Benthic Infaunal Communities and Sediment Properties in Pile Fields within the Hudson River Park Estuarine Sanctuary

Final report to:
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INTRODUCTION

A core mission of the NY-NJ Harbor & Estuary Program, along with the Hudson River Foundation, is to advance research to facilitate the restoration of more, and better quality, habitat. In urban estuaries such as the NY-NJ Harbor Estuary, restoring shorelines and shallow waters to their natural or pre-industrial state is not an option in most cases because human activities have extensively modified the shorelines since the time of European contact (Squires 1992). Therefore, organizations that work to restore habitat need to dig deeper to find out what creates the most desirable habitat for estuarine wildlife.

Pile fields are legacy piers that have lost their surfaces and exist as wooden piles sticking out of the sediment. Pile fields have been extolled as good habitat for fish. It is even written into the Hudson River Park Estuarine Sanctuary Management Plan that the Hudson River pile fields must be maintained for their habitat value. There is no definitive answer, however, as to why and how fish and other estuarine organisms use the pile fields. The project and results described in this report address a small portion of that larger question by assessing if the structure of the benthic community may have some bearing on how the pile fields are used as habitat. Benthic infauna, the invertebrates living in bottom sediments, were the focus of this project. The composition of the benthic infaunal community (the species and their abundances) depends on physical, chemical, and biological characteristics of the environment, especially the properties of the sediment they inhabit. Therefore, basic physical (grain size) and chemical (total carbon, nitrogen, phosphorus concentrations) sediment properties were also measured. The presence of pile fields may affect these sediment properties, for example by altering currents and the deposition or erosion of sediment, which in turn could affect benthic community composition.

METHODS

<u>Sampling and laboratory analyses</u>

Seven pile fields along the western waterfront of Manhattan were sampled. Samples were collected at two positions along a transect extending at a right angle from the shoreline, 'near' (pre-sampling target distance 50 m from shore) and 'far' (target distance 200 m from shore).

At each of the seven pile fields, samples were also collected at a control location approximately 100 m from the pile field stations. These controls samples were also positioned along a transect at right angles to the shore.

Surface and bottom water salinity, temperature, dissolved oxygen concentration, and pH at each location was measured with a YSI hand-held meter (Yellow Springs Instruments Professional Plus, Yellow Springs, OH).

Sediment samples at each location were taken using a 0.04-m^2 Ted Young Modified Van Veen grab (US EPA 1995, 2001). One grab at each location was taken for invertebrate macrofauna analysis. Sediment from these grabs was immediately sieved over a 0.5-mm-mesh screen. Water for sieving was supplied by a submersible pump deployed just below the surface at each sampling location. The material remaining on the screen was fixed in 3.7% formaldehyde solution in seawater, buffered with sodium borate and containing Rose Bengal to stain organisms. Benthic infauna samples were shipped to Cove Corporation (Lusby MD), where they were sorted and identified to the lowest practical identification level, usually the species level. If fragments of animals were present, only fragments that included the anterior part of the animal were counted. Validity of each species identified was checked against the continuously updated list in the World Register of Marine Species (WoRMS, http://www.marinespecies.org/index.php) to bring species names up to date with their current taxonomic status for consistency with currently acceptable standards (International Code of Zoological Nomenclature), thus facilitating future analyses of the benthic data, and allowing for cross study comparisons. Certain invertebrates that were unlikely to be fully sampled using the 0.5-mm-mesh screen used for this study (e.g., oligochaetes) were generally identified to the phylum or class level.

A second Van Veen grab at each location was taken for sediment properties (see below). The top 2-cm layer of sediment from these grabs was transferred to a stainless steel bowl, homogenized by stirring with a stainless steel spoon for 10 minutes (US EPA 2001), and 500 mL of the homogenized sediment transferred to a Whirl-Pak bag and stored on ice during transport to the laboratory. All sampling equipment was rinsed between samples with surface water from the submersible pump.

Sediment grain size was determined as described in detail in the EMAP-Estuaries Laboratory Methods Manual (US EPA 1995). Sediment was first treated with 10% hydrogen peroxide solution to disaggregate mineral-organic matter aggregates, then wet-sieved through a 63-µm-mesh sieve in distilled water with dispersant (10% sodium hexametaphosphate solution) to separate the silt and clay fraction (<63 µm) from the sand-sized fraction. Silt and clay mass was determined by drying a known volume of the water-particle mixture passing through the sieve and correcting for the mass of dispersant in the sample volume. The sand fraction was dried and then sieved into the following size fractions: 63–125 µm (very fine sand), 125–250 µm (fine sand), 250–500 µm (medium sand), 500–1000 µm (coarse sand), 1000–2000 µm (very coarse sand), >2000 µm (gravel). Each fraction was weighed and grain size statistics computed using the United States Geological Survey software program GSSTAT (Poppe et al. 2004).

Sediment for measurement of chemical properties was air-dried and homogenized with an agate mortar and pestle. Total volatile solids concentration was measured as mass loss after combustion at 500° for 5 h. Total carbon, total nitrogen, and total phosphorus concentrations of sediment were measured using standard methods (elemental analysis EPA Method 440.0 for total C and N (US EPA 1992), colorimetric analysis of total phosphate for P (US EPA 2010, chapter 6)).

<u>Data analyses</u>

Data analyses were performed using Statistix 10 (Analytical Software, Tallahassee, FL) for univariate measures and Primer 6.1.16 (Primer-E Ltd, Plymouth, UK) for multivariate measures. Prior to principal component analysis, environmental variables (e.g., water column properties, sediment chemical and physical properties) were normalized (subtracting the mean for each value and dividing by the standard deviation for that variable). Multivariate analyses of benthic infauna were based on square-root transformed Bray-Curtis similarity matrices of per-grab species abundances. Hierarchical cluster analysis was based on group average clustering. Nonmetric multidimensional scaling was used to compare with the cluster analysis. Stations were assumed to belong to different clusters if the probability level was <5% from a similarity permutation test (Clarke et al. 2008). When dissimilar station groups were identified the relative contributions of infaunal species to the dissimilarity were evaluated with a similarity percentage test (Clarke 1993).

Benthic infauna data were used to compute the Multivariate AZTI Marine Biotic Index (M-AMBI) (Borja et al. 2012) (Muxika et al. 2007) for each station. This index is based on the proportions of benthic macroinvertebrates that fall into one of five Ecological Groups, based on their tolerance or response to organic enrichment: sensitive, indifferent, tolerant, second-order opportunists, and first-order opportunists. The assignments of species to these Ecological Groups was based on the November 2014 species list in the software program. These Ecological Groups are described by Grall and Glémarec (1997) as:

"Group 1: Species very sensitive to organic enrichment and present in normal conditions.
Group 2: Species indifferent to enrichment, always present in low densities with non-significant variations in time.
Group 3: Species tolerant of excess organic matter enrichment. These species may occur in normal conditions but their populations are stimulated by organic enrichment.

Group 4: Second-order opportunistic species. These are the small species with a short life cycle, adapted to a life in reduced sediment where they can proliferate.
Group 5: First-order opportunistic species. These are the deposit feeders that proliferate in sediments reduced up to the surface."
The M-AMBI value categorizes a site into one of five classes: bad, poor, moderate, good, or high.

RESULTS and DISCUSSION

Spatial relationships between Pile Field and Control locations

Because of field conditions some adjustments in station locations were necessary (Figure 1). In particular, tidal currents, tide stage, and wind conditions required the boat captain to maintain safe distances from nearby structures, while still keeping as close as possible to the pre-designated sampling coordinates (actual station coordinates in Appendix 1). The actual distances from shore for the 'near' stations were greater than the target distances, while most of the 'far' stations were less distant than the targets (Table 1). The distance between pile field and control samples varied from 70 to 170 m (Table 2). For six of the seven locations the control samples were nearer the corresponding pile field than to another existing structure.

Water column properties

Differences between surface and bottom water properties, and between pile field and control locations, were slight (all data in Appendix 1, summary in Table 3). Dissolved oxygen concentrations were ≥6.1 mg L^{-1}, pH was approximately 7.5, salinity 23—25, and temperature approximately 19. A qualitative comparison of the water properties is given here.

	Controls vs. Pile Fields	Surface vs. bottom	'Near' vs 'far'
Dissolved oxygen	Slightly greater in Pile Fields	Slightly greater at surface	Slightly greater farther from shore
pH	No difference	No difference	No difference
Salinity	Slightly greater in Pile Fields	Greater at bottom	No difference
Temperature	No difference	Slightly greater at surface	No difference

This indicates that at the time of sampling the water column was well mixed both vertically and horizontally on the spatial scales in Tables 1 and 2.

Principal component analysis of the normalized water properties showed that 84% of the variation among locations was explained by the first two components (Figure 2). No consistent groupings of sample locations was evident, as would be expected given the short gradients in the variables.

Sediment properties

Concentrations of total C, N, P, and volatile solids were consistently greater at pile fields relative to controls (all data in Appendix 2, summary in Table 4). Except for total volatile solids, concentrations were also greater at locations nearer the shoreline. Silt-sized particles made up 76—92% of sediment mass, and were more abundant at pile fields and near shore. Somewhat paradoxically, however, sediments at pile fields and near shore were better sorted. A qualitative comparison of the sediment properties is given here.

	Controls vs. Pile Fields	'Near' vs 'far'
% TVS	Greater at Pile Fields	No difference

% N	Greater at Pile Fields	Greater near shore
% C	Greater at Pile Fields	Greater near shore
	<u>Controls vs. Pile Fields</u>	<u>'Near' vs 'far'</u>
% P	Greater at Pile Fields	Greater near shore
% gravel	No difference	Greater far from shore
% sand	Greater at Controls	Greater far from shore
% silt	Greater at Pile Fields	Greater near shore
IGSD	Better sorted at Pile Fields	Better sorted near shore
Skewness (grain-size distributions)	More coarsely skewed at Controls	No difference
Kurtosis	No difference	No difference

Principal component analysis of the normalized sediment properties showed that 85% of the variation among locations was explained by the first two components (Figure 3). Percentages of silt, total C, total N, and total volatile solids were tightly correlated with each other, while total P was essentially uncorrelated with any other chemical property. Locations at the southern end (locations 1, 2, 3 in Figure 1) tended to align with higher concentrations while those at the northern end (locations 6 and 7) were associated with lower concentrations.

<u>Benthic infauna</u>

A total of 11076 individuals from 71 taxa were collected (Appendix 2). Ten taxa accounted for 90% of the total abundance (Table 5), with three of these accounting for nearly 75%. At the higher, Class level of taxonomy, Polychaeta were the numerical dominants accounting for 75% of all individuals (Figure 5), followed by Gastropoda (11.4%), Clitellata (8.4%), Bivalvia (2.1%), Palaeonemertea (1.5%), Malacostraca (1.3%), and "others" (Ascidiacea, Anopla, Anthozoa, Enopla, Pycnogonida, Holothuroidea, Rhabditophora, 0.4%).

Rarefaction curves show the relationships between numbers of individuals and numbers of species in a sample. Rarefaction curves readily convey four types of information: the total abundance of individuals; species richness (total number of species); species richness expected for a given number of individuals; and whether the sampling effort was adequate to have collected most of the species likely present in the environment. The expected number of species for a given number of individuals were 'back-calculated' using Hurlbert's expected number of species formula (Hurlbert 1971). The near-shore pile field station at location 5 had the lowest total abundance (65 per grab) and the lowest species richness (14) of any sample (Figure 6). The most individuals (807 per grab) were collected at the far control station at location 7 while the near pile field station at location 4 and the far control station at location 2 had the most species (35). For all stations considered together there were no consistent differences in rarefaction curves of control and pile field stations. At some locations (e.g., location 2), rarefaction curves were clearly ascending indicating that one grab was inadequate to fully sample the community, while at other locations (e.g., location 7) there was better evidence that an asymptote was being approached.

The importance of the size of grab used to sample the benthos was evident when comparing the present results to prior sampling along the West Manhattan waterfront. Sampling in 2014 (e4sciences-Earthworks LLC 2015) used a Ponar grab, which has a sample size of 0.0225 m^2, while the present study used a 0.04 m^2 Van Veen grab. Five stations were sampled in 2014 that were near stations sampled in the present study (Figure 1). At four of the five locations, substantially fewer individuals, or species, or both, were recorded in 2014 than in 2017 (Figure 6). While it is possible that these differences were due to time between sampling, it is most likely due to differences in grab size. While it is common practice to adjust for differences in sample size by extrapolating per-grab abundances to a common area (typically 1 m^2), it is incorrect to do so. Neither abundances of individuals or number of species increase linearly with area.

Cluster analysis resulted in two dissimilar groups of stations, a large group of 25 stations (Group A) and a smaller group of three stations (Group B) (Figure 7). The three stations in Group B were all nearshore locations, two pile field locations and a control location. Nonmetric multidimensional scaling analysis gave the same results (Figure 8). The average dissimilarity between the two groups was 50.5, driven mostly by the higher average abundances in Group A stations of 24 out of the 31 species that cumulatively contributed 90% of the dissimilarity (Table 6). The three Group B stations (C2-N, P2-N, and P5-N) stood out from most other stations by virtue of their low total abundances (Figure 6).

The majority of individuals at all stations belonged to species in Ecological Croup 3, tolerant of organic matter enrichment (Table 7). The second most abundant species on average were Group 1, very sensitive to organic enrichment. As a result, all stations were classified as either 'High' or 'Good,' the top two categories in the M-AMBI classification scheme. Control and pile field stations were equally likely to be classified as either High or Good. There was some indication of a spatial pattern; seven of the eight High stations were at locations 1—4, on the southern half of the transect (Figure 9). Rarefaction curves showed striking differences for the five Ecological Groups (Figure 10). Tolerant species, opportunists, and extreme opportunists were well sampled, but the species accumulation curves for sensitive and indifferent species were still sharply ascending. This indicates that more species in these two latter groups would be expected to be collected with a more comprehensive sampling effort.

<u>Comparison with Barnegat Bay, New Jersey</u>

The benthos and sediments at 100 locations in Barnegat Bay were sampled yearly in 2012–2013 with the same methods, permitting comparisons with the present data from New York Harbor. Because of the greater areal coverage and wider range of environmental properties in Barnegat Bay, only a subset of those stations can be validly compared. There were four Barnegat Bay stations with water column salinity (22–26) and dissolved oxygen concentrations (5–7.4 mg L^{-1}), and sediment total carbon (0.2–1.5%) and silt/clay content (3–57%) (Taghon et al. 2015) similar to the present stations. Nonmetric multidimensional scaling analysis of species abundances resulted in two main groups (Figure 11). Twenty-five of the 28 stations in New York Harbor were clearly separated from the four Barnegat Bay stations. The average dissimilarity between these two groups was 64.2 (Table 8). The top seven species driving the dissimilarity were common in Barnegat Bay, but absent in the samples from New York Harbor.

SUMMARY and RECOMMENDATIONS

There were only slight, often asymmetrical differences in water column properties, sediment properties, and the benthic infaunal community at pile field and nearby control locations along the West Manhattan waterfront. Species diversity was generally high, and based on a widely used index the status of the benthic community at all locations was good to high. The good—high status of the benthic infauna is likely due to the generally good environmental properties at these sites. While bottom water dissolved oxygen was a one-time only measurement in this study, and thus may not be indicative of long-term patterns, the values were >6 mg L^{-1}. These are well above the threshold level of 5 mg L^{-1} indicative of good environmental conditions for benthos (Hale et al. 2004, Pelletier et al. 2010). Sediment total carbon concentrations were 0.9—3.4% by mass, within the range of 1—3.5% associated with intermediate risk of reduced species richness (Hyland et al. 2005).

In terms of species richness, most species collected are categorized as sensitive or indifferent to organic enrichment, while in the basis of abundance most invertebrates belong to species considered tolerant of organic enrichment. Although a total of 28 samples were collected at the seven locations along the West Manhattan waterfront, it is likely that this sampling effort was inadequate to capture the full diversity of sensitive and indifferent species. It is worth noting that the combined area of the bottom sampled in this study was 1.12 m^2. More extensive sampling would almost certainly add to the number of sensitive and indifferent species present in this habitat.

This study showed no differences between pile fields and nearby control sites, but this conclusion is restricted to the infauna living in bottom sediments. The pilings themselves, as a substrate for colonization by epifauna, could be a target for further study.

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Figure 1. Sampling locations on 19 November 2017 along West Manhattan waterfront (yellow markers and labels). C = control, P = pile field, N = near shore, F = far from shore. Also shown (white markers and labels) are locations nearby sampled in 2014 by e4sciences {e4sciences-Earthworks LLC, 2015 #10647}.

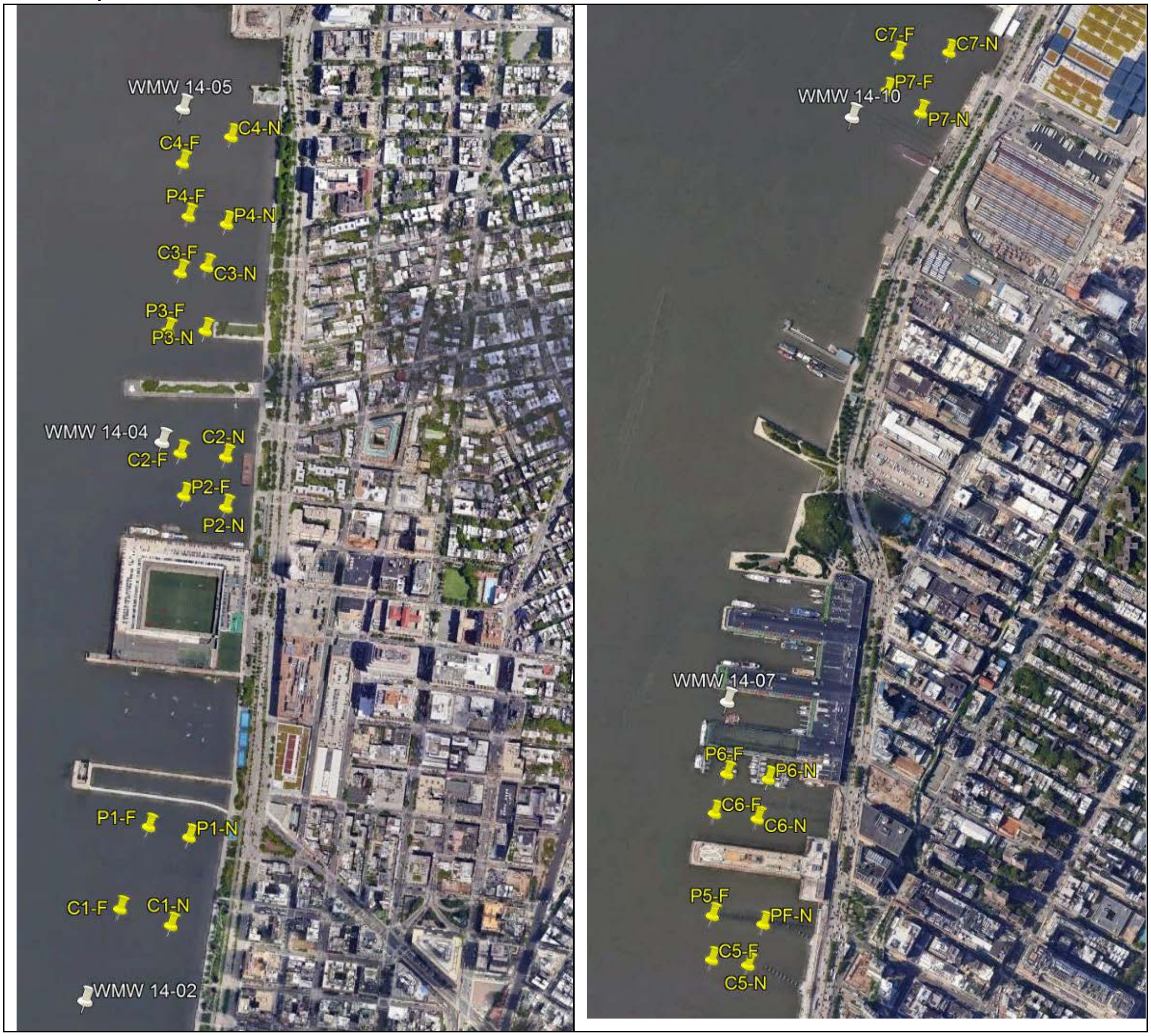


Figure 2. Principle component analysis of water column properties (labels in blue). For stations, C = control, P = pile field, N = near shoreline, F = far from shoreline.

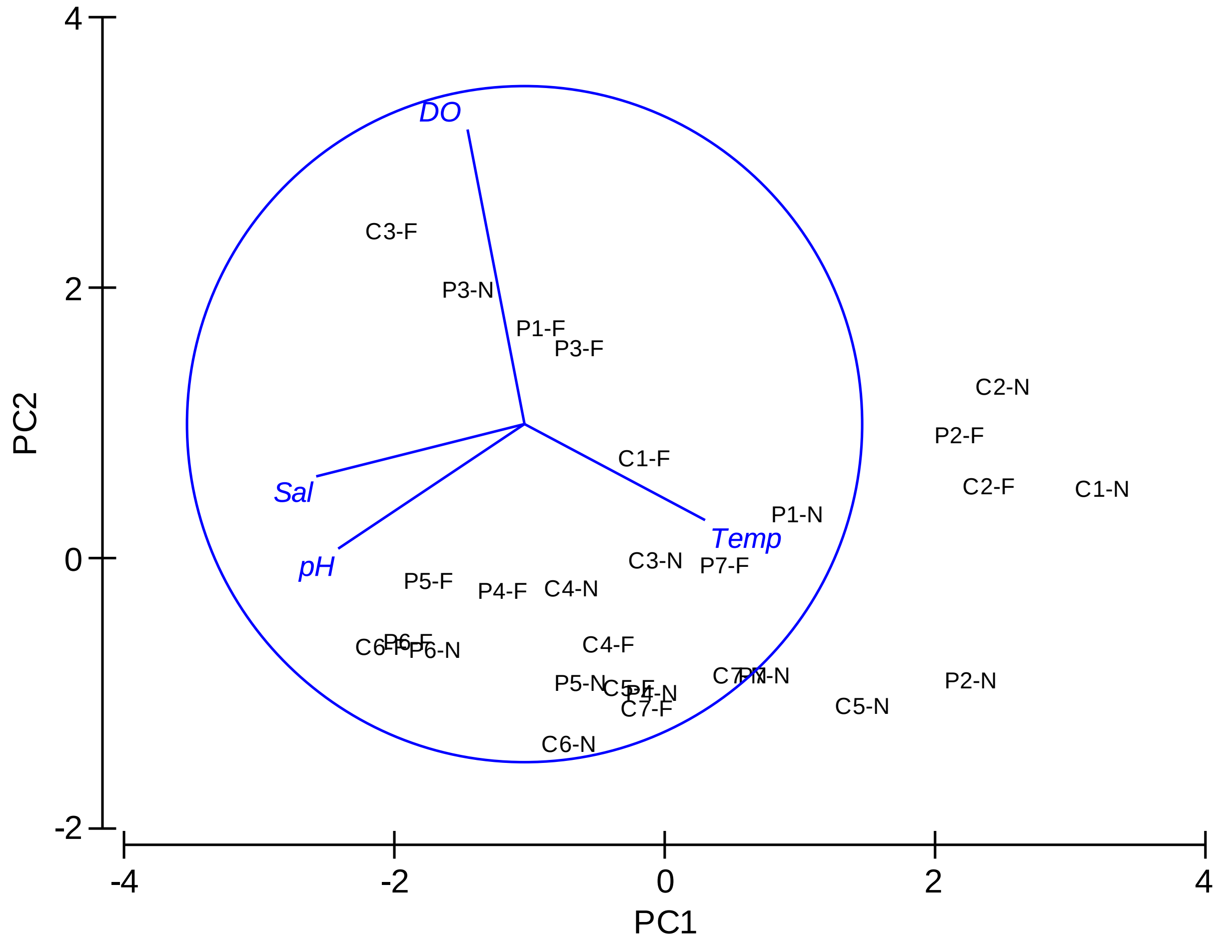


Figure 3. Principle component analysis of sediment properties (labels in blue). For stations, C = control, P = pile field, N = near shoreline, F = far from shoreline.

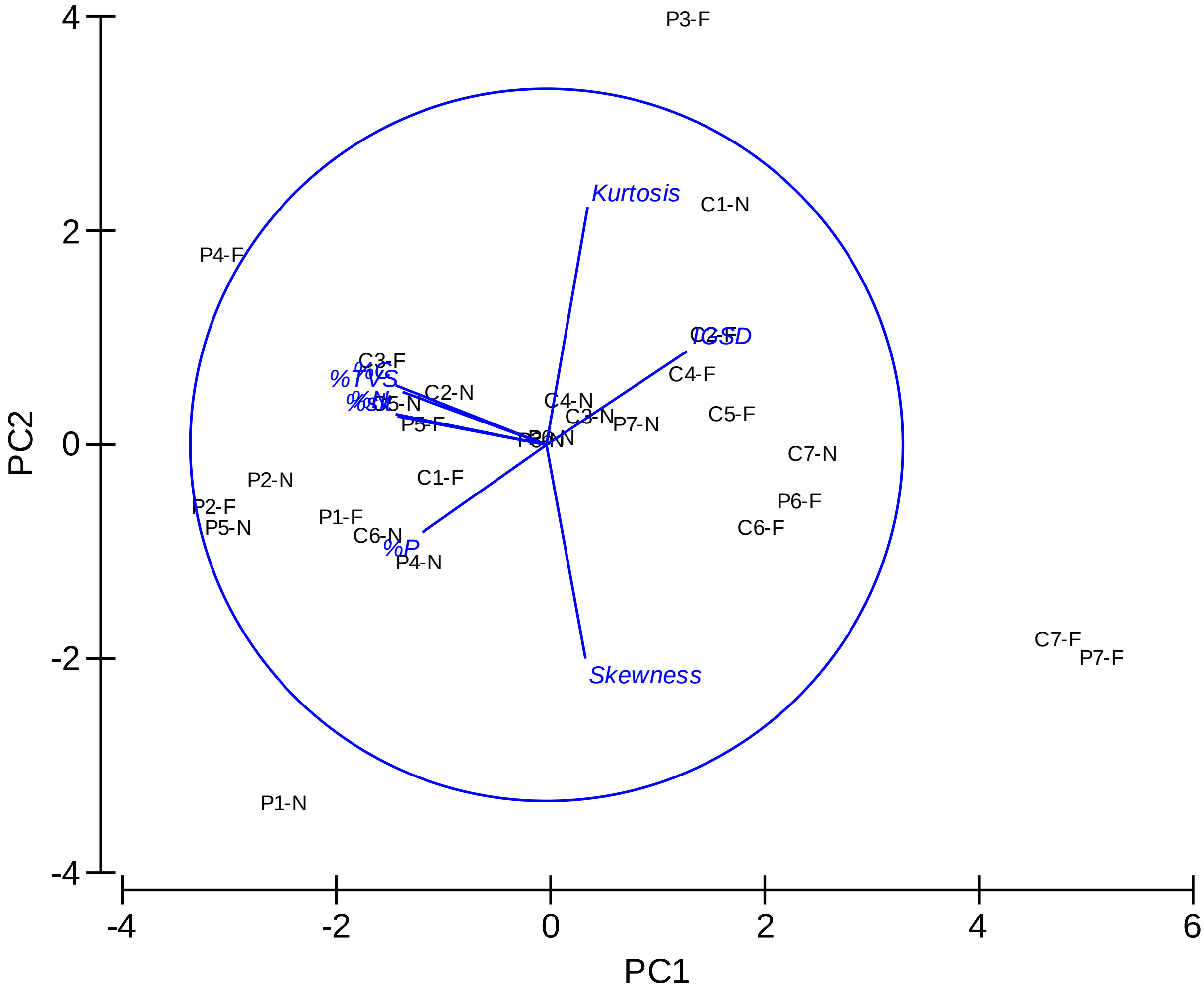


Figure 4. Species rank (1 = most abundant) vs cumulative percentage total abundance of macroinvertebrates at all stations.

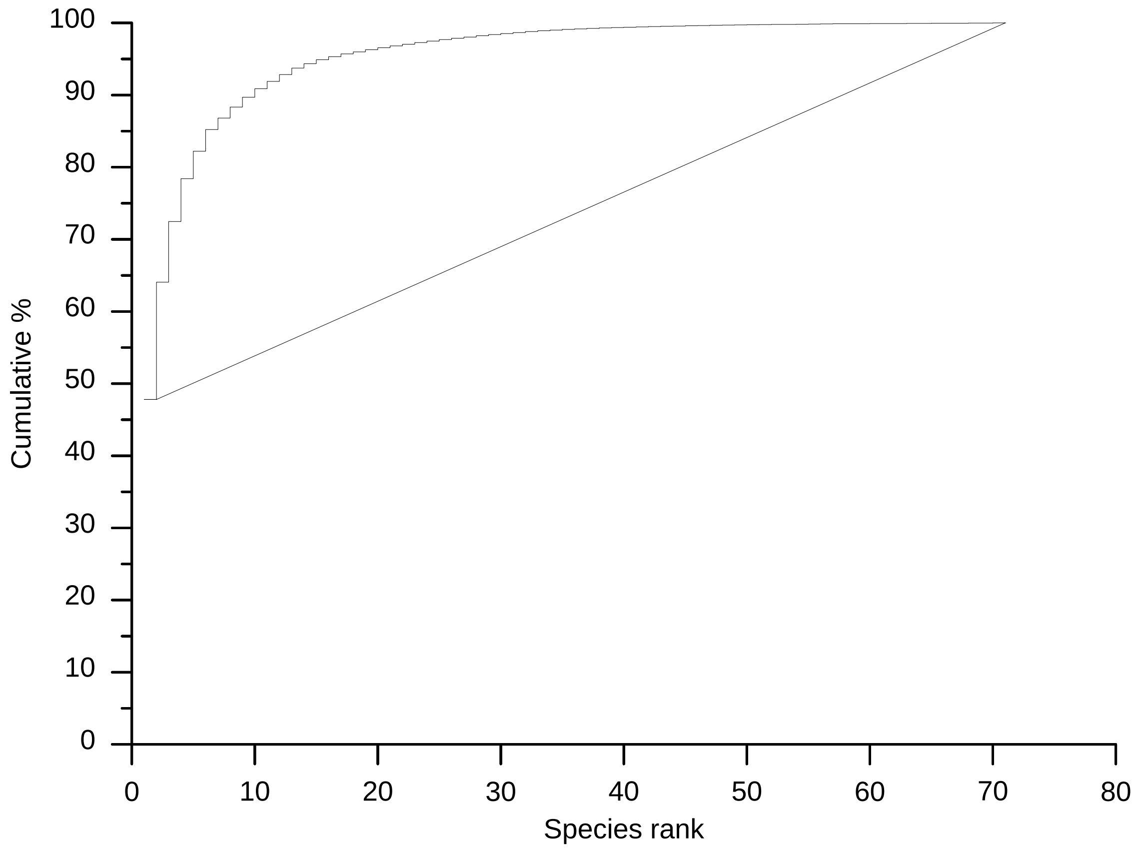


Figure 5. Relative abundances of infauna at the Class taxonomic level.

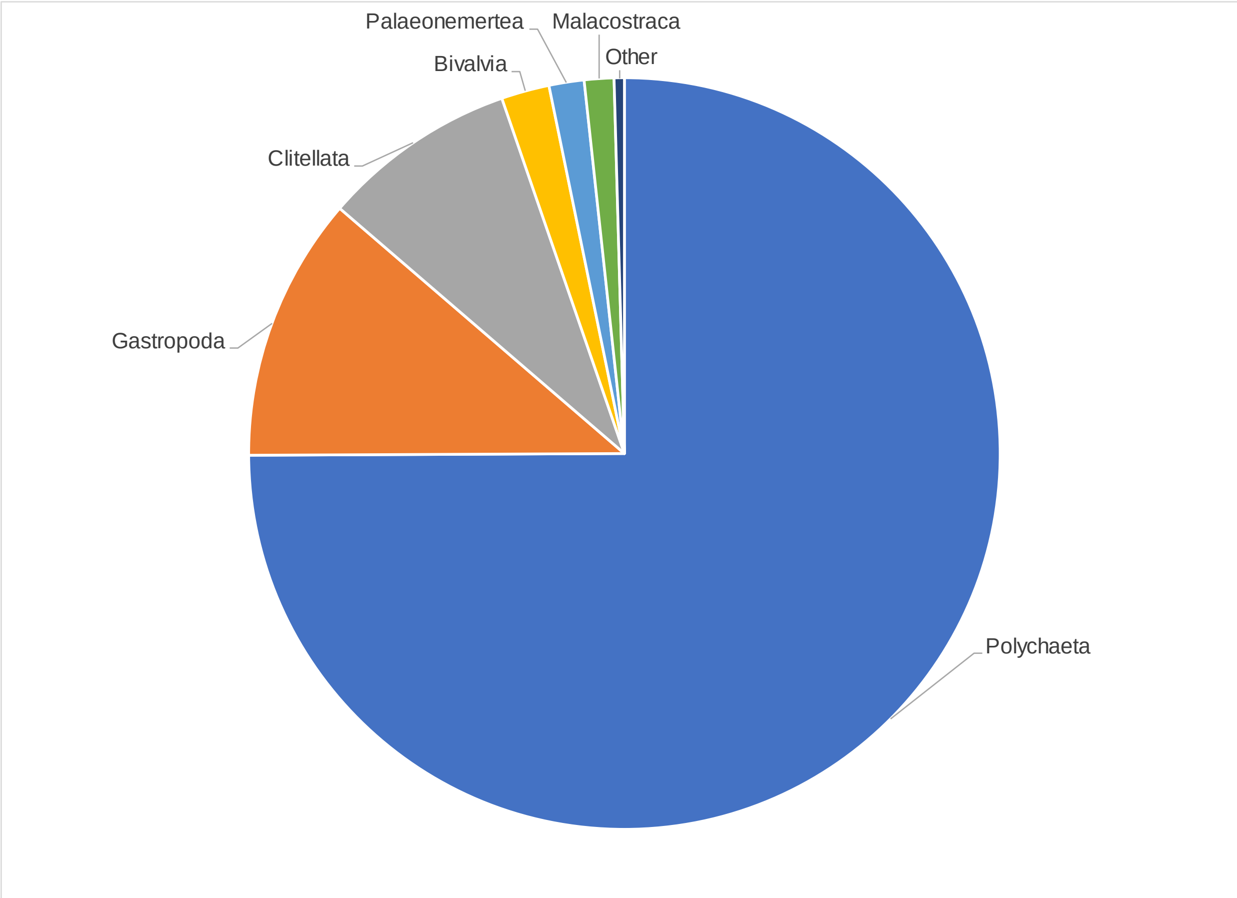
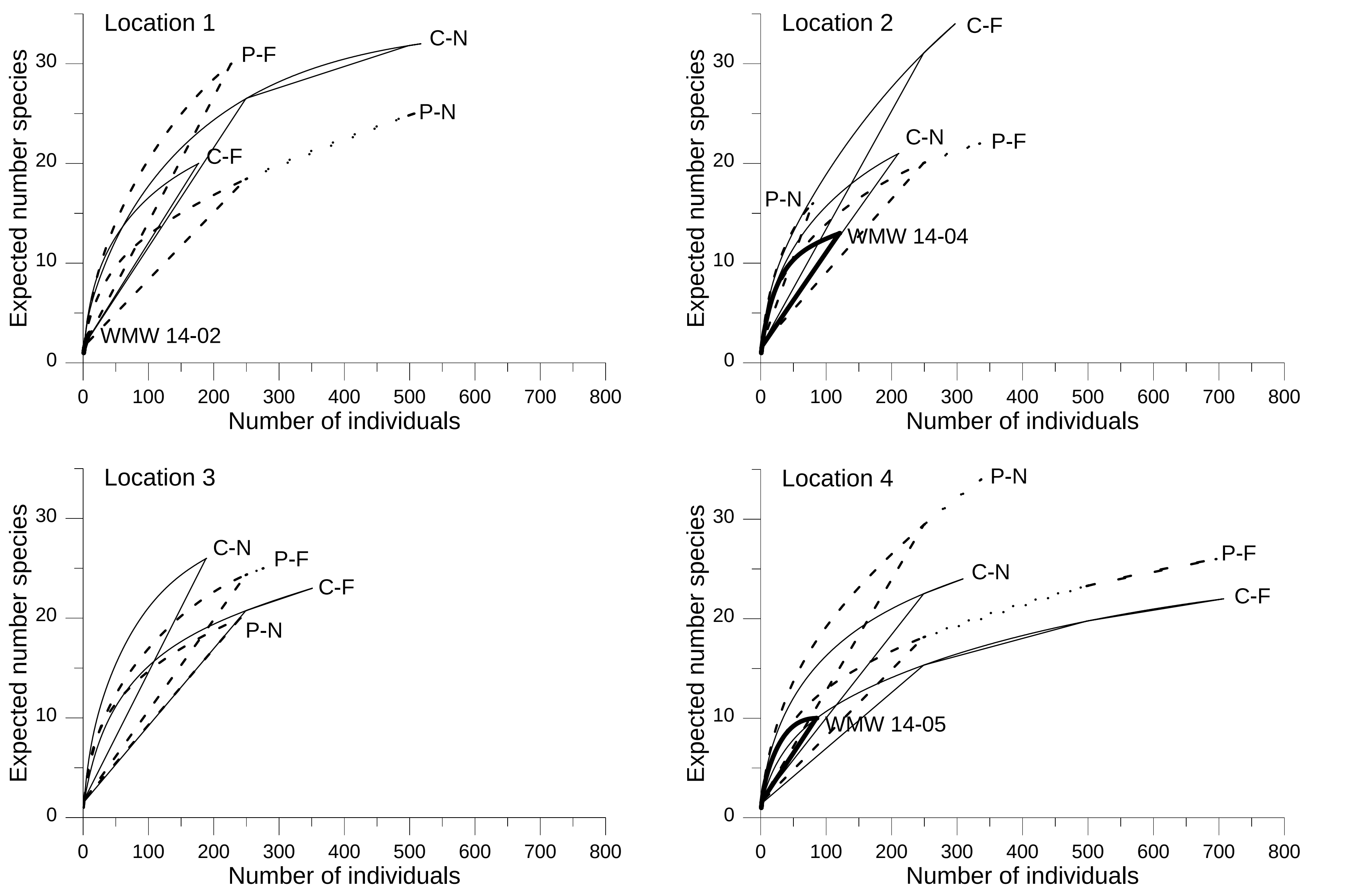


Figure 6. Rarefaction curves for benthic infauna. C=control sites (thin solid lines); P=pile field sites (dashed lines); WMW=West Manhattan Waterfront sites (thick solid lines) sampled in 2014 {e4sciences-Earthworks LLC, 2015 #10647} that were closest to locations in present study.



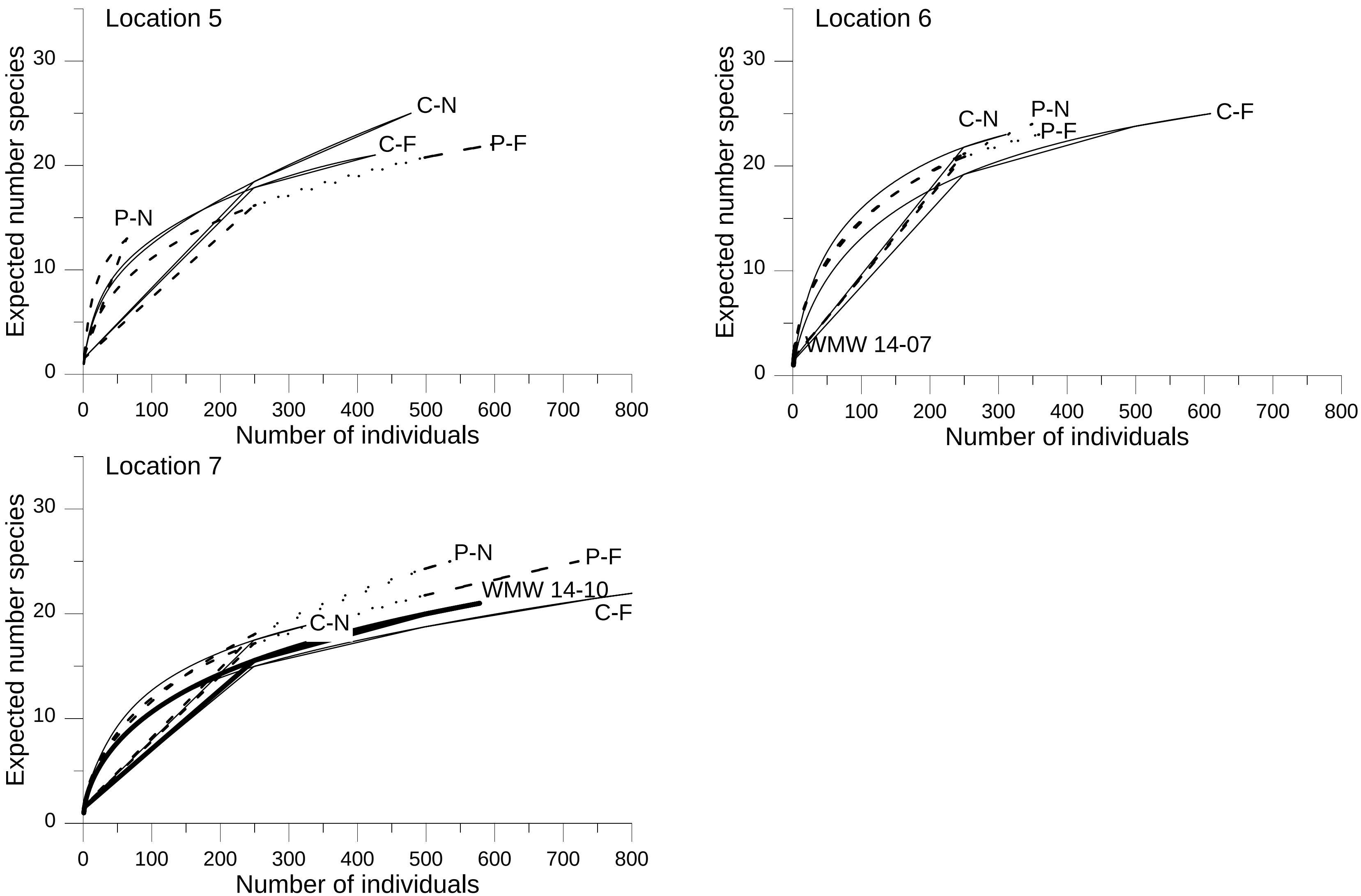

Location 5
Expected number species
Number of individuals
C-N
C-F
P-F
P-N
Location 6
C-N
P-N
P-F
C-F
WMW 14-07
Location 7
P-N
P-F
WMW 14-10
C-N
C-F

Figure 7. Cluster analysis of stations based on benthic infauna data. C = Control samples, P = Pile field samples, F = far, N = near. Groups A and B based on similarity profile permutation tests.

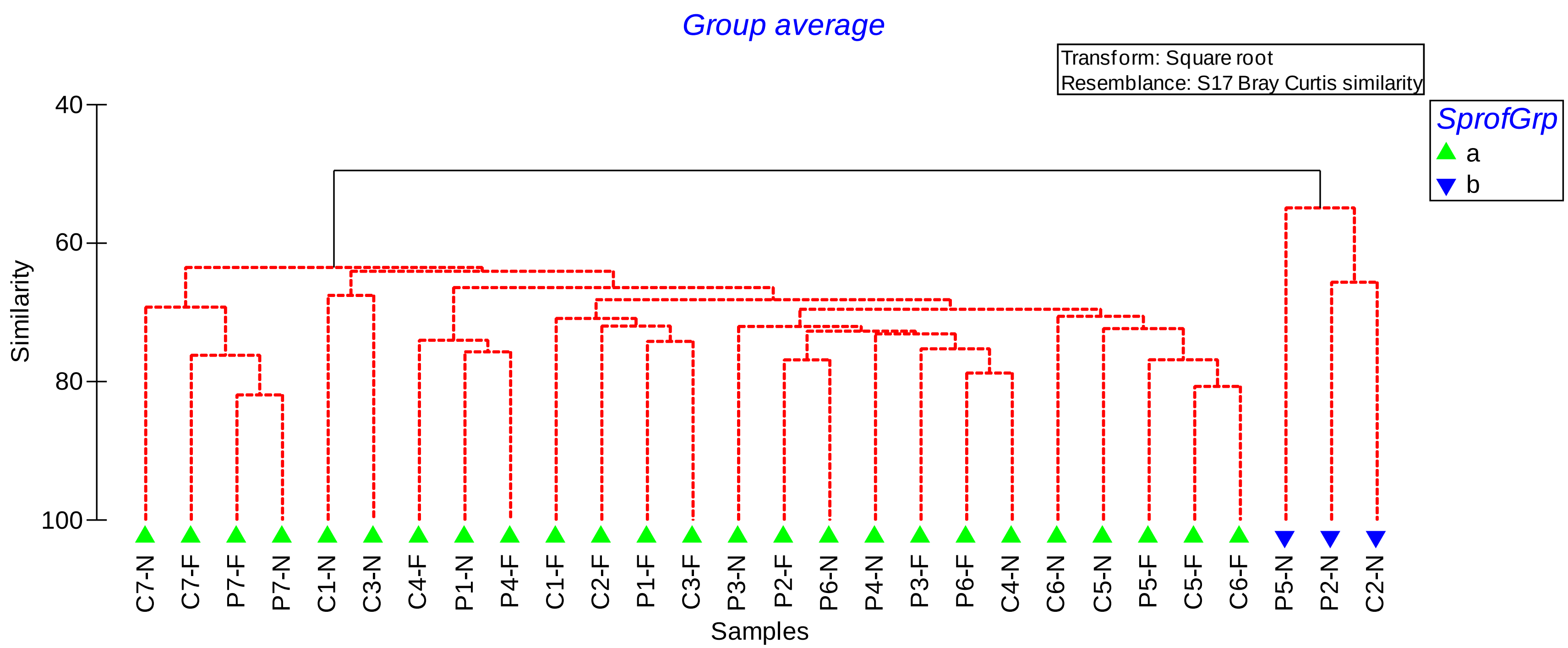


Figure 8. Nonmetric multidimensional scaling analysis of stations based on benthic infauna data. Station identifications as in Figure 7. Groups A and B based on similarity profile permutation tests.

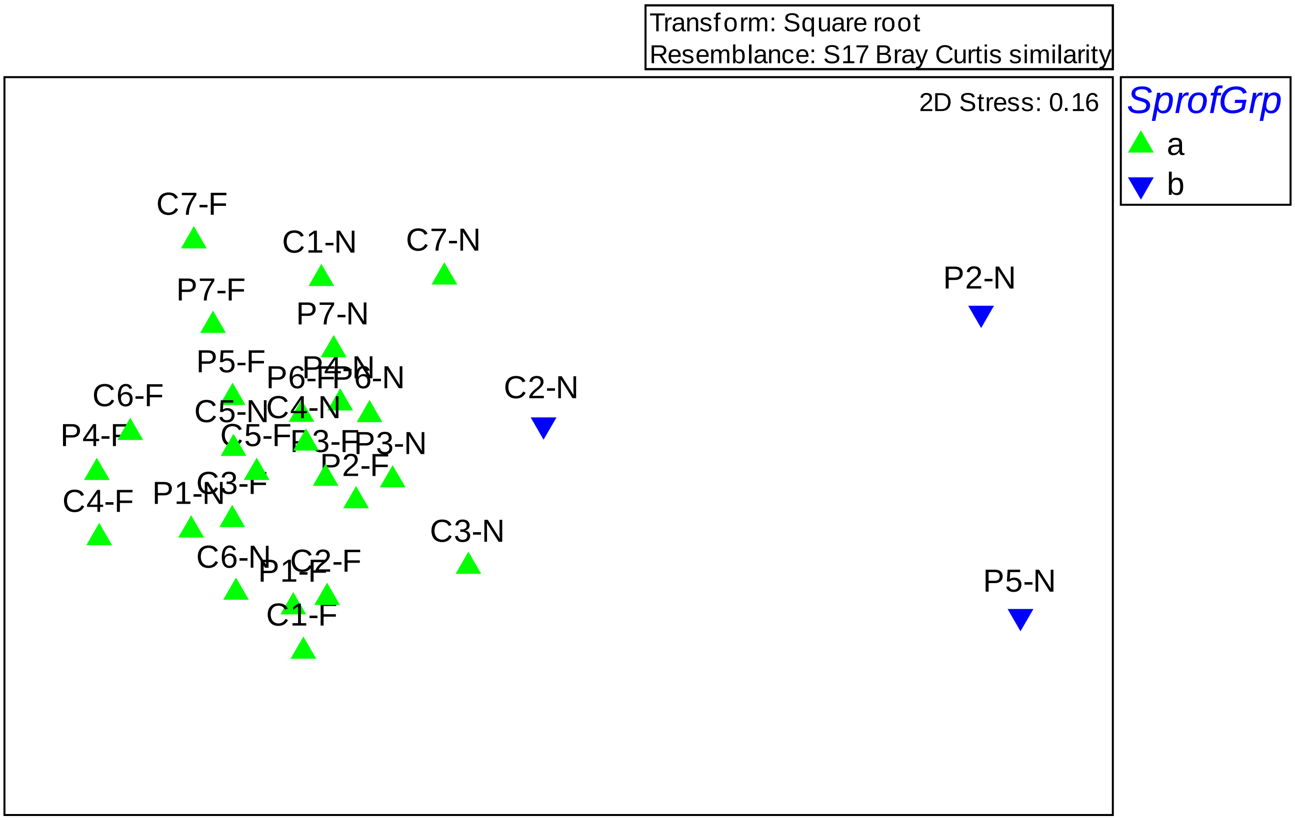


Figure 9. Classification of stations based on M-AMBI analysis of benthic infaunal community. Color coding: blue=High, green=Good

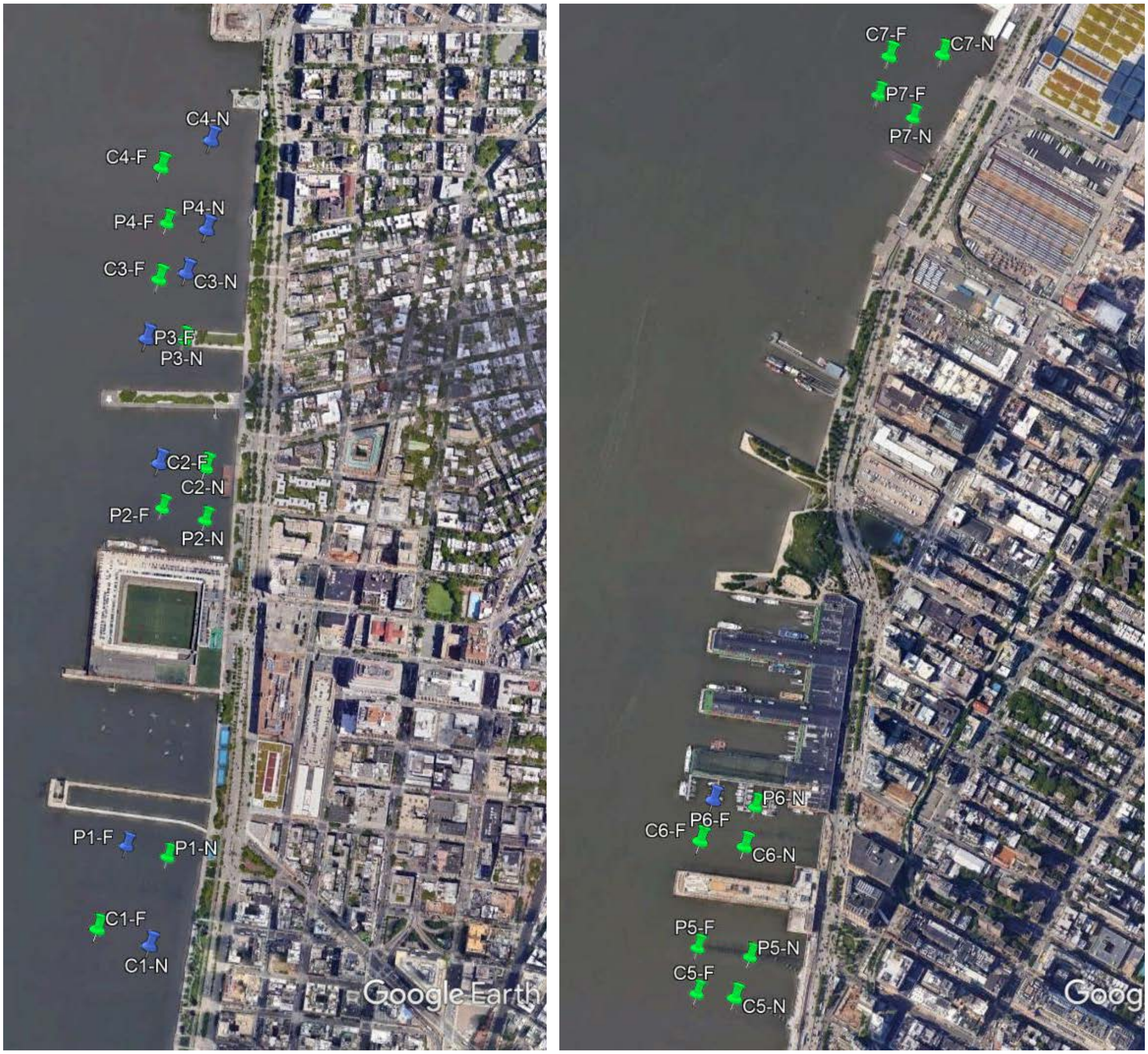


Figure 10. Rarefaction curves based on Ecological Groups.

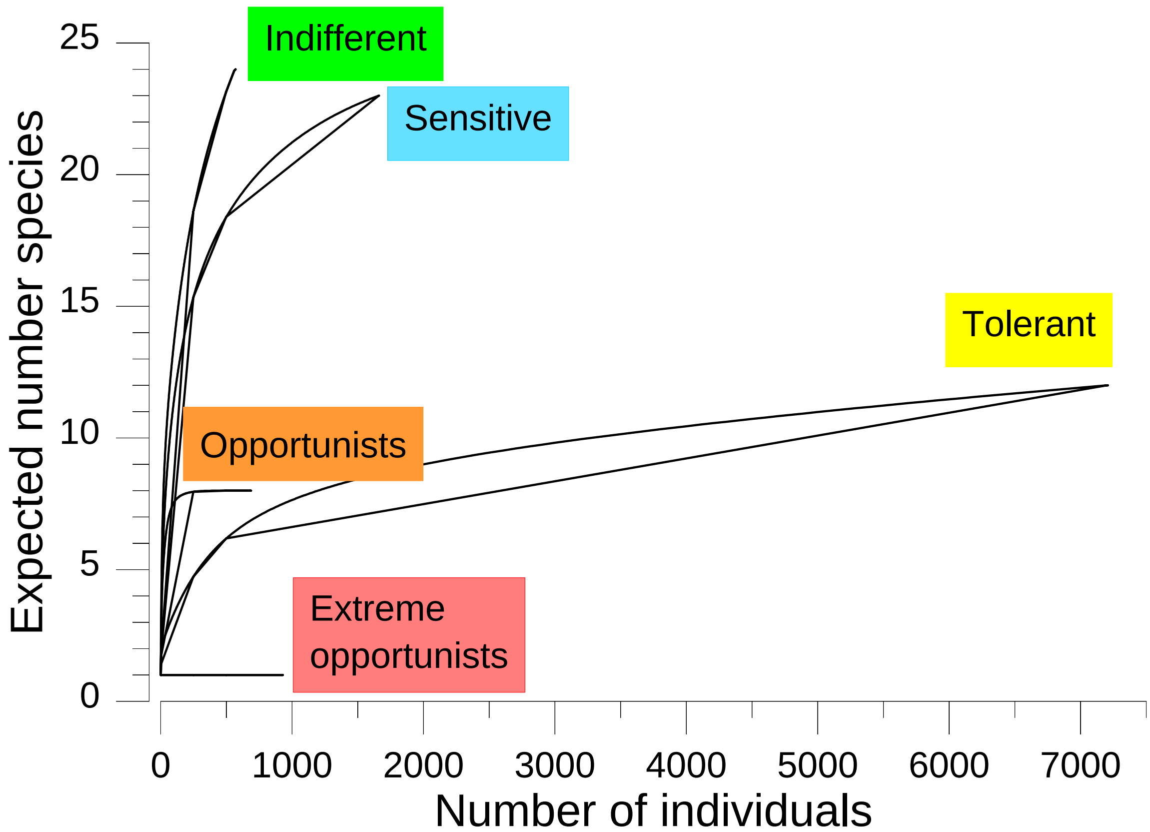


Figure 11. Nonmetric multidimensional scaling analysis of stations based on benthic infauna data. Groups A–D based on similarity profile permutation tests. Group A are averages for three years of samples at four locations in Barnegat Bay, NJ. Groups B–D are from present study, station identifications as in Figure 7.

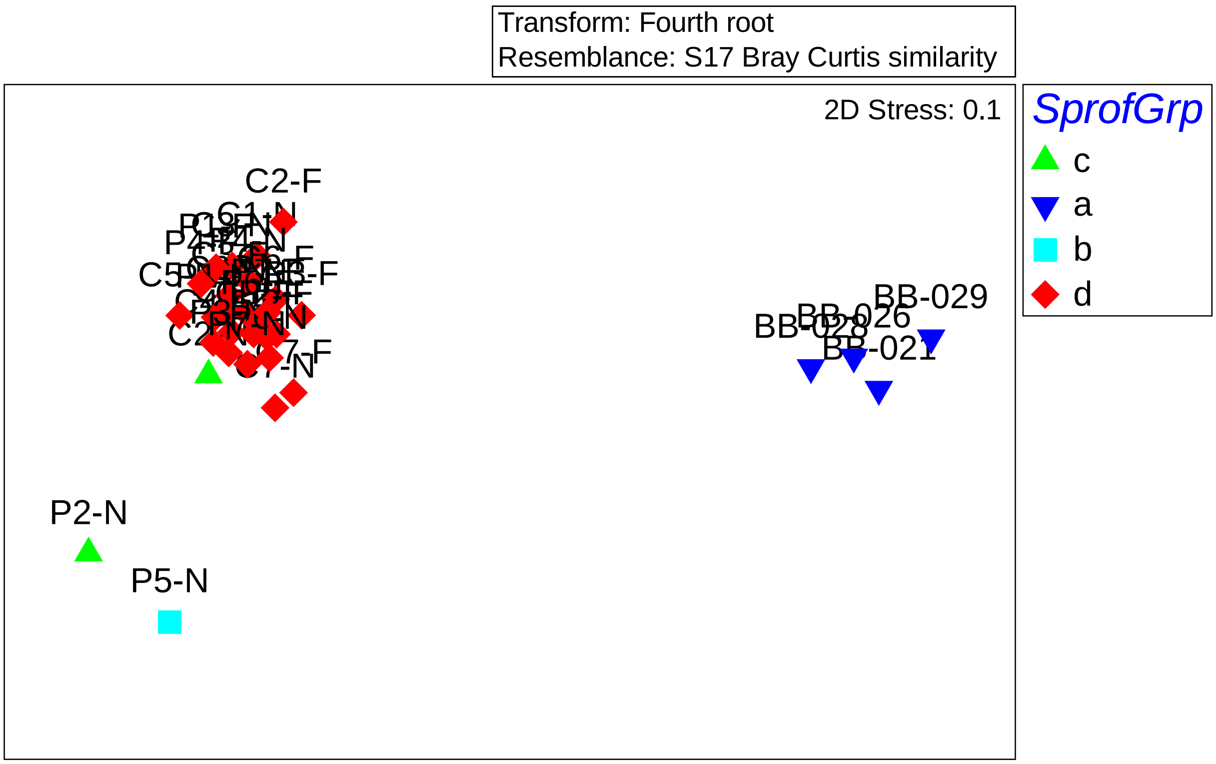


Table 1. Distances from shore of stations at the seven locations along the West Manhattan waterfront.

	Actual distance of 'near' station from shore (m)	Actual distance of 'far' station from shore (m)
Control 1	77	179
Pile Field 1	70	150
Control 2	61	150
Pile Field 2	56	139
Control 3	124	175
Pile Field 3	119	191
Control 4	94	184
Pile Field 4	92	167
Control 5	116	189
Pile Field 5	99	201
Control 6	76	160
Pile Field 6	131	215
Control 7	70	154
Pile Field 7	61	139

Table 2. Distances between pile field and control locations, and distances from each control location to the nearest existing structure. Distances from ruler tool in Google Earth Pro version 7.3.1.4507.

Location	Distance between Pile Field and Control (m)	Distance from Control to nearest existing structure (m)
1	170	250
2	80	130
3	120	200
4	130	225
5	90	100
6	70	45
7	95	150

Table 3. Mean values (SD) of surface and bottom water properties. N = 7 for all measurements.

	Surface 'near'		Surface 'far'	
	Controls	Pile Fields	Controls	Pile Fields
DO (mg L^{-1})	6.17 (0.24)	6.11 (0.24)	6.23 (0.53)	6.39 (0.42)
pH	7.47 (0.11)	7.52 (0.03)	7.50 (0.03)	7.50 (0.03)
Salinity	22.8 (1.4)	23.5 (0.9)	22.9 (1.7)	23.3 (0.7)
Temperature	19.0 (0.1)	19.0 (0.1)	19.0 (0.2)	19.0 (0.1)

	Bottom 'near'		Bottom 'far'	
	Controls	Pile Fields	Controls	Pile Fields
DO (mg L^{-1})	6.10 (0.15)	6.11 (0.30)	6.19 (0.32)	6.29 (0.18)
pH	7.49 (0.05)	7.50 (0.03)	7.51 (0.03)	7.51 (0.03)
Salinity	24.3 (0.9)	24.6 (0.8)	24.8 (1.0)	24.8 (0.9)
Temperature	19.0 (0.1)	18.9 (0.1)	18.9 (0.1)	18.9 (0.1)

Table 4. Mean values (SD) of sediment properties. N = 7 for all measurements.

	'Near'		'Far'	
	Controls	Pile Fields	Controls	Pile Fields
%TVS	6.68 (1.46)	7.73 (1.63)	5.95 (1.19)	7.98 (3.59)
%N	0.172 (0.039)	0.212 (0.058)	0.155 (0.054)	0.208 (0.081)
%C	2.27 (0.49)	2.50 (0.50)	1.97 (0.62)	2.45 (0.85)
%P	0.103 (0.015)	0.113 (0.010)	0.097 (0.011)	0.102 (0.015)
% gravel	0.37 (0.50)	0.16 (0.32)	0.49 (0.73)	0.58 (1.39)
% sand	13.4 (6.5)	7.72 (5.99)	23.6 (14.8)	20.4 (21.3)
% silt	86.2 (6.2)	92.1 (4.9)	75.9 (14.6)	79.0 (21.3)
IGSD	0.441 (0.081)	0.367 (0.060)	0.509 (0.094)	0.477 (0.153)
Skewness	-0.359 (0.036)	-0.237 (0.234)	-0.286 (0.137)	-0.276 (0.204)
Kurtosis	1.011 (0.115)	0.869 (0.129)	0.959 (0.101)	1.001 (0.266)

Table 5. Species accounting for 90% of all individuals collected. C=clitellata, G=Gastropoda, M=Malacostraca, P=Polychaeta, Pa= Palaeonemertea.

Species (class)	Abundance	Cumulative %
Mediomastus ambiseta (P)	5295	47.81
Streblospio benedicti (P)	1802	64.08
Tubificoides sp. (C)	930	72.47
Japonactaeon punctostriatus (M)	658	78.41
Acteocina canaliculata (G)	422	82.22
Leitoscoloplos robustus (P)	331	85.21
Sabellaria vulgaris (P)	178	86.82
Carinomella lacteal (Pa)	167	88.33
Cossura sp. A Maciolek (P)	153	89.71
Odostomia sp. juvenile (G)	129	90.87

Table 6. Similarity percentages; species contributions to Groups A and B (stations as in Figures 7 and 8) identified by similarity profile permutation test on square-root transformations of abundances, however, abundances tabulated here are untransformed, original data. Cut off for cumulative contribution is 50%.

Average dissimilarity between groups = 50.50

Species	Group A Av.Abund	Group B Av.Abund	Av.Diss	Contrib%	Cum.%
Mediomastus ambiseta	210	17	9.44	18.69	18.69
Streblospio benedicti	67	45	3.66	7.24	25.93
Tubificoides sp.	35	17	3.08	6.10	32.03
Japonactaeon punctostriatus	26	6	2.64	5.22	37.25
Acteocina canaliculata	16	4	2.37	4.69	41.94
Glycinde multidens	4	0	1.83	3.63	45.57
Leitoscoloplos robustus	13	4	1.60	3.16	48.74
Cossura sp. A Maciolek	6	3	1.46	2.90	51.64

Table 7. Ecological Group classifications of benthic infauna species as percentages of total abundance in Control and Pile Field stations. Percentages do not always sum to 100 because some species could not be assigned to an Ecological Group.

Station	% Group 1	% Group 2	% Group 3	% Group 4	% Group 5	M-AMBI	Status
C1-F	22.6	6.8	39.5	16.9	14.1	0.746	Good
P1-F	22.2	5.8	51.6	6.2	14.2	0.848	High
C1-N	39.8	4.1	46.4	5.8	3.9	0.940	High
P1-N	12.2	3	47.3	8.3	29.2	0.675	Good
C2-F	26.1	4.7	51.2	9.2	8.8	0.915	High
P2-F	9.6	3.9	48.5	8.4	29.6	0.665	Good
C2-N	14.7	3.8	55	7.1	19.4	0.702	Good
P2-N	17.5	8.8	53.8	8.8	11.3	0.710	Good
C3-F	19.3	4	64.9	6	5.7	0.733	Good
P3-F	19.9	6.2	61.6	6.5	5.8	0.802	High
C3-N	35.5	9.7	45.2	8.1	1.6	0.927	High
P3-N	21.6	5.4	55.2	10.8	7.1	0.762	Good
C4-F	8.6	2.3	73	6.6	9.5	0.622	Good
P4-F	14.7	4.2	61.2	5.9	14.1	0.720	Good
C4-N	16.8	6.1	60.2	6.5	10.4	0.781	High
P4-N	14.4	10.1	63.8	5.5	6.1	0.897	High
C5-F	12.4	4.5	66.7	7.5	8.9	0.680	Good
P5-F	10.6	2.2	79	6.4	1.8	0.674	Good
C5-N	13	2.9	73.8	5.2	5	0.722	Good
P5-N	25	6.3	46.9	20.3	1.6	0.722	Good
C6-F	14.1	4.4	73.7	5.4	2.3	0.706	Good
P6-F	24.2	5	56.8	2.8	11.1	0.784	High
C6-N	16.4	2.9	62.1	18	0.6	0.735	Good
P6-N	13.5	4.6	68.5	8.6	4.9	0.758	Good
C7-F	10	3.6	81.8	1.2	3.4	0.684	Good
P7-F	11.4	4.3	78.8	1.7	3.9	0.732	Good
C7-N	10.5	2.7	80.8	4.8	1.2	0.679	Good
P7-N	9.2	3.6	75.1	2.6	9.5	0.714	Good

Table 8. Species contributions to Groups A (four stations in Barnegat Bay, NJ) and D (25 of 28 stations in present study; see Figure 10) and their assignments to Ecological Groups. Similarity percentages calculated by similarity profile permutation test on fourth-root transformations of abundances, however, abundances tabulated here are untransformed, original data. Cut off for cumulative contribution is 50%.

Average dissimilarity = 64.20

Species	Ecol.Grp.	Group A Av.Abund	Group D Av.Abund	Av.Diss	Contrib%	Cum.%
Notomastus sp. A Ewing	3	29	0	2.20	3.43	3.43
Pentamera pulcherrima	1	17	0	1.86	2.89	6.32
Clymenella zonalis	1	14	0	1.70	2.65	8.97
Clymenella torquata	1	10	0	1.69	2.64	11.61
Exogone (Exogone) dispar	2	10	0	1.66	2.58	14.19
Ampelisca verrilli	1	11	0	1.58	2.46	16.65
Idunella barnardi	2	6	0	1.52	2.37	19.02
Carinomella lactea	1	0	6	1.46	2.27	21.29
Ampelisca abdita	3	27	1	1.37	2.14	23.43
Monocorophium tuberculatum	3	4	0	1.34	2.08	25.51
Tubificoides sp.	5	2	35	1.32	2.06	27.57
Melinna maculata	2	4	0	1.32	2.05	29.62
Podarkeopsis levifuscina	2	4	0	1.30	2.02	31.64
Odostomia sp. juvenile	2	0	5	1.27	1.97	33.61
Ampharete oculata	2	0	4	1.16	1.80	35.42
Oligochaeta sp.	5	4	0	1.16	1.80	37.21
Leptosynapta tenuis	1	3	0	1.14	1.77	38.98
Heteromastus filiformis	4	7	1	1.13	1.76	40.75
Paraprionospio alata	4	8	1	1.06	1.65	42.40
Cossura sp. A Maciolek	4	0	6	1.06	1.65	44.05
Loimia medusa	3	2	0	1.06	1.64	45.69
Macoploma tenta	3	1	0	1.01	1.58	47.27
Scolelepis (Parascolelepis) bousfieldi	3	1	0	0.96	1.50	48.77
Polycirrus eximius	4	3	0	0.92	1.43	50.20

Appendix 1. Station locations and water properties. C=control, P=pile field, N=near, F=far. All samples collected on 10/19/2017.

Station	Latitude	Longitude	Time	Depth (m)	Surface salinity	Surface DO (mg/L)	Surface pH	Surface temp	Bottom salinity	Bottom DO (mg/L)	Bottom pH	Bottom temp
C1-F	40.72405	-74.01418	8:43	4.1	20.1	6.66	7.45	18.8	24.45	6.23	7.48	18.8
C1-N	40.72377	-74.01303	8:23	ND	21.01	6.4	7.23	18.8	23.93	6.07	7.38	19.1
P1-F	40.72547	-74.01353	8:53	ND	22.36	6.78	7.49	18.9	24.78	6.57	7.5	18.8
P1-N	40.72528	-74.01262	9:05	ND	22.66	6.49	7.48	18.9	24.18	6.24	7.48	19
P2-F	40.73115	-74.01273	9:17	4.3	22.3	6.97	7.46	19	22.86	6.28	7.46	19
P2-N	40.73095	-74.01178	9:24	4.3	22.32	5.86	7.48	19	23.21	5.79	7.46	19
C2-F	40.73188	-74.01282	9:36	3.8	21.33	6.42	7.46	18.8	22.88	6.15	7.45	19
C2-N	40.73182	-74.01178	9:43	3.9	21.89	6.57	7.45	19	22.55	6.34	7.45	19
P3-F	40.73398	-74.01310	9:54	4.1	23.52	6.62	7.48	18.9	24.9	6.48	7.48	18.8
P3-N	40.73398	-74.01225	10:05	3.7	23.01	6.4	7.51	19	25.22	6.7	7.51	18.8
C3-F	40.73498	-74.01282	10:14	ND	24.5	7.12	7.51	18.9	25.64	6.87	7.52	18.8
C3-N	40.73508	-74.01222	10:21	3.5	23.33	6.2	7.5	19	24.66	6.15	7.5	18.9
P4-F	40.73595	-74.01263	10:37	3.7	23.55	5.92	7.52	19	24.99	6.12	7.53	18.8
P4-N	40.73598	-74.01177	10:45	3.4	24.14	5.96	7.52	19	24.74	5.91	7.51	18.9
C4-F	40.73687	-74.01277	10:53	4.2	23.98	6.02	7.52	19.1	24.84	6.04	7.52	18.9
C4-N	40.73732	-74.01167	10:59	3.4	23.32	6.02	7.53	19.2	25.12	6.17	7.52	18.9
C5-F	40.74167	-74.01172	11:11	2.7	22.51	5.59	7.51	19.2	24.95	5.93	7.51	18.9
C5-N	40.74157	-74.01088	11:19	2.3	22.47	5.88	7.55	19.2	24.01	5.96	7.5	19.1
P5-F	40.74243	-74.01170	11:35	2.7	23.3	6.04	7.52	19.1	25.5	6.19	7.54	18.8
P5-N	40.74228	-74.01053	11:43	2.6	23.56	6.01	7.55	19.1	25.21	5.98	7.52	18.9
C6-F	40.74422	-74.01165	11:53	2.5	23.34	5.77	7.52	19.1	25.88	6.1	7.55	18.8
C6-N	40.74412	-74.01067	12:00	2.3	23.24	6.04	7.52	19.1	25.2	5.88	7.53	18.9
P6-F	40.74490	-74.01137	12:09	2.3	23.84	5.99	7.53	19	25.81	6.08	7.54	18.8
P6-N	40.74480	-74.01042	12:18	2.3	24.62	6.09	7.54	19	25.56	6.05	7.54	18.8
P7-F	40.75678	-74.00768	12:35	2.1	24.32	6.44	7.52	19.2	24.66	6.34	7.52	19.1
P7-N	40.75640	-74.00692	12:42	ND	24.4	5.95	7.53	19.1	24.48	6.1	7.52	19.1
C7-F	40.75742	-74.00745	12:50	1.9	24.76	6.04	7.54	19	24.92	6.01	7.53	19
C7-N	40.75745	-74.00627	12:56	3.0	24.3	6.07	7.53	19.1	24.5	6.13	7.53	19.1

Appendix 2. Station locations and sediment properties. C=control, P=pile field, N=near, F=far. All samples collected on 10/19/2017.

Station	%TVS	%N	%C	%P	% gravel	% sand	%silt	Median phi	Mean phi	IGSD	Skewness	Kurtosis
C1-F	7.38E+00	1.91E-01	2.51E+00	1.10E-01	0.12	7.6	92.28	4.62	4.56	0.36	-0.33	0.9
C1-N	6.32E+00	1.63E-01	2.28E+00	7.63E-02	0.16	19.9	79.94	4.51	4.41	0.57	-0.43	1.23
C2-F	5.42E+00	1.54E-01	1.95E+00	9.27E-02	2.01	19.11	78.88	4.49	4.4	0.54	-0.38	1.1
C2-N	8.03E+00	2.04E-01	2.56E+00	1.02E-01	1.44	6.37	92.2	4.63	4.56	0.38	-0.37	0.99
C3-F	9.16E+00	2.42E-01	2.87E+00	1.08E-01	0.46	9.54	90	4.61	4.54	0.41	-0.37	1.03
C3-N	6.01E+00	1.57E-01	2.10E+00	1.08E-01	0.26	14.44	85.32	4.55	4.49	0.45	-0.35	1.03
C4-F	5.73E+00	1.57E-01	1.98E+00	8.67E-02	0	19.15	80.86	4.51	4.43	0.49	-0.35	1.03
C4-N	6.37E+00	1.64E-01	2.23E+00	1.06E-01	0.4	13.74	85.86	4.56	4.49	0.44	-0.36	1.04
C5-F	5.89E+00	1.52E-01	1.93E+00	9.59E-02	0.79	27.81	71.4	4.39	4.29	0.58	-0.33	0.96
C5-N	8.11E+00	2.21E-01	2.96E+00	1.09E-01	0.34	9.4	90.27	4.61	4.54	0.39	-0.35	0.98
C6-F	5.00E+00	1.24E-01	1.62E+00	1.06E-01	0.03	31.3	68.66	4.34	4.27	0.56	-0.25	0.87
C6-N	7.84E+00	1.95E-01	2.42E+00	1.26E-01	0	6.67	93.32	4.63	4.57	0.34	-0.32	0.85
C7-F	3.06E+00	6.69E-02	9.15E-01	8.05E-02	0	50.82	49.19	3.98	4.01	0.62	0.01	0.82
C7-N	4.06E+00	1.02E-01	1.35E+00	9.21E-02	0	23.25	76.75	4.45	4.37	0.52	-0.33	0.96
P1-F	8.43E+00	2.45E-01	2.72E+00	1.06E-01	0	3.73	96.28	4.66	4.6	0.31	-0.3	0.79
P1-N	9.06E+00	2.63E-01	2.88E+00	1.23E-01	0	0.51	99.5	4.31	4.37	0.32	0.29	0.69
P2-F	1.03E+01	2.88E-01	3.17E+00	1.19E-01	0	4.73	95.27	4.65	4.59	0.32	-0.3	0.79
P2-N	9.59E+00	2.86E-01	3.15E+00	1.03E-01	0.85	3.9	95.25	4.65	4.59	0.32	-0.31	0.79
P3-F	7.66E+00	2.04E-01	2.55E+00	9.13E-02	3.73	18.92	77.36	4.48	4.36	0.7	-0.49	1.55
P3-N	6.47E+00	1.71E-01	2.07E+00	1.12E-01	0	11.98	88.02	4.58	4.52	0.42	-0.35	1
P4-F	1.41E+01	2.93E-01	3.43E+00	1.02E-01	0.17	7.13	92.71	4.64	4.57	0.4	-0.4	1.09
P4-N	7.03E+00	1.81E-01	2.33E+00	1.20E-01	0.03	5.91	94.05	4.64	4.58	0.33	-0.3	0.81
P5-F	7.45E+00	2.21E-01	2.57E+00	1.22E-01	0.07	12.28	87.64	4.58	4.51	0.42	-0.35	1.01
P5-N	9.65E+00	2.71E-01	3.00E+00	1.23E-01	0	2.65	97.36	4.67	4.61	0.31	-0.3	0.79
P6-F	4.88E+00	1.38E-01	1.72E+00	9.19E-02	0.12	33.64	66.25	4.3	4.23	0.58	-0.24	0.86
P6-N	6.35E+00	1.63E-01	2.07E+00	1.12E-01	0.27	12.43	87.31	4.58	4.51	0.42	-0.35	1.01
P7-F	3.04E+00	6.92E-02	9.71E-01	8.14E-02	0	62.72	37.28	3.78	3.86	0.61	0.15	0.92
P7-N	5.99E+00	1.51E-01	1.97E+00	9.77E-02	0	16.63	83.35	4.53	4.46	0.45	-0.34	0.99

Appendix 3. Species collected at each station and their Ecological Group classification. Data are number per grab (0.04 m²).

Phylum	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida
Class	Clitellata	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta
Order	Haplotaxida	Canalipalpata	Eunicida	Phyllodocida	Phyllodocida	Phyllodocida	Phyllodocida	Phyllodocida
Family	Tubificidae	Sabellariidae	Onuphidae	Glyceridae	Glyceridae	Glyceridae	Goniadidae	Hesionidae
Species	*Tubificoides* sp.	*Sabellaria vulgaris*	*Diopatra cuprea*	*Glycera americana*	*Glycera dibranchiata*	*Glycera* sp. juvenile	*Glycinde multidens*	*Podarkeopsis levifuscina*
Ecol Grp	5	1	1	1	2	2	2	2
P1-F	32	0	1	1	0	1	3	0
P1-N	148	0	0	3	0	1	1	0
P2-F	99	0	0	2	0	0	2	0
P2-N	9	0	0	0	0	0	0	0
P3-F	16	0	0	3	0	0	7	0
P3-N	17	0	0	0	0	1	7	0
P4-F	98	0	0	2	0	3	8	0
P4-N	20	0	1	2	0	2	5	0
P5-F	11	0	0	3	0	1	3	0
P5-N	1	0	0	0	0	1	0	0
P6-F	40	2	0	4	0	1	1	0
P6-N	17	0	0	2	0	0	1	1
P7-F	28	0	0	2	1	5	6	0
P7-N	51	0	0	2	0	2	3	0
C1-F	25	0	0	3	0	0	5	0
C1-N	20	157	0	2	0	0	3	0
C2-F	26	3	1	1	0	1	5	0
C2-N	41	0	0	2	0	0	0	0
C3-F	20	1	0	1	0	0	2	0
C3-N	3	15	0	2	0	1	3	0
C4-F	67	0	0	1	0	2	2	0
C4-N	32	0	0	1	0	2	3	0
C5-F	38	0	0	2	0	0	7	0
C5-N	24	0	0	0	0	0	0	0
C6-F	14	0	0	2	0	2	6	0
C6-N	2	0	0	2	0	2	2	0
C7-F	27	0	0	2	1	2	11	0
C7-N	4	0	0	0	0	2	4	0

Appendix 3, continued.

Phylum	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida
Class	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta
Order	Phyllodocida	Phyllodocida	Phyllodocida	Phyllodocida	Phyllodocida	Phyllodocida	Phyllodocida	Phyllodocida
Family	Nephtyidae	Nephtyidae	Nereididae	Phyllodocidae	Phyllodocidae	Phyllodocidae	Phyllodocidae	Polynoidae
Species	Nephtyidae sp. juvenile	*Nephtys incisa*	*Alitta succinea*	*Eumida sanguinea*	*Hypereteone foliosa*	*Hypereteone heteropoda*	*Phyllodoce arenae*	*Lepidonotus sublevis*
Ecol Grp	2	2	3	2	3	4	2	2
P1-F	0	0	0	1	0	1	0	0
P1-N	0	0	0	0	0	1	0	0
P2-F	0	0	0	0	0	0	0	0
P2-N	0	0	0	0	0	1	2	0
P3-F	0	0	0	0	0	0	0	0
P3-N	0	0	0	0	0	0	0	0
P4-F	0	0	0	0	0	0	0	0
P4-N	1	0	1	0	0	1	0	1
P5-F	0	0	0	0	0	0	0	0
P5-N	0	0	0	0	0	1	0	0
P6-F	1	0	0	0	0	0	0	0
P6-N	0	0	1	0	0	0	0	0
P7-F	0	0	0	0	0	0	1	0
P7-N	0	0	0	0	0	1	1	0
C1-F	0	0	0	0	0	0	0	0
C1-N	0	0	3	3	0	0	0	0
C2-F	0	1	0	1	0	0	0	0
C2-N	0	0	0	0	0	0	1	0
C3-F	0	0	0	0	0	0	0	0
C3-N	0	0	0	0	0	1	0	0
C4-F	0	0	0	0	0	0	1	0
C4-N	1	0	0	0	0	0	0	0
C5-F	0	0	0	0	0	0	0	0
C5-N	0	0	0	0	1	0	0	0
C6-F	1	0	0	0	0	0	0	0
C6-N	0	0	0	0	0	0	0	0
C7-F	0	0	0	0	0	0	0	0
C7-N	0	0	0	0	0	0	0	0

Appendix 3, continued.

Phylum	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida
Class	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta
Order	Phyllodocida	Sabellida	Scolecida	Scolecida	Scolecida	Scolecida	Scolecida	Spionida
Family	Syllidae	Sabellidae	Capitellidae	Capitellidae	Cossuridae	Maldanidae	Orbiniidae	Chaetopteridae
Species	*Opisthodonta longocirrata*	*Parasabella microphthalma*	*Heteromastus filiformis*	*Mediomastus ambiseta*	*Cossura* sp. A Maciolek	*Maldanidae* sp. juvenile	*Leitoscoloplos robustus*	*Spiochaetopterus oculatus*
Ecol Grp	2	1	4	3	4	1	4	2
P1-F	1	2	0	103	6	0	6	3
P1-N	0	0	1	220	24	0	13	0
P2-F	0	0	0	89	9	0	13	0
P2-N	0	0	3	12	0	0	2	0
P3-F	0	0	2	130	0	0	2	1
P3-N	0	0	1	86	1	0	17	3
P4-F	0	0	0	408	28	1	4	1
P4-N	0	1	1	137	2	0	8	2
P5-F	0	0	2	377	3	1	24	0
P5-N	0	0	0	15	3	0	4	0
P6-F	0	0	0	128	0	0	7	2
P6-N	0	0	0	150	3	0	17	0
P7-F	0	0	1	282	0	0	6	1
P7-N	0	0	3	207	0	0	4	1
C1-F	0	0	0	67	10	2	16	2
C1-N	0	0	0	131	1	0	18	4
C2-F	0	2	0	118	7	0	17	0
C2-N	0	0	1	23	5	0	5	1
C3-F	0	0	0	216	6	0	12	5
C3-N	0	0	0	56	0	0	8	6
C4-F	0	0	0	512	23	1	22	2
C4-N	0	0	0	108	2	0	11	2
C5-F	0	0	0	255	2	0	21	2
C5-N	0	0	0	293	6	0	17	2
C6-F	0	0	0	432	1	0	23	1
C6-N	0	0	0	183	11	0	22	0
C7-F	0	0	1	431	0	0	7	0
C7-N	0	0	2	126	0	0	5	1

Appendix 3, continued.

Phylum	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida	Annelida
Class	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta	Polychaeta
Order	Spionida	Spionida	Spionida	Spionida	Spionida	Terebellida	Terebellida	Terebellida
Family	Spionidae	Spionidae	Spionidae	Spionidae	Spionidae	Ampharetidae	Cirratulidae	Pectinariidae
Species	*Paraprionospio alata*	*Polydora cornuta*	*Pygospio elegans*	*Scolelepis (Parascolelepis) bousfieldi*	*Streblospio benedicti*	*Ampharete oculata*	*Tharyx* sp. A (MWRA)	*Pectinaria gouldii*
Ecol Grp	4	4	3	3	3	2	4	1
P1-F	0	0	0	0	6	2	1	2
P1-N	1	1	0	0	16	2	1	8
P2-F	0	0	0	0	71	1	4	2
P2-N	0	1	0	0	31	4	0	1
P3-F	2	0	0	0	35	0	1	2
P3-N	1	0	0	0	44	2	2	0
P4-F	0	1	0	0	14	2	0	3
P4-N	1	2	0	0	67	7	1	1
P5-F	2	0	0	0	92	2	0	1
P5-N	0	0	0	0	15	7	0	0
P6-F	0	0	0	0	73	3	1	5
P6-N	0	1	0	0	84	8	5	0
P7-F	0	1	0	0	285	16	1	6
P7-N	0	2	0	0	192	7	0	1
C1-F	3	0	0	0	3	1	0	2
C1-N	1	2	0	0	95	5	1	2
C2-F	1	1	0	0	31	0	0	2
C2-N	2	2	0	0	90	6	0	1
C3-F	0	1	0	0	3	5	0	6
C3-N	1	2	0	0	23	3	0	2
C4-F	2	0	0	1	4	3	0	5
C4-N	1	2	0	0	77	0	0	5
C5-F	0	0	0	0	28	1	2	2
C5-N	0	0	0	0	55	6	1	0
C6-F	0	0	0	0	9	1	2	3
C6-N	2	12	0	0	8	3	1	0
C7-F	0	0	1	0	217	10	0	0
C7-N	0	0	0	0	134	7	0	0

Appendix 3, continued.

Phylum	Arthropoda	Arthropoda	Arthropoda	Arthropoda	Arthropoda	Arthropoda	Arthropoda	Arthropoda
Class	Malacostraca	Malacostraca	Malacostraca	Malacostraca	Malacostraca	Malacostraca	Malacostraca	Malacostraca
Order	Amphipoda	Amphipoda	Amphipoda	Amphipoda	Amphipoda	Cumacea	Cumacea	Decapoda
Family	Ampeliscidae	Aoridae	Caprellidae	Ischyroceridae	Oedicerotidae	Diastylidae	Leuconidae	Crangonidae
Species	*Ampelisca abdita*	*Grandidierella japonica*	*Paracaprella tenuis*	*Cerapus* sp. C LeCroy, 2007	*Ameroculodes* spp. complex	*Oxyurostylis smithi*	*Leucon americanus*	*Crangon septemspinosa*
Ecol Grp	3	3	1	1	1	1	2	1
P1-F	1	2	0	0	0	0	0	0
P1-N	0	1	0	0	0	0	1	0
P2-F	1	0	0	0	1	0	2	0
P2-N	0	0	0	0	0	2	2	0
P3-F	2	2	0	0	0	1	0	0
P3-N	3	0	0	0	0	0	0	0
P4-F	0	1	0	1	0	0	0	0
P4-N	0	1	0	0	0	0	0	0
P5-F	1	0	0	0	0	0	0	0
P5-N	0	0	0	0	0	0	4	0
P6-F	2	0	0	0	0	2	0	0
P6-N	2	0	0	0	0	0	4	0
P7-F	0	1	0	0	0	0	0	0
P7-N	1	1	0	0	0	0	0	0
C1-F	0	0	0	0	0	1	0	0
C1-N	3	5	0	0	0	0	0	0
C2-F	1	0	2	0	0	1	0	0
C2-N	2	0	0	0	0	0	1	0
C3-F	1	5	0	0	0	0	0	0
C3-N	3	1	0	0	0	0	0	0
C4-F	0	0	0	0	0	0	1	0
C4-N	0	1	0	0	1	0	0	0
C5-F	1	0	0	0	0	0	1	0
C5-N	1	3	0	0	0	1	0	1
C6-F	5	3	0	0	0	0	0	0
C6-N	1	1	0	0	0	0	0	0
C7-F	0	0	0	0	0	0	1	0
C7-N	1	0	0	0	0	1	0	0

Appendix 3, continued.

Phylum	Arthropoda	Arthropoda	Arthropoda	Arthropoda	Arthropoda	Chordata	Cnidaria	Cnidaria
Class	Malacostraca	Malacostraca	Malacostraca	Pycnogonida	Pycnogonida	Ascidiacea	Anthozoa	Anthozoa
Order	Decapoda	Isopoda	Isopoda	Pantopoda	Pantopoda	Stolidobranchia	Actiniaria	Actiniaria
Family	Paguridae	Idoteidae	Idoteidae	Callipallenidae	Phoxichilidiidae	Molgulidae	Edwardsiidae	Haloclavidae
Species	*Pagurus longicarpus*	*Edotia triloba*	*Synidotea laevidorsalis*	*Callipallene brevirostris*	*Anoplodactylus petiolatus*	*Molgula manhattensis*	*Edwardsia elegans*	*Haloclava producta*
Ecol Grp	2	2	NA	1	2	1	2	1
P1-F	0	2	2	0	0	1	0	0
P1-N	0	2	0	0	0	0	0	0
P2-F	0	1	1	0	0	0	0	0
P2-N	0	1	0	0	0	0	0	0
P3-F	0	1	0	0	0	0	0	0
P3-N	0	0	0	0	0	0	0	0
P4-F	0	1	1	0	0	1	0	0
P4-N	0	2	10	0	0	0	1	0
P5-F	0	0	0	0	0	0	0	0
P5-N	0	0	0	0	0	0	0	0
P6-F	0	0	0	0	0	0	0	0
P6-N	0	0	0	0	0	0	0	0
P7-F	0	0	0	0	0	0	0	1
P7-N	1	1	0	0	0	0	0	0
C1-F	0	0	0	0	0	0	0	0
C1-N	0	3	1	0	0	2	0	0
C2-F	0	1	2	1	0	1	0	1
C2-N	0	1	0	0	0	0	0	0
C3-F	0	0	3	0	0	1	0	0
C3-N	0	3	2	0	0	1	0	0
C4-F	0	0	0	0	0	0	1	0
C4-N	0	0	0	0	0	0	0	0
C5-F	0	0	0	0	0	0	0	1
C5-N	0	2	0	0	0	1	0	0
C6-F	0	0	0	0	3	0	1	1
C6-N	0	1	0	0	0	6	0	0
C7-F	0	2	1	0	0	0	0	0
C7-N	0	1	0	0	0	0	1	0

Appendix 3, continued.

Phylum	Echinodermata	Mollusca	Mollusca	Mollusca	Mollusca	Mollusca	Mollusca	Mollusca
Class	Holothuroidea	Bivalvia	Bivalvia	Bivalvia	Bivalvia	Bivalvia	Bivalvia	Bivalvia
Order	Apodida	Anomalodesmata	Anomalodesmata	Anomalodesmata	Cardiida	Cardiida	Cardiida	Imparidentia
Family	Synaptidae	Lyonsiidae	Lyonsiidae	Pandoridae	Solencurtidae	Solencurtidae	Tellinidae	Mactridae
Species	*Leptosynapta tenuis*	*Lyonsia hyalina*	*Lyonsia* sp. juvenile	*Pandora* sp. juvenile	*Tagelus* sp. juvenile	*Tagelus divisus*	*Ameritella agilis*	*Mulinia lateralis*
Ecol Grp	1	1	1	1	2	2	2	4
P1-F	0	0	1	1	0	0	1	0
P1-N	0	0	0	0	0	0	1	0
P2-F	0	0	0	0	0	0	2	2
P2-N	0	0	0	0	0	0	0	0
P3-F	0	2	0	3	0	0	2	11
P3-N	0	0	0	0	1	0	0	4
P4-F	0	2	0	0	0	0	0	8
P4-N	0	0	0	0	0	0	5	2
P5-F	0	0	0	0	0	0	1	7
P5-N	0	3	0	0	0	0	0	5
P6-F	0	0	1	0	0	0	4	2
P6-N	0	0	2	0	0	0	1	4
P7-F	0	0	4	1	0	0	6	3
P7-N	0	0	0	0	0	0	2	4
C1-F	0	0	0	1	0	0	1	1
C1-N	0	0	2	0	0	0	3	7
C2-F	2	0	1	2	0	1	1	1
C2-N	0	0	0	0	0	0	0	0
C3-F	0	0	0	0	0	0	1	2
C3-N	0	0	0	1	0	0	0	3
C4-F	0	0	0	2	0	0	2	0
C4-N	0	0	4	3	0	0	3	4
C5-F	0	0	0	0	0	0	4	7
C5-N	0	0	2	1	0	0	1	1
C6-F	0	0	3	2	0	0	9	7
C6-N	0	1	3	2	0	0	3	8
C7-F	0	0	2	0	0	1	11	2
C7-N	0	0	0	0	0	0	2	9

Appendix 3, continued.

Phylum	Mollusca	Mollusca	Mollusca	Mollusca	Mollusca	Mollusca	Mollusca	Mollusca
Class	Bivalvia	Gastropoda	Gastropoda	Gastropoda	Gastropoda	Gastropoda	Gastropoda	Gastropoda
Order	Myida	Acteonimorpha	Cephalaspidea	Littorinimorpha	Littorinimorpha	Neogastropoda	Neogastropoda	Nudibranchia
Family	Myidae	Acteonidae	Acteocinidae	Calyptraeidae	Naticidae	Muricidae	Nassariidae	
Species	*Mya arenaria*	*Japonactaeon punctostriatus*	*Acteocina canaliculata*	*Crepidula* sp. juvenile	*Neverita duplicata*	*Eupleura caudata*	*Tritia obsoleta*	*Nudibranchia* sp.
Ecol Grp	2	1	1	3	2	NA	3	NA
P1-F	0	14	15	2	0	0	2	0
P1-N	0	25	22	0	0	0	2	0
P2-F	0	17	8	0	0	0	0	0
P2-N	0	6	0	0	0	0	0	0
P3-F	1	26	11	0	0	0	0	0
P3-N	0	21	20	0	0	0	0	0
P4-F	2	42	18	0	0	0	2	0
P4-N	0	17	12	0	0	0	1	1
P5-F	1	35	18	0	1	0	1	0
P5-N	0	1	4	0	0	0	0	0
P6-F	0	48	20	0	0	0	0	0
P6-N	0	22	13	0	0	0	1	0
P7-F	0	39	6	0	0	0	1	0
P7-N	0	31	7	0	0	0	1	0
C1-F	0	15	13	0	0	0	0	0
C1-N	0	10	13	0	0	1	2	0
C2-F	0	30	26	0	0	0	0	0
C2-N	0	12	9	0	0	0	1	0
C3-F	0	25	20	0	0	0	0	0
C3-N	0	24	17	0	0	0	0	1
C4-F	0	16	24	0	0	0	0	0
C4-N	0	20	11	0	0	0	0	0
C5-F	0	18	24	0	0	0	0	0
C5-N	0	22	26	0	0	0	0	0
C6-F	0	46	25	0	0	0	0	0
C6-N	0	14	19	0	0	0	0	0
C7-F	0	52	8	9	0	0	0	0
C7-N	0	10	13	8	0	0	0	0

Appendix 3, continued.

Phylum	Mollusca	Mollusca	Nemertea	Nemertea	Nemertea	Nemertea	Platyhelminthes
Class	Gastropoda	Gastropoda	Anopla	Anopla	Enopla	Palaeonemertea	Rhabditophora
Order	Tectipleura	Tectipleura	Heteronemertea	Heteronemertea	Monostilifera		Polycladida
Family	Pyramidellidae	Pyramidellidae	Lineidae	Lineidae	Amphipoidae	Carinomidae	Stylochidae
Species	*Boonea bisuturalis*	*Odostomia* sp. juvenile	*Micrura* sp.	*Tenuilineus bicolor*	*Amphiporus bioculatus*	*Carinomella lactea*	*Stylochus ellipticus*
Ecol Grp	1	2	1	3	3	1	2
P1-F	0	1	0	0	0	11	0
P1-N	1	7	0	0	1	4	0
P2-F	0	4	0	0	1	3	0
P2-N	0	2	0	0	0	1	0
P3-F	0	2	0	0	1	10	0
P3-N	1	1	0	0	0	8	1
P4-F	4	15	0	0	0	28	0
P4-N	1	14	0	1	0	7	0
P5-F	0	4	0	0	0	6	0
P5-N	0	0	0	0	0	1	0
P6-F	2	6	0	0	1	4	0
P6-N	1	7	0	0	1	1	0
P7-F	0	13	0	0	0	10	0
P7-N	0	8	1	0	0	2	0
C1-F	0	1	0	0	0	5	0
C1-N	3	3	5	0	0	6	0
C2-F	0	2	0	0	1	3	0
C2-N	0	2	0	0	0	3	0
C3-F	0	5	0	0	1	9	0
C3-N	0	4	0	1	0	3	0
C4-F	0	5	0	0	0	10	0
C4-N	1	9	1	0	0	6	0
C5-F	0	2	1	0	0	7	0
C5-N	1	8	0	0	0	1	1
C6-F	0	3	0	0	0	6	0
C6-N	0	1	0	0	0	3	0
C7-F	0	0	1	0	0	7	0
C7-N	0	0	2	0	0	2	0