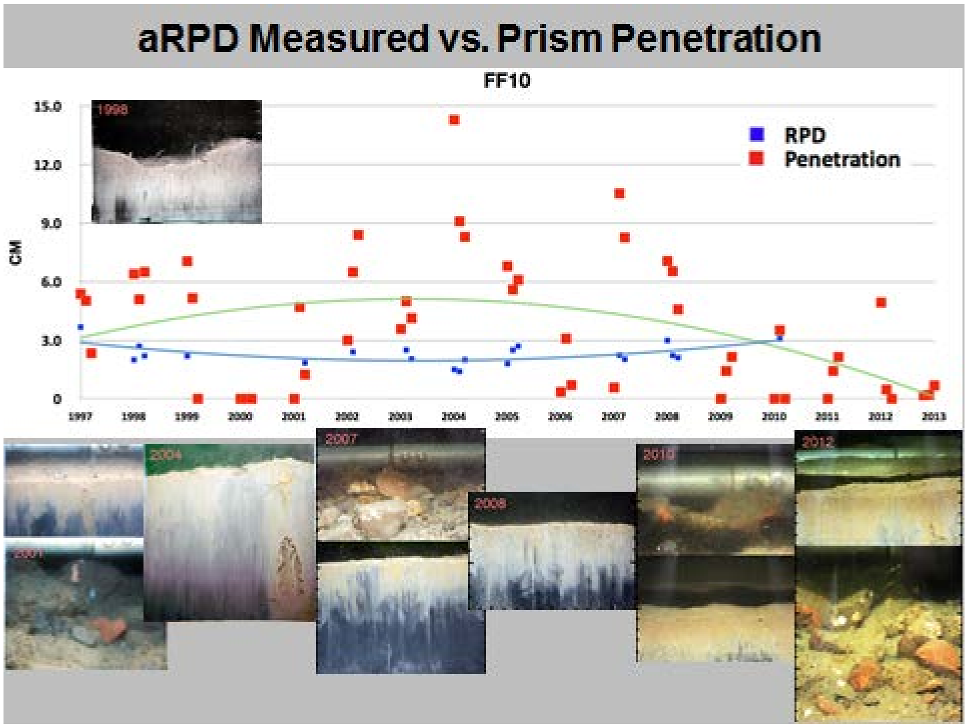
Penetration declining - aRPD increasing:
NF05, NF07, NF08, NF09, NF10,
NF12, NF16, NF21, NF22

Penetration declining - aRPD remaining the same:
FF10, FF13, NF14

Penetration - aRPD both remaining the same:
NF02, NF23, NF24



aRPD vs. Prism Penetration



aRPD Measured vs. Prism Penetration

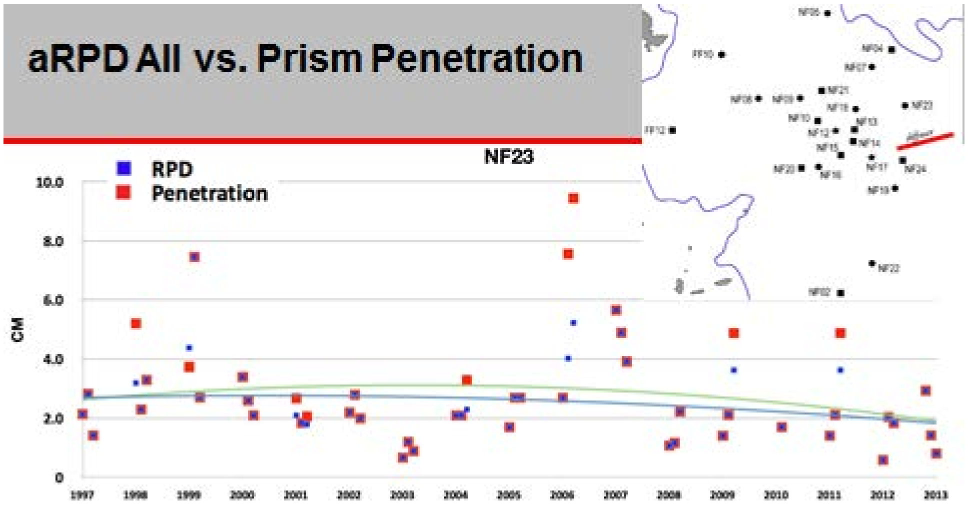
aRPD compared with Prism Penetration

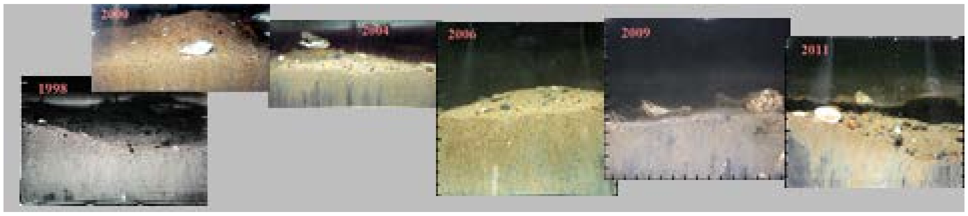
Penetration declining - aRPD increasing:
NF05, NF07, NF08, NF09, NF10,
NF12, NF16, NF21, NF22

Penetration declining - aRPD remaining the same:
FF10, FF13, NF14

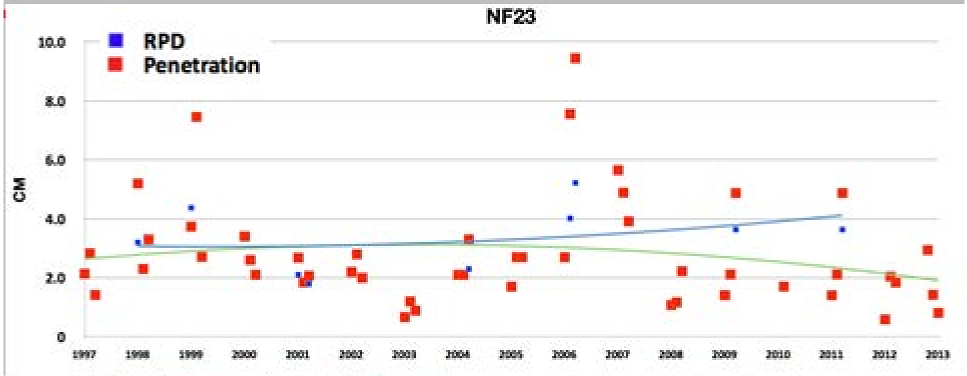
Penetration - aRPD both remaining the same:
NF02, NF23, NF24

aRPD All vs. Prism Penetration





aRPD Measured vs. Prism Penetration

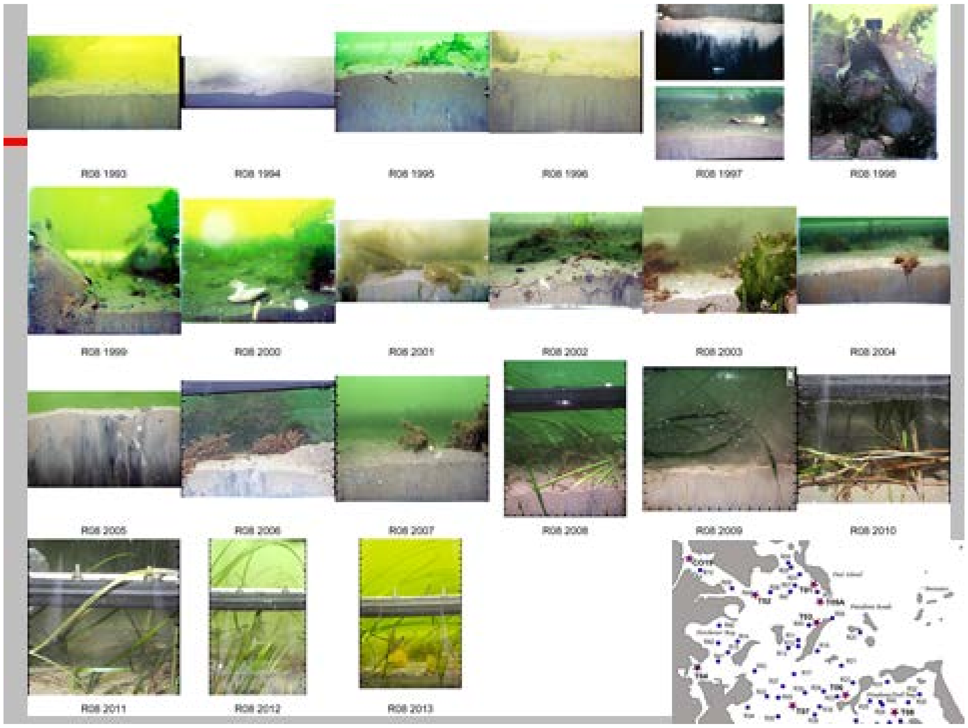


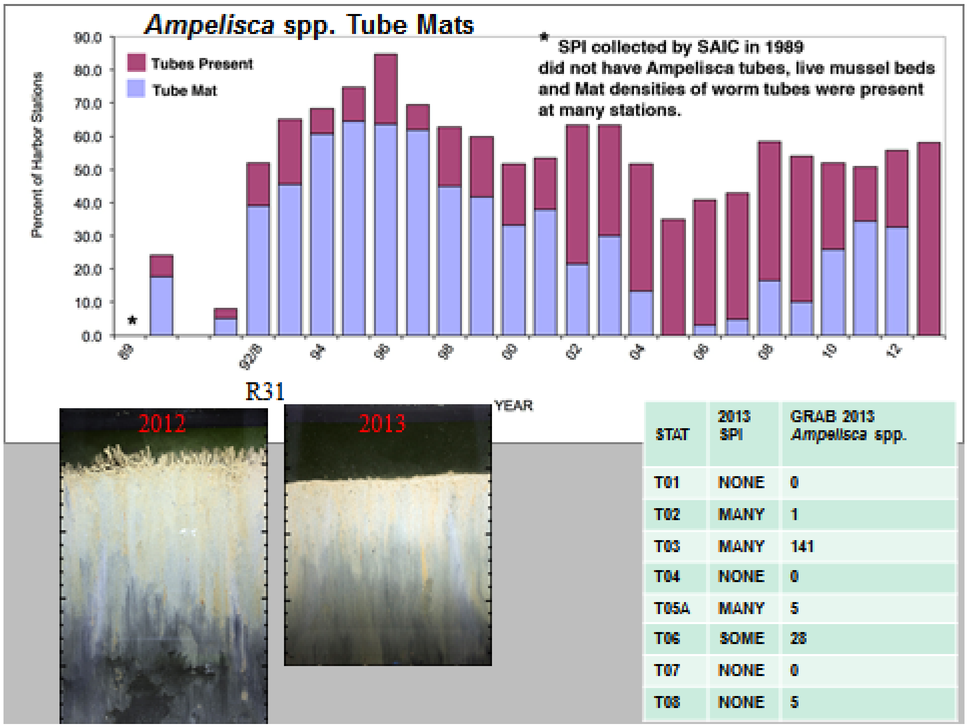
Nearfield Summary

- Operation of outfall, starting in 2001, did not effect benthic habitat quality
- aRPD Post-Baseline deeper than Baseline
- Sediment and benthic habitat quality characteristics remained similar through time
- Prism penetration needs to be improved

Harbor for 2013

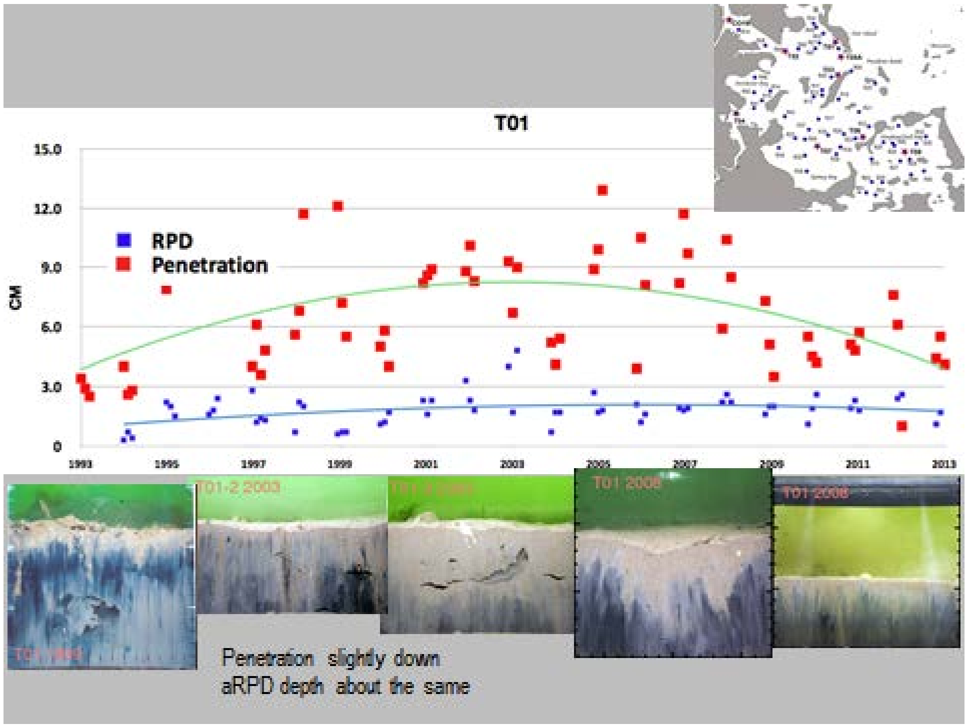
- Sediments, aRPD, Successional Stage, and OSI about the same.
- Eel grass bed at R08 on Deer Island Flats, 6th year.
- No *Ampelisca* spp. tube mats. Only the second time in 24 years of SPI monitoring. 2005 had no mats.
- *Leptocheirus pinguis* bioturbation, obvious at many stations since 1995, was not observed.
- Physical processes prominent in structuring surface sediments.
- More megafauna in 2013
- Microalgal mat observed at R32 and T08.



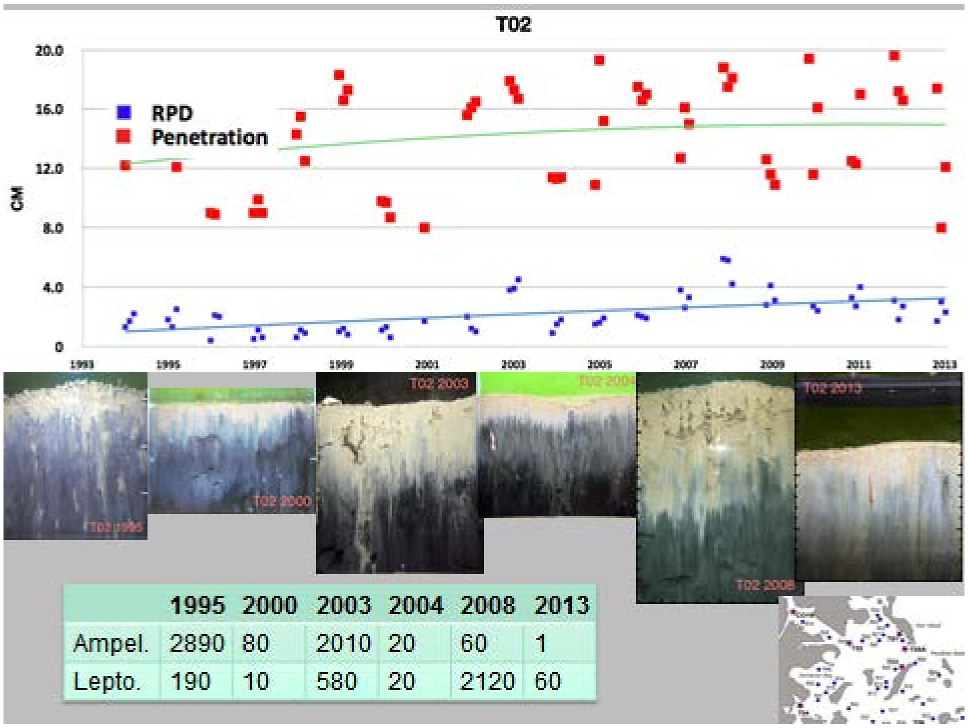


* SPI collected by SAIC in 1989 did not have Ampelisca tubes, live mussel beds and Mat densities of worm tubes were present at many stations.

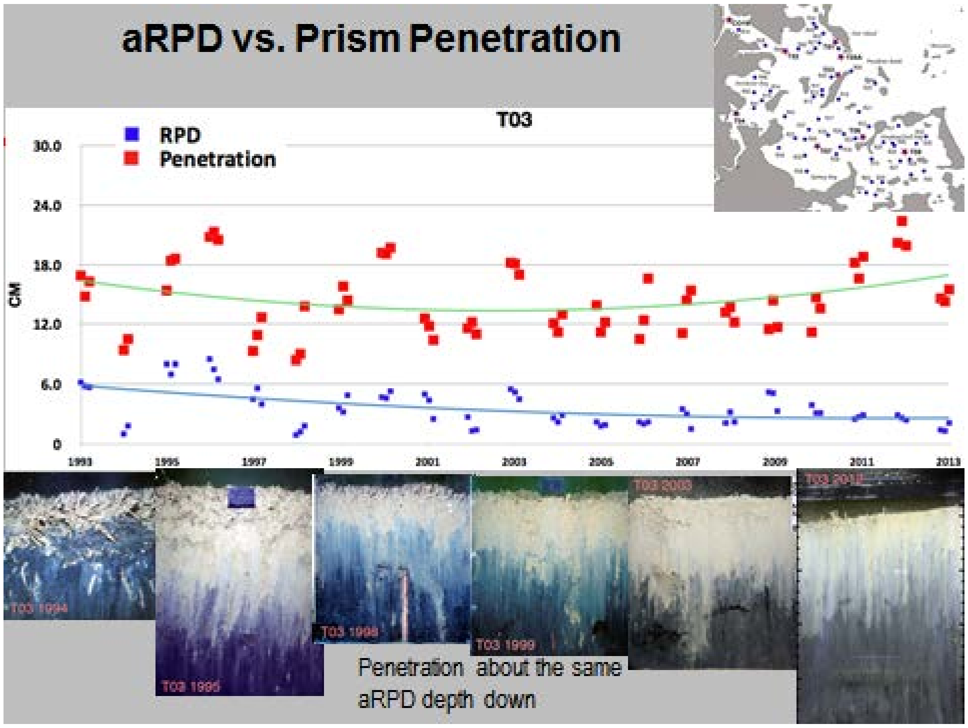
STAT	2013 SPI	GRAB 2013 *Ampelisca* spp.
T01	NONE	0
T02	MANY	1
T03	MANY	141
T04	NONE	0
T05A	MANY	5
T06	SOME	28
T07	NONE	0
T08	NONE	5



Penetration slightly down
aRPD depth about the same

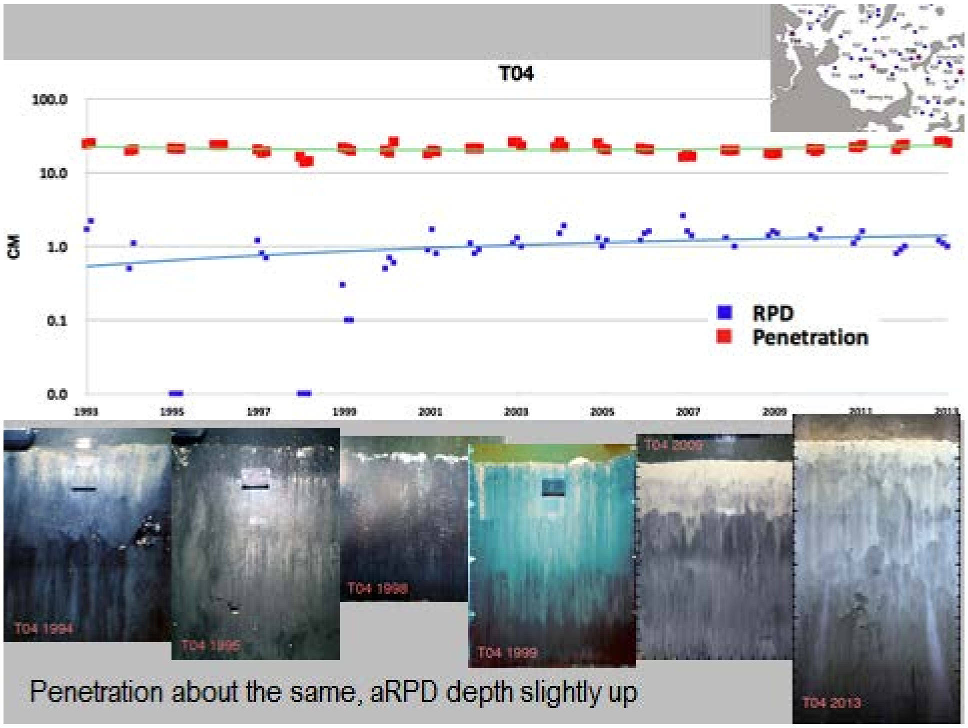


	1995	2000	2003	2004	2008	2013
Ampel.	2890	80	2010	20	60	1
Lepto.	190	10	580	20	2120	60

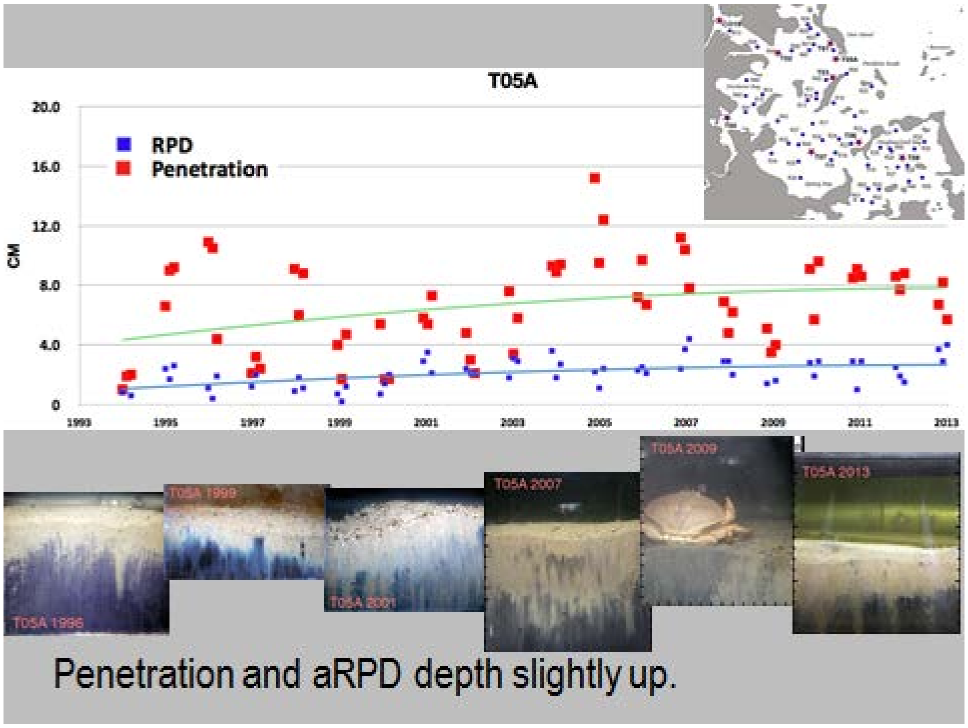


aRPD vs. Prism Penetration

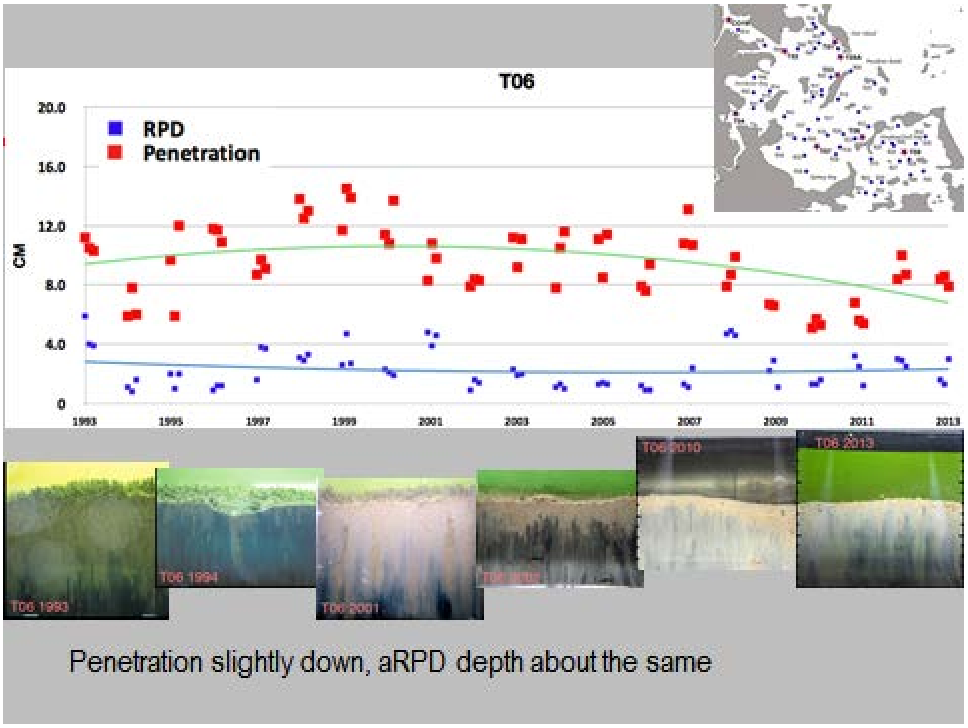
Penetration about the same
aRPD depth down



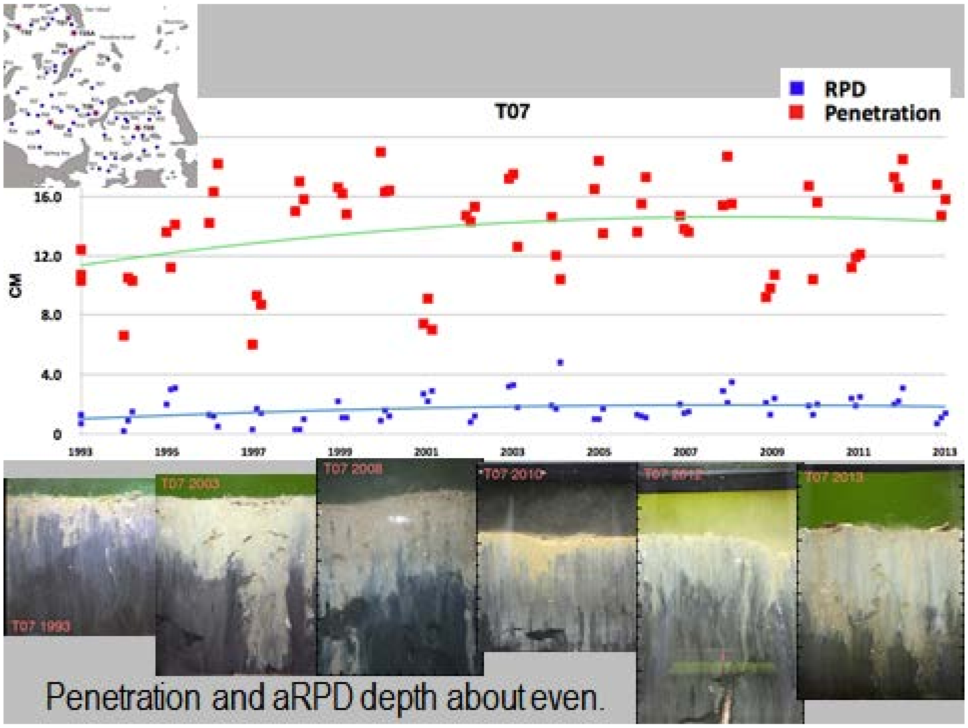
Penetration about the same, aRPD depth slightly up



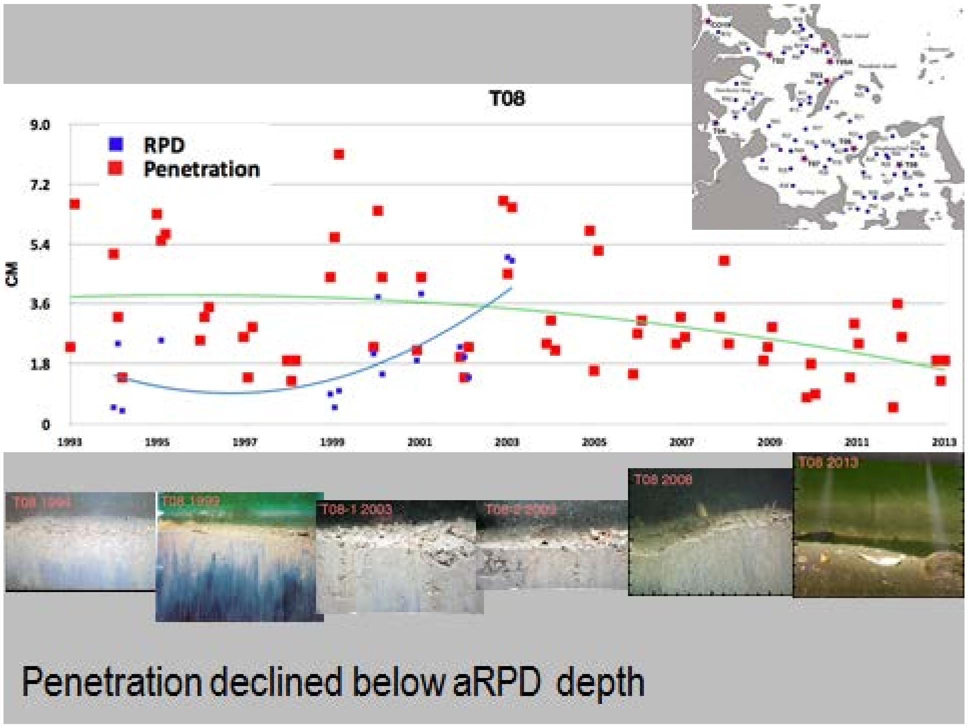
Penetration and aRPD depth slightly up.



Penetration slightly down, aRPD depth about the same



Penetration and aRPD depth about even.

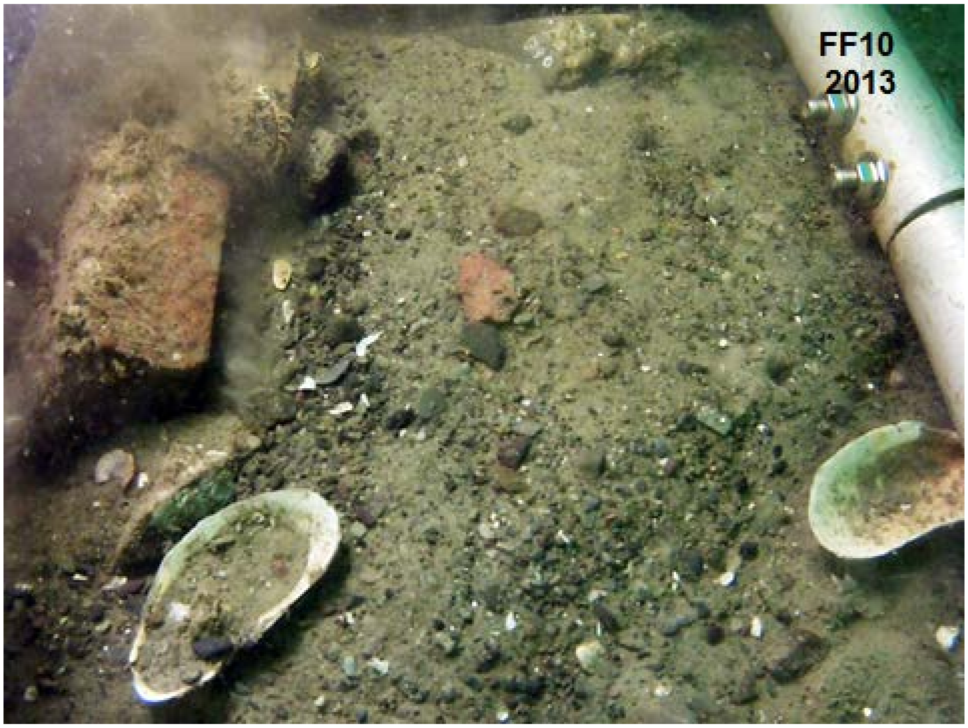


Penetration declined below aRPD depth

Summary for Harbor

Benthic habitat quality for infauna has been about the same for last several years. Initial improvements in 1990s were related to changes in discharge and treatment.

Inner to outer harbor gradient remains prominent and related to hydrodyanimics.


FF10
2013

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