APPENDICES FOR:

SEDIMENT QUALITY OF THE NY/NJ HARBOR SYSTEM

EPA/902-R-98-001

Darvene A. Adams
U.S. Environmental Protection Agency - Region 2
Edison, NJ

Joel S. O'Connor
U.S. Environmental Protection Agency - Region 2
New York, NY

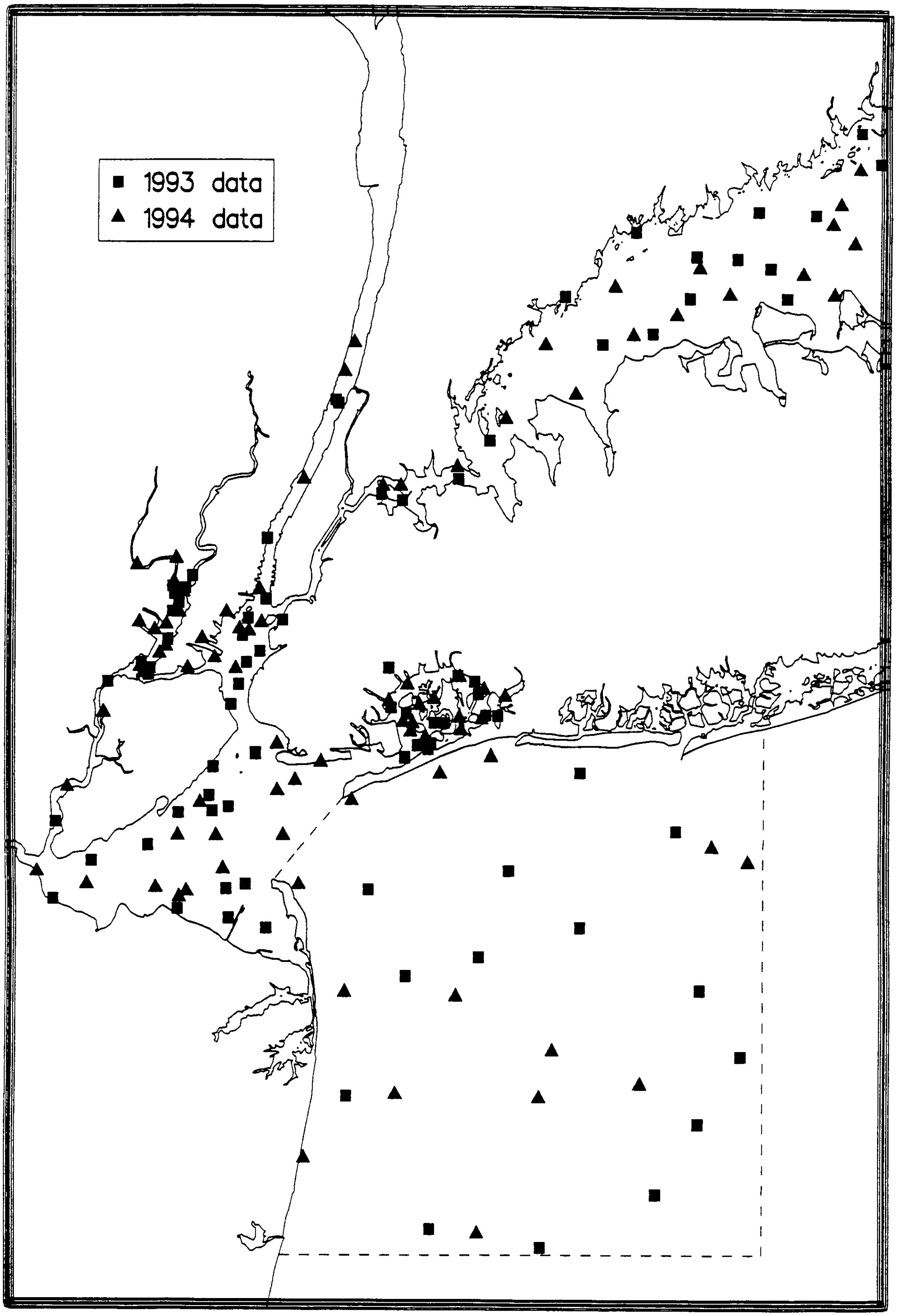
Stephen B. Weisberg
Southern California Coastal Water Research Project
Westminster, CA

March 1998

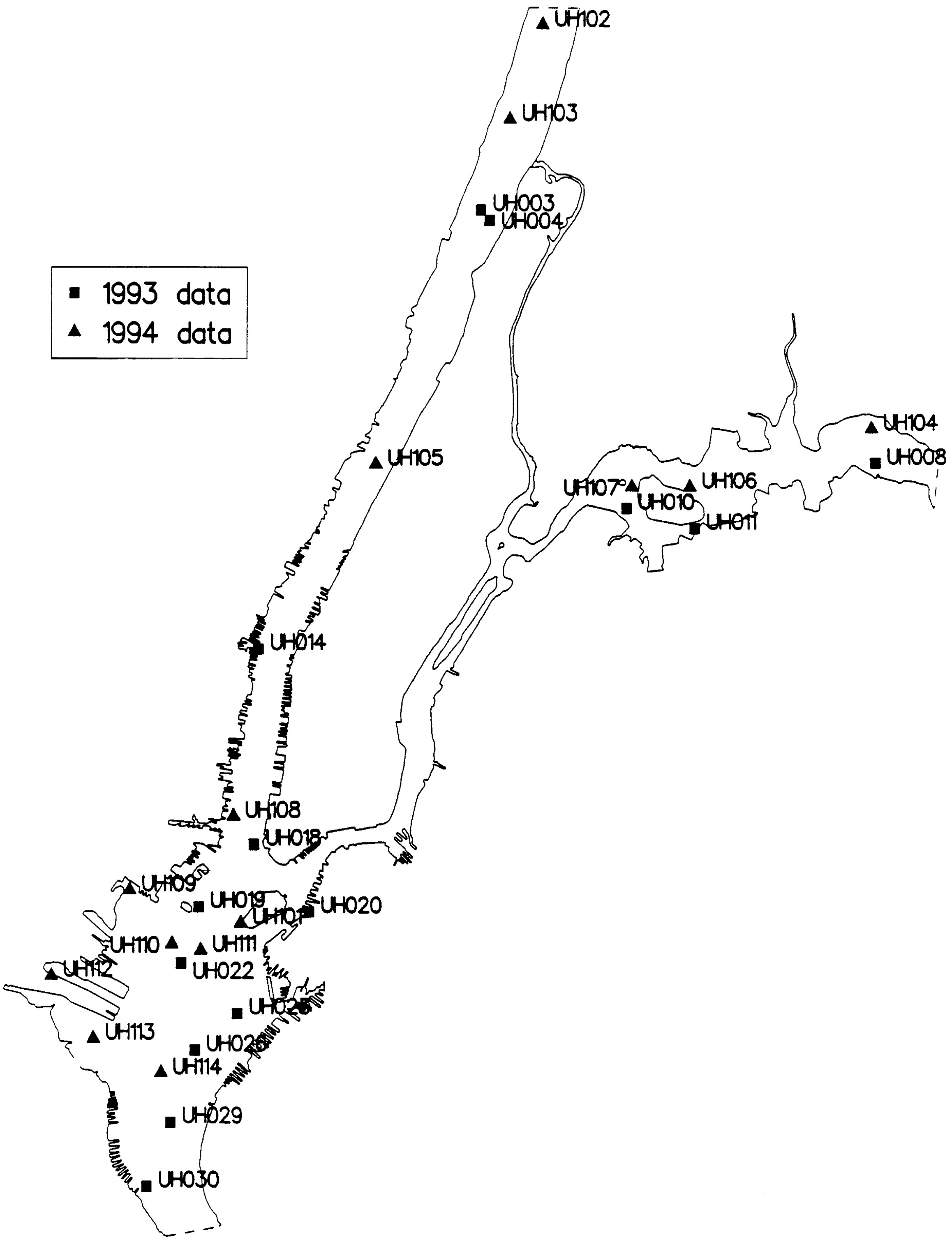
Appendix A

Sampling station maps

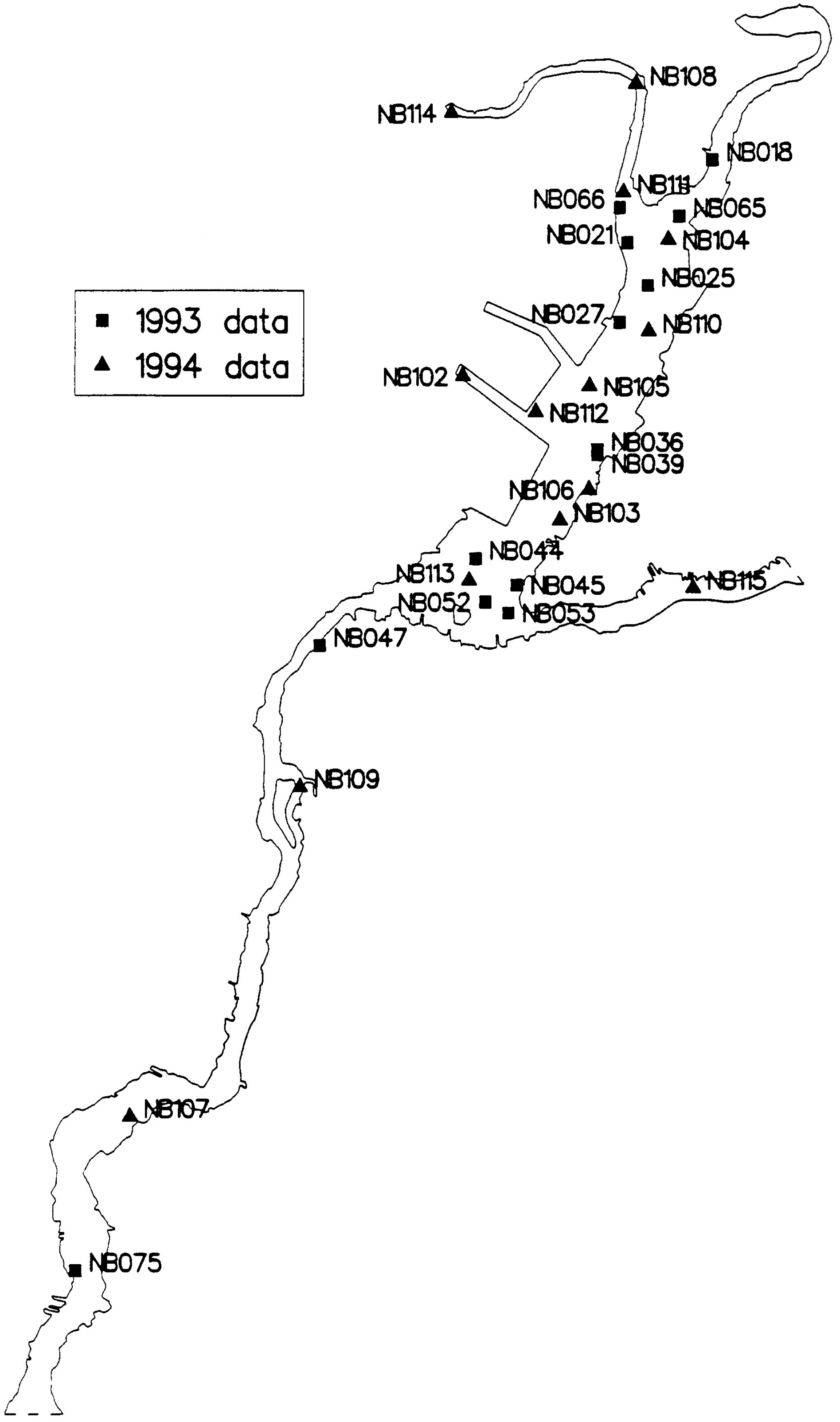
R-EMAP SUMMER 1993 AND 1994 SAMPLING LOCATIONS, NY/NJ HARBOR



R-EMAP SUMMER 1993 AND 1994 SAMPLING LOCATIONS, UPPER NEW YORK HARBOR



R–EMAP SUMMER 1993 AND 1994 SAMPLING LOCATIONS, NEWARK BAY



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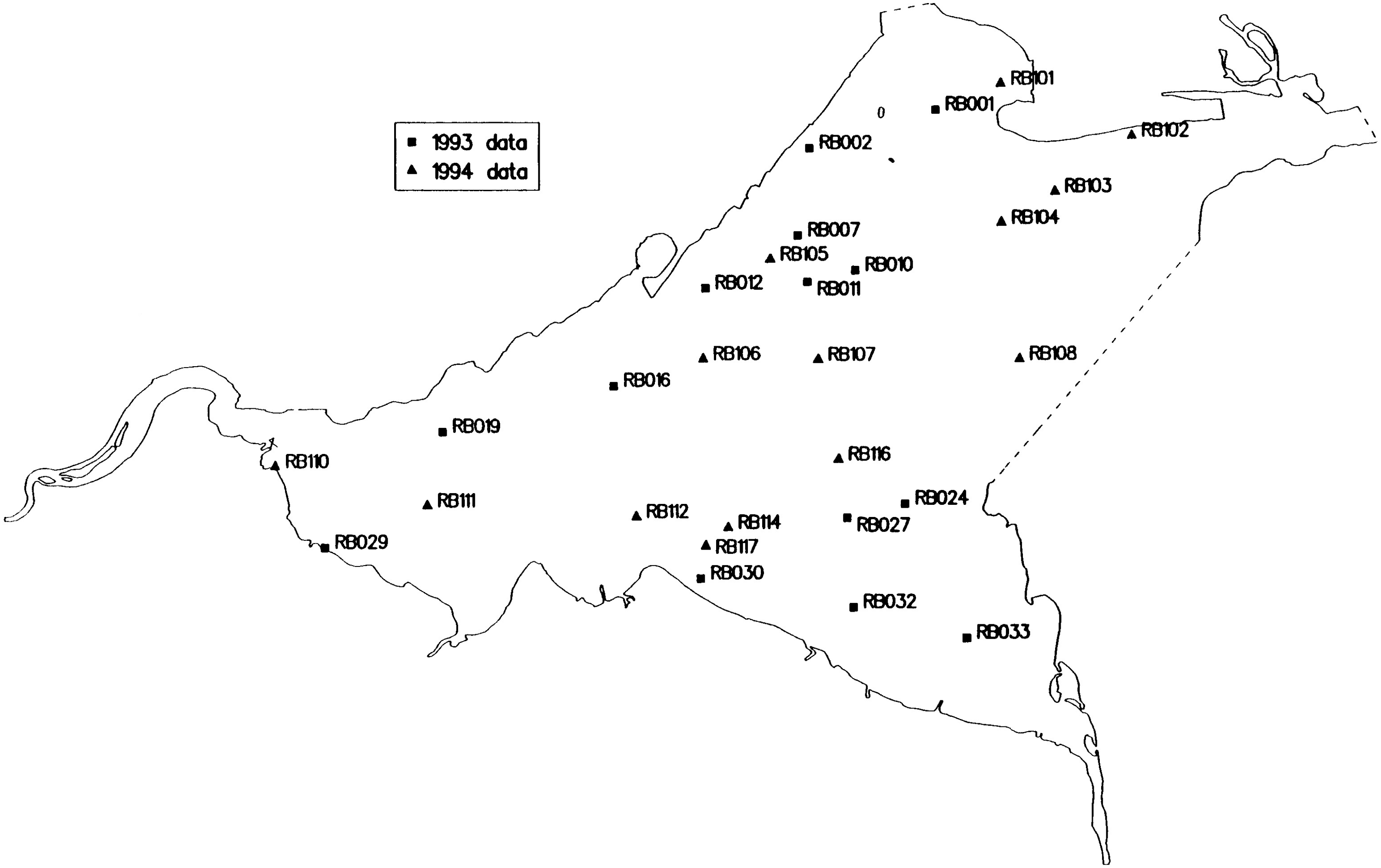
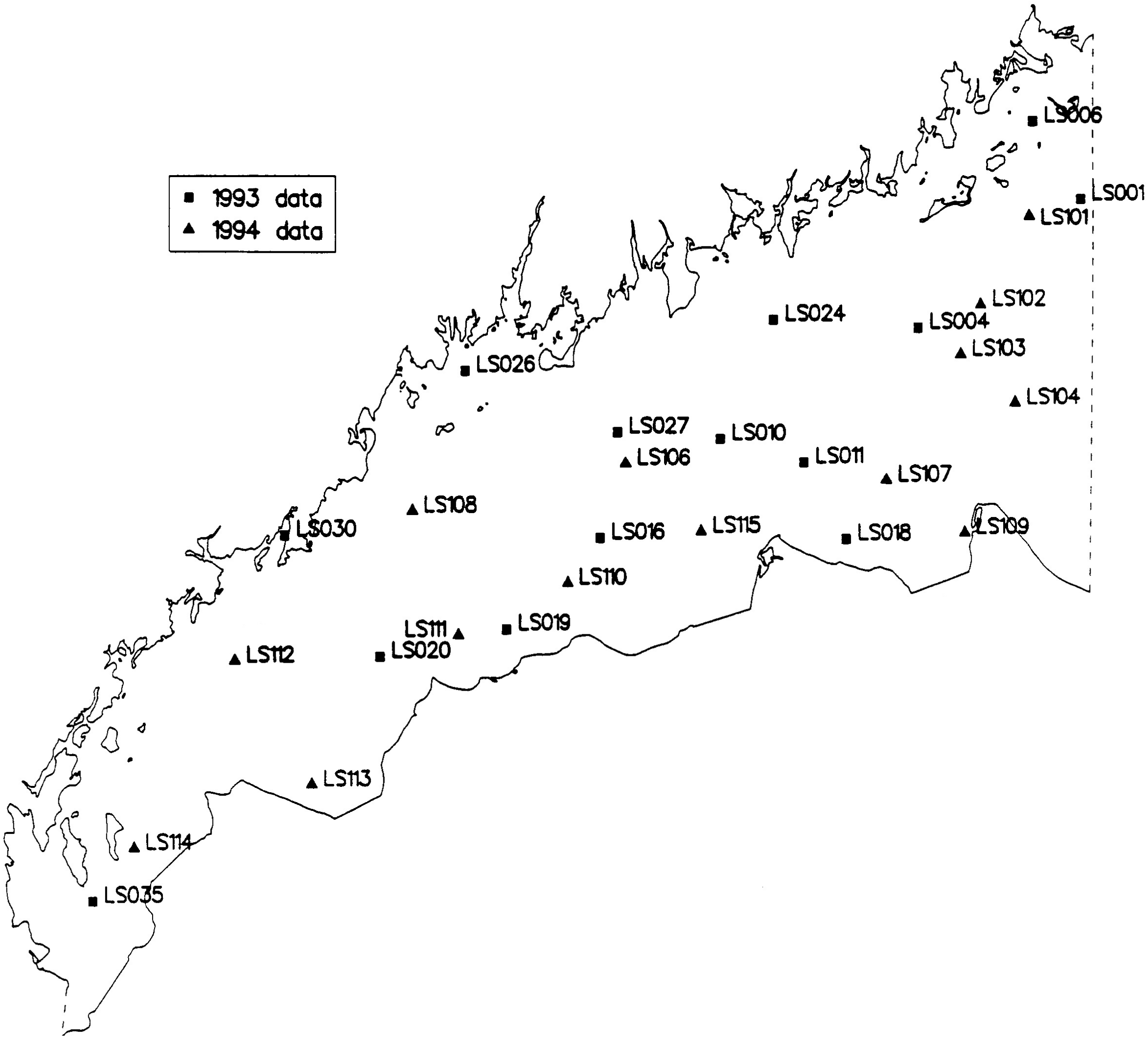
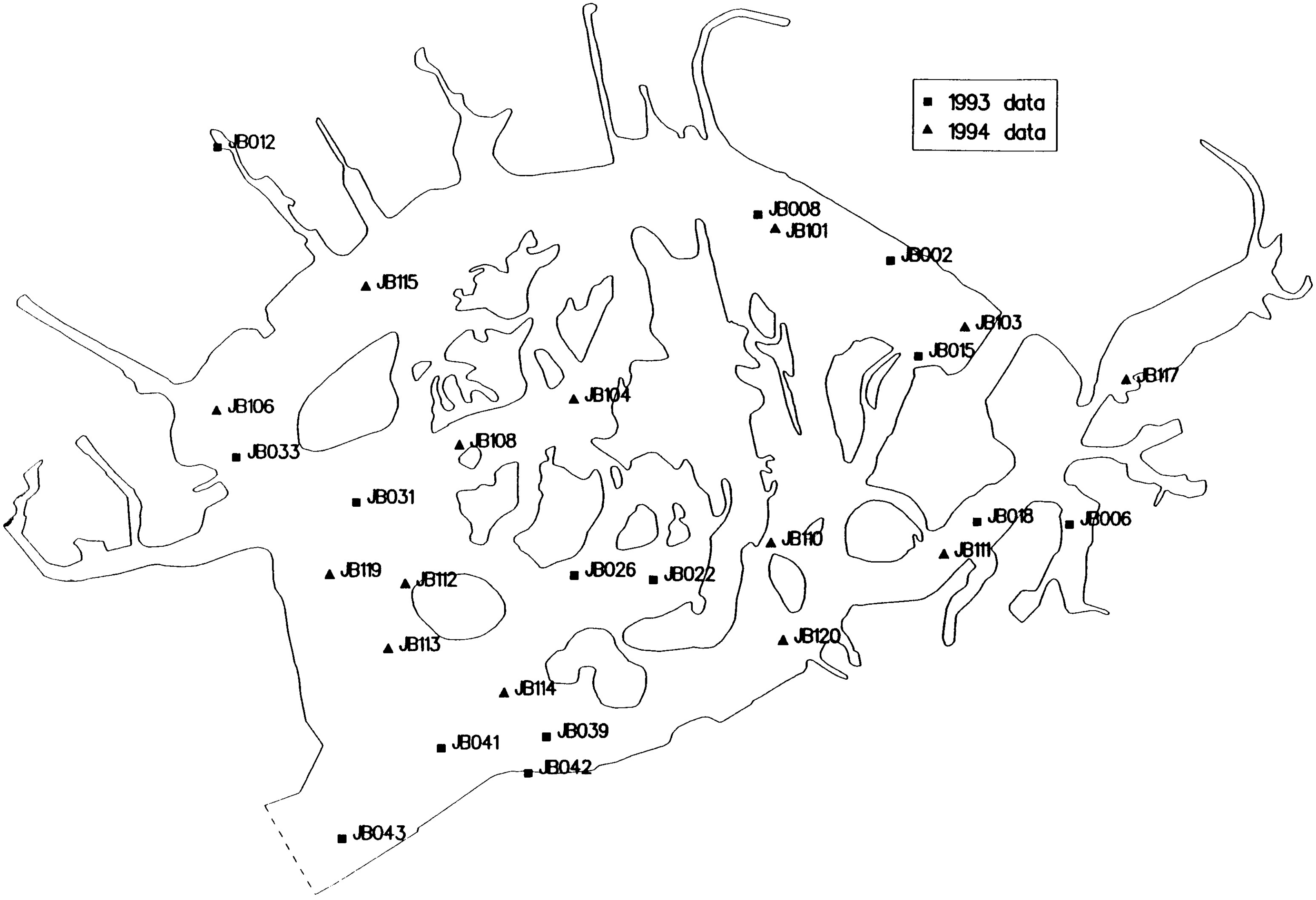


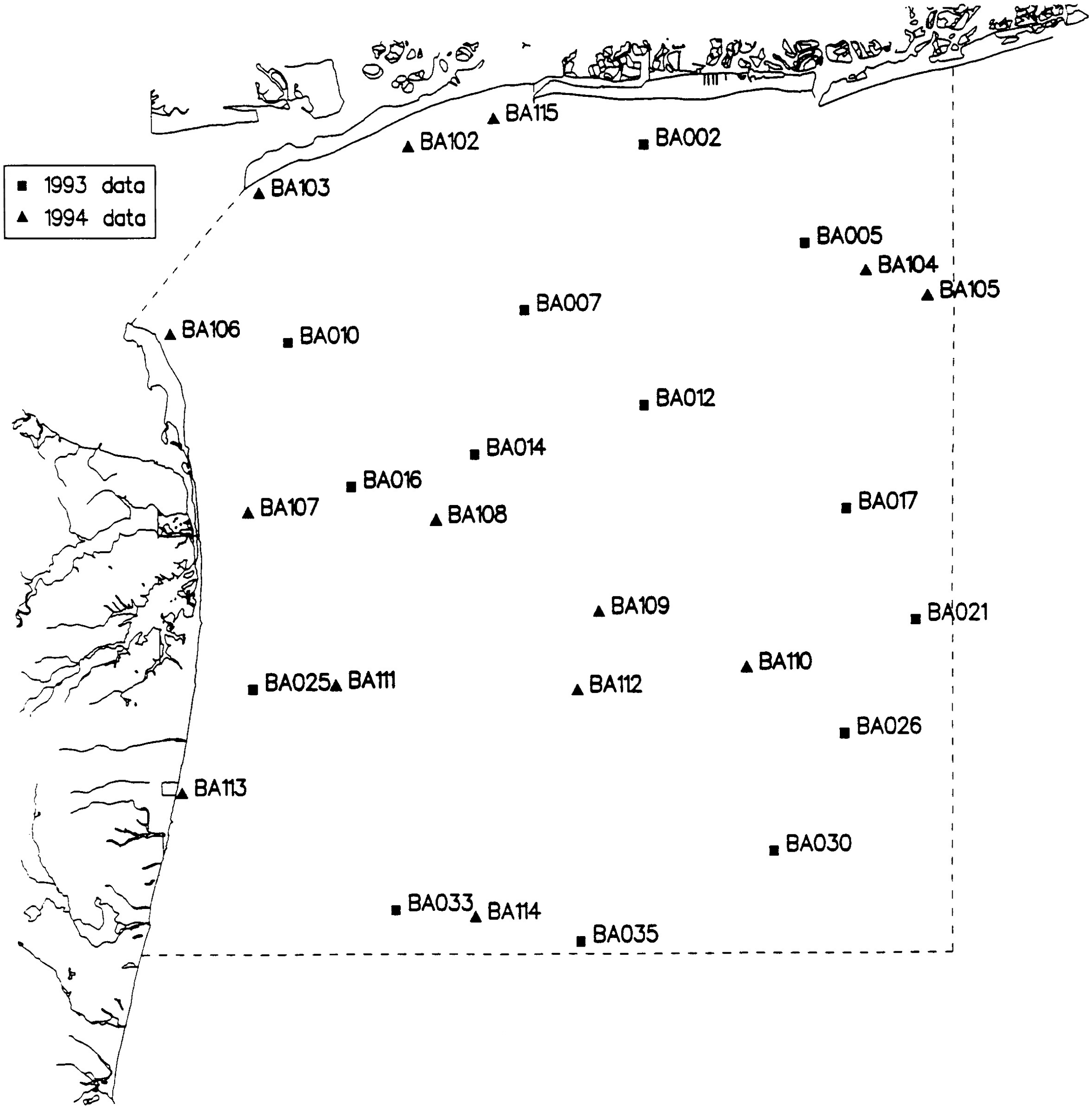
R-EMAP SUMMER 1993 AND 1994 SAMPLING LOCATIONS, WESTERN LONG ISLAND SOUND



R-EMAP SUMMER 1993 AND 1994 SAMPLING LOCATIONS, JAMAICA BAY



R-EMAP SUMMER 1993 AND 1994 SAMPLING LOCATIONS, NEW YORK BIGHT APEX



Appendix B

Analytical detection values

Analytical Detection Values for Sediment Samples

Parameter	DL	Parameter	DL
PAHs (ug/kg, dry wt.)		**Major and Trace Elements** (ug/g, dry wt.)	
Acenaphthene	12,24	Aluminum (Al)	200
Acenaphthylene	12	Antimony (Sb)	0.1
Anthracene	12	Arsenic (As)	0.24
Benzo(a)anthracene	12	Cadmium (Cd)	0.018
Benzo(b,k)fluoranthene	12,31	Chromium (Cr)	0.1
Benzo(g,h,i)perylene	12,25	Copper (Cu)	0.44
Benzo(a)pyrene	12	Iron (Fe)	40
Benzo(e)pyrene	12	Lead (Pb)	0.15
Biphenyl	12,24	Manganese (Mn)	3.5
Chrysene	12	Mercury (Hg)	0.01
Dibenz(a,h)anthracene	12,32	Nickel (Ni)	0.4
2,6-Dimethylnaphthalene	12	Selenium (Se)	0.1
Fluoranthene	12	Silver (Ag)	0.013
Fluorene	12,24	Tin (Sn)	0.1
Indeno(1,2,3-C,D)pyrene	12,30	Zinc (Zn)	1.5
2-Methylnaphthalene	12		
1-Methylnaphthalene	12,24	**PCBs** (ng/g, dry wt.)	
1-Methylphenanthrene	12,30	2,4'-dichlorobiphenyl (8)	2
Naphthalene	12	2,2',5-trichlorobiphenyl (18)	2
Perylene	12	2,4,4'-trichlorobiphenyl (28)	2
Phenanthrene	12	2,2',3,5'-tetrachlorobiphenyl (44)	2
Pyrene	12	2,2',5,5'-tetrachlorobiphenyl (52)	2
2,3,5-Trimethylnaphthalene	12,33	2,3',4,4'-tetrachlorobiphenyl (66)	2
		2,2',4,5,5'-pentachlorobiphenyl (101)	2
Pesticides (ng/g, dry wt.)		2,3,3',4,4'-pentachlorobiphenyl (105)	2
o,p’-DDD	1	2,3',4,4',5-pentachlorobiphenyl (118)	2
p,p’-DDD	1	2,2',3,3',4,4'-hexachlorobiphenyl (128)	2
o,p’-DDE	1	2,2',3,4,4',5'-hexachlorobiphenyl (153)	2
p,p’-DDE	1	2,2',4,4',5,5'-heptachlorobiphenyl (170)	2
o,p’-DDT	1	2,2',3,3',4,4',5-heptachlorobiphenyl (180)	2
p,p’-DDT	1	2,2',3,3',4,4',5,5'-heptachlorobiphenyl (187)	2
Aldrin	1	2,2',3,3',4,4',5,6-octachlorobiphenyl (195)	2
alpha-Chlordane	1	2,2',3,3',4,4',5,5',6-nonachlorobiphenyl (206)	2
trans-Nonachlor	1	2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl (209)	2
Dieldrin	1		
Heptachlor	1	**Butyltins** (ng/g, dry wt.)	
Heptachlor epoxide	1	Monobutyltin	5
Hexachlorbenzene	1	Dibutyltin	5
Lindane (gamma-BHC)	1	Tributyltin	5
Mirex	1	Tetrabutyltin	5
AVS/SEM (ug/g, dry wt.)		**Dioxin & Furan Congeners** (ng/kg, dry wt.)	
AVS	5	Detection limits for dioxins and furans varied by sample. See accompanying data disk for detection limits.	
SEM-Cd	0.2		
SEM-Cu	0.5		
SEM-Hg	0.07		
SEM-Ni	0.5		
SEM-Pb	1		
SEM-Zn	5		

Two values for a detection limit represent values achieved for 1993 and 1994 samples, respectively.

Appendix C

Development of the Benthic Index of Biotic Integrity (B-IBI)

Running Head: NY/NJ Harbor B-IBI

A BENTHIC INDEX OF BIOTIC INTEGRITY (B-IBI) FOR THE NEW YORK/NEW JERSEY HARBOR

Stephen B. Weisberg[1*]

J. Ananda Ranasinghe[1]

Joel S. O'Connor[2]

Darvene A. Adams[3]

[1]Versar, Inc.
9200 Rumsey Road
Columbia, Maryland 21045

[2]U. S. Environmental Protection Agency
Water Management Division
290 Broadway
New York, NY 10007

[3]U. S. Environmental Protection Agency
Environmental Services Division
2890 Woodbridge Avenue
Edison, NJ 08837

[*]Present Address:
Southern California Coastal Water Research Project
7171 Fenwick Lane
Westminster, CA 92683
(714) 894-2222

ABSTRACT

A multi-metric benthic index of biotic integrity (B-IBI) for the New York/New Jersey Harbor was developed by comparing the response of nine candidate measures of benthic condition (metrics) between a set of minimally-affected reference sites and a set of sites with known anthropogenic stress. The index was developed independently for each of four habitats defined by salinity and substrate. All nine candidate metrics differed significantly between reference sites and stressed sites in the calibration data set for at least one habitat. Six metrics differed significantly between reference and stressed sites in all habitats: species richness, species diversity, biomass, percent of abundance as pollution-sensitive taxa, percent of abundance as pollution-tolerant taxa, and percent of abundance as carnivores/omnivores. The index was calculated by scoring each of five selected metrics as 5, 3, or 1 depending on whether its value approximated, deviated slightly from, or deviated greatly from conditions at the best reference sites. Validation using independent data from 72 sites in the NY/NJ Harbor complex showed that the index was 93% effective at distinguishing anthropogenically stressed sites from reference sites.

INTRODUCTION

Numerous studies have documented a high degree of toxic contamination of sediments in the New York/New Jersey Harbor complex (Ianuzzi et al. 1995, Huntley et al 1993, Bonnevie et al. 1993, Williams et al. 1978). Billions of dollars have been spent to reduce source loads, which have declined by more than 90% in the last decade (Crawford et al. 1995). The proximal goal of these expenditures has been reduction of toxic contaminant inputs and ambient sediment concentrations, but the ultimate goal is protection of biological and human health resources. Few studies, though, have examined the extent of contaminant effects on the quality of biological assemblages (Steimle and Caracciolo-Ward 1989, Franz et al. 1988); most biological assessments conducted in the New York Harbor have focused on food chain effects of contaminants in tissues (Stainken and Rollwagen 1979, Burger and Gochfeld 1993, Zongwei et al. 1994, Peven et al. 1996).

The condition of benthic macrofaunal invertebrate assemblages is a good candidate for assessing the present condition and future changes in biotic condition of the NY/NJ Harbor. Benthos have limited mobility and cannot avoid adverse conditions (Gray 1979) so their condition accurately reflects local environmental conditions. Benthos live in sediments, where exposure to contaminant and hypoxia stress is generally most severe. Benthos are an important component of the food web, serving as an important link between primary producers and higher trophic levels (Holland et al. 1980, Baird and Ulanowicz 1989). Benthos also significantly affect oxygen, nutrient, and carbon cycles and may control the coupling of benthic and pelagic processes (Rhoads and Young 1970, Kemp and Boynton 1981, Blackburn and Henriksen 1983).

One factor limiting use of benthos for assessing condition of New York Harbor sediment is a lack of clear expectations for benthic assemblage characteristics in non-stressed habitats. These expectations are a necessary first step in using benthic community measures in assessments because expectations establish criteria for distinguishing between non-stressed sites and those with varying degrees of anthropogenic alteration. Such criteria could also be used to identify areas most in need of restoration and provide a quantitative endpoint for restoration.

One approach that has been used extensively in fresh water to define expectations at non-stressed sites is the Index of Biotic Integrity (IBI) (Kerans and Karr 1994, Simon and Lyons 1995). This approach defines community characteristics expected at sites free from anthropogenic stress, and scores metrics that quantify those expectations based upon observations at non-stressed reference sites. Characteristics of biota at other sites are then compared with these expectations to provide an assessment of site conditions. In this paper, we use that approach to develop a benthic index of biotic integrity (B-IBI) for application to summer estuarine benthic communities of the New York/New Jersey Harbor complex.

METHODS

Data Sources

The B-IBI was developed using data from EPA's Environmental Monitoring Assessment Program (EMAP), which collected benthos, sediment chemistry and sediment toxicity samples at 525 randomly selected sites in the Virginian biogeographic province in August and September between 1990 and 1993 (Paul et al 1992). At each site, triplicate samples of benthic macrofaunal communities were collected using a 440-cm^2, stainless steel, Young-modified VanVeen grab, and sieved in the field using a 0.5-mm screen and preserved in a 10% solution of buffered formaldehyde stained with rose bengal. A 50-ml core from each grab was frozen in a plastic bag for analysis of silt-clay content. Sediment samples for analysis of sediment chemistry and toxicity and were also collected using the VanVeen grab. A teflon spoon was used to remove the top 2 cm of sediment to a clean glass jar with a teflon lid, which was stored frozen. Dissolved oxygen and salinity were measured near the bottom of each site using a SeaBird CTD.

In the laboratory, macroinvertebrates were identified to the lowest practical taxonomic level and counted. Biomass was measured for 30 dominant species; other taxa were combined by feeding type and major taxonomic group (i.e., subsurface, deposit-feeding polychaetes). Biomass was determined as shell-free dry weight after drying at 60 °C for 48 hours. Bivalves longer than 2 cm were shucked and smaller shells removed by acidification in 10% HCl before determining biomass. Percent sand in the sediment was estimated as the fraction retained on a 63 u sieve. Percent silt and percent clay were determined using pipette analysis of the filtrate.

Sediment samples were analyzed for the NOAA Status and Trends Program list of chemicals (O'Connor and Ehler 1991) using standard methodologies (Table 1). Sediment toxicity was measured using the ten-day acute, static, non-renewal <u>Ampelisca</u> <u>abdita</u> test following ASTM (1990) protocols. For each toxicity test, 200 ml of composited, press-sieved sample was placed in 1 L glass test chambers and covered with 600 ml of seawater. Five replicate test chambers were used for each sample, with 20 organisms placed into each replicate.

The index was validated using independent data from 168 randomly selected sites in the New York/New Jersey Harbor complex between August and September in 1993 and 1994. The validation data set included the same variables collected using the same field and laboratory methods as described above, except that only two benthic macrofaunal samples were processed for each site.

Index Development

The B-IBI was developed by testing and quantifying previously established principles that benthic assemblages respond to improvements in habitat quality in at least four ways: (1) species diversity increases as new taxa that are unable to tolerate poor habitat quality flourish (Pearson and Rosenberg 1978); (2) the abundance and biomass of organisms increases (Pearson and Rosenberg 1978, Warwick and Clarke 1991); (3) the dominant species at the site change from pollution-tolerant to pollution-sensitive (Boesch 1973, Warwick 1986, Dauer 1993); and 4) the diversity of feeding guilds increases (Brown et al. in press). These hypotheses were tested by comparing benthic assemblages at reference sites with those at anthropogenically stressed sites, selecting attributes that differed significantly between the two groups for inclusion in the index, and establishing thresholds for the selected attributes based on the range of attribute values at the reference sites.

Reference sites were selected by eliminating locations near known point-source discharges, and selecting from the remaining sites those where bioassay survival exceeded 80% of controls, and no contaminant exceeded Long et al.'s (1995) Effects Range-Median (ER-M) concentration, and no more than two contaminants exceeded Long et al's Effects Range-Low (ER-L) concentration, and total organic content of the sediment was less than 2.5%, and dissolved oxygen concentration at the time of sampling exceeded 5 ppm. Sites were also screened to exclude those that occurred in areas of known frequent hypoxia, such as western Long Island Sound. The anthropogenically stressed sites used for comparison of response were identified as sites where any sediment contaminant exceeded Long et al.'s (1995) ER-M concentration and survival in sediment toxicity tests was less than 80% of control, or dissolved oxygen content was below 2 ppm.

Two criteria were used to compare attribute values between reference and stressed sites. First, a Mann-Whitney U-test was used to test for difference in median. Second, the Kolmogorov-Smirnov two-sample test was used to test for other distributional differences. The latter is particularly important for attributes such as abundance and biomass, for which the anticipated response at stressed sites could be higher or lower than at reference sites, depending on the severity of the stress.

Nine candidate metrics from the four categories of benthic response were tested (Table 2). The feeding guild and pollution-sensitivity metrics required classification of collected species into groups. Feeding modes were assigned using literature descriptions of feeding behavior (Jorgensen 1966; Bousfield 1973; Fauchald and Jumars 1979; Dauer et al. 1981). Lists of pollution-indicative (Table 3) and pollution-sensitive (Table 4) taxa were developed by comparing relative abundance of taxa between the reference sites and stressed sites in the calibration data set. Pollution-indicative taxa were selected as those for which average abundance, average percent of abundance, and frequency of occurrence were all higher at stressed than reference sites (Table 3). Pollution-sensitive taxa were selected as those for which average abundance, average percent of abundance, and frequency of occurrence were all higher at reference than stressed sites, and for which percent of abundance at reference sites averaged at least 0.2% (Table 4).

Attributes were tested separately for each of four habitats defined by salinity and substrate type (Table 5). The four habitats were established using cluster analysis (Bray-Curtis similarity coefficient, flexible sorting, β=-0.25) on species abundances in the calibration data set to identify major site groupings, followed by ANOVA to determine whether salinity, grain size or depth differed significantly among the site groupings (Ranasinghe et al. in prep). Results from the cluster analysis were also used to identify geographical limitations for selection of reference sites; reference sites were selected from estuarine and coastal areas between Chincoteague Bay and Cape Cod, because euhaline and polyhaline benthic assemblages within the Virginian Province, except for Chesapeake Bay, exhibited a high degree of similarity (Ranasinghe et al. in prep).

Thresholds for each selected metric were established based on the distribution of its values at the reference sites. The IBI approach involves scoring each metric as 5, 3, or 1, depending on whether its value at a site approximates, deviates slightly from, or deviates greatly from conditions at the best reference sites (Karr et al. 1986). Threshold values were established as approximately the 5th and 50th (median) percentile values for reference sites in each habitat. For each metric, values below the 5th percentile were scored as 1; values between the 5th and 50th percentiles were scored as 3, and values above the 50th percentile were scored as 5. The scored values of the metrics were combined into an index by computing the mean attribute score across all selected metrics. Assemblages with an index score less than 3 are considered stressed, as they have metric values that on average are less than that at the poorest reference sites.

Two of the attributes, abundance and biomass, respond to stress bimodally, where the response can be greater than reference at sites with moderate degrees of stress and less than reference at sites with high degrees of stress (Pearson and Rosenberg 1978, Dauer and Conner 1980, Stull et al. 1986, Ferraro et al. 1991). These two attributes were scored as 5 for those values falling between the 25th and 75th percentile response at reference sites, and as a 3 for those values between the 5-25th and 75-95th percentiles at reference sites. Abundance values lower than the 5th percentile or higher than the 95th percentile were scored as a 1; biomass values higher than the 95th percentile were scored as a 3 since high biomass can occur naturally at non-stressed sites where biomass is dominated by large bivalves.

Index validation was conducted in three ways. First, we examined index values at reference sites and anthropogenically-stressed sites in the validation data set, which was independent of the data set used to develop the index. Our criteria for defining reference sites and known stressed sites from the validation data set were the same as those for the calibration data set; our hypothesis was that reference sites should have index values of three or greater, while stressed sites should have values less than three. Second, we examined the relationship between the index and TOC concentration, hypothesizing that stressed assemblages would occur at higher concentrations of TOC. We examined the B-IBI relationship with TOC in a correlative, rather than in a categorical, fashion because threshold levels for anticipated biological response to TOC levels are not well established. Third, we calculated the correlation between replicates in the validation data set to examine stability of the index over small spatial scales.

RESULTS

One hundred and twenty-five sites from the calibration data set met our criteria for reference sites. There were at least 25 reference sites for each habitat class, except for the polyhaline mud habitat, for which only eleven reference sites were available (Table 5). Twenty-five sites met our criteria as anthropogenically-stressed (Figure 1), though only two were identified for the euhaline sand habitat (Table 5).

All nine candidate metrics differed significantly between reference sites and stressed sites for at least one habitat in the calibration data set (Table 2). Species richness (number of species per sample), species diversity, biomass, percentage of abundance as pollution-sensitive taxa, percent of abundance as pollution-indicative taxa, and percent of abundance as carnivore/omnivores significantly differentiated reference and stressed sites in all four habitats.

Our initial list of metrics selected for the B-IBI, and their thresholds, are presented in Table 6. In developing the index, we chose to include the abundance metric in the index for all habitats even though it statistically distinguished reference and stressed sites in only three of the four habitats; we did so because the pattern of response was similar in all habitats, and the response in the fourth habitat was significant at $p = 0.2$.

We excluded species diversity from the index because it was highly correlated with species richness, and species richness was slightly more effective at differentiating reference and stressed sites.

Validation

The initial index developed from the calibration data set classified 89% of the validation sites correctly, with classification efficiency equalling or exceeding 80% in each habitat except polyhaline sand (Table 7). When we examined the validation efficiency of each metric individually, we found that the proportion of abundance as carnivore/omnivores was the least effective metric for differentiating reference from stressed sites and was the metric that differed most in classification efficiency between the calibration and validation data sets (Table 8). We also found that when the carnivore/omnivore metric was removed from the index, classification efficiency of the index at validation sites improved slightly (Tables 7). Therefore, we removed this metric from the index, improving overall validation efficiency to 93%.

The final index was significantly correlated with total organic carbon in both the calibration (r = -0.50) and validation (r = -0.54) data sets. Ninety-two percent of the samples for which TOC exceeded 3%, and all of the samples for which TOC exceeded 4%, had an index value less than 3, indicating a stressed benthic assemblage.

Index scores were significantly correlated (r = 0.84) between replicates; average difference in index scores between replicates was 0.32. Ninety-one percent of replicates at the same site classified the same; at most sites where replicates classified differently, the replicates had similar index values, but were close to, and on either side of, the index threshold value of 3.

DISCUSSION

The premise of the IBI approach is that there are selected quantifiable characteristics of biotic assemblages which are held in common at reference sites and which differ from those at anthropogenically stressed sites. Our study found that this was the case for at least five different metrics, each of which was effective at discriminating stressed sites in all of the habitats we studied. Cumulatively, these metrics were 93% effective at differentiating reference and stressed sites.

Another premise of the IBI approach is that biotic communities respond to stress in numerous ways, often in a staged fashion, and that multiple metrics are required to appropriately integrate these responses (Barbour et al. 1995). Pearson and Rosenberg (1978) erected a paradigm along these lines for marine benthos, with different metrics providing better discrimination of effect at varying distances from sources of stress. Our results are consistent with the multi-metric premise, as we found that the combination of metrics provided greater discrimination than any of the metrics alone (Tables 7 and 8).

We found the most efficient metrics were those based on pollution-tolerance of species occurring at the sites (Table 8). Our empirical approach to defining pollution-indicative taxa differs from most previous efforts at categorizing marine species groups, in which pollution tolerance has been largely inferred from life history characteristics (Dauer 1993). The two approaches are not inconsistent, as indicated by the similarity of our list of pollution-indicative taxa and the lists of opportunistic taxa from other studies of east coast benthic macrofauna (Grassle and Grassle 1974, McCall 1977, Dauer 1993). One possible reason for the similarity in lists is that our approach for identifying pollution-indicative taxa does not discriminate between pollution-tolerant taxa and those that recolonize quickly following stress events. The similarity of the lists suggests that the latter is the predominant mechanism.

Our list of pollution-sensitive taxa is less consistent with previously developed lists of equilibrium taxa. Perhaps the difference results from incomplete knowledge of life histories for many benthic organisms, as Seitz and Schaffner (1995) have suggested. Despite this difference, the pollution-sensitive taxa metric had a higher classification efficiency than the pollution-indicative taxa metric for the validation sites. Perhaps this is because the pollution-indicative taxa are ubiquitous colonizing taxa, and their presence alone is not necessarily an indicator of poor habitat conditions at the site; only when the pollution-indicative taxa constitute a sizable portion of the assemblage do they become reliable indicators. In contrast, the pollution-sensitive taxa show a high fidelity to reference sites and may be the first to die or leave the site as stress occurs.

In developing the index, we chose a species richness metric in preference to species diversity. We did so because the richness metric was more effective at distinguishing reference from stressed sites in the calibration (and subsequently in the validation) data set. Species richness has the disadvantage, though, of being gear-specific, whereas diversity is less so (Ewing et al. 1988). We felt comfortable including richness because we used the same sampling device at all of our sites. If the index is applied to historical data, or to data collected using a different gear type, we recommend substituting a diversity metric in place of species richness. The thresholds for the diversity metric based on our calibration data set were 1.9 and 3.2 for all habitats. In our validation data set, substituting the diversity metric for species richness reduced validation efficiency to 89%.

Biomass is a metric in our index that is not measured by some benthic programs because of cost. We found it to be the least effective of our metrics at distinguishing stressed sites. It was also the metric that varied most among replicates (Table 9), probably because it can be so easily skewed by a single large individual. Calculating the final index without the biomass metric, as if these data were not available, reduced validation efficiency to 89%.

Although index development was conducted on a habitat-specific basis, the metric response values at reference sites were largely habitat-independent. Applying metric threshold values averaged across habitat reduced classification efficiency of the index by only 2% in the calibration data set and not at all in the validation data set. Weisberg et al. (In press), conducting a similar effort to establish thresholds for benthic assemblage response variables at reference sites in Chesapeake Bay, also found consistency in response among higher salinity habitats. Lopez (1988) suggested that many of the factors that structure benthic communities are similar over gradients as sharp as those from freshwater to saltwater. Such cross-habitat comparative studies are rare in benthic ecology; the consistency of our assemblage metric thresholds across habitats, despite substantial differences in species composition in the different habitats, suggests that further comparative work is warranted.

There has been recent debate as to whether the condition of benthic communities is more appropriately assessed using multivariate examination of individual species responses, or by using assemblage level metrics, as was used here (Norris 1995, Gerritsen 1995). We suggest that these approaches are not mutually exclusive and may be best employed together; multivariate approaches are sensitive enough to illuminate even minor changes in species composition, whereas the assemblage level approach provides perspective on the importance of those changes. The multivariate approach, though, may be harder to employ. Both approaches require description of reference condition. Assemblage level metrics appear to be relatively robust to physical habitat variation; species composition is not. The high degree of habitat specificity of individual species may lead to difficultly in defining reference condition for the multivariate approach, with false positives resulting if there are minor differences in natural physical habitat between the reference and potentially affected sites.

While our B-IBI was validated using data only from the NY/NJ Harbor, it was developed based on data from a large portion of the mid-Atlantic coast. One issue that remains unresolved is whether it is applicable over the larger geographic scale of the calibration data set, which will be difficult to address because their are few independent data sets from the east coast with concurrently collected benthic and stressor data that could be used for validation. One such data set, to which we applied the B-IBI, was collected from the Delmarva peninsula (Chaillou and Weisberg 1995) located at the southern boundary of our calibration data set. We found that the index validated at all sixteen sites in that data set that met our criteria as reference or stressed sites, suggesting that the index is applicable to at least the southern portion of the province. In contrast to our NY/NJ Harbor validation, however, the percent of abundance as pollution-sensitive taxa was only 69% efficient at discriminating sites, indicating that either the taxa list, or the thresholds used for this metric, may not be uniformly applicable at extreme ends of the province. Attempts at validation with data sets from other areas will be required to assess the degree of index modification necessary to assure that the index is applicable to the remainder of the Virginian Province.

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Table 1. Physical/Chemical Analytical Methods

Parameter	Method
PAHs	Methylene chloride extraction; determination by GC/MS
PCBs/Pesticides	Methylene chloride extraction; determination by HRGC/ECD
Major and Trace Elements	HNO_3 and HF acid digestion: Hg - CVAAS; Cu, Ni, Pb, Cr, Sb, Sn, As, Se, Ag, Cd - GFAAS; Al, Fe, Mn, Si, Zn - FAAS
Dioxins & Furans	Extraction with toluene; determination by HRGC/HRMS; second column confirmation for 2,3,7,8-TCDD
TOC	Acidification with H_3PO_4; determination using a CO_2 analyzer
Grain size	Sieving and pipette analysis

Table 2. Mean benthic assemblage values at reference sites (top number) and stressed sites (bottom number). Top number shaded indicates pair is different by Mann-Whitney test; bottom number shaded indicates different by Kolmogorov-Smirnov test.

	Polyhaline Sand	Polyhaline Mud	Euhaline Sand	Euhaline Mud
Species Diversity				
Number of Taxa	19.5	21.2	28.3	24.0
	15.4	6.0	14.7	7.5
Shannon-Weiner	2.58	2.81	3.04	2.73
	2.15	1.01	0.85	1.11
Abundance and Biomass				
Abundance (#/m^2)	9111	7319	11686	83
	8656	6638	14027	7234
Biomass (g dry	4.9	6.8	7.4	14.4
	15.2	22.1	1.7	36.6
Species Composition				
Percent of abundance as pollution-indicative taxa	11.4	15.1	12.4	14.6
	68.1	79.3	52.2	90.5
Percent of abundance as pollution-intolerant taxa	18.5	18.3	30.2	8.8
	1.9	0.1	0.2	0.1
Trophic Composition				
Percent of abundance as carnivore/ omnivores	17.0	14.8	13.2	13.1
	5.5	5.2	0.5	2.0
Percent of abundance as deposit feeders	42.1	40.6	27.1	53.5
	34.6	24.7	27.8	56.3
Percent of abundance as suspension feeders	40.4	44.6	59.5	33.3
	59.8	66.5	38.4	41.7

Table 3. Mean abundance percent of abundance, and frequency of occurrence of pollution-indicative taxa at reference and stressed sites in the calibration data set

	Abundance ($\#/m^2$)		**% of Abundance**		**Frequency of Occurrence**	
	Reference Sites	**Stressed Sites**	**Reference Sites**	**Stressed Sites**	**Reference Sites**	**Stressed Sites**
Streblospio benedicti	332	2299	3.1	32.7	38.8	66.7
Capitella spp.	26	42	0.3	5.5	12.9	14.8
Polydora cornuta	92	355	1.0	2.5	29.8	42.6
Mulinia lateralis	84	2786	2.0	15.8	28.6	46.3
Oligochaetes	524	738	7.1	24.9	77.7	77.8

Table 4. Mean abundance, percent of abundance, and frequency of occurrence of pollution-sensitive taxa at reference and stressed sites in the calibration data set

	Abundance ($\#/m^2$)		**Percent of Abundance**		**Frequency of Occurrence**	
	Reference Sites	**Stressed Sites**	**Reference Sites**	**Stressed Sites**	**Reference Sites**	**Stressed Sites**
Polychaeta						
Ampharete arctica	42.5	0.0	0.4	0.0	16.9	0.0
Aricidea catherinae	176.5	0.8	2.1	0.0	33.7	1.9
Caulleriella spp.	9.4	0.0	0.3	0.0	15.7	0.0
Clymenella torquata	25.6	0.0	0.2	0.0	13.7	0.0
Glycinde solitaria	45.4	6.7	0.7	0.1	25.9	13.0
Levinsenia gracilis	93.3	0.0	0.7	0.0	13.3	0.0
Macrocylmene zonalis	16.0	0.0	0.2	0.0	17.6	0.0
Nephtys picta	30.9	0.0	1.0	0.0	29.0	0.0
Ninoe nigripes	27.8	0.0	0.4	0.0	14.1	0.0
Polygordius spp.	53.7	0.0	0.6	0.0	15.7	0.0
Sabaco elongatus	32.9	0.4	0.5	0.0	16.5	1.9
Scalibregma inflatum	61.2	0.0	0.5	0.0	8.2	0.0
Spiophanes bombyx	82.3	0.0	1.5	0.0	31.4	0.0
Mollusca						
Spisula solidissima	28.3	0.0	0.7	0.0	18.8	0.0
Tellina agilis	313.4	15.6	4.4	0.4	54.9	18.5
Acteocina canaliculata	88.7	1.3	1.6	0.0	32.6	3.7
Arthropoda						
Ampelisca agassizi	68.3	0.0	0.3	0.0	3.5	0.0
Ampelisca verrilli	224.5	0.0	2.1	0.0	26.3	0.0
Byblis serrata	40.5	0.0	0.2	0.0	5.9	0.0
Rhepoxynius hudsoni	23.1	0.4	0.7	0.0	11.8	1.9

Table 5. Number of sites in calibration data set

	Habitat	Environmental Conditions	
Salinity Class	**Sediment Type**	**Reference Sites**	**Stressed Sites**
Polyhaline (15-28 ppt)	Mud (≥40% silt/clay)	11	12
	Sand (<40% silt/clay)	28	6
Euhaline (28-35 ppt)	Mud (≥40% silt/clay)	26	5
	Sand (<40% silt/clay)	60	2

Table 6. Thresholds used to score each metric of the NY-NJ Harbor B-IBI

	Scoring Criteria		
	5	3	1
Number of Species			
Polyhaline Sand	> 20	15 - 20	< 15
Polyhaline Mud	> 20	15 - 20	< 15
Euhaline Sand	> 25	15 - 25	< 15
Euhaline Mud	> 25	15 - 25	< 15
Abundance (#/m^2)			
Polyhaline Sand	2,500 - 10,000	1,000 - 2,500 or 10,000 - 25,000	< 1,000 or > 25,000
Polyhaline Mud	3,000 - 10,000	1,500 - 3,000 or 10,000 - 20,000	< 1,500 or > 20,000
Euhaline Sand	3,000 - 10,000	1,500 - 3,000 or 10,000 - 50,000	< 1,500 or > 30,000
Euhaline Mud	3,500 - 10,000	2,000 - 3,500 or 10,000 - 25,000	< 2,000 or > 25,000
Biomass			
Polyhaline Sand	2 - 8	0.8 - 2 or > 8	< 0.8
Polyhaline Mud	3 - 10	1 - 3 or > 10	< 1
Euhaline Sand	2 - 10	0.8 - 2 or > 10	< 0.8
Euhaline Mud	4 - 10	1 - 4 or > 10	< 1
Abundance of Pollution-Indicative Taxa (%)			
Polyhaline Sand	< 10	10 - 40	> 40
Polyhaline Mud	< 10	10 - 40	> 40
Euhaline Sand	< 10	10 - 40	> 40
Euhaline Mud	< 10	10 - 40	> 40

Table 6. Continued

	Scoring Criteria		
	5	3	1
Abundance of Pollution-Sensitive Taxa (%)			
Polyhaline Sand	> 15	3 - 15	< 3
Polyhaline Mud	> 15	3 - 15	< 3
Euhaline Sand	> 15	3 - 15	< 3
Euhaline Mud	> 10	2 - 10	< 2
Abundance of Carnivores/Omnivores (%)			
Polyhaline Sand	> 15	3 - 15	< 3
Polyhaline Mud	> 15	4 - 15	< 4
Euhaline Sand	> 10	2 - 10	< 2
Euhaline Mud	> 10	3 - 10	< 3

Table 7. Percent of sites in the validation data set correctly classified by the B-IBI, with and without the carnivore/omnivore metric

Habitat	**Number of Sites**	**Percent Correctly Classified**	**Percent Correctly Classified Without Carnivore/Omnivore Metric**
Polyhaline Sand	19	74	79
Polyhaline Mud	20	100	100
Euhaline Sand	23	96	100
Euhaline Mud	10	80	90
Overall	72	88.9	93.1

Table 8. Classification efficiency (%) of reference and stressed sites for the individual metrics

Metric	**Calibration Data Set**	**Validation Data Set**
Number of Taxa	84.7	68.1
Shannon-Weiner Diversity	78.2	58.3
Abundance	75.3	63.9
Biomass	81.3	63.9
% of Abundance as Pollution-indicative Taxa	90.0	77.8
% of Abundance as Pollution-sensitive Taxa	83.3	88.9
% of Abundance as Carnivores/Omnivores	81.3	56.9

Table 9. Correlation between replicate samples for each of the metric values in the index

Metric	**Correlation Coefficient**
Number of Species	0.89
Shannon-Weiner Diversity	0.84
Abundance	0.84
Biomass	0.62
Percent Abundance as Pollution-Indicative Taxa	0.86
Percent Abundance as Pollution-Sensitive Taxa	0.95

Appendix D

Aluminum-normalization procedure

Comparison of sediment metal:aluminum relationships between the eastern and gulf coasts of the United States

S. B. Weisberg[1*]

H. T. Wilson[2]

D. G. Heimbuch[2]

H. L. Windom[3]

J. K. Summers[4]

[1]Versar
9200 Rumsey Road
Columbia, MD 21045

[2]Coastal Environmental Services
1099 Winterson Rd.
Linthicum, MD 21090

[3]Skidaway Institute of Oceanography
10 Ocean Science Circle
Savannah, GA 31411

[4]US EPA
Sabine Island
Gulf Breeze, FL 32561

[*]Present Address:
Southern California Coastal Water Research Project
7171 Fenwick Lane
Westminster, CA 92683
Stevew@sccwrp.org

INTRODUCTION

Metal contamination of sediments is a concern to the normal function of estuarine and nearshore systems [1,2]. A portion of the metals in sediments comes from natural weathering of crustal rocks, with naturally higher concentrations of metals occurring in finer-grained fractions of sediments. One challenge in assessing the spatial extent of metal contamination is separating anthropogenic contributions of metals from natural contributions.

Several techniques have been developed for making this distinction [3], the most popular of which is aluminum-normalization [4,5,6,7,8,9]. Using this approach, aluminum is treated as a conservative tracer of the natural metal-bearing phases (i.e., aluminosilicates) in the fine sediment fraction. Anthropogenic contributions to aluminum concentrations are trivial compared to the natural contribution, and the natural metal-to-aluminum ratio should be relatively constant within a region and similar to the crustal ratio [10] or to the ratio observed in source rocks in the regional watershed. Using the normalization approach, a set of uncontaminated sites are identified, and statistical relationships between each metal and aluminum are identified for those sites. Significant deviation from those relationships indicates anthropogenic enrichment.

Metal-to-aluminum ratios have been determined on several spatial scales ranging from individual estuarine systems [11,12,13] to entire countries [7,8,14]. Differences in metal-to-aluminum ratios have been found among studies conducted on these different spatial scales, which could be explained by regional differences in the ratios within source rocks or by differences in the fractionation of metals between soluble and particulate phases during weathering. These geologic explanations, though, are confounded by differences in data analysis approaches used by various investigators in defining the relationships. The most important methodological differences among such studies are in the assumed functional form of the relationship and in the means of ensuring that only non-contaminated sites are included in the data sets used to derive the relationships.

The uncertainty concerning differences in normalization techniques among studies hampers inter-regional comparisons of anthropogenic influence. If the metal-to-aluminum ratios in crustal or source rock, or weathering characteristics differ between regions, then locally derived aluminum relationships would be the most appropriate basis for such comparisons. Alternatively, if differences in metal-to-aluminum ratios are artifacts of data analysis techniques used to define the relationship, then using locally derived relationships would bias inter-regional comparisons. This paper addresses these concerns by applying a common analytical methodology to data collected on the Atlantic and Gulf coasts to identify the most appropriate spatial scales for developing aluminum-normalization curves.

METHODS

Data Sources

Sampling was conducted in two biogeographical provinces: the Virginian Province, extending from Cape Cod to Cape Henry on the Atlantic coast (Figure 1), and the Louisianian Province, extending from Tampa Bay to the Mexican border along the Gulf Coast (Figure 2). Sampling in the Virginian Province was conducted from late July to early September annually between 1990 and 1993. Sampling in the Louisianian Province was conducted from July 1 through August 30 annually between 1991 and 1994. Between 100 and 160 sites were sampled in each province each year. Sampling sites were selected using a stratified random design in which the estuaries were classified as large estuaries (surface area >250 km^2); large tidal rivers (surface area >250 km^2 with an aspect ratio of 18:1 or greater); and small estuarine systems, which included all other systems with a surface area of at least 2.5 km^2. Sampling sites within each stratum were selected randomly.

Sediment samples were collected at each site using a 440-cm^2 Young-modified VanVeen grab. A teflon spoon was used to remove the top 2 cm of sediment to a clean glass jar with a teflon lid, which was stored frozen. Metals were analyzed in the laboratory by HF/HNO_3 digestion, followed by inductively coupled plasma mass emission spectrometry (Ag, Al, Cr, Cu, Fe, Ni, Pb, Zn), microwave digestion using HNO_3/HCl followed by graphite furnace atomic absorption spectrophotometry (Cd, Sb, Se, Sn), or cold vapor atomic absorption spectrophotometry (Hg). Silver, antimony, selenium, and tin were measured in the Virginian Province only during the last three years. Reagent and procedural blanks were analyzed to check for laboratory contamination during processing. Approximately every tenth sample was split and processed as a laboratory duplicate. In addition, National Research Council of Canada Certified Reference Material BCSS-1 was analyzed with approximately every 10 samples to assess accuracy and precision.

Data Analysis

The relationship between the concentration of aluminum and a response metal was estimated based on a linear model:

$$Y = \beta * Al + m + e$$

where,

Y = concentration of the response metal

β = slope relating the response metal to aluminum

Al = aluminum concentration

m = intercept

e = random measurement error

Anthropogenically contaminated sites were removed from the data set by comparing the residual of the regression with an estimate of laboratory measurement error. This approach was based on the premise that if the data set did not include anthropogenically enriched sites, the mean square error (MSE) from the regression would equal measurement error. If the MSE exceeded measurement error, the site with the highest residual in the model was removed, and the model was reparameterized. This procedure was repeated until the MSE was no greater than measurement error. Laboratory measurement error was estimated based on repeated measurements from blind laboratory duplicates and standard reference materials.

To compare metal-to-aluminum relationships between the two provinces, we applied our estimation method separately to data from each year, providing four independent slope and intercept estimates for each province. These annual estimates for each province served as replicates to test whether the intercept differed significantly from zero, and whether slope or intercept differed between provinces, based on a t-test ($\alpha=0.05$). Initial applications of the model included an intercept term. If the average intercept for a given metal did not differ significantly from zero in our initial runs, the regression was recalculated with a no-intercept model. If the intercepts were significantly different from zero, but not different between provinces, the regression was recalculated after setting the intercept equal to the average intercept between provinces. If the intercepts for both provinces were equivalent, the four independent yearly estimates were used to assess whether slopes differed significantly between provinces.

RESULTS

Mean and maximum aluminum concentrations differed between the two provinces by about 15%. Mean concentration of other metals differed by a substantially greater margin, with differences of 100% or more for 5 of the 12 metals examined (Table 1). For every metal except aluminum, the mean and maximum observed concentrations were higher in the Virginian Province.

Six of the 10 metals we examined had intercepts that differed significantly from zero in at least one of the provinces (Table 2). In all cases where the intercept was significant, the intercepts were positive values. For only three metals did the intercept differ significantly between provinces. Most intercept values were small compared with the mean value for the province; however, for silver in the Louisianian Province and selenium in the Virginian Province the intercept values were almost half of the mean values for the province.

Of the six metals that had an equivalent intercept between provinces, only three (Hg, Pb, Ni) had significantly different slopes (Table 3). For each of these metals the slope was higher in the Virginian Province than in the Louisianian Province. For nickel, the slope difference was only 30%; for lead and mercury, the difference was almost 100% (Table 3).

The number of samples removed from the regression based on deviation greater than measurement error differed substantially among chemicals and between the provinces (Table 4). Thirty-six percent of the sites in the Virginian Province and 22% in the Louisianian Province were eliminated from the regression for at least one chemical. Most of the sites that were eliminated for one chemical were eliminated for several chemicals (Table 5). The spatial pattern of eliminated sites was highly clustered, with most sites occurring around the major cities of New York, Philadelphia, Baltimore, Galveston, Mobile, and New Orleans (Figures 1 and 2).

DISCUSSION

Most of the differences in metal-to-aluminum ratios between the mid-Atlantic and Gulf coasts of the United States were small. Slopes differed by more than 30% only for mercury, lead, silver, and selenium, and comparisons for the latter two were confounded by differences in intercept. Differences in slope or intercept were mostly limited to metals with small natural concentrations; there were no significant differences in slope or intercept for the naturally most abundant metals (e.g., copper, zinc, chromium).

We used a new approach for ensuring that only unenriched sites were used to estimate the natural metal-to-aluminum relationships within a province. Previous authors have used a variety of techniques for accomplishing this objective. Some authors have removed sites with large concentrations or sites where biological effects are suspected [9]. This may lead to a shallower slope if naturally occurring high concentrations are removed from the regression. Other authors have screened their sites based on the uses of the surrounding land by equating low population density or absence of known point sources with a lack of anthropogenic input [5,7,8,14]. This approach is probably suitable for sparsely populated areas, but becomes highly subjective in densely populated areas such as the Virginian Province.

Our approach is most similar to that of Schropp et al. [5], in which sites were sequentially eliminated from the regression until the residuals were distributed normally. Our approach, however, uses additional information to identify a quantitative stopping rule for data removal; Schropp et al.'s approach of examining kurtosis is more subjective. Our approach, though, requires an unbiased estimate of measurement error, which can be hard to develop because many laboratories fail to quantify error or do so as part of a performance evaluation in which the analyst knows which samples are being used for the test.

Our approach also assumes that the study area encompasses enough unenriched sites to define a baseline relationship. This may not be the case for lead in the Virginian Province because atmospheric deposition is a primary source of lead. If atmospheric deposition enhanced concentrations equally everywhere, then our approach would quantify the deposited lead as an addition to the intercept term. If atmospheric inputs varied within a region, or if these additions bound disproportionately to the fine-grained sediment, our approach would quantify the additional lead as an increase in slope. The higher slope we observed in the Virginian Province probably reflects widespread enrichment, and the lead-to-aluminum relationship we defined for the Virginian Province may underestimate enrichment.

An alternate approach for obtaining reliable baseline conditions for defining metal-to-aluminum relationships is to sample deep sediments that were deposited before the industrial period. Obtaining such samples requires expensive coring equipment and specialized techniques for dating the sediments accurately. Such data records are few, and they typically do not include a sufficient range of aluminum concentrations to identify metal-to-aluminum relationships. The available coring data, however, provide a benchmark for validating the relationships we identified in other ways. For the Virginian Province, we compared our metal-to-aluminum relationships with those in pre-industrial sediment cores collected by Goldberg et al. in Chesapeake Bay [15] and Narragansett Bay [16]. For copper, cadmium, nickel and zinc, the historic data matched our findings well; all of the historic samples were bisected by and within the measurement error of our regression line (Figure 3). Our relationship for lead was steeper than suggested by the deep sediment samples, confirming our concern that widespread contamination has caused us to overestimate the underlying relationship. Our relationship for chromium had a shallower slope than suggested by the deep sediment samples.

For the Louisianian Province, we compared our findings to ratios in pre-industrial cores from the Mississippi River [17] and Texas [18]. Data for all metals, except copper, were mostly within the measurement error of our metal-to-aluminum relationships (Figure 4). For copper, our data matched the data from Texas well but had a shallower slope than the data from the Mississippi River. Our shallower slope for copper than in sediments from the Mississippi River is not an artifact of our data analysis because we eliminated very few data points in identifying the relationship between copper and aluminum.

We also compared our metal-to-aluminum relationships with those identified by other authors working in our geographic study areas and found considerable similarity for all metals except lead in the Virginian Province. For lead, most previous studies suggested a relationship more similar to the slope we found for the Louisianian Province. Interestingly, all of the previous studies found slopes for chromium in the Virginian Province that were equivalent to or less than those we found in the pre-industrial cores (Figure 5). It is unclear why samples of pre-industrial sediment contained larger chromium-to-aluminum ratios than those estimated in all other studies, but suggests the earlier data may contain a systematic analytical error. Standard reference materials were not readily available during the earlier studies; therefore, researchers had no way to assess the quality of their data, and because of its refractory nature, chromium is a difficult metal to analyze accurately. Perhaps our disagreement with copper data for the Mississippi River can be explained similarly.

One substantial difference between the relationships we defined and those defined in other studies is the magnitude and sign of the intercept term. We found the intercept to be nonsignificant in more than half of the cases we examined; when the intercept was significant, it was always a positive value. Many previous studies have reported negative intercepts. We believe the theoretical basis for a negative intercept is weak. The model of the metal-to-aluminum relationship is based on conservative mixing of aluminosilicates, which naturally contain large concentrations of metals, with quartz or other low metal-bearing phases such as carbonates. The intercept term should be equal to the concentration of the dependent metal in the low-metal phase end member.

In many of the previous studies, the negative intercept values were small enough to have resulted from random measurement error, which we were able to assess because we had four independent intercept estimates. Negative intercepts can also be analytical artifacts introduced when concentrations of the dependent metals fall below detection limits. An artificial negative slope would occur if samples with concentrations below detection limits were treated as zeros and combined with positive aluminum measurements (concentrations of aluminum typically exceed detection limits). Conversely, setting values of undetected dependent metals equal to detection limits of the analytical technique would artificially create a positive intercept. In our study, we chose to remove samples with values below the detection limit from analyses.

One shortcoming of our analytical approach is that we were unable to incorporate a measurement error term for aluminum. To determine if our results were sensitive to this shortcoming, we used the same analytical approach employing iron, which is also abundant in crustal rock, as the conservative tracer and tested to see if the same samples fell outside the background relationship. Eighty-three percent of the samples that we identified as enriched by aluminum-normalization were also identified as enriched by normalizing to iron. Another 9% were identified as enriched by the iron analyses only. Re-running our models, eliminating only samples that were identified as enriched in both the iron and aluminum analyses, had a negligible effect on the slopes of our metal-to-aluminum relationships.

One issue that we chose not to address in our analysis was mean-to-variance relationships. The data suggested a small mean-to-variance relationship in laboratory measurement error for most metals. Adjusting our model to exclude points based on a mean-to-variance relationship resulted in eliminating most samples closest to the origin. This difficulty arose because measurement error was not a linear function of concentration; rather there was a "nugget effect" in which measurement error relative to the mean increased at lower concentrations. We had too few replicate data at low concentrations to quantify the nugget effect. Modelling measurement error would be a fruitful area for refining our approach.

One advantage of our approach for examining metal-to-aluminum relationships is that our results can be applied easily to other data sets that either are too small or are collected from geographic areas that are too enriched to identify metal-to-aluminum relationships. Within our study areas, the base metal-to-aluminum relationship is constant for most metals. The only thing that changes among studies is the allowable deviation from these relationships. We suggest that there are three components of allowable deviation: (1) variance of the slope estimate, which can be estimated from the variability among our four independent slope estimates (Table 6); (2) variance of the intercept (where appropriate), which also can be estimated from our four yearly estimates (Table 6); and (3) measurement variance of the specific study. The probability that a sample has an enriched concentration of a metal can be estimated by dividing the difference between the observed and predicted concentrations of the metal by the square root of the sum of the three sources of error and comparing the quotient to standard normal critical values. Samples with quotients exceeding 1.96 have a 95% probability of enrichment.

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Table 1. Mean and maximum concentrations (ppm, except for aluminum, which is percent) of metals measured in each province. Table is based on all data collected.

	Mean Concentration		**Maximum Concentration**	
	Virginian Province	**Louisianian Province**	**Virginian Province**	**Louisianian Province**
Aluminum	4.1	4.6	9.8	13.8
Silver	0.4	0.1	9.7	0.9
Cadmium	0.5	0.2	8.0	1.5
Chromium	48.2	43.5	365.0	149.0
Copper	30.9	11.3	680.0	104.0
Mercury	0.1	0.1	3.3	0.4
Nickel	18.3	16.7	136.0	51.2
Lead	62.6	16.4	13,600.0	610.0
Antimony	1.0	0.6	152.0	3.8
Selenium	0.4	0.3	9.1	1.8
Tin	3.3	1.4	48.7	13.5
Zinc	115.6	64.3	1,090.0	625.1

Table 2. Annual intercept estimates for each province (ND = no data). Asterisk indicates the mean intercept value was significantly different from zero in the Virginia Province; Δ indicates the same for the Louisianian Province.

	Virginian Province				**Louisianian Province**			
Metal	**90**	**91**	**92**	**93**	**91**	**92**	**93**	**94**
AgΔ	ND	-0.005	0.029	-0.008	0.083	0.019	0.055	0.049
Cd*Δ	0.098	0.114	0.107	0.262	0.058	-0.004	0.085	0.086
Cr	-0.694	-1.762	0.976	-4.85	5.340	3.009	-0.488	1.389
Cu	-1.48	-1.07	-1.21	0.137	0.203	-0.359	-0.957	0.448
Hg*Δ	0.013	0.017	0.007	0.000	0.018	0.012	0.015	0.000
Ni	-5.88	-2.04	3.31	-4.29	-0.381	0.334	-1.18	2.36
Pb*Δ	6.97	2.85	1.58	-0.41	3.11	1.19	1.40	2.57
Sb*Δ	ND	0.066	0.158	0.265	0.216	0.083	0.162	0.160
Se*Δ	ND	0.159	0.179	0.352	0.057	0.062	0.056	0.106
Sn*	ND	0.087	0.210	0.225	0.081	0.010	0.189	-0.040
Zn	6.47	-3.57	3.05	-2.05	1.28	0.89	4.01	0.63

Table 3. Annual slope estimates for each province and the intercept values used in estimating the slopes.

Metal	**Virginian Province**				**Louisianian Province**				**Intercept Values**	
	90	**91**	**92**	**93**	**91**	**92**	**93**	**94**	**VP**	**LP**
Ag	ND	0.0247	0.0382	0.0360	0.0140	0.0186	0.0121	0.0135	0	0.0514
Cd	0.0447	0.0337	0.0426	0.0147	0.0265	0.0440	0.0172	0.0321	0.1008	0.1008
Cr	8.970	9.084	10.627	9.238	10.353	8.821	9.470	7.391	0	0
Cu	2.257	3.213	3.657	2.624	2.406	2.394	2.203	2.407	0	0
Hg	0.0152	0.0122	0.0193	0.0187	0.0074	0.0073	0.0083	0.0099	0.0103	0.0103
Ni	4.633	4.813	5.115	4.171	3.932	3.709	3.500	3.225	0	0
Pb	5.218	5.016	5.193	5.193	2.996	2.787	2.992	2.514	2.0954	2.0954
Sb	ND	0.0817	0.0762	0.0529	0.0963	0.0905	0.0780	0.676	0.1586	0.1586
Se	ND	0.0429	0.0286	0.0208	0.0460	0.0394	0.0499	0.0186	0.2296	0.0703
Sn	ND	0.5233	0.5096	0.4700	0.3282	0.3190	0.2134	0.3222	0.1732	0
Zn	13.527	14.028	15.403	12.212	11.992	13.424	12.919	10.765	0	0

Table 4. Percent of sites removed from the regression for each metal in each province.

	Virginian Province	**Louisianian Province**
Silver	20.0	0.0
Cadmium	12.5	0.0
Chromium	17.4	6.1
Copper	41.8	0.8
Mercury	13.7	0.0
Nickel	0.5	0.0
Lead	32.9	0.3
Antimony	10.5	2.8
Selenium	35.7	17.1
Tin	12.5	0.0
Zinc	51.6	11.2

Table 5. Frequency distribution of number of metals removed from the regression

Number of Metals Removed	Percent of Sites	
	Virginian Province	Louisianian Province
0	41.4	66.1
1	14.9	18.6
2	11.5	9.2
3	7.5	2.0
4	5.3	1.4
5	3.6	0.9
6	4.3	0.8
7	3.8	0.2
8	2.8	0.2
9	3.2	0.0
10	1.3	0.0
11	0.4	0.0

Table 6. Variance associated with parameter estimates for the metal:aluminum models in each province

Metal	Province	Slope	Intercept	Slope Variance	Intercept Variance
Silver	Louisianian	0.0146	0.0514	0.0	0.0002
Silver	Virginian	0.0330	-	0.0	0
Cadmium	Both	0.0323	0.1008	0.0	0.0007
Chromium	Both	9.2442	-	0.1233	-
Copper	Both	2.6451	-	0.0338	-
Mercury	Louisianian	0.0082	0.0103	0.0	0.0
Mercury	Virginian	0.0164	0.0103	0.0	0.0
Nickel	Louisianian	3.5914	-	0.0227	-
Nickel	Virginian	4.6826	-	0.0390	-
Lead	Louisianian	2.8223	2.0954	0.0129	0.5509
Lead	Virginian	4.6600	2.0954	0.2461	0.5509
Antimony	Both	0.0776	0.1586	0.0	0.0007
Selenium	Louisianian	0.0385	0.0703	0.0001	0.0001
Selenium	Virginian	0.0308	0.2296	0.0	0.0038
Tin	Louisianian	0.2957	-	0.0008	-
Tin	Virginian	0.5009	0.1737	0.0003	0.0019
Zinc	Both	13.0336	-	0.2485	-

Figure 1. Number of metals found to be anthropogenically enriched at study sites in the Virginian Province.

Figure 2. Number of metals found to be anthropogenically enriched at study sites in the Louisianian Province.

Figure 3. Metal-to-aluminum relationships in pre-industrial sediment cores from the Virginian Province and samples used in the present study. Dashed lines represent 95% confidence intervals based on laboratory measurement error. Circles are from Goldberg et al.'s Core #1314 [16]. Squares are from Goldberg et al.'s Core #1411 [16]. Asterisks are from Goldberg et al.'s Core #7408 [15].

Figure 4. Metal-to-aluminum relationships in pre-industrial sediment cores from the Louisianian Province and those from the present study. Dashed lines represent 95% confidence intervals based on laboratory measurement error. Squares are data from the Mississippi River [17]. Asterisks are data from Texas [18].

Figure 5. Chromium-to-aluminum relationships among several studies and in deep sediment cores. Symbols are the same as in Figure 3.

Appendix E

Tables:

Table E-1

Area-Weighted Mean Sediment Contaminant Concentrations

(± represent 90% confidence intervals)

	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
METALS (ppm)							
Aluminum	43456 ±4229	31862 ±3761	64633 ±4207	38706 ±6466	56705 ±4551	62745 ±4324	26345 ±3376
Antimony	1.49 ±0.48	0.84 ±0.52	6.27 ±6.80	1.24 ±0.30	1.11 ±0.18	0.70 ±0.11	0.81 ±0.19
Arsenic	10.33 ±2.05	5.07 ±1.26	25.51 ±20.15	10.01 ±2.49	9.04 ±1.14	7.05 ±0.84	8.48 ±2.12
Cadmium	0.79 ±0.13	0.95 ±0.53	2.52 ±0.58	0.54 ±0.18	0.93 ±0.18	0.70 ±0.14	0.17 ±0.10
Chromium	78.09 ±10.11	50.96 ±9.17	137.31 ±14.08	71.48 ±15.32	92.44 ±12.27	80.66 ±10.70	35.74 ±9.46
Copper	72.53 ±17.40	55.15 ±35.09	226.69 ±105.28	47.29 ±16.01	110.12 ±57.65	70.43 ±11.63	9.26 ±5.23
Iron	23483.6 ±2897.0	16883.4 ±3230.7	33980.2 ±3830.8	22170.9 ±4405.9	27269.04 ±3208.9	28149.3 ±2665.1	16066.0 ±3447.2
Lead	78.84 ±12.83	63.29 ±37.42	193.92 ±60.70	63.78 ±17.47	96.55 ±18.40	57.38 ±9.39	21.69 ±5.71
Manganese	495.26 ±44.14	390.86 ±66.24	427.94 ±53.12	481.32 ±63.71	605.71 ±78.59	988.18 ±120.43	483.18 ±98.54

Table E-1 Continued.	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
Mercury	0.74 ±0.14	0.29 ±0.13	2.59 ±0.58	0.61 ±0.21	0.80 ±0.16	0.22 ±0.04	0.12 ±0.10
Nickel	24.07 ±2.90	17.80 ±10.31	50.81 ±8.72	20.08 ±4.03	30.92 ±3.80	26.92 ±3.45	8.69 ±2.50
Selenium	3.82 ±1.02	1.34 ±0.56	10.98 ±4.14	3.60 ±1.50	3.41 ±1.28	2.16 ±0.73	0.85 ±0.71
Silicon	354788 ±16077	349968 ±26009	315399 ±16061	367569 ±24327	330116 ±17836	300703 ±19640	412862 ±12327
Silver	1.59 ±0.30	1.14 ±0.42	2.98 ±0.61	1.29 ±0.44	2.28 ±0.46	1.19 ±0.32	0.23 ±0.14
Tin	4.96 ±1.54	2.84 ±1.43	15.29 ±13.27	3.43 ±1.40	7.45 ±4.44	2.98 ±0.96	1.57 ±0.66
Zinc	170.06 ±25.56	134.89 ±74.55	308.04 ±55.85	162.56 ±37.38	166.68 ±26.28	177.34 ±24.25	47.02 ±10.06
ORGANICS (ppb)							
Total PCBs = (∑congeners) x 2	224.35 ±42.25	112.34 ±67.57	755.62 ±270.28	120.46 ±43.88	428.74 ±124.62	85.51 ±22.11	55.26 ±40.98
Parent DDT	9.57 ±9.38	0.92 ±0.15	132.97 ±147.29	1.28 ±0.31	0.99 ±0.19	0.97 ±0.20	1.33 ±0.57
Total DDD	14.16 ±5.98	2.83 ±1.32	122.41 ±89.49	5.71 ±2.60	11.94 ±3.60	3.00 ±0.65	1.75 ±1.30

Table E-1 Continued.	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
DDE	8.53 ±2.54	3.18 ±1.60	65.20 ±35.68	4.04 ±1.66	7.32 ±2.04	2.72 ±0.54	1.18 ±0.69
Total DDT	31.59 ±16.64	5.95 ±2.90	320.31 ±256.91	10.28 ±4.52	19.84 ±5.07	6.38 ±1.30	2.78 ±2.63
Chlordane	5.11 ±1.01	5.19 ±2.50	21.64 ±2.83	2.95 ±1.21	6.60 ±1.77	2.65 ±0.74	14.32 ±22.58
Dieldrin	0.80 ±0.12	0.73 ±0.35	2.34 ±0.36	0.53 ±0.13	1.19 ±0.33	0.69 ±0.17	0.28 ±0.10
Endrin	0.67 ±0.19	0.47 ±0.04	0.76 ±0.42	0.51 ±0.05	1.22 ±0.90	1.56 ±1.44	0.41 ±0.07
Acenaphthene	82.78 ±65.43	45.05 ±48.02	92.82 ±30.15	17.81 ±5.69	294.62 ±312.96	28.21 ±12.24	10.57 ±4.38
Acenaphthylene	122.93 ±41.89	50.00 ±34.26	202.46 ±30.69	40.84 ±14.13	381.64 ±195.75	95.05 ±40.25	16.86 ±11.72
Anthracene	365.05 ±220.76	151.36 ±144.73	511.49 ±163.77	63.54 ±26.52	1335.14 ±1054.25	105.14 ±45.35	26.86 ±19.85
Benzo(a)anthracene	486.83 ±129.35	231.11 ±185.03	905.11 ±199.37	141.74 ±50.53	1525.6 ±593.1	395.20 ±320.69	49.34 ±39.34
Benzo(a)pyrene	303.05 ±83.12	138.96 ±111.32	516.92 ±79.50	113.25 ±40.94	889.96 ±375.20	194.09 ±52.38	33.19 ±24.55
Benzo(k)fluoranthene	781.78 ±177.51	531.68 ±415.14	1669.94 ±264.54	294.28 ±99.79	2107.79 ±769.94	518.25 ±164.81	94.86 ±68.05

Table E-1 Continued.	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
Benzo(g,h,i)perylene	302.69 ±72.98	186.48 ±173.51	579.08 ±101.00	112.75 ±41.96	849.14 ±315.35	173.15 ±67.70	30.65 ±19.81
Biphenyl	32.16 ±11.74	38.86 ±42.83	45.73 ±7.67	15.02 ±4.21	77.14 ±51.31	17.01 ±4.11	9.06 ±3.10
Chrysene	544.76 ±145.85	313.48 ±271.91	1076.9 ±217.0	161.69 ±56.44	1653.2 ±664.7	311.20 ±123.95	51.54 ±41.17
Dibenz(a,h)anthracene	79.42 ±31.10	17.32 ±6.72	146.12 ±25.41	26.66 ±9.59	247.84 ±146.29	34.93 ±10.65	13.00 ±8.15
2,6-Dimethylnaphthalene	198.15 ±57.34	582.37 ±382.91	181.20 ±52.59	135.41 ±62.49	219.79 ±95.74	116.40 ±34.59	17.25 ±11.02
Fluoranthene	743.25 ±278.61	568.79 ±481.83	1280.0 ±397.6	201.34 ±80.22	2308.0 ±1292.0	325.36 ±109.31	65.51 ±51.71
Fluorene	176.41 ±182.11	77.62 ±87.06	107.72 ±23.17	28.20 ±13.07	693.43 ±873.05	37.15 ±13.42	12.32 ±5.96
Ideno(1,2,3-c,d)pyrene	291.62 ±90.08	132.04 ±106.36	575.81 ±74.23	117.62 ±42.01	806.89 ±409.94	195.27 ±60.61	35.54 ±27.73
2-Methylnaphthalene	89.91 ±42.02	95.08 ±122.30	114.36 ±21.63	33.04 ±13.05	253.21 ±189.86	43.72 ±12.86	14.33 ±7.65
1-Methylnaphthalene	46.37 ±24.30	59.61 ±81.69	47.24 ±6.97	15.16 ±4.83	135.10 ±109.67	19.08 ±5.86	9.71 ±3.65
1-Methylphenanthrene	156.10 ±88.28	130.93 ±187.12	150.03 ±84.70	9.65 ±3.57	615.18 ±414.55	29.18 ±27.49	6.00 ±0.00

Table E-1 Continued.	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
Naphthalene	163.96 ±100.34	96.04 ±92.26	217.87 ±28.42	48.90 ±16.84	528.57 ±477.41	82.89 ±24.35	26.32 ±12.43
Perylene	333.54 ±113.69	113.98 ±55.94	608.35 ±173.42	127.84 ±47.68	975.43 ±523.23	169.73 ±67.87	37.83 ±43.06
Phenanthrene	628.06 ±520.48	363.98 ±412.31	417.30 ±61.09	116.85 ±45.44	2368.6 ±2489.5	197.89 ±69.24	48.20 ±35.82
Pyrene	767.60 ±269.73	508.73 ±440.02	1144.7 ±288.8	202.19 ±77.94	2491.0 ±1255.0	364.17 ±141.09	69.63 ±57.35
2,3,5-Trimethylnaphthalene	47.00 ±29.87	183.02 ±287.39	70.47 ±37.44	9.82 ±2.60	91.21 ±57.89	10.70 ±3.60	7.29 ±1.48
Total PAHs	7177.4 ±2607.9	4838.5 ±4279.8	11471 ±1836.3	2179.2 ±723.5	22141 ±12165	3749.7 ±1310.2	730.0 ±521.7
Monobutyltin	5.32 ±1.37	8.51 ±5.13	11.74 ±3.92	4.48 ±1.93	4.46 ±1.38	1.21 ±0.24	2.77 ±1.28
Dibutyltin	16.33 ±6.04	11.25 ±6.78	38.95 ±22.07	15.45 ±9.06	14.39 ±5.02	2.45 ±0.46	6.08 ±3.33
Tributyltin	30.08 ±8.52	38.64 ±19.50	69.31 ±23.39	24.07 ±11.77	32.50 ±16.17	23.98 ±8.02	19.54 ±9.35
Tetrabutyltin	4.17 ±0.52	4.99 ±2.18	5.39 ±2.28	3.95 ±0.66	4.11 ±0.88	3.75 ±0.40	3.61 ±0.45

Table E-2
Percent of Area Exceeding Sediment Contaminant ERMs (Long & Morgan, 1991; Long et al., 1995a)

values in parentheses represent 90% confidence intervals

	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
METALS							
Antimony	1 (-1-2)	0 (0-8)	12 (-8-32)	0 (0-8)	0 (0-8)	0 (0-8)	0 (0-8)
Arsenic	1 (-1-2)	0 (0-8)	12 (-8-32)	0 (0-8)	0 (0-8)	0 (0-8)	0 (0-8)
Cadmium	0 (0-0)	0 (0-8)	2 (-1-4)	0 (0-8)	0 (0-8)	0 (0-8)	0 (0-8)
Chromium	0 (0-0)	0 (0-8)	0 (0-0)	0 (0-8)	0 (0-8)	0 (0-8)	0 (0-8)
Copper	3 (1-5)	4 (0-13)	32 (8-56)	0 (0-8)	4 (0-13)	0 (0-8)	7 (0-8)
Lead	4 (2-6)	4 (0-13)	35 (11-59)	0 (0-8)	7 (2-18)	0 (0-8)	0 (0-8)
Mercury	34 (24-44)	4 (0-13)	91 (82-99)	29 (17-42)	46 (33-60)	0 (0-8)	4 (0-13)
Nickel	4 (2-6)	4 (0-13)	52 (30-73)	0 (0-8)	4 (0-13)	0 (0-8)	0 (0-8)
Silver	13 (6-20)	7 (2-18)	32 (8-56)	11 (4-22)	18 (9-31)	4 (0-13)	0 (0-8)

Table E-2 Continued.	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
Zinc	3 (1-4)	4 (0-13)	35 (11-59)	0 (0-8)	0 (0-8)	0 (0-8)	0 (0-8)
ORGANICS							
Total PCBs = (∑congeners) x 2	39 (35-43)	14 (3-25)	75 (51-93)	32 (18-46)	61 (46-76)	4 (0-10	7 (0-15)
Parent DDT	3 (2-4)	0 (0-8)	46 (24-67)	0 (0-8)	0 (0-8)	0 (0-8)	4 (0-13)
Total DDD	12 (6-18)	0 (0-8)	73 (52-94)	7 (2-18)	14 (6-27)	0 (0-8)	4 (0-13)
p,p'-DDE	3 (2-5)	0 (0-8)	51 (29-73)	0 (0-8)	0 (0-8)	0 (0-8)	0 (0-8)
Total DDE	13 (7-19)	4 (0-13)	79 (58-99)	7 (2-18)	14 (6-27)	0 (0-8)	0 (0-8)
Total DDT	8 (4-12)	0 (0-8)	65 (44-87)	4 (0-13)	7 (2-18)	0 (0-8)	0 (0-8)
Chlordane	32 (23-42)	29 (17-42)	91 (82-99)	25 (14-38)	39 (27-53)	14 (6-27)	7 (2-18)
Dieldrin	0 (0-0)	0 (0-8)	0 (0-0)	0 (0-8)	0 (0-8)	0 (0-8)	0 (0-8)
Endrin	0 (0-0)	0 (0-8)	0 (0-0)	0 (0-8)	0 (0-8)	0 (0-8)	0 (0-8)

Table E-2 Continued.	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
Acenaphthene	1 (0-2)	4 (0-13)	1 (0-1)	0 (0-8)	4 (0-13)	0 (0-8)	0 (0-8)
Anthracene	6 (3-9)	4 (0-13)	12 (-7-32)	0 (0-8)	21 (12-35)	0 (0-8)	0 (0-8)
Acenaphthylene	3 (1-5)	0 (0-8)	1 (0-1)	0 (0-8)	14 (6-27)	4 (0-13)	0 (0-8)
Benzo(a)anthracene	7 (4-10)	4 (0-13)	10 (0-20)	0 (0-8)	29 (17-42)	4 (0-13)	0 (0-8)
Benzo(a)pyrene	6 (3-9)	4 (0-13)	6 (0-11)	0 (0-8)	25 (14-38)	4 (0-13)	0 (0-8)
Chrysene	4 (2-7)	4 (0-13)	1 (0-1)	0 (0-8)	18 (9-31)	0 (0-8)	0 (0-8)
Dibenz(a,h)anthracene	5 (2-7)	0 (0-8)	3 (0-6)	0 (0-8)	21 (12-35)	0 (0-8)	0 (0-8)
Fluoranthene	3 (0-5)	4 (0-13)	0 (0-0)	0 (0-8)	11 (4-22)	0 (0-8)	0 (0-8)
Fluorene	2 (0-4)	4 (0-13)	1 (0-1)	0 (0-8)	7 (2-18)	0 (0-8)	0 (0-8)
2-Methylnaphthalene	1 (0-2)	4 (0-13)	1 (0-1)	0 (0-8)	4 (0-13)	0 (0-8)	0 (0-8)
Naphthalene	1 (0-2)	0 (0-8)	0 (0-8)	0 (0-8)	4 (0-13)	0 (0-8)	0 (0-8)

Table E-2 Continued.	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. Long Is. Sound	Bight Apex
Phenanthrene	6 (3-8)	4 (0-13)	1 (0-1)	0 (0-8)	25 (14-38)	0 (0-8)	0 (0-8)
Pyrene	6 (3-9)	4 (0-13)	7 (-2-17)	0 (0-8)	25 (14-38)	0 (0-8)	0 (0-8)
Low Molec. Wt. PAHs	9 (5-12)	0 (0-8)	4 (0-8)	0 (0-8)	39 (27-53)	4 (0-13)	0 (0-8)
High Molec. Wt. PAHs	12 (9-16)	4 (0-13)	46 (23-68)	0 (0-8)	43 (30-57)	7 (2-18)	0 (0-8)
Total PAHs	3 (0-5)	4 (0-13)	1 (0-1)	0 (0-8)	11 (4-22)	0 (0-8)	0 (0-8)

Appendix F

Dioxin bioaccumulation calculation

Theoretical Bioaccumulation Potential (TBP) Calculation

Because the relative toxicity of congeners to humans may differ from toxicity to aquatic organisms, different toxicity equivalents have been defined for humans and for [aquatic] "ecological systems." Human toxicity equivalents are probably closer to those of other mammals and birds than the equivalents for aquatic organisms. Preliminary efforts to define toxicity equivalency factors for aquatic "ecological systems" are based solely upon laboratory mortalities of early life-stage fishes (U.S. EPA 1993; Cura, Heiger-Bernays and Bucholz 1995, p.2-11). These preliminary toxicity equivalency factors for aquatic ecosystems are so uncertain (indeed, completely unknown for several congeners) that they are not used here. Further, it is clear that fish-eating birds and mammals, including humans, are at much greater risk from dioxins/furans than the benthos (U.S. EPA 1993; Cura, Heiger-Bernays and Bucholz 1995). Consequently this investigation attempts to estimate dioxin/furan concentrations in sediments which would not be a risk to humans or fish-eating wildlife.

Measured concentrations of 2,3,7,8-TCDD and the "human health toxicity equivalents" of all dioxin/furan congeners - expressed as weighted additive equivalents - are summarized in Table 4.3.1. The biotic effects of 2,3,7,8-TCDD alone are not interpretable.   Concentrations of this single isomer are shown only because they are comparable to commonly reported 2,3,7,8-TCDD values.

We attempt to estimate a “safe” concentration of dioxins/furans (expressed as human health toxicity equivalents) in sediments, based upon a presumably protective range of concentrations in fishes, and an estimated relationship between sediment and fish concentrations. First, we specify dioxins/furans concentrations in fishes that seem to pose low and high risks to humans and wildlife. The range of 0.7 to 7 pptr dioxins/furans in fishes is presumed to embrace low to high risks for piscivorous mammals - probably the organisms at greatest potential risk (U.S. EPA 1993, Table E-1). Following the NYS Department of Health, we presume that 10 pptr in fishes protects against effects of dioxins/furans in adult humans unless exceptionally large quantities of fishes are eaten. Thus we consider a protective range for mammalian wildlife of one pptr (low risk) to 7 pptr mean fish concentration (high risk), and presume that 7 pptr is also a low risk to most adult humans.

We then work down the food web from fishes to estimate a “safe” range of dioxins/furans in sediments. Wide ranges have been measured for dioxin/furan biomagnification from benthic invertebrates to fishes. We use an intermediate value of two (U.S. EPA 1993; Cura, Heiger-Bernays and Buckolz 1995). Thus, our “high risk” concentration of 7 pptr in fishes would result from 7/2 = 3.5 pptr in the benthos. Dioxin/furan concentrations in the benthos are estimated from: (1) the “accumulation factor” of dioxin/furan transfer from sediment to benthos, (2) dioxin/furan concentration in sediment, (3) lipid content of the benthos, and (4) fraction of organic carbon in the sediments. This relationship has been expressed as an estimator of “theoretical bioaccumulation potential” (TBP) of benthic infaunal organisms (U.S. EPA 1993):

$$TBP = AF(C_s@\%L)/\%TOC$$

where: TBP = 2,3,7,8-TCDD human health equivalents in benthic tissue (pptr, wet wt), AF =
accumulation factor, or dioxin/furan concentration in benthos as fraction of concentration
in sediment,
C_s = dioxin/furan concentration in sediments,
%L = percent lipid in fishes, and
%TOC = percent total organic carbon in sediments.

In our “high risk” case, TBP=3.5 pptr. Measured accumulation of 2,3,7,8-TCDD and 2,3,7,8-TCDF from sediments to marine invertebrates has ranged from 0.24 to 1.0 times the sediment concentration (Pruell et al. 1993). We assume an intermediate sediment to polychaete “accumulation factor” (AF) of 0.5. Percentages of lipid in the benthos are typically near 1%, and 3% total organic carbon is common in Harbor sediments.

Using these assumed and typical values, we can solve for a range of presumably safe, but mammalian wildlife “high risk” dioxin/furan concentrations in sediments:

$$3.5 \text{ pptr} = 0.5(C_s@.01)/.03$$
$$C_s = 21 \text{ pptr.}$$

Similarly, our estimate of “low risk” concentration in the benthos (TBP) is half the low risk protective concentration in fishes (1/2=0.5 pptr). So, low risk sediment concentrations are:

$$0.5 \text{ pptr} = 0.5(C_s@.01)/.03$$
$$C_s = 3.$$

As mentioned above, we presume that even the high risk sediment concentrations (21 pptr) pose low risks for most adult humans. Hence these sediment concentrations apply to piscivorous birds and mammals. Several major uncertainties are inescapable in estimating these presumably “high” and “low” risk sediment concentrations for wildlife. Some uncertainties are so great that we can not even rank their severity. One obvious uncertainty is variability in wildlife exposures to dioxins/furans, and assimilation efficiencies, from foods, sediments and water. This obviously varies with the top carnivore involved, food available to the carnivore, differential bioaccumulation in the food web, etc. (U.S. EPA 1993). Also, dose-response relationships such as the above equation for theoretical bioaccumulation potential have little empirical support from few environments. Even if the TBP equation is robust, all the predictor variables are spatially heterogeneous, probably ensuring imprecise estimates of mean dioxin/furan concentrations in the benthos even if field measurements were extensive. Further, there are few direct measurements of variability in the most important variables, e.g., concentrations of dioxins/furans in commercial and recreational fishes. Hence, there is little basis for estimating the distributions of these variables.

Appendix G

Area-weighted mean abundances of all benthic macroinvertebrate species (mean #/.04 m^2)

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Cnidaria : Anthozoa	Anthozoa	0.3214	0.0179	0.2857	0.0517	4.5714	0.0000
Cnidaria : Anthozoa	Ceriantheopsis americanus	4.3393	0.1429	0.0000	0.3276	0.0357	0.0000
Platyhelminthes : Turbellaria	Turbellaria	0.0000	0.3571	0.3571	1.2931	0.2679	6.6071
Nemertinea	Malacobdella grossa	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Nemertinea	Nemertinea	4.1964	7.6250	1.4107	0.6379	1.3571	0.1786
Annelida : Polychaeta	Aglaophamus circinata	0.3036	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Amastigos caperatus	0.5179	0.0000	0.0000	0.0517	0.0000	0.0000
Annelida : Polychaeta	Ampharete arctica	0.6607	0.3750	0.0000	0.0172	0.3036	0.0000
Annelida : Polychaeta	Ampharetidae	103.2321	0.2679	1.0179	0.8621	2.0714	0.1964
Annelida : Polychaeta	Ancistrosyllis hartmanae	0.0357	0.3393	0.0000	0.0000	0.0179	0.0000
Annelida : Polychaeta	Anobothrus gracilis	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Aphelochaeta spp.	12.8036	0.1429	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Aphrodita hastata	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Apoprionospio pygmaea	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Aricidea catherinae	21.8393	1.1071	0.0000	29.5690	2.1071	2.1071
Annelida : Polychaeta	Aricidea cerrutti	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Aricidea spp.	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Aricidea wassi	2.3571	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Asabellides oculata	11.8036	0.0714	1.6429	0.9310	1.6071	0.1429

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Autolytus spp.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Annelida : Polychaeta	Brada villosa	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Brania clavata	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Brania spp.	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
Annelida : Polychaeta	Brania wellfleetensis	0.0000	0.0357	0.0000	0.3793	0.0000	0.0000
Annelida : Polychaeta	Capitella spp.	0.5536	0.0714	0.2321	0.0000	0.0000	7.1964
Annelida : Polychaeta	Capitellidae	0.0714	0.0000	0.0179	0.3448	0.0179	0.0000
Annelida : Polychaeta	Carazziella hobsonae	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Caulleriella sp. B Blake	3.6607	0.0179	0.0000	3.8966	0.0179	13.5536
Annelida : Polychaeta	Chaetopterus variopedatus	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Chone infundibuliformis	1.5179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Cirratulidae	8.8036	0.4643	0.0000	0.0345	0.0000	5.2500
Annelida : Polychaeta	Cirriformia grandis	0.0000	0.0000	0.0000	0.0172	1.5714	0.0357
Annelida : Polychaeta	Cirrophorus sp. A Morris	0.0000	0.0357	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Clymenella torquata	2.6964	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Cossura longocirrata	10.4464	10.8393	0.0000	0.0000	0.0179	0.0179
Annelida : Polychaeta	Demonax microphthalmus	0.0000	0.0714	0.0000	0.0345	0.3036	0.0714
Annelida : Polychaeta	Diopatra cuprea	0.0000	0.0000	0.0000	0.0345	0.0000	0.0000
Annelida : Polychaeta	Dispio uncinata	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Dodecaceria fimbriata	0.0000	0.1071	0.0000	0.0000	0.0714	0.0000
Annelida : Polychaeta	Dorvillea rudolphi	0.0000	0.0000	0.0000	0.0000	0.0536	0.0714
Annelida : Polychaeta	Dorvilleidae sp. A Hilbig	0.0357	0.2679	0.0000	0.0517	0.0000	0.0000
Annelida : Polychaeta	Drilonereis longa	0.3571	0.0000	0.0000	0.1379	0.0000	0.0000
Annelida : Polychaeta	Euchone elegans	0.1250	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Euchone incolor	14.7143	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Euchone spp.	0.1964	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Eumida sanguinea	0.3571	0.5179	0.1071	4.1724	4.6071	5.0536
Annelida : Polychaeta	Exogone dispar	0.0893	0.0357	0.0000	1.2931	0.0000	14.3750
Annelida : Polychaeta	Exogone hebes	9.1607	0.0000	0.0179	0.0000	0.0000	0.0000
Annelida : Polychaeta	Exogone spp.	0.0357	0.0179	0.0000	0.0345	0.0000	0.0536
Annelida : Polychaeta	Exogone verugera	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Flabelligeridae	3.5893	0.0179	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Glycera americana	0.0000	0.3393	0.1607	1.6034	0.7857	0.1429
Annelida : Polychaeta	Glycera dibranchiata	0.6964	0.0714	0.0000	0.5345	0.0000	0.3571
Annelida : Polychaeta	Glycera spp.	0.3929	0.6607	1.7143	0.8966	1.1250	0.6071
Annelida : Polychaeta	Goniada maculata	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Goniadella gracilis	2.2679	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Goniadidae	0.1607	0.0000	0.0000	0.0000	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Harmothoe extenuata	0.0000	0.0000	0.0000	0.1034	0.7143	0.0536
Annelida : Polychaeta	Harmothoe imbricata	0.0000	0.0000	0.0000	0.0172	0.2679	0.1964
Annelida : Polychaeta	Hemipodus roseus	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Hesionidae	0.0000	0.0000	0.0000	0.0172	0.0000	0.0536
Annelida : Polychaeta	Heteromastus filiformis	0.0000	0.0179	6.8571	30.5517	7.8036	0.5357
Annelida : Polychaeta	Hobsonia florida	0.0000	0.0000	0.0179	0.0000	0.0000	0.0000
Annelida : Polychaeta	Hydroides dianthus	0.0000	0.0536	0.0000	0.0000	0.0000	14.1786
Annelida : Polychaeta	Hydroides protulicola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0357
Annelida : Polychaeta	Hydroides spp.	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Hypereteone foliosa	0.0893	0.0000	0.0893	0.0690	0.0000	0.0000
Annelida : Polychaeta	Hypereteone heteropoda	0.0000	0.5179	3.2500	10.9138	2.9821	7.0357
Annelida : Polychaeta	Hypereteone longa	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Laeonereis culveri	0.0000	0.0000	2.5357	0.0000	0.0000	0.0000
Annelida : Polychaeta	Laonice spp.	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Leitoscoloplos robustus	0.3036	0.3571	23.9286	1.4483	5.4464	0.5357
Annelida : Polychaeta	Leitoscoloplos spp.	0.4107	1.9643	10.3214	2.8793	7.3929	1.8929
Annelida : Polychaeta	Lepidonotus spp.	0.0000	0.0179	0.0000	0.0690	0.1786	0.0000
Annelida : Polychaeta	Lepidonotus squamatus	0.0000	0.0000	0.0000	0.0000	0.0179	0.0000
Annelida : Polychaeta	Lepidonotus sublevis	0.0000	0.0179	0.0000	0.0517	0.0000	0.0179

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Levinsenia gracilis	18.5893	0.0179	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Loimia medusa	0.0000	0.0536	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Lumbrineridae	14.9107	0.2143	0.0000	0.0000	0.0000	0.0357
Annelida : Polychaeta	Lumbrinerides acuta	0.6607	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Lumbrinerides spp.	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Macroclymene zonalis	0.0179	1.9464	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Magelona spp.	1.3571	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Maldanidae	1.8929	4.7500	0.0000	0.0172	0.0000	0.0000
Annelida : Polychaeta	Marenzelleria viridis	0.0000	0.0000	1.2143	0.0690	0.1607	0.0000
Annelida : Polychaeta	Marphysa belli	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Mediomastus ambiseta	5.1250	131.5000	13.7321	511.4483	97.9643	79.1071
Annelida : Polychaeta	Mediomastus spp.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0536
Annelida : Polychaeta	Microphthalmus aberrans	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Annelida : Polychaeta	Microphthalmus fragilis	0.4107	0.0000	0.0000	0.0000	0.0179	0.0000
Annelida : Polychaeta	Microphthalmus sczelkowii	0.1786	0.0536	0.7679	0.2414	0.2321	0.0000
Annelida : Polychaeta	Microphthalmus similis	3.6071	0.0000	0.0000	0.0000	0.2500	0.1429
Annelida : Polychaeta	Microphthalmus spp.	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
Annelida : Polychaeta	Monticellina baptisteae	5.4286	0.0536	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Neanthes arenaceodentata	0.0000	0.0000	0.0000	0.0345	0.1429	5.8929

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Neanthes succinea	0.0179	3.1964	0.3393	0.9310	4.2143	2.0000
Annelida : Polychaeta	Neanthes virens	0.0000	0.0000	0.0000	0.0000	0.2857	0.0000
Annelida : Polychaeta	Nephtyidae	4.7500	2.3214	0.0179	0.0690	0.1250	0.0714
Annelida : Polychaeta	Nephtys bucera	0.0714	0.0000	0.0000	0.0172	0.0000	0.0000
Annelida : Polychaeta	Nephtys incisa	1.5179	4.0714	0.0357	0.0345	0.0714	0.0000
Annelida : Polychaeta	Nephtys picta	0.8929	0.1429	0.0000	1.0517	0.5000	0.4821
Annelida : Polychaeta	Nephtys spp.	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Nereididae	0.0714	0.0179	0.0536	0.0690	1.4107	0.3750
Annelida : Polychaeta	Nereis grayi	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Nicolea zostericola	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Ninoe nigripes	2.8393	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Notocirrus spiniferus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Annelida : Polychaeta	Notomastus spp.	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Odontosyllis fulgurans	0.0000	0.0179	0.0000	0.0000	0.0179	0.0000
Annelida : Polychaeta	Onuphidae	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Opheliidae	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Ophelina acuminata	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Owenia fusiformis	0.0536	4.1964	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Oweniidae	0.0000	0.4643	0.0000	0.0000	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Paradoneis sp. A Morris	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Paradoneis sp. B Morris	1.3929	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Parahesione luteola	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Annelida : Polychaeta	Paranaitis speciosa	0.0536	0.0357	0.0179	0.3793	0.2143	0.0179
Annelida : Polychaeta	Paraonis fulgens	0.0536	0.0000	0.0000	0.0690	0.0000	0.0000
Annelida : Polychaeta	Paraonis pygoenigmatica	0.4286	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Parapionosyllis longicirrata	0.4643	0.0357	0.0000	0.0690	0.0000	0.0000
Annelida : Polychaeta	Parougia caeca	3.9286	0.0179	0.0179	0.0000	0.0000	0.0000
Annelida : Polychaeta	Pectinaria gouldii	0.0357	4.7321	0.7500	2.3793	2.5000	2.1964
Annelida : Polychaeta	Pectinaria spp.	0.0000	0.0000	0.3214	0.0000	0.0000	0.0000
Annelida : Polychaeta	Pherusa affinis	1.5893	0.7857	0.0000	0.0517	0.0179	0.0357
Annelida : Polychaeta	Pherusa spp.	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Pholoe minuta	0.1429	0.1964	0.0000	0.0000	0.0179	0.0000
Annelida : Polychaeta	Phyllodoce arenae	0.3750	0.0714	0.0536	0.2414	0.1250	0.1786
Annelida : Polychaeta	Phyllodoce mucosa	0.5357	0.0357	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Pilargidae	0.0000	0.0000	0.0000	0.0000	0.0179	0.0000
Annelida : Polychaeta	Pisione remota	0.1607	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Podarke obscura	0.0000	0.0536	0.0000	0.0000	0.4643	10.0000
Annelida : Polychaeta	Podarkeopsis levifuscina	0.0000	0.0536	0.1071	3.0862	0.1786	0.8571

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Polychaeta: Unidentified	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Annelida : Polychaeta	Polycirrus eximius	0.0000	0.7500	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Polycirrus spp.	0.6429	2.7143	0.0000	0.3103	0.5714	0.5179
Annelida : Polychaeta	Polydora aggregata	0.0000	0.0357	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Polydora caulleryi	0.6607	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Polydora cornuta	0.1250	1.9286	3.2143	31.5517	15.5893	19.2500
Annelida : Polychaeta	Polydora quadrilobata	0.6250	0.0000	0.0000	0.1207	0.0179	0.0000
Annelida : Polychaeta	Polydora socialis	3.6250	0.0893	0.0000	0.2069	0.1429	0.0179
Annelida : Polychaeta	Polydora spp.	0.0714	0.0536	0.0536	0.1207	0.0179	2.8571
Annelida : Polychaeta	Polydora websteri	0.0000	0.0000	0.0000	0.6379	0.0179	0.3571
Annelida : Polychaeta	Polygordius spp.	551.8929	7.2321	0.5893	0.2759	0.8571	0.0000
Annelida : Polychaeta	Polynoidae	0.1071	0.1786	0.0000	0.0862	0.9464	0.0179
Annelida : Polychaeta	Praxillura ornata	0.0893	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Prionospio spp.	0.0000	0.0357	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Prionospio steenstrupi	222.5893	1.0714	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Proceraea cornuta	0.0000	0.1250	0.0000	0.0000	0.0536	0.1071
Annelida : Polychaeta	Pseudopotamilla reniformis	0.0000	0.0357	0.0000	0.1207	0.0714	0.1250
Annelida : Polychaeta	Pygospio elegans	0.0000	0.0000	0.3929	0.1897	0.0000	0.0000
Annelida : Polychaeta	Sabaco elongatus	0.0000	0.2143	0.0000	0.0345	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Sabellaria vulgaris	0.0536	0.7679	0.4821	2.8276	18.2143	39.1607
Annelida : Polychaeta	Sabellariidae	0.0000	0.0357	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Sabellidae	0.4107	0.0714	0.0000	0.0517	0.8750	0.5357
Annelida : Polychaeta	Scalibregma inflatum	4.8393	0.0893	0.0000	0.0172	0.0000	0.0000
Annelida : Polychaeta	Scolelepis bousfieldi	0.0000	0.0893	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Scolelepis spp.	0.0000	0.0179	0.0000	0.1034	0.0000	0.0357
Annelida : Polychaeta	Scolelepis squamata	0.7143	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Scolelepis texana	0.0000	0.0000	0.0179	0.1379	0.0000	0.4286
Annelida : Polychaeta	Scoletoma acicularum	0.2500	0.0714	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Scoletoma hebes	3.4286	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Scoletoma tenuis	0.0000	0.0179	0.0000	0.0000	0.0000	0.0357
Annelida : Polychaeta	Scoloplos rubra	0.0000	0.0357	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Scoloplos spp.	0.0893	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Sigalion arenicola	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Sigalionidae	0.0357	0.0000	0.0000	0.0000	0.0536	0.0000
Annelida : Polychaeta	Sigambra tentaculata	0.0000	1.6607	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Sphaerosyllis spp.	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Spio filicornis	0.9821	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Spio setosa	1.2679	0.0000	2.2143	4.1897	7.8571	1.2321

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Annelida : Polychaeta	Spio spp.	0.0357	0.0000	0.0000	0.1207	0.0000	0.0000
Annelida : Polychaeta	Spiochaetopterus costarum	0.0536	0.5357	0.0179	0.5345	0.2321	0.1250
Annelida : Polychaeta	Spionidae	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Spiophanes bombyx	7.6607	0.4286	0.0000	0.8966	0.4286	0.0357
Annelida : Polychaeta	Sthenelais boa	0.0000	0.0714	0.0000	0.0000	0.1250	0.0000
Annelida : Polychaeta	Sthenelais limicola	0.0893	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Sthenelais spp.	1.8214	0.0179	0.0000	0.0000	0.0357	0.0000
Annelida : Polychaeta	Streblospio benedicti	0.0893	36.3750	309.8393	262.7586	148.6786	339.9464
Annelida : Polychaeta	Streptosyllis pettiboneae	0.3750	0.0000	0.0536	0.1724	0.0357	0.0536
Annelida : Polychaeta	Syllidae	0.2500	0.0000	0.0000	0.0000	0.0000	0.1071
Annelida : Polychaeta	Syllides convoluta	1.3929	0.0000	0.0000	0.0000	0.0000	0.0179
Annelida : Polychaeta	Syllides verrilli	0.0893	0.0000	0.0000	0.0000	0.0000	0.0714
Annelida : Polychaeta	Terebellides stroemi	0.2143	0.0000	0.0000	0.0000	0.0000	0.0000
Annelida : Polychaeta	Tharyx acutus	6.0179	0.1429	0.0000	0.0000	0.0000	0.0179
Annelida : Polychaeta	Tharyx sp. A Morris	17.4464	2.2679	8.3214	25.8621	26.5357	14.7679
Annelida : Polychaeta	Travisia sp. A Morris	0.3393	0.0000	0.0000	0.0345	0.0000	0.0000
Annelida : Polychaeta	Typosyllis alternata	0.0357	0.0000	0.0000	0.0000	0.0000	0.2857
Annelida : Oligochaeta	Oligochaeta	38.7500	27.5179	50.8036	71.9483	137.8571	48.5357
Mollusca : Gastropoda	Acteocina canaliculata	0.0179	4.9107	0.0000	0.1034	0.0179	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Mollusca : Gastropoda	Alvania spp.	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Gastropoda	Boonea bisuturalis	0.0000	0.0179	0.0357	1.3448	0.1964	5.4107
Mollusca : Gastropoda	Buccinidae	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
Mollusca : Gastropoda	Colus pygmaeus	0.1250	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Gastropoda	Cratena pilata	0.0000	0.1429	0.0000	0.0000	0.0000	0.0000
Mollusca : Gastropoda	Crepidula convexa	0.0000	0.0893	0.0000	0.0000	0.4464	0.0000
Mollusca : Gastropoda	Crepidula fornicata	0.0000	0.0000	0.0000	1.5517	0.5893	2.7143
Mollusca : Gastropoda	Crepidula maculosa	0.0000	0.0357	0.0000	2.7241	0.0000	2.6786
Mollusca : Gastropoda	Crepidula plana	0.0357	0.0179	0.0000	0.9828	0.1607	0.0000
Mollusca : Gastropoda	Crepidula spp.	0.5536	0.5179	0.0357	1.7414	1.1071	2.6786
Mollusca : Gastropoda	Cylichnella bidentata	0.0000	0.0536	0.0179	0.0000	0.0000	0.0000
Mollusca : Gastropoda	Doridella obscura	0.0000	0.0357	0.0357	0.0690	0.0714	0.1250
Mollusca : Gastropoda	Epitonium rupicola	0.0000	0.0000	0.0357	0.0000	0.0000	0.0000
Mollusca : Gastropoda	Eupleura caudata	0.0000	0.0000	0.0000	0.1034	0.0000	0.0179
Mollusca : Gastropoda	Gastropoda: Other	0.0179	0.0357	0.1071	0.3621	0.1071	0.0714
Mollusca : Gastropoda	Haminoea solitaria	0.0000	1.4286	4.0536	0.0000	0.0000	0.0000
Mollusca : Gastropoda	Hydrobia spp.	0.0000	0.0000	0.0536	0.0000	0.0000	0.0000
Mollusca : Gastropoda	Ilyanassa obsoleta	0.0000	0.0714	0.2857	2.1207	0.0357	12.6786
Mollusca : Gastropoda	Muricidae	0.0000	0.0000	0.0000	0.0172	0.0000	0.0179

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Mollusca : Gastropoda	Nassarius trivittatus	0.2500	16.9643	0.0357	10.9655	1.4821	0.0536
Mollusca : Gastropoda	Nassarius vibex	0.0000	0.0000	0.1964	0.0690	0.0000	0.0714
Mollusca : Gastropoda	Nudibranchia	0.0000	0.0000	0.0000	0.0000	0.0000	0.0714
Mollusca : Gastropoda	Odostomia engonia	0.0000	0.0000	0.8214	0.0000	0.0179	0.0000
Mollusca : Gastropoda	Odostomia spp.	0.0000	2.1429	1.1607	3.8276	1.8393	0.2321
Mollusca : Gastropoda	Polinices duplicata	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Gastropoda	Pyramidellidae	0.0179	0.0000	0.0000	0.0000	0.0357	0.0179
Mollusca : Gastropoda	Rictaxis punctostriatus	0.0357	13.0357	2.3571	5.9828	2.2500	1.2321
Mollusca : Gastropoda	Turbonilla interrupta	0.0179	4.0893	0.0000	0.1379	0.0000	0.0000
Mollusca : Gastropoda	Turbonilla spp.	0.0000	0.0357	0.0000	0.0172	0.0000	0.0000
Mollusca : Gastropoda	Urosalpinx cinerea	0.0000	0.0000	0.0000	0.0345	0.0000	0.0000
Mollusca : Bivalvia	Aligena elevata	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Anadara transversa	0.0000	0.2679	0.0000	0.0172	0.0000	0.1250
Mollusca : Bivalvia	Anomia simplex	0.0000	0.0536	0.0000	0.0000	0.0179	0.0000
Mollusca : Bivalvia	Anomia spp.	0.0000	0.0357	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Astarte castanea	0.0357	0.1429	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Astarte spp.	0.1250	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Astarte undata	0.3929	0.0714	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Asthenothaerus hemphilli	0.4286	0.0000	0.0000	0.0000	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Mollusca : Bivalvia	Bivalvia: Other - Suspension Feeders	0.1429	0.0357	0.0179	0.0862	0.0714	0.1250
Mollusca : Bivalvia	Bivalvia: Other - Unidentified	0.2857	0.0000	0.0179	0.0517	0.0000	0.0000
Mollusca : Bivalvia	Bushia elegans	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Cerastoderma pinnulatum	0.4821	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Crassostrea virginica	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Crenella decussata	0.0357	0.0000	0.0000	0.0000	0.0357	0.0000
Mollusca : Bivalvia	Crenella glandula	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Crenella spp.	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Cyclocardia borealis	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Ensis directus	0.2857	0.1071	0.2143	3.4655	0.0357	0.0536
Mollusca : Bivalvia	Gemma gemma	0.7143	0.1071	0.0179	11.2414	1.1250	32.4286
Mollusca : Bivalvia	Lyonsia arenosa	0.0179	0.1250	0.0000	0.1379	0.0357	0.0000
Mollusca : Bivalvia	Lyonsia hyalina	0.0000	0.0000	0.0000	0.0517	0.0000	0.0000
Mollusca : Bivalvia	Lyonsia spp.	0.1429	0.1607	0.0179	0.4483	0.1429	0.0000
Mollusca : Bivalvia	Macoma balthica	0.0000	0.0000	0.9464	0.0172	0.2500	0.0000
Mollusca : Bivalvia	Macoma tenta	0.0000	11.9107	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Mercenaria mercenaria	0.0179	0.3036	0.0000	1.7069	0.0536	4.5536
Mollusca : Bivalvia	Mulinia lateralis	0.0179	128.1786	7.8214	7.8276	1.9107	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Mollusca : Bivalvia	Musculus niger	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Mya arenaria	0.0000	0.0357	2.5714	67.6897	2.8929	0.4643
Mollusca : Bivalvia	Mysella planulata	0.0000	0.0000	0.0000	0.0000	0.0000	0.3214
Mollusca : Bivalvia	Mytilidae	0.0179	0.0179	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Mytilus edulis	0.0536	0.1071	0.0893	0.1379	46.4643	0.0000
Mollusca : Bivalvia	Nucula annulata	198.1786	179.9643	0.0179	62.6724	1.1250	8.7857
Mollusca : Bivalvia	Nucula delphinodonta	0.6250	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Nucula spp.	1.5714	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Pandora gouldiana	0.0000	0.3393	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Pandora spp.	0.0357	0.5893	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Parvilucina multilineata	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Mollusca : Bivalvia	Petricola pholadiformis	0.0357	0.2143	0.0000	1.3621	0.0893	0.8214
Mollusca : Bivalvia	Pitar morrhuanus	0.3393	0.3750	0.0000	0.1552	0.0000	0.0000
Mollusca : Bivalvia	Spisula solidissima	6.1786	1.9464	0.0000	2.0517	0.0179	0.0000
Mollusca : Bivalvia	Tellina agilis	7.2857	12.8393	0.3036	8.4828	11.1071	2.3571
Mollusca : Bivalvia	Tellinidae	0.0000	0.0000	0.0000	0.0000	0.0179	0.0000
Mollusca : Bivalvia	Yoldia limatula	0.4643	22.6071	0.0000	0.0000	0.0179	0.0000
Arthropoda : Merostomata	Limulus polyphemus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Arthropoda : Cephalocarida	Hutchinsoniella macracantha	0.0179	0.1250	0.0000	0.0000	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Arthropoda : Cirripedia	Balanus improvisus	0.0000	0.0357	4.3750	0.0000	6.1607	0.0000
Arthropoda : Cirripedia	Balanus spp.	0.0000	0.2500	0.0179	0.1034	0.0357	0.0000
Arthropoda : Cirripedia	Balanus venustus	0.0000	0.0714	0.0000	0.0000	0.0000	0.0000
Arthropoda : Stomatopoda	Squilla empusa	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Arthropoda : Mysidacea	Heteromysis formosa	0.0000	0.1964	0.0000	0.9483	0.2321	0.2500
Arthropoda : Mysidacea	Neomysis americana	0.0357	0.0536	0.7321	0.3621	0.2143	0.1964
Arthropoda : Cumacea	Diastylis quadrispinosa	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Cumacea	Diastylis spp.	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Cumacea	Eudorella pusilla	0.5357	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Cumacea	Leucon americanus	0.0000	0.7679	8.0536	0.0000	3.1071	0.0000
Arthropoda : Cumacea	Oxyurostylis smithi	0.1786	0.1250	0.2321	0.7759	0.2857	0.1071
Arthropoda : Cumacea	Pseudoleptocuma minor	0.1071	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Tanaidacea	Tanaissus psammophilus	2.2143	0.0000	0.0000	0.0862	0.0000	0.0000
Arthropoda : Isopoda	Anthuridae	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
Arthropoda : Isopoda	Chiridotea spp.	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Isopoda	Cyathura burbancki	0.0000	0.0000	0.0179	0.4138	0.1786	0.0536
Arthropoda : Isopoda	Cyathura polita	0.0000	0.0000	0.9107	0.1207	0.3571	0.0000
Arthropoda : Isopoda	Edotea triloba	0.7321	0.1429	1.6786	2.1207	3.2143	0.0179
Arthropoda : Isopoda	Pleurogonium inerme	0.1071	0.0000	0.0000	0.0000	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Arthropoda : Isopoda	Pleurogonium spinosissmum	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Isopoda	Politolana polita	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Isopoda	Ptilanthura tenuis	0.5179	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Acanthohaustorius millsi	0.0536	0.0000	0.0000	0.0172	0.0000	0.0000
Arthropoda : Amphipoda	Acanthohaustorius similis	0.0357	0.0000	0.0000	0.0345	0.0000	0.0000
Arthropoda : Amphipoda	Acanthohaustorius spp.	0.0536	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Aeginina longicornis	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Ampelisca abdita	0.0000	55.0357	0.3393	443.2414	1.0179	405.4464
Arthropoda : Amphipoda	Ampelisca abdita-vadorum complex	0.0536	97.4286	0.6071	596.7586	1.2857	606.4821
Arthropoda : Amphipoda	Ampelisca agassizi	11.9464	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Ampelisca spp.	1.3393	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Ampelisca vadorum	0.0000	0.2143	0.0000	0.0000	0.0000	29.0179
Arthropoda : Amphipoda	Ampelisca verrilli	3.9286	0.5179	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Ampithoe valida	0.0000	0.0000	0.0000	0.0000	0.0893	0.0000
Arthropoda : Amphipoda	Ampithoidae	0.0000	0.0000	0.0000	0.0000	0.0179	0.0000
Arthropoda : Amphipoda	Aoridae	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Arthropoda : Amphipoda	Argissa hamatipes	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Byblis serrata	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Arthropoda : Amphipoda	Caprella penantis	0.0000	0.0179	0.0000	0.0000	0.6429	0.1071
Arthropoda : Amphipoda	Caprellidae	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
Arthropoda : Amphipoda	Casco bigelowi	0.0893	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Cerapus tubularis	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Corophium acherusicum	0.0000	0.0000	0.0000	0.0000	0.4821	0.0000
Arthropoda : Amphipoda	Corophium bonellii	0.0000	0.0000	0.0000	0.0000	0.0179	0.0000
Arthropoda : Amphipoda	Corophium crassicorne	1.3214	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Corophium insidiosum	0.0000	0.0000	0.0000	0.0000	0.6071	0.0000
Arthropoda : Amphipoda	Corophium spp.	0.0714	0.0000	0.0179	0.0345	0.7857	0.0536
Arthropoda : Amphipoda	Corophium tuberculatum	0.0179	0.0000	0.0000	283.0517	0.2143	220.8214
Arthropoda : Amphipoda	Dyopedos monacanthus	0.4464	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Elasmopus laevis	0.0357	0.0000	0.0000	6.6724	3.0000	94.4643
Arthropoda : Amphipoda	Eobrolgus spinosus	0.0000	0.0000	0.0000	0.4483	9.0179	14.5714
Arthropoda : Amphipoda	Ericthonius brasiliensis	0.0000	0.0714	0.0179	0.2241	1.3393	0.9107
Arthropoda : Amphipoda	Gammarus annulatus	0.1250	0.0000	0.0000	0.4828	0.0000	0.0714
Arthropoda : Amphipoda	Gammarus daiberi	0.0000	0.0000	10.3750	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Gammarus spp.	0.0714	0.0000	0.0000	0.1379	0.0000	0.0000
Arthropoda : Amphipoda	Harpinia propinqua	1.2143	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Hippomedon serratus	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Arthropoda : Amphipoda	Jassa marmorata	0.0000	0.0536	0.0000	0.0000	0.0179	0.0000
Arthropoda : Amphipoda	Leptocheirus pinguis	0.6607	0.0714	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Listriella clymenellae	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Luconacia incerta	0.0000	0.0536	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Lysianopsis alba	0.0000	0.0000	0.0000	0.0172	1.1250	19.1964
Arthropoda : Amphipoda	Melita nitida	0.0000	0.0000	0.3929	0.5862	2.8571	2.0536
Arthropoda : Amphipoda	Microdeutopus gryllotalpa	0.0000	0.3036	0.0000	0.0345	1.8393	263.1429
Arthropoda : Amphipoda	Microprotopus raneyi	0.0000	0.0179	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Monoculodes sp. 1 Watling	0.0000	0.0000	0.0000	0.2759	0.2679	0.0000
Arthropoda : Amphipoda	Mucrogammarus mucronatus	0.0000	0.0000	0.0000	0.0000	0.3393	0.0000
Arthropoda : Amphipoda	Orchomenella minuta	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Paracaprella tenuis	0.0000	0.0893	0.0536	0.4828	5.3750	0.5179
Arthropoda : Amphipoda	Parametopella cypris	0.0000	0.3929	0.0000	0.0690	1.1786	0.0000
Arthropoda : Amphipoda	Parapleustes aestuarius	0.0000	0.0000	0.0000	0.0000	0.0536	0.0000
Arthropoda : Amphipoda	Photis dentata	0.0714	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Photis pollex	1.2500	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Phoxocephalus holbolli	0.0357	1.6964	0.0000	0.3448	0.0714	0.0000
Arthropoda : Amphipoda	Protohaustorius cf. deichmannae	2.5714	0.0000	0.0000	0.0000	0.0000	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Arthropoda : Amphipoda	Protohaustorius wigleyi	0.0357	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Pseudohaustorius borealis	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Pseudunciola obliquua	6.1964	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Rhepoxynius epistomus	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
Arthropoda : Amphipoda	Rhepoxynius hudsoni	2.7679	0.0000	0.0000	1.2759	0.0179	0.0357
Arthropoda : Amphipoda	Stenothoe minuta	0.0357	0.0000	0.0000	0.0345	0.0179	0.0714
Arthropoda : Amphipoda	Synchelidium americanum	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Unciola dissimilis	0.0000	0.0000	0.0000	0.8793	0.0179	0.4107
Arthropoda : Amphipoda	Unciola inermis	0.2857	0.0000	0.0000	0.0000	0.0000	0.0000
Arthropoda : Amphipoda	Unciola irrorata	2.8750	0.3929	0.0000	0.1552	0.0000	0.0000
Arthropoda : Amphipoda	Unciola serrata	0.0000	0.0179	0.8750	1.3276	12.1071	0.8214
Arthropoda : Amphipoda	Unciola spp.	1.7857	0.4464	0.2321	2.1207	4.0893	0.9107
Arthropoda : Decapoda	Callinectes sapidus	0.0000	0.0000	0.0179	0.0000	0.0000	0.0000
Arthropoda : Decapoda	Cancer irroratus	0.3214	0.1071	0.0000	0.2586	0.1071	0.0179
Arthropoda : Decapoda	Caridea	0.0000	0.0000	0.0000	0.0172	0.0000	0.0000
Arthropoda : Decapoda	Crangon septemspinosa	0.3214	0.3393	0.2857	0.3793	0.5000	0.1786
Arthropoda : Decapoda	Dyspanopeus sayi	0.0000	0.0179	0.0000	2.0690	0.2679	4.7143
Arthropoda : Decapoda	Hexapanopeus angustifrons	0.0000	0.0000	0.0000	0.0172	0.0536	0.0000
Arthropoda : Decapoda	Libinia spp.	0.0000	0.0536	0.0000	0.0172	0.0000	0.0357

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Arthropoda : Decapoda	Ovalipes ocellatus	0.0000	0.0357	0.0000	0.0862	0.0000	0.0536
Arthropoda : Decapoda	Pagurus longicarpus	0.0536	0.0714	0.0000	0.7069	0.0357	0.2321
Arthropoda : Decapoda	Pagurus spp.	0.0536	0.0357	0.0000	0.0172	0.1250	0.0357
Arthropoda : Decapoda	Palaemonetes intermedius	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Arthropoda : Decapoda	Paleomonetes vulgaris	0.0000	0.0000	0.0000	0.0000	0.0000	0.3750
Arthropoda : Decapoda	Panopeus herbstii	0.0000	0.0000	0.0000	0.0000	0.1607	0.0000
Arthropoda : Decapoda	Pinnixa spp.	0.0000	0.0536	0.0000	0.0000	0.0000	0.0179
Arthropoda : Decapoda	Rhithropanopeus harrisii	0.0000	0.0000	1.1786	0.0000	0.7321	0.0000
Arthropoda : Decapoda	Upogebia affinis	0.0000	0.0357	0.0000	0.0000	0.0000	0.0000
Arthropoda : Decapoda	Xanthidae	0.0000	0.2500	0.0893	0.1897	0.2321	0.0536
Arthropoda : Chironomidae	Chironomidae	0.0000	0.0000	0.0000	0.0000	0.0000	0.0179
Sipuncula	Sipuncula	0.1786	0.0000	0.0000	0.0000	0.0000	0.0000
Phoronida	Phoronis spp.	3.2679	5.0536	0.0000	0.1207	0.0357	0.0000
Echinodermata : Asteroidea	Asteroidea	0.1429	0.0179	0.0000	0.0862	0.0357	0.0000
Echinodermata : Echinoidea	Echinarachnius parma	0.4286	0.0000	0.0000	0.0000	0.0000	0.0000
Echinodermata : Echinoidea	Echinoidea	10.1429	0.0000	0.0000	0.0000	0.0000	0.0000
Echinodermata : Holothuroidea	Havelockia scabra	0.0179	0.0000	0.0000	0.0000	0.0000	0.0000
Hemichordata	Saccoglossus kowalevskii	0.0714	0.1250	0.0000	0.0000	0.0000	0.0000
Chordata : Ascidiacea	Ascidiacea	0.0357	0.0000	0.0536	0.0345	0.6429	0.0000

Taxon Group	Taxon Name	Bight Apex	West. Long Island Sound	Newark Bay	Raritan Bay	Upper Harbor	Jamaica Bay
Chordata : Ascidiacea	Molgula manhattensis	0.0000	0.0179	0.0893	0.0862	4.5357	0.0000

Appendix H

Clostridium perfringens results

Clostridium perfringens results

Concentrations of *Clostridium perfringens* spores have been used as an indicator of sewage contamination (Hill et al., 1993; O'Reilly et al., 1995). *C. perfringens* is a obligate anaerobe bacterium found in fecal material. It can survive extreme environmental conditions. This study evaluated the concentrations of the spores in Harbor sediments. The laboratory procedure was the membrane filter method of Emerson and Cabelli (1982). Mean concentrations of *C. perfringens* spores are expressed as confirmed counts per gram (wet weight) of sediment.

The Lower Harbor had the lowest mean spore count of the sub-basins in the Harbor (Table J-1). The other three sub-basins of the Harbor all had similar mean spore concentrations, although variability was high. The mean spore concentration in western Long Island Sound was an order of magnitude lower than the Harbor mean.

Table J-1
Area-weighted Mean Concentrations of *C. perfringens*
(± represent 90% confidence intervals)

	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. LI. Sound	Bight Apex
Mean number of *C. perfringens* spores (# spores/g-wet weight)	2440 716	4171 5187	5977 3335	935 355	5156 2015	237 67	556 536

Background concentrations of *C. perfringens* in surficial sediments from the outer New York Bight continental shelf of Georges Bank are 10-20 spores/g (dry weight) (Cabelli and Pedersen, 1982). Mean concentrations in the Harbor, western Long Island Sound and the Bight Apex were significantly above background (even after converting from wet weight to dry weight).

Literature Cited

Cabelli, V.J., and D. Pedersen. 1982. The movement of sewage sludge from the New York Bight dumpsite as seen from *Clostridium perfringens* spore densities. *In* Oceans '82 conference record, p. 995-999. Inst. Electr. Electron. Eng., Piscataway, New Jersey.

Emerson, D.J., and V.J. Cabelli. 1982. Extraction of *Clostridium perfringens* spores from bottom sediment samples. *Appl. Environ. Microbiol.* **44**:1144-1149.

Hill, R.T., I.T. Knight, M.S. Anikis, and R.R. Colwell. 1993. Benthic distribution of sewage sludge indicated by *Clostridium perfringens* at a deep-ocean dump site. *Appl. Environ.*

Microbiol. **59**(1):47-51.

O'Reilly, J.E., I. Katz, and A.F.J. Draxler. 1995. Changes in the abundance and distribution of *Clostridium perfringens*, a microbial indicator, related to cessation of sewage sludge dumping in the New York Bight, p. 113-132. *In* U.S. Dept. Of Commerce NOAA Technical Report NMFS 124.

Appendix I

Benthic Index (B-IBI) values for individual stations

```
           UPDATED 93/94 NY/NJ DATA                                  1
                Benthic Index  11:12 Tuesday, February 13, 1996

         OBS     STATION     RINDEX52

           1      BA002         3.4
           2      BA005         4.0
           3      BA007         3.2
           4      BA010         3.2
           5      BA012         3.4
           6      BA014         3.8
           7      BA016         4.4
           8      BA017         3.8
           9      BA021         4.6
          10      BA025         4.4
          11      BA026         4.0
          12      BA030         3.4
          13      BA033         4.2
          14      BA035         3.8
          15      BA102         3.4
          16      BA103         3.4
          17      BA104         4.4
          18      BA105         4.4
          19      BA106         3.4
          20      BA107         4.6
          21      BA108         3.8
          22      BA109         4.4
          23      BA110         4.6
          24      BA111         4.2
          25      BA112         4.0
          26      BA113         3.0
          27      BA114         4.6
          28      BA115         4.0
          29      JB002         2.4
          30      JB006         2.4
          31      JB008         1.4
          32      JB012         1.4
          33      JB015         1.2
          34      JB018         2.4
          35      JB022         2.0
          36      JB026         3.0
          37      JB031         2.2
          38      JB033         3.0
          39      JB039         3.0
          40      JB041         3.0
          41      JB042         3.8
          42      JB043         2.6
          43      JB101         1.8
          44      JB103         1.0
          45      JB104         2.6
          46      JB106         2.6
          47      JB108         2.2
          48      JB110         2.8
          49      JB111         2.6
          50      JB112         3.0
          51      JB113         2.8
          52      JB114         3.0
          53      JB115         3.4
```

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OBS     STATION      RINDEX52

 54     JB117           2.8
 55     JB119           3.2
 56     JB120           3.2
 57     LS001           5.0
 58     LS004           3.2
 59     LS006           3.8
 60     LS010           3.4
 61     LS011           2.6
 62     LS016           3.0
 63     LS018           3.4
 64     LS019           2.8
 65     LS020           2.4
 66     LS024           4.2
 67     LS026           2.4
 68     LS027           3.0
 69     LS030           2.8
 70     LS035           1.6
 71     LS101           4.2
 72     LS102           3.2
 73     LS103           4.2
 74     LS104           4.2
 75     LS106           2.4
 76     LS107           2.6
 77     LS108           2.0
 78     LS109           3.2
 79     LS110           2.8
 80     LS111           2.2
 81     LS112           2.4
 82     LS113           1.8
 83     LS114           2.8
 84     LS115           2.4
 85     NB018           2.2
 86     NB021           2.0
 87     NB025           2.4
 88     NB027           2.2
 89     NB036           3.0
 90     NB039           2.6
 91     NB044           2.4
 92     NB045           2.6
 93     NB047           1.2
 94     NB052           2.6
 95     NB053           2.0
 96     NB065           2.4
 97     NB066           1.6
 98     NB075           1.2
 99     NB102           1.8
100     NB103           2.6
101     NB104           2.4
102     NB105           2.0
103     NB106           2.6
104     NB107           2.6
105     NB108           1.8
106     NB109           2.2
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          UPDATED 93/94 NY/NJ DATA                                   3
               Benthic Index  11:12 Tuesday, February 13, 1996

        OBS     STATION      RINDEX52

        107     NB110           2.8
        108     NB111           2.4
        109     NB112           2.2
        110     NB113           2.4
        111     NB114           1.6
        112     NB115           2.6
        113     RB001           2.8
        114     RB002           3.6
        115     RB007           3.2
        116     RB010           4.0
        117     RB011           4.6
        118     RB012           4.4
        119     RB016           3.0
        120     RB019           2.6
        121     RB024           2.8
        122     RB027           2.8
        123     RB029           3.0
        124     RB030           4.4
        125     RB032           3.8
        126     RB033           2.6
        127     RB101           2.8
        128     RB102           3.0
        129     RB103           3.0
        130     RB104           2.6
        131     RB105           3.4
        132     RB106           4.8
        133     RB107           3.4
        134     RB108           3.0
        135     RB110           2.2
        136     RB111           2.2
        137     RB112           2.8
        138     RB114           3.0
        139     RB116           2.6
        140     RB117           3.0
        141     UH003           2.0
        142     UH004           2.8
        143     UH008           4.0
        144     UH010           3.2
        145     UH011           3.2
        146     UH014           1.8
        147     UH018           2.6
        148     UH019           2.4
        149     UH020           1.4
        150     UH022           2.2
        151     UH023           2.6
        152     UH026           2.6
        153     UH029           3.2
        154     UH030           4.0
        155     UH101           2.2
        156     UH102           2.2
        157     UH103           2.2
        158     UH104           2.8
        159     UH105           2.6
```

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        OBS     STATION      RINDEX52

        160     UH106           3.4
        161     UH107           1.4
        162     UH108           2.2
        163     UH109           2.2
        164     UH110           2.0
        165     UH111           2.6
        166     UH112           1.8
        167     UH113           2.4
        168     UH114           3.4
```

Appendix J

Data disk explanatory information

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                     CONTENTS PROCEDURE

        -----Alphabetic List of Variables and Attributes-----

 #    Variable     Type   Len   Pos   Format   Label
___________________________________________________________________

 74   ACENTHE      Num     8    596            Acenaphthene (ppb)
 73   ACENTHY      Num     8    588            Acenaphthylene (ppb)
 48   AG           Num     8    390            Silver (ppm)
 93   AG_RECOV     Num     8    748            Silver partial (ppm)
 60   AL           Num     8    486            Aluminum (ppm)
119   ALDRIN       Num     8    956            Aldrin (ppb)
120   ALPHACHL     Num     8    964            Alpha-chlordane (ppb)
 94   AL_RECOV     Num     8    756            Aluminum partial (ppm)
172   AMB_DO       Num     8   1380            Amb DO (mg/L)
170   AMB_SAL      Num     8   1364            Amb Salinity (ppt)
171   AMB_TEMP     Num     8   1372            Amb Temp. (C)
 77   ANTHRA       Num     8    620            Anthracene (ppb)
 49   AS           Num     8    398            Arsenic (ppm)
 95   AS_RECOV     Num     8    764            Arsenic partial (ppm)
 33   AVS          Num     8    270            AVS (ppm)
 40   AVS_MM       Num     8    326            AVS (mmol)
 65   BASAREA      Num     8    526            Total Basin Area (sq km)
  1   BASINCOD     Char    2      0            Basin Code
 80   BENANTH      Num     8    644            Benzo[a]anthracene (ppb)
 82   BENAPY       Num     8    660            Benzo[a]pyrene (ppb)
 86   BENEPY       Num     8    692            Benzo[e]pyrene (ppb)
110   BENZOFL      Num     8    884            Benzo[b,k]fluoranthene (ppb)
 85   BENZOP       Num     8    684            Benzo[g,h,i]perylene (ppb)
108   BIO10DS1     Num     8    868
 87   BIPHENYL     Num     8    700            Biphenyl (ppb)
165   BT_TOT       Num     8   1324            Total Butyl tins (ppb)
175   B_BAC        Num     8   1404            Bottom BAC
176   B_COND       Num     8   1412            Bottom Conductivity (mS/cm)
 21   B_DEPTH      Num     8    174            Bottom depth (m)
 22   B_DO         Num     8    182            Bottom DO (mg/L)
 26   B_ORP        Num     8    214            Bottom ORP (mV)
 24   B_PH         Num     8    198            Bottom pH
 23   B_SAL        Num     8    190            Bottom Salinity (ppt)
```

★ biomass — g/sample (.04 m² grab)

★ abundance — # organisms/sample

★ note that there are 2 replicates for each of these and they are separate sheets on the spreadsheet.

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                              CONTENTS PROCEDURE

                  #   Variable    Type   Len   Pos   Format   Label
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                 25   B_TEMP      Num     8    206            Bottom Temp (C)
                 50   CD          Num     8    406            Cadmium (ppm)
                 96   CD_RECOV    Num     8    772            Cadmium partial (ppm)
                 69   CHAN_TYP    Char    8    558            Channel Type
                121   CHL_TOTC    Num     8    972            Total Chlordane (ppb)
                 81   CHRYSENE    Num     8    652            Chrysene (ppb)
                109   CLOSTR      Num     8    876            Clostridium (#/gm)
                 51   CR          Num     8    414            Chromium (ppm)
                 97   CR_RECOV    Num     8    780            Chromium partial (ppm)
                 52   CU          Num     8    422            Copper (ppm)
                 98   CU_RECOV    Num     8    788            Copper partial (ppm)
                  3   DATE        Num     8     12   DATE7.   Date
                159   DBT         Num     8   1276            Dibutyltin (ppb)
                168   DDD_TOT     Num     8   1348            Total DDD (ppb)
                167   DDE_TOT     Num     8   1340            Total DDE (ppb)
                169   DDT_STOT    Num     8   1356            Total DDT parent (ppb)
                122   DDT_TOT     Num     8    980            Total DDT (ppb)
                  7   DEPTH       Num     8     61            Depth (m)
                 84   DIBENZ      Num     8    676            Dibenz[a,h]anthracene (ppb)
                123   DIELDRIN    Num     8    988            Dieldrin (ppb)
                 88   DIMETH      Num     8    708            2,6-Dimethylnaphthalene (ppb)
                124   ENDRIN      Num     8    996            Endrin (ppb)
                 61   FE          Num     8    494            Iron (ppm)
                 99   FE_RECOV    Num     8    796            Iron partial (ppm)
                 78   FLUORANT    Num     8    628            Fluoranthene (ppb)
                 75   FLUORENE    Num     8    604            Fluorene (ppb)
                125   HEPTACHL    Num     8   1004            Heptachlor (ppb)
                126   HEPTAEPO    Num     8   1012            Heptachlor Epoxide (ppb)
                127   HEXACHL     Num     8   1020            Hexachlorobenzene (ppb)
                 63   HG          Num     8    510            Mercury (ppm)
                101   HG_RECOV    Num     8    812            Mercury partial (ppm)
                 83   INDENO      Num     8    668            Indeno[1,2,3-C,D]pyrene (ppb)
                  4   LAT         Char   20     20
                128   LINDANE     Num     8   1028            Lindane - Gamma-BHC (ppb)
                  5   LONG        Char   20     40
                160   MBT         Num     8   1284            Monobutyltin (ppb)
                 89   MENAP1      Num     8    716            1-Methylnaphthalene (ppb)
                 72   MENAP2      Num     8    580            2-Methylnaphthalene (ppb)
                 90   MEPHEN1     Num     8    724            1-Methylphenanthrene (ppb)
                129   MIREX       Num     8   1036            Mirex (ppb)
                 59   MN          Num     8    478            Mangenese (ppm)
                100   MN_RECOV    Num     8    804            Manganese partial (ppm)
                 71   NAPH        Num     8    572            Naphthalene (ppb)
                 53   NI          Num     8    430            Nickel (ppm)
                102   NI_RECOV    Num     8    820            Nickel partial (ppm)
                130   OPDDD       Num     8   1044            o,p, DDD (ppb)
                131   OPDDE       Num     8   1052            o,p, DDE (ppb)
                132   OPDDT       Num     8   1060            o,p, DDT (ppb)
                163   OPDDTTOT    Num     8   1308            Total OPDDT (ppb)
                117   PAH_HMWC    Num     8    940            High Molecular Wt PAHs (ppb)
                116   PAH_LMWC    Num     8    932            Low Molecular Wt PAHs (ppb)
                118   PAH_TOTC    Num     8    948            Total PAHs (ppb)
                 54   PB          Num     8    438            Lead (ppm)
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                         CONTENTS PROCEDURE

         #  Variable   Type  Len   Pos  Format  Label
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       103  PB_RECOV   Num     8   828          Lead partial (ppm)
       152  PCB8       Num     8  1220          PCB Congener 8 (ppb)
       142  PCB18      Num     8  1140          PCB Congener 18 (ppb)
       148  PCB28      Num     8  1188          PCB Congener 28 (ppb)
       149  PCB44      Num     8  1196          PCB Congener 44 (ppb)
       150  PCB52      Num     8  1204          PCB Congener 52 (ppb)
       151  PCB66      Num     8  1212          PCB Congener 66 (ppb)
       133  PCB101     Num     8  1068          PCB Congener 101 (ppb)
       134  PCB105     Num     8  1076          PCB Congener 105 (ppb)
       136  PCB118     Num     8  1092          PCB Congener 118 (ppb)
       137  PCB126     Num     8  1100          PCB Congener 126 (ppb)
       138  PCB128     Num     8  1108          PCB Congener 128 (ppb)
       139  PCB138     Num     8  1116          PCB Congener 138 (ppb)
       140  PCB153     Num     8  1124          PCB Congener 153 (ppb)
       141  PCB170     Num     8  1132          PCB Congener 179 (ppb)
       143  PCB180     Num     8  1148          PCB Congener 180 (ppb)
       144  PCB187     Num     8  1156          PCB Congener 187 (ppb)
       145  PCB195     Num     8  1164          PCB Congener 195 (ppb)
       146  PCB206     Num     8  1172          PCB Congener 206 (ppb)
       147  PCB209     Num     8  1180          PCB Congener 209 (ppb)
       135  PCB11077   Num     8  1084          PCB Congener 110/77 (ppb)
       166  PCB_TOTC   Num     8  1332          Total PCBs (ppb)
        29  PCTCON_A   Num     8   238          Ampelisca Surv as % of Control
        32  PCTCON_M   Num     8   262          Microtox Surv as % of Control
        30  PCTSUR_A   Num     8   246          Ampelisca % Survival
        91  PERYLENE   Num     8   732          Perylene (ppb)
        76  PHENANTH   Num     8   612          Phenanthrene (ppb)
         6  POSEQUIP   Char    1    60          Pos Unit
       153  PPDDD      Num     8  1228          p,p, DDD (ppb)
       154  PPDDE      Num     8  1236          p,p, DDE (ppb)
       155  PPDDT      Num     8  1244          p,p, DDT (ppb)
       164  PPDDTTOT   Num     8  1316          Total PPDDT (ppb)
        79  PYRENE     Num     8   636          Pyrene (ppb)
       179  RINDEX45   Num     8  1437          RGI Analogue # 2 Value
        70  SAMPLE     Char    6   566          Sample ID
       177  SAMPTYPE   Char    9  1420          Sample Type
        55  SB         Num     8   446          Antimony (ppm)
       104  SB_RECOV   Num     8   836          Antimony partial (ppm)
        57  SE         Num     8   462          Selinium (ppm)
        11  SEAS       Char   10    92          Sea condition
         9  SECCHI     Num     8    70          Secchi depth (m)
        66  SEGAREA    Num     8   534          Segment Area (sq km) (NB only)
        27  SEGMENT    Num     8   222          Segment (NB only)
        34  SEM_CD     Num     8   278          SEM Cd (ppm)
        41  SEM_CD_M   Num     8   334          SEM Cd (mmol)
        35  SEM_CU     Num     8   286          SEM Cu (ppm)
        42  SEM_CU_M   Num     8   342          SEM Cu (mmol)
        39  SEM_HG     Num     8   318          SEM Hg (ppm)
        46  SEM_HG_M   Num     8   374          SEM Hg (mmol)
        37  SEM_NI     Num     8   302          SEM Ni (ppm)
        44  SEM_NI_M   Num     8   358          SEM Ni (mmol)
        36  SEM_PB     Num     8   294          SEM Pb (ppm)
        43  SEM_PB_M   Num     8   350          SEM Pb (mmol)
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                         CONTENTS PROCEDURE

          #   Variable   Type  Len   Pos   Format  Label
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         47   SEM_TOT    Num    8    382           Total SEM (mmol)
         38   SEM_ZN     Num    8    310           SEM Zn (ppm)
         45   SEM_ZN_M   Num    8    366           SEM Zn (mmol)
        105   SE_RECOV   Num    8    844           Selinium partial (ppm)
         62   SI         Num    8    502           Silicon (ppm)
         28   SIG_AMP    Num    8    230           Ampelisca Significance (1=signif)
         31   SIG_MIC    Num    8    254           Microtox Significance (1=sig)
         64   SILTCLAY   Num    8    518           Percent Siltclay Content
         56   SN         Num    8    454           Tin (ppm)
          2   STATION    Char  10      2   $F8.    Station Identifier
         67   STA_LAT    Num    8    542           Station Latitude
         68   STA_LNG    Num    8    550           Station Longitude
         18   S_AMBDO    Num    8    150
         14   S_AMBSAL   Num    8    118
         16   S_AMBTMP   Num    8    134
        173   S_BAC      Num    8   1388           Surface BAC
        174   S_COND     Num    8   1396           Surface Conductivity (mS/cm)
         12   S_DEPTH    Num    8    102           Surface depth (m)
         17   S_DO       Num    8    142           Surface DO (mg/L)
         20   S_ORP      Num    8    166           Surface ORP (mV)
         19   S_PH       Num    8    158           Surface pH
         13   S_SAL      Num    8    110           Surface Salinity (ppt)
         15   S_TEMP     Num    8    126           Surface Temp (C)
        111   T2PAHC     Num    8    892           2-Ring PAHs (ppb)
        112   T3PAHC     Num    8    900           3-Ring PAHs (ppb)
        113   T4PAHC     Num    8    908           4-Ring PAHs (ppb)
        114   T5PAHC     Num    8    916           5-Ring PAHs (ppb)
        115   T6PAHC     Num    8    924           6-Ring PAHs (ppb)
        158   TBT        Num    8   1268           Tributyltin (ppb)
        161   TCDD       Num    8   1292           Dioxin (2,3,7,8-TCDD) (ng/kg)
        162   TCDF       Num    8   1300           Furan (2,3,7,8-TCDF) (ng/kg)
        157   TETBT      Num    8   1260           Tetrabutyltin (ppb)
        156   TNONCHL    Num    8   1252           Trans-Nonachlor (ppb)
        107   TOC        Num    8    860           Total Organic Carbon (ppm)
          8   TRASH      Char   1     69           Trash?
         92   TRI235     Num    8    740           2,3,5 Trimethylnaphthalene (ppb)
         10   WEATHER    Char  14     78           Weather cond.
        178   YEAR       Num    8   1429
         58   ZN         Num    8    470           Zinc (ppm)
        106   ZN_RECOV   Num    8    852           Zinc partial (ppm)
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