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Feasibility of mapping benthic biotopes in the Hudson River

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ABSTRACT

Successful management of aquatic resources requires comprehensive maps that identify the spatial distribution and extent of potentially vulnerable habitats and their resident biota (e.g., essential fish habitat). We illustrate a technique that describes submerged landscapes not only in terms of geophysical properties, but also in terms of the resident biotic communities. Biological community distribution was highly correlated with the geophysical provinces initially identified by Bell *et al.* (2000). However, fewer groups of stations (created mainly by combining provinces) explained almost as much of the variation in benthic community structure and was a better description of the major biotopes in this stretch of the Hudson River Estuary. The findings of this pilot study can lead to sampling design criteria for the rest of the Hudson River Estuary.

INTRODUCTION

Ecosystem approaches for conservation and management of natural resources have been used extensively in terrestrial systems where maps derived from aerial and satellite images provide synoptic views of the landscape. Until recently, ecosystem approaches were limited in aquatic systems due to the lack of high resolution images of the seafloor that reveal the spatial patterning and geographic distribution of sedimentary characteristics and faunal assemblages on a landscape scale.

Early benthic habitat assessments relied on intensive, discrete, grab sample programs, which are extremely labor intensive, time consuming, costly, and result in, at best, restricted spatial coverage. The patchiness of natural benthic assemblages complicates interpolation of discrete sample measurements over large areas. These sampling designs do not provide information on the extent of regions with similar characteristics; reveal the location, extent or sharpness of boundaries and transition zones; and they potentially overlook regions of unique bottom type

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positioned between point samples. In a very amusing but appropriate analogy, Solan *et al.* (2003) compare this traditional sampling method to the parable of *The Blind Men And The Elephant*.

Recent progress in remote sensing and acoustic classification of the seafloor allows techniques previously limited to terrestrial ecology to be applied to mapping marine benthic landscapes. Acoustic surveys of the seafloor have become the underwater analog of aerial photography enabling large areas to be rapidly and relatively efficiently surveyed (Ryan and Flood, 1996; Greenstreet *et al.*, 1997). The acoustic remote sensing tools currently employed in geophysical surveys (side scan sonar, multibeam bathymetry etc.) collect continuous data across large areas and thus have the potential to characterize bottom type at a level of resolution well beyond traditional discrete bottom sampling methods (e.g., cores, grab samples, etc.) (Ryan and Flood, 1996). These acoustic records provide an image of the benthic landscape that once interpreted, can reveal the location and extent of areas of similar bottom type and the boundaries between areas of dissimilar sediment characteristics.

In order to be effective for ecosystem management, aquatic landscapes must encompass both geophysical properties and resident benthic communities. Strict interpretation of the term "habitat" incorporates primarily the physical attributes of a spatially defined area; however, "biotope" is a more specific term that encompasses both the physical attributes of habitat and the composition of the resident biological community. Sediment habitat maps alone are not sufficient for predicting the distribution of benthic communities. Some of the geophysical features detectable by acoustic surveys that appear to characterize distinct sedimentary regions are not biologically relevant (Brown *et al.*, 2002).

This study is part of the Hudson River Estuary Benthic Mapping Project funded by the New York Department of Environmental Conservation (NY DEC), and conducted jointly with investigators at the Lamont-Doherty Earth Observatory and at the Institute for Ecosystem Studies. The specific goals of this project were to: 1) demonstrate the feasibility of utilizing geophysical mapping and faunal data to identify benthic biotopes in the Hudson River estuary; 2) begin to develop an approach for benthic biotope mapping and monitoring based on multivariate environmental and biotic data; and 3) produce a biotope map of the study area.

METHODS

Study Area

The study area was a 3 nautical mile stretch of the Hudson River estuary just north of the Tappan Zee Bridge. Bell *et al.* (2000) refer to this stretch of the river as Area 1. The Hudson River estuary is a seasonal estuary; while the exact salinity structure is a function of seasonal variation in freshwater input, the rate of salinity change is gradual. The river in this stretch is tidally mixed and brackish (mesohaline). Salinity at the time of sampling ranged from 8.5 to 11.5 ppt.

Site Selection

Bell *et al.* (2000) conducted a geophysical survey in this study area by means of side-scan sonar, multibeam bathymetry, CHIRP sub-bottom profiling, sediment cores and grabs. Based on these surveys they identified fifteen different geophysical provinces with similar acoustic signal, sediment surface features, granulometry and sediment mobility. Stratified random sampling was used to identify five sampling stations within each of the 10 most well represented geophysical provinces in Area 1 (Figure 1). Geophysical provinces that consisted of multiple patches were sampled by positioning three sampling stations within one patch and two stations within a second patch in order to characterize each patch with a minimum of two stations per strata. Sampling stations were restricted to be at least 35 meters from any geophysical class boundary or any other stations within that strata, and 80 meters away from any mapped shipwreck and outside of mooring fields.

Faunal and Sediment sampling

Faunal and sediment sampling was conducted in August of 2001 aboard the R/V Pritchard operated by Stony Brook University. Bottom water temperature and salinity were also measured at each sampling site at this time. A total of 100 samples were collected. Two replicate grabs for

benthic macrofauna (>0.5mm) were collected at each of 5 sampling stations within each geophysical province using a modified Van Veen grab, (1/25th m²). Subsamples of sediments for grain size, water content, and organic content were drawn from each of these grab samples.

The remaining sediment was washed through a 0.5 mm sieve to describe the benthic community. All remaining material was preserved in 10% buffered formalin stained with rose bengal. Samples were rewashed and transferred to 70% Ethanol before sorting and identification. Faunal samples were processed by Versar Corporation in Columbia, MD. Individual organisms were sorted and identified to species level whenever possible and the total for each taxon enumerated.

Sediment water content was calculated by comparing wet and dry weights of sediment subsamples. Sediment organic content was estimated by loss on ignition (LOI). Dry sediment samples were combusted at 500 degrees C for at least 4 hours. Sediment grain-size analyses are ongoing. We are still processing samples to measure % composition by weight (gravel, sand, & mud) as well as detailed grain size distribution curves via sedigraph, settling column, and dry sieves for the fine, sand and gravel fractions respectively. These data will be incorporated into the analysis as soon as they are processed.

Sediment Profile Image (SPI) sampling

In September of 2001, we revisited the 50 sampling stations aboard the R/V Walford operated by the New Jersey Marine Science Consortium at Sandy Hook to collect sediment profile images. We contracted Science Applications International Corporation (SAIC) of Newport, RI to obtain REMOTS sediment profile images. Every effort was made to obtain at least one analyzable image from each of the fifty sampling stations. Sediment profile data consist of parameters such as prism penetration depth, apparent RPD, small-scale boundary roughness, sediment grain size major mode and range, presence or absence of biogenic structures such as tubes and burrows, and presence or absence of surface and subsurface features such as shell hash and oxic voids.

At this stage of the analysis we have not incorporated the sample grain-size data or the sediment profile data in any quantitative way. Instead, we focused on the geophysical mapping of the river

floor to examine its utility in predicting the distribution of benthic communities and biotopes. Future work will incorporate the fine scale sediment grain-size and sediment profile variables to evaluate whether those variables can account for any small-scale variability between sampling stations.

Analysis methods

A combination of multivariate direct gradient ordination analysis followed by a cluster analysis of the ordination scores was used to identify biotopes. Direct gradient analysis reveals the trends in benthic species community variation that are related to the measured environmental data. Cluster analysis identifies the natural breaks along these environmental gradients that separate distinct biotopes from one another.

The principal direct gradient analysis technique we applied was redundancy analysis (RDA). RDA, first suggested by Rao (1964), is a direct gradient ordination technique that simultaneously relates community structure to environmental data within a single analysis. It is essentially a combination of regression and ordination that displays the covariance between the species data and the environmental data (Jongman *et al.*, 1995). By examining the environmental and biological data simultaneously, this analysis depicts the trends in the species data that are related to the selected environmental data. This design allows us to better predict species distributions based on the set of preselected environmental variables. This capability is particularly important because our goal was to describe benthic community variation with respect to a particular set of environmental variables (e.g. geophysical classification of the estuary floor). The original design of RDA is based on the Euclidean distance measure, which is not the most appropriate resemblance measure for species data. In order to circumvent this shortcoming, a Hellinger distance transformation was applied to species abundances as recommended by Legendre and Gallagher (2001) in order to obtain ecologically meaningful relationships between samples.

Principal Components Analysis (PCA) was also computed for the species abundance data in order to compare the results of an unconstrained (i.e., indirect gradient) ordination technique to the environmentally constrained RDA. Abundance data were Hellinger distance transformed as

in the RDA analysis. If the constrained RDA ordination resembles the unconstrained PCA results, then it can be concluded that the environmental variables are capturing the major gradients controlling community structure.

Ordinations such as RDA assume a continuous environmental gradient and do not always display obvious breaks between groups of samples. In contrast, cluster analyses identify discontinuities and form discrete groups of samples. Many clustering algorithms exist. They differ based on the way that they identify groups of similar samples. We applied Ward's clustering; this is a hierarchical agglomerative clustering method that minimizes the sum of squared differences when forming groups of samples. We clustered the scores from the first four constrained axes of the RDA ordination to identify the natural breaks in community structure that are related to the geophysical provinces.

RESULTS

General description of the faunal community

We collected a total of 10,343 animals representing 40 taxa in the 100 samples. Of the 40 taxa, 17.5% were polychaetes, 17.5% were bivalves, 15% were amphipods, 15% were decapods, and the remainder were distributed among nine other groups (Table 1). Numerical dominants included the aorid amphipod *Leptocheirus plumulosus* (464 m^{-2}), the barnacle *Balunus improvisus* (438 m^{-2}), spionid polychaete *Marenzelleria viridis* (399 m^{-2}), the tubificid oligochaete *Tubificoides* spp. (243 m^{-2}), the anthurid isopod *Cyathura polita* (164 m^{-2}), the bivalve *Rangia cuneata* (149 m^{-2}), the capitellid polychaete *Heteromastus filiformis* (118 m^{-2}), and the spionid polychaete *Boccardiella ligerica* (114 m^{-2}). These eight taxa represented about 81% of the total number of individuals collected (Table 2). Average abundance at the 50 sampling stations was 2,586 m^{-2}.

Ordination analysis

RDA was applied using the 10 geophysical provinces as nominal environmental variables (Figure 2). The ten nominal variables explained more than half of the species variance (56.9%). Faunal communities in these geophysical provinces differed significantly from one another (F-ratio = 16.281; P-value = 0.0010). While some grouping of stations is apparent in the ordination diagram, there is considerable mixing of stations among many of the geophysical provinces.

A visible pattern of similarity among stations is clear comparing the RDA (Figure 2) to an unconstrained PCA (Figure 3). The fact that the constrained RDA ordination bears a strong resemblance to the unconstrained PCA ordination implies that the environmental variables included in the constrained RDA were related to the major structuring processes controlling community composition.

Figure 2b (bottom panel) displays those species (17 of the 40 total) for which the first two RDA axes explain over 20% of their variance. Species such as *Mytilopsis leucophaeata, Neanthes succinea*, and *Balanus improvisus* increase in abundance in samples that plot in the upper right quadrant of the ordination. Species such as *Heteromastus filiformis, Streblospio benedicti, Carinoma tremaphoros, Leuco americanus, Macoma balthica,* and *Ameroculodes species complex,* increase in abundance in samples that plot in the bottom half of the ordination. Species such as *Leptocheirus plumulosus, Hobsonia florida,* and *Rangia cuneata* increase in abundance in samples that plot in the upper left quadrant of the ordination.

Clustering of sample ordination scores

Cluster analysis of sample ordination scores from the first 4 constrained axes of the RDA ordination suggested the occurrence of three major groups of stations (Figure 4). To preserve the identity of the original composition of stations in these newly formed groups, we generated names by merging the 10 geophysical province names where three or more stations joined the same group. Group AEG was composed mainly of stations from geophysical provinces A, E, and G. This group can potentially be split into two subgroups by separating A from E and G. A

second group, BIJ was primarily comprised of stations from geophysical provinces B, I, and J. A final group, DFCH contained stations largely from the remaining provinces (D, F, C, and H), and can potentially be split further into two subgroups by separating H from the other provinces.

To identify the appropriate cutoff point on the dendrogram and the appropriate number of biotopes, we re-ran the RDA analysis assuming three, four, or five different biotopes with site assignments based on the classification results in Figure 4. Applying RDA to the samples using the 5 biotope assignments (Biotopes A, EG, BIJ, DFC, and H) as nominal environmental variables explained 56.2% of the species variance (F-ratio = 21.227; P-value = 0.0010). These five nominal variables account for 98.8% of the variance that was explained by using the full suite of 10 geophysical provinces. Four and three biotope assignments accounted for 52.2% and 42.7% of the species variance respectively. Thus, the results strongly suggest the presence of 5 biotopes. Final biotope assignments are plotted on the ordination diagram in Figure 5.

We found that both LOI and water content variables could account for a significant amount of the variance in the species data when they were considered individually. However, when the five nominal biotope variables were included in the model, neither of these sedimentary variables explained any additional variance in the species data.

Biotope Descriptions

Abundance differed among the five final biotopes (Table 1). Highest abundance was observed at A (4,688 m^{-2}) and was 370% greater than DFC (1,279 m^{-2}), the biotope with lowest abundance. While species richness also differed by as much as 150% among biotopes, differences probably reflect the lower sampling effort (i.e., fewer stations) within biotopes A and H relative to the other biotopes. The distribution and abundance of those species best explained by the ordination results are given in Figure 6. Station symbols are proportional to abundance.

Figure 7 is an approximate map of the final assignment of the five biotopes. We did not redraw the boundaries to reflect the cases in which one or two individual stations were moved into another biotope. Redrawing the boundaries to reflect new assignments would require

incorporating the sediment grain-size, sediment profile image variables and most importantly reinterpretation of the acoustic surveys.

Relict Oyster Reef (A)

Biotope A consists of 4 out of the 5 original stations that were located within the oyster reef geophysical province (Figure 4). The remaining station not included in this biotope (A4) had distinctly different sediment profile images relative to the other oyster reef stations. Camera penetration depth at A4 was almost 10 cm compared to only 0-1 cm at the other stations, indicating the presence of a layer of very soft sediment underlying some surficial shell and shell hash. Sediment profile images indicated that stations in Biotope A were all characterized by the presence of considerable amount of oyster shells and shell hash at the surface that prevented camera penetration into the sediments. No live oysters were collected at stations within geophysical province A, so these features are relict reefs. Relict oyster reefs are located in shallow areas primarily along the western side of the river, although several, small, unsampled patches also occurr along the eastern margin (Figure 1).

The faunal assemblage in biotope A was dominated by the barnacle *Balanus improvisus* (1,709 m^{-2}), representing about 37% of all the animals collected. Other dominants included the infaunal deposit feeding tubificid oligochaete, *Tubificoides* spp. (553 m^{-2}), the infaunal surface deposit feeding polychaetes *Neanthes succinea* (694 m^{-2}), *Boccardiella ligerica* (272 m^{-2}), *Marenzelleria viridis* (169 m^{-2}), the suspension feeding bivalves *Mytilopsis leucophaeata* (134 m^{-2}) and *Rangia cuneata* (519 m^{-2}), and the tube-building suspension feeding amphipods *Leptocheirus plumulosus* (106 m^{-2}) and *Apocorophium lacustre* (119 m^{-2}). Thus, almost half of the 19 taxa present were abundant (i.e., with an average > 100 m^{-2}).

Biotopes A and EG were both characterized by the presence of coarse-grained material, and multivariate analysis indicated that the faunal assemblages are related (Figures 2, 4, 5 and 6). Both were dominated by the barnacle *Balanus improvisus*, the polychaete *Neanthes succinea*, and spionid polychaetes. Biotope A had fewer individuals of *Tubificoides* spp. and also had fewer bivalve and crustacean species present.

Coarse-Grained Central Channel Deposits (EG)

This biotope is located in the center of the navigation channel and is composed of four stations from the original geophysical province E (E1, E2, E3, and E5), three stations from G (G1, G2, and G5), and station C3 (Figures 5 and 8). Sediment profile images indicated that all of these stations had a substantial amount of coarse-grained material. While some shell was present, this coarse material consisted primarily of anthropogenic debris such as boiler slag, coal, brick, and angular pieces of gravel. Although they were not found in the relict oyster reef biotope A, live oysters (*Crassostrea virginica*) were found attatched to coarse particles in samples within biotope EG (Table 1).

There were four dominant taxa in this biotope: the barnacle *Balanus improvisus* (1,709 m^{-2}), the depositing feeding capitellid polychaete *Heteromastus filiformis* (284 m^{-2}), the surface deposit feeding nereid polychaete *Neanthes succinea* (170 m^{-2}), and the surface deposit feeding spionid polychaete *Marenzelleria viridis* (414 m^{-2}) (Table 1). The faunal assemblage was, however, dominated by the barnacle *Balanus improvisus*; this one species represented over 51% of all the animals collected. As stated above, this faunal assemblage is closely related to the relict oyster reef assemblage. Biotope EG had the highest species richness (Table 1), but individuals were less evenly distributed among the taxa when compared to the other biotopes (Figure 8).

West Channel Margin Deposits (DFC)

This biotope was located primarily along the western margin of the navigation channel (Figure 7). Sediments were mainly fine-grained but sediment profile images lacked the anthropogenic debris that characterized the central channel deposits. A total of 17 stations are represented: 5 from the original geophysical province D, 5 from F, 3 from C (C1, C2, and C5), and stations G3, G4, H4, and J4 (Figure 4). Stations C5, H4, and J4 are the only sampling locations east of the channel center.

Dominant taxa included the infaunal deposit feeding oligochaete *Tubificoides* spp. (226 m^{-2}), the polychaetes *Heteromastis filiformis* (109 m^{-2}) and *Marenzelleria viridis* (178 m^{-2}), the tube building amphipod *Leptocheirus plumulosus* (204 m^{-2}), the barnacle *Balanus improvisus* (121 m^{-2}), and the epifaunal omnivorous isopod *Cyathura polita* (101 m^{-2}) (Table 1 and Figure 6). Individuals tended to be more evenly distributed among the taxa present in this biotope than in other biotopes (Figure 8). For example, this is the only biotope where the most abundant taxa represented < 20% of the individuals present. The faunal assemblage in Biotope H is similar in composition.

East Channel Margin Deposits (H)

This biotope consisted of 4 out of 5 of the stations in the original geophysical habitat H (H1, H2, H3, and H5) plus stations C4 and E4 (Figure 4). This biotope is closely related to DFC; it is, however, primarily located along the eastern margin of the navigation channel (with the exception of E4) (Figure 8). The principal faunal differences between DFC and H were the occurrences of high numbers of the surface deposit feeding spionid polychaetes *Boccardiella ligerica* and *Streblospio benedicti* and relatively fewer individuals of the amphipod *Leptocheirus plumulosus* (Table 1 and Figure 6). In addition to *Boccardiella ligerica* (683 m^{-2}) and *Streblospio benedicti* (267 m^{-2}), other dominants included the deposit feeding polychaetes *Heteromastis filiformis* (108 m^{-2}) and *Marenzelleria viridis* (685 m^{-2}), and the isopod *Cyathura polita* (221 m^{-2}) (Table 1 and Figure 6).

Mud Flats (BIJ)

Biotope BIJ consists of extensive mud flats along the western side of the study area along with margin and tributary deposit areas on the eastern side of the river (Figure 7). This biotope includes all of the stations in the original geophysical habitats B and I, 4 of 5 stations in J (J1, J2, J3, and J5), and A4 (Figure 4). It was characterized by moderate abundance and high species richness relative to the other biotopes. The suspension feeding, tube-building amphipod *Leptocheirus plumulosus* (1,263 m^{-2}) was the most abundant species (Table 1 and Figure 6). The isopod *Cyathura polita* was also very common (299 m^{-2}) (Table 1 and Figure 6). All other

dominants were deposit feeders. These included the oligochaete *Tubificoides* spp. (339 m^{-2}), the polychaetes *Hybsonia florida* (178 m^{-2}) and *Marenzelleria viridis* (180 m^{-2}), and the snail *Littoridinops tenuipes* (121 m^{-2}) (Table 1 and Figure 6).

DISCUSSION

The percent of variance explained by the original 10 geophysical provinces (56.9%) far exceeded our original expectation. Based on prior experience, we estimated that 20-25% of the variation would be explained by defining the geophysical provinces as nominal variables. The considerably higher amount of explained variance suggests that the geophysical classification reflected important large-scale environmental variables that influenced benthic community structure, such as sediment texture, sediment mobility, and current regime. With the addition of smaller scale environmental variables from grain-size data and sediment profile images, we expect the explained variation to eventually increase by another 5-10%.

Our results clearly justified the presence of 5 biotopes rather than the 10 original areas. The 10 geophysical provinces were a good initial approximation of benthic faunal distributions and explained a significant amount of the community variance. The 5 final biotopes, however, explained almost the same amount of variance (56.2%) with only half the number of nominal variables. Thus, acoustic mapping alone was not sufficient to describe the distribution of faunal assemblages. This result supports the conclusion in Brown *et al.* (2002) that some of the geophysical features detectable by acoustic surveys that appear to characterize distinct sedimentary regions are not always biologically relevant.

Geophysical provinces that were combined tended to be contiguous and/or geographically related. For example, biotopes EG and DFC were formed by merging adjacent provinces. While B was not contiguous with either I or J, all 3 geophysical provinces shared common geographic positions along the margins of the river. Sedimentary associations were also apparent in the final selection of biotopes. A and EG, for example, were related because a number of species common to both biotopes required the presence of course material (e.g., barnacles)

We believe that the process used in this study, i.e., a process that starts with a large number of subdivisions and then reduces them is far preferable to one that starts with too few. A faunal analysis that combines areas will be more robust than one that splits them. Starting conservatively with more areas than can be justified insures that each will be adequately sampled. That is not the case if initial subdivisions need to be split; splitting in the current study with only 5 stations per province could potentially have resulted in too few samples within areas to adequately describe community structure. The low species richness in biotopes A and H, for example, probably reflects the relatively small number of stations in these groups compared to the other biotopes.

Only a small percentage of stations (16%) were not classified with members of their original geographic province. All five stations in B, D, F, and I remained together in the final biotope assignments. Provinces A, E, H, and J had one station reassigned to a different biotope. C and G had the worst initial assignments, with two stations in each classified into different biotopes. No province was split to the extent that its stations were so scattered among multiple biotopes that it lost its identity. The high degree to which the geophysical provinces retained their identity suggests that the acoustic analysis was very successful in stratifying the study area into geophysically homogeneous regions.

There are a number of potential reasons why individual stations were not classified with members of their original geographic province. Benthic faunal populations and communities are patchy in space and time and have long been described as spatial and temporal mosaics produced by variations in biotic and physical processes (e.g., Johnson 1970, Rhoads et al. 1978, Barry and Dayton 1991). It is not surprising to us, therefore, that we found variability among stations within a geophysical province. Even in homogeneous environments, variation in recruitment, mortality, and other biological processes will create spatial patchiness. Replicates can provide some protection by reducing variability, but modest replication with n=2 will not eliminate all patchiness. The current biological study was also limited to one-time sampling, and a single snapshot cannot be expected to represent long-term conditions.

Classification differences among individual stations may also reflect small-scale spatial heterogeneity in environmental conditions. The geophysical provinces were meant to reflect important large-scale environmental processes such as sediment mobility and current regime. Therefore, small patches would not have been identified in the Bell *et al.,* (2000) study. Small-scale environmental variability even if not readily apparent in the acoustic data could still affect the faunal assemblage. For example, a small meter-sized patch of coarse material or anthropogenic debris might not be visible in the acoustic analysis. It would, however, be discovered and settled by larvae of benthic species requiring an attachment site (e.g., barnacles) or species that require shelter from predation (e.g., small crabs).

Classification differences among individual stations may also have resulted from larger-scale environmental differences and occurred because the boundaries between provinces were inaccurately drawn. In our experience with interpreting acoustic data, the transition between geophysical provinces is often gradational, and the location of a boundary then becomes subjective. Examples where we believe this may have occurred include station A4 (classified with stations in nearby area B) and C4 (classified with stations in nearby area G). Detailed examination of grain-size and sediment profile images could help determine whether boundaries should have been drawn differently. We also believe there is a large amount of biologically-relevant information that has yet to be extracted from the acoustic data and further multivariate analysis of the acoustic texture data could reduce the these classification differences.

CONCLUSIONS AND FUTURE DIRECTIONS

Acoustic mapping of the estuary floor provided a useful foundation from which to map benthic biotopes. Geophysical surveys produced an image of the benthic landscape unattainable by discrete point sampling. Once interpreted, the acoustic survey revealed the location and extent of areas of similar bottom type and the boundaries between areas of dissimilar sediment characteristics. However, some of the physical variables that are important for differentiating geophysical boundaries are not important for discriminating biological community boundaries. Acoustic mapping alone was not sufficient to describe benthic biotopes and this result

underscores the continued need for groundtruthing in future studies. Landscape views of sedimentary provinces need to be supplemented by biological community data, grain-size measurements and variables of intermediate scale such as sediment profile images.

The connection between the geophysically surveyed bottom type and community structure has not yet been fully explored. In using acoustic records for the purpose of habitat and biotope (the combination of both the physical environment and the resident biota) mapping, variables extracted from the acoustic records need to be biologically relevant (in both variable and scale). This restriction will optimize the classification of bottom type based on the faunal community, as well as geophysical habitat characteristics. In future work, we will need to determine the most appropriate method for extracting landscape texture variables from the acoustic images and the best scale for these sampling blocks. We will then explore the best way to link these acoustic texture variables to the individual faunal and sediment samples.

Furthermore, hierarchy theory suggests that multiple scales of pattern exist in ecosystems because of the multiple scales at which processes function (Wu and Loucks, 1995). Some ecological processes operate on very large scales such as latitude and biogeographic province; some operate on more intermediate geographic or hydrodynamic scales; and others are more localized phenomena such as individual organism interactions and local sediment grain-size composition. Collectively, these processes influence the faunal composition of ecological communities. Considering a suite of variables across multiple appropriate scales (multi-scale analysis) captures a greater amount of information and is a more complete way to describe ecosystems than by focusing on just one scale. When we finish analyzing the sediment samples drawn from each of the biology samples, we plan to see if those small-scale sediment variables and the intermediate-scaled sediment profile variables can each explain a portion of the variance in the biological community than is not accounted for by the larger-scale acoustic classification of the riverbed.

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Tables

Table 1. Mean abundance and standard deviation of macroinvertebrate taxa within each biotope. Abundance is expressed as the number of individuals m^{-2}.

Taxon	Family	Species	Sp. Code	A Mean	A StdDev	EG Mean	EG StdDev	BIJ Mean	BIJ StdDev	DFC Mean	DFC StdDev	H Mean	H StdDev	All Stations Mean	All Stations StdDev
Nemertinea		*Carinoma tremaphoros*	Catr	28.1	12.0	73.4	32.3	39.2	29.1	41.91	20.22	56.25	34.23266	46.8	28.9
Platyhelminthes : Turbellaria		*Stylochus ellipticus*	Stel	3.1	6.3	1.6	4.4	2.5	9.7					1.3	5.8
Annelida : Oligochaeta	Tubificidae	Imm. Tubificid w/o Cap. Chaete	Immt			4.7	9.3			6.6	10.9			3.0	7.8
	Tubificidae	*Tubificoides* spp.	Tubsp	553.1	178.4	73.4	35.0	339.2	483.4	225.7	283.1	72.9	42.9	243.3	338.0
	Unidentified	Unidentified Oligochaete	Olig							0.7	3			0.3	1.8
Annelida : Polychaeta	Ampharetidae	*Hobsonia florida*	Hofl	31.3	12.5	9.4	12.9	177.5	137.3	9.6	16.3	20.8	12.9	63.0	106.3
	Capitellidae	*Heteromastus filiformis*	Hefi	78.1	59.0	284.4	141.1	54.2	45.2	108.8	68.1	108.3	36.8	118.0	106.0
	Nereididae	*Neanthes succinea*	Nesu	693.8	411.1	170.3	122.5	5.0	19.4	14	25.3	16.7	21.9	91.0	220.3
	Spionidae	*Boccardiella ligerica*	Boli	271.9	307.3	46.9	68.7	3.3	12.9	3.7	9.6	683.3	547.5	113.5	295.9
	Spionidae	*Marenzelleria viridis*	Mavi	168.8	106.3	414.1	368.2	589.2	364.9	177.9	160.3	685.4	451.3	399.3	360.2
	Spionidae	*Polydora cornuta*	Poco			1.6	4.4							0.3	1.8
	Spionidae	*Streblospio benedicti*	Stbe	3.1	6.3	84.4	77.3	26.7	36.2	64	50	266.7	135.5	75.5	98.0
Mollusca : Bivalvia	Dreissenidae	*Mytilopsis leucophaeata*	Myle	134.4	124.3	4.7	9.3	5.0	16.2	0.7	3			13.3	48.4
	Mactridae	*Mulinia lateralis*	Mula							0.7	3			0.3	1.8
	Mactridae	*Rangia cuneata*	Racu	518.8	921.4	4.7	9.3	336.7	576.9	12.5	19.3	8.3	10.2	148.5	425.9
	Myidae	*Mya arenaria*	Myar			3.1	5.8							0.5	2.5
	Ostreidae	*Crassostrea virginica*	Crvi			10.9	17.0							1.8	7.6
	Tellinidae	*Macoma balthica*	Maba			10.9	14.1	25.0	28.7	28.7	22.4	29.2	17.1	22.5	23.3
	Unidentified	Unidentifed bivalve sp.	Bivsp							0.7	3			0.3	1.8
Mollusca : Gastropoda	Hydrobiidae	*Littoridinops tenuipes*	Lite			50.0	75.6	120.8	149.1	22.8	34.3	6.3	10.5	52.8	98.9
Arthropoda : Amphipoda	Aoridae	*Leptocheirus plumulosus*	Lepl	106.3	142.0	21.9	35.8	1262.5	675.8	204.4	347.6	29.2	35.9	463.8	675.0
	Corophiidae	*Apocorophium lacustre*	Apla	118.8	140.1	10.9	14.1	16.7	51.2	2.2	6.6	6.3	15.3	17.8	54.4
	Gammaridae	*Gammarus daiberi*	Gada					0.8	3.2					0.3	1.8
	Haustoriidae	*Lepidactylus dytiscus*	Ledy			3.1	8.8							0.5	3.5
	Melitidae	*Melita nitida*	Meni	68.8	80.7	25.0	25.9	3.3	10.0					10.5	30.0
	Oedicerotidae	*Ameroculodes* species complex	Amsp			1.6	4.4	5.0	9.2	11	12.4	4.2	6.5	6.0	9.9
Arthropoda : Chironomidae	Tanypodinae	*Coelotanypus* spp.	Cosp	28.1	32.9			44.2	59.0	3.7	5.9	2.1	5.1	17.0	38.0
	Tanypodinae	*Procladius* spp.	Prsp					0.8	3.2	0.7	3			0.5	2.5
Arthropoda : Cirripedia	Balanidae	*Balanus improvisus*	Baim	1709.4	494.4	1465.6	787.7	62.5	103.8	121.3	199.8	56.3	76.1	438.0	721.4
Arthropoda : Cumacea	Leuconidae	*Leucon americanus*	Leam			3.1	5.8	1.7	6.5	95.6	101.1	4.2	10.2	34.0	73.2
Arthropoda : Decapoda	Crangonidae	*Crangon septemspinosa*	Crse			4.7	9.3	0.8	3.2			4.2	6.5	1.5	4.8
	Palaemonidae	*Palaemonetes pugio*	Papu					0.8	3.2					0.3	1.8
	Portunidae	*Callinectes sapidus*	Casa			1.6	4.4							0.3	1.8
	Portunidae	Unidentified Portunid crab	Port									2.1	5.1	0.3	1.8
	Xanthidae	*Rhithropanopeus harrisi*	Rhha	96.9	47.2	18.8	24.1	39.2	50.6	4.4	7.6	10.4	9.4	25.3	40.5
	Xanthidae	Unidentied Xanthid crab	Xant					0.8	3.2					0.3	1.8
Arthropoda : Isopoda	Anthuridae	*Cyathura polita*	Cypo	71.9	27.7	50.0	50.0	299.2	244.2	100.7	74.9	220.8	123.9	164.3	176.2
	Idoteidae	*Edotea triloba*	Edtr	3.1	6.3	1.6	4.4	3.3	10.0					1.5	6.0
	Idoteidae	*Synidotea laticauda*	Syla			12.5	25.9	5.0	19.4	15.4	57.4	2.1	5.1	9.0	36.2
Arthropoda : Mysidacea	Mysidae	*Neomysis americana*	Neam									2.1	5.1	0.3	1.8
Mean				4687.5		2868.8		3470.8		1278.7		2297.9		2585.8	
SD				1096.8		1394.5		1551.2		796.8		816.5		1590.8	
No. Stations				4		8		15		17		6		50	
Sp.Richness				19		30		29		26		23		40	

Table 2. Percent abundance of macroinvertebrate taxa within each biotope.

Taxa	Family	Species	Sp. Code	A Mean	EG Mean	BIJ Mean	DFC Mean	H Mean	All Stations Mean
Nemertinea		*Carinoma tremaphoros*	Catr	0.6%	2.6%	1.1%	3.3%	2.4%	1.8%
Platyhelminthes : Turbellaria		*Stylochus ellipticus*	Stel	0.1%	0.1%	0.1%			0.0%
Annelida : Oligochaeta	Tubificidae	Imm. Tubificid w/o Cap. Chaete	Immt		0.2%		0.5%		0.1%
	Tubificidae	*Tubificoides* spp.	Tubsp	11.8%	2.6%	9.8%	17.7%	3.2%	9.4%
	Unidentified	Unidentified Oligochaete	Olig				0.1%		0.0%
Annelida : Polychaeta	Ampharetidae	*Hobsonia florida*	Hofl	0.7%	0.3%	5.1%	0.8%	0.9%	2.4%
	Capitellidae	*Heteromastus filiformis*	Hefi	1.7%	9.9%	1.6%	8.5%	4.7%	4.6%
	Nereididae	*Neanthes succinea*	Nesu	14.8%	5.9%	0.1%	1.1%	0.7%	3.5%
	Spionidae	*Boccardiella ligerica*	Boli	5.8%	1.6%	0.1%	0.3%	29.7%	4.4%
	Spionidae	*Marenzelleria viridis*	Mavi	3.6%	14.4%	17.0%	13.9%	29.8%	15.4%
	Spionidae	*Polydora cornuta*	Poco		0.1%				0.0%
	Spionidae	*Streblospio benedicti*	Stbe	0.1%	2.9%	0.8%	5.0%	11.6%	2.9%
Mollusca : Bivalvia	Dreissenidae	*Mytilopsis leucophaeata*	Myle	2.9%	0.2%	0.1%	0.1%		0.5%
	Mactridae	*Mulinia lateralis*	Mula				0.1%		0.0%
	Mactridae	*Rangia cuneata*	Racu	11.1%	0.2%	9.7%	1.0%	0.4%	5.7%
	Myidae	*Mya arenaria*	Myar		0.1%				0.0%
	Ostreidae	*Crassostrea virginica*	Crvi		0.4%				0.1%
	Tellinidae	*Macoma balthica*	Maba		0.4%	0.7%	2.2%	1.3%	0.9%
	Unidentified	Unidentifed bivalve sp.	Bivsp				0.1%		0.0%
Mollusca : Gastropoda	Hydrobiidae	*Littoridinops tenuipes*	Lite		1.7%	3.5%	1.8%	0.3%	2.0%
Arthropoda : Amphipoda	Aoridae	*Leptocheirus plumulosus*	Lepl	2.3%	0.8%	36.4%	16.0%	1.3%	17.9%
	Corophiidae	*Apocorophium lacustre*	Apla	2.5%	0.4%	0.5%	0.2%	0.3%	0.7%
	Gammaridae	*Gammarus daiberi*	Gada			0.0%			0.0%
	Haustoriidae	*Lepidactylus dytiscus*	Ledy		0.1%				0.0%
	Melitidae	*Melita nitida*	Meni	1.5%	0.9%	0.1%			0.4%
	Oedicerotidae	*Ameroculodes* species complex	Amsp		0.1%	0.1%	0.9%	0.2%	0.2%
Arthropoda : Chironomidae	Tanypodinae	*Coelotanypus* spp.	Cosp	0.6%		1.3%	0.3%	0.1%	0.7%
	Tanypodinae	*Procladius* spp.	Prsp			0.0%	0.1%		0.0%
Arthropoda : Cirripedia	Balanidae	*Balanus improvisus*	Baim	36.5%	51.1%	1.8%	9.5%	2.5%	16.9%
Arthropoda : Cumacea	Leuconidae	*Leucon americanus*	Leam		0.1%	0.0%	7.5%	0.2%	1.3%
Arthropoda : Decapoda	Crangonidae	*Crangon septemspinosa*	Crse		0.2%	0.0%		0.2%	0.1%
	Palaemonidae	*Palaemonetes pugio*	Papu			0.0%			0.0%
	Portunidae	*Callinectes sapidus*	Casa		0.1%				0.0%
	Portunidae	Unidentified Portunid crab	Port					0.1%	0.0%
	Xanthidae	*Rhithropanopeus harrisi*	Rhha	2.1%	0.7%	1.1%	0.3%	0.5%	1.0%
	Xanthidae	Unidentied Xanthid crab	Xant			0.0%			0.0%
Arthropoda : Isopoda	Anthuridae	*Cyathura polita*	Cypo	1.5%	1.7%	8.6%	7.9%	9.6%	6.4%
	Idoteidae	*Edotea triloba*	Edtr	0.1%	0.1%	0.1%			0.1%
	Idoteidae	*Synidotea laticauda*	Syla		0.4%	0.1%	1.2%	0.1%	0.3%
Arthropoda : Mysidacea	Mysidae	*Neomysis americana*	Neam					0.1%	0.0%
Total				100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Figures

A	Oyster reef
B	Mud flat
C	Margin deposit-sediment waves
D	Margin deposit- fine scale sediment waves
E	Channel deposit-sediment waves

F	Margin deposit-coarse
G	Channel deposit-coarse
H	Channel deposit-sand
I	Margin deposit-fine
J	Tributary-fine
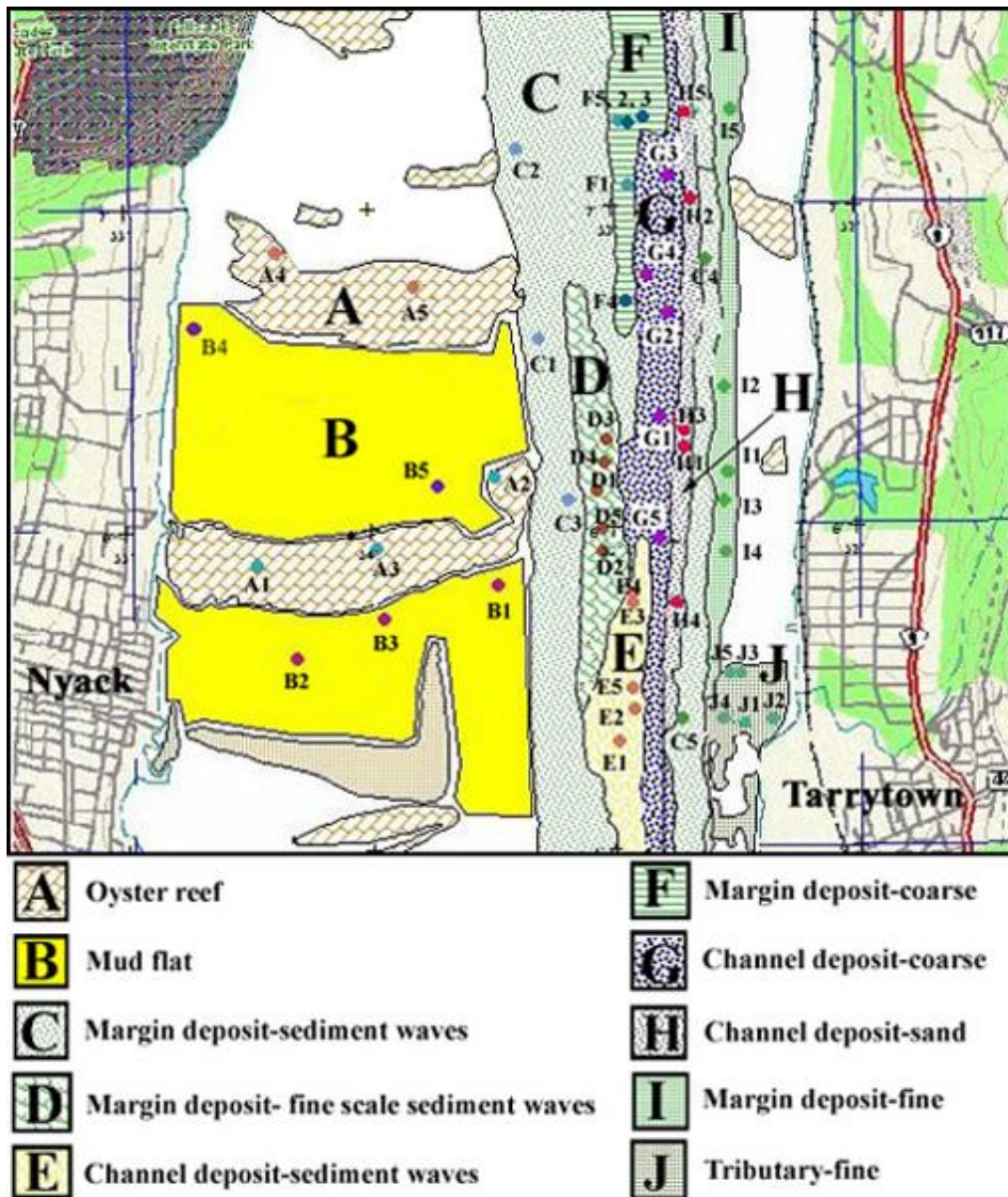
Figure 1. Map of the Hudson River study area just north of the Tappan Zee Bridge. This map displays the configuration of the ten geophysical provinces as outlined by Bell *et al.* (2000) and the locations of the five stratified random sampling stations within each province. North is towards the top of the page.
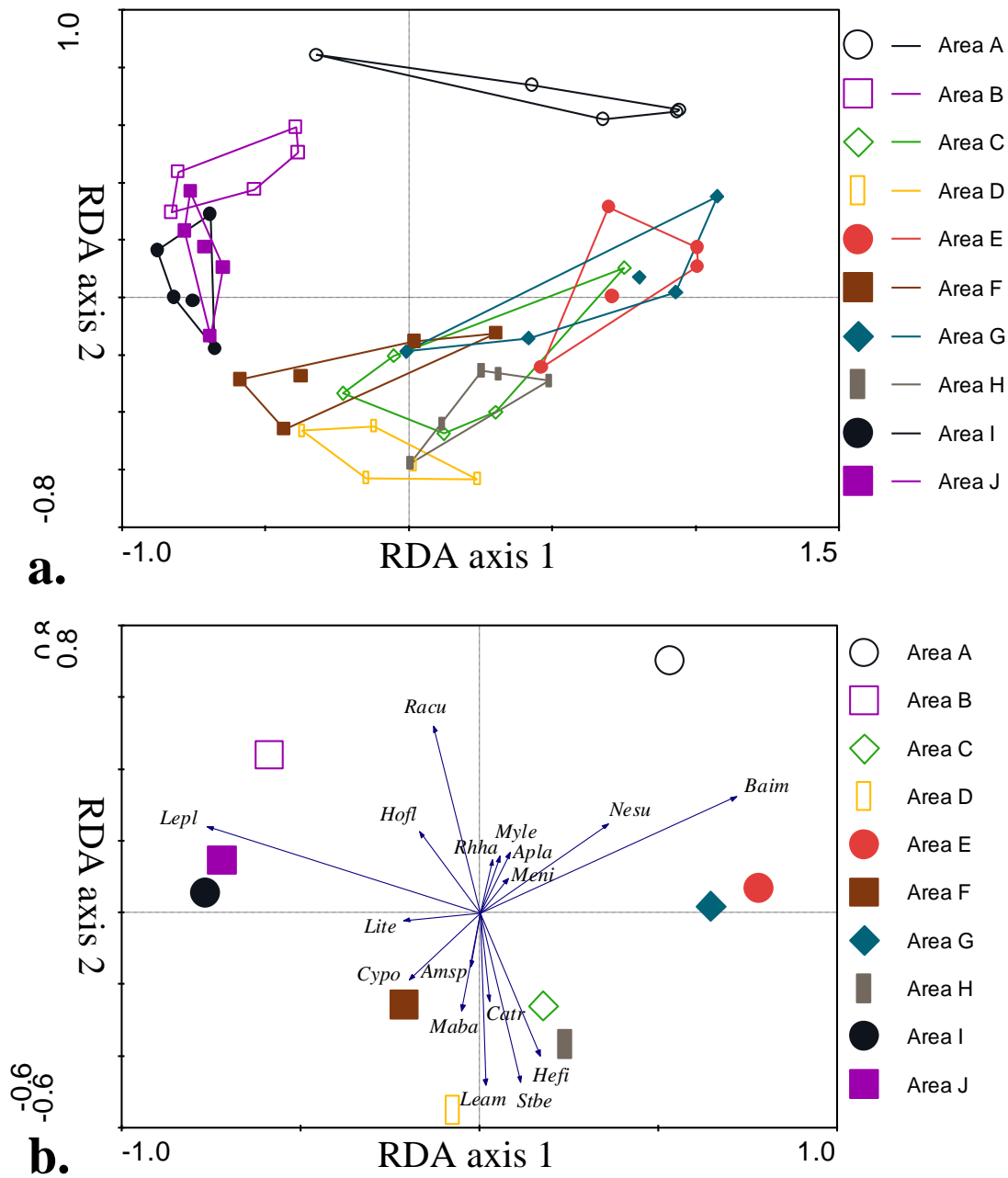
Figure 2. Direct gradient Redundancy Analysis (RDA) of 50 sampling stations. This analysis explains 56.9% of the variance in the species community data. a) Envelopes are drawn around stations within each of the 10 geophysical provinces. Station proximity implies similarity in species composition. b) Symbols represent the centroids of stations within the ten geophysical provinces. Blue vectors represent the trends in the 17 species with >20% variance explained by the first two axes of the ordination. Abundances of those species increase in the direction of the vector at a rate proportional to vector length.
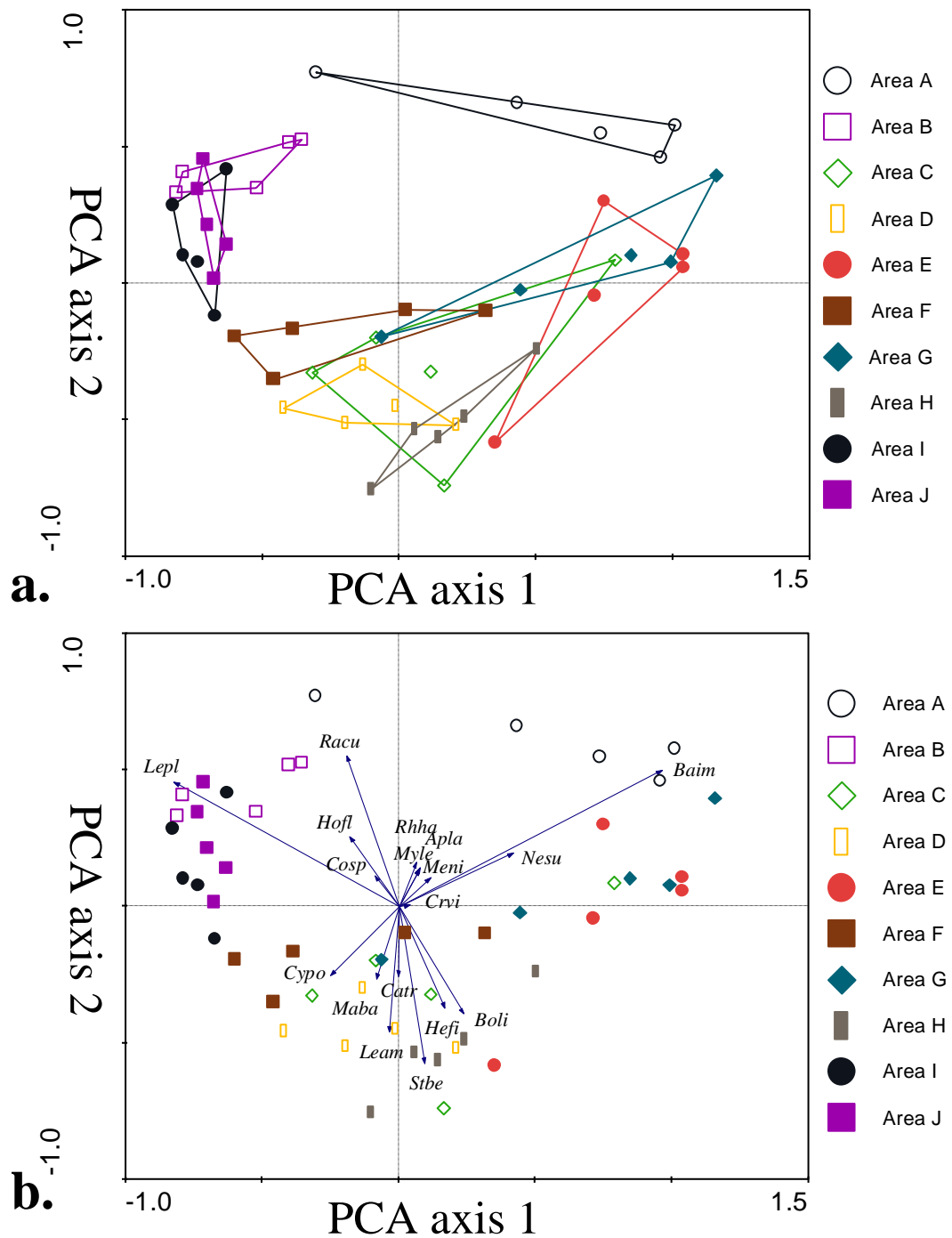
Figure 3. PCA ordination of 50 sampling stations. Station proximity implies similarity in species composition. a) Colored envelopes are drawn around stations from each of the 10 geophysical provinces. b) Points represent sampling stations. Blue arrows represent the 18 species for which greater than 20% variance is displayed in these first two PCA axes. Abundances of those species increase in the direction of the vector at a rate proportional to vector length.
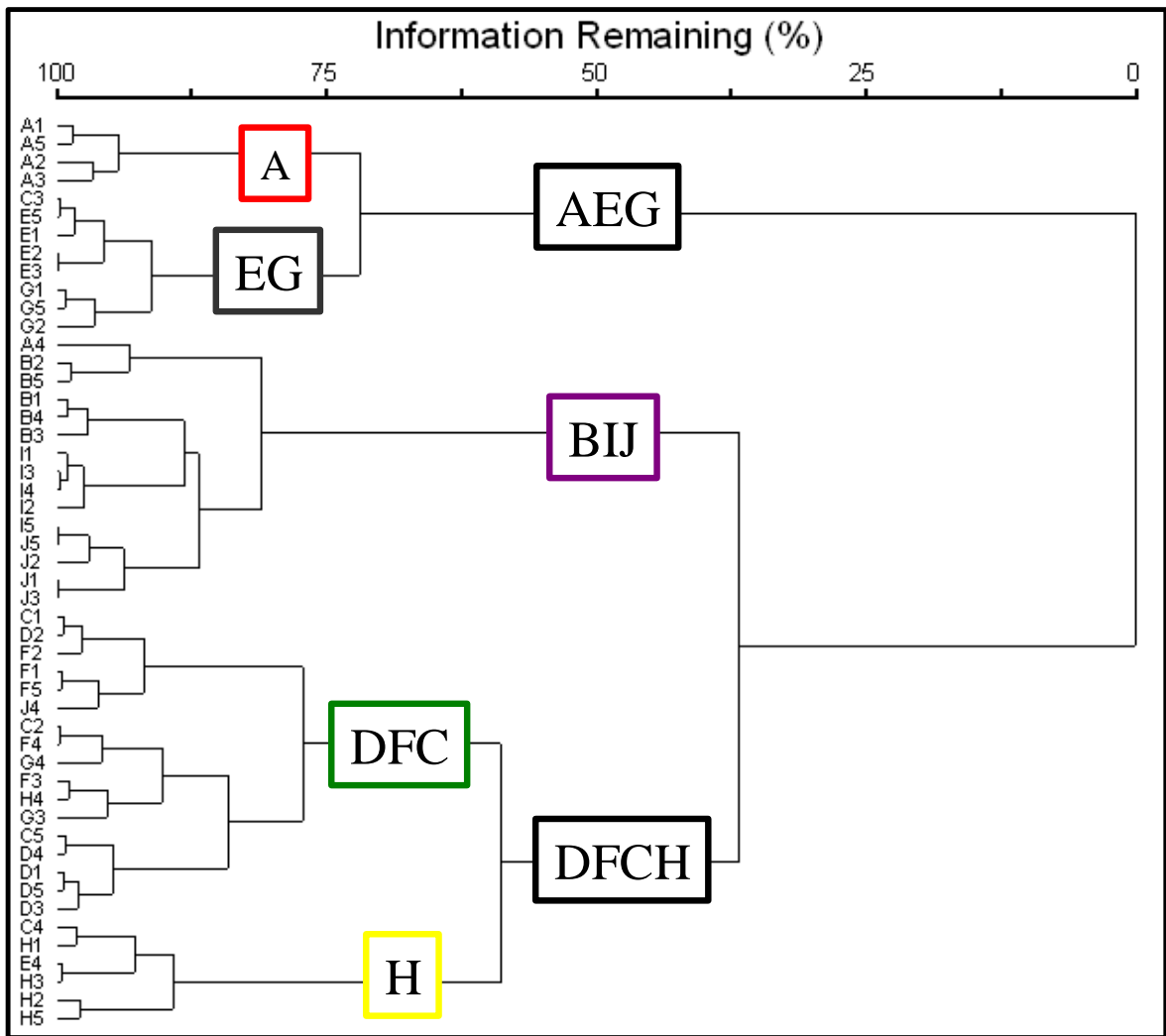
Figure 4. Dendrogram of the Ward's cluster analysis of station scores. Sampling stations are identified on the left. Three major groups emerge (AEG, BIJ, DFCH) with the potential to split two of the major groups into subgroups. The five suggested biotopes are A, EG, BIJ, DFC, and H.
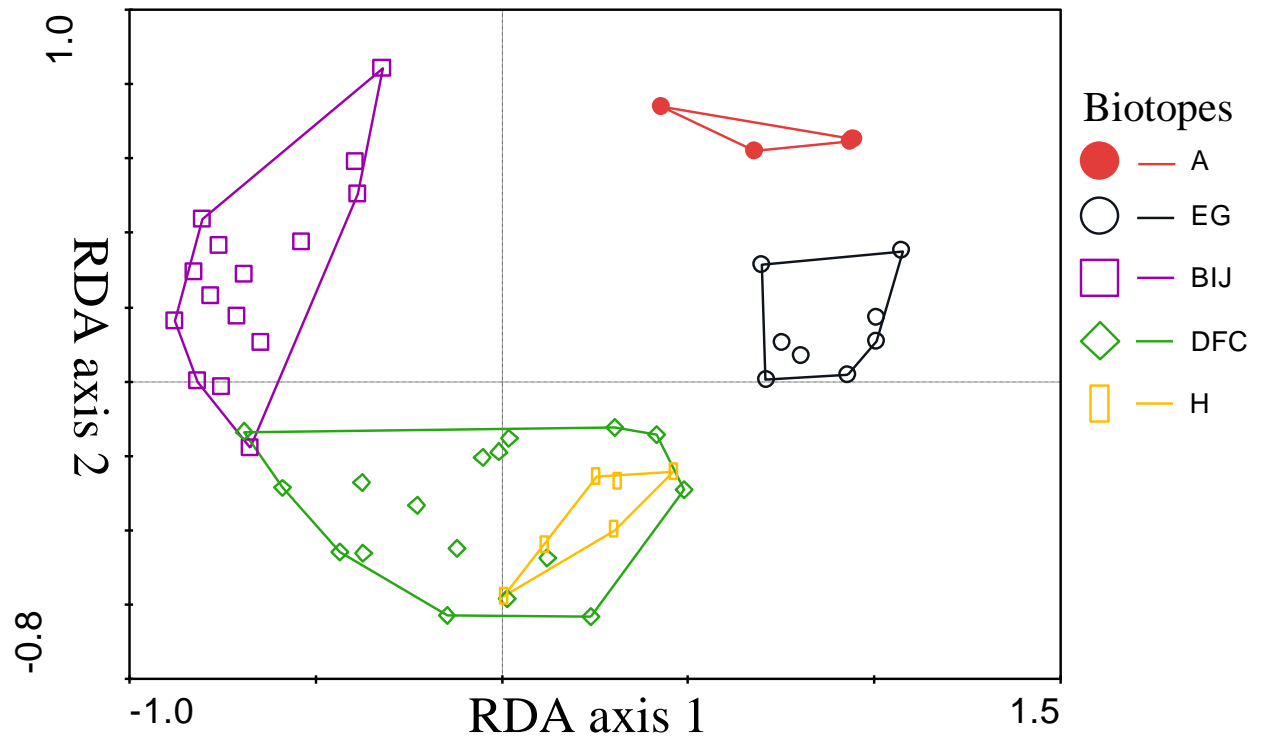
Figure 5. RDA ordination of sampling stations constrained by the 10 geophysical provinces as first presented in Figure 2 with stations color-coded to represent the 5 biotope clusters identified by Ward's clustering.
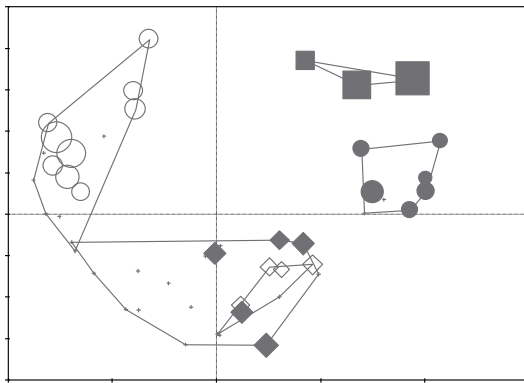
Rhithropanopeus harrisi
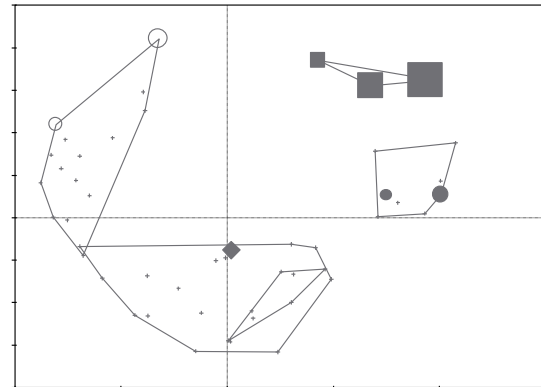
Mytilopsis leucophaeata
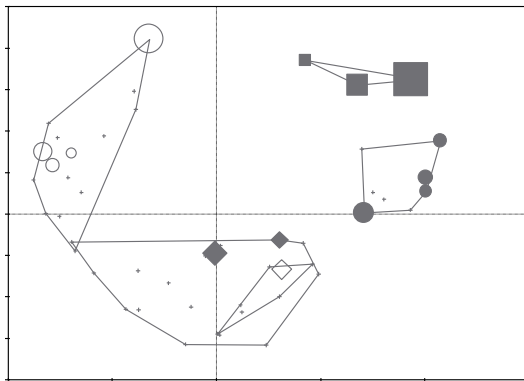
Apocorophium lacustre
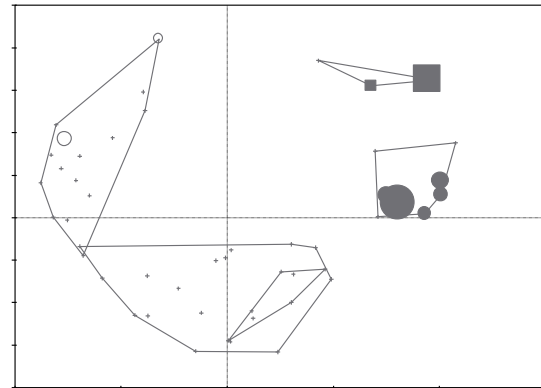
Melita nitida
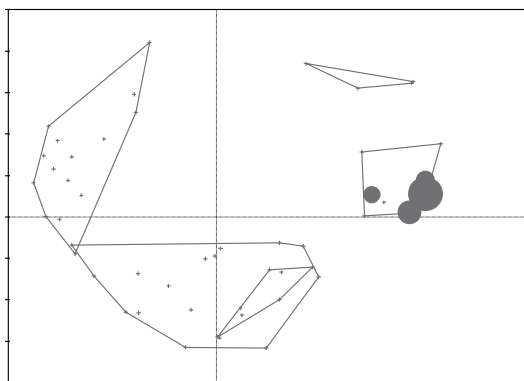
Crassostrea virginica
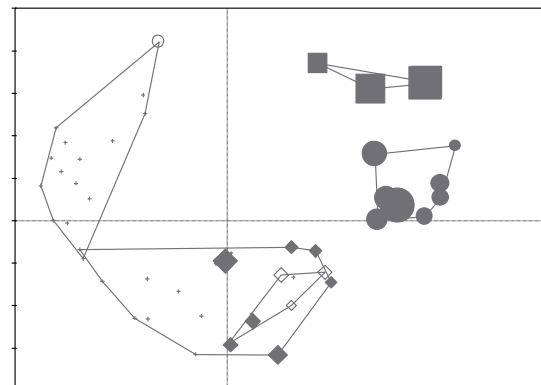
Neanthes succinea

Figure 6. RDA ordination diagrams displaying the relative abundances of noteworthy species. Station positions represent the ordination of stations from the RDA constrained on the 10 geophysical provinces as in Figures 2 and 5. Envelopes around stations correspond to the 5 biotope clusters. Station symbol size reflects relative abundance of that species.
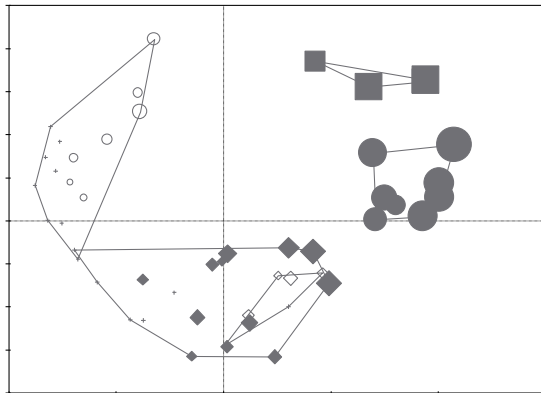
Balanus improvisus
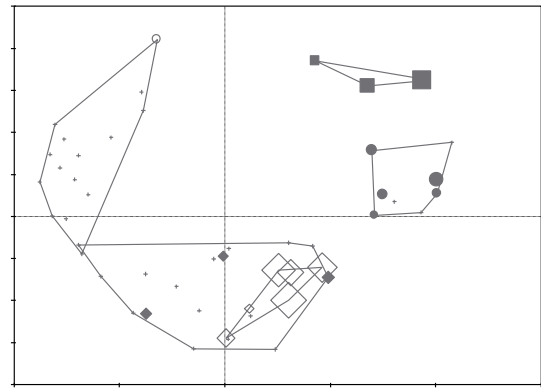
Boccardiella ligerica
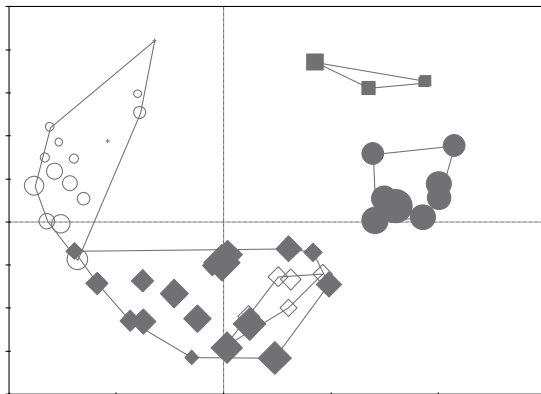
Heteromastus filiformis
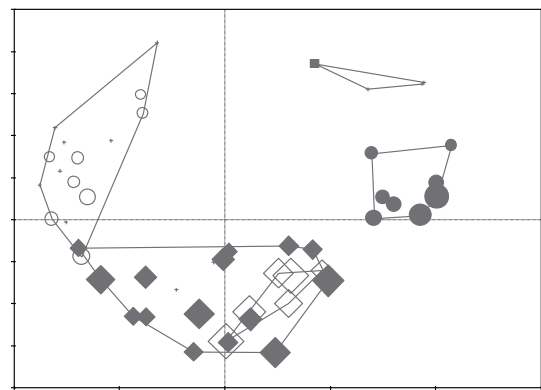
Streblospio benedicti
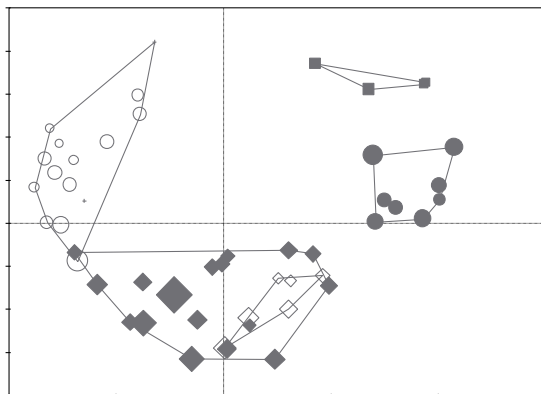
Carinoma tremaphoros
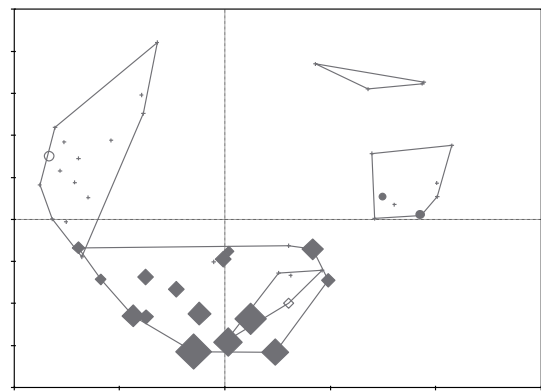
Leucon americanus

Figure 6 (continued). RDA ordination diagrams displaying the relative abundances of noteworthy species. Station positions represent the ordination of stations from the RDA constrained on the 10 geophysical provinces as in Figures 2 and 5. Envelopes around stations correspond to the 5 biotope clusters. Station symbol size reflects relative abundance of that species.

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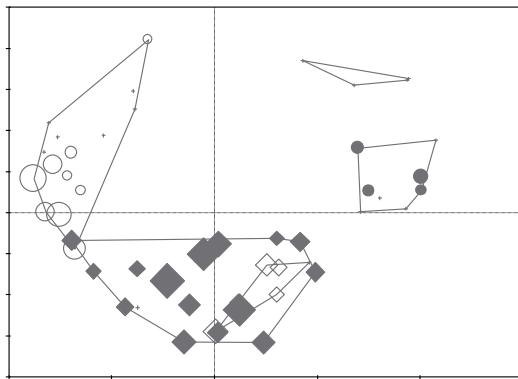
Macoma balthica
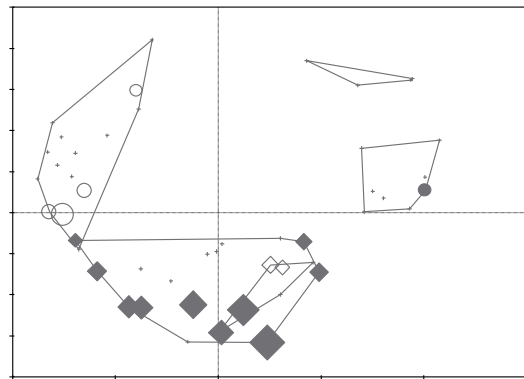
Ameroculodes species complex
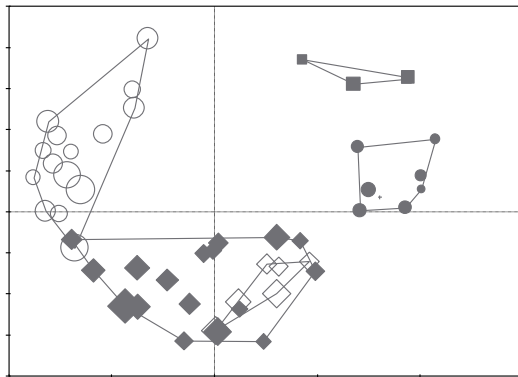
Leptocheirus plumulosus
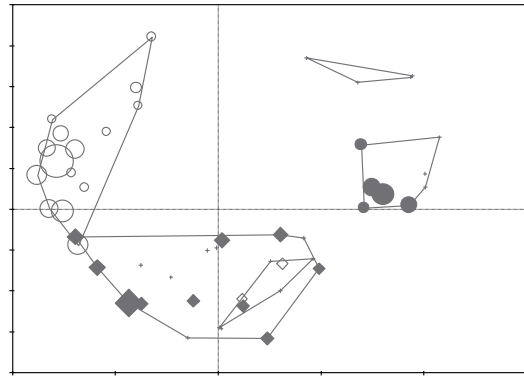
Hobsonia florida
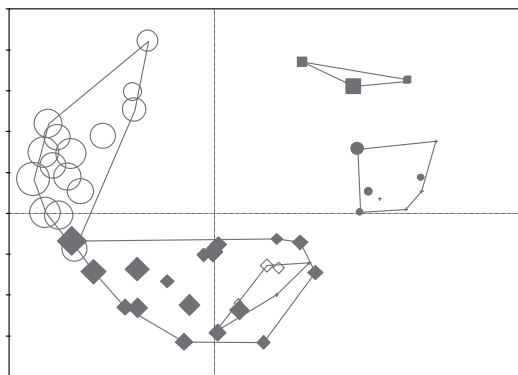
Cyathura polita
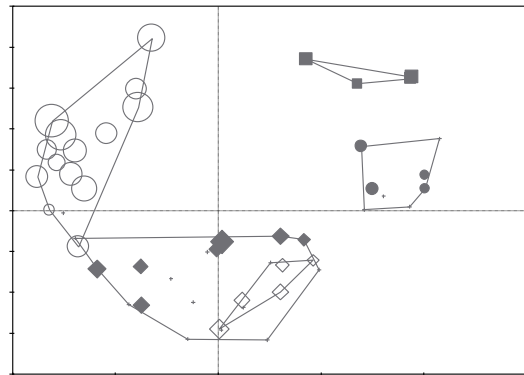
Littoridinops tenuipes

Figure 6 (continued). RDA ordination diagrams displaying the relative abundances of noteworthy species. Station positions represent the ordination of stations from the RDA constrained on the 10 geophysical provinces as in Figures 2 and 5. Envelopes around stations correspond to the 5 biotope clusters. Station symbol size reflects relative abundance of that species.
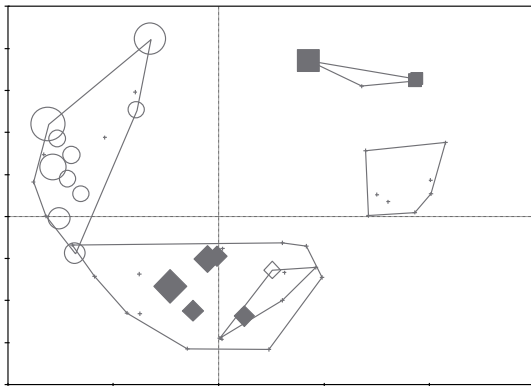
Coelotanypus spp.
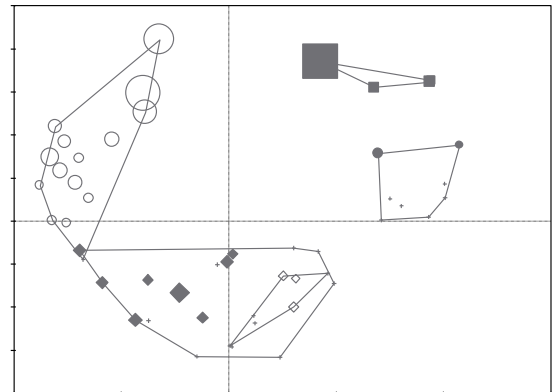
Rangia cuneata
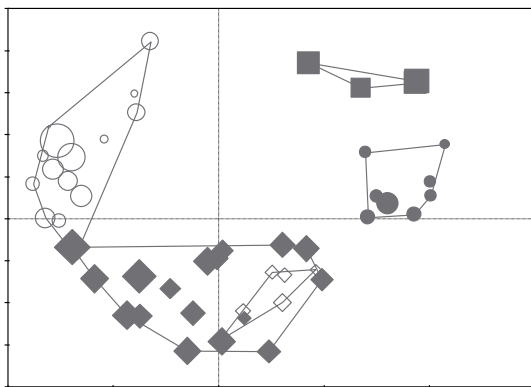
Tubificoides spp.
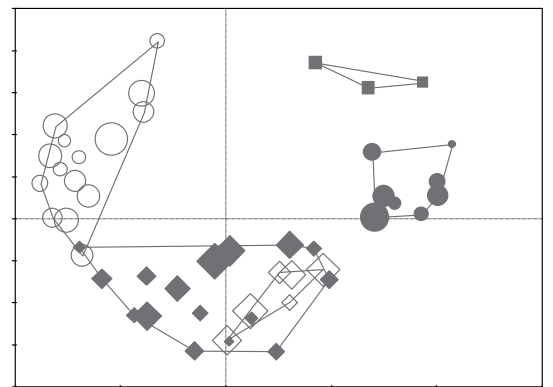
Marenzelleria viridis

Figure 6 (continued). RDA ordination diagrams displaying the relative abundances of noteworthy species. Station positions represent the ordination of stations from the RDA constrained on the 10 geophysical provinces as in Figures 2 and 5. Envelopes around stations correspond to the 5 biotope clusters. Station symbol size reflects relative abundance of that species.
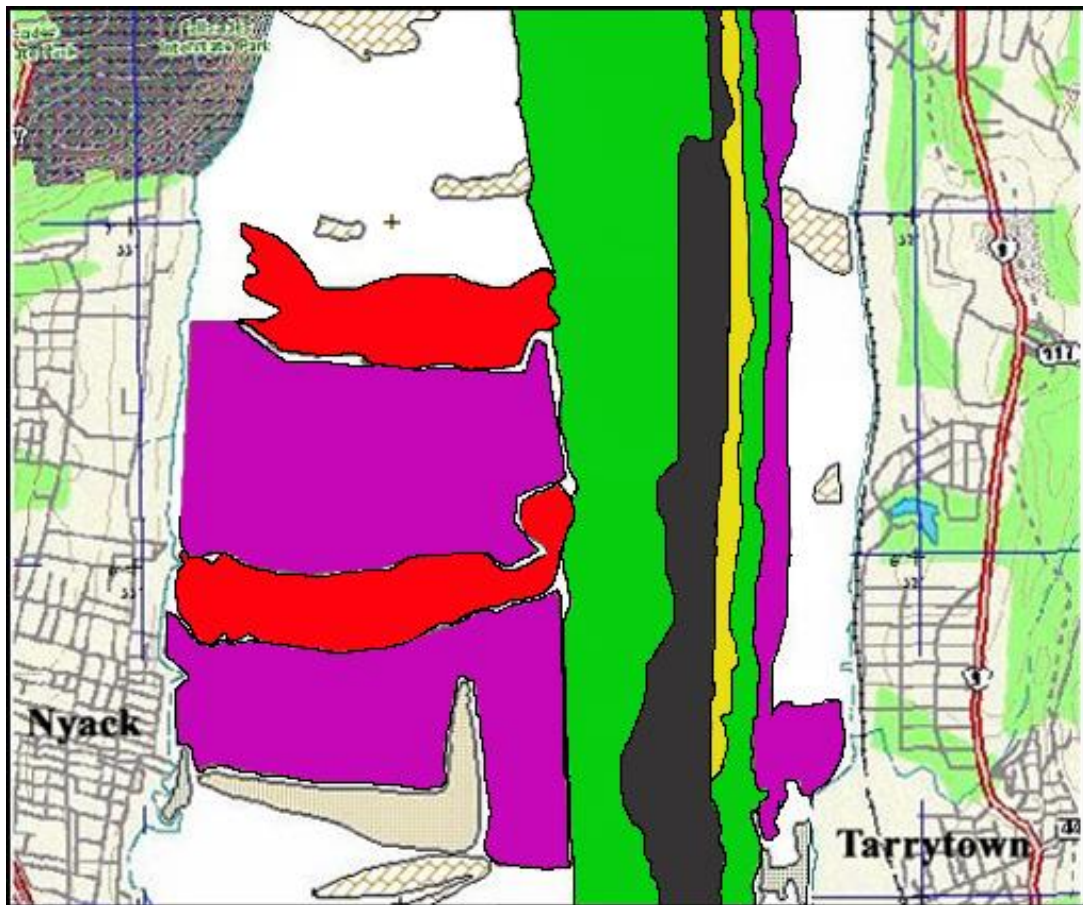
Figure 7. Approximate map of the five biotopes in the Hudson River study area just north of the Tappan Zee Bridge based on Ward's clustering of sample scores from the first 4 constrained RDA axes. North is towards the top of the page.

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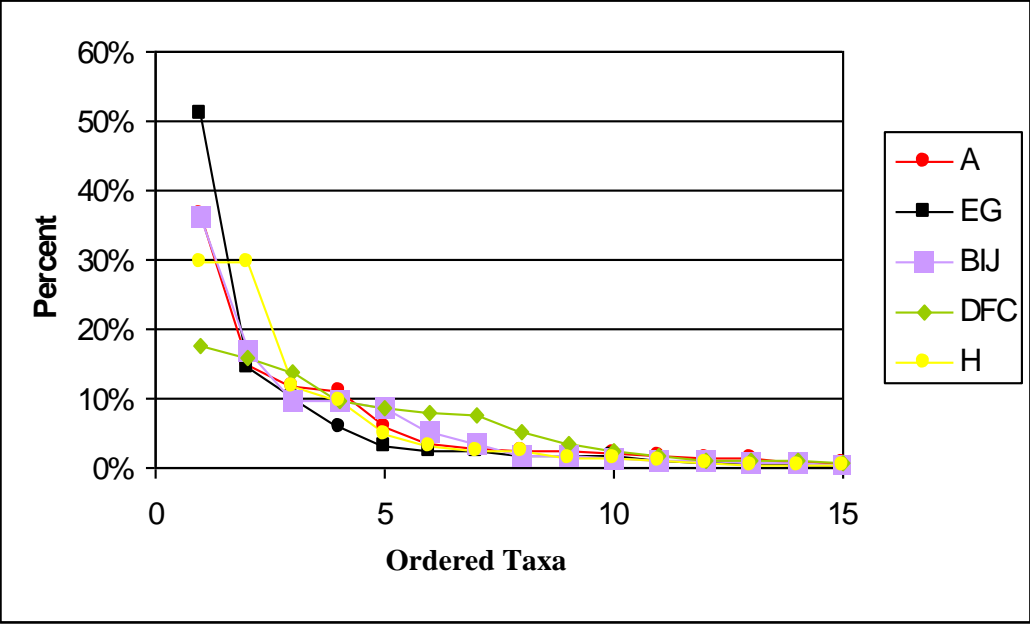
Figure 8. Percent composition of taxa in each biotope. This figure was created from data in Table 2 after sorting taxa within each biotope by percent abundance.

Appendix I: Species counts

Sample Code		A1b	A1c	A2a	A2b	A3a	A3c	A4a	A4b	A5a	A5b
Geophysical province		A	A	A	A	A	A	A	A	A	A
Station		A1	A1	A2	A2	A3	A3	A4	A4	A5	A5
Replicate		1	2	1	2	1	2	1	2	1	2
Ameroculodes species compl	Amsp										
Apocorophium lacustre	Apla	5	1	1		1	4	16		16	10
Balanus improvisus	Baim	74	81	83		33	101	24	1	70	105
Bivalvia	Bivsp										
Boccardiella ligerica	Boli	6	4	4		3	12	4		30	28
Callinectes sapidus	Casa										
Carinoma tremaphoros	Catr	1		3		1	2				2
Coelotanypus spp.	Cosp	1		1	5			11	6	2	
Crangon septemspinosa	Crse										
Crassostrea virginica	Crvi										
Cyathura polita	Cypo	5	2	2	1	4	4	18	21	2	3
Edotea triloba	Edtr										1
Gammarus daiberi	Gada										
Heteromastus filiformis	Hefi	3		8	5	2	4			2	1
Hobsonia florida	Hofl	1	2		3	1		13	17	3	
Imm. Tubificid w/o Cap. Chae	Immt										
Lepidactylus dytiscus	Ledy										
Leptocheirus plumulosus	Lepl	1			7	16	9	46	46	1	
Leucon americanus	Leam										
Littoridinops tenuipes	Lite							3			
Macoma balthica	Maba								1		
Marenzelleria viridis	Mavi	1		18	2	7	9	18	16	9	8
Melita nitida	Meni	11	3				1	1		6	1
Mulinia lateralis	Mula										
Mya arenaria	Myar										
Mytilopsis leucophaeata	Myle	7	2	2		2	5	3	2	14	11
Neanthes succinea	Nesu	40	17	19	1	7	39	6		52	47
Neomysis americana	Neam										
Oligochaeta	Olig										
Palaemonetes pugio	Papu										
Polydora cornuta	Poco										
Portunidae	Port										
Procladius spp.	Prsp										
Rangia cuneata	Racu		2		152	1	3	68	63	4	4
Rhithropanopeus harrisi	Rhha	8	4	2	1	1	6	4		6	3
Streblospio benedicti	Stbe				1						
Stylochus ellipticus	Stel										1
Synidotea laticauda	Syla										
Tubificoides spp.	Tubsp	33	16	1	43	6	19	19	9	23	36
Xanthidae	Xant										

Sample Code	B1a	B1b	B2a	B2b	B3a	B3b	B4a	B4b	B5a	B5b
Geophysical province	B	B	B	B	B	B	B	B	B	B
Station	B1	B1	B2	B2	B3	B3	B4	B4	B5	B5
Replicate	1	2	1	2	1	2	1	2	1	2
Ameroculodes species compl Amsp									1	
Apocorophium lacustre Apla	2									
Balanus improvisus Baim			21	2		7			8	
Bivalvia Bivsp										
Boccardiella ligerica Boli										
Callinectes sapidus Casa										
Carinoma tremaphoros Catr	2	1	2	2	1	3	1		3	1
Coelotanypus spp. Cosp			1	1			5	6		
Crangon septemspinosa Crse										
Crassostrea virginica Crvi										
Cyathura polita Cypo	6	1	7	15	9	5	9	14	3	13
Edotea triloba Edtr									1	
Gammarus daiberi Gada								1		
Heteromastus filiformis Hefi		1	1	3				1		1
Hobsonia florida Hofl	5		1	20	3	5	10	15	7	5
Imm. Tubificid w/o Cap. Chae Immt										
Lepidactylus dytiscus Ledy										
Leptocheirus plumulosus Lepl	31	55	19	51	49	23	41	62	38	10
Leucon americanus Leam	2									
Littoridinops tenuipes Lite	6	1		1	1			1	4	
Macoma balthica Maba										
Marenzelleria viridis Mavi	33	6	30	16	76	26	20	40	70	26
Melita nitida Meni										
Mulinia lateralis Mula										
Mya arenaria Myar										
Mytilopsis leucophaeata Myle								1		
Neanthes succinea Nesu										
Neomysis americana Neam										
Oligochaeta Olig										
Palaemonetes pugio Papu										
Polydora cornuta Poco										
Portunidae Port										
Procladius spp. Prsp										
Rangia cuneata Racu	12	2	15	28	5	5		8	131	13
Rhithropanopeus harrisi Rhha			3				1	1	2	1
Streblospio benedicti Stbe	1		1	1					1	1
Stylochus ellipticus Stel										
Synidotea laticauda Syla										
Tubificoides spp. Tubsp	2	1	14	2		1				1
Xanthidae Xant				1						

Sample Code		C1a	C1b	C2a	C2b	C3a	C3b	C4a	C4b	C5a	C5b
Geophysical province		C	C	C	C	C	C	C	C	C	C
Station		C1	C1	C2	C2	C3	C3	C4	C4	C5	C5
Replicate		1	2	1	2	1	2	1	2	1	2
Ameroculodes species complex	Amsp									1	2
Apocorophium lacustre	Apla										
Balanus improvisus	Baim				2	162	7			9	
Bivalvia	Bivsp										
Boccardiella ligerica	Boli						7	94	22		
Callinectes sapidus	Casa										
Carinoma tremaphoros	Catr	2	3	1		6	2	1	7		1
Coelotanypus spp.	Cosp	1			1					1	
Crangon septemspinosa	Crse										
Crassostrea virginica	Crvi					1					
Cyathura polita	Cypo		2	2		7	6	25	12	1	2
Edotea triloba	Edtr						1				
Gammarus daiberi	Gada										
Heteromastus filiformis	Hefi	1	2	1	1	31	14	5	2	5	10
Hobsonia florida	Hofl						3	1	2		
Imm. Tubificid w/o Cap. Chaete	Immt					2					
Lepidactylus dytiscus	Ledy										
Leptocheirus plumulosus	Lepl		1	2		2	2			3	9
Leucon americanus	Leam		1				1	2		9	16
Littoridinops tenuipes	Lite					14	4			1	
Macoma balthica	Maba	2			3		2	2		2	4
Marenzelleria viridis	Mavi	3	3	14	8	44	34	10	6	3	1
Melita nitida	Meni					5					
Mulinia lateralis	Mula										
Mya arenaria	Myar										
Mytilopsis leucophaeata	Myle					1					
Neanthes succinea	Nesu					34	1		1	1	1
Neomysis americana	Neam										
Oligochaeta	Olig										
Palaemonetes pugio	Papu										
Polydora cornuta	Poco										
Portunidae	Port										
Procladius spp.	Prsp										
Rangia cuneata	Racu	2						1	1		
Rhithropanopeus harrisi	Rhha					6				1	
Streblospio benedicti	Stbe					6	1	20	2	3	2
Stylochus ellipticus	Stel										
Synidotea laticauda	Syla					2	4				
Tubificoides spp.	Tubsp	1	1	3	5	9	2	8	4	2	
Xanthidae	Xant										

Sample Code		D1a	D1b	D2a	D2b	D3a	D3b	D4a	D4b	D5a	D5b
Geophysical province		D	D	D	D	D	D	D	D	D	D
Station		D1	D1	D2	D2	D3	D3	D4	D4	D5	D5
Replicate		1	2	1	2	1	2	1	2	1	2
Ameroculodes species complex	Amsp		1		1		2	2	1		
Apocorophium lacustre	Apla										
Balanus improvisus	Baim		2			4	2	4			1
Bivalvia	Bivsp										
Boccardiella ligerica	Boli			1							
Callinectes sapidus	Casa										
Carinoma tremaphoros	Catr	1	1	1	5	1	2	1	2	3	2
Coelotanypus spp.	Cosp					1					
Crangon septemspinosa	Crse										
Crassostrea virginica	Crvi										
Cyathura polita	Cypo	2	6	3	5	2	4		2	1	2
Edotea triloba	Edtr										
Gammarus daiberi	Gada										
Heteromastus filiformis	Hefi	3	5	3	3	4	5	5	7		1
Hobsonia florida	Hofl				1						
Imm. Tubificid w/o Cap. Chaete	Immt			1					1	1	
Lepidactylus dytiscus	Ledy										
Leptocheirus plumulosus	Lepl	5		6	4	7	7		3	4	2
Leucon americanus	Leam	7	5	1	1	7	3	2	11	14	10
Littoridinops tenuipes	Lite				1	1		1			
Macoma balthica	Maba	1				2			2	2	
Marenzelleria viridis	Mavi		1	14	8	6		3	3	5	2
Melita nitida	Meni										
Mulinia lateralis	Mula		1								
Mya arenaria	Myar										
Mytilopsis leucophaeata	Myle										
Neanthes succinea	Nesu		1					3			
Neomysis americana	Neam										
Oligochaeta	Olig										
Palaemonetes pugio	Papu										
Polydora cornuta	Poco										
Portunidae	Port										
Procladius spp.	Prsp										
Rangia cuneata	Racu						1				
Rhithropanopeus harrisi	Rhha							1			
Streblospio benedicti	Stbe	2		1	1	4	5	2	6		2
Stylochus ellipticus	Stel										
Synidotea laticauda	Syla										
Tubificoides spp.	Tubsp	6	3	6	3	5	6	1	7	2	9
Xanthidae	Xant										

Sample Code		E1a	E1b	E2a	E2c	E3a	E3b	E4a	E4b	E5a	E5b
Geophysical province		E	E	E	E	E	E	E	E	E	E
Station		E1	E1	E2	E2	E3	E3	E4	E4	E5	E5
Replicate		1	2	1	2	1	2	1	2	1	2
Ameroculodes species complex	Amsp						1				
Apocorophium lacustre	Apla			1	1		1				3
Balanus improvisus	Baim	79		155	27	48	104	5		44	21
Bivalvia	Bivsp										
Boccardiella ligerica	Boli	3		16		3		26	50		1
Callinectes sapidus	Casa			1							
Carinoma tremaphoros	Catr	4	4	5	2	1	2	3	1	2	4
Coelotanypus spp.	Cosp										
Crangon septemspinosa	Crse									1	1
Crassostrea virginica	Crvi			1		4					
Cyathura polita	Cypo	3		1	3	1		6	8	1	4
Edotea triloba	Edtr										
Gammarus daiberi	Gada										
Heteromastus filiformis	Hefi	9	3	15	16	18	7	8	3	11	13
Hobsonia florida	Hofl	1			1		1		1		
Imm. Tubificid w/o Cap. Chaete	Immt										
Lepidactylus dytiscus	Ledy					2					
Leptocheirus plumulosus	Lepl	1	7		1					1	
Leucon americanus	Leam										
Littoridinops tenuipes	Lite	2								1	1
Macoma balthica	Maba		1	1	2		1				
Marenzelleria viridis	Mavi	17	2	15	18	26	20	84	22	46	25
Melita nitida	Meni			4		2					
Mulinia lateralis	Mula										
Mya arenaria	Myar			1							1
Mytilopsis leucophaeata	Myle						2				
Neanthes succinea	Nesu	16		12	2	5	5	2	2	6	8
Neomysis americana	Neam										
Oligochaeta	Olig										
Palaemonetes pugio	Papu										
Polydora cornuta	Poco										
Portunidae	Port							1			
Procladius spp.	Prsp										
Rangia cuneata	Racu	2									
Rhithropanopeus harrisi	Rhha	1		1		1	1	2			
Streblospio benedicti	Stbe	1	1	2	5	3	17	4	8	3	2
Stylochus ellipticus	Stel						1				
Synidotea laticauda	Syla						1				1
Tubificoides spp.	Tubsp	3		6		5			2	8	
Xanthidae	Xant										

Sample Code		F1a	F1b	F2a	F2b	F3a	F3b	F4a	F4b	F5a	F5b
Geophysical province		F	F	F	F	F	F	F	F	F	F
Station		F1	F1	F2	F2	F3	F3	F4	F4	F5	F5
Replicate		1	2	1	2	1	2	1	2	1	2
Ameroculodes species complex	Amsp			1							1
Apocorophium lacustre	Apla					1					
Balanus improvisus	Baim	2					28	10	7		
Bivalvia	Bivsp										
Boccardiella ligerica	Boli										
Callinectes sapidus	Casa										
Carinoma tremaphoros	Catr	2	1	4	1	2	2	1	1	2	
Coelotanypus spp.	Cosp										
Crangon septemspinosa	Crse										
Crassostrea virginica	Crvi										
Cyathura polita	Cypo	5	6	4	7	2	15	2	6	1	18
Edotea triloba	Edtr										
Gammarus daiberi	Gada										
Heteromastus filiformis	Hefi	2	4	5	2	6	7	10	7	2	2
Hobsonia florida	Hofl		1		2	1	1	1	4		
Imm. Tubificid w/o Cap. Chaete	Immt										
Lepidactylus dytiscus	Ledy										
Leptocheirus plumulosus	Lepl	8	15	19	12		3	8	2	1	5
Leucon americanus	Leam	2	2		1				1	2	6
Littoridinops tenuipes	Lite			2	1	1	2	3			9
Macoma balthica	Maba	1			1	1		3	2	1	
Marenzelleria viridis	Mavi	9	2	8	7	28	13	16	32	5	
Melita nitida	Meni										
Mulinia lateralis	Mula										
Mya arenaria	Myar										
Mytilopsis leucophaeata	Myle							1			
Neanthes succinea	Nesu						2				
Neomysis americana	Neam										
Oligochaeta	Olig										
Palaemonetes pugio	Papu										
Polydora cornuta	Poco										
Portunidae	Port										
Procladius spp.	Prsp				1						
Rangia cuneata	Racu	1		2				1			2
Rhithropanopeus harrisi	Rhha						1				
Streblospio benedicti	Stbe	2	3	8	3		5		3		2
Stylochus ellipticus	Stel										
Synidotea laticauda	Syla										
Tubificoides spp.	Tubsp	21	7	14	7	1	20	8	4	5	10
Xanthidae	Xant										

Sample Code		G1a	G1b	G2a	G2b	G3a	G3b	G4a	G4b	G5b	G5e
Geophysical province		G	G	G	G	G	G	G	G	G	G
Station		G1	G1	G2	G2	G3	G3	G4	G4	G5	G5
Replicate		1	2	1	2	1	2	1	2	1	2
Ameroculodes species complex	Amsp					1					
Apocorophium lacustre	Apla				1			2			
Balanus improvisus	Baim	59	41	163	17	9	46		1	6	5
Bivalvia	Bivsp								1		
Boccardiella ligerica	Boli								1		
Callinectes sapidus	Casa										
Carinoma tremaphoros	Catr	1	5	5	3	3	1	1	1		1
Coelotanypus spp.	Cosp								1		
Crangon septemspinosa	Crse	1									
Crassostrea virginica	Crvi		1								
Cyathura polita	Cypo	3	1		2	2	4	2	2		
Edotea triloba	Edtr										
Gammarus daiberi	Gada										
Heteromastus filiformis	Hefi	14	4	9	7	4	2	14	7	6	5
Hobsonia florida	Hofl					1			1		
Imm. Tubificid w/o Cap. Chaete	Immt	1						1			
Lepidactylus dytiscus	Ledy										
Leptocheirus plumulosus	Lepl					7	4	3	11		
Leucon americanus	Leam	1				4	13		4		
Littoridinops tenuipes	Lite	6								2	2
Macoma balthica	Maba					1	2	1			
Marenzelleria viridis	Mavi	8	4	3		8	4	9	4	2	1
Melita nitida	Meni	1								1	3
Mulinia lateralis	Mula										
Mya arenaria	Myar										
Mytilopsis leucophaeata	Myle										
Neanthes succinea	Nesu	5	1	2		1	1	5	3	7	5
Neomysis americana	Neam										
Oligochaeta	Olig								1		
Palaemonetes pugio	Papu										
Polydora cornuta	Poco	1									
Portunidae	Port										
Procladius spp.	Prsp										
Rangia cuneata	Racu			1				2			
Rhithropanopeus harrisi	Rhha	1		1		1	1	1			
Streblospio benedicti	Stbe	8	2	1	1		6		5		1
Stylochus ellipticus	Stel										
Synidotea laticauda	Syla					18	1	1			
Tubificoides spp.	Tubsp	5	1	2		18	9		10	2	4
Xanthidae	Xant										

Sample Code	H1a	H1b	H2a	H2b	H3a	H3b	H4a	H4b	H5a	H5b
Geophysical province	H	H	H	H	H	H	H	H	H	H
Station	H1	H1	H2	H2	H3	H3	H4	H4	H5	H5
Replicate	1	2	1	2	1	2	1	2	1	2
Ameroculodes species complex — Amsp		1			1			1		
Apocorophium lacustre — Apla						3				
Balanus improvisus — Baim		1				16	27	11	5	
Bivalvia — Bivsp										
Boccardiella ligerica — Boli	57	12		7	42	17	3		1	
Callinectes sapidus — Casa										
Carinoma tremaphoros — Catr	1		1	4		2	1	2	3	4
Coelotanypus spp. — Cosp	1									
Crangon septemspinosa — Crse		1				1				
Crassostrea virginica — Crvi										
Cyathura polita — Cypo	7	3	6	7	5	8	4	2	11	8
Edotea triloba — Edtr										
Gammarus daiberi — Gada										
Heteromastus filiformis — Hefi	3	4	3	2	5	8	4	6	3	6
Hobsonia florida — Hofl			2		1	1			2	
Imm. Tubificid w/o Cap. Chaete — Immt							2			
Lepidactylus dytiscus — Ledy										
Leptocheirus plumulosus — Lepl	2	4	1		5	1	3	4		1
Leucon americanus — Leam							2	1		
Littoridinops tenuipes — Lite					1	1		1	1	
Macoma balthica — Maba	1	3	1	2	1	2	2		2	
Marenzelleria viridis — Mavi	12	15	18	10	54	23	2	10	56	19
Melita nitida — Meni										
Mulinia lateralis — Mula										
Mya arenaria — Myar										
Mytilopsis leucophaeata — Myle										
Neanthes succinea — Nesu	2	1						1		
Neomysis americana — Neam						1				
Oligochaeta — Olig										
Palaemonetes pugio — Papu										
Polydora cornuta — Poco										
Portunidae — Port										
Procladius spp. — Prsp										
Rangia cuneata — Racu	1					1				
Rhithropanopeus harrisi — Rhha		1				1			1	
Streblospio benedicti — Stbe	3	14	12	2	21	21	9	6	11	10
Stylochus ellipticus — Stel										
Synidotea laticauda — Syla			1					1		
Tubificoides spp. — Tubsp	1	3		5		7	5	7	3	2
Xanthidae — Xant										

Sample Code		I1a	I1b	I2a	I2b	I3a	I3b	I4a	I4b	I5a	I5b
Geophysical province		I	I	I	I	I	I	I	I	I	I
Station		I1	I1	I2	I2	I3	I3	I4	I4	I5	I5
Replicate		1	2	1	2	1	2	1	2	1	2
Ameroculodes species complex	Amsp					2		1			
Apocorophium lacustre	Apla										1
Balanus improvisus	Baim									8	
Bivalvia	Bivsp										
Boccardiella ligerica	Boli										
Callinectes sapidus	Casa										
Carinoma tremaphoros	Catr	1		4	4	1	3	2	1		3
Coelotanypus spp.	Cosp			2		2				4	1
Crangon septemspinosa	Crse									1	
Crassostrea virginica	Crvi										
Cyathura polita	Cypo	2	3	15	7	3	3	11	5	6	12
Edotea triloba	Edtr										
Gammarus daiberi	Gada										
Heteromastus filiformis	Hefi	3	5	3	6	2	4	2	4	1	2
Hobsonia florida	Hofl	2	4	3	2			1		8	15
Imm. Tubificid w/o Cap. Chaete	Immt										
Lepidactylus dytiscus	Ledy										
Leptocheirus plumulosus	Lepl	58	34	21	24	17	37	57	46	103	154
Leucon americanus	Leam										
Littoridinops tenuipes	Lite	5	4	6	3	6	4	3	7	9	20
Macoma balthica	Maba	3	4	1	3	1	4	3	1	2	1
Marenzelleria viridis	Mavi	4	11	20	8	26	5	20	11	24	9
Melita nitida	Meni										
Mulinia lateralis	Mula										
Mya arenaria	Myar										
Mytilopsis leucophaeata	Myle										
Neanthes succinea	Nesu										
Neomysis americana	Neam										
Oligochaeta	Olig										
Palaemonetes pugio	Papu										
Polydora cornuta	Poco										
Portunidae	Port										
Procladius spp.	Prsp										
Rangia cuneata	Racu	1					1	1	1	4	2
Rhithropanopeus harrisi	Rhha									8	5
Streblospio benedicti	Stbe			2	2			2	1	1	5
Stylochus ellipticus	Stel									2	1
Synidotea laticauda	Syla									6	
Tubificoides spp.	Tubsp	4	1	1	1	1	3	8	10	42	64
Xanthidae	Xant										

Sample Code		J1a	J1b	J2a	J2b	J3a	J3b	J4a	J4b	J5a	J5b
Geophysical province		J	J	J	J	J	J	J	J	J	J
Station		J1	J1	J2	J2	J3	J3	J4	J4	J5	J5
Replicate		1	2	1	2	1	2	1	2	1	2
Ameroculodes species complex	Amsp		2						1		
Apocorophium lacustre	Apla									1	
Balanus improvisus	Baim		3			1					
Bivalvia	Bivsp										
Boccardiella ligerica	Boli										
Callinectes sapidus	Casa										
Carinoma tremaphoros	Catr			1		3	4	3	3	2	2
Coelotanypus spp.	Cosp	2	1	1	2		3			2	3
Crangon septemspinosa	Crse										
Crassostrea virginica	Crvi										
Cyathura polita	Cypo	47	26	12	11	9	52	10	11	7	7
Edotea triloba	Edtr									2	1
Gammarus daiberi	Gada										
Heteromastus filiformis	Hefi	6	1		1	5	6	4	4	3	4
Hobsonia florida	Hofl	12	11	19	14	5	12			3	1
Imm. Tubificid w/o Cap. Chaete	Immt							2	1		
Lepidactylus dytiscus	Ledy										
Leptocheirus plumulosus	Lepl	67	70	79	49	67	91	44	76	29	41
Leucon americanus	Leam							4	1		
Littoridinops tenuipes	Lite	2		6	7	1	1	4	4	25	19
Macoma balthica	Maba		1				1	2	4	2	2
Marenzelleria viridis	Mavi	57	26	11	8	36	40	6	5	4	10
Melita nitida	Meni			2	1						
Mulinia lateralis	Mula										
Mya arenaria	Myar										
Mytilopsis leucophaeata	Myle										
Neanthes succinea	Nesu										
Neomysis americana	Neam										
Oligochaeta	Olig										
Palaemonetes pugio	Papu			1							
Polydora cornuta	Poco										
Portunidae	Port										
Procladius spp.	Prsp										1
Rangia cuneata	Racu	3	2	9	4	7	9	3	3	4	6
Rhithropanopeus harrisi	Rhha	1	2	6	5	4	2				2
Streblospio benedicti	Stbe	5	5			3	1	3	4		
Stylochus ellipticus	Stel										
Synidotea laticauda	Syla										
Tubificoides spp.	Tubsp	11	34	76	50	14	18	40	61	3	17
Xanthidae	Xant										

Appendix II: Sample positions

Geophysical Province A	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	A1	A1b	1	8/20/2001	18:48	41	5.88	-73	-54.46
	A1	A1c	2	8/20/2001	18:59	41	5.88	-73	-54.47
	A2	A2a	1	8/21/2001	8:51	41	6.15	-73	-53.49
	A2	A2b	2	8/21/2001	8:54	41	6.15	-73	-53.49
	A3	A3a	1	8/21/2001	8:30	41	5.94	-73	-53.97
	A3	A3c	2	8/21/2001	8:41	41	5.94	-73	-53.97
	A4	A4a	1	8/21/2001	9:23	41	6.88	-73	-54.38
	A4	A4b	2	8/21/2001	9:26	41	6.88	-73	-54.38
	A5	A5a	1	8/21/2001	9:44	41	6.75	-73	-53.81
	A5	A5b	2	8/21/2001	9:47	41	6.75	-73	-53.81
Geophysical Province B	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	B1	B1a	1	8/20/2001	16:22	41	5.80	-73	-53.47
	B1	B1b	2	8/20/2001	16:41	41	5.82	-73	-53.48
	B2	B2a	1	8/20/2001	17:21	41	5.59	-73	-54.30
	B2	B2b	2	8/20/2001	17:34	41	5.59	-73	-54.30
	B3	B3a	1	8/20/2001	16:57	41	5.71	-73	-53.94
	B3	B3b	2	8/20/2001	17:08	41	5.71	-73	-53.94
	B4	B4a	1	8/20/2001	18:17	41	6.62	-73	-54.70
	B4	B4b	2	8/20/2001	18:28	41	6.62	-73	-54.71
	B5	B5a	1	8/20/2001	17:53	41	6.12	-73	-53.71
	B5	B5b	2	8/20/2001	18:04	41	6.12	-73	-53.71
Geophysical Province C	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	C1	C1a	1	8/21/2001	10:49	41	6.59	-73	-53.30
	C1	C1b	2	8/21/2001	10:53	41	6.59	-73	-53.29
	C2	C2a	1	8/21/2001	10:21	41	7.18	-73	-53.39
	C2	C2b	2	8/21/2001	10:26	41	7.18	-73	-53.39
	C3	C3a	1	8/21/2001	11:16	41	6.09	-73	-53.18
	C3	C3b	2	8/21/2001	11:19	41	6.09	-73	-53.17
	C4	C4a	1	8/22/2001	15:15	41	6.82	-73	-52.62
	C4	C4b	2	8/22/2001	15:20	41	6.82	-73	-52.62
	C5	C5a	1	8/22/2001	8:40	41	5.38	-73	-52.72
	C5	C5b	2	8/22/2001	8:44	41	5.38	-73	-52.72

Geophysical Province D	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	D1	D1a	1	8/21/2001	15:44	41	6.09	-73	-53.06
	D1	D1b	2	8/21/2001	15:49	41	6.09	-73	-53.05
	D2	D2a	1	8/21/2001	14:30	41	5.92	-73	-53.05
	D2	D2b	2	8/21/2001	14:34	41	5.92	-73	-53.05
	D3	D3a	1	8/21/2001	16:39	41	6.26	-73	-53.02
	D3	D3b	2	8/21/2001	16:43	41	6.26	-73	-53.02
	D4	D4a	1	8/21/2001	16:17	41	6.18	-73	-53.02
	D4	D4b	2	8/21/2001	16:22	41	6.18	-73	-53.02
	D5	D5a	1	8/21/2001	14:59	41	5.98	-73	-53.06
	D5	D5b	2	8/21/2001	15:03	41	5.98	-73	-53.05
Geophysical Province E	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	E1	E1a	1	8/21/2001	12:02	41	5.35	-73	-52.99
	E1	E1b	2	8/21/2001	12:06	41	5.35	-73	-52.99
	E2	E2a	1	8/21/2001	12:31	41	5.44	-73	-52.92
	E2	E2c	2	8/21/2001	12:39	41	5.44	-73	-52.93
	E3	E3a	1	8/21/2001	13:31	41	5.77	-73	-52.91
	E3	E3b	2	8/21/2001	13:35	41	5.77	-73	-52.91
	E4	E4a	1	8/21/2001	13:52	41	5.80	-73	-52.92
	E4	E4b	2	8/21/2001	13:57	41	5.80	-73	-52.91
	E5	E5a	1	8/21/2001	13:04	41	5.51	-73	-52.93
	E5	E5b	2	8/21/2001	13:08	41	5.51	-73	-52.92
Geophysical Province F	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	F1	F1a	1	8/22/2001	16:24	41	7.06	-73	-52.93
	F1	F1b	2	8/22/2001	16:27	41	7.06	-73	-52.93
	F2	F2a	1	8/22/2001	17:51	41	7.23	-73	-52.92
	F2	F2b	2	8/22/2001	17:54	41	7.23	-73	-52.92
	F3	F3a	1	8/22/2001	17:29	41	7.28	-73	-52.87
	F3	F3b	2	8/22/2001	17:34	41	7.28	-73	-52.86
	F4	F4a	1	8/22/2001	14:25	41	6.70	-73	-52.93
	F4	F4b	2	8/22/2001	14:32	41	6.70	-73	-52.93
	F5	F5a	1	8/22/2001	18:11	41	7.27	-73	-52.96
	F5	F5b	2	8/22/2001	18:15	41	7.27	-73	-52.96

Geophysical Province G	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	G1	G1a	1	8/21/2001	17:03	41	6.32	-73	-52.80
	G1	G1b	2	8/21/2001	17:06	41	6.32	-73	-52.80
	G2	G2a	1	8/22/2001	13:59	41	6.66	-73	-52.76
	G2	G2b	2	8/22/2001	14:04	41	6.66	-73	-52.76
	G3	G3a	1	8/22/2001	16:00	41	7.08	-73	-52.76
	G3	G3b	2	8/22/2001	16:05	41	7.08	-73	-52.76
	G4	G4a	1	8/22/2001	14:50	41	6.78	-73	-52.85
	G4	G4b	2	8/22/2001	14:55	41	6.78	-73	-52.84
	G5	G5b	1	8/22/2001	12:46	41	5.98	-73	-52.80
	G5	G5e	2	8/22/2001	12:55	41	5.98	-73	-52.80
Geophysical Province H	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	H1	H1a	1	8/21/2001	17:51	41	6.24	-73	-52.70
	H1	H1b	2	8/21/2001	17:56	41	6.24	-73	-52.70
	H2	H2a	1	8/22/2001	15:37	41	7.02	-73	-52.68
	H2	H2b	2	8/22/2001	15:42	41	7.02	-73	-52.68
	H3	H3a	1	8/21/2001	17:26	41	6.28	-73	-52.70
	H3	H3b	2	8/21/2001	17:30	41	6.28	-73	-52.70
	H4	H4a	1	8/22/2001	11:44	41	5.75	-73	-52.74
	H4	H4b	2	8/22/2001	11:51	41	5.76	-73	-52.74
	H5	H5a	1	8/22/2001	17:08	41	7.27	-73	-52.70
	H5	H5b	2	8/22/2001	17:14	41	7.27	-73	-52.70
Geophysical Province I	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	I1	I1a	1	8/21/2001	18:17	41	6.15	-73	-52.51
	I1	I1b	2	8/21/2001	18:20	41	6.15	-73	-52.51
	I2	I2a	1	8/22/2001	13:28	41	6.43	-73	-52.54
	I2	I2b	2	8/22/2001	13:34	41	6.43	-73	-52.54
	I3	I3a	1	8/21/2001	18:41	41	6.06	-73	-52.54
	I3	I3b	2	8/21/2001	18:47	41	6.06	-73	-52.54
	I4	I4a	1	8/22/2001	12:11	41	5.92	-73	-52.53
	I4	I4b	2	8/22/2001	12:16	41	5.92	-73	-52.53
	I5	I5a	1	8/22/2001	16:46	41	7.28	-73	-52.50
	I5	I5b	2	8/22/2001	16:51	41	7.28	-73	-52.50

Geophysical Province J	Station	Sample	Replicate	Date	Local time	Degrees Latitude	dec.minutes	Degrees Longitude	dec.minutes
	J1	J1a	1	8/22/2001	9:39	41	5.40	-73	-52.44
	J1	J1b	2	8/22/2001	9:44	41	5.40	-73	-52.44
	J2	J2a	1	8/22/2001	10:06	41	5.40	-73	-52.35
	J2	J2b	2	8/22/2001	10:10	41	5.40	-73	-52.35
	J3	J3a	1	8/22/2001	10:41	41	5.55	-73	-52.47
	J3	J3b	2	8/22/2001	10:45	41	5.55	-73	-52.47
	J4	J4a	1	8/22/2001	9:05	41	5.41	-73	-52.55
	J4	J4b	2	8/22/2001	9:09	41	5.41	-73	-52.55
	J5	J5a	1	8/22/2001	11:11	41	5.55	-73	-52.52
	J5	J5b	2	8/22/2001	11:16	41	5.55	-73	-52.52