2025 Outfall Benthic Monitoring Results

Massachusetts Water Resources Authority
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Submitted to

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EXECUTIVE SUMMARY

Background. The Massachusetts Water Resources Authority (MWRA) operates the Deer Island Wastewater Treatment Plant, where sewage from more than 40 communities in Greater Boston undergoes primary and secondary treatment followed by disinfection. Following treatment, the effluent is discharged to Massachusetts Bay more than 5 miles (8 km) from the nearest shoreline. Massachusetts Bay has been the site of the effluent discharge since 2000 (the "post-diversion" period), when MWRA moved the Deer Island discharge from Boston Harbor as part of the Boston Harbor Project to alleviate harbor pollution. MWRA has gathered environmental data in the Bay since 1992 to evaluate the potential effects of the discharge.

MWRA is required to monitor the benthos (seafloor community) in Massachusetts Bay. The MWRA discharge permit requires benthic monitoring to detect any effects of the effluent on the ocean environment. The monitoring focuses on three main concerns: (1) eutrophication (excess organic material and nutrients) and related low levels of dissolved oxygen; (2) deposits of toxic contaminants; and (3) smothering of animals by sewage effluent solids, or other changes to benthic communities. MWRA measures levels of total organic carbon to assess whether effluent discharge has resulted in organic enrichment; tracks areas of possible contamination based on levels of a sewage indicator bacterium, *Clostridium perfringens*; and reports on benthic animal abundance and diversity. As animal communities vary naturally across different benthic habitats, monitoring is designed to detect variation in habitat attributes, such as sediment grain size. Within the context of natural variation, potential outfall impacts can then be assessed.

Benthic habitat quality has remained in high/good condition near the outfall. The discharge is located in an area dominated by hydrodynamic and physical factors, including tidal and storm currents, turbulence, and sediment transport (Butman et al. 2008). These physical factors, combined with the well-treated effluent discharged into the Bay (Taylor 2010, Werme et al. 2021), are the principal reasons that benthic habitat quality has remained in high/good (undisturbed/slightly disturbed) condition near the outfall. MWRA's discharge permit includes a Contingency Plan which sets out caution and warning threshold levels of key indicators including the diversity of benthic animals. There were no exceedances of these thresholds for any infaunal (soft-sediment) community in 2025. Data on these macrobenthic (larger than 0.3 mm) animals continue to suggest that the communities near the outfall remain healthy and diverse. Hard-bottom benthic communities near the outfall have not changed substantially during the post-diversion period. Some modest changes in hard-bottom communities (e.g., coralline algae, upright algae cover, sponge abundance, and barnacle settlement events) have been observed; nonetheless, factors driving these changes are unclear and may reflect natural cycles, interspecific competition, or other shifts in the environment. In addition, years of monitoring have shown that solids from the wastewater discharge do not reach levels that disturb or smother animals near the outfall.

The effluent discharge has not degraded sediment conditions. Sediment grain size and total organic carbon have remained generally consistent over time, with relatively small year-to-year changes. Results in 2025 were consistent with this historical pattern for these parameters (Nestler et al. 2025, Maciolek et al. 2008). Concentrations of the sewage tracer, *Clostridium perfringens*, continued to decrease to levels comparable to other post-diversion years in all areas of the Bay in 2025, after sharp increases in 2022. *Clostridium perfringens* counts were highest at the station located closest to the discharge. This spatial pattern of higher counts closer to the discharge has remained consistent since outfall relocation to the Bay in 2000 (e.g., Nestler and Madray 2023, Maciolek et al. 2007, 2008). These results provide evidence that effluent solids have settled at sites within about 2 km (1.25 miles) of the outfall, however there is no indication that the wastewater discharge has resulted in organic enrichment or changes to the sediment grain size composition near the outfall.

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1 INTRODUCTION

Under its Ambient Monitoring Plan (MWRA 1991, 1997, 2001, 2004, 2010, 2021) the MWRA has collected extensive information over a nine-year "baseline" period (1992–2000) and a twenty-five-year "post-diversion" period (2001–2025) after the wastewater discharge was moved to Massachusetts Bay. Data are from surveys of sediments and soft-bottom communities using traditional grab sampling and sediment profile imaging (SPI; 1992–2019) as well as surveys of hard-bottom communities using a remotely operated vehicle (ROV). The SPI survey and the sediment contaminant evaluation in Massachusetts Bay were discontinued in 2020, as these studies had fully answered their monitoring questions. Data collected by this program 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.

Benthic monitoring during 2025 was conducted following the current Ambient Monitoring Plan (MWRA 2021), which is required under MWRA's effluent discharge permit for the Deer Island Treatment Plant. Under this current plan, monitoring includes annual soft-bottom sampling for sediment conditions and infauna at fourteen stations, including: ten nearfield (NF) stations, three farfield (FF) stations, and Station FF12, located in a "transition" area between Boston Harbor and the offshore outfall. Nearfield stations are located within five kilometers (km) from the offshore outfall. The nearfield area is in close proximity to the wastewater discharge, where impacts to benthos could potentially be measured. Farfield stations are all more than 13 km from the outfall, with Stations FF01A and FF04 both over 20 km away. Stations located in the farfield area are presumably beyond the influence of the wastewater discharge. Changes detected in both nearfield and farfield areas are expected to represent large-scale, region-wide trends, unrelated to the wastewater discharge.

Every third year, hard-bottom surveys are conducted at twenty-three nearfield stations. The most recent hard-bottom survey was conducted in 2023. Monitoring results for 2023 indicated that hard-bottom benthic communities near the outfall have not changed substantially during the post-diversion period as compared to the baseline period (Goode et al. 2024). Some modest changes in hard-bottom communities (e.g., coralline algae, upright algae cover, and sponge abundance) have been observed; nonetheless, factors driving these changes are unclear. Since declines in upright algae started in the late 1990s, it is unlikely that the decrease was attributable to diversion of the outfall (Goode et al. 2024).

This report summarizes key findings from the 2025 benthic surveys, with a focus on the most noteworthy observations relevant to understanding the potential effects of the discharge on the offshore benthic environment.

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. 2025, Maciolek et al. 2008). Detailed descriptions of the methods are contained in the Quality Assurance Project Plan (QAPP) for Benthic Monitoring 2020–2023 (Rutecki et al. 2020). 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 12, 2025 (Figure 2-1). To aid in analyses of potential spatial patterns reported herein, these stations are grouped, based on distance from the discharge, into four "monitoring areas" within Massachusetts Bay[1]:

- Nearfield stations NF13, NF14, NF17, and NF24 are located in close proximity (less than 2 km) to the offshore outfall.
- Nearfield stations NF04, NF10, NF12, NF20, NF21, and NF22 are located farther than 2 km and less than 5 km from the offshore outfall.
- Transition station FF12 is located between Boston Harbor and the offshore outfall (just under 8 km from the offshore outfall).
- Farfield reference stations FF01A, FF04, and FF09 are located in Massachusetts Bay but farther than 13 km from the offshore outfall.

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-2023-002.

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

[1] The current monitoring areas form a subset of stations that were sampled before 2011. For example, the transition area formerly included station FF12 and two others that are no longer sampled.

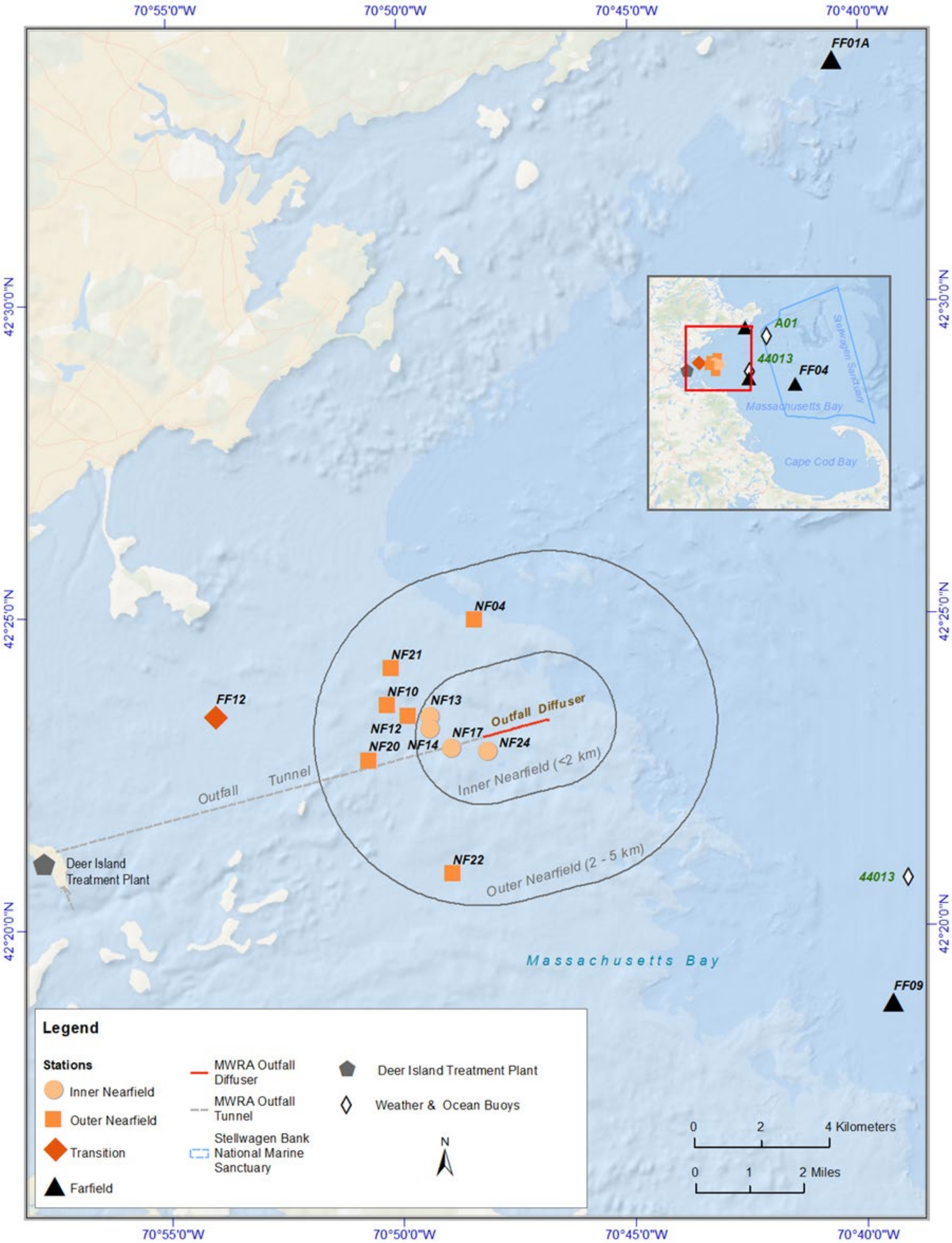

Figure 2-1. Locations of soft-bottom sampling stations for 2025. Inset map shows farfield station FF04.

2.2 LABORATORY METHODS

All bacteriological, physical, and chemical analyses were conducted by MWRA's Department of Laboratory Services Central Laboratory or its contractors following the procedures described in Constantino et al. (2014). All sample processing, including sorting, identification, and enumeration of infaunal organisms, was done following methods consistent with the QAPP (Rutecki et al. 2020).

2.3 DATA HANDLING, REDUCTION, AND ANALYSIS

All benthic data were extracted directly from the MWRA's database and imported into Excel. Data handling, reduction, graphical presentations, and statistical analyses were performed as described in the QAPP (Rutecki et al. 2020) or by Maciolek et al. (2008). Additional multivariate techniques were used to evaluate infaunal communities. Multivariate analyses were performed using PRIMER v7 (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 (nMDS). 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 (Clarke and Gorley 2015).

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. nMDS 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 nMDS ordination plot (Clarke 1993). Stress levels less than 0.05 indicate an excellent representation of relative similarities among samples with little 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 nMDS ordination provide a highly informative representation of patterns of community-level similarity among samples. The "similarity profile test" (SIMPROF) was used to provide statistical support for the identification of faunal assemblages (i.e., selection of cluster groups). The 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.

To help with assessment of spatial patterns, stations have been grouped into regions according to distance from the outfall. The monitoring areas include nearfield stations <2 km from the outfall, nearfield stations >2 km from the outfall, a transition station, and farfield stations (see Section 2.1). All Contingency Plan thresholds and comparisons to those thresholds to assess potential exceedances are based on the nearfield stations, including the transition station (FF12). The nearfield annual means and associated threshold limits reported herein are both based on the list of stations currently sampled (since the 2010 revision to the Ambient Monitoring Plan; MWRA 2010).

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 2025 at each of the 14 sampling stations: (1) *Clostridium perfringens*, (2) grain size (categories from coarse to fine: gravel, sand, silt, and clay), and (3) total organic carbon (Table 3-1).

Table 3-1. Monitoring results for sediment condition parameters in 2025.

Monitoring Area	Station	*Clostridium perfringens* (cfu/g dry/%fines)	Total Organic Carbon (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Percent Fines (Silt + Clay)
Nearfield (<2 km from outfall)	NF13	46.7	0.28	0.5	78.6	5.7	15.2	20.9
	NF14	48.3	0.41	9.3	69.8	7.6	13.3	20.9
	NF17	49.8	0.11	0.1	85.0	1.7	13.3	15.0
	NF24	110.5	0.79	0.0	45.3	30.9	23.8	54.7
Nearfield (>2 km and <5 km from outfall)	NF04	33.9	0.11	0.5	86.4	1.5	11.6	13.0
	NF10	55.2	0.72	0.4	50.1	25.5	24.0	49.5
	NF12	46.9	1.42	0.0	17.8	48.2	34.1	82.2
	NF20	42.5	0.67	4.6	54.6	17.9	22.9	40.8
	NF21	39.0	1.32	0.1	26.4	44.0	29.6	73.5
	NF22	28.5	1.32	0.1	26.2	39.8	33.8	73.7
Transition (~ 8 km from outfall)	FF12	33.3	0.46	1.0	51.4	25.2	22.4	47.6
Farfield (>13 km from outfall)	FF01A	24.8	0.37	0.2	71.2	12.4	16.2	28.6
	FF04	29.0	2.59	0.0	0.9	49.2	49.9	99.1
	FF09	29.1	0.38	0.2	73.6	6.9	19.3	26.2

3.1.1.1 Clostridium perfringens

Spores of the anaerobic bacterium *Clostridium perfringens* provide a sensitive tracer of effluent solids due to their presence in wastewater and the inability to remove them by conventional treatment practices. *Clostridium perfringens* abundances were reported as colony forming units per gram dry weight, normalized to percent fines (silt and clay; cfu/g dry/% fines). Abundances were normalized because the distribution of *C. perfringens* varies with the proportion of fine-grained material in the sediments, and normalization provides a more conservative means of evaluating the data for trends (Parmenter and Bothner 1993). A sharp increase in *C. perfringens* concentrations at sites within two kilometers from the diffuser occurred coincident with diversion of effluent to the offshore outfall (Figure 3-1). *C. perfringens* concentrations declined or remained comparable to the baseline at all other monitoring locations during the post-diversion period until 2022. Statistical analyses reported in Maciolek et al. (2007, 2008) confirmed that concentrations of *C. perfringens* were significantly higher at stations close to the outfall in 2006 and 2007 compared to pre-diversion concentrations and consistent with an impact of the outfall discharge. *C. perfringens* counts in samples collected during 2022 increased sharply at most stations, and in two areas of the Bay, were measured at the highest concentrations of the 1992 to 2025 time series, more than four times the historical averages for the areas (NF<2km and FF, Figure 3-1). *C. perfringens* counts decreased just as sharply in 2023, remaining at levels comparable to other past post-diversion concentrations in all areas of the Bay during 2025 (Figure 3-1). Normalized *C. perfringens* spore counts in samples collected in 2025 were highest at NF24, the Nearfield station located closest to the discharge (Table 3-1, Figure 3-2).

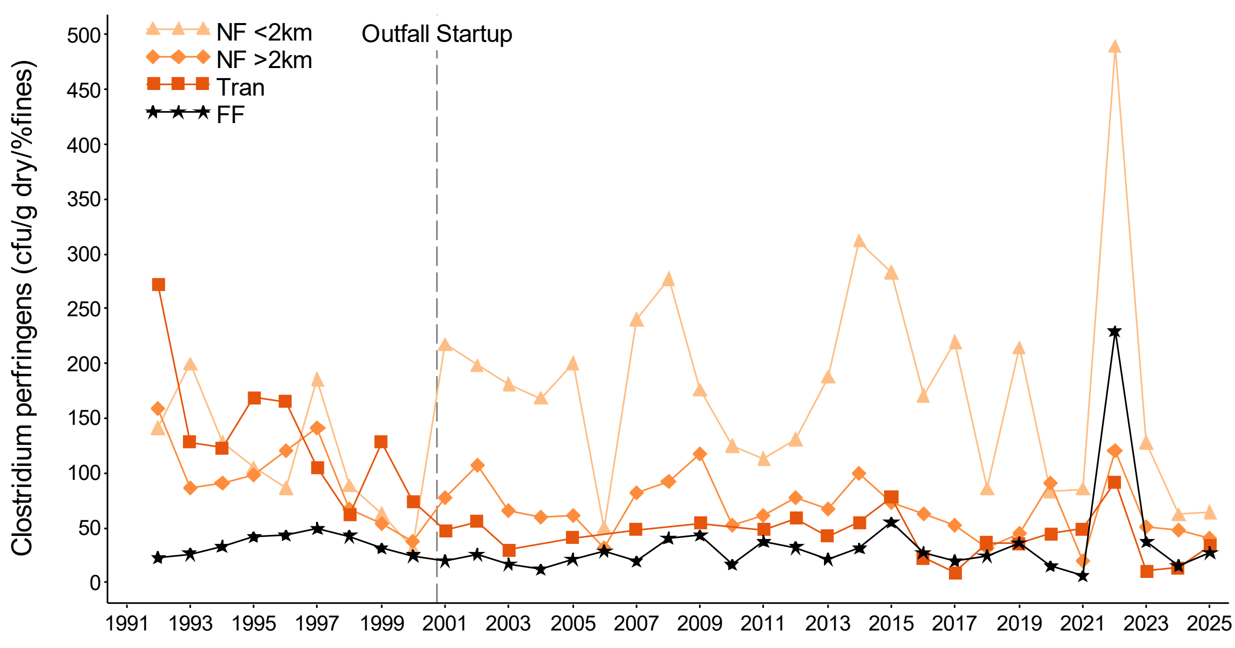

Figure 3-1. Mean concentrations of *Clostridium perfringens* in four areas of Massachusetts Bay, 1992 to 2025. Tran=Transition; NF<2km=nearfield, less than two kilometers from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield.

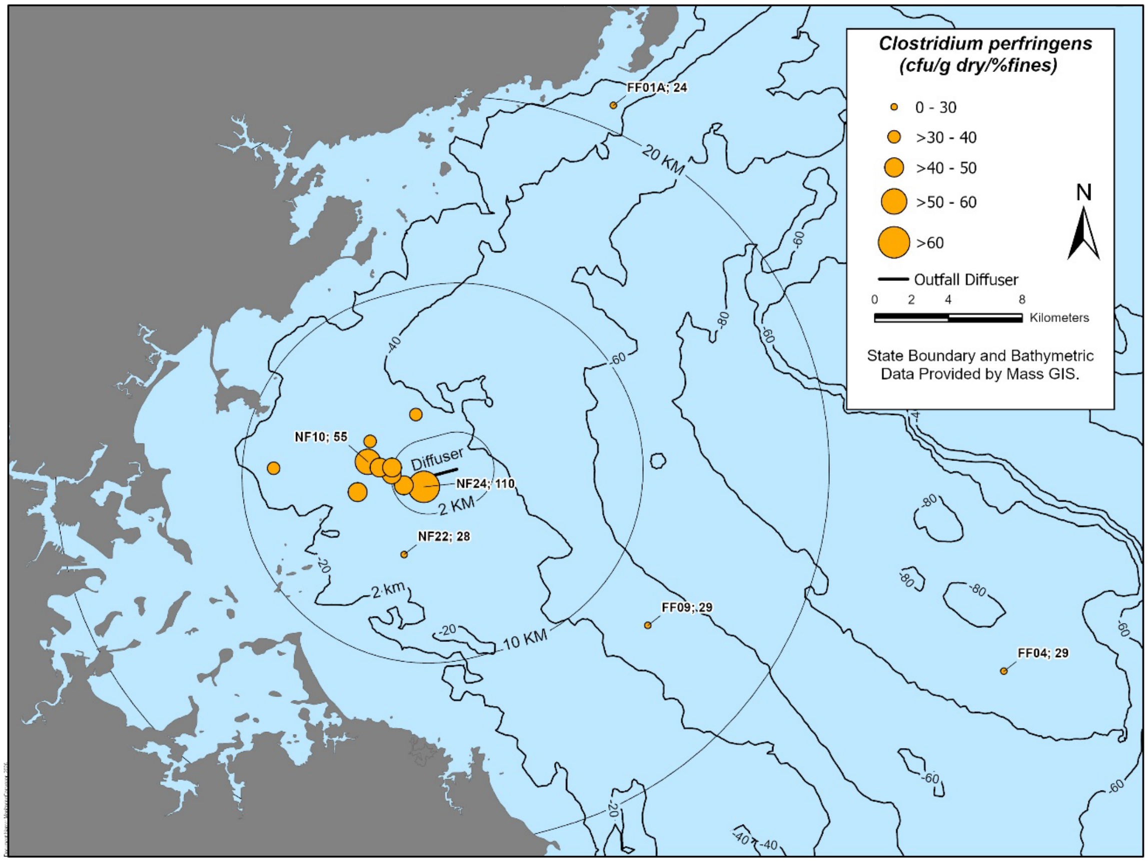

Figure 3-2. Monitoring results for *Clostridium perfringens* in 2025.

3.1.1.2 Sediment Grain Size

Sediment texture in 2025 varied considerably among the 14 stations, ranging from mostly sand (e.g., NF17 and NF04) to predominantly silt and clay (i.e., NF12 and FF04), with most stations having mixed sediments (Figure 3-3). Although sediment texture has remained generally consistent over time with relatively small year-to-year changes in the percent fine sediments at most stations, sharp increases in percent fines were reported at several stations in recent years and remained relatively high in 2025 (e.g., FF01A, NF17; Figure 3-4). Annual variability in sediment texture at the Massachusetts Bay stations has typically been associated with strong storms. 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 storms (Bothner et al. 2002). Another source of year-to-year variability in sediment textures could be small-scale spatial variability of benthic habitat in the vicinity of a sampling location. Factors such as storm-driven sediment transport may explain the relatively high interannual variability at stations such as FF01A or NF17, where the percent fine sediments were higher in 2024 and 2025 than in previously reported years (Figure 3-4).

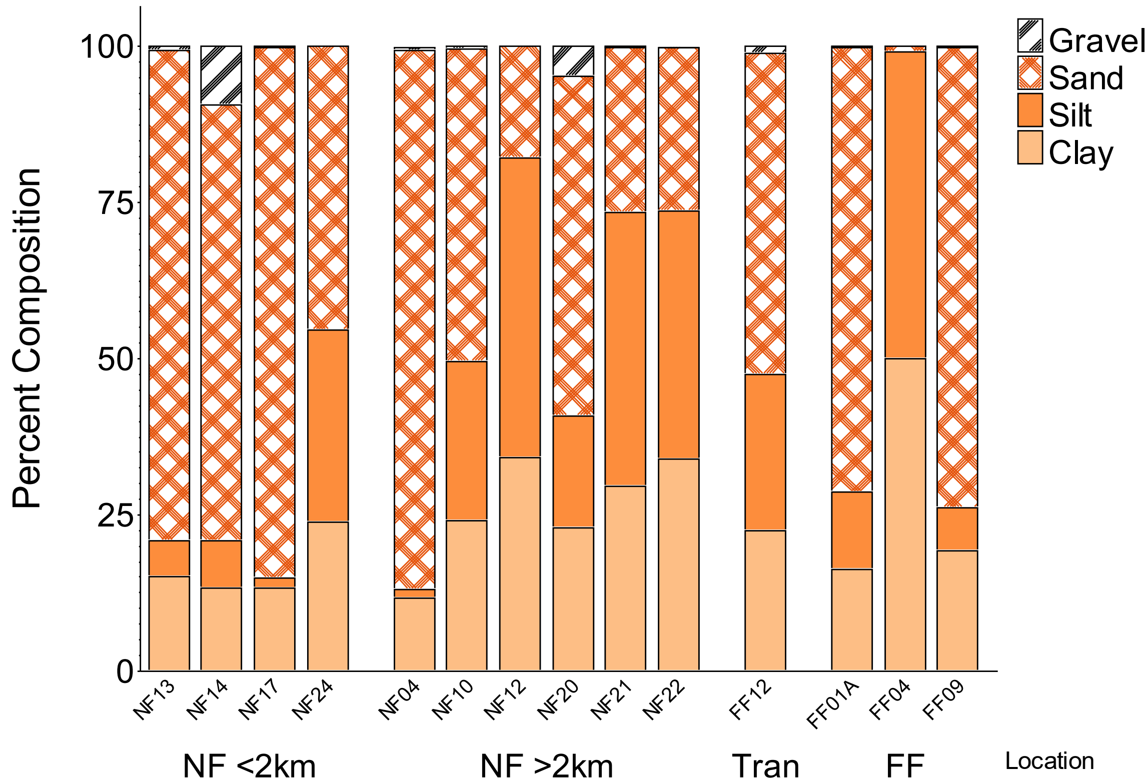

Figure 3-3. Monitoring results for sediment grain size in 2025.

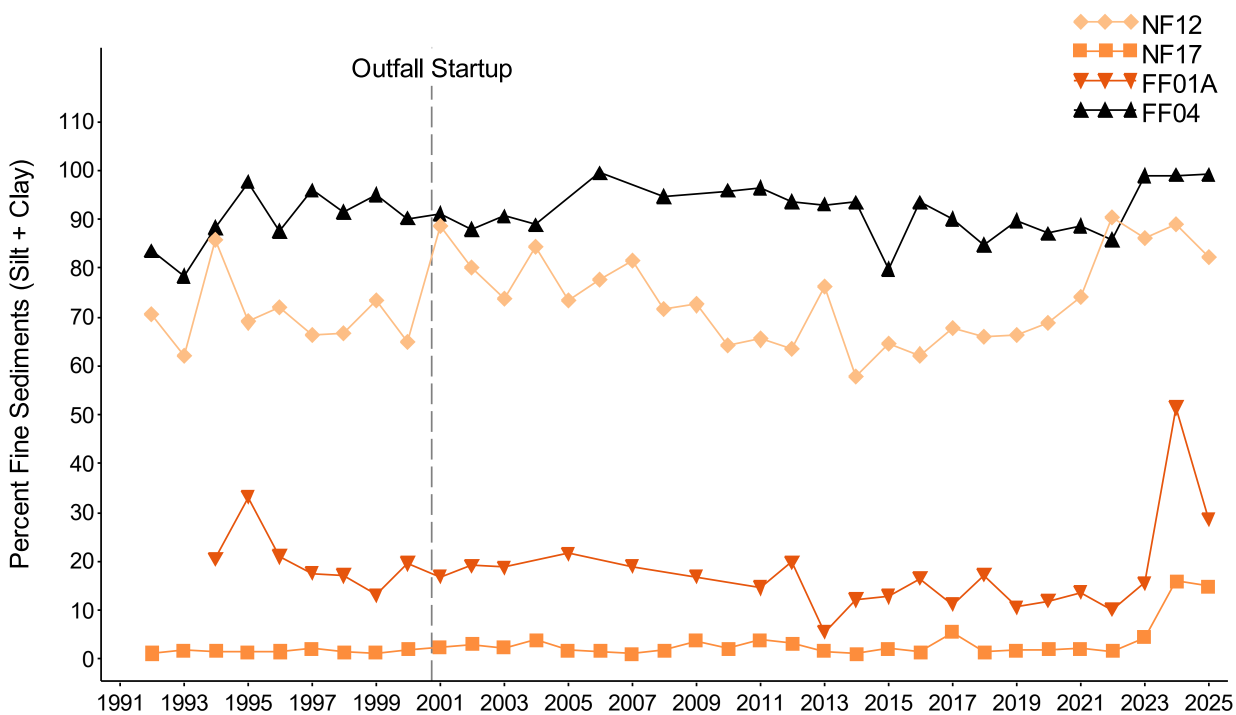

Figure 3-4. Mean percent fine sediments at FF01A, FF04, NF12 and NF17; 1992 to 2025.

3.1.1.3 Total Organic Carbon

Concentrations of TOC in 2025 were similar to the previous year at several nearfield stations (e.g., NF17 and FF01A), with more year-to-year variability at others further from the outfall (e.g., NF12; Figure 3-5). Despite year-to-year variability, TOC values were generally consistent with historically reported values at different locations within the Bay (Figure 3-5). Higher TOC values are generally associated with higher percent fines (compare Figures 3-4 and 3-5). To further assess spatial patterns in TOC concentrations while accounting for the association between TOC and percent fine sediments, TOC values were normalized to percent fines (Figure 3-6). To normalize the TOC values, the percentage of TOC was divided by the percentage of percent fine sediments (i.e., silt and clay).

While *C. perfringens* counts continue to provide evidence of effluent solids depositing near the outfall (Table 3.1), there is no indication that the wastewater discharge has resulted in changes to the sediment grain size composition and no indication of organic enrichment at the Massachusetts Bay sampling stations. Overall, TOC concentrations remain comparable to values reported during the baseline period, even at sites closest to the outfall (Figures 3-7 and 3-8).

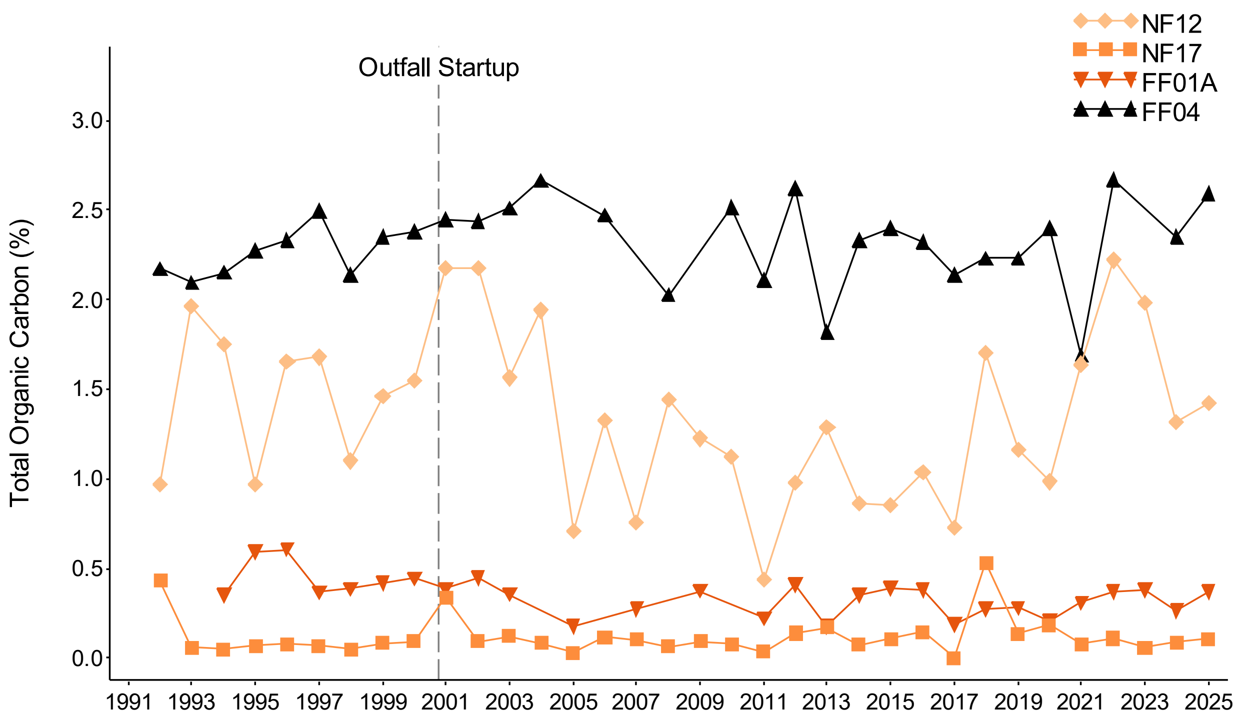

Figure 3-5. Mean concentrations of TOC at four stations in Massachusetts Bay, 1992 to 2025*.
***2023 value at Station FF04 was flagged as suspect and excluded from analyses (see Goode et al. 2024).**

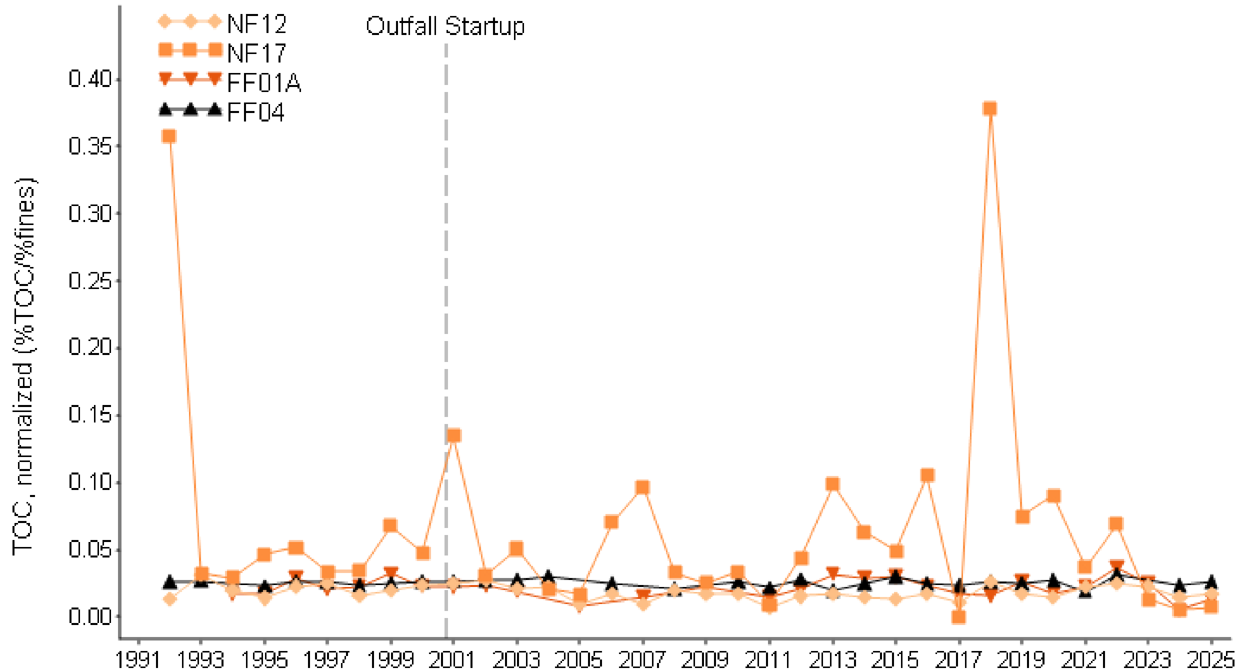

Figure 3-6. Normalized mean concentrations of TOC at four stations in Massachusetts Bay, 1992 to 2025.

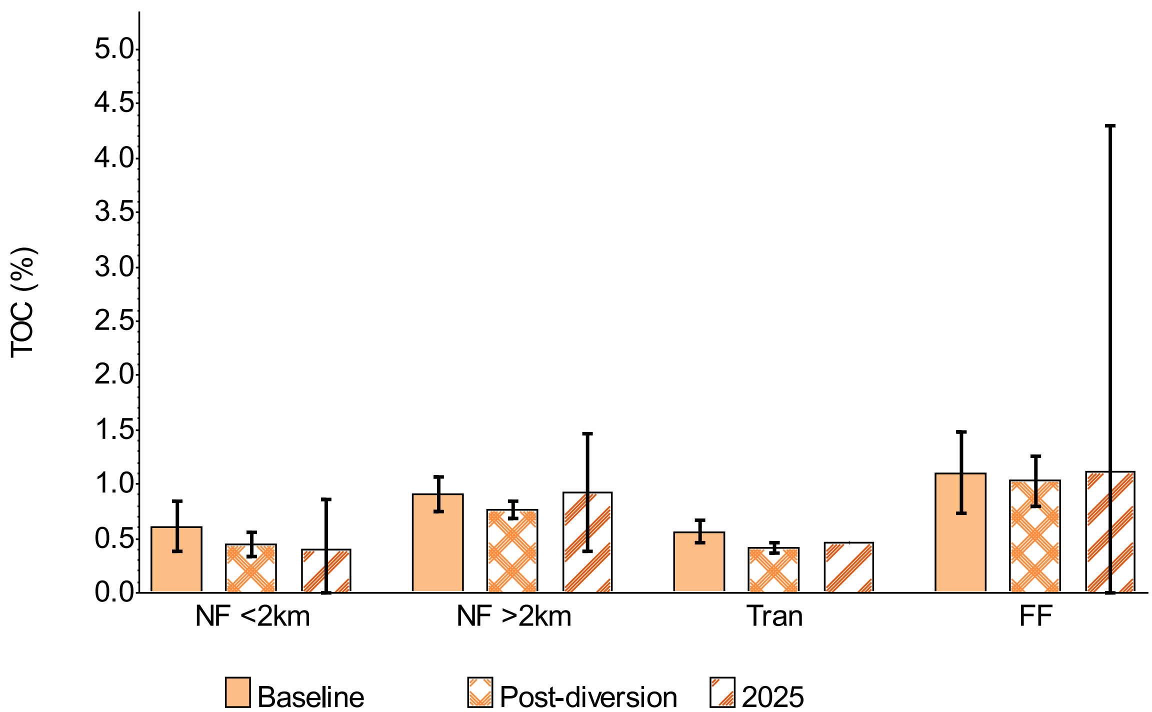

Figure 3-7. Mean (with 95% confidence intervals) concentrations of TOC at four areas in Massachusetts Bay during the baseline (1992-2000) and post-diversion (2001 to 2024) compared to 2025.

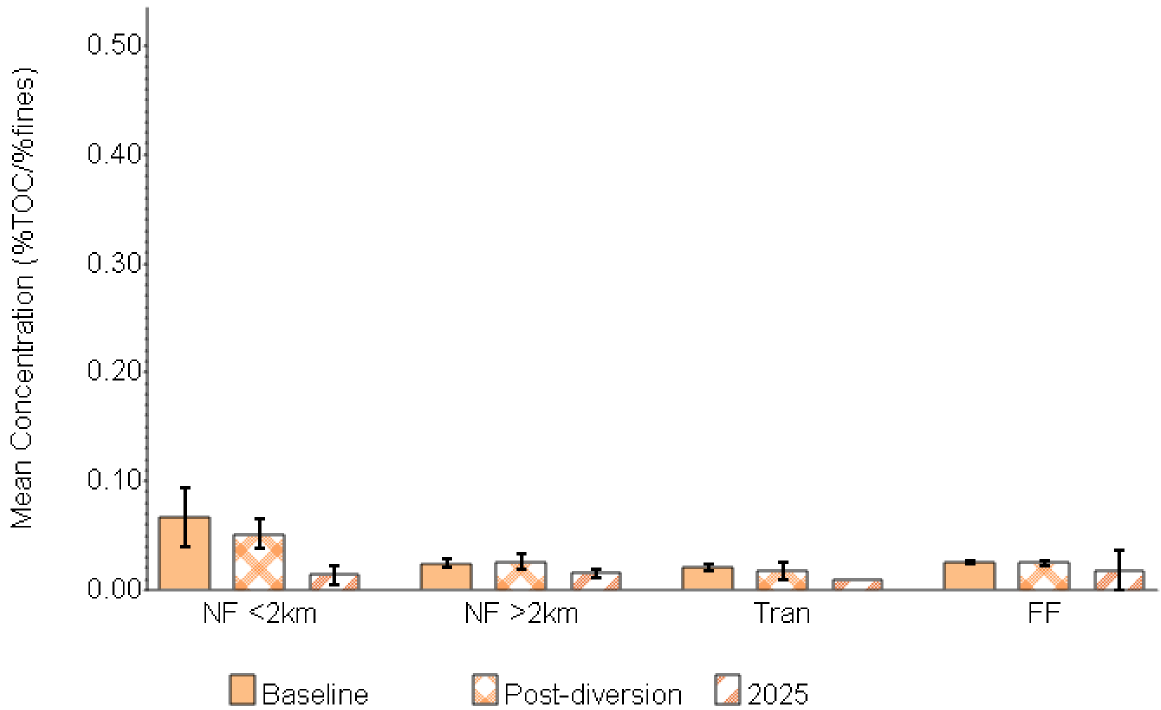

Figure 3-8. Normalized mean (with 95% confidence intervals) concentrations of TOC at four areas in Massachusetts Bay during the baseline (1992 to 2000) and post-diversion (2001 to 2024) periods compared to 2025. Tran=Transition; NF<2km=nearfield, less than two kilometers from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield.

3.2 BENTHIC INFAUNA

3.2.1 Community Parameters

A total of 19,123 infaunal organisms were counted from the 14 samples (one sample per station) in 2025. Organisms were classified into 184 discrete taxa; 157 of those taxa were species-level identifications. The abundance values reported herein reflect the total counts from both species and higher taxonomic groups, while all diversity measures and multivariate analyses are based on the species-level identifications only (Table 3-2).

Table 3-2. Monitoring results for infaunal community parameters in 2025.

Monitoring Area	Station	Total Abundance (per grab)	Number of Species (per grab)	Log-series alpha	Shannon-Wiener Diversity (H′)	Pielou's Evenness (J')
Nearfield (<2 km from outfall)	NF13	1524	71	15.79	4.84	0.79
	NF14	1484	60	12.65	4.13	0.70
	NF17	768	57	14.31	3.97	0.68
	NF24	2368	52	9.41	3.31	0.58
Nearfield (>2 km and <5 km from outfall)	NF04	711	60	15.78	4.51	0.76
	NF10	1434	53	10.90	3.76	0.66
	NF12	1006	48	10.53	3.95	0.71
	NF20	1963	61	12.00	3.60	0.61
	NF21	1637	54	10.80	4.01	0.70
	NF22	1644	48	9.27	3.54	0.63
Transition (~ 8 km from outfall)	FF12	1706	42	7.80	3.53	0.65
Farfield (>13 km from outfall)	FF01A	1242	58	12.77	3.90	0.67
	FF04	471	32	7.77	3.31	0.66
	FF09	1165	66	15.54	4.47	0.74

Total abundance values in 2025 were lower than the 2024 values in both nearfield and farfield areas except for those stations within two km of the discharge (Figure 3-9). The numbers of species per sample in 2025 were higher than in 2024 in all areas, with the sharpest increases at the nearfield < 2km and transition areas (Figure 3-10). However, species richness continues to be low at the transition area (Station FF12; 42 species). Shannon-Wiener Diversity (H’) and Pielou’s Evenness (J’) values were higher in 2025 compared to the previous year at the nearfield stations and were within the range of historical variability (Figures 3-11 and 3-12). The spionid polychaete *Prionospio steenstrupi* was the historical dominant from 1997 to 2005, when abundance of this species was considerably higher than all other dominant taxa. *P. steenstrupi* abundance has remained well below these levels from 2007 to 2025 (Figure 3-13). Nonetheless, this species remained among the top dominant taxa, along with other historically dominant polychaetes such as *Aricidea catherinae* and *Mediomastus californiensis* (Figure 3-13).

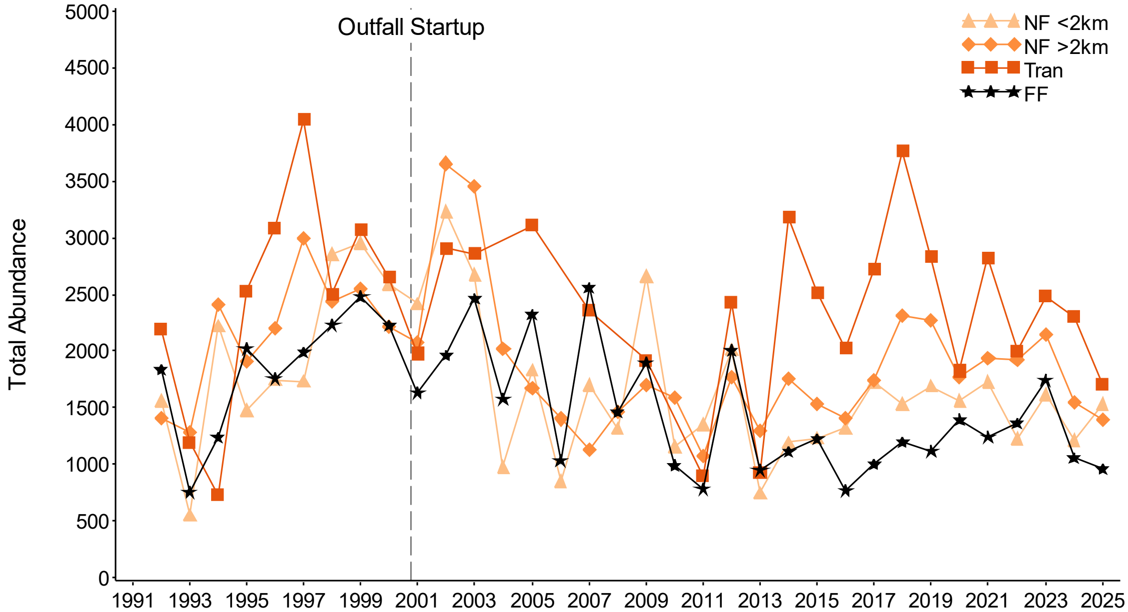

Figure 3-9. Mean infaunal abundance per sample at four areas of Massachusetts Bay, 1992 to 2025. Tran=Transition; NF<2km=nearfield, less than two kilometers from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield.

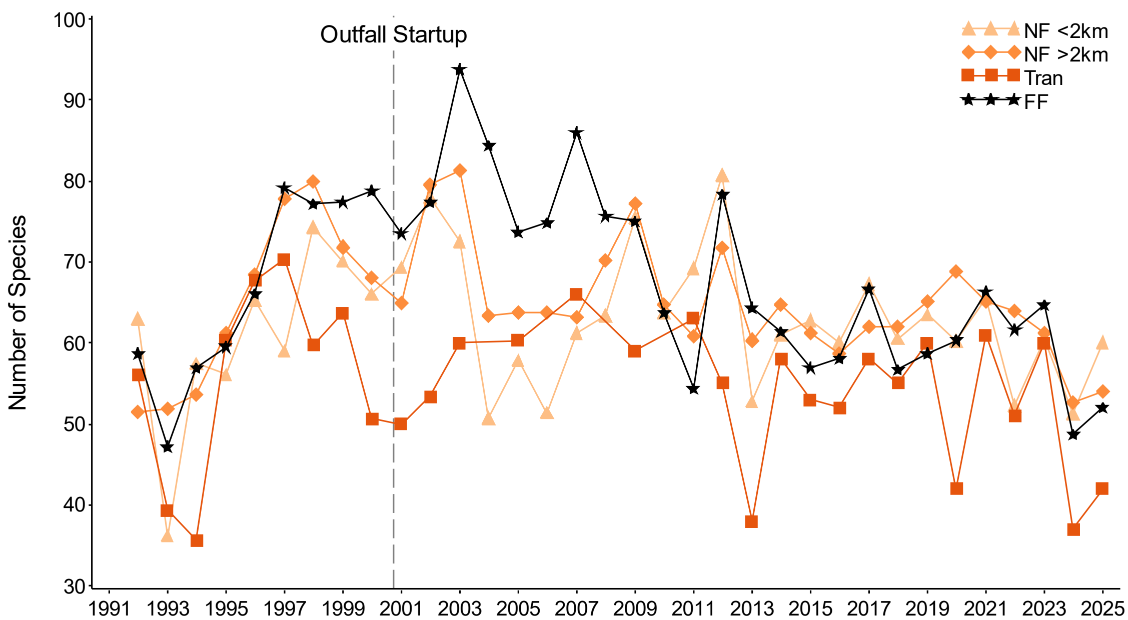

Figure 3-10. Mean number of species per sample at four areas of Massachusetts Bay, 1992 to 2025. Tran=Transition; NF<2km=nearfield, less than two kilometers from the outfall; NF>2km=nearfield, more than two kilometers from the outfall; FF=farfield.

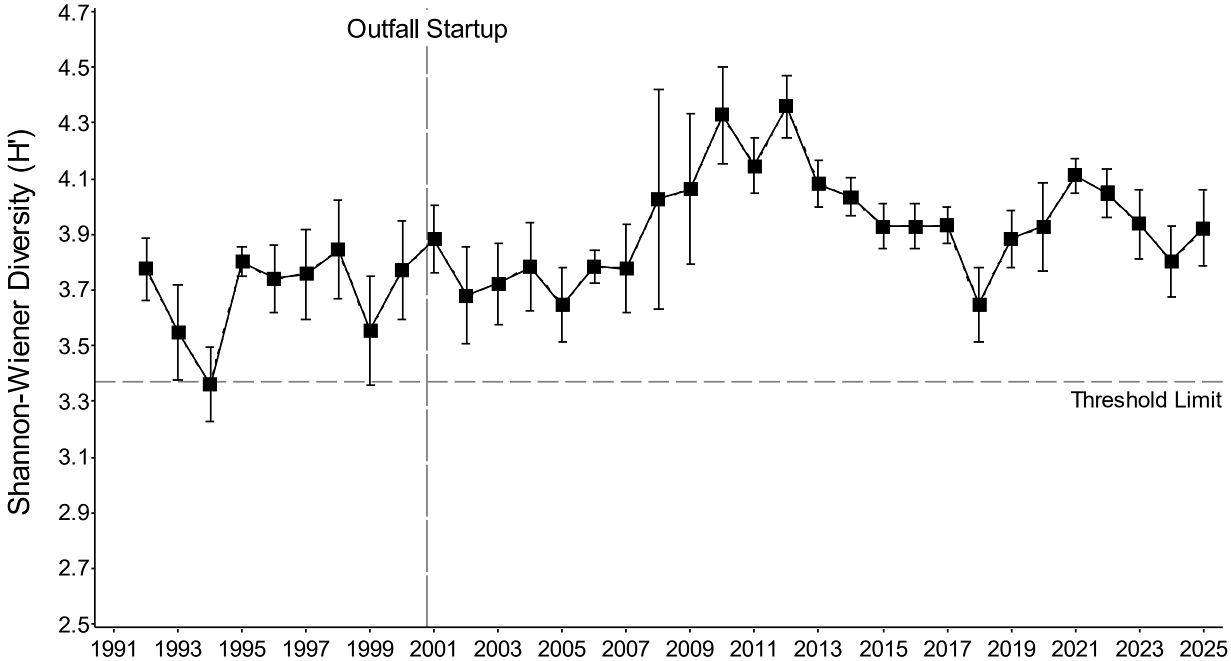

Figure 3-11. Mean (and 95% confidence intervals) Shannon-Wiener Diversity (H′) at nearfield stations in comparison to threshold limit, 1992 to 2025.

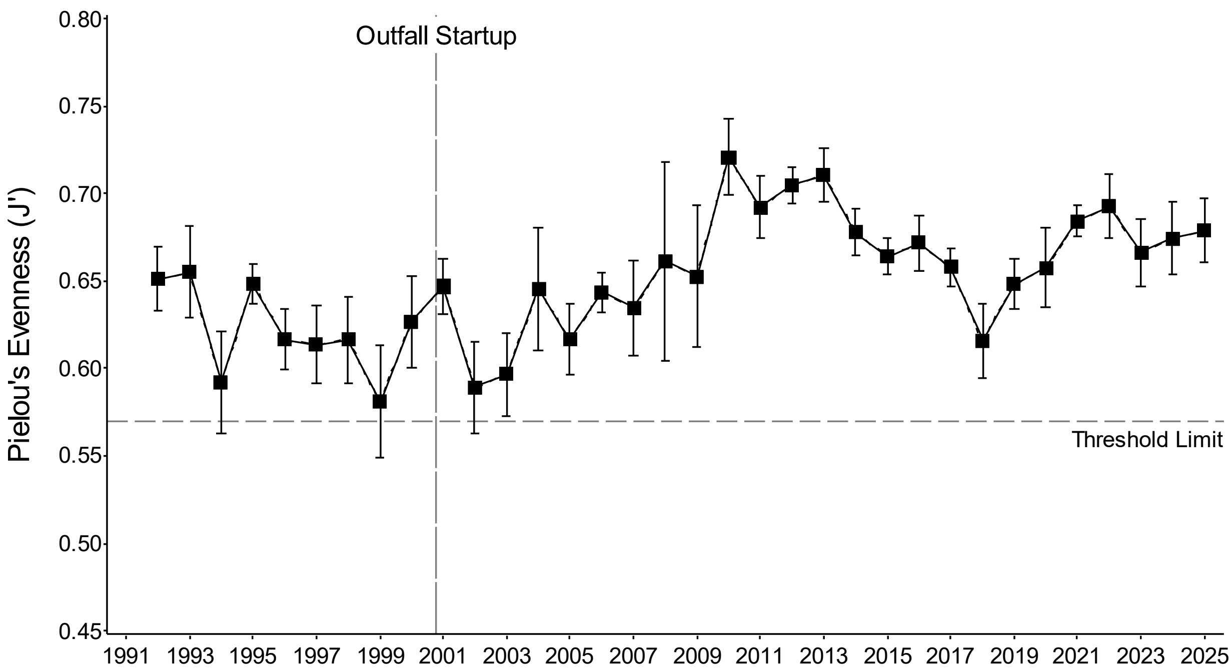

Figure 3-12. Mean (and 95% confidence intervals) Pielou's Evenness (J′) at nearfield stations in comparison to threshold limit, 1992 to 2025.

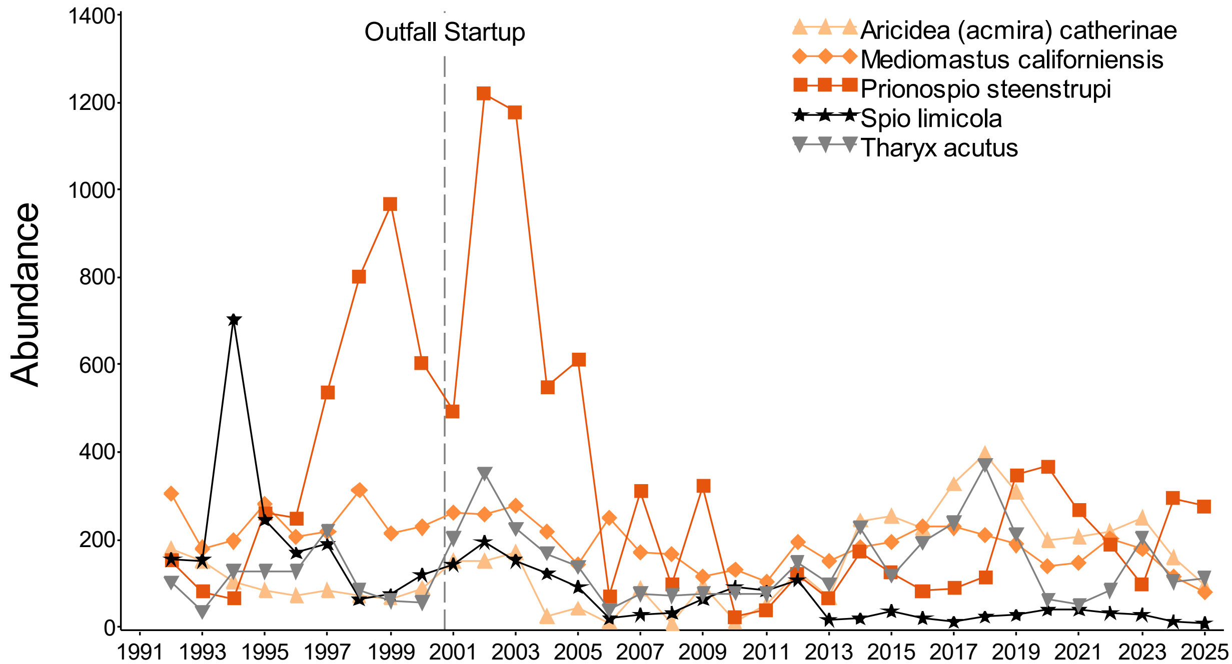

Figure 3-13. Mean abundance from 1992 to 2025, of the five numerically dominant taxa at nearfield stations in Massachusetts Bay.

There were no Contingency Plan threshold exceedances for any infaunal diversity measures in 2025 (Table 3-3). Spatial and temporal patterns of abundance, species richness, species diversity and evenness generally support the conclusion that there is no evidence of negative impacts caused by operation of the offshore outfall.

Table 3-3. Infaunal monitoring Contingency Plan threshold results, August 2025 samples.

Parameter	Thresholds*		Result	Exceedance?
	Value	Limit		
Total species	42.99	Low	55.09	No
Log-series Alpha	9.42	Low	11.75	No
Shannon-Weiner H′	3.37	Low	3.92	No
Pielou's J'	0.57	Low	0.68	No
Percent opportunists	10% (Caution)	High	0.05%	No
Percent opportunists	25% (Warning)	High	0.05%	No

*Threshold exceedances occur when current year results are below threshold values for a "low" limit or above the values for a "high" limit for a given parameter.

3.2.2 Infaunal Assemblages

Multivariate analyses based on Bray-Curtis Similarity were used to assess spatial patterns in the faunal assemblages at the Massachusetts Bay sampling stations. Two main assemblages (Groups I and II) and outlier farfield station FF04 were identified in a cluster analysis of the 14 samples from 2025 (Figure 3-14). The groups were distinguished based on species composition and the relative abundances of each taxon in the samples. Clear differences in the mean abundances of dominant taxa were identified. Despite varying faunal composition in terms of both the species present and their abundances, all 2025 assemblages were dominated by polychaetes except for Group I which dominated by an amphipod. Assemblages in 2025 were similar to those reported for previous years. The Group I assemblage comprised three Nearfield stations (NF17, NF04, and NF13); the Group II assemblage included two sub-assemblages, Group IIA and Group IIB, and the farfield stations FF01A and FF09 as outliers (Figure 3-14). The Group IIA and IIB assemblages were found at stations with mixed sediments, including sand and fine materials. Stations FF01A and FF09 each supported unique assemblages, reflecting change in the faunal community with increasing depth and habitat type. Bottom depth at Station FF01A is similar to the nearfield stations (35 meters or less), but with more sand and lower percent fines than almost all other stations within the Group II assemblage. Station FF09 is approximately 50 meters in depth, deeper than all other stations in Group II. Station FF04 which was not within either Group I or II is the deepest station at about 90 meters with the highest level of percent fines (nearly 100%).

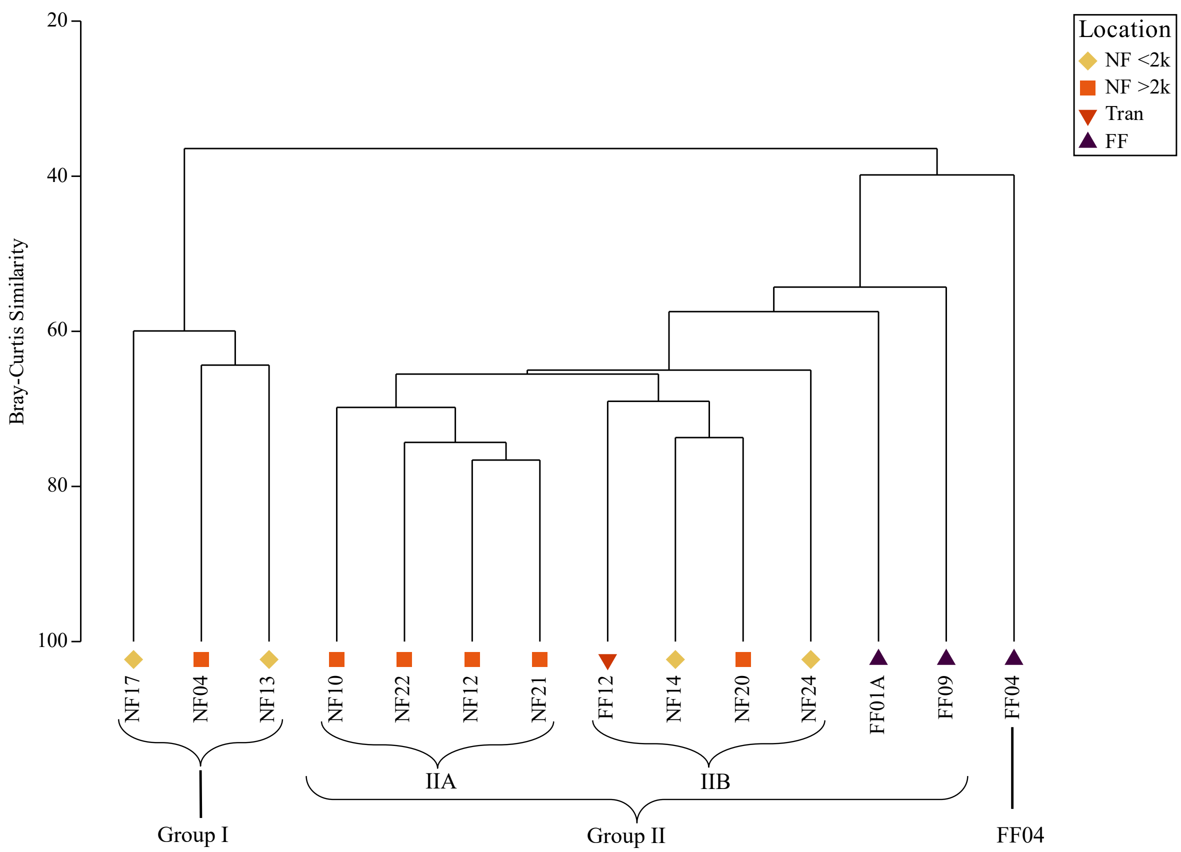

Figure 3-14. Results of cluster analysis of the 2025 infauna samples.

Table 3-4. Abundance (mean # per grab) of numerically dominant taxa (10 most abundant per group) composing infaunal assemblages identified by cluster analysis of the 2025 samples.

Family	Species	Group I	Group II				Outlier
		I	IIA	IIB	FF01A	FF09	FF04
Annelida (Polychaeta)							
Ampharetidae	*Anobothrus gracilis*	-	1.8	1.3	-	21.0	16.0
Capitellidae	*Mediomastus californiensis*	7.0	99.8	97.3	59.0	29.0	9.0
Cirratulidae	*Chaetozone anasimus*	6.7	-	-	-	1.0	185.0
	Kirkegaardia baptisteae	13.7	108.0	78.5	33.0	-	-
	Kirkegaardia hampsoni	1.7	61.5	56.3	75.0	-	-
	Tharyx acutus	15.3	104.5	191.8	25.0	68.0	17.0
Cossuridae	*Cossura longocirrata*	-	13.0	1.5	-	4.0	77.0
Lumbrineridae	*Ninoe nigripes*	-	43.3	29.0	22.0	24.0	26.0
Nephtyidae	*Aglaophamus circinata*	18.3	-	2.0	36.0	1.0	-
Orbiniidae	*Leitoscoloplos acutus*	-	53.0	21.3	17.0	15.0	5.0
Paraonidae	*Aricidea (acmira) catherinae*	33.3	80.0	160.8	83.0	23.0	-
	Aricidea (strelzovia) quadrilobata	-	8.5	0.3	1.0	24.0	24.0
	Levinsenia gracilis	2.0	339.0	185.3	74.0	152.0	26.0
Phyllodocidae	*Phyllodoce mucosa*	32.0	13.5	44.3	11.0	2.0	-
Sabellidae	*Euchone incolor*	3.0	115.5	63.5	48.0	63.0	15.0
Spionidae	*Prionospio steenstrupi*	16.7	164.0	581.3	402.0	163.0	12.0
	Spiophanes bombyx	51.3	1.8	34.5	61.0	-	-
Syllidae	*Parexogone hebes*	82.3	1.3	26.3	2.0	9.0	-
Trichobranchidae	*Terebellides atlantis*	-	1.3	2.0	1.0	34.0	7.0
Annelida (Oligochaeta)							
Enchytraeidae	*Marionina welchi*	49.3	-	-	-	-	-
Arthropoda (Amphipoda)							
Corophiidae	*Crassicorophium crassicorne*	105.3	-	-	-	-	-
Unciolidae	*Pseudunciola obliquua*	64.0	-	0.3	-	-	-
Arthropoda (Tanaidacea)							
Tanaissuidae	*Tanaissus psammophilus*	34.0	0.3	-	-	-	-
Mollusca (Bivalvia)							
Cardiidae	*Parvicardium pinnulatum*	23.7	-	1.3	55.0	7.0	-
Mytilidae	*Crenella decussata*	39.0	-	7.0	-	69.0	-
Nuculidae	*Ennucula delphinodonta*	31.0	27.5	46.0	42.0	126.0	3.0
Periplomatidae	*Periploma papyratium*	-	11.3	11.0	3.0	25.0	2.0
Thyasiridae	*Thyasira gouldii*	-	2.3	0.3	2.0	34.0	2.0
Chordata (Tunicata)							
Molgulidae	*Molgula manhattensis*	41.7	-	-	-	-	-

Dominant taxa in Group I included the amphipod *Crassicorophium crassicorne* and polychaetes *Parexogone hebes* and *Spiophanes bombyx* (Table 3-4). All three stations at which the Group I assemblage was found were characterized by sandy sediments (Table 3-4, Figure 3-3). The two Group II subassemblages and two outliers could be differentiated by species composition and total abundance, that occurred along gradients in habitat type. Group IIA was dominated by the polychaetes *Levinsenia gracilis*, *Prionospio steenstrupi*, and *Euchone incolor*. Group IIB was dominated by the polychaetes *Prionospio steenstrupi*, *Tharyx acutus, and L. gracilis*. Groups IIA and IIB were found at stations characterized by mixed sediments (Table 3-4, Figures 3-3 and 3-16). The Group IIA assemblage was found at stations with more silt and clay than stations where Group IIB was found (Table 3-4, Figure 3-3). Stations FF01A and FF09 contain sandy sediment with some fines. Station FF01A was separated by the presence of the polychaete *Kirkegaardia hampsoni*, while Station FF09, a relatively deep farfield station, was separated by the presence of the bivalve *Ennucula delphinodonta.* The deepest station, Station FF04, was characterized by a high percentage of fine sediments, and an infaunal assemblage with low abundances and species richness (Table 3-4, Figure 3-3). Dominant species at Station FF04 (e.g., *Chaetozone anasima* and *Aricidea (stretzovia) quadrilobata*) are characteristic of the soft sediment community observed throughout Stellwagen Basin (e.g., Maciolek et al. 2008).

Both main assemblages occurred at the four stations within two kilometers of the discharge; and those assemblages were also found at stations more than two kilometers from the discharge (Figures 3-14 and 3-15). Thus, stations closest to the discharge were not characterized by a unique faunal assemblage reflecting effluent impacts. Comparisons of faunal distribution to habitat conditions indicated that patterns in the distribution of faunal assemblages follow differences in habitat types at the sampling stations (e.g. depth and sediment type).

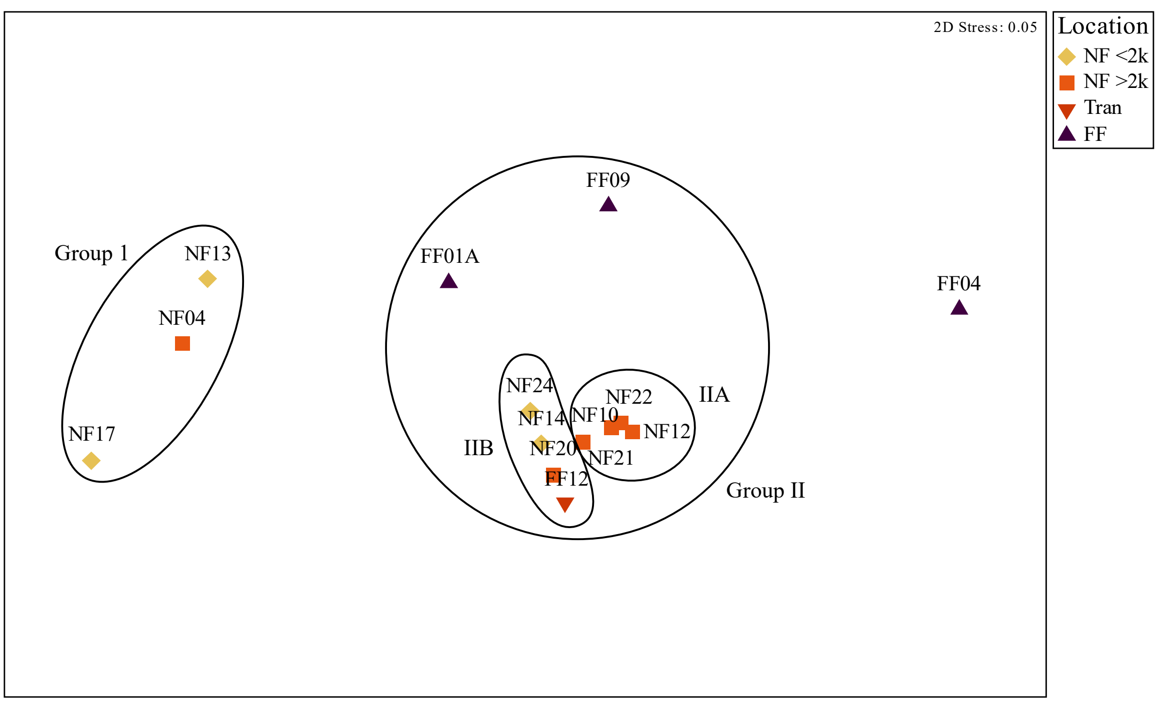

Figure 3-15. Results of a nMDS ordination of the 2025 infauna samples from Massachusetts Bay showing distance from the outfall.

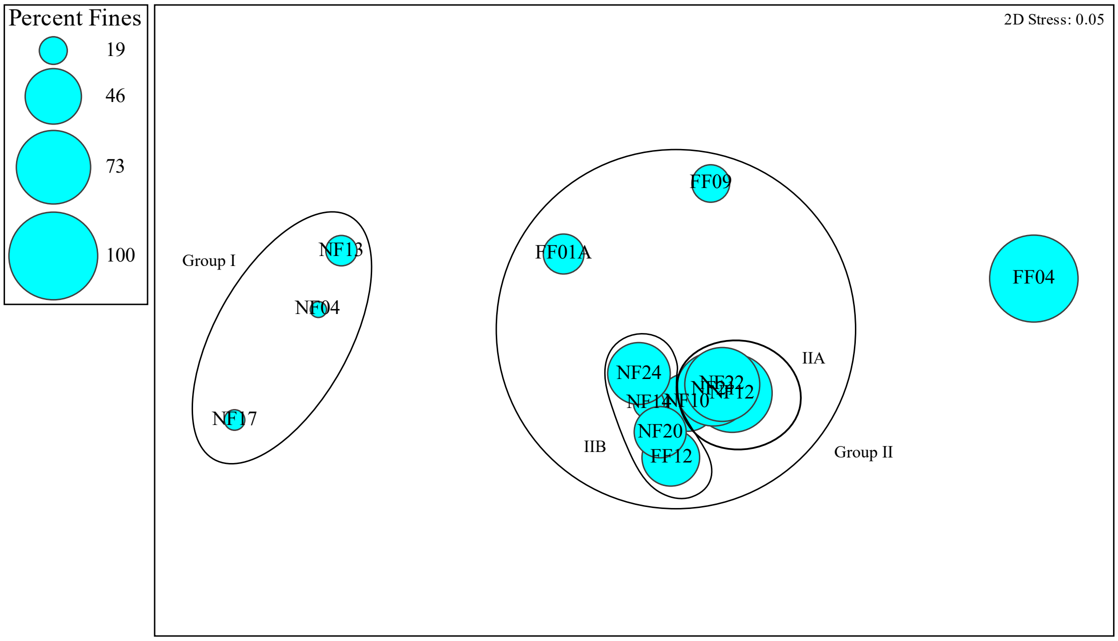

Figure 3-16. Percent fine sediments superimposed on the nMDS ordination plot of the 2025 infauna samples. Each point on the plot represents one of the 14 samples; similarity of species composition is indicated by proximity of points on the plot. Faunal assemblages (Group I, Group II, and sub-groups) identified by cluster analysis are circled on the plot. The ordination and cluster analysis are both based on Bray-Curtis Similarity.

Patterns identified in these analyses were highly consistent with previous years. No evidence of impacts from the offshore outfall on infaunal communities in Massachusetts Bay was found. The outfall is located in an area dominated by hydrodynamic and physical factors (e.g., tidal and storm currents, turbulence, and sediment transport; Butman et al. 2008). These factors combined with the high quality of the effluent discharged into the Bay (Taylor 2010, Werme et al. 2021), are the principal reasons that benthic habitat quality has remained high in the nearfield area. Previous assessments have indicated that changes in the benthic habitat quality and infaunal communities in the nearfield are related to physical processes associated with increased storminess (Nestler et al. 2020).

Multivariate analyses were also used to assess temporal patterns in the faunal assemblages at four Massachusetts Bay sampling stations. Samples from 1992 to 2025 at stations NF17, NF24, FF01A, and FF04, were analyzed using Bray-Curtis Similarity and an nMDS ordination (Figure 3-17). Relatively high levels of similarity over time among samples collected from each station were found. Characteristic assemblages were unique to each of the four stations analyzed; those assemblages appeared relatively stable over time (Figure 3-17). This analysis provided confirmation that the faunal assemblages in samples collected during 2025 were very similar to those that have been found in previous years.

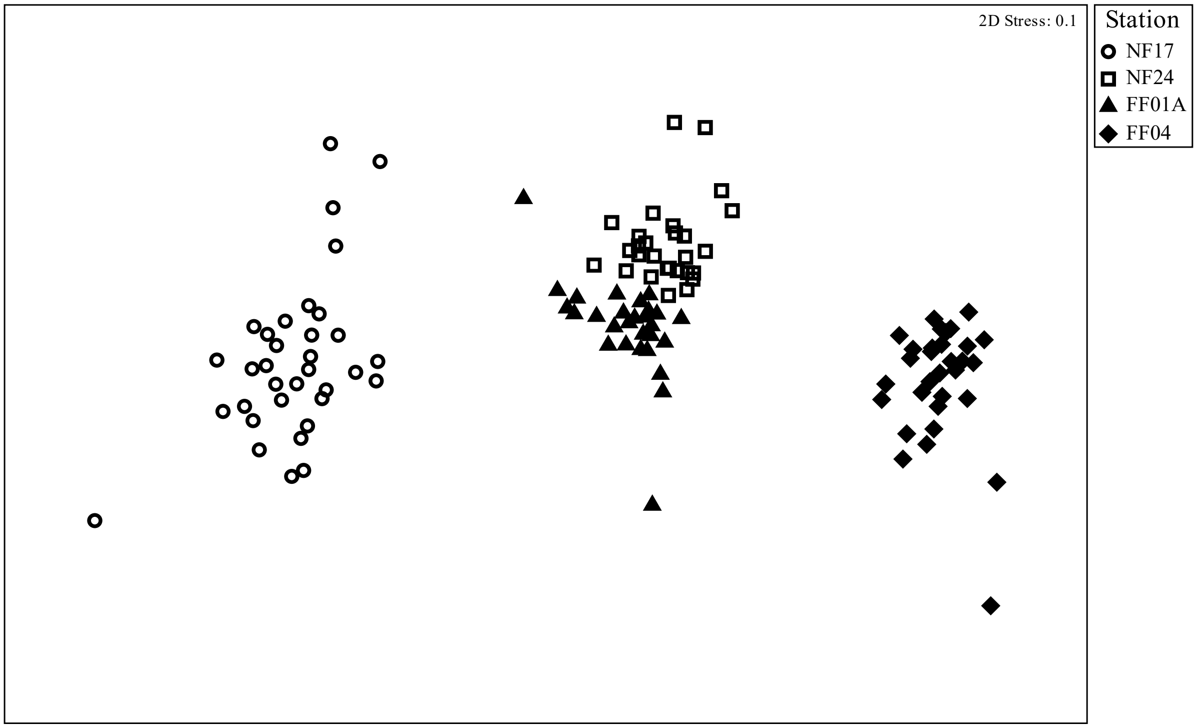

Figure 3-17. Results of an nMDS ordination of the infauna samples from 1992 to 2025 at stations NF17, NF24, FF01A, and FF04. Each point on the plot represents a sample; similarity of species composition is indicated by proximity of points on the plot. The ordination is based on Bray-Curtis Similarity.

4 SUMMARY OF RELEVANCE TO MONITORING OBJECTIVES

Benthic monitoring for MWRA's offshore ocean outfall 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.

Findings from previous assessments found no indication that the wastewater discharge has resulted in low levels of dissolved oxygen or the accumulation of toxic contaminants in nearfield sediments (Nestler et al. 2025, Nestler et al. 2020, Maciolek et al. 2008). As result, SPI surveys in Massachusetts Bay and the sediment contaminant evaluation every third year at the nearfield and farfield stations were discontinued in 2020.

Surveys of soft-bottom benthic communities presented in this report continue to suggest that animals near the outfall have not been smothered by particulate matter from the wastewater discharge or experienced stress resulting from increased deposition of organic matter. The percentage of fine grain sediments has not increased at stations closest to the discharge since the diversion, indicating no pattern of settlement of particulate matter from the discharge. There were no Contingency Plan threshold exceedances for any infaunal diversity measures in 2025.

Hard-bottom benthic community monitoring in 2023 also found no evidence that particulate matter from the wastewater discharge has smothered benthic organisms (Goode et al. 2024). Although some changes in this community (e.g., decreased coralline algae, temporal variability in upright algae cover, decreased sponge abundance, and increases in barnacle settlement events) have been observed, comparisons between the post-diversion and baseline periods indicate that these changes are not substantial (Goode et al. 2024). These changes may reflect natural variability in the benthic communities from multi-year population cycles and interspecies competition or may represent other environmental shifts.

Benthic monitoring results continued to indicate that the three potential impacts of primary concern have not occurred at the MWRA stations. Results also continue to demonstrate that the benthic monitoring program can detect both the influence of the outfall and the subtle natural changes in benthic communities. The spatial extent of particulate deposition from the wastewater discharge is measurable in the *Clostridium perfringens* concentrations in nearfield sediments. The *C. perfringens* concentrations provide evidence of the discharge footprint at stations close to the outfall. Within this footprint, no other changes to sediment composition and infaunal communities have been detected. Patterns identified in analyses of sediments and infauna in 2025 were largely consistent with previous years. Nonetheless, subtle variations in the species composition of infaunal assemblages clearly delineate natural spatial variation in the benthic community based on habitat (e.g., associated with different sediment grain sizes) and bottom energy (e.g., turbulence and sediment transport associated with storm events). Changes over time have also been detected including region-wide shifts in diversity, with peaks from 2010 to 2012, in the Massachusetts Bay infaunal assemblages. Detection of these spatial and temporal patterns in the benthos suggests that any ecologically significant adverse impacts from the outfall would be readily detected by the monitoring program if those impacts had occurred.

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