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INFAUNAL INVERTEBRATE ASSESSMENT*

For the

ECOLOGICAL RISK ASSESSMENT FOR PORTSMOUTH NAVAL SHIPYARD, KITTERY, MAINE

Prepared by

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FINAL REPORT - Infaunal Invertebrat Assessment
(UNH subcontract No. 93-17)

Ecological Risk Assessment for Naval Shipyard, Portsmouth, NH

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This is the final report on the infaunal (benthic) invertebrate assessment portion of the overall risk assessment. It consists mainly of an expanded analysis of invertebrate data provided by Normandeau Associates, Inc. (NAI) and physicochemical data collected as part of the Phase I efforts. These data were preliminarily assessed in the Phase I report (Shipman 1993) and in the Media Protection Standards report (Johnston 1993). The present report also incorporates most of the information contained in a preliminary report on a comparison of the NAI data collected from 23 sites in September 1991 with data from a re-sampling of 5 of the 23 sites in October 1992 (Grizzle 1993). In sum, the present report represents the completion of the requirements of the University of New Hampshire Subcontract 93-17 with Campbell University.

I. Comparison of 1992 Benthic Samples at Five Sites with 1991 NAI Data

Five sites (of 23 sampled by NAI in early September 1991) were re-sampled in late October 1992. A 10-cm ID corer (0.008 m^2) was used to take five replicate cores at each site (total area sampled: 0.04 m^2); this is compared to four replicate Shipek grabs taken by NAI (each 0.04 m^2; total area sampled: 0.16 m^2). Otherwise, samples for the present study and those of NAI were processed using the same techniques: 0.5mm mesh sieve, formalin/alcohol treatment, sorting, identification to lowest taxonomic level, counting. A major purpose of the re-sampling effort was to provide additional data on spatial variability at some of the sites; among-replicate variability in abundances appeared to be excessive for some sites in the NAI data. The purpose of this part of the report is to compare 1992 Campbell University (CU) data with 1991 NAI data.

Abundances. All abundance data are expressed as density, number of individuals m^{-2}. The mean total community densities were similar for three (sites 3, 7, and 9) of the five sites re-sampled compared to the NAI mean densities for these sites (Fig. 1). In contrast, sites 4 and 19 showed wide disparities between the CU and NAI data. These two sites, however, were the two sites with the greatest amount of variability around the mean in the NAI data set. Inspection of the error bars suggests that only the means from sites 4 and 19 would be significantly different.

The CU abundance data overall showed less variability among replicates than the NAI data. Coefficients of variation (C.V. = [Standard Deviation/Mean] x 100) ranged from approximately 60% to 84% for the NAI data, compared to 12 to 83% for the CU data (also compare error bars in Fig. 1). Based on my past experiences sampling the Great Bay system, C.V. values of up to 50% are common for benthic data with 4 to 6 replicates. Only two of the CU means exceeded 50%, compared to all of the NAI means. Because the sites were sampled at different times, the most straightforward explanation is to postulate that the communities simply had different spatial characteristics when sampled. There is no way refute this explanation, and it is probably a cause for some amount of the differences in mean densities b tween CU and NAI

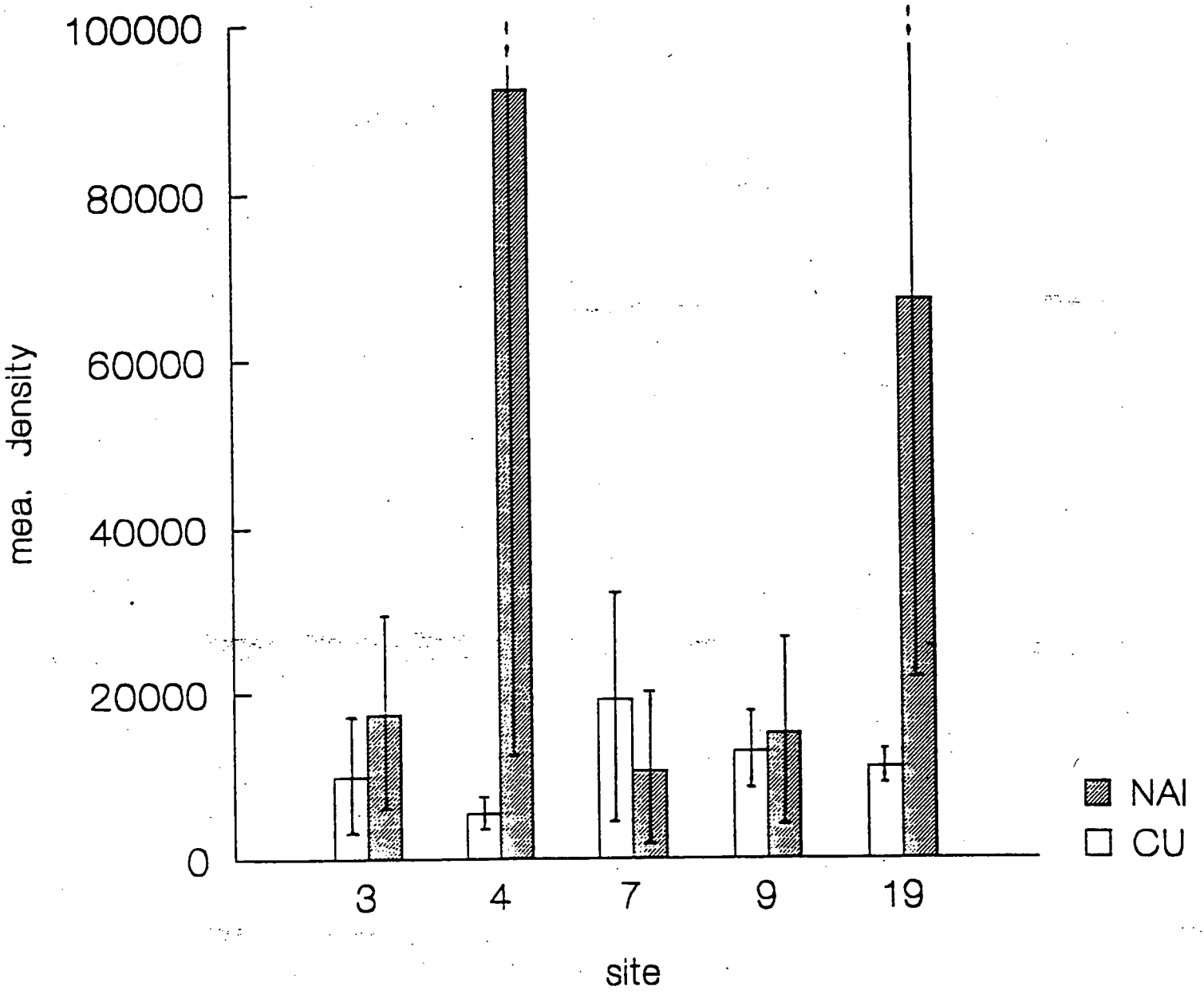

Fig. 1. Mean total densities for CU and NAI data. Error bars show + or - one S.D.

data. Year-to-year variability in benthic data is generally expected, even when samples from the same season are compared. Another possible cause for less variability in the CU data is the difference in sampling gear. A Shipek grab was used for the NAI sampling; a hand-held, flow-through corer was used for the CU sampling. Grabs are inherently less efficient than flow-through corers because of their greater variability in sediment penetration, tendency to disturb near-surface sediments when they approach the bottom, and possible sample loss when retrieved.

Species numbers. The numbers of species encountered by site cannot be directly compared because the sediment surface areas sampled by CU and NAI were different (see above). The general relationship between area sampled and number of species encountered in most biotic communities is positive; as more area is sampled more species are encountered. However, the total relationship is always nonlinear; it is usually approximately linear for the first few replicates, then it levels off as the maximum number of species present in the sampling area is approached (Holme and McIntyre 1984). Hence, even though it would be expected that the CU data would show fewer total species at each site because the total area sampled was 1/4 the NAI total, the magnitude of the difference can only be estimated.

There is no straightforward way to accurately compare data on total species present in a benthic community using samples collected by different sampling devices that remove different amounts of sediment. The major approaches that have been used include adjustments based on individuals collected, or area of sediment sampled, or volume of sediment sampled (see Holme & Mcintyre 1984 for review). However, in all cases only an approximation can be achieved. This is primarily because of two facts: the species in the community can have very different spatial scales relative to the size of the sampling unit; and sampling units of different size show different overall species/area relationships. For comparing the CU and NAI data sets, the range of possible adjustment factors is 1 to 4. For example, if the overall relationship was linear (and it never is), then simply multiplying the CU species total by four would allow a direct comparison of the two data sets. But because the relationship is always nonlinear, an adjustment factor of <4x was used. I chose 2x as a conservative adjustment factor to allow comparison of the CU and NAI data with respect to species numbers encountered.

The CU adjusted species totals were quite comparable to the NAI species totals at all of the sites except 7 (Fig. 2). These data strongly suggest that the sampled communities were very similar with respect to species numbers.

Dominant species. The top ten species based on mean population density at each site from CU and NAI samples are listed in Table 1. For the CU data, the top ten species represented from 85 to 99% of the total individuals collected from each site; compared to 78 to 98% for the NAI data. Four to six of the dominant species were found in both CU and NAI samples at each of the sites, and these common species represented from 39 to 92% of the total individuals collected. These data strongly indicate that the community species composition was very similar in the CU and NAI samples.

Conclusions. One of the options considered as part of the CU re-sampling effort was the possibility of incorporating the CU data into the NAI data set for further analyses. For two reasons, I concluded that only the Phase I NAI data set will be used in further analyses aimed at relating spatial variations in benthic invertebrate data to pollutant and other environmental data.

First, I think the CU and NAI data compare quite well. Based on sp cies numbers estimates and community species composition, the data sets were quite similar. And three of the five sites showed very similar total community densities. There were substantial differences in densities at two of the five sites, but these may have been because of the differences in sampling gear and/or year-to-year variations in community dynamics.

Secondly, because of problems (e.g. comparing total species numbers, as

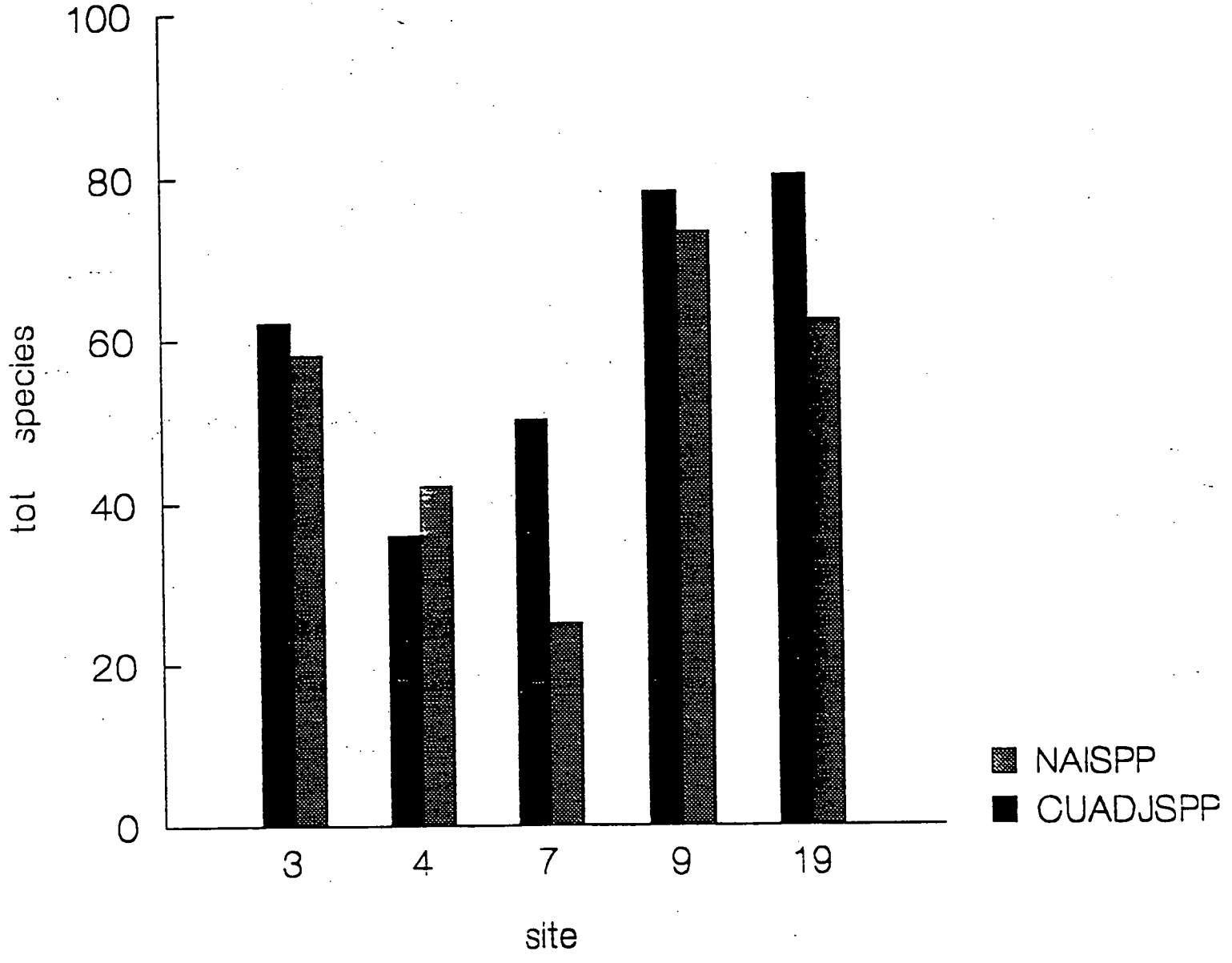

Fig. 2. Total species collected at each site from CU and NAI data. "Adjusted totals" for CU data; see text.

Table 1. Percent composition of the ten most abundant benthic infauna at the five ations re-sampled in October 1992 compared t ten most abundant from the NAI sampling in 991 and found in Table 2 in the "Draft Phase I Final Report."

SITE:	3		4		7		9		19	
Taxon	CU	NAI	CU	NAI	CU	NAI	CU	NAI	CU	NAI
Aglaophamus neotenus.....			8.8		3.5					
Ampelisca abdita				0.9		4.0				
Ampelisca sp.....		6.1		1.6		2.8				1.1
Anomia sp.								3.3		
Aricidea catherinae.....								1.6		
Capitella capitata.....					1.0			1.3		1.3
Cirratulidae (Tharyx ?).....	5.2	3.3	3.2	20.6	3.4	8.2	6.0	3.6	2.7	1.0
Cirratulus grandis.....	6.7						19.8	6.0		
Erichthonius brasiliensis.....									4.3	
Gamaridae (unident.).....	14.5		6.0				24.5		5.2	
Leptocheirus pinquis.....	1.7									
Lumbrineris tenuis.....	4.8		26.7		1.0		12.6		8.8	
Mediomastus sp.....			4.6	0.3	1.7		1.8	1.4		
Microphthalmus aberrans.....				0.9		3.4				
Mytilidae (Mytilus edulis ?)..		9.8				1.3	4.0	18.6		0.8
Nephtyidae.....		1.6		1.2		15.1				
Ninoe nigripes.....	1.4	1.2	8.3						1.6	
Oligochaeta	19.3	42.8	7.8	12.8	9.0	45.9	8.0	38.0	7.5	27.4
Phyllodoce mucosa.....							1.4		1.4	
Phoxocephalus holbolli.....	8.3		5.5		1.0		5.6		27.2	3.8
Prionospio sp.....						1.4				
Prionospio steenstrupi.....	1.9		12.0	0.4	4.7	2.7	1.9			
Pygospio elegans.....		3.3		1.0	2.7					1.8
oletoma hebes.....								3.0		2.2
coletoma sp.....		2.5						2.0		3.0
Streblospio benedicti.....	24.8	14.0	16.6	58.3	69.1	10.4			28.3	52.9
Tellina agilis.....		1.4								
Total for top ten taxa:	88.6	86.0	99.5	98.0	97.1	95.2	85.6	78.8	88.0	95.3
# of taxa Common to CU & NAI:		4		5		4		5		4
Common taxa total percent:	49.3	60.1	44.2	92.4	86.2	67.2	39.6	67.6	65.7	85.1

discussed above) associated with different sampling methods, as well as the fact that the CU and NAI samples were taken 1 year apart, it would not be appropriate to combine the data sets. The 1 year time difference results in the samples being taken from two possibly very different overall "populations" (in a statistical sense). As mentioned above, temporal variations (including seasonal and year-to-year) in benthic communities are to be expected, so when spatial variations are the main concern it is best to compare data taken over as short a time period as possible.

II. Assessment of 1991 NAI Benthic Invertebrate Data

Assessment of the NAI benthic invertebrate data and relevant environmental data was carried out according to the procedures outlined in Table 2. The following sections correspond to the assessment steps listed there. All statistical analyses were done using SYSTAT programming (SYSTAT 1992).

Reduction of NAI raw count data. The Phase I benthic invertebrate data set (Appendix XI in Johnston et al. 1993) was re-arranged into a conventional taxa-by-site data matrix, and means by site were calculated (using density values [individuals m^{-2}] and raw count data) for each taxon (Appendix B herein). Means of the density data were used to determine the top 15 numerically dominant taxa by site, and each count was converted to a percent value ([count of taxon/total individuals in sample] x 100; Appendix C herein). This newly created data set was used in the cluster analysis discussed below.

Geographic variations in benthic communities. The conceptual model showing potential contaminant release areas from Seavey Island suggests three major groupings of the study sites: Clark Cove (sites 3, 4, 5, 6, 7, 8); the back channel area (sites 13, 17, 18, 19); and sites along Seavey Island on the main channel of the Piscataqua River (sites 9, 10, 12, 14). The model suggests that sites in other areas (sites 1, 2, 11, 15, 16, 20, 21, 22, 23) probably would not be as affected by contaminant releases from Seavey Island, though they could be affected by contaminants from other sources. The first analysis of the NAI data set was done to determine if benthic community species composition showed groupings (affinities) relative to position in the estuary. This analysis was carried out in two stages. First, a cluster analysis was done based on species composition (top 15 numerical dominants). Secondly, community-level characteristics (total species present, and total densities) were compared after grouping the 23 sites into four groups based on geographic location.

Cluster analysis. Several types of cluster analysis were used on the overall data set in Appendix C, and most gave similar results. Only the following techniques are reported here. A data matrix consisting of a Pearson product-moment correlation coefficient (a "distance" measure) for all possible pairs of site-by-site comparisons was constructed. The coefficients were then clustered into groups with increasing distances (dissimilarity) using the average linkage method, and the results were plotted as a dendrogram (tree diagram; Fig. 3).

Only three strongly similar clusters were evident. Sites 2, 4, 6, 8 and 19 grouped at a Pearson r value of >0.9 (note that 1-Pearson r is plotted in Fig. 3); of these five, sites 4, 6 and 8 were in Clark Cove. A second cluster with r>0.9 consisted of sites 1, 3, 11, 15, 20 and 21; sites 20 and 21 were in Spruce Creek. This second group was clustered with site 7 at r=0.9, and sites 9, 16, 17 and 18 at r=0.8; of these, sites 15 and 16 were up river sites. Five of the six Clark Cove sites clustered at an r value of about 0.35; site 5 (the sixth Clark Cove site) was strongly dissimilar to most of the sites, and clustered with 21 of the 23 sites at r=0.2. In sum, cluster analysis showed two groupings (sites 4, 6, and 8 at r>0.9; sites 3 and 7 at r=0.9) which included a total of five of the six Clark Cove sites with strong similarities in species composition. The two up river sites were similar (r=0.8), as were the two sites in Spruce Creek (r>0.9). Hence, cluster analysis indicated that

Table 2. Major steps carried out in analysis of NAI benthic invertebrate data and relevant environmental data.

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1. Reduction of raw count data (Appendix XI in Johnston et al. 1993) to means by taxon (rows) and site (columns). [Appendix B]

2. Reduction of Appendix B to top 15 numerically dominant taxa at each of the 23 sites. [Appendix C]

3. Analysis of geographic variations in benthic communities using data in Appendix C, and community-level descriptors.

4. Analysis of benthos/environment relationships using newly created data set [Appendix D] consisting of community-level descriptors (total species and total abundances) and selected environmental data from Johnston (1993) and Johnston et al. (1993).

DISTANCE METRIC IS 1-PEARSON CORRELATION COEFFICIENT
AVERAGE LINKAGE METHOD

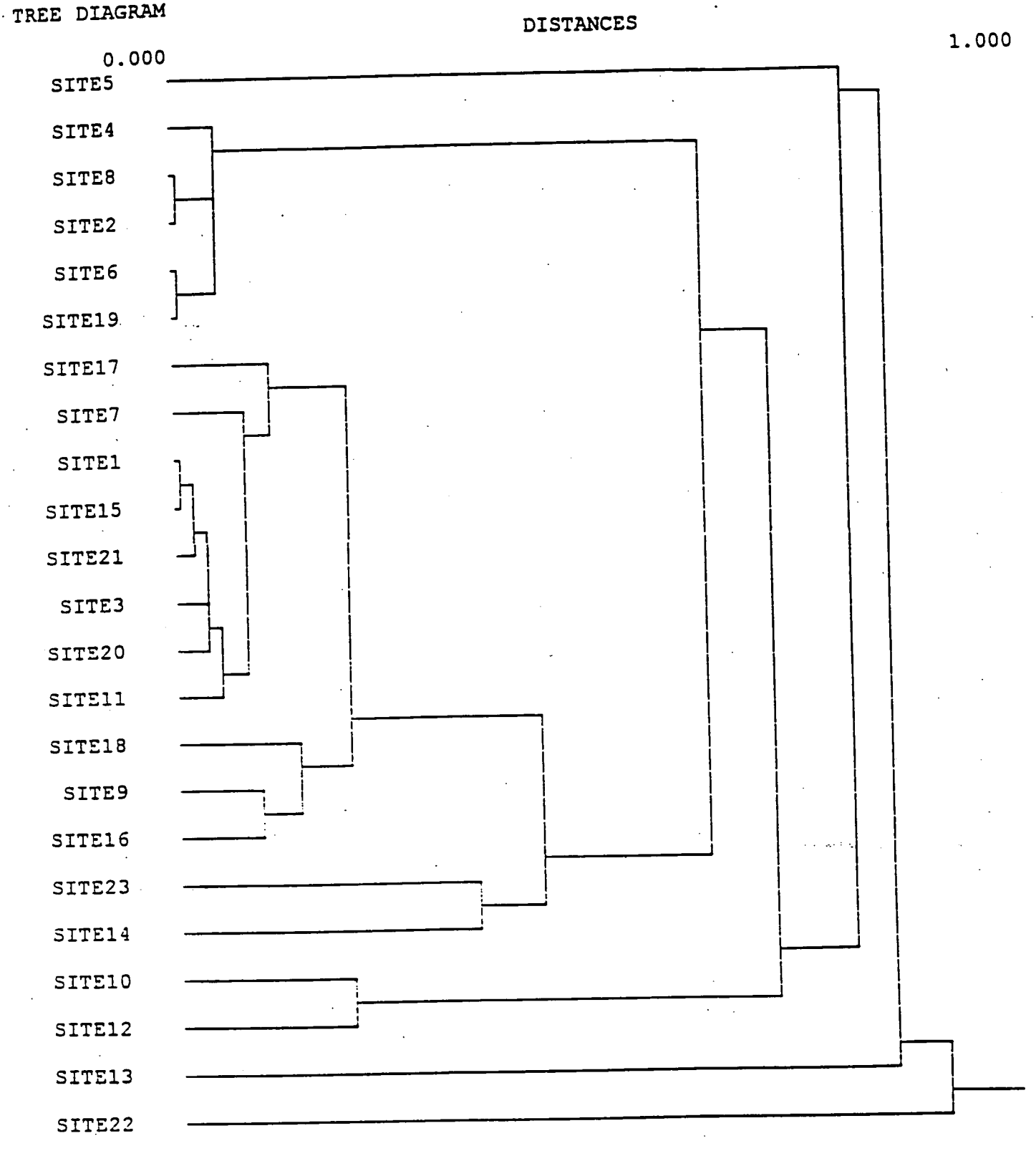

Fig. 3. Dendrogram from cluster analysis using top 15 numerical dominant taxa from each site.

of the three potentially contaminated areas around Seavey Island, only Clark Cove showed strong departures in species composition from the other sites.

Geographic groupings. The 23 sites were separated into four groups based on geographic location, as listed above. ANOVA of the benthic species numbers data (Table 1, p. 3.12-5 in Johnston et al. 1993) after being grouped geographically, showed that Clark Cove had substantially and significantly (P=0.034) fewer species than the other groups (Fig. 4a; see Fig. 4b for bar graph of total species collected at each site). A Tukey's Multiple Comparison test showed Clark Cove different from the main channel and back channel, but not from a fourth group consisting of sites up river (sites 15, 16), down river (sites 1, 2), Spruce Creek (sites 20, 21), and cross river (site 11). In contrast, the mean total community densities were very similar among the four geographic groups (Fig. 5).

Taken together, the cluster analysis (based on species composition) and the analysis of total species numbers by geographic location showed three site groupings based on variations in benthic communities: 1) Clark Cove; 2) Spruce Creek (sites 20, 21); and 3) up river (sites 15, 16). Otherwise, there were no strong affinities based on species composition and species numbers related to geographic variations among the other sites. And with respect to potentially contaminated areas (based on the conceptual model), only Clark Cove was different from the other areas.

Benthos/environmental factor relationships. The above analyses indicate that the Clark Cove benthos differed from other areas, but they give no information on what (if any) environmental factors might cause these differences. Appendix D is a data set consisting of two benthic community characteristics (total species and total abundances) and selected environmental factors, by site. It was constructed to assess potential relationships between benthic variations and environmental factors. The analysis was carried out in three stages. First, a comparison of benthic communities and environmental factors based on the four geographic groups discussed above was done. Secondly, multiple linear regression was used on the total data set to develop models relating environmental factors to variations in community-level benthic characteristics, irrespective of geographic location. Finally, an assessment of the benthic data from the perspective of pollution indicator species was carried out. Data from graphical and correlation analyses of total amphipod species and densities compared to environmental factors are presented.

Geographic variations. Table 3 shows the means for total species in the benthic communities and several environmental factors after combining the data into four geographic groups. The means for environmental factors are from several sources, and each is given in the table legend. The total species means are the same as shown in Figure 4. (There were no significant differences in community densities [Fig. 5], so only total species data are discussed in this section.) ANOVAs on each variable showed significant differences among the geographic groups for total species (as discussed above), sediment grain size measurements (most were different but only mean phi size is shown), total sediment PCBs, and a measurement of total sediment metals using the Effects Range-Low values. In all cases, Tukey's groupings indicated the Clark Cove group was different from one or more of the other groups; it had fewer species, higher total PCBs and total metals, and finer mean grain size.

Multiple linear regression. A Pearson correlation coefficient data matrix was constructed to show all pairwise r values and Bonferroni-adjusted probabilities. Only sediment characteristics and eelgrass biomass showed strong correlations to total species, and examples of these were plotted (Figs. 6 - 9). However, there were weak (and not statistically significant) correlations between total species and water toxicity data as well as a measure of total metals contamination of the sediments. There were no strong correlations between any of the environmental characteristics and total community densities.

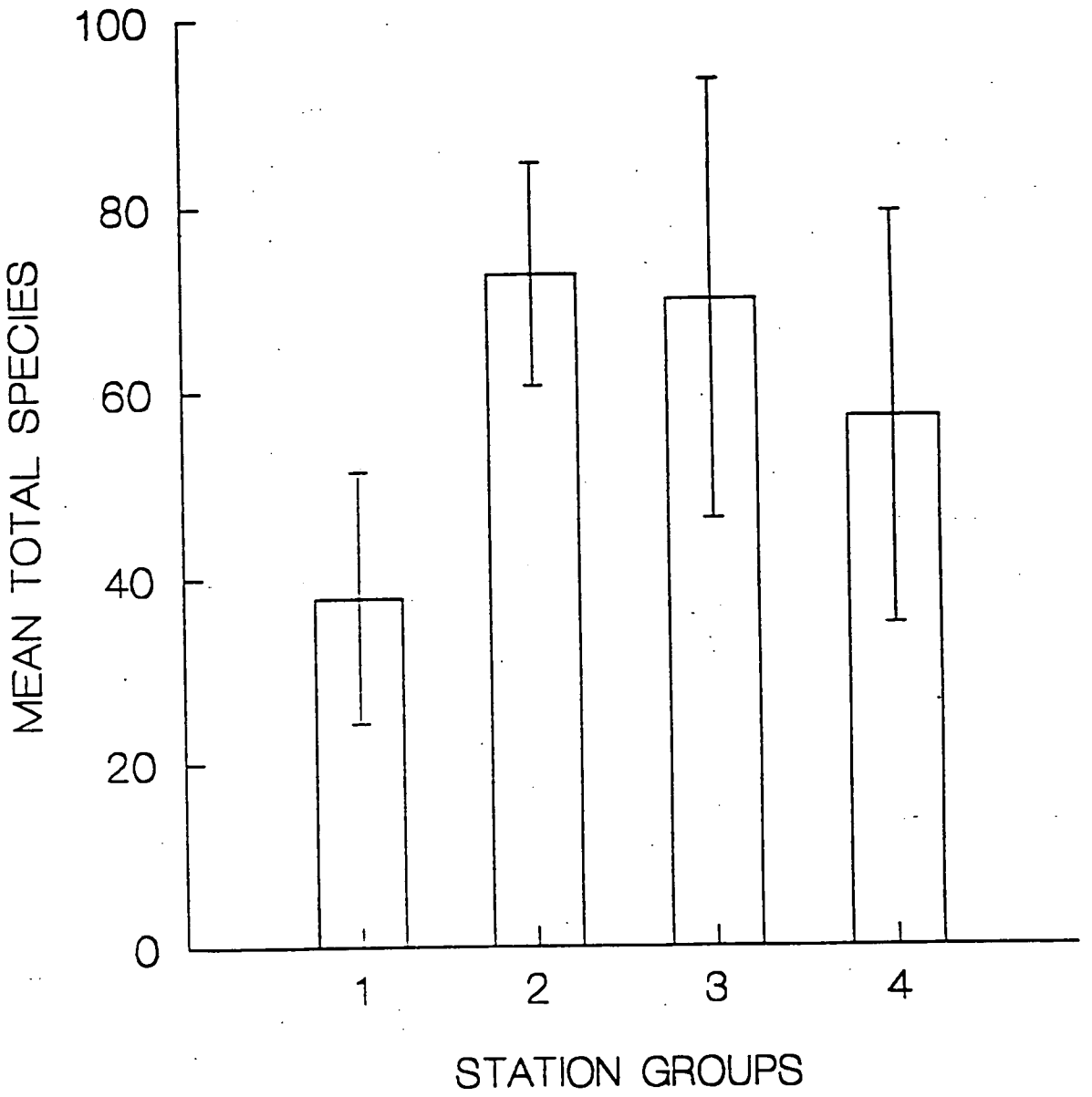

Fig. 4a. Mean total species from NAI data by geographic location. Group 1: Clark Cove. Group 2: Main channel. Group 3: Back channel. Group 4: Down and up river, Spruce Creek, and Cross River.

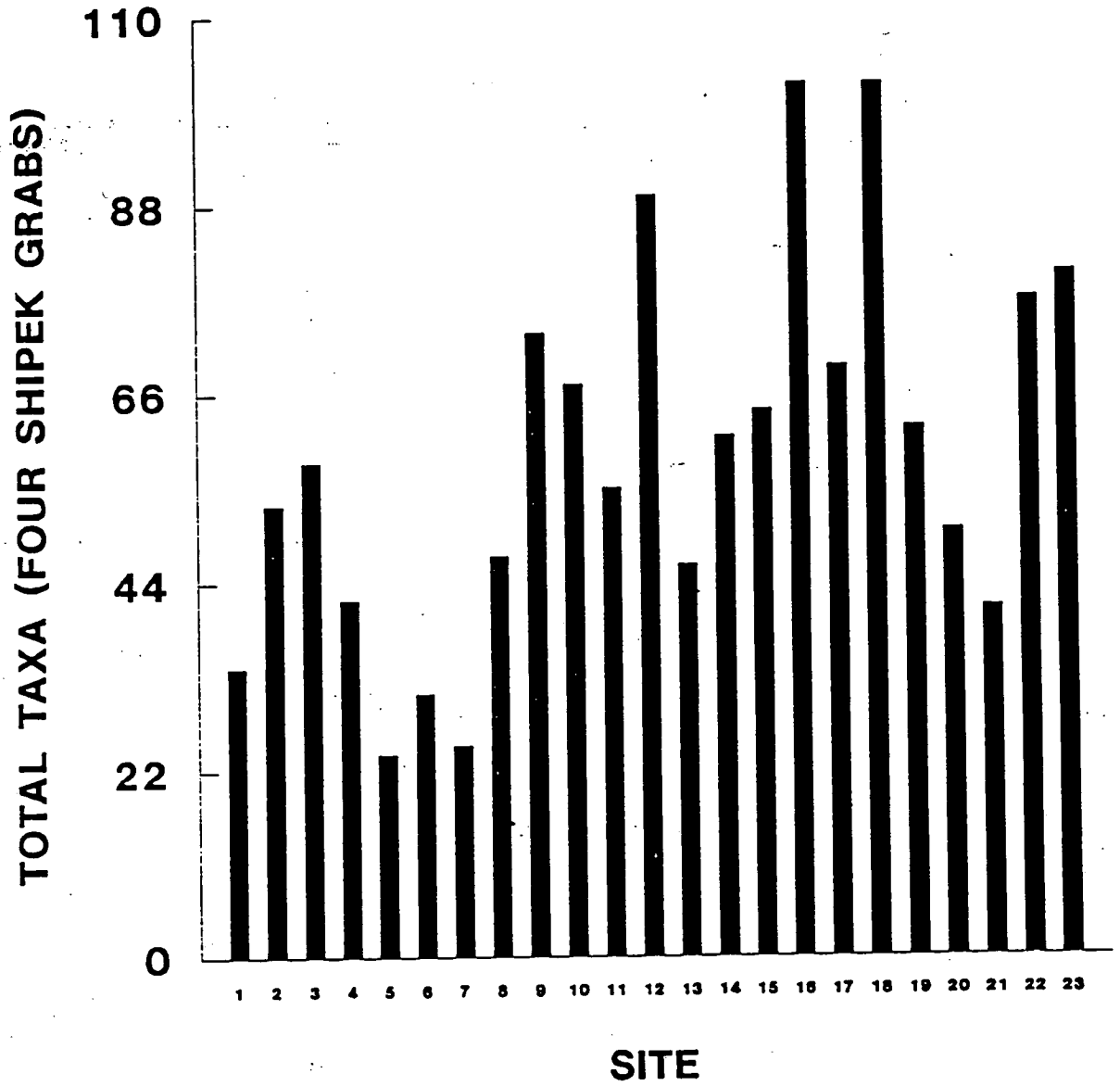

Fig. 4b. Total taxa collected in four Shipek grabs at each site.

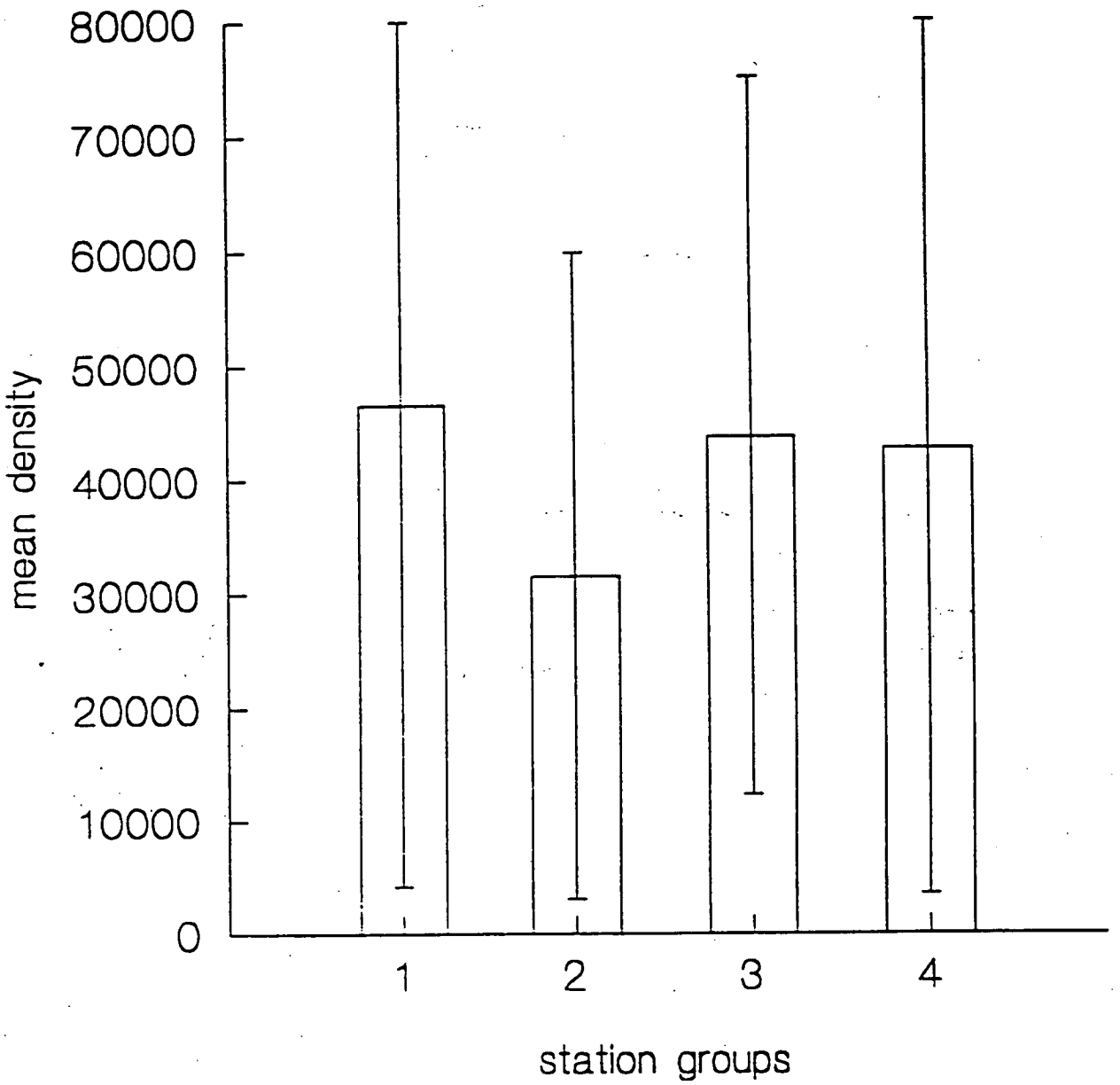

Fig. 5. Mean densities from NAI data by geographic location (see Fig. 3 for group definitions).

Table 3. Total species in the benthic communities and selected environmental factors by geographic groupings. Total spp. (total taxa collected in 4 Shipek grabs). Grain size (means sediment grain size in Phi units). Eelgrass (wet weight, g m^{-2}). Sediment toxicity (relative toxicity of sediment to *Ampelisca* sp. [amphipod] expressed as: 100 - percent survival relative to control [see Fig. 1, p. 3.2-4 in Johnston et al. 1993; range of values 0 to 100, with 0=no toxicity). Water toxicity (as sediment toxicity except *Arbacia* sp. [sea urchin] fertilization success). Total PAHs (summation of all PAH means from Table 3.9, p. 3-55 Johnston 1993). Total PCBs (summation of all PCB means from Table 3.10, p. 3-58 Johnston 1993). Total DDT (total of means for DDT, DDD, DDE in Table 3.11, p. 3-61 Johnston 1993). Total metals (summation of all metals means expressed as Effects Range-Low values in Table 3.8(C), p. 3-48 Johnston 1993).

Geographic Grouping		Total* Spp.	Grain* size	Eel-grass	Sed. tox.	Water tox.	Total PAHs	Total* PCBs	Total DDT	Total* metals
Clark Cove	Mean:	37.8[a]	7.4[a]	50.0	1.0	7.3	3986	66.3[a]	23.9	9.6[a]
(n=6)	SE:	5.5	0.4	50.0	0.8	4.2	503	15.9	3.8	1.6
Main Channel	Mean:	72.5[b]	4.6[b]	202.5	29.0	1.3	7387	56.5[a]	47.6	7.3[a]
(n=4)	SE:	6.0	0.8	162.1	22.0	1.3	2120	10.1	22.6	2.1
Back Channel	Mean:	69.8[b]	4.8[ab]	192.5	40.5	0	7804	45.5[a]	17.0	7.2[a]
(n=4)	SE:	11.8	1.2	78.4	20.2	0	2106	4.6	9.3	0.6
Other	Mean:	61.8[b]	4.1[b]	192.2	12.0	1.4	2904	24.0[b]	10.5	4.4[b]
(n=9)	SE:	7.1	0.5	50.5	5.8	1.0	1065	7.3	2.2	0.8

*ANOVA, $p<0.05$. Tukey's groupings shown by superscripts; means with same letter were not significantly different.

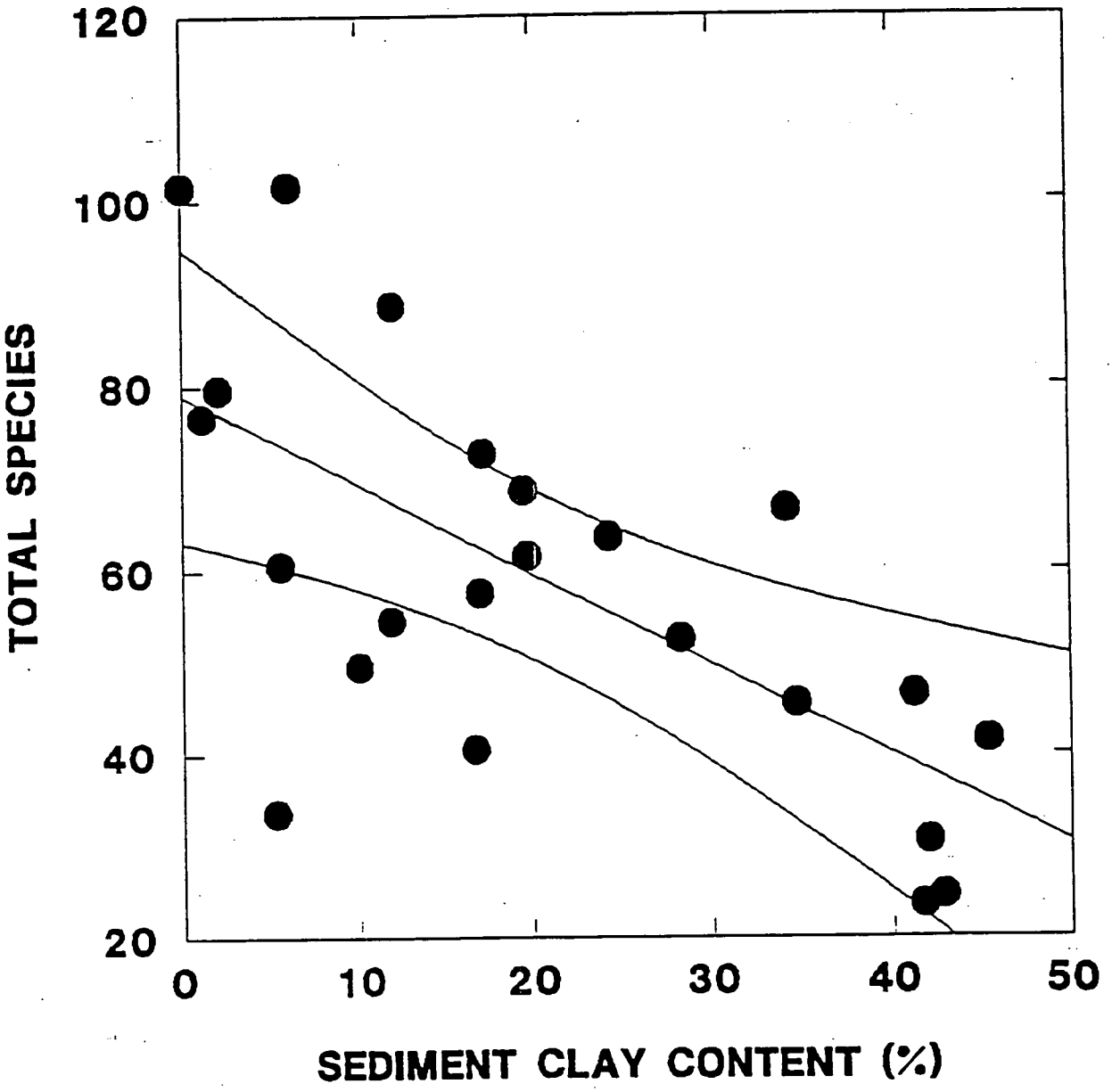

Fig. 6. Sediment clay content (% dry wt.) vs. total species collected in four Shipek grabs at each site. r=-0.668, P=0.027.

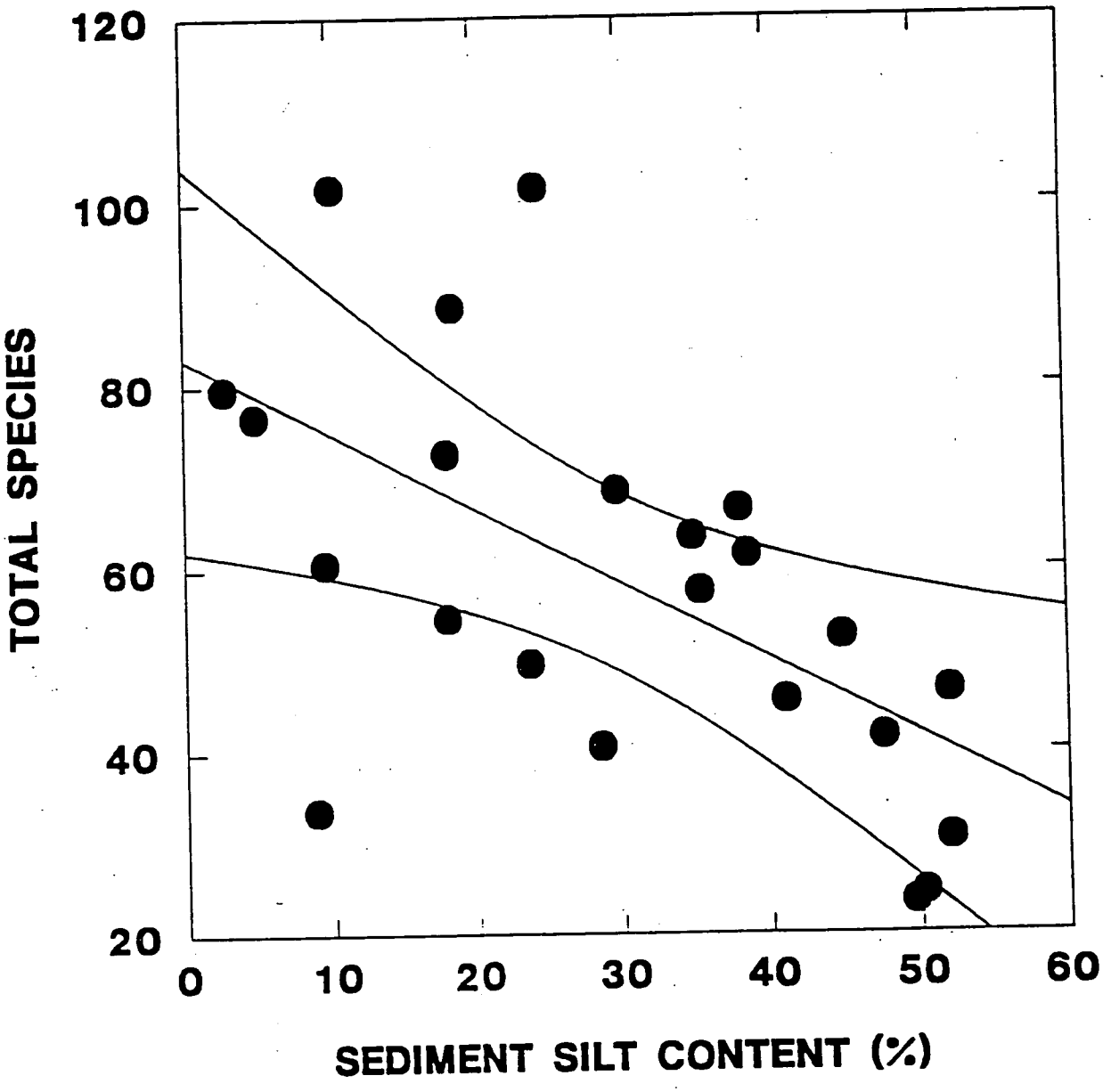

Fig. 7. Sediment silt content (% dry wt.) vs. total species collected in four Shipek grabs at each site. r=-0.602, P=0.132.

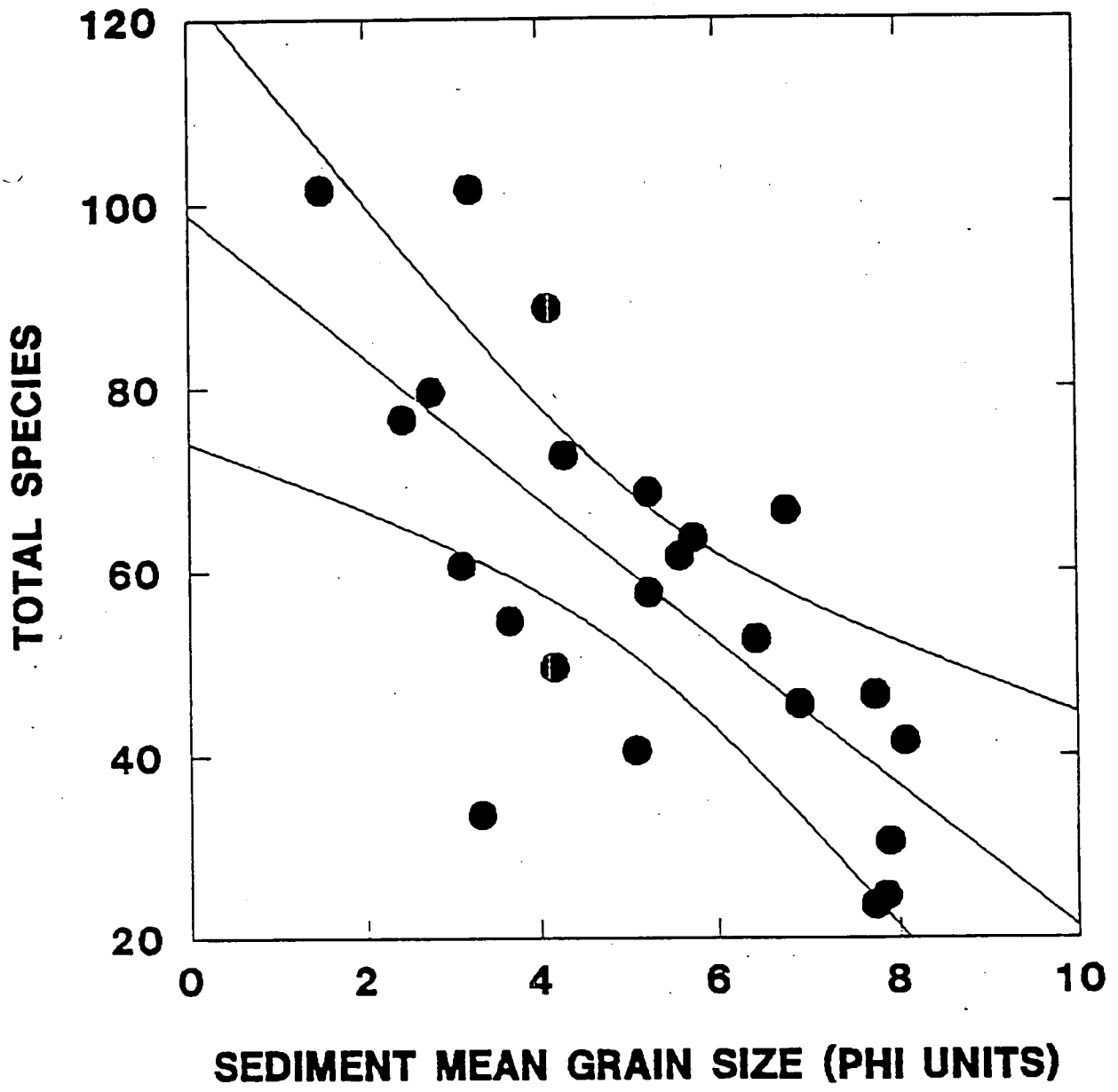

Fig. 8. Sediment mean grain size (phi units) vs. total species collected in four Shipek grabs at each site. r=-0.704, P=0.010.

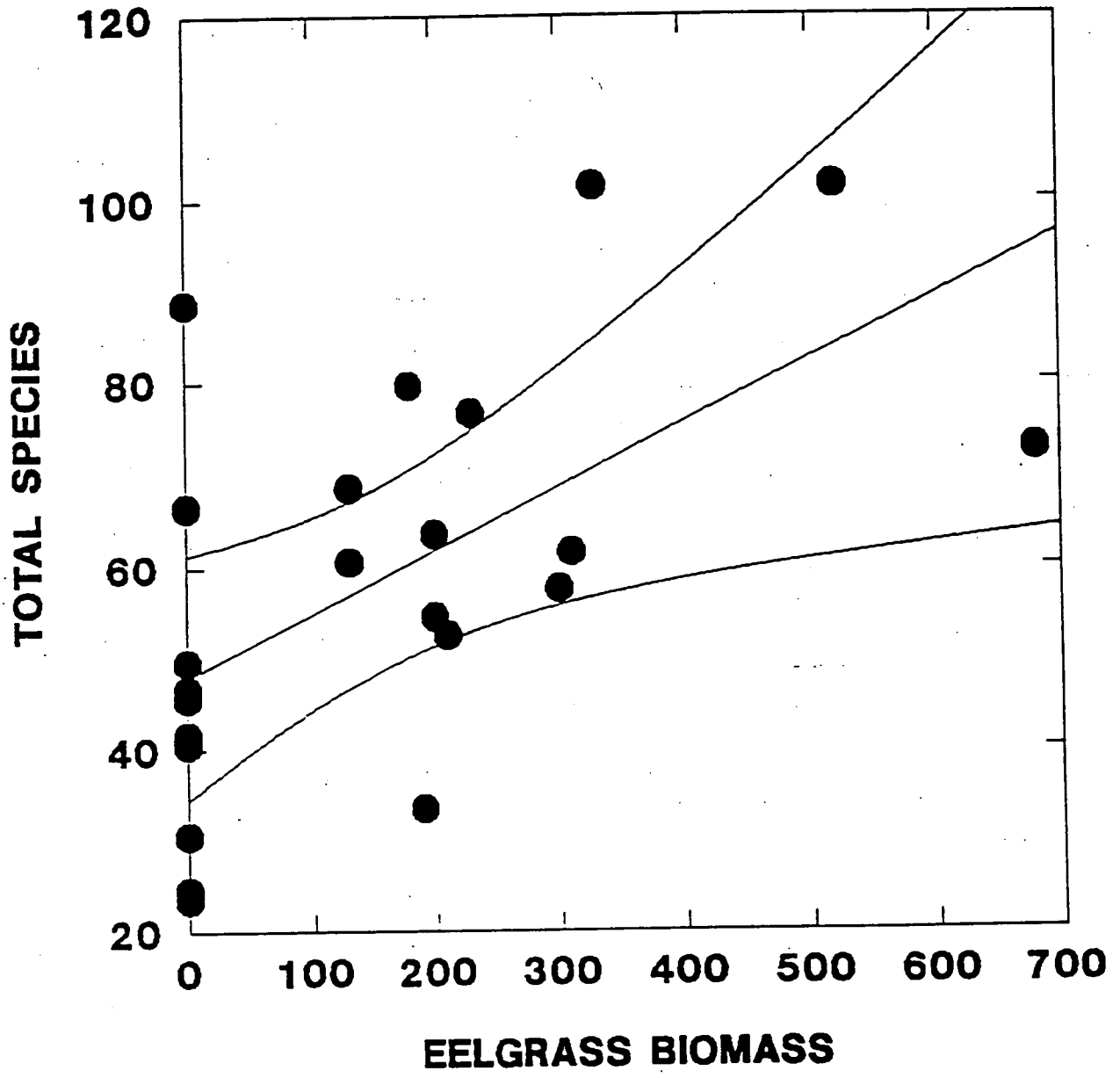

Fig. 9. Eelgrass biomass (g/m^2) vs. total species collected in four Shipek grabs at each site. r=0.577, P=0.216.

Multiple regression was used to develop best-fit linear models using several environmental factors that the correlation analysis (and the above [Table 3] analysis based on geographic grouping) indicated might contribute to variations in total benthic species at each site (Table 4). Of the sediment texture parameters, only sediment mean grain size (expressed in phi units) was used in the model because many sediment characteristics showed high collinearity. (Normal probability plots of residuals vs. expected values from the model showed approximately normal error terms; and a plot of studentized residuals [observed residuals approximately distributed following the t-statistic] vs. estimated residuals showed approximately equal variances. So, no data transformations were necessary.) The first model included only s diment grain size and eelgrass biomass; it had R=0.744 (R^2=0.553). Hence, a model with no pollutant factors explained 55% of the variation in total species in the benthic communities. As pollutant factors were added, the R values increased. The model explaining the most variation in total species included sediment grain size, eelgrass biomass, water toxicity, total sediment metals, and total sediment PCBs. This model had R=0.854 (R^2=0.729), with P=0.000. Thus, by adding three contaminant factors an additional 17.6% of the variation in total species in the benthic communities was achieved.

Pollution indicator species. The term "pollution indicator species" has typically been used to designate taxa that tolerate polluted conditions, often showing numerical dominance in the benthic community (e.g. Grizzle 1984). The concept has developed primarily based on data from areas affected by organic enrichment (e.g. sewage wastes), and lists of "pollution indicator species" generally have been restricted to dominant species in eutrophic areas (Pearson and Rosenberg 1978). However, taxa that are sensitive to contaminants and eliminated from an area because of polluted conditions are sometimes included in the term. Because the intent of the present study was to assess the impact of contaminants with potentially toxic effects, as contrasted with the "enriching" effect of contaminants like sewage wastes, most of the literature on indicator species is not relevant. An exception to this generalization is the literature on contaminant-sensitive taxa.

Amphipods are particularly sensitive to many kinds of chemical contaminants, so they are usually among the first species to be eliminated from benthic communities polluted by complex wastes including toxins (Hart and Fuller 1979; Chang et al. 1992). The total number of amphipod species and the total amphipod density at each of the 23 study sites were compared with all environmental factors using correlation analysis and scatterplots. Overall, the results of analyses using amphipods were very similar to those carried out using total community data as dependent variables (e.g. compare Figs. 9 and 10). But the resulting correlation values were lower for the amphipod data compared to community-level data, and the results are not presented in the present report. Nonetheless, Figure 11 indicates one interesting finding of the amphipod analysis. In this figure, relative sediment toxicity using the data from Mueller and Anderson (1993; see their Fig. 1, p. 3.2-4) were compared to total amphipod densities by site. Stations with very low amphipods densities covered the entire range of sediment toxicities. However, only the sites with low toxicity had high amphipod densities, and no sites with high toxicity levels had high amphipod densities. Definitive conclusions cannot be drawn from this analysis, but it does suggest some potential for use of amphipods (and perhaps other taxa) in combination with toxicity tests for further studies.

III. Summary, Conclusions, and Recommendations.

The conceptual model of potential contaminant release areas on Seavey Island indicated that benthic communities in Clark Cove, along the back channel, and along the main channel would be the most likely to have been affected by contaminants discharged from the Island. Sites in other areas that were sampled could also show effects of contaminants, but if so, sources other than Seavey Island might be implicated. Cluster analysis based on the top 15 numerical dominants at each site strongly separated two subgroups

Table 4. Linear multiple regression models relating total species in the benthic community to environmental factors.

Model	R	R^2
Total Species = sediment phi size + eelgrass biomass	0.744	0.553
Total Species = sediment phi size + eelgrass biomass + sediment metals	0.828	0.685
Total Species = sediment phi size + eelgrass biomass + sediment metals + water toxicity	0.833	0.693
Total Species = sediment phi size + eelgrass biomass + sediment metals + water toxicity + total PCBs	0.854	0.729

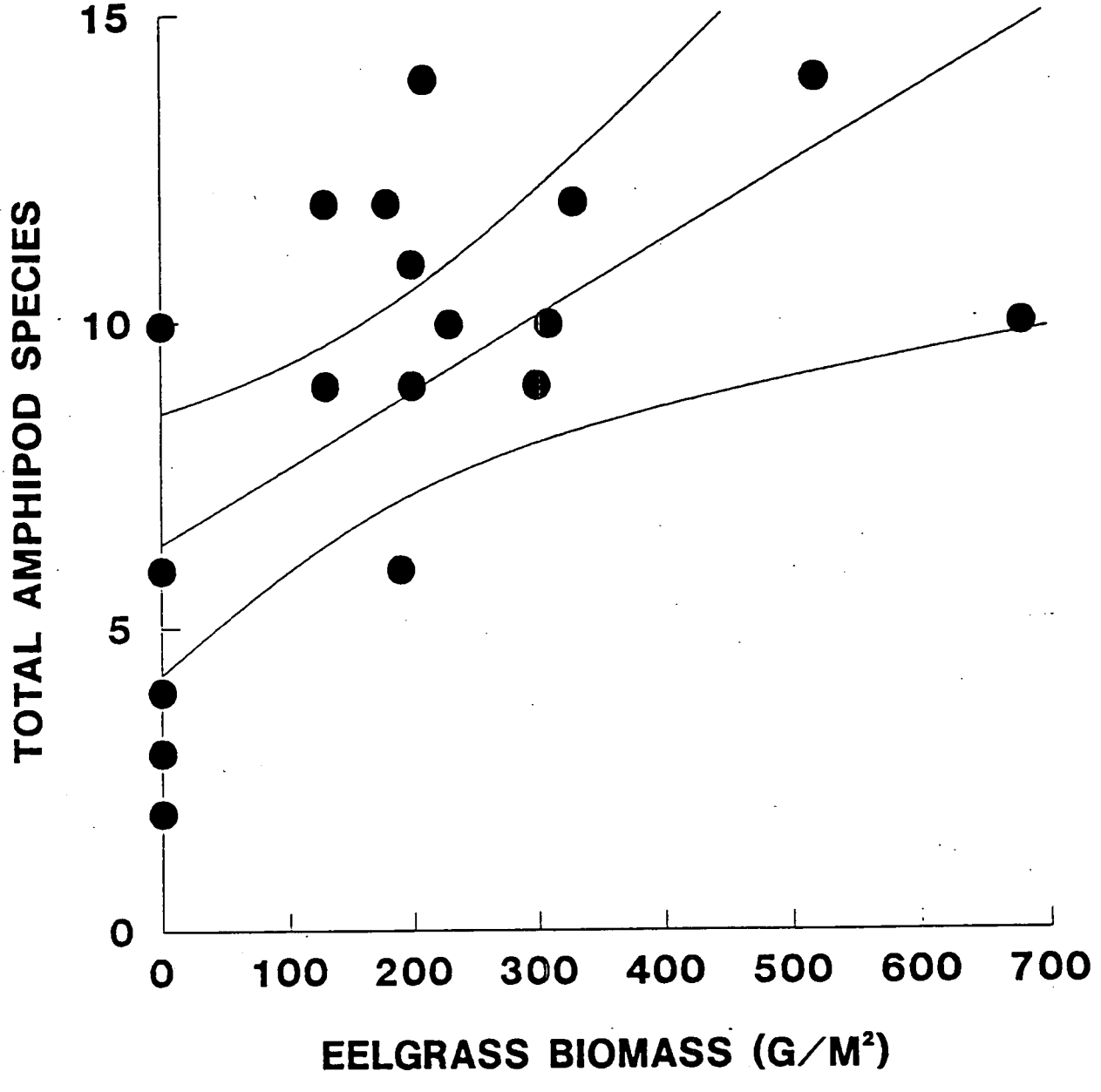

Fig. 10. Eelgrass biomass vs. total amphipod taxa by site. r=0.618, P=0.002.

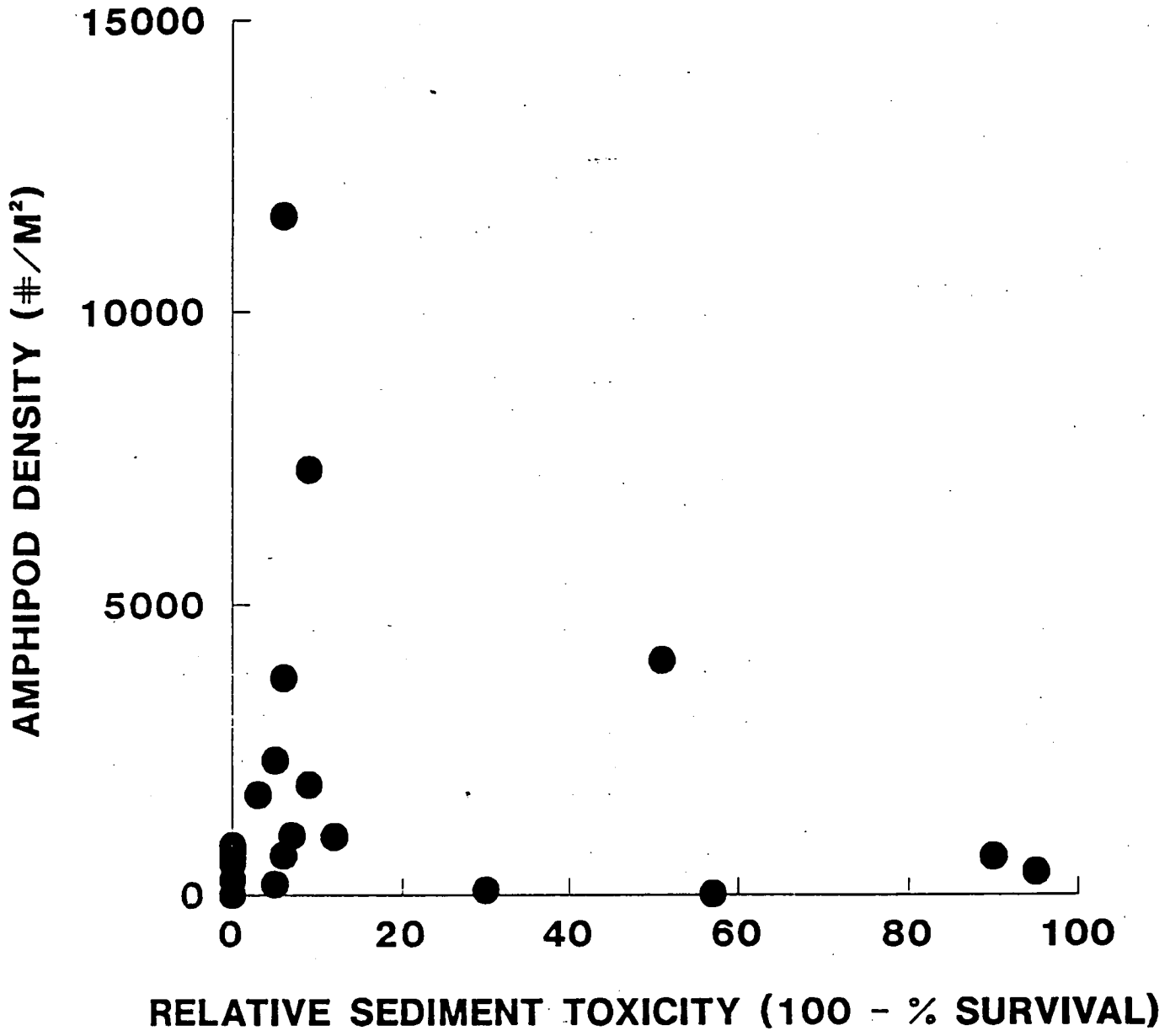

Fig. 11. Relative sediment toxicity as determined using Ampelisca abdita (amphipods) (data from Mueller and Anderson 1993 - note that data here are % survival subtracted from 100 so that the higher the number the greater the toxicity) vs. density of all amphipod taxa collected, by site.

(which included five of the six sites in the Cove) of sites in Clark Cove from the other sites. After geographically grouping the 23 sites into four groups, ANOVA showed that the Clark Cove sites differed significantly from one or more of the other groups in total benthic species collected, mean sediment grain size, total sediment PCBs, and total sediment metals (expressed in Effects Range-Low values). Multiple linear regression models developed using all 23 sites (not grouped geographically) showed that 55.3% of the variation in total species in the benthic communities were explained by variations in mean sediment grain size and eelgrass biomass. The addition of several contaminant parameters increased the R^2 to 0.729, an additional 17.6% of the variation.

In sum, all analyses indicate that the benthic communities in Clark Cove wer different from those in other areas. There was no clear indication that benthic communities at sites in the back channel or along the main channel near Seavey Island have been affected by contaminant releases from the Island. Reduction in total species at most of the Clark Cove sites particularly suggests environmental degradation in this area. However, variations in water and sediment contaminant measures only explained part of the reduction. Most was explained by variations in sediment grain size and eelgrass biomass.

Additional studies could be carried out to further characterize the extent of contaminant impact on the benthos in the Seavey Island area. The analyses using amphipod data suggested that additional information could be obtained in future studies by using species-level analysis based on the pollution indicator concept. There are also approaches other than the "traditional" approach used in the present study that could reduce costs for benthic sampling and processing. For example, recent studies have indicated that taxonomic discrimination to levels as high as phylum can be useful in detecting pollution impacts (Warwick 1988). Sediment profile imaging might also be useful in providing a low-cost approach to benthic monitoring (Grizzle and Penniman 1991).

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TAYLOR UNIVERSITY

27 February 1995

Dr. Robert K. Johnston
US Environmental Protection Agency
Environmental Research Laboratory Narragansett
27 Tarzwell Drive
Narragansett, RI 02882-1154

Dear Bob,

Enclosed are several items we spoke about by phone last week: a copy of all appendices ("A" - "D") that were attached to my Final Report for the Portsmouth Naval Shipyard project; electronic copies (in ASCII and SYSTAT formats) of Appendices C and D; and an addendum to my Final Report.

Please note -- as I think I indicated on the phone to you -- the original data set that is enclosed in hardcopy as "Appendix B" has been lost in electronic form. So, further analyses will be difficult if the entire NAI data set is needed; unless, of course, you can make use of the data in the form that NAI originally provided it (good luck!).

Instead of trying to go through and revise my Final Report, I thought an addendum to it would be most effective. As you will see, the addendum report relies heavily on figures and tables in my Final Report. So, I would like for the two to be considered together as my assessment of the NAI benthic data.

Hope all this is useful. If you have any comments or questions, please give me a call.

Take care.

Sincerely yours,

Ray

Ray Grizzle

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Upland, Indiana 46989-1001
317-998-2751

ADDENDUM TO FINAL REPORT - Infaunal Invertebrate Assessment
(UNH subc ntract No. 93-17)

Ecological Risk Assessment for Naval Shipyard, Portsmouth, NH

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February 1995

This is an addendum to my Final Report (dated May 1994, and cited as Grizzle 1994 herein) on the infaunal (benthic) invertebrate assessment portion of the overall risk assessment. It consists f a r vised and expanded assessment of my previous analysis of invertebrate data provided by Normandeau Associates, Inc. (NAI) and physicochemical data collected as part of the Phase I efforts. It is arranged into sections corresponding to major comments or questions concerning Grizzle (1994). Th Summary and Conclusions section below is a revised statement of my overall assessment, including the analyses in Grizzle (1994) and the present report.

Comparison of NAI data with previous Piscataqua River studies

Shipman (1993, p. 3.12-1) stated that the benthic infauna in "...the Piscataqua River/Great Bay system have been fairly well characterized..." (see Short 1992 for summary of benthic studies to that time). Shipman's statement is accurate in several ways. Most of the infaunal species that occur in the system probably have been identified. The relative abundances of the major species in many areas hav been measured, at least once. And there is knowledge of the overall changes spatially in species composition that occur along the estuarine system from low-salinity tributaries upstream to the mouth f the Piscataqua River. There is also a general knowledge of the patterns of seasonal changes in abundance that occur. Hence, it is possible to offer additional assessments herein of the NAI data relative to other Piscataqua River system studies that were not included in Grizzle (1994). I do not, however, think it would be advisable to incorporate any of the data from other studies directly into the NAI data set in order to quantitatively analyze them because of differences in sampling equipment, sampling times, and sample processing techniques (also see relevant discussion in Grizzle 1994, pp. 3-6). This section is a brief comparison of the NAI data to other studies.

A 2-year study by NH Fish and Game Department in the early 1980s resulted in a total of ab ut 120 species of macroinvertebrates collected from both intertidal and subtidal sites throughout the stuary (Nelson 1981, 1982). Benthic samples taken during 1993 and 1994 from subtidal sites upstream from the Seavey Island area in the Piscataqua River resulted in about 150 different taxa (Grizzle, unpublished data). The NAI data set used in the present study consists of a total of about 190 differ nt species (Grizzle 1994, Appendix B). A greater number of species should be expected from th NAI data set because it included more stations that were nearer the Atlantic and hence more ceanic with respect to ambient salinity. There is a strong gradient of increasing total species present in the faunal benthos extending from tributaries to Great Sound through the Sound, the Piscataqua Riv r to the mouth of Portsmouth Harbor (Grizzle, unpublished data). Hence, from the perspectiv of total species encountered when considering the entire NAI data set, nothing unusual is indicated. Nonetheless, the six sites in Clark Cove had reduced species numbers compared to three other ge graphic groupings of the 23 study sites, and three (sites 5, 6, and 7) of the Clark Cove sites had th low st total species collected compared to the other twenty study sites (Grizzle 1994, Figs. 4a, 4b; se more discussion below).

Several studies (Nelson 1981, 1982; NAI 1980; Grizzle unpublished data) taken together showed the following species as numerical dominants at subtidal sites in the Piscataqua River system:

ligochaetes, *Aricidea catherinae* (polychaet), *Streblospio benedicti* (polycha t), *H teromastus filiformis* (polychaete), and *Ampelisca* spp. (amphipods). Thes fiv taxa ft n represented more than 50% of the total community d nsity, and s metimes ov r 70%. Thes five taxa in th NAI data set from the present study (when considering all 23 sites, or the thirteen Seavey Island sites alone) were also numerically important, representing >50% of the total community density at most sites, and exc eding 90% in some (Shipman 1993, Table 2). Hence, the species composition of the NAI data set as a whole also does not indicate anything unusual. However, a cluster analysis of the NAI data set did show several sites as consisting of widely divergent species composition (Grizzle 1994, Fig. 3); thes sites included three sites in Clark Cove (4, 6, and 8), one site in the back channel area (site 19), and site 2 which was in a small cove downstream from Seavey Island. In other words, four of the thirteen sites in the immediate vicinity of Seavey Island differed substantially in species composition from the other study sites (see more on Clark Cove sites below).

In sum, I think this comparison (from the perspective of total species encountered and species composition of the benthic community) of the NAI data from the present study to other studies in th general area, strongly indicates that several sites in the vicinity of Seavey Island (i.e. sites 4, 6, 8, and 19) differ in benthic community structure. Previously, I used multiple regression modeling in an attempt to identify the environmental factors that might be responsible for variations in species numbers (Grizzle 1994). This analysis showed that 55.3% of the variation in species numbers was accounted for statistically by differences in bottom sediment texture and eelgrass biomass. An additional 17.6% of the variance was accounted for by three different contaminant measures. Hence, contaminants were correlated with species reductions in the data set as a whole (and Clark Cove sites had the low st average species numbers; see more discussion below).

Comparison of Grizzle (1994) with Johnston's (1993) "Benthic Community Anomaly" approach

Figures 3.9 (community density) and 3.10 (density/total taxa) in Johnston (1993) indicat four sites as falling outside the 5th or 95th percentile boundaries compared to the other nineteen sit s. These sites (2, 4, 8, and 13) were together considered to represent a "benthic community anomaly." Sites 4 and 8 were in Clark Cove. Site 2 was in a small cove downstream of Seavey Island. Sit 13 was on the west end of Seavey Island. Sites 2, 4, and 8 were also identified as strongly differing in species composition from the other study sites by Grizzle (1994; also see discussion above). H nce, thr e of four of these "anomalous" sites were also identified by other means as differing in benthic community structure, and two of the sites (4 and 8) were in Clark Cove, which overall had the lowest mean species number when the 23 sites were geographically grouped. Site 13 was not identified as differing in benthic community structure by other analyses. I think Johnston's benthic community anomaly approach essentially corroborates other analyses, and adds site 13 to the list of Seavey Island sites that differ from other study sites.

Further comments on Seavey Island and Clark Cove

Thirteen sites were sampled around Seavey Island and six were in Clark Cove. When considering all data analysis approaches discussed above, five Seavey Island sites (4, 6, 8, 13, and 19) were identified as differing in some way in benthic community structure compared to the other eight n study sites. Three (sites 4, 6, and 8) of these five sites were in Clark Cove. Benthic communities in Clark Cove substantially differed from other study areas, and there is good evidence that contaminants are involved. Nonetheless, other environmental factors are also involved. Hence, further discussion of the Clark Cove area is warranted.

Clark Cove was characterized as a "closed embayment" with "very little transport" hydrodynamically by Swift and Celikkol (1993, p. 3.6-3). Ward (1993, p. 3.1-2) noted that sedim nts in Clark Cove differed from other areas, and he characterized them as "extremely poorly sorted mud." Mean grain size of the six Clark Cove sites was significantly lower than mean grain size in the other thre geographic groupings of the study sites (Grizzle 1994, Table 3), and Cove sediments consist d largely of clay-sized particles (Grizzle 1993, Appendix D). Tidal currents and sediment texture are major environmental factors known to affect benthic community structure. Hence, it could be expected

fr m this information alon that benthic communities in Clark Cove w uld differ from oth r areas. For the present study which was primarily aimed at assessing contaminant ffects, these two factors represent confounding factors. I pr viously used multiple regression to estimate the effects of a variety f environmental factors n ne important benthic community structur measurement: speci s number coll cted at each site (Grizzle 1994). As discussed above, the regression analysis showed 55.3% of th variation in species numbers could be accounted for by average grain size of the bottom sedim nts and eelgrass biomass; both factors were positively correlated to species number. Three contaminant measures accounted for an additional 17.6% variation (i.e. reduction; contaminant measures were negatively correlated to species number) in total species number at each site. And two of the three contaminant measures had their highest concentrations in Clark Cove (Grizzle 1994, Table 3). I think these data strongly point to Clark Cove as an area that has been affected by contaminants.

Summary and conclusions

Statistical analyses in Grizzle (1994) and additional assessments herein point to four major conclusions with respect to benthic infaunal communities.

(1) Community structure at most of the 23 NAI study sites was similar in both species composition and total community densities to other areas in the Piscataqua River system that are not known to have been affected by contaminants when they were sampled.

(2) Five (sites 4, 6, 8, 13, and 19) of the thirteen Seavey Island study sites were identified as differing in some way in community structure from the other eighteen study sites.

(3) Clark Cove benthos showed the lowest average species number per site when compared as a geographic group to the three other geographic groupings of the 23 study sites. Clark Cove differed environmentally from other areas in sediment texture and elevated levels of two contaminants.

(4) Multiple regression analysis of data from all 23 NAI study sites with species number as the dependent variable indicates that sediment texture and eelgrass biomass accounted for 55.3% of the variation in species numbers, and three contaminant measures accounted for 17.6% of the observed reductions in species numbers.

As a whole, I think this analysis shows that although there have been no apparent catastrophic changes in the benthos in the Seavey Island area, there is evidence of impact by contaminants.

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APPENDICES

Appendix A - Taxonomic codes for taxa names in appendices B and C.

Appendix B - Mean densisites (individuals m^{-2}) and one standard deviation (SD) for all taxa collected; n=4 for all means.
NOT INCLUDED

Appendix C - Numerically dominant 15 taxa at each site showing the percent of the overall community density each taxon represented. (Filename: EPABEN)

Appendix D - Total species collected (TOTSPP) and mean community density (TOTDENS; individuals m^{-2}) with environmental factors by site. SEDCOMB=percent combustibles. SEDPHI=mean grain size in phi units. SEDGRAV=percent gravel. SEDSAND=percent sand. SEDSILT=percent silt. SEDCLAY=percent clay. SEDTOX=sediment toxicity using amphipods (100 - percent of control fertilization). WATTOX=water toxicity using sea urchin eggs/sperm (100 - percent of control survivorship). SEDMPN=MPN per g sediment for *C. perfringens*. EELGRASS=eelgrass wet weight (g m^{-2}). SUMPAH=sum of sediment PAHs (ng g^{-1}). TOTPCB=total sediment PCBs (ng g^{-1}). SUMDDT=sum of sediment DDT (ng g^{-1}). METALERL=total sediment metals expressed in Effects Range-Low values. DDTERL=sum of sediment DDT expressed in Effects Range-Low values. EPADENEN

APPENDIX A

Taxonomic Codes for New Hampshire Benthic Data April 1993

ACHELIA SPINOSA	6001040202	ACHSPI
ACMAEA TESTUDINALIS	5102050108	ACMTES
AGLAOPHAMUS CIRCINATA	5001250304	AGLCIR
AGLAOPHAMUS NEOTENUS	5001250305	AGLNEO
ALDERIA MODESTA	5123069898	ALDMOD
ALVANIA CASTANEA	5103200108	ALVCAS
ALVANIA SP.	5103200199	ALVSPP
AMPELISCA ABDITA	6169020108	AMPABD
AMPELISCA SP.	6169020199	AMPSPP
AMPHARETE ARCTICA	5001670201	AMPARC
AMPHARETE SP.	5001670299	AMPSP2
AMPHIPHOLIS SQUAMATA	8129030202	AMPSQU
ANAITIDES MACULATA	5001130106	ANAMAC
ANAITIDES MUCOSA	5001130104	ANAMUC
ANAITIDES SP.	5001130199	ANASPP
ANOMIA SP.	5509090299	ANOSPP
APLIDIUM SP.	8403020199	APLSPP
ARICIDEA (ACMIRA) CATHERINAE	5001410208	ARICAT
ARICIDEA (ACMIRA) SP.	5001410299	ARISPP
ASABELLIDES OCULATA	5001670802	ASAOCU
ASTARTE SP.	5515190199	ASTSPP
BALANUS CRENATUS	6134020104	BALCRE
BARENTSIA SP.	7902010299	BARSPP
BIVALVIA	55	BIVALV
BOTRYLLUS SCHLOSSERI	8406010701	BOTSCH
BOWERBANKIA GRACILIS	7805010201	BOWGRA
BRADA SP.	5001540199	BRASPP
CALLOPORA AURITA	7815080101	CALAUR
CALLOPORA COMPLEX	7815080198	CALCOM
CALYCELLA SYRINGA	3704019898	CALSYR
CANCER IRRORATUS	6188030108	CANIRR
CANCER SP.	6188030199	CANSPP
CAPITELLA CAPITATA	5001600101	CAPCAP
CAPRELLA PENANTIS	6171010727	CAPPEN
CAPRELLIDAE	617101	CAPREL
CARCINUS MAENAS	6189010701	CARMAE
CERASTODERMA PINNULATUM	5515220601	CERPIN
CERIANTHUS SP.	3743010199	CERSPP
CHIRIDOTEA TUFTSI	6162020503	CHITUF
CIRRATULIDAE	5001500000	CIRRAT
CIRRATULUS GRANDIS	5001500104	CIRGRA
CIRRIPEDIA	6130	CIRRIP
CISTENIDES GRANULATA	5001660202	CISGRA
CLYMENELLA TORQUATA	5001630202	CLYTOR
COROPHIUM ACHERUSICUM	6169150201	CORACH
COROPHIUM BONELLI	6169150202	CORBON
COROPHIUM INSIDIOSUM	6169150211	CORINS
COROPHIUM SP.	6169150299	CORSPP
COSSURA SOYERI	5001520196	COSSOY
CRANGON SEPTEMSPINOSA	6179220103	CRASEP
CRENELLA GLANDULA	5507010203	CREGLA
CRENELLA SP.	5507010299	CRENEL
CREPIDULA SP.	5103640299	CRESPP
CRIBRILINA PUNCTATA	7815300102	CRIPUN
CUMACEA	6154	CUMACE
DENDROBEANIA MURRAYANA	7815250201	DENMUR

Taxon mic Codes for N w Hampshire Benthic Data April 1993

A	DEXAMINE THEA	6169170401 DEXTHE
	DISPORELLA HISPIDA	7813010298 DISHIS
	DODECACERIA SP.	5001500599 DODSPP
	DYNAMENA PUMILA	3704050697 DYNPUM
	EDOTEA TRILOBA	6162020798 EDOTRI
	EDWARDSIA ELEGANS	3759010101 EDWELE
	EDWARDSIA SP.	3759010199 EDWSPP
	ELECTRA PILOSA	7815050103 ELEPIL
	ENSIS DIRECTUS	5515290301 ENSDIR
	ETEONE LONGA	5001130205 ETELON
	ETEONE SP.	5001130299 ETESPP
	EUCLYMENE ZONALIS	5001631103 EUCZON
	EUCRATEA LORICATA	7815020101 EUCLOR
	EUDENDRIUM DISPAR	3703080198 EUDDIS
	EUDENDRIUM RUGOSUM	3703080197 EUDRUG
	EUDENDRIUM SP.	3703080199 EUDSPP
	EULALIA VIRIDIS	5001130301 EULVIR
	EXOGONE HEBES	5001230707 EXOHEB
	FABRICIA SABELLA	5001701301 FABSAB
	FLABELLIGERIDAE	5001540000 FLABEL
A	GAMMARUS OCEANICUS	6169210711 GAMOCE
	GAMMARUS SP.	6169210799 GAMSPP
	GASTROPODA	51 GASTRO
	GEMMA GEMMA	5515471301 GEMGEM
	GLYCERA DIBRANCHIATA	5001270105 GLYDIB
	HALECIUM DIMINUTIVUM	3704060198 HALDIM
	HALICHONDRIA PANICEA	3665020202 HALPAN
	HALICLONA OCULATA	3663020298 HALOCU
	HARMOTHOE EXTENUATA	5001020803 HAREXT
	HARMOTHOE IMBRICATA	5001020806 HARIMB
	HARMOTHOE SP.	5001020899 HARSPP
	HETEROMASTUS FILIFORMIS	5001600201 HETFIL
	HETEROTANAIS LIMICOLA	6157029898 HETLIM
	HIATELLA SP.	5517060299 HIASPP
	HIPPOTHOA HYALINA	7816020101 HIPHYA
	HOLOTHUROIDEA	8170 HOLOTH
I	IDOTEA BALTHICA	6162020308 IDOBAL
	IDOTEA PHOSPHOREA	6162020309 IDOPHO
A	ISCHYROCERUS ANGUIPES	6169270202 ISCANG
	ISODICTYA DEICHMANNE	3663989898 ISODEI
I	JAERA MARINA	6163060298 JAEMAR
A	JASSA MARMORATA	6169270302 JASMAR
	LACUNA VINCTA	5103090305 LACVIN
	LEITOSCOLOPLOS ROBUSTUS	5001409898 LEIROB
	LEITOSCOLOPLOS SP.	5001400399 LEISPP
	LEPIDONOTUS SQUAMATUS	5001021103 LEPSQU
A	LEPTOCHEIRUS PINGUIS	6169060702 LEPPIN
	LEPTOCHEIRUS SP.	6169060799 LEPSPP
	LEPTOGNATHA CAECA	6157020201 LEPCAE
	LEUCON AMERICANUS	6154040110 LEUAME
	LITTORINA LITTOREA	5103100108 LITLIT
	LUNATIA HEROS	5103760410 LUNHER
	LUNATIA SP.	5103760499 LUNSPP
	LYONSIA HYALINA	5520050206 LYOHYA
	LYONSIA SP.	5520050299 LYOSPP
	MACOMA SP.	5515310199 MACSPP

Taxonomic Codes for New Hampshire Benthic Data April 1993

MALDANIDAE	500163	MALDAN
MEDIOMASTUS SP.	5001600499	MEDSPP
MEMBRANIPORA MEMBRANACEA	7815040101	MEMMEM
METRIDIUM SENILE	3760060101	METSEN
METRIDIUM SP.	3760060199	METSPP
MICRODEUTOPUS GRYLLOTALPA	6169060401	MICGRY
MICRODEUTOPUS SP.	6169060499	MICSPP
MICROPHTHALMUS ABERRANS	5001210202	MICABE
MINUSPIO SP.	5001432699	MINSPP
MUNNA SP.	6163120199	MUNSPP
MYA ARENARIA	5517010201	MYAARE
MYTILIDAE	5507010000	MYTILI
MYTILUS EDULIS	5507010101	MYTEDU
NAINERIS QUADRICUSPIDA	5001400202	NAIQUA
NASSARIUS TRIVITTATUS	5105080103	NASTRI
NEANTHES VIRENS	5001240302	NEAVIR
NEPHTYIDAE	5001250000	NEPHTY
NEPHTYS CAECA	5001250103	NEPCAE
NEPHTYS CILIATA	5001250102	NEPCIL
NEPHTYS INCISA	5001250115	NEPINC
NEREIDAE	500124	NEREID
NEREIS PELAGICA	5001240403	NERPEL
NINOE NIGRIPES	5001310204	NINNIG
NUCULA DELPHINODONTA	5502020206	NUCDEL
NUCULA SP.	5502020299	NUCSPP
OBELIA DICHOTOMA	3704010205	OBEDIC
OBELIA GENICULATA	3704010298	OBEGEN
ODOSTOMIA SP.	5108010199	ODOSPP
OLIGOCHAETA	5004000000	OLIGOC
OPHELINA ACUMINATA	5001580698	OPHACU
OPHIUROIDEA	8120	OPHIUR
A-ORCHOMENELLA PINGUIS	6169345203	ORCPIN
ORCHOMENELLA SP.	6169345299	ORCSPP
OWENIA FUSIFORMIS	5001640102	OWEFUS
OWENIIDAE	500164	OWENII
C-OXYUROSTYLIS SMITHI	6154050801	OXYSMI
D-PAGURUS SP.	6183060299	PAGSPP
A-PARACAPRELLA TENUIS	6171010901	PARTEN
PARAONIS FULGENS	5001410302	PARFUL
PARAONIS GRACILIS	5001410301	PARGRA
PEDICELLINA CERNUA	7902010101	PEDCER
PHOLOE MINUTA	5001060101	PHOMIN
PHORONIS SP.	7700010299	PHOSPP
A-PHOTIS MACROCOXA	6169260208	PHOMAC
P-PHOXICHILIDIUM FEMORATUM	6001060102	PHOFEM
PHOXOCEPHALUS HOLBOLLI	6169420702	PHOHOL
POLYCIRRUS SP.	5001680899	POLSPP
POLYDORA CORNUTA	5001430498	POLCOR
POLYDORA QUADRILOBATA	5001430408	POLQUA
POLYDORA SOCIALIS	5001430402	POLSOC
POLYNOIDAE	500102	POLYNO
PRIONOSPIO SP.	5001430599	PRISPP
PRIONOSPIO STEENSTRUPI	5001430506	PRISTE
PROTODORVILLEA SP.	5001360299	PROSPP
PYGOSPIO ELEGANS	5001431302	PYGELE
RHYNCHOCOELA	4300000000	RHYNCH

Taxonomic Codes for New Hampshire Benthic Data April 1993

SCOLELEPIS TEXANA	5001432006	SCOTEX
SCOLETOMA HEBES	5001319898	SCOHEB
SCOLETOMA SP.	5001319899	SCOSPP
SEMIBALANUS BALANOIDES	6134029898	SEMBAL
SERTULARIA CUPRESSINA	3704050316	SERCUP
SIPUNCULA	72	SIPUNC
SOLEMYA SP.	5504010199	SOLSPP
SOLEMYA VELUM	5504010101	SOLVEL
SOLENIDAE	551529	SOLENI
SPIO SETOSA	5001430704	SPISET
SPIONIDAE	500143	SPIONI
SPIOPHANES BOMBYX	5001431001	SPIBOM
SPISULA SOLIDISSIMA	5515250102	SPISOL
STREBLOSPIO BENEDICTI	5001431801	STRBEN
STRONGYLOCENTROTUS DROEBACHIENSIS	8149030201	STRDRO
SYLLIDAE	500123	SYLLID
SYLLIS CORNUTA	5001230306	SYLCOR
SYLLIS SP.	5001230399	SYLSPP
TANAIDACEA	6155	TANAID
TELLINA AGILIS	5515310205	TELAGI
TEREBELLIDAE	500168	TEREBE
TONICELLA RUBRA	5303020604	TONRUB
TRICELLARIA PEACHII	7815280398	TRIPEA
TUBULARIA SP.	3703030299	TUBSPP
TURBELLARIA	3901000000	TURBEL
TURTONIA MINUTA	5515140101	TURMIN
UNCIOLA IRRORATA	6169150703	UNCIRR
UNCIOLA SP.	6169150799	UNCSPP

EPAID	STA	AGLANEO	AMPELABD	AMPELSP	AMPHISQU	ANOMIASP	ARICCATH	ARICSP	CAPCAP	CIRRAT	CIRRGRAN	CLYTORQ
110221	1	0	0	0.07	0	0.27	0	0	6.64	9.86	0	0
110230	2	0	0	0.08	0	0	0.08	0.13	0.03	0.05	0	0
110231	3	0	0.54	6.14	0	0	0	0.07	0.54	3.29	0	0
110222	4	0	0.91	1.61	0	0	0.12	0	0	20.56	0	0
110232	5	0	1.61	0	0	0	0	0	0.55	6.12	0	0
110224	6	0	1.33	0	0	0	0.32	0	0	8.15	0	0
110226	7	0	3.98	2.75	0	0	0.24	0	0.42	8.18	0	0
110225	8	0	0.52	0.29	0	0	0.11	0	0.12	2.16	0	0
110229	9	0	0	0	0	3.26	1.57	0	1.33	3.56	5.98	0
110220	10	0	11.48	17.16	0	0	16.95	0.53	0	14.65	0	0
110216	11	2.73	0	0.41	0	0	0.41	0.53	1.36	2.94	0	0
110218	12	0	8.99	4.13	0	0	35.22	3.1	0	14.86	0	1.63
110219	13	0	0.63	0.63	0	2.48	10.74	0.5	41.87	3.06	0	0
110214	14	0	1	0	0	0	0	0	0	4.75	0	13.24
110215	15	0.19	0	0.61	0	0	1.08	0.3	8.04	2.38	0	0
110212	16	0	0	0	0	0	10.54	1.03	0	7.07	0	8.99
110217	17	0	0.25	1.82	0	0	0.5	0.37	0	2.25	0	0
110211	18	0	0	0	1.21	6.37	2.26	0	16.91	4.24	1.74	0
110210	19	0	0.28	1.07	0	0	0.24	0	1.29	1.03	0	0
110223	20	0	0.42	2.68	0	0	1.25	0.5	0	2.72	0	0
110213	21	1.01	0.92	2.98	0	0	0.9	0	0	2.06	0	0
110228	22	0	0	0	0	7.17	0	0	0.61	2.51	0	6.33
110227	23	0	0	0	0	0	16.02	2.51	0.77	0.67	0	4.22

EPAID	STA	COROPHIN	COROPHSP	ETEOLONG	EXOGHEB	FABSAB	GAMOCEAN	GASTROP	HIATELSP	JAERMAR	LACVINC	LEITOROB
110221	1	0	0	0	0	0	0	0	0	0	0	0
110230	2	0	0	0	0	0	0	0	0	0	0	0
110231	3	0	0	0	0	0	0	0	0	0	0	0
110222	4	0	0	0.04	0	0	0	0	0	0	0	0
110232	5	0	0	0	0	0	0	0	0	0	0	0
110224	6	0	0	0	0	0	0	0	0	0	0	0.06
110226	7	0	0	0	0	0	0	0	0	0	0	0
110225	8	0	0	0	0	0	0	0	0	0	0	0
110229	9	0	0.83	0	0	0	0	0	0.45	0	0	0
110220	10	0	0	0	0	0	0	0	0	0	0	0
110216	11	2.73	0	0	0	0	0	1.05	0	0	0	0
110218	12	0	0	0	0	0	0	0	0	0	0	0
110219	13	0	0	0	0	0	0	0	0	0	0	0
110214	14	0	0	0	0	0	5.56	2.34	0	0	0	0
110215	15	0	0	0	0	0.23	0	0	0	0	0	0
110212	16	0	0	0	1.36	0	0	0	0	0	0	0
110217	17	0	0	0	0	0	0	0	0	0	0	0
110211	18	0	0.45	0	0	0	0	0.52	0	0	0	0
110210	19	0	0	0	0	0	0	0	0	0	0	0
110223	20	0	0	0	0.95	0	0	0	0	0	0	0
110213	21	0	0	0	0.76	0	0	0	0	0	0	0.39
110228	22	0	0	0	2.39	0	0	0	0	0	2.05	0
110227	23	2.76	0	0	1.78	0	0	6.92	0	1.23	0	0

EPAID	STA	LEITOSP	LEPISQU	LITLIT	LYOHYA	MACOMASP	MALDANID	MEDIOMSP	MICRODGR	MICRODSP	MICROPAB	MYAAREN
110221	1	0	0	1.57	0	0	0	0	0.07	0.27	0	0
110230	2	0	0	0	0	0	0	0.04	0	0	0	0
110231	3	0	0	0	0	0	0	0.82	0	0	0	0
110222	4	0	0	0	0	0	0	0.33	0	0	0.91	0
110232	5	0	0	0	0	0	0	0	0	0	1.33	0
110224	6	0	0	0	0	0	0	0.34	0	0	0.28	0.06
110226	7	0	0	0	0	0	0	0	0	0	3.36	0
110225	8	0	0	0	0	0	0	0.11	0	0	0.15	0
110229	9	0	0	0	1.04	0	0	1.38	0	0	0	0
110220	10	0	0	0	0	0	0	1.38	0	0	0	0
110216	11	0	0	0	0	0	0	0	0	0	0	0
110218	12	0	0	0	0	0	0	0	0	0	0	0
110219	13	0	0	0	0	0	0	0.76	0	0	0	0
110214	14	0	0	0	0	0.72	4.49	0	0	0	0	0
110215	15	0	0	0	0	0.31	0	0	0.19	0	0	0
110212	16	0	0	0	0	0	1.82	0	0	0	0	0
110217	17	0	0	0	0	0	0	0	0	0	0	0
110211	18	0	0.99	0	0	0	0	0	0	0	0	0
110210	19	0	0	0	0	0	0	0.56	0	0	0	0
110223	20	0	0	0	0	0	0	1.36	0	0	0	0
110213	21	2.18	0	0	0	0	0	0.26	0	0	0	0
110228	22	0	0	0	0	0	2.44	0	0	0	0	0
110227	23	0	0	0	0	0	0	0	0.86	0.77	0	0

EPAID	STA	MYTILID	NASSTRIV	NEANVIR	NEPHTCIL	NEPHTINC	NEPHTYID	NEREID	NINOENIG	NUCULDEL	OLIGO	ORCHOPIN
110221	1	0	0	0.41	0	0	0	0.34	0	0	55	0
110230	2	1.51	0	0	0	0	0	0	0	0	13.71	0
110231	3	9.84	0	0	0	0	1.6	0	1.23	0	42.8	0
110222	4	0.18	0	0	0	0	1.22	0	0.2	0	12.79	0
110232	5	0.79	0	0	0	0.08	63.33	0	0.12	0	20.56	0
110224	6	0.17	0	0	0	0	1.48	0	0	0	25.81	0
110226	7	1.27	0	0	0	0.18	15.13	0	0.18	0	45.9	0
110225	8	0.28	0	0	0	0	0.74	0	0	0	12.33	0
110229	9	18.62	0	0	0	0	0	0	0	1.04	38	0
110220	10	2.74	0	0	0	0	0.85	0	2.33	0	15.14	0
110216	11	9.75	0	0.41	0	0	0	0	0	0	60.8	0
110218	12	0.79	0	0	0	0	0	0	0	0	11.5	1.24
110219	13	9.59	0	0	0	0	0	0	0	0	4.79	0
110214	14	11.08	0	0	0	0	0	0	0	0	15.76	0
110215	15	4.46	0	0	0	0	0	0	0	0	60.55	0
110212	16	20.62	0	0	0	0	0	0	0	0	29.72	0
110217	17	1.3	0	0.3	0	0	0	0	0	0	48.03	0
110211	18	11.95	0	0	0	0	0	0	0	0	36.58	0
110210	19	0.81	0	0	0	0	0.47	0	0.26	0	27.4	0
110223	20	0	0	0	0	0	0	0	0	0	51.44	0
110213	21	0	0	0	0	0	0	0	0.35	0	64.23	0
110228	22	14.39	4.12	0	0.68	0	0	0	0	0	2.58	0
110227	23	21.94	0	0	0	0	0	0	0	0	17.35	0

EPAID	STA	OXYSMITH	PHOLOMIN	PHOTMACR	PHOXOHOL	POLYDCOR	POLYDQUA	PRIONSP	PRIONSTE	PYGOELEG	RHYNCHO	SCOLEHEB
110221	1	0	0	0	0	3.11	0	0	0	0.07	0	0
110230	2	0	0	0.16	1.17	0	0	0	0	0.3	0	2.4
110231	3	0	0	0	0	0	0	0	0	3.25	0	1.04
110222	4	0	0	0	0	0	0	0	0.38	1.01	0.06	0
110232	5	0	0	0	0	0	0	0.86	0.86	0.08	0.36	0.08
110224	6	0	0	0	0	0	0	0.56	0.59	0.82	0	0
110226	7	0	0	0	0	0	0	1.4	2.69	0	0.42	0
110225	8	0	0	0	0	0	0	0.28	0.15	0.75	0.09	0
110229	9	0	0	0	0	0	0	0	0	0	0	2.95
110220	10	0	0.67	0	0	0	0	0	0.93	0	1.43	1.39
110216	11	0	0.53	0	0	1.36	0	0	0	0	0	0
110218	12	0.59	0	0	0	0	0	0	0.63	0	0	5.84
110219	13	0	1.98	0	0	0	0	0	0	0.63	0	1.49
110214	14	0	0.77	0	0	1.04	0	0	0	13.27	0	0
110215	15	0	0	0	0	0.24	0	0	0	0.17	0	0
110212	16	0	0.61	0	0	0	0.49	0	0	3.05	0.87	0.51
110217	17	0	0	0	0.26	0.15	0	0	0	1.18	0	1.6
110211	18	0	1.05	0	0	0	0	0	0	0	0.61	0
110210	19	0	0	0	3.83	0	0	0	0	1.84	0	2.2
110223	20	0	0	0	0.65	0.5	0	0	0	1.8	0	6.5
110213	21	0	0	0	0	3.91	0	0	0	0	0	0.57
110228	22	0	2.45	0	0	0	0	0	0	6.61	0	0
110227	23	0	0	0	3.93	0	0	0	0	6.01	0	0

EPAID	STA	SCOLESP	SPIOSETO	SPIOBOMB	STREBBEN	STRODROE	TELLAGIL
110221	1	0.07	0.07	0	19.51	0	0
110230	2	2.84	0	0	75.89	0	0.21
110231	3	2.45	0	0	14.01	0	1.35
110222	4	0	0	0	58.33	0	0
110232	5	0	0	0	0.71	0	0
110224	6	0	0	0	57.92	0	0.17
110226	7	0	0	0	10.42	0	0
110225	8	0	0	0	80.55	0	0
110229	9	1.99	0	0	0	0	0.83
110220	10	0	0	0	1.94	0	0
110216	11	0	0	0	2.78	0	0.77
110218	12	1.24	0.48	0	0	0	1.36
110219	13	0	0	0	5.21	0	3.64
110214	14	0	3.66	0	1.68	0	1.09
110215	15	0	0	0	17.19	0	0.4
110212	16	1.15	0	0	0	0	1.78
110217	17	1.14	0	0	36.47	0	0.2
110211	18	0	0	0	0	0.4	0.67
110210	19	3.04	0	0	52.86	0	0
110223	20	10.94	0	0	10.79	0	0.31
110213	21	0	0	0	12.86	0	0.26
110228	22	0	0	15.98	0	0	8.06
110227	23	0	0	0	0	0	0

SITE	TOTSPP	TOTDENS	SEDCOMB	SEDPHI	SEDGRAV	SEDSAND	SEDSILT	SEDCLAY	SEDTOX	WATTOX	SEDMPN	EELGRASS	SUMPAH
1	34	17663	2	3.32	0	86	8.8	5.2	0	0	1300	190	805
2	53	113956	6.8	6.42	0	27	44.8	28.2	3	8	3850	210	9232
3	58	17438	5	5.23	0	47.7	35.3	17	0	7	4025	300	.
4	42	92256	8.3	8.06	0	7.2	47.5	45.3	5	27	4000	0	3985
5	24	15519	8.8	7.73	0	8.8	49.5	41.7	0	0	4750	0	2564
6	31	36325	8	7.89	0	6	52	42	0	0	4900	0	.
7	25	10531	9	7.85	0	7	50.2	42.8	0	8	3850	0	4666
8	47	107231	9	7.73	0	6.8	52	41.2	0	2	2450	0	4731
9	73	15075	4.3	4.28	2	62.8	18	17.2	95	0	6350	680	6649
10	67	23425	7.5	6.76	0	27.8	38	34.2	9	0	9680	0	3360
11	55	10650	4	3.65	4.3	65.8	18	11.9	5	0	1635	200	5826
12	89	73581	3.5	4.1	0	69.5	18.5	12	6	0	6700	0	13363
13	46	4963	9.8	6.9	0	24.3	41	34.7	57	0	3300	0	7408
14	61	13813	1.8	3.1	0	85	9.5	5.5	6	5	1475	130	6176
15	64	71206	6	5.73	0	41	34.8	24.2	7	0	5400	200	5707
16	102	54588	1.8	3.22	0	83.8	10.2	6	12	0	3600	520	1234
17	69	71181	4.3	5.23	0	50.8	29.7	19.5	9	0	6450	130	5123
18	102	31538	5.5	1.5	27.3	48.3	24.4	0	90	0	3875	330	13878
19	62	67181	6	5.58	0	41.8	38.5	19.7	6	0	3015	310	4805
20	50	16269	2.8	4.16	2	64.3	23.7	10	0	0	390	0	298
21	41	14313	4	5.08	0	54.8	28.5	16.7	0	5	3100	0	1422
22	77	10969	1.3	2.43	4.3	89.8	4.8	1.1	30	0	600	230	488
23	80	33956	1	2.76	0	95.3	2.7	2	51	0	1225	180	1128

SITE	TOTPCB	SUMDDT	METALERL	DDTERL	GROUP	AMPHSPP	AMPHDENS
1	14.9	2.98	2.4	1	4	6	63
2	54.4	19.25	7.2	6.4	4	14	1781
3	.	.	4.2	0	1	9	844
4	44.9	22.7	13.6	7.6	1	4	2381
5	43.4	16.78	5.3	5.6	1	2	325
6	.	.	12.8	0	1	3	606
7	111.6	21.6	11.4	7.2	1	2	750
8	65.3	34.6	10	11.5	1	6	906
9	49	72	5.6	24	2	10	456
10	53.6	8.98	8.7	3	2	10	7356
11	21.7	10.6	4.7	3.5	4	11	250
12	85.2	99.18	12.5	33.1	2	10	11706
13	48.6	5.13	6.1	1.7	3	4	75
14	38.3	10.12	2.5	3.4	2	9	744
15	67.7	21.56	9.2	7.2	4	9	1081
16	10.4	12.97	2.8	4.3	4	14	1063
17	36.7	11.91	9	4	3	12	1956
18	56.9	44.35	6.5	14.8	3	12	719
19	39.9	6.47	7.3	2.2	3	10	3800
20	8.7	3	3.5	1	4	6	650
21	19.2	7.75	5.5	2.6	4	6	606
22	12.8	7.11	2.3	2.4	4	10	144
23	6.4	8.89	2.3	3	4	12	4100