# Tampa Bay Benthic Monitoring Program: Status of Middle Tampa Bay: 1993-1998


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# Environmental Protection Commission of Hillsborough County

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# INTRODUCTION

The Environmental Protection Commission of Hillsborough County (EPCHC) has been collecting samples in Middle Tampa Bay 1993 as part of the bay-wide benthic monitoring program developed to (Tampa Bay National Estuary Program 1996). The original objectives of this program were to discern the “health”—or “status”-- of the bay’s sediments by developing a Benthic Index for Tampa Bay as well as evaluating sediment quality by means of Sediment Quality Assessment Guidelines (SQAGs). The Tampa Bay Estuary Program provided partial support for this monitoring.

This report summarizes data collected during 1993-1998 from the Middle Tampa Bay segment of Tampa Bay.

# METHODS

***<u>Field Collection and Laboratory Procedures</u>***: A total of 127 stations (20 to 24 per year) were sampled during late summer/early fall "Index Period" 1993-1998 (Appendix A). Sample locations were randomly selected from computer- generated coordinates. Benthic samples were collected using a Young grab sampler following the field protocols outlined in Courtney *et al*. (1993). Laboratory procedures followed the protocols set forth in Courtney *et al*. (1995).

***<u>Data Analysis</u>***: Species richness, Shannon-Wiener diversity, and Evenness were calculated using PISCES Conservation Ltd.'s (2001) "Species Diversity and Richness II" software. Descriptive statistics, the Tampa Bay Benthic Index (TBBI), regression analysis, the Kolmogorov-Smirnov "two-sample" test was to compare frequency distributions (by year), and graphs generated using SYSTAT 10 (SSPS Inc. 2000). Sediment status was assessed by comparing measured concentrations with the Predicted Effects Level (PEL) developed for Florida sediments by McDonald Environmental Sciences Ltd. (1994). A composite PEL quotient (based upon PAHs, PCBs and metals) >0.34 and TBBI scores <4.6 were considered to be "degraded"—*i.e*., having a high likelihood of being associated with toxic sediments (MacDonald *et al*. 2002). Maps were generated using GIS Arcview ver. 3.2 (ESRI 1999).

Principal Components Analysis (PCA) was used to examine the resemblance of the Middle Tampa Bay sites, by year, based on normalized hydrographic (temperature, salinity, dissolved oxygen) and sediment (%SC) variables. The objective of this ordination is to reduce the multiple variables into a lower dimensional (2) "map" based upon the percentage of the total variance explained (principal component) (Clarke and Warwick 2001) "Bubble plots" were superimposed over the ordination diagram representing the variables with the highest "loading" (*i.e*., the "importance" of a particular variable to that PC; Johnson and Wichern 1988) in the first two PCs to facilitate interpretation of the ordination.

Non-metric Multidimensional Scaling (MDS) is another ordination technique in which rank similarities of a large number of variables are expressed as a two-dimensional map (Clarke and Warwick 2001). Taxa abundances were fourth root transformed n+0.1; the similarity coefficient was Bray-Curtis. Bubble plots" were superimposed over the MDS projection representing selected taxa and physico-chemical variables to facilitate interpretation of the MDS analysis.

Numerical classification analysis was used to evaluate the structure of the benthic community (site x year and taxa). The site x year structure was evaluated using fourth root transformed n+0.1 abundances (all taxa). Taxa were analyzed using the 50 most abundant taxa (standardized densities). The similarity measure was Bray-Curtis and the clustering algorithm was "group average". Primer's (PRIMER-E Ltd. 2001) SIMPER program was used to rank the various taxa's contribution to the dissimilarity between identified clusters.

Primer's (PRIMER-E Ltd. 2001) BIO-ENV program was used to determine the association (weighted Spearman rank correlation) between the benthic community similarity matrix (fourth root transformed n+0.1 abundances; Bray-Curtis similarity) and selected physical (depth, %SC), hydrographic (temperature, DO, salinity), and contaminant variables (total PAHs, total PCBs, chlordane, DDT, Ag, As, Cd, Cr, Cu, Ni, Pb, Sn, Zn) ($Log_{10}$ (x+1) transformed and standardized; normalized Euclidean distance) for the 1995-1998 data (Clarke and Ainsworth 1993).

# RESULTS

***Hydrographic***: Table 1 summarizes the surface and bottom water quality measures, including temperature, salinity, dissolved oxygen (DO) and pH, as well as sample depth for the 104 stations sampled. Median sample depth was >3.5-m, although depths ranged to >11-m (Figure 1) near in the shipping channel approximately mid-way between Apollo Beach and the Interbay peninsula.

**Table 1. Summary of Mean Physicochemical Variables: Middle Tampa Bay, 1993-1998**

**SURFACE**

| | Temperature ($^o$ C) | Salinity (ppt) | Dissolved Oxygen (ppm) | pH ( units) |
|---|---|---|---|---|
| **Minimum** | 26.5 | 4.4 | 2.9 | 7.26 |
| **Maximum** | 39.2 | 31.6 | 9.3 | 8.46 |
| **Median** | 29.0 | 26.1 | 6.0 | 7.94 |
| **Mean** | 29.1 | 25.1 | 5.9 | 7.96 |

**BOTTOM**

| | Depth (meters) | Temperature ($^o$ C) | Salinity (ppt) | Dissolved Oxygen (ppm) | pH ( units) |
|---|---|---|---|---|---|
| **Minimum** | 0.1 | 26.7 | 8.2 | 0.3 | 7.25 |
| **Maximum** | 11.1 | 39.2 | 32.0 | 9.6 | 8.44 |
| **Median** | 3.7 | 28.9 | 26.6 | 5.2 | 7.90 |
| **Mean** | 3.6 | 28.9 | 25.5 | 5.4 | 7.93 |

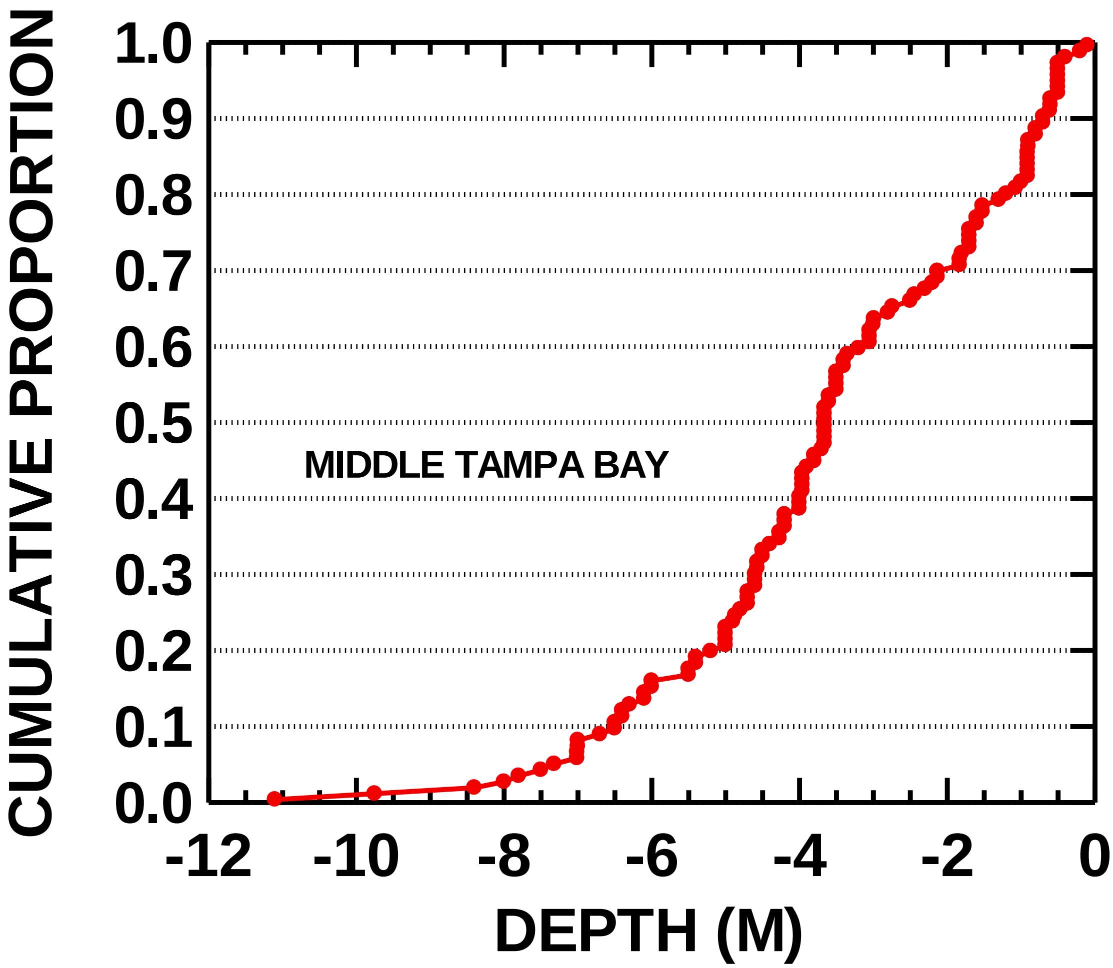


**Figure 1. CDF plot of sample depths in Middle Tampa Bay, 1993-1998 inclusive**.

The temperature-salinity plot suggests that the near-bottom water mass characteristics differed among years (Figure 2). Highest water temperatures were observed during 1993, 1996, and 1996 (Figure 3). The frequency distribution of water temperatures during these three years differed from those of 1997 and 1998 (KS test $p<0.05$).

Salinities were generally highest in 1997 and lowest during the 1995 (Figure 4). The frequency distributions of near-bottom salinity were similar during 1993 and 1996 as well as during 1998 and 1994 (KS test $p>0.05$). Salinities were rarely within either the mesohaline or euhaline zones.

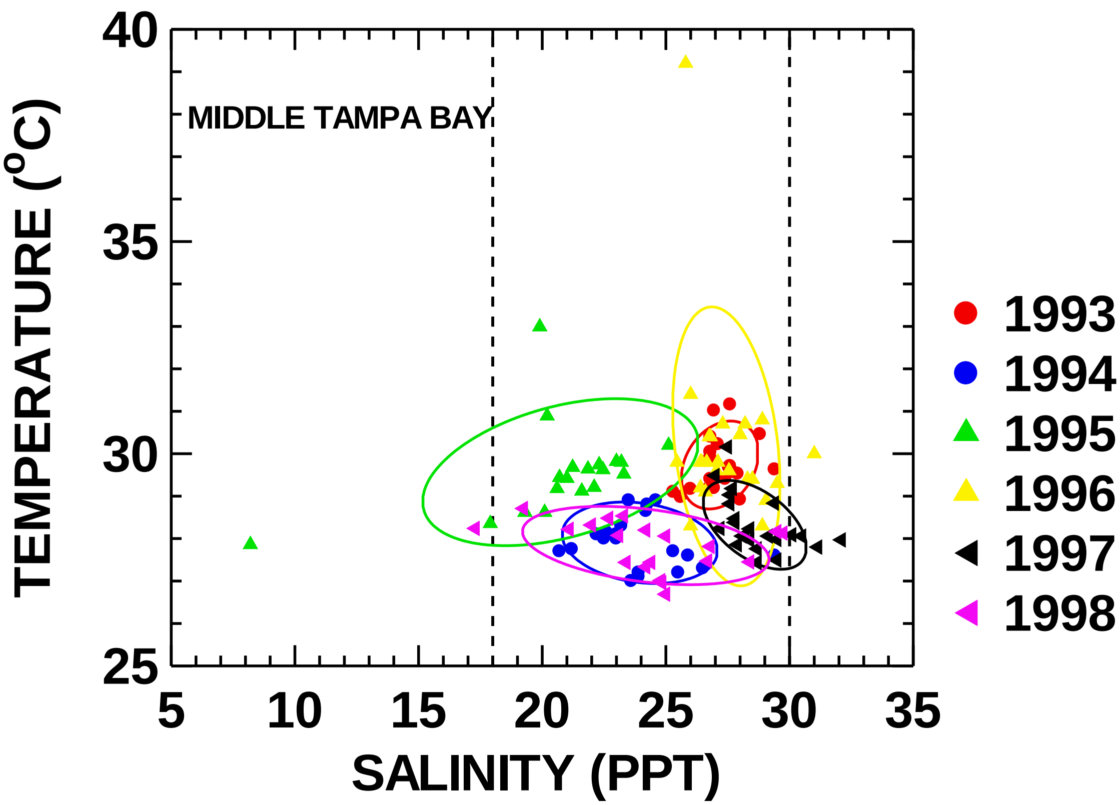


**Figure 2. Temperature-salinity plot, by year, Middle Tampa Bay 1993-1998. Ellipses embrace +-1S.D. within each year**.

Near-bottom dissolved oxygen concentrations were generally >4 ppm (Figure 5). In any year <20% of samples had concentrations <4 ppm and there was only a single observation <2 ppm (Figure 6). The lone hypoxic site was found in northeastern North Apollo Bay. The frequency distribution of near-bottom DO during 1996 differed all other years except 1994 (KS test $p$<0.05).

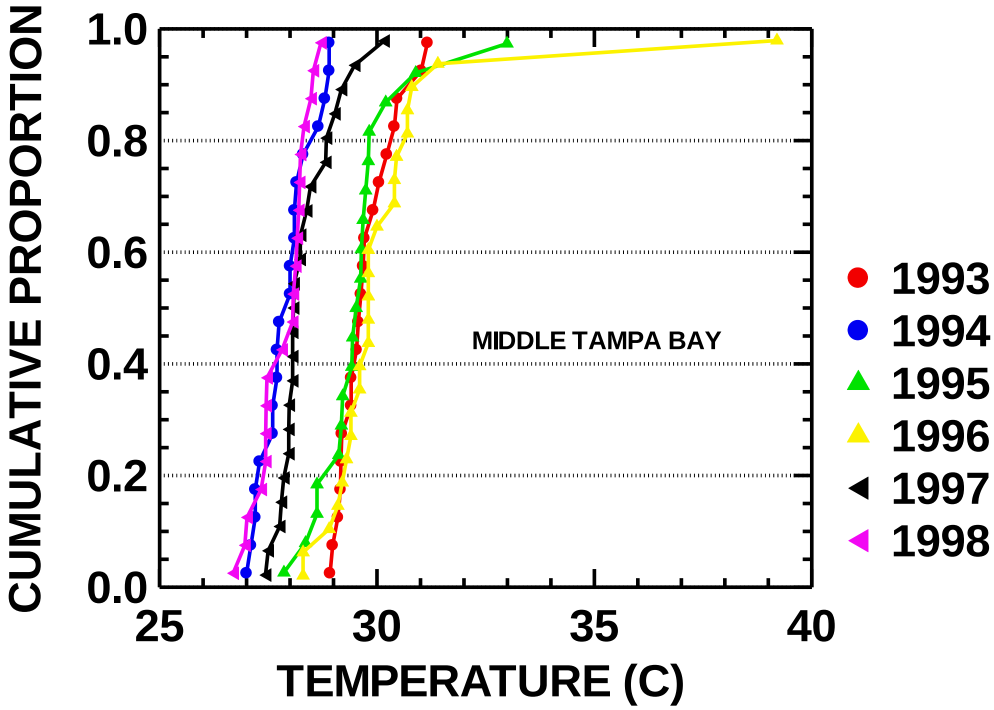


**Figure 3 CDF plot of near-bottom temperatures in Middle Tampa Bay, by year 1993-1998.**

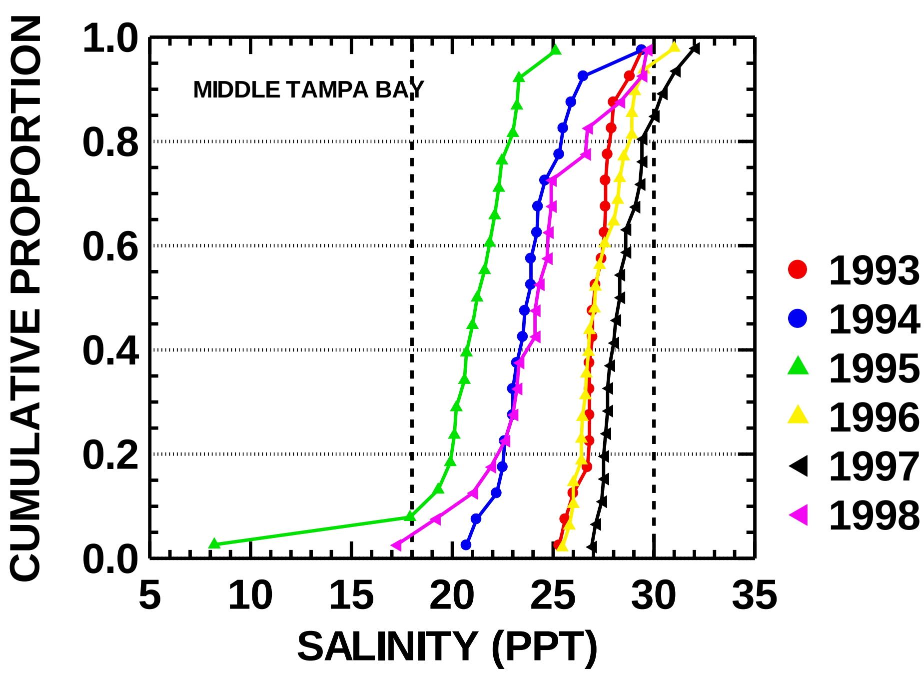


**Figure 4. CDF plot of near-bottom salinities in Middle Tampa Bay, by year 1993-1998.**

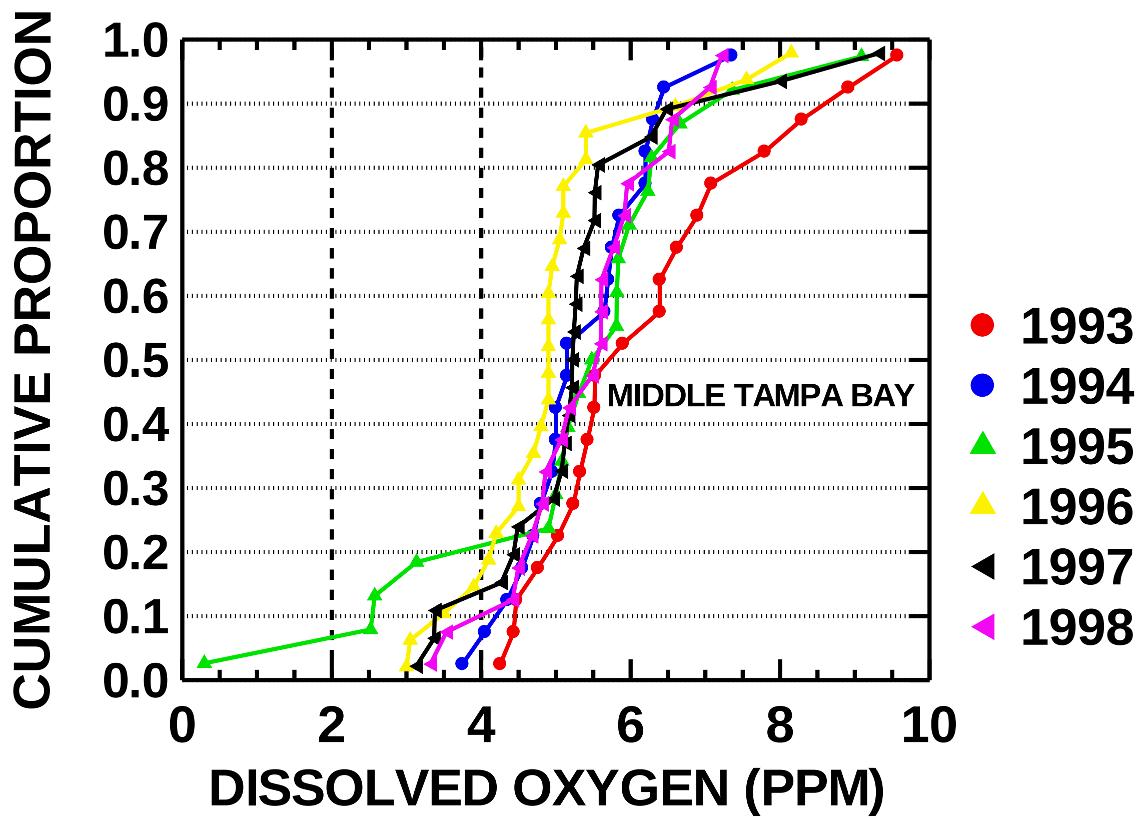


**Figure 5. CDF plot of dissolved oxygen concentration in Middle Tampa Bay, 1993-1998, by year.**

***Sediment Characteristics***: Sandy sediments (<25.95 %SC), especially medium sands, predominate in Middle Tampa Bay (Figures 8 and 9). Muddy sediments are located proximate to shipping channels and near the big Bend/Apollo Beach canal system (Figure 9).

The apparent RPD ranged from 0 to >100 mm (Figure 10). An RPD>50-mm, indicative of aerobic sediments, was observed in >50% of the samples wheras in approximately 30% of the samples the RPD was <10-mm, indicative of anaerobic sediments. RPD was negatively correlated with %SC (Figure 11) and positively correlated with DO (Figure 12).

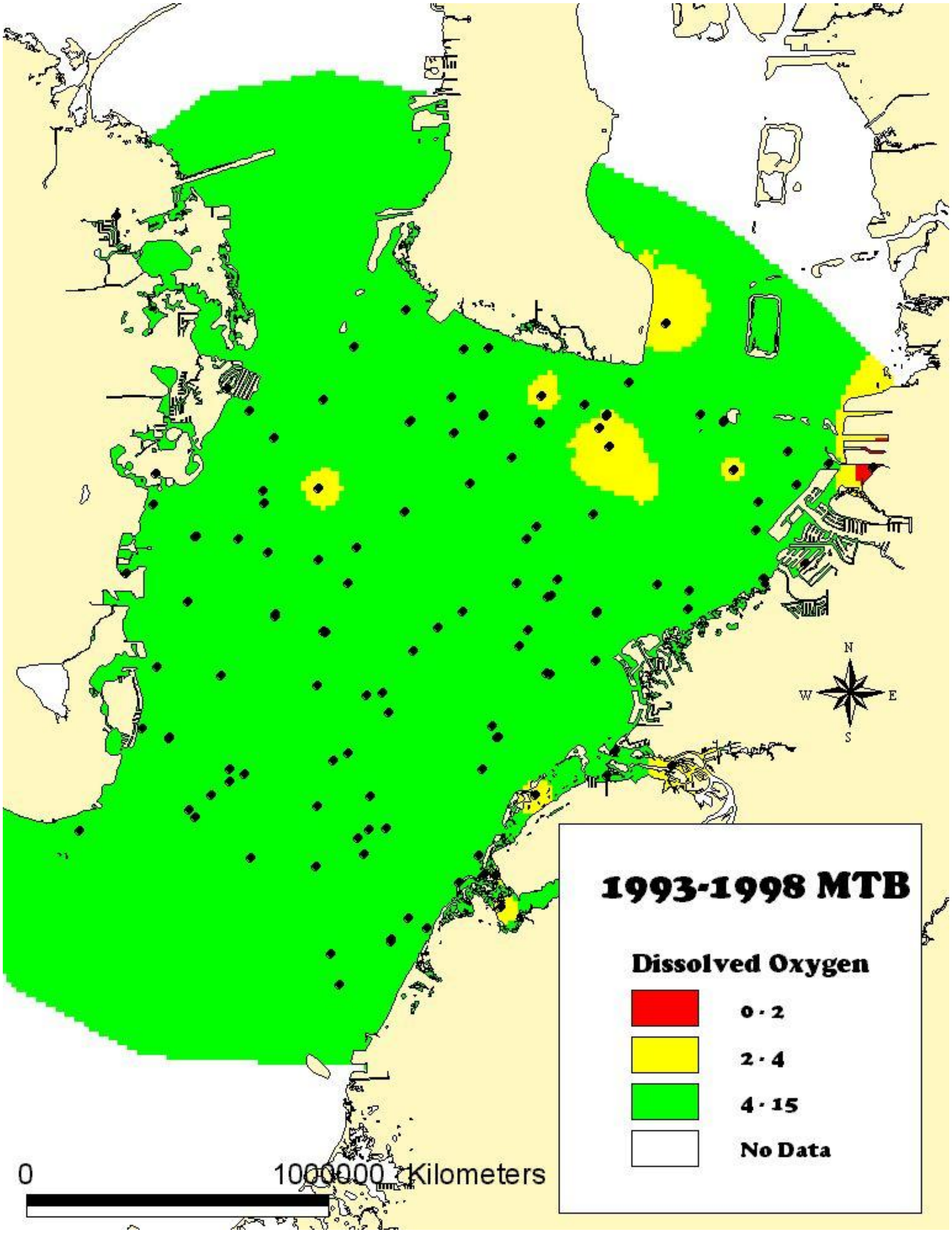


**Figure 6. Near-bottom dissolved oxygen concentrations in Middle Tampa Bay, 1993-1998.**

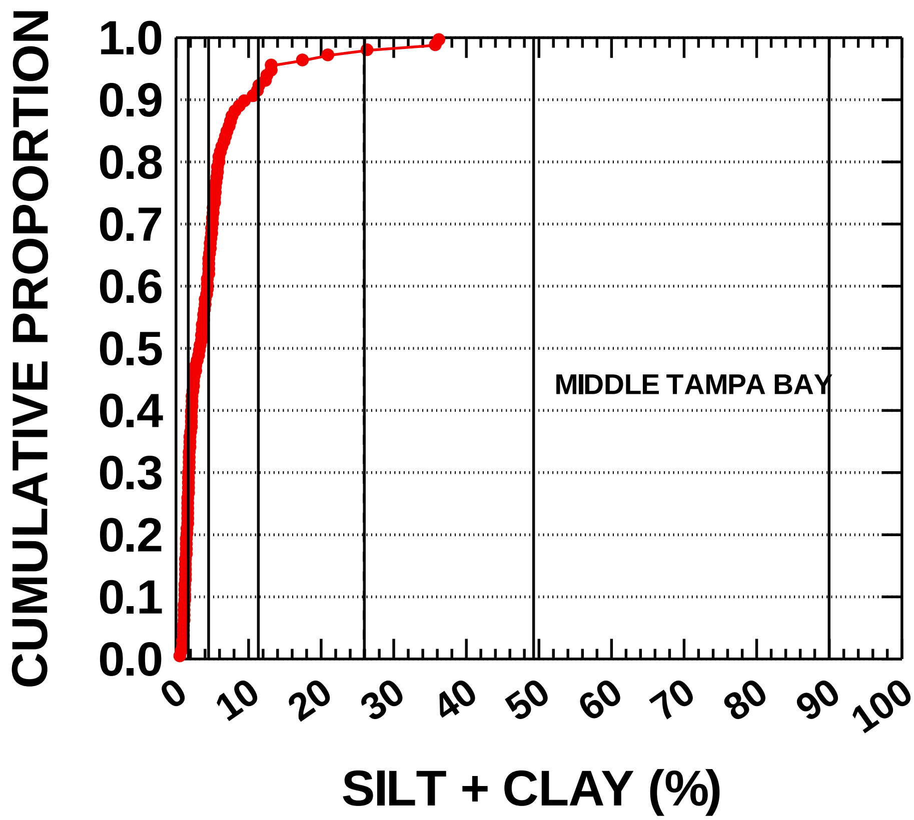


**Figure 7. CDF plot of %SC in Middle Tampa Bay sediments, 1993-1998 inclusive. Vertical lines demarcate sediment types: coarse sand (<1.70% SC), medium sand (4.51 %SC), fine sand (11.35%SC), very fine sand (25.95%SC), coarse silt (49.28%SC), medium silt (89.98%SC), and fine silt (>89.98%).**

***Principal Components Analysis (PCA) of Hydrographic and Site Characteristics:***

PCA showed that the first two PCs explained almost 60% of the overall variation in Middle Tampa Bay hydrography and site characteristics (Table 2). The highest loadings (Table 2-B) in PC1 were for %SC and sample depth. %SC generally increased with depth (Figure 12). Salinity and DO had the highest loadings in PC2, with highest DO tending to occur with highest salinities (Figure 12).

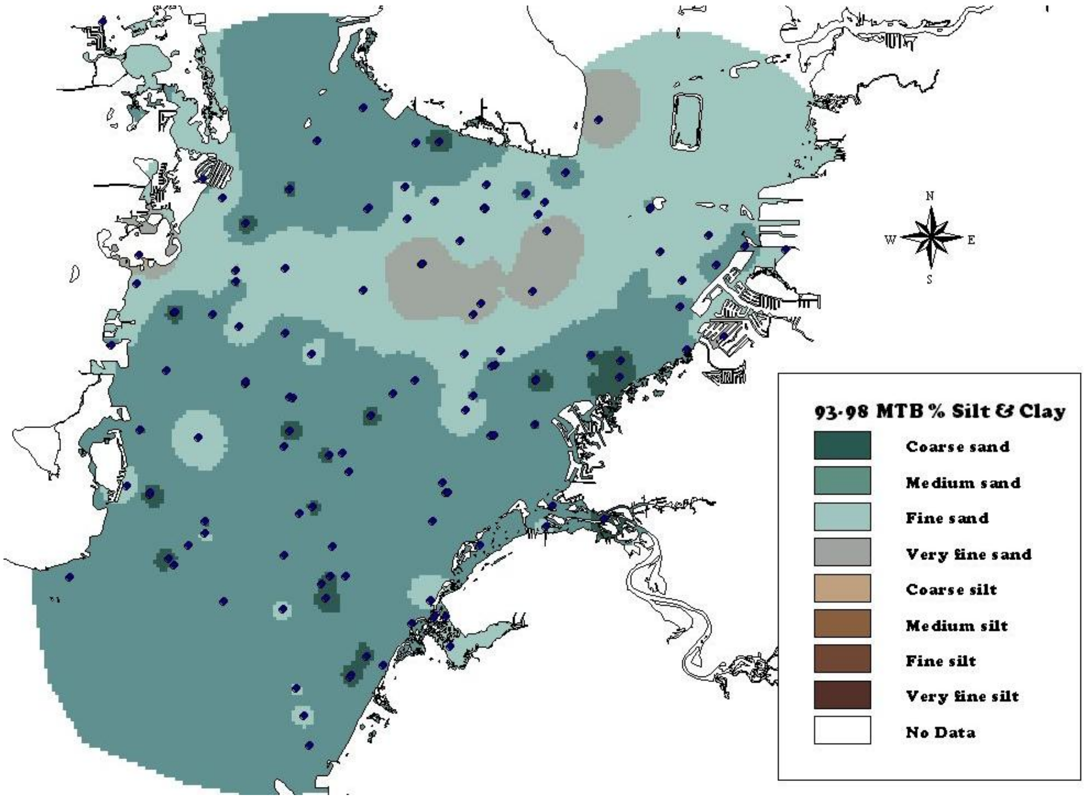


**Figure 8. Map depicting the distribution of sediment types in Middle Tampa Bay, 1993-1998.**

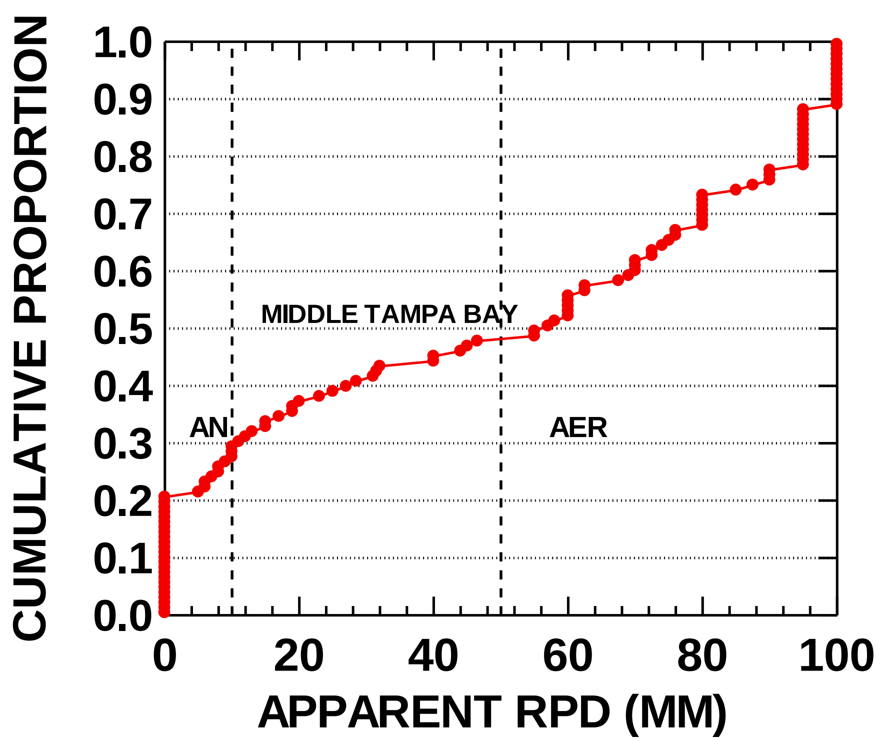

**Figure 9. CDF of apparent RPD in Middle Tampa Bay, 1993-1999. AN=anaerobic sediments; AER=aerobic sediments.**

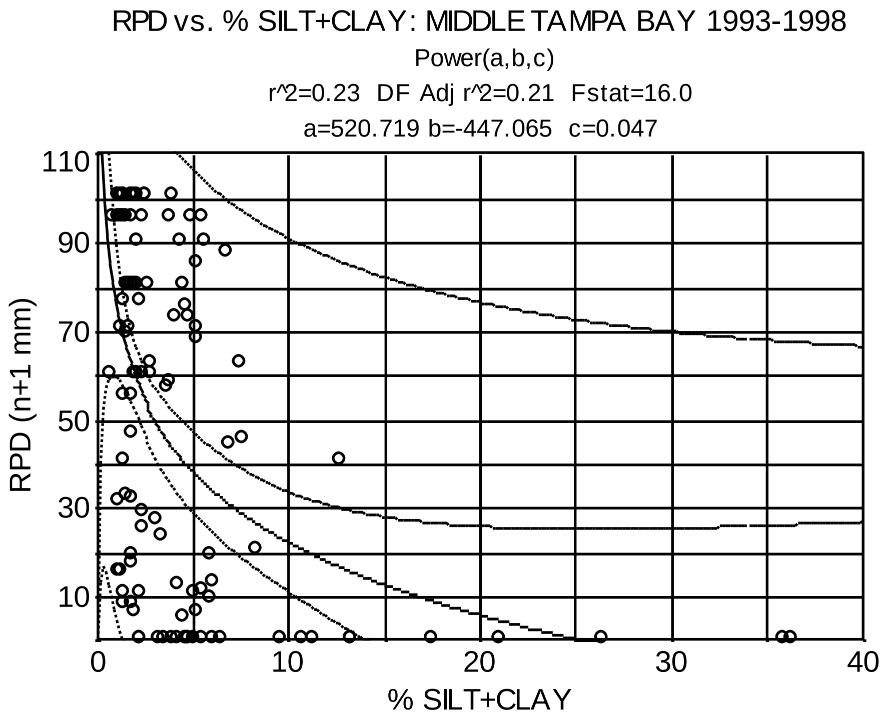


**Figure 10. Association between apparent RPD and %SC in Middle Tampa Bay, 1993-1998.**

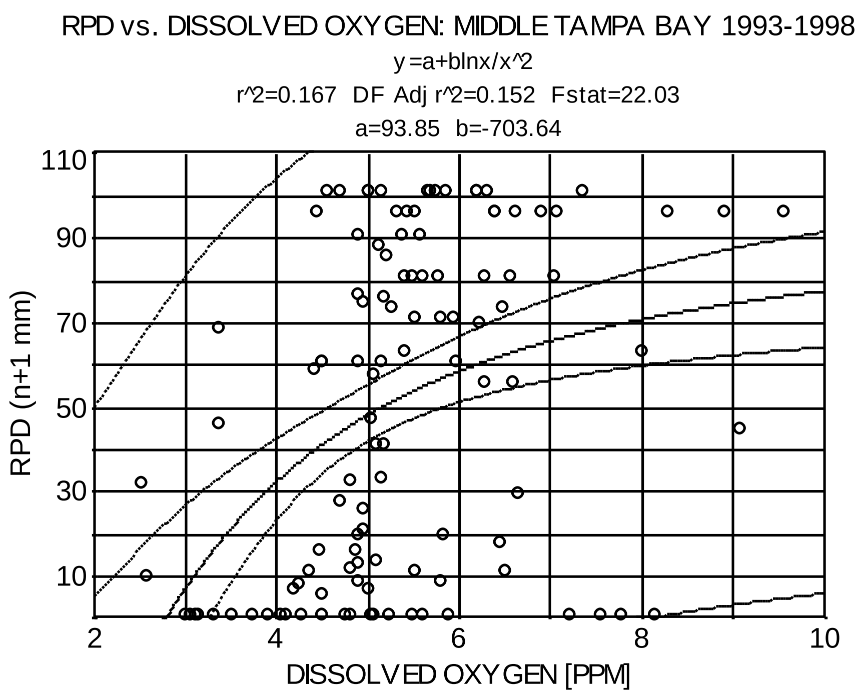


**Figure 12. Association between apparent RPD and near-bottom dissolved oxygen, Middle Tampa Bay, 1993-1998.**

**Table 2. Summary of PCA for hydrographic and site variables, Middle Tampa Bay 1993-1998**

**A. PEARSON CORRELATION MATRIX (*p*)**

| | **D.O.** | **% SILT+CLAY** | **SALINITY** | **DEPTH** |
|---|---|---|---|---|
| **D.O.** | -- | | | |
| **% SILT + CLAY** | -0.35 (<0.001) | -- | | |
| **SALINITY** | 0.10 (0.26) | 0.14 (0.13) | -- | |
| **DEPTH** | -0.24 (<0.01) | 0.34 (<0.001) | 0.38 (<0.001) | -- |
| **TEMPERATURE** | -0.02 (0.86) | 0.08 (0.41) | 0.05 (0.57) | -0.08 (0.34) |

**B. EIGENVALUES and VARIANCE EXPLAINED**

| **PC** | **EIGENVALUE** | **% VARIANCE EXPLAINED** | **CUMULATIVE VARIANCE EXPLAINED** |
|---|---|---|---|
| **1** | 1.72 | 34.5 | 34.5 |
| **2** | 1.16 | 23.2 | 57.6 |
| **3** | 1.03 | 20.6 | 78.2 |
| **4** | 0.50 | 12.1 | 90.3 |
| **5** | 0.49 | 9.7 | 100.0 |

**C. EIGENVECTORS**

| **VARIABLE** | **PC1** | **PC2** | **PC3** | **PC4** | **PC5** |
|---|---|---|---|---|---|
| **DEPTH** | **-0.50** | 0.24 | 0.19 | -0.30 | **0.67** |
| **TEMPERATURE** | -0.03 | -0.06 | **-0.96** | -0.18 | 0.18 |
| **D.O.** | 0.43 | **0.61** | -0.06 | 0.51 | 0.41 |
| **SALINITY** | -0.36 | **0.71** | -0.12 | -0.09 | **-0.58** |
| **% SILT+CLAY** | **-0.56** | -0.24 | -0.12 | **0.78** | -0.03 |

***Sediment Contaminants***: A composite PEL Quotient (Figure 14) suggested that, in any year surveyed to date, none of the of the sediment samples collected from Middle Tampa Bay had a high likelihood of being toxic to aquatic life. “Marginal” habitat accounted for <10% of the samples in any year with the highest frequency during 1995. Sediments deemed of “marginal’ quality were found both along the periphery of the bay segment and a selected locations along the center of the segment’s long axis (Figure 15). Middle Tampa Bay sediment quality was more likely affected by trace metals (Figure 16) than by PAHs (Figure 16) and PCBs (Figure 17). Although OCL pesticides were not included in the computation of the composite PEL quotient, at least one sample had a chlordane concentration within the "marginal" range, although the method detection limit employed during 1995 was, in fact >TEL. (Figure 18). DDT levels were all <TEL (Figure 19).

***Benthic Community***: Table 3 summarizes selected benthic community measures for 1993-1998. At least 506 taxa were identified during this period (Appendix B). Numerically abundant species included the grass cerith (gastropod), *Caecum strigosum*, the lancelet *Branchiostoma floridae*, and the polychaete worm *Monticellina dorsobranchialis* (Table 4). Dominants varied by year, with 1995 samples characterized by two seagrass associated species (the polychaete *Janua steueri* and the little bittium, *Bittiolum varium*).

There also appeared to be some differences in dominants between salinity zones (Table 5). The two numerical dominants in the higher salinity habitats were identical, but other ranked taxa differed. Mesohaline sites only had one taxonomic group, tubificid oligochaetes, in common with polyhaline habitats and none in common with euhaline habitats.

**Table 3. Summary of Benthic Community Measures: Middle Tampa Bay, 1993-1998**

| | Abundance (#/m$^2$) | Species Richness (S) | Diversity (H') | Evenness (J) | TBBI |
|---|---|---|---|---|---|
| **Minimum** | 75 | 3 | 1.1 | 0.2 | 2.8 |
| **Maximum** | 67750 | 84 | 4.8 | 1.0 | 29.8 |
| **Median** | 6800 | 35 | 3.1 | 0.6 | 17.9 |
| **Mean** | 9794 | 35 | 3.1 | 0.6 | 17.6 |

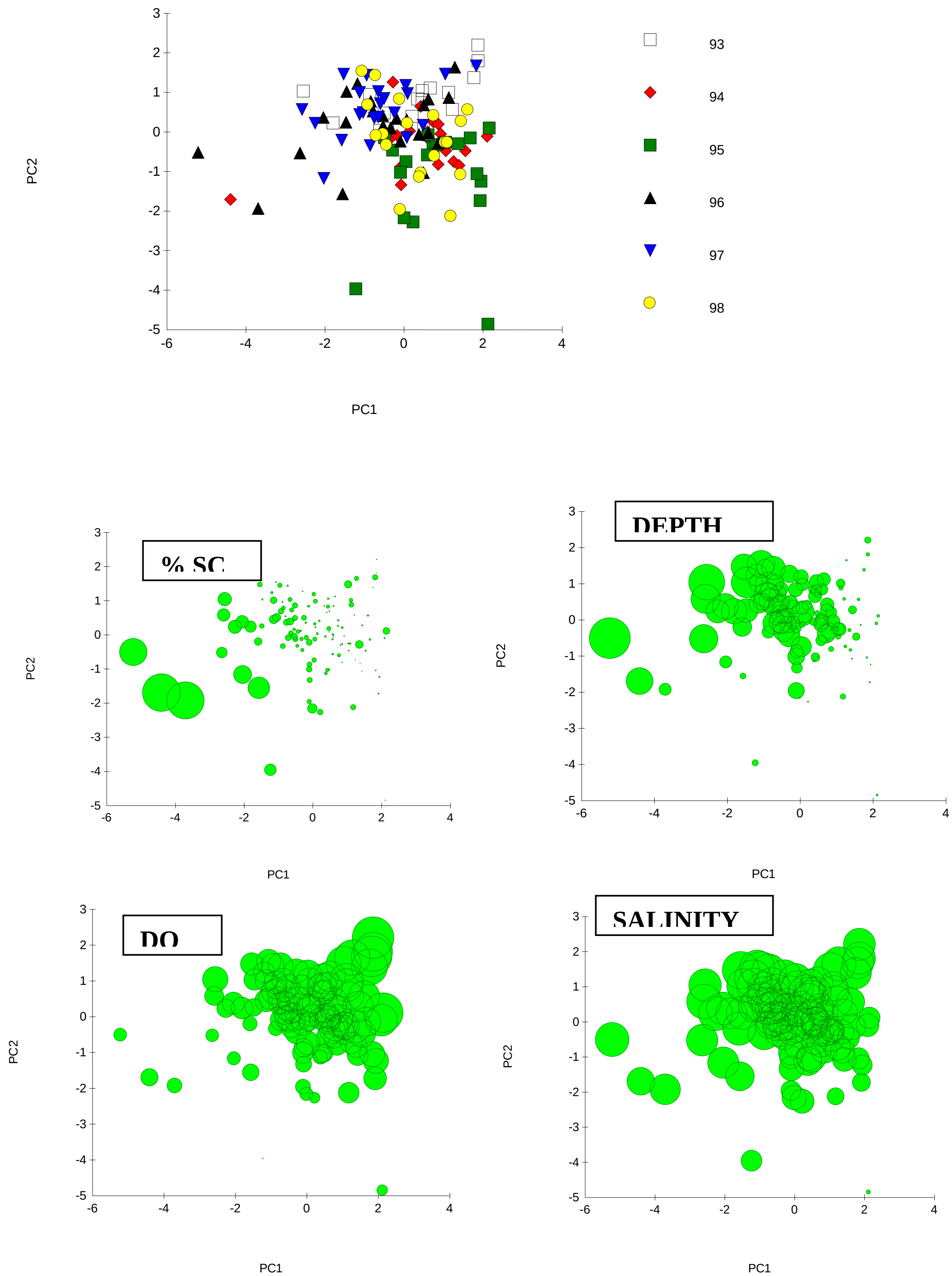


**Figure 13. PCA of sample sites in Middle Tampa Bay, 1993-1998 and bubble plots of %SC, depth, DO, and salinity superimposed on the samples: by year.**

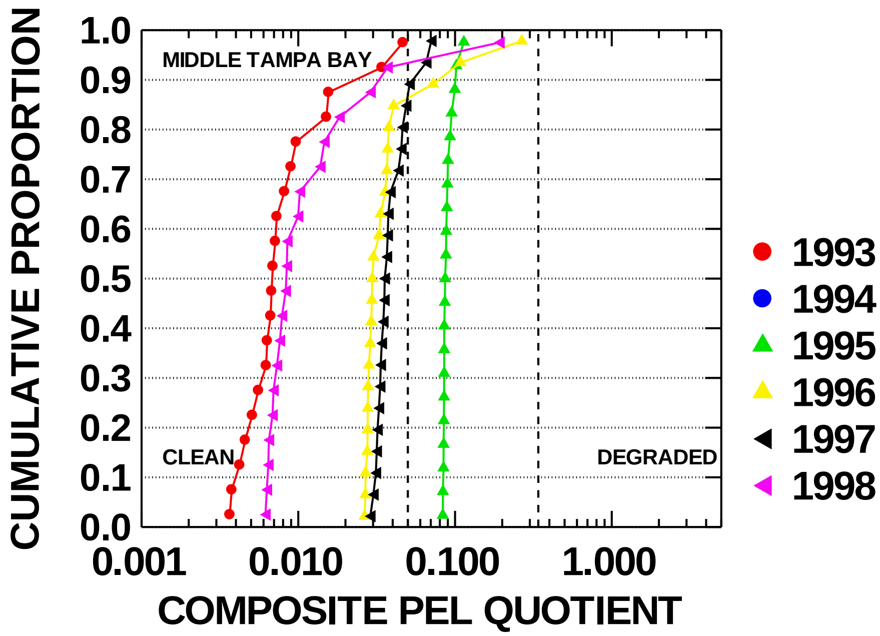


**Figure 14. CDF plot of the composite (metals, PAHs, PCBs) PEL quotient for sediment contaminants in Middle Tampa Bay, by year. Vertical lines demarcate "clean" (<0.05) and "degraded" (>0.34) sediments.**

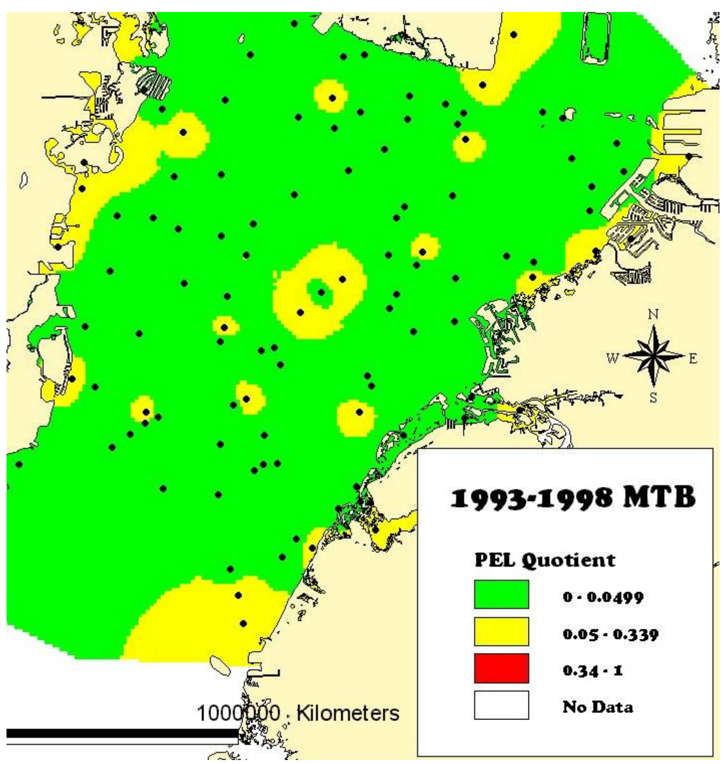


**Figure 15. Map depicting the distribution of sediment quality, based on the composite PEL quotient, in Middle Tampa Bay, 1993-1998.**

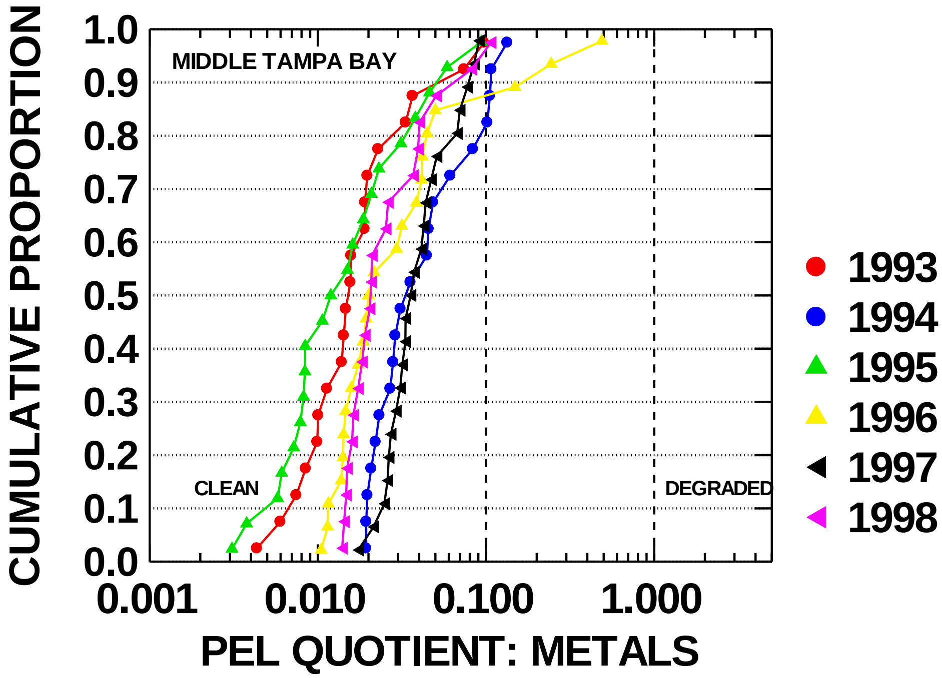


**Figure 16. CDF plot of the PEL quotient for metals (composite) in Middle Tampa Bay, by year. Vertical lines demarcate "clean" (PEL quotient <0.1) and "degraded" (PEL quotient >1) sediments.**

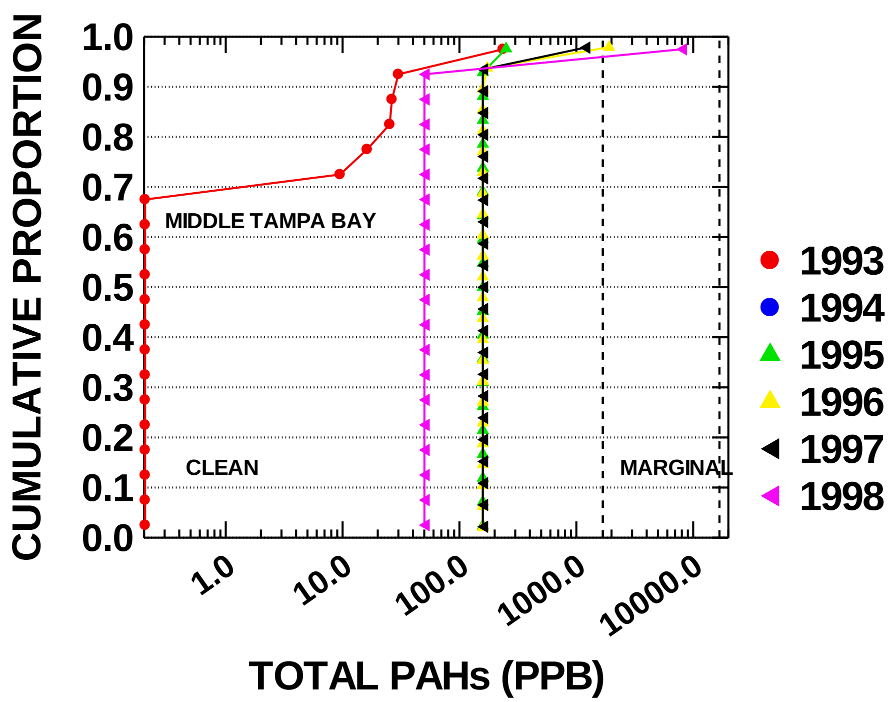


**Figure 17. CDF plot of total PAH concentrations in Middle Tampa Bay, by year. Vertical lines demarcate TEL (1684 ppb) and PEL (16770 ppb).**

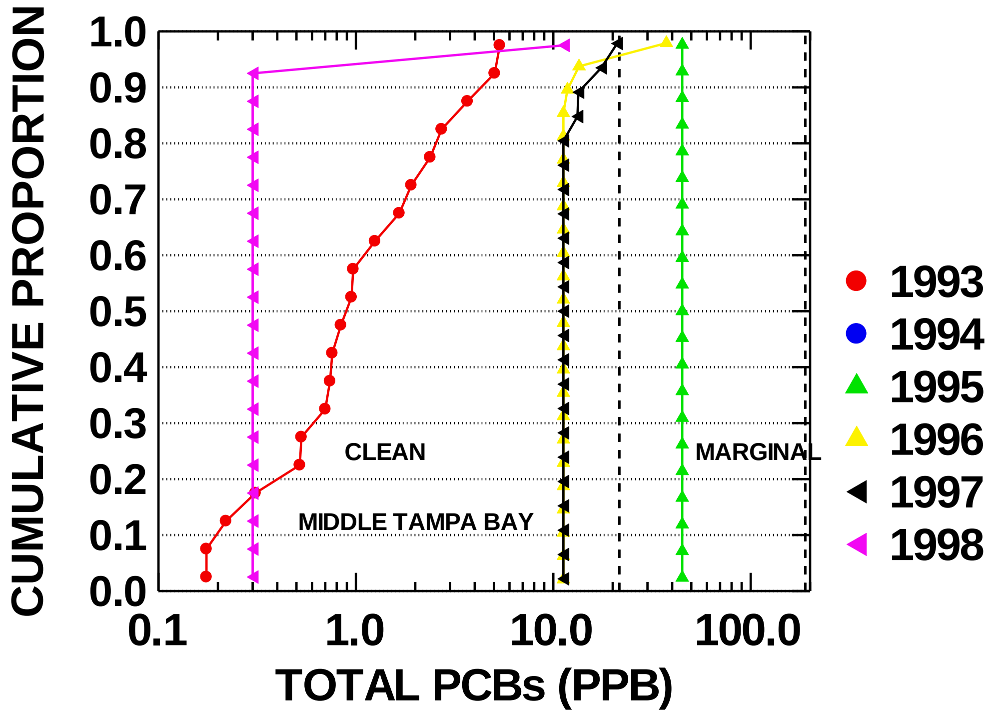


**Figure 18. CDF plot of total PCB concentrations in Middle Tampa Bay, by year. Vertical lines demarcate TEL (21.6 ppb) and PEL (189 ppb).**

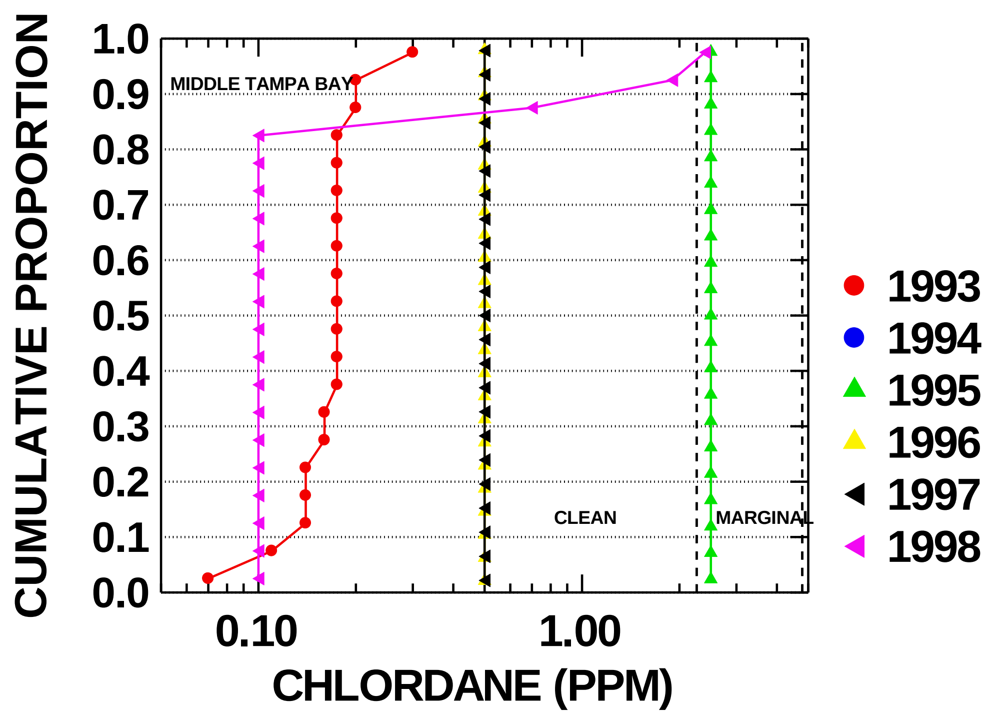


**Figure 19. CDF plot of total chlordane concentrations in Middle Tampa Bay, by year. Vertical lines demarcate TEL (2.26 ppb) and PEL (4.79 ppb).**

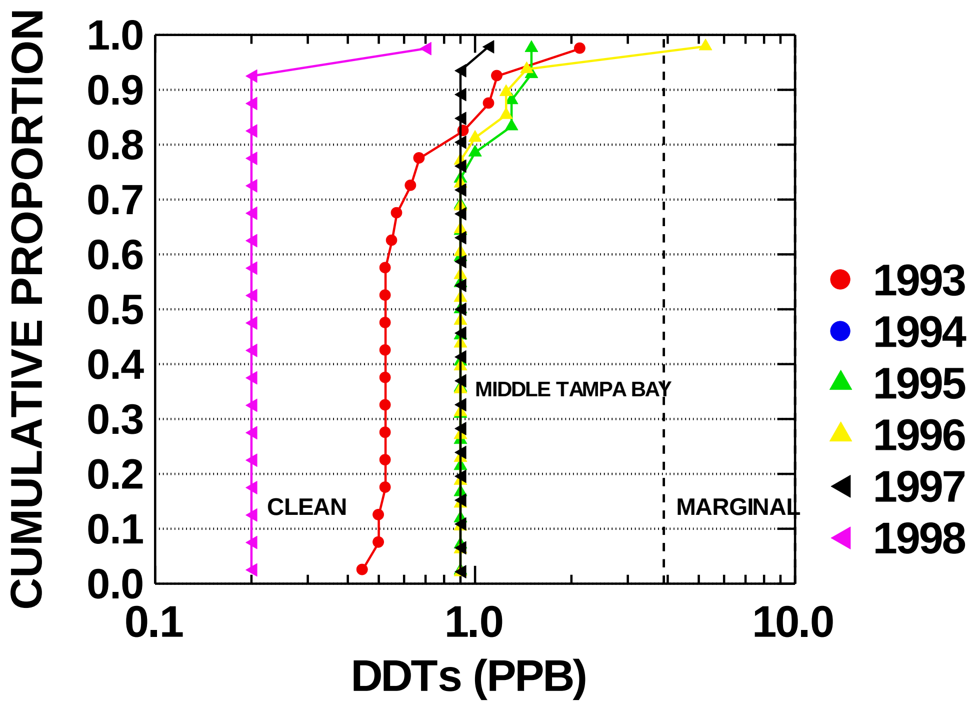


**Figure 20. CDF plot of total DDTs concentrations in Middle Tampa Bay, by year. Vertical line demarcates the TEL (3.89 ppb).**

Numbers of taxa per station were variable over years (Figure 21). During 1997, the median numbers of taxa per $m^2$ was higher than during other years. The frequency distribution was also different from all other years except 1996 (KS test; $p<0.05$).

Tampa Bay Benthic Index (TBBI) scores were almost wholly within the "healthy" range (Figure 22). The frequency distributions during 1997 and 1998 were similar to each other but different (lower) from other years (KS test; $p<0.05$). The only "degraded" sites were found upstream of Riviera Bay and within the St. Petersburg Yacht Club mooring area.

**Table 4. Ten Most Abundant Macroinvertebrate Taxa (# $m^{-2}$) in Middle Tampa Bay, 1993-1998: By Year.**

| 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|
| *Monticellina dorsobranchialis (1,272)* | *M. dorsobranchialis (1,248)* | *Janua (Dexiospira) steueri (2,235)* | *C. strigosum (2,114)* | *B. floridae (2,955)* | *C. strigosum (1,649)* |
| *Branchiostoma floridae (719)* | *C. strigosum (1,000)* | *Bittiolum varium (850)* | *Rudilemboides naglei (1,120)* | *C. strigosum (1,652)* | *B. floridae (1,315)* |
| *Prionospio perkinsi (657)* | *B. floridae (580)* | *Laeonereis culveri (367)* | *Mysella planulata (568)* | *Tubificidae-gen. undet. (472)* | *M. dorsobranchialis (748)* |
| *Mediomastus californiensis (628)* | *M. californiensis (414)* | *B. floridae (342)* | *B. floridae (472)* | *Glottidia pyramidata (460)* | *P. perkinsi (592)* |
| *Caecum strigosum (500)* | *P. perkinsi (250)* | *Tellina sp. (244)* | *Carazziella hobsonae (462)* | *Phascolion cryptum (418)* | *Tubificidae-gen. undet. (330)* |
| *Acanthohaustorius uncinus (395)* | *Nucula crenulata (240)* | *E. floridana (224)* | *Axiothella mucosa (435)* | *T. versicolor (365)* | *Mediomastus sp. (245)* |
| *Erycina floridana (295)* | *Tubificidae-gen. undet. (235)* | *C. strigosum (214)* | *M. floridana (390)* | *Macoma tenta (360)* | *Pinnixa spp. (142)* |
| *Brania sp. A (200)* | *Tellina sp. (184)* | *Synelmis ewingi (178)* | *M. dorsobranchialis (309)* | *Tornatina inconspicua (332)* | *S. ewingi (141)* |
| *Ampelisca sp. C (191)* | *E. floridana (154)* | *Metharpinia floridana (125)* | *Ampelisca sp. C (300)* | *M. dorsobranchialis (325)* | *Ophiuroidea-gen. undet. (141)* |
| *Ophiuroidea- gen. undet. (170)* | *Diplodonta semiaspera (146)* | *Tubificidae-gen. undet. (122)* | *A. holmesi (285)* | *P. perkinsi (300)* | *Echinoidea-gen. undet. (138)* |

**Table 5. Ten Most Abundant Macroinvertebrate Taxa (#/ $m^{-2}$) in Middle Tampa Bay, 1993-1998: By Salinity Zone (Venice System).**

| **MESOHALINE (5.0-18.0 ppt) (N=3)** | **POLYHALINE (18.0-30.0 ppt) (N=117)** | **EUHALINE (>30 ppt) (N=5)** |
|---|---|---|
| *Nereis succinea (600)* | *Caecum strigosum (1,228)* | *B. floridae (8,475)* |
| *Streblospio gynobranchiata (358)* | *Branchiostoma floridae (916)* | *C. strigosum (2,317)* |
| *Tubificidae-gen. undet. (233)* | *Monticellina dorsobranchialis (678)* | *Phascolion cryptum (1,875)* |
| *Pectinaria gouldi (142)* | *Janua (Dexiospira) steueri (391)* | *Ophelina cylindricaudata (1,725)* |
| *Amygdalum papyrium (142)* | *Prionospio perkinsi (340)* | *Axiothella mucosa (817)* |
| *Mysella planulata (133)* | *Rudilemboides naglei (264)* | *Armandia maculata (442)* |
| *Ampelisca holmesi (133)* | *Tubificidae-gen. undet. (253)* | *Grubeosyllis clavata (300)* |
| *Mulinia lateralis (108)* | *Erycina floridana (175)* | *Sphaerosyllis taylori (283)* |
| *Tellina versicolor (100)* | *Metharpinia floridana (172)* | *Litocorsa attenuata (233)* |
| *Haminoea succinea (50)* | *Bittiolum varium (161)* | *Tornatina antennata (233)* |

Correlation analysis showed that the TBBI was associated with %SC (r=-0.21; $p<0.05$) (Figure 24). The associations of the TBBI with RPD (r=0.18) (Figure 25), temperature (r=0.17) (Figure x), the composite PEL quotient (r=-0.09) (Figure 27), depth (r=-0.03) (Figure 28), DO (r=-0.01) (Figure x), and salinity (r=-0.01) (Figure x) were not significant ($p>0.05$). Stepwise multiple regression yielded the following relationship:

TBBI ($\log_{10}$ n+1) =

-0.85 –0.13*DO ($\log_{10}$ n+1) + 1.50*Temperature ($\log_{10}$ n+1) – 0.71*%SC (ASN)

(adjusted multiple $r^2 = 0.06^*$; n=120)

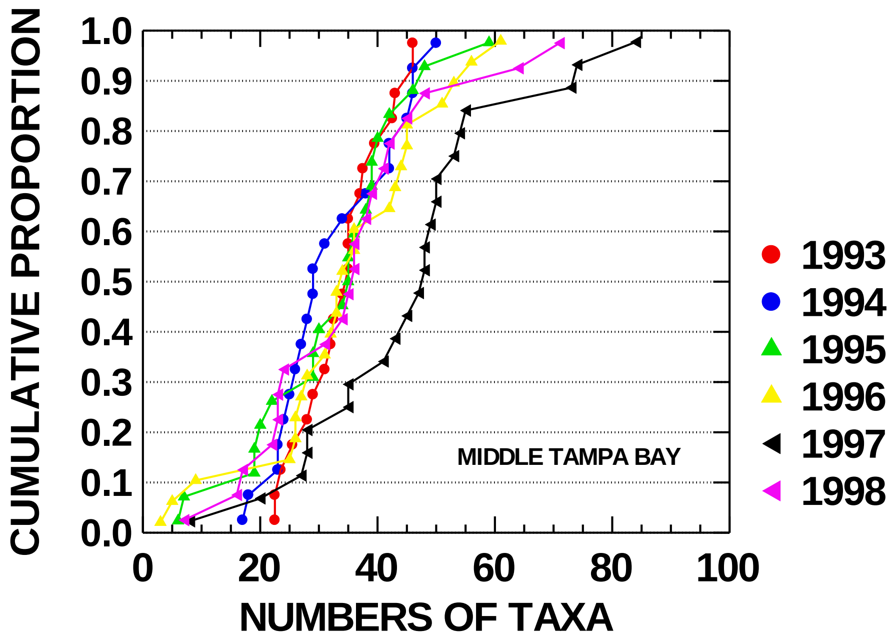


**Figure 21. CDF for numbers of taxa in Middle Tampa Bay benthos, by year, 1993-1998.**

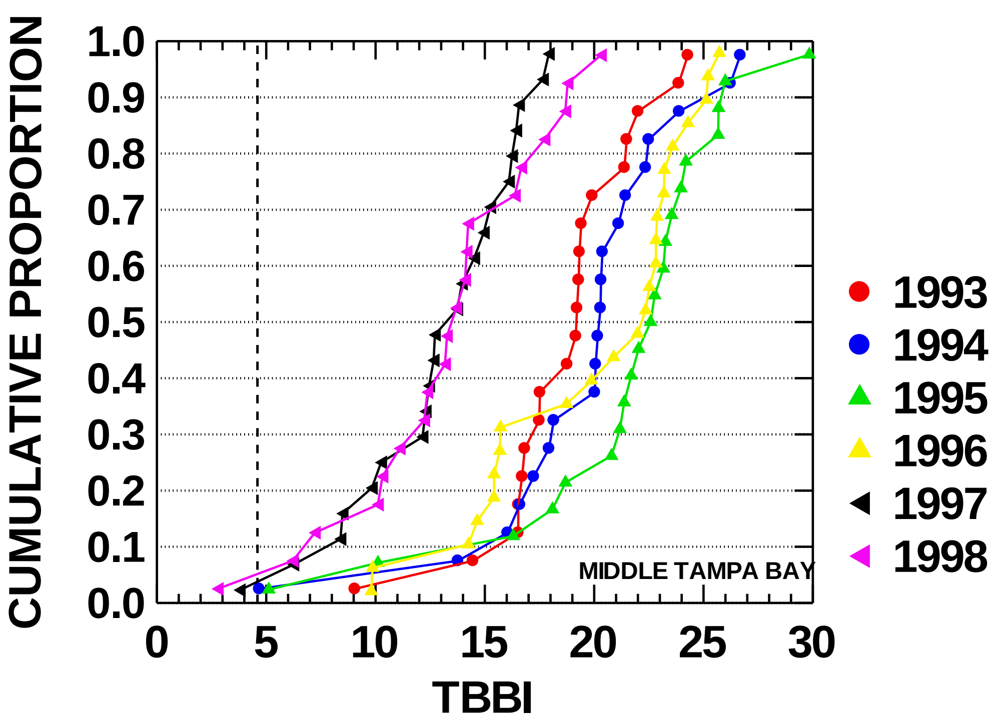


**Figure 22. CDF of the Tampa Bay Benthic Index for Middle Tampa Bay benthos, by year, 1993-1998. Scores <4.6 indicate "degraded" benthic habitat.**

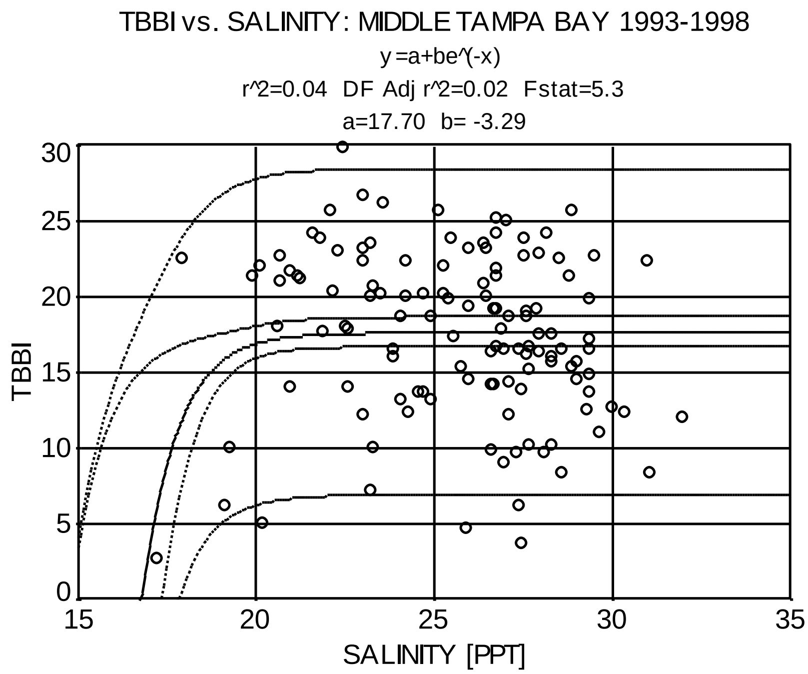


**Figure 23. Association between the Tampa Bay Benthic Index and salinity in Middle Tampa Bay, 1993-1998. TBBI scores <4.6 indicate degraded habitat.**

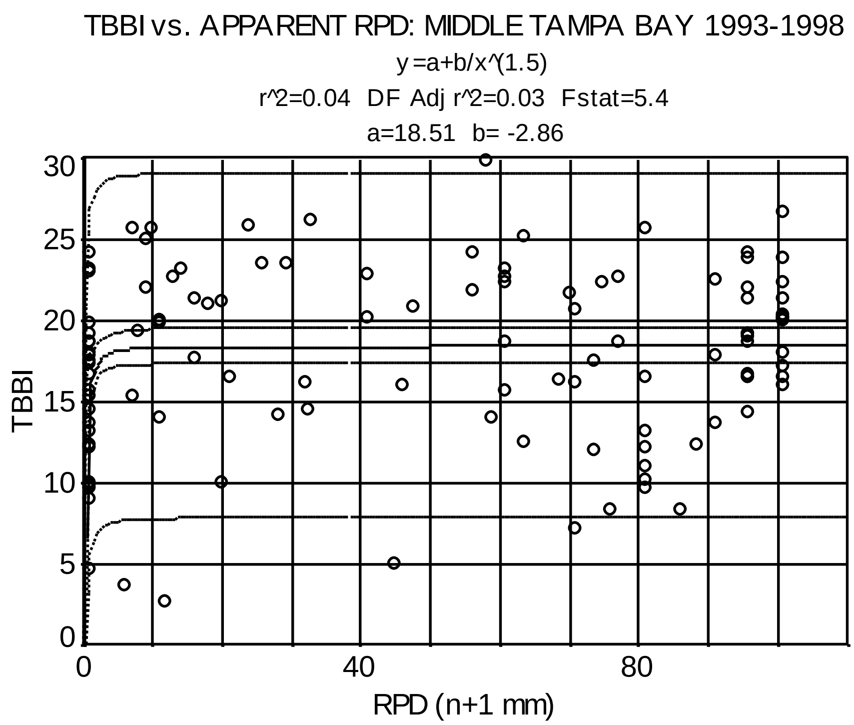


**Figure 24. Association between the Tampa Bay Benthic Index and the apparent redox potential discontinuity layer (RPD) in Middle Tampa Bay, 1993-1998. TBBI scores <4.6 indicate "degraded" habitat.**

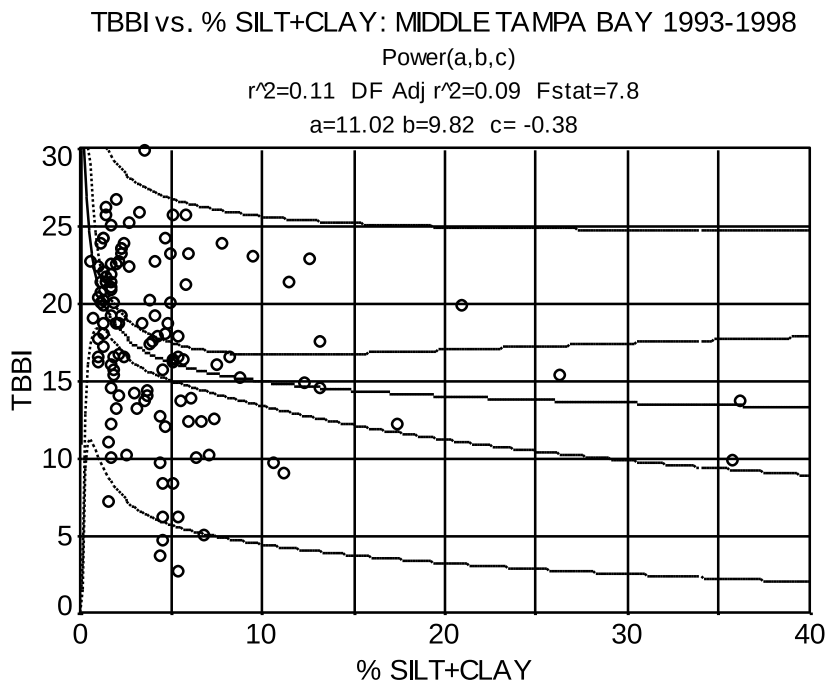


**Figure 25. Association between the Tampa Bay Benthic Index and %SC in Middle Tampa Bay, 1993-1998. TBBI scores <4.6 indicates "degraded" habitat.**

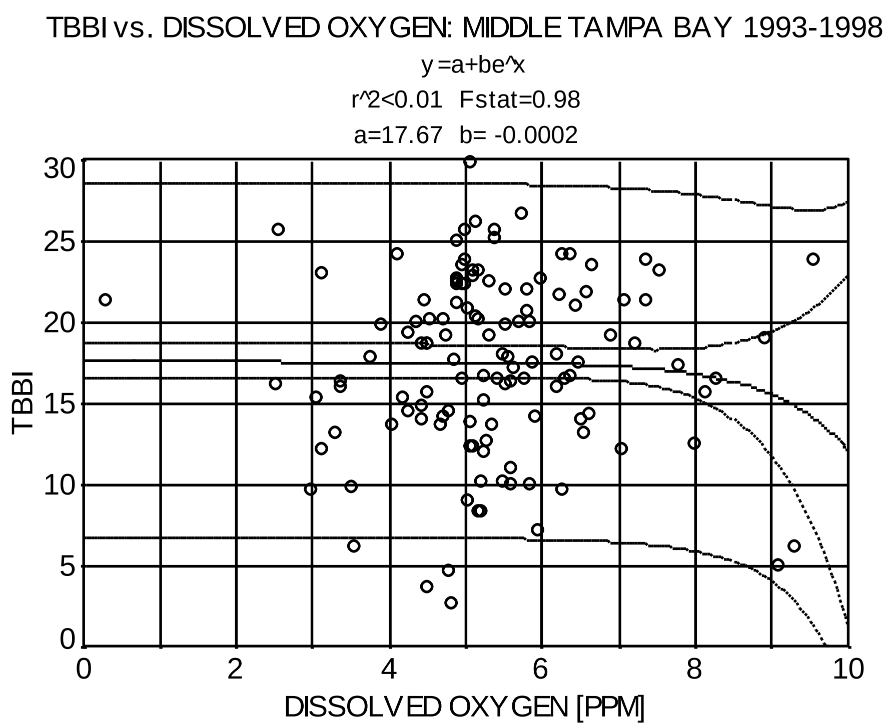


**Figure 26. Association between the Tampa Bay Benthic Index and near-bottom dissolved oxygen concentrations in Middle Tampa Bay, 1993-1998. TBBI scores <4.6 and DO <2.0 indicate "degraded" habitat.**

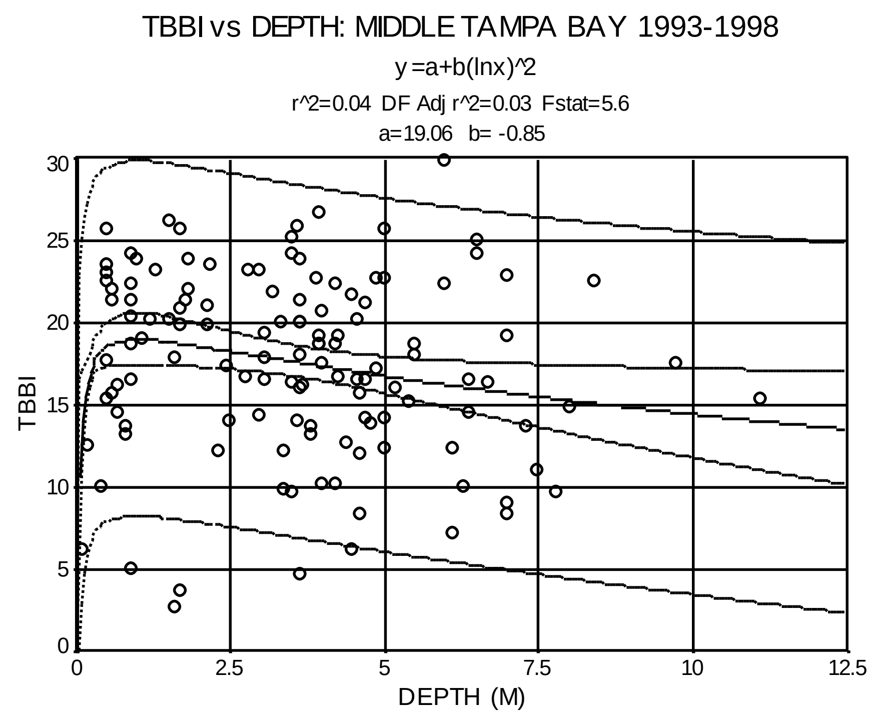


**Figure 27. Association between the Tampa Bay Benthic Index and sample depth in Middle Tampa Bay, 1993-1998. TBBI scores <4.6 indicate degraded habitat.**

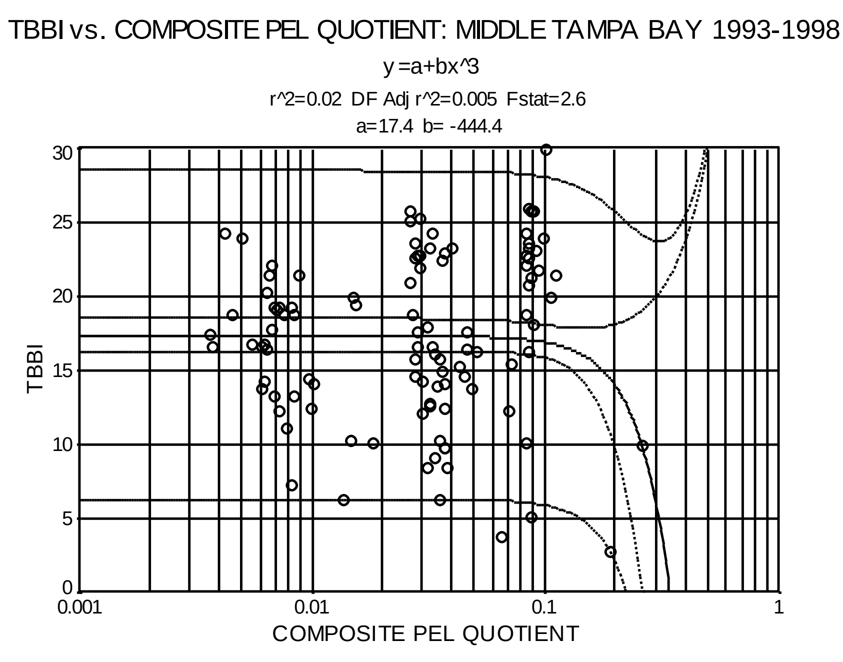


**Figure 28. Association between the Tampa Bay Benthic Index and the composite PEL quotient in Middle Tampa Bay, 1993-1998. TBBI scores <4.6 and PEL quotients >0.34 indicate degraded habitat; PEL quotients <0.05 indicate "clean" sediments.**

*<u>Benthic Community Structure</u>*: Eight "clusters" were identified in the classification analysis of sites (Figure 30) and 13 "clusters" were identified in the classification analysis of taxa (Figure 31). The two-way coincidence table, reordering the sites and taxa to reflect the dendrograms, summarizes the mean taxa abundance within each cluster (Table 7). Cluster A was a single station "outlier". Depth and %SC were most often the variables which demarcated the higher order clusters; temperature, salinity, dissolved oxygen and sediment contaminants were lesser factors (Table 8).

Clusters B1 and B2 differed somewhat by sediment type (%SC). The sites in Cluster B1 sites were also collected most often during 1993 and 1994 (36%) whereas only 23% of the B2 sites were from these years. SIMPER analyses (Clarke and Warwick 2001) showed that dissimilarities between the biotic assemblages in Clusters B1 and B2 were due to the distribution of the grass cerith *Caecum strigosum* and the lancelet *Branchiostoma floridae*. Both species were much more abundant at the sites with the coarser sediments (B1), which tended to be located more in the south-central portions of Middle Tampa Bay (Figure x). B2 sites were more often located along the periphery and northern portions of of Middle Tampa Bay (Figure x).

Sample depth appeared to be the primary variable discriminating clusters B1A and B1B (Table 9), although 47% of the B1B sites were sampled during 1993 and 1994. Among the key species contributing to the dissimilarity between these two clusters were three species more abundant at the deeper sites (*C. strigosum*, the sipunculan *Phascolion cryptum*, *B. floridae*) and two species more abundant at the shallower sites (the polychaete *Mediomastus californiensis* and the amphipod *Eudevenopus honduranus*) (Table xx). Two sites in southern Middle Tampa Bay, dominated by species in Cluster 8A (Table 7) formed an outlier of B1A (*cf*. Figure 30).

Clusters B1B1 and B1B2 showed little differences in any of the measured physical and chemical variables (Table 9) or little spatial segregation. Fify-four percent of the B1B2 sites were 1995-1997 collections, whereas only 8% of the B1B1 sites were from these years.

Clusters B2A and B2B were differentiated by depth and, to a lesser extent by %SC, salinity and DO (Table 9). B2A sites were located in the shallower, peripheral portions of Middle Tampa Bay, whereas B2B sites were located more in the northeast-central portion the segment (Figure x). Sixty-four percent of the B2A sites were sampled during 1995 and 1998 whereas 46% of the B2B sites were sampled during 1996 and 1997. *Monticellina dorsobranchialis*, *Erycina floridana* and *Prionospio perkinsi* were more characteristic of the deeper B2B sites and tubificid oligochaetes and the polychaete *Aricidea philbinae* were more characteristic of the shallower B2A sites (Table x).

The B2B1 and B2B2 clusters showed some differences in %SC with the higher values associated with the B2B2 sites generally located in northern Middle Tampa Bay. B2B1 sites were primarily (28%) 1996 and 1995 (19%) collections. No samples in cluster B2B2 were collected during 1995 and 21% were collected during 1996.Taxa which were more abundant at B2B2 sites included the polychaetes *M. dorsobranchialis*, *P. perkinsi* and *Carazziella hobsonae* (Table x).

***Linkage of Biotic and Abiotic Variables ( 1995-1998):*** Primer's BIO-ENV procedure was used to explore the extent to which the benthic community structure can be explained by the measured physico-chemical characteristics. In order to maximize the physico-chemical variable list (site characteristics, DO, chlordane, DDT, PCBs, total PAHs, and metals), the analysis was restricted to 1995-1998 data. The MDS plot suggested that the benthic assemblages in Middle Tampa Bay during 1997 were much more variable than other years and the structure during 1995 seemed to be the least variable (Figure 31). The Spearman rank correlations between the biological data (Figure 32) was only 0.09, thereby explaining very little of the structure of the benthic assemblages. The "best fit" was provided for the metals arsenic and copper (Figure 33).

Taxa which contributed most to the dissimilarity of benthic community structure included *B. floridae, C. strigosum, M. dorsobranchialis*, and the amphipod *Rudilemboides naglei* (Figure 33). Both *B. floridae* and *C. strigosum* tended to be abundant in the coarser sediments located in deeper waters of south-central Middle Tampa Bay (see *Benthic Community Structure* above). *Monticellina* was most abundant in deeper waters of northeastern Middle Tampa Bay. *Rudilemboides* abundance appeared to be more indicative of temporal factors (less abundant during 1998) than spatial distribution (*cf*. Figure 30 and Table 7).

***Interannual Trends***: MDS of average abundance of all benthic taxa, by year, show that the benthic community experienced more pronounced shifts in structure from 1996 to 1997 than during other sequential years (Figure 34). BIO-ENV analysis using site, hydrographic, and contaminant (metals only; no organic data for 1994) variables showed that the best fit (Spearman r=0.47) for environmental variables with the biotic data were for arsenic, depth, DO, %SC, and temperature. However, within these variables there appear to be little difference in the means between 1996 and 1997 (Figure 35).

Taxa which contributed the most to the dissimilarity in community structure from 1993-1998 included *M. dorsobranchialis*, *C. strigosum*, *B. floridae*, and *P. perkinsi* (Appendix C; Figure 35). For the 1996-1997 transition, *B. floridae* and *C. strigosum* (Appendix C; Figure 35) contributed *ca*. 2% to the dissimilarity in community structure.

***<u>Status of Middle Tampa Bay Sediments</u>***: Middle Tampa Bay appears not to be affected by subnominal DO, sediment contaminants, or degradation of benthic habitat relative to that reported for the Louisianian Province (northern Gulf of Mexico south to Tampa Bay) as a whole (Table 13).

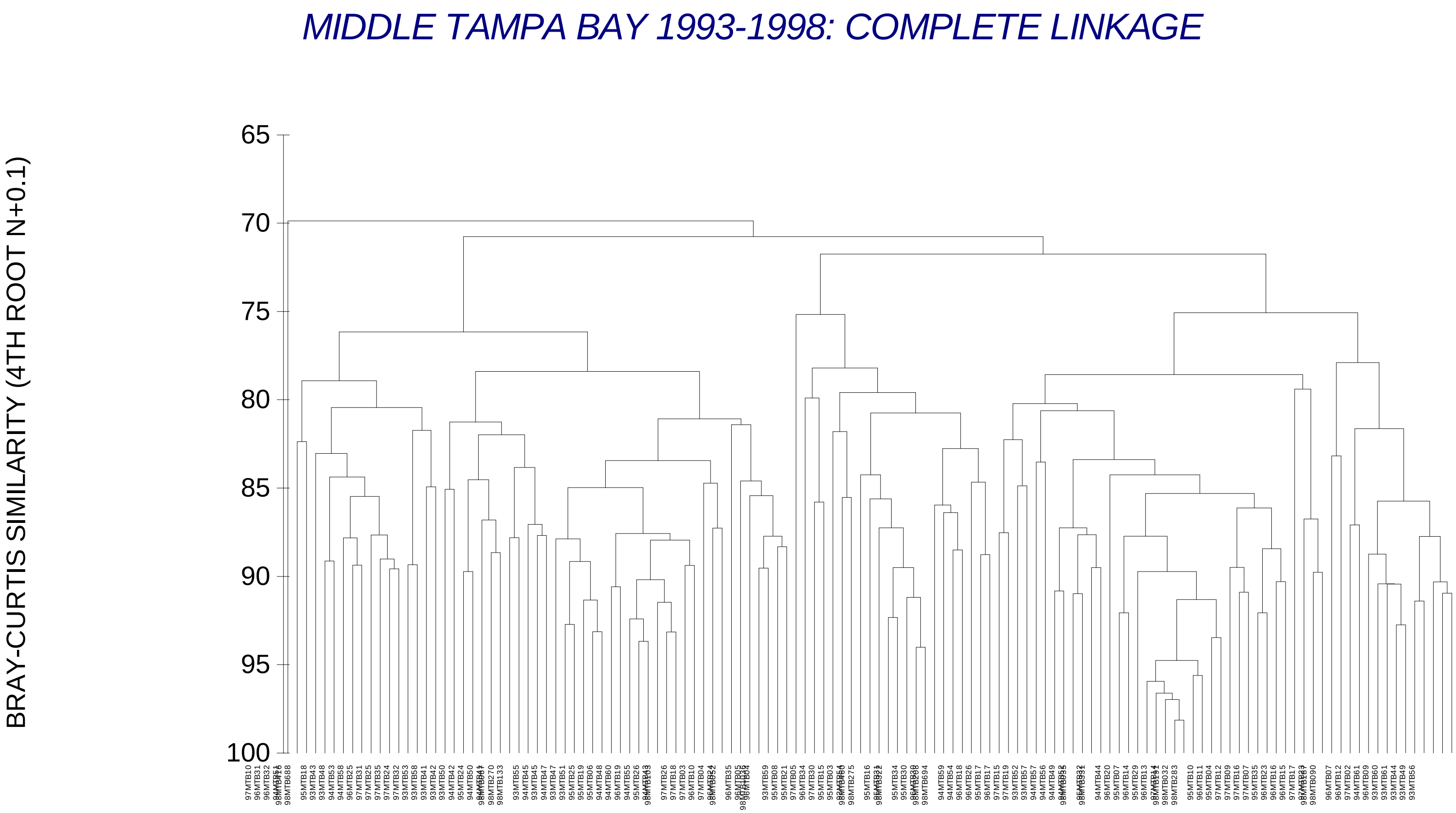


**Figure 29. Dendrogram depicting the similarity of sites in Middle Tampa Bay 1993-1998 (4$^{th}$ root transformed abundance; Bray-Curtis similarity; group average clustering).**

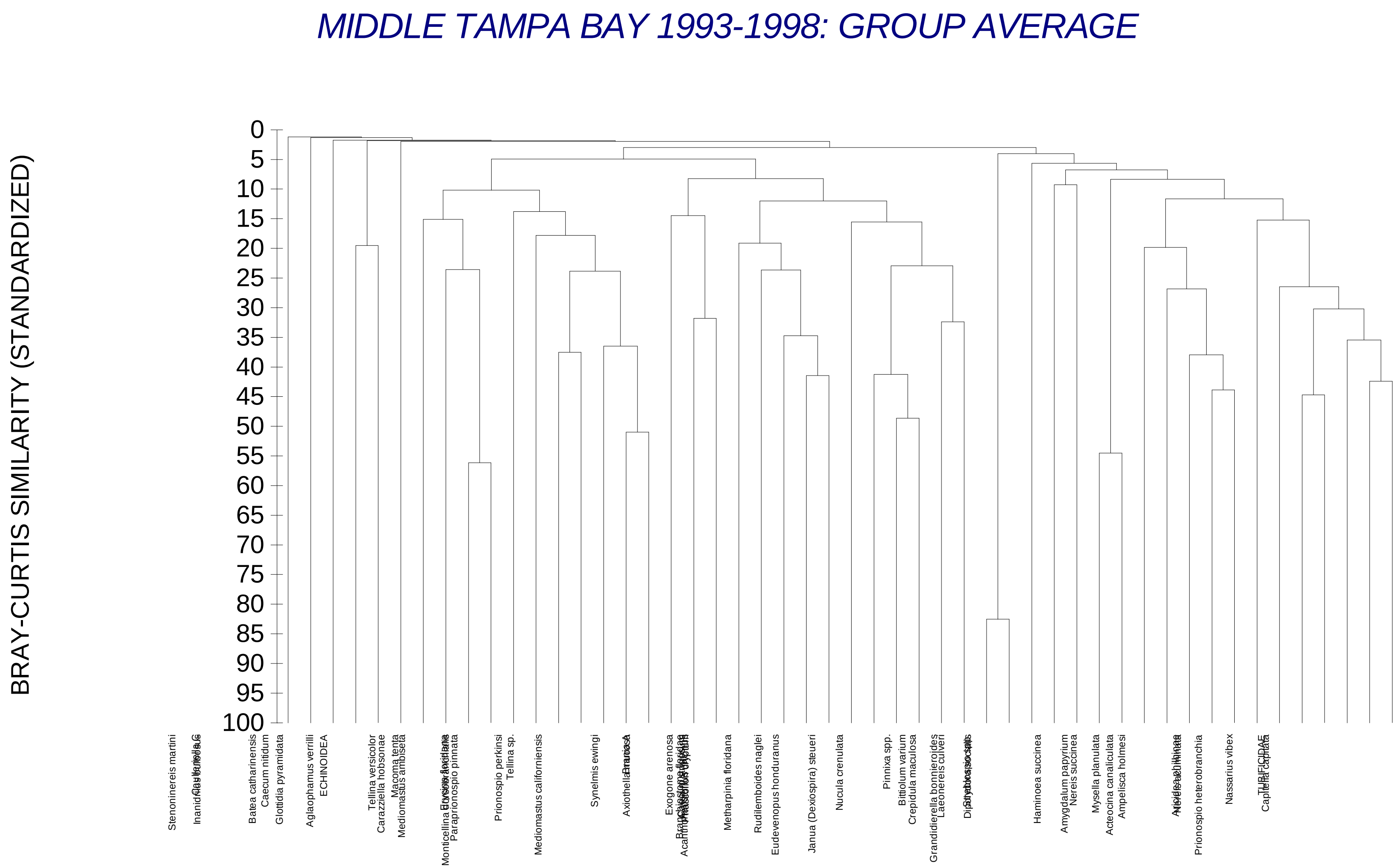


**Figure 30. Dendrogram depicting the similarity of 50 most abundant taxa (standardized abundance; Bray-Curtis similarity; Group-average clustering): Middle Tampa Bay 1993-1998.**

**Table 7. Two-way coincidence table (taxa by site cluster), Middle Tampa Bay benthos, 1993-1998.**

| CLUSTER | | A | B1A1 | B1A2 | B1B1 | B1B2 | B2A | B2B1 | B2B2 |
|---|---|---|---|---|---|---|---|---|---|
| **1** | *Caulleriella C* | 0 | 0 | 0 | 0 | 0 | 0 | 41 | 0 |
| | | | | | | | | | |
| **2** | *Stenoninereis martini* | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 |
| | | | | | | | | | |
| **3** | *Inanidrilus bulbosus* | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 6 |
| | | | | | | | | | |
| **4** | *Caecum nitidum* | 0 | 0 | 0 | 0 | 0 | 64 | 0 | 0 |
| | *Batea catharinensis* | 0 | 0 | 4 | 2 | 11 | 4 | 2 | 0 |
| | | | | | | | | | |
| **5** | *ECHINOIDEA* | 0 | 0 | 5 | 4 | 104 | 0 | 0 | 0 |
| | | | | | | | | | |
| **6A** | *Glottidia pyramidata* | 1725 | 25 | 0 | 0 | 143 | 16 | 197 | 25 |
| | *Aglaophamus verrilli* | 0 | 0 | 2 | 0 | 3 | 0 | 98 | 41 |
| | *Macoma tenta* | 350 | 0 | 0 | 5 | 1 | 3 | 29 | 567 |
| | *Tellina versicolor* | 200 | 0 | 9 | 21 | 30 | 17 | 92 | 436 |
| | | | | | | | | | |
| **6B** | *Carazziella hobsonae* | 0 | 12.5 | 0 | 0 | 8 | 21 | 9 | 1108 |
| | *Mediomastus ambiseta* | 0 | 0 | 0 | 4 | 0 | 0 | 99 | 28 |
| | *Erycina floridana* | 0 | 0 | 0 | 59 | 2 | 0 | 381 | 471 |
| | *Tellina sp.* | 0 | 0 | 12 | 28 | 70 | 9 | 223 | 35 |
| | *Paraprionospio pinnata* | 75 | 0 | 0 | 8 | 20 | 65 | 62 | 163 |
| | *Prionospio perkinsi* | 1650 | 0 | 12 | 282 | 99 | 101 | 211 | 1776 |
| | *Monticellina dorsobranchialis* | 3550 | 37.5 | 7 | 55 | 21 | 31 | 889 | 3304 |
| | | | | | | | | | |
| **7** | *Brania A* | 0 | 0 | 60 | 267 | 0 | 0 | 0 | 2 |
| | *Synelmis ewingi* | 0 | 50 | 428 | 377 | 61 | 0 | 9 | 1 |
| | *Mediomastus californiensis* | 0 | 0 | 151 | 1846 | 56 | 17 | 4 | 65 |
| | | | | | | | | | |
| **8A** | *Axiothella mucosa* | 0 | 1300 | 125 | 14 | 279 | 22 | 2 | 10 |
| | *Exogone arenosa* | 0 | 1438 | 631 | 21 | 0 | 0 | <1 | 2 |
| | *Caecum strigosum* | 0 | 6475 | 4611 | 3216 | 1465 | 0 | 2 | 4 |
| | *Phascolion cryptum* | 25 | 2012 | 793 | 0 | 54 | 4 | 8 | 4 |
| | *Branchiostoma floridae* | 250 | 75 | 4887 | 1858 | 1537 | 71 | 55 | 64 |
| | | | | | | | | | |
| **8B** | *Acanthohaustorius uncinus* | 0 | 0 | 12 | 1 | 508 | 77 | 6 | 3 |
| | *Metharpinia floridana* | 0 | 88 | 125 | 149 | 599 | 0 | 50 | 0 |
| | *Rudilemboides naglei* | 0 | 0 | 63 | 128 | 439 | 2 | 481 | 2 |
| | *Eudevenopus honduranus* | 0 | 0 | 5 | 111 | 297 | 2 | 95 | 1 |
| | *Nucula crenulata* | 100 | 38 | 38 | 259 | 361 | 1 | 149 | 78 |
| | *Pinnixa spp.* | 525 | 262 | 134 | 121 | 157 | 15 | 176 | 150 |
| | | | | | | | | | |
| **9** | *Janua (Dexiospira) steueri* | 0 | 0 | 0 | 0 | 0 | 2132 | 0 | 0 |
| | *Bittiolum varium* | 0 | 0 | 0 | 0 | 0 | 877 | 1 | 0 |

| CLUSTER | | A | B1A1 | B1A2 | B1B1 | B1B2 | B2A | B2B1 | B2B2 |
|---|---|---|---|---|---|---|---|---|---|
| **10** | *Crepidula maculosa* | 0 | 0 | 2 | 0 | 0 | 86 | 0 | 0 |
| | | | | | | | | | |
| **11** | *Laeonereis culveri* | 25 | 0 | 0 | 2 | 0 | 360 | 5 | 0 |
| | *Streblospio spp.* | 0 | 0 | 2 | 0 | 0 | 9 | 27 | 0 |
| | | | | | | | | | |
| **12** | *Dipolydora socialis* | 50 | 0 | 2 | 0 | 0 | 26 | 4 | 4 |
| | *Grandidierella bonnieroides* | 25 | 0 | 0 | 0 | 2 | 20 | 3 | 0 |
| | | | | | | | | | |
| **13A** | *Haminoea succinea* | 0 | 0 | 0 | 0 | 15 | 173 | 16 | 0 |
| | *Nereis succinea* | 0 | 0 | 0 | 5 | 1 | 104 | 6 | 2 |
| | *Amygdalum papyrium* | 75 | 12 | 4 | 0 | 0 | 68 | 16 | 0 |
| | *Mysella planulata* | 0 | 0 | 0 | 5 | 3 | 234 | 372 | 38 |
| | *Ampelisca holmesi* | 0 | 12 | 5 | 0 | 14 | 261 | 137 | 17 |
| | | | | | | | | | |
| **13B** | *Acteocina canaliculata* | 0 | 0 | 0 | 0 | 78 | 34 | 1 | 0 |
| | *Nereis acuminata* | 0 | 0 | 0 | 0 | 2 | 103 | 0 | 0 |
| | *Aricidea philbinae* | 25 | 0 | 0 | 1 | 0 | 228 | 54 | 2 |
| | *Nassarius vibex* | 0 | 0 | 0 | 0 | 2 | 56 | 1 | 0 |
| | *TUBIFICIDAE* | 275 | 50 | 24 | 167 | 27 | 669 | 261 | 346 |
| | *Prionospio heterobranchia* | 25 | 0 | 2 | 0 | 2 | 414 | 20 | 0 |
| | *Capitella capitata* | 25 | 150 | 2 | 0 | 52 | 207 | 23 | 2 |

**Table 9. Mean values of selected physical, chemical, and biotic variables by “cluster”: Middle Tampa Bay, 1993-1998.**

| CLUSTER | DEPTH (m) | RPD (mm) | % SILT+CLAY | TEMPERATURE | SALINITY | D.O. |
|---|---|---|---|---|---|---|
| **B1** | 3.8 | 76 | 2.3 | 28.8 | 26.3 | 5.8 |
| **B2** | 3.4 | 24 | 6.6 | 29.1 | 24.8 | 5.1 |
| | | | | | | |
| **B1A** | 5 | 82 | 2.7 | 28.7 | 27.8 | 5.6 |
| **B1B** | 3.3 | 73 | 2.2 | 28.9 | 25.6 | 5.8 |
| | | | | | | |
| **B1A1** | 7.2 | 75 | 2.4 | 29.7 | 29.8 | 4.9 |
| **B1A2** | 4.6 | 83 | 2.8 | 28.6 | 27.5 | 5.7 |
| | | | | | | |
| **B1B1** | 3.8 | 81 | 2.2 | 28.8 | 25.6 | 5.8 |
| **B1B2** | 3 | 70 | 2.1 | 28.9 | 25.7 | 5.8 |
| | | | | | | |
| **B2A** | 0.9 | 30 | 3.6 | 28.8 | 23.7 | 6.2 |
| **B2B** | 4.4 | 22 | 8 | 29.2 | 25.4 | 4.6 |
| | | | | | | |
| **B2B1** | 4 | 24 | 6.7 | 29.2 | 24.9 | 4.5 |
| **B2B2** | 5.7 | 16 | 11.2 | 29.2 | 26.5 | 4.7 |

| CLUSTER | COMPOSITE PEL QUOTIENT | METALS PEL QUOTIENT | PAH PEL QUOTIENT | PCB PEL QUOTIENT | CHLORDANE PEL QUOTIENT |
|---|---|---|---|---|---|
| **B1** | 0.03 | 0.03 | 0.01 | 0.06 | 0.14 |
| **B2** | 0.05 | 0.05 | 0.02 | 0.09 | 0.18 |
| | | | | | |
| **B1A** | 0.03 | 0.03 | 0.01 | 0.06 | 0.11 |
| **B1B** | 0.03 | 0.03 | 0.01 | 0.06 | 0.15 |
| | | | | | |
| **B1A1** | 0.03 | 0.03 | 0.01 | 0.06 | 0.1 |
| **B1A2** | 0.03 | 0.04 | 0.01 | 0.05 | 0.11 |
| | | | | | |
| | | | | | |
| **B1B1** | 0.02 | 0.02 | <0.01 | 0.03 | 0.08 |
| **B1B2** | 0.04 | 0.03 | 0.01 | 0.08 | 0.18 |
| | | | | | |
| **B2A** | 0.04 | 0.02 | 0.01 | 0.11 | 0.24 |
| **B2B** | 0.05 | 0.06 | 0.02 | 0.08 | 0.16 |
| | | | | | |
| **B2B1** | 0.06 | 0.06 | 0.03 | 0.1 | 0.2 |
| **B2B2** | 0.03 | 0.06 | 0.01 | 0.04 | 0.07 |

**Table 9 (continued)**

| CLUSTER | ABUNDANCE (# $m^2$) | BS | TBBI |
|---|---|---|---|
| **B1** | 11,670 | 37 | 18.4 |
| **B2** | 8,238 | 34 | 16.9 |
| | | | |
| **B1A** | 15,962 | 41 | 16.8 |
| **B1B** | 9,863 | 35 | 19.1 |
| | | | |
| **B1B1** | 12,243 | 42 | 17.2 |
| **B1B2** | 9,764 | 32 | 20 |
| | | | |
| **B2A** | 9,115 | 36 | 18.1 |
| **B2B** | 7,852 | 33 | 16.4 |
| | | | |
| **B2B1** | 6,385 | 31 | 17.3 |
| **B2B2** | 11,623 | 38 | 14.1 |

**Table 10. Results of SIMPER analysis comparing the dissimilarity between Middle Tampa Bay Cluster pairs.**

### A. B1 vs B2. Average dissimilarity =85.44.

| Species | Group B1 Av.Abund | Group B2 Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| *Caecum strigosum* | 2855.32 | 1.74 | 2.41 | 1.54 | 2.82 | 2.82 |
| *Branchiostoma floridae* | 2422.69 | 61.46 | 2.19 | 1.64 | 2.57 | 5.39 |
| *Metharpinia floridana* | 357.18 | 24.13 | 1.59 | 1.61 | 1.87 | 7.26 |
| *Travisia hobsonae* | 169.21 | 8.16 | 1.37 | 1.68 | 1.61 | 8.86 |
| *Tornatina inconspicua* | 260.19 | 1.04 | 1.21 | 1.22 | 1.42 | 10.28 |

### B. Clusters B1A1 vs. B1A2. Average dissimilarity = 66.82.

| *Species* | *Group B1A1 Av.Abund* | *Group B1A2 Av.Abund* | *Av.Diss* | *Diss/SD* | *Contrib%* | *Cum.%* |
|---|---|---|---|---|---|---|
| *Branchiostoma floridae* | *75.00* | *4886.61* | *1.63* | *1.96* | *2.44* | *2.44* |
| *Sphaerosyllis taylori* | *462.50* | *0.00* | *1.29* | *2.99* | *1.94* | *4.38* |
| *Axiothella mucosa* | *1300.00* | *125.00* | *1.22* | *1.69* | *1.83* | *6.21* |
| *Phascolion cryptum* | *2012.50* | *792.86* | *1.21* | *1.45* | *1.81* | *8.02* |
| *Exogone arenosa* | *1437.50* | *631.25* | *1.16* | *1.24* | *1.73* | *9.75* |
| *Caulleriella sp.* | *225.00* | *5.36* | *1.13* | *4.00* | *1.69* | *11.44* |

### C. Clusters B1B1 vs. B1B2. Average dissimilarity = 67.49.

| Species | Group B1B1 Av.Abund | Group B1B2 Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| *Mediomastus californiensis* | 1845.83 | 55.77 | 2.12 | 2.35 | 3.14 | 3.14 |
| *Caecum strigosum* | 3215.63 | 1465.38 | 1.49 | 1.37 | 2.20 | 5.34 |
| *Syllis cornuta* | 237.50 | 5.77 | 1.11 | 1.69 | 1.65 | 6.99 |
| *Synelmis ewingi* | 377.08 | 60.58 | 1.08 | 1.29 | 1.60 | 8.59 |
| *Acanthohaustorius uncinus* | 1.04 | 508.17 | 1.00 | 0.88 | 1.48 | 10.07 |

### D. Clusters B2A vs. B2B. Average dissimilarity = 87.17.

| Species | Group B2A Av.Abund | Group B2B Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| *Monticellina dorsobranchialis* | 30.68 | 1516.75 | 1.47 | 1.11 | 1.68 | 1.68 |
| TUBIFICIDAE | 668.75 | 283.25 | 1.34 | 1.11 | 1.54 | 3.22 |
| *Prionospio perkinsi* | 100.57 | 618.25 | 1.32 | 1.17 | 1.51 | 4.73 |
| *Ampelisca holmesi* | 260.80 | 105.75 | 1.24 | 1.09 | 1.43 | 6.16 |
| *Mysella planulata* | 233.52 | 285.00 | 1.18 | 1.03 | 1.35 | 7.52 |
| *Erycina floridana* | 0.00 | 404.75 | 1.14 | 0.97 | 1.30 | 8.82 |
| *Aricidea philbinae* | 228.41 | 40.50 | 1.07 | 1.06 | 1.22 | 10.04 |

### E. B2B1 vs B2B2. Average dissimilarity = 74.59.

| Species | Group B2B1 Av.Abund | Group B2B2 Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| *Monticellina dorsobranchialis* | 888.85 | 3303.85 | 2.41 | 1.30 | 3.24 | 3.24 |
| *Carazziella hobsonae* | 9.46 | 1107.69 | 2.01 | 1.30 | 2.69 | 5.92 |
| *Prionospio perkinsi* | 211.49 | 1775.96 | 1.98 | 1.22 | 2.66 | 8.58 |
| *Sigambra tentaculata* | 15.54 | 226.92 | 1.44 | 1.39 | 1.93 | 10.51 |
| *Erycina floridana* | 381.42 | 471.15 | 1.39 | 1.14 | 1.86 | 12.37 |
| TUBIFICIDAE | 261.15 | 346.15 | 1.20 | 1.18 | 1.61 | 13.98 |
| *Malmgreniella maccraryae* | 53.72 | 170.19 | 1.12 | 1.19 | 1.50 | 15.48 |

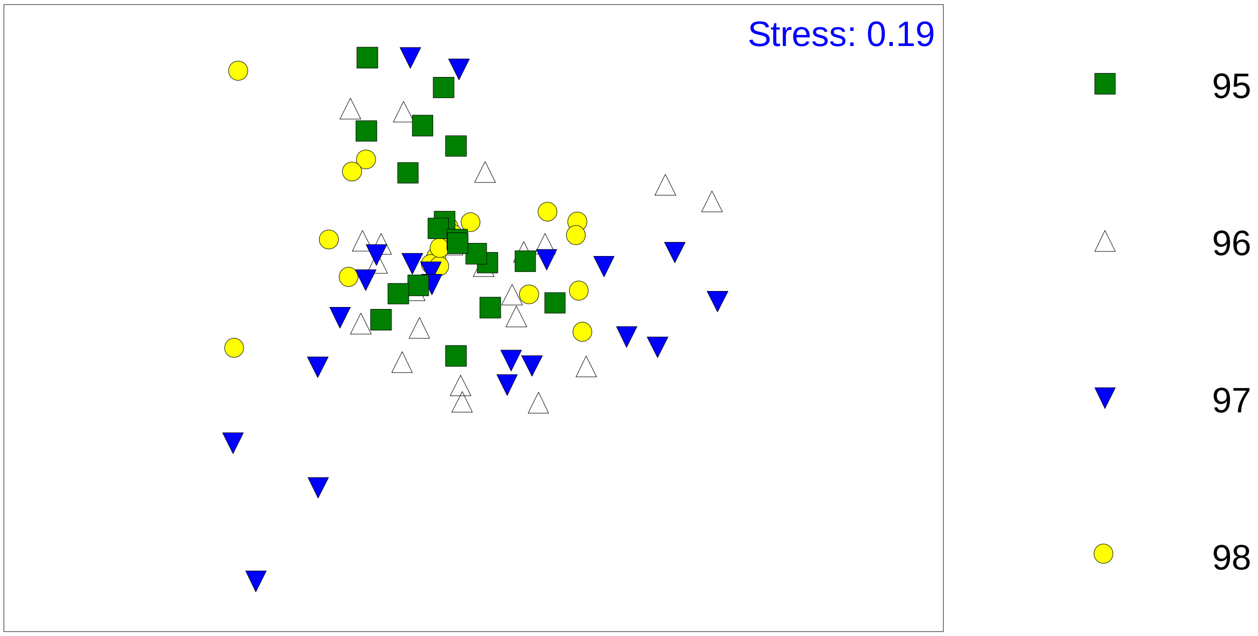


**Figure 31. MDS representation of benthic community structure in Middle Tampa Bay, 1995-1998, by year.**

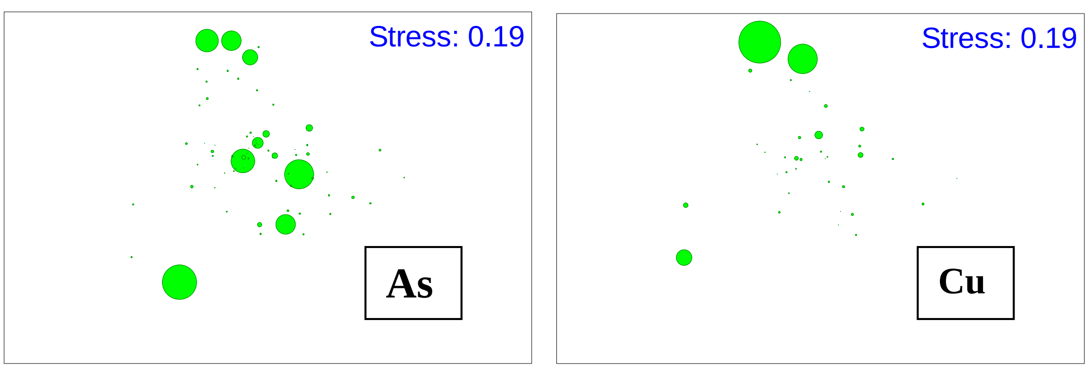


**Figure 32. Bubble plots of Arsenic and Copper superimposed over the MDS plot depicting benthic community structure, by year, in Middle Tampa Bay 1995-1998.**

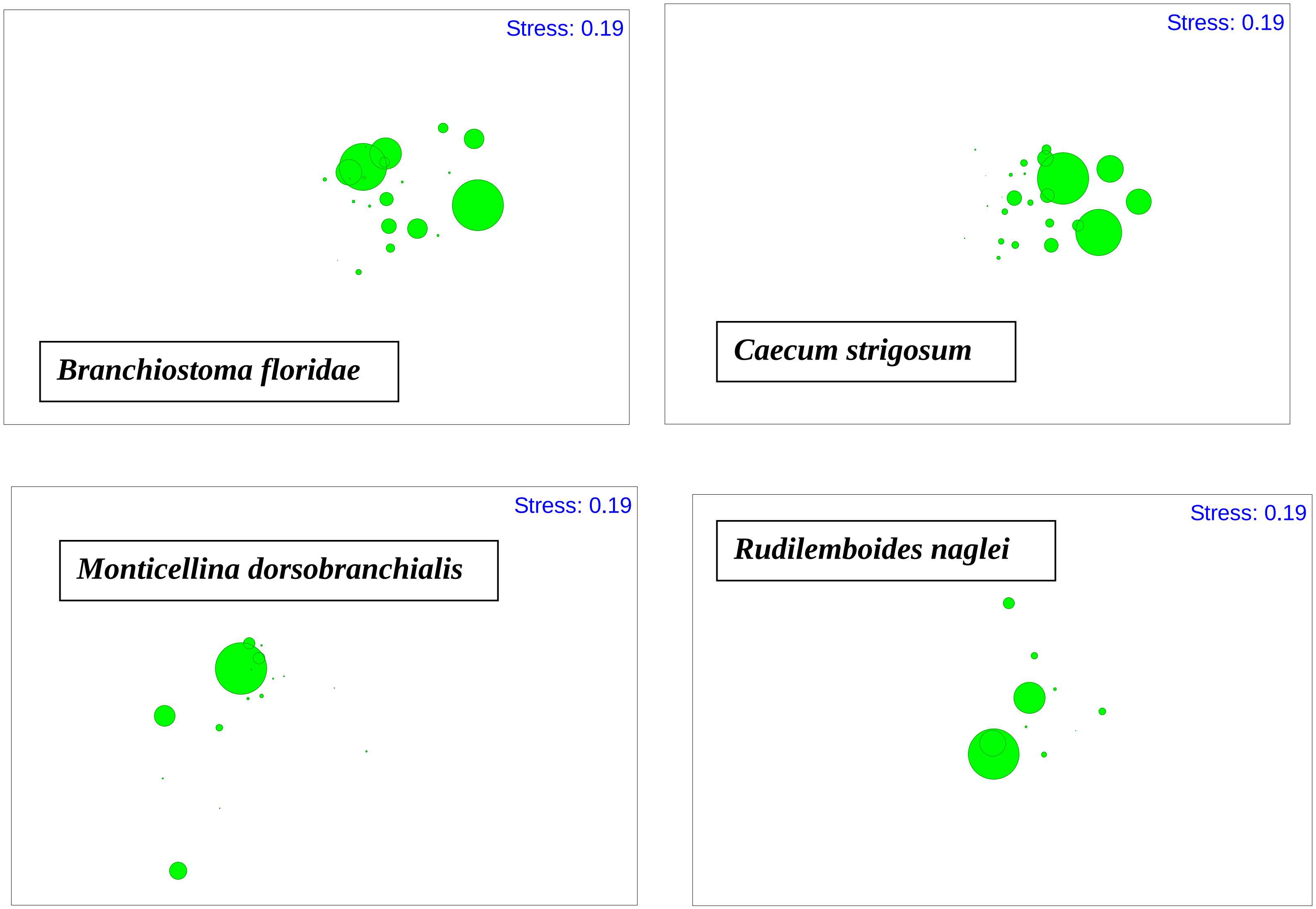


**Figure 33. Bubble plots of *Branchiostoma floridae*, *Caecum strigosum*, *Monticellina dorsobranchialis*, and *Rudilemboides naglei* densities superimposed over MDS plot (cf. Figure xx) depicting benthic community structure in Middle Tampa Bay, 1995-1998.**

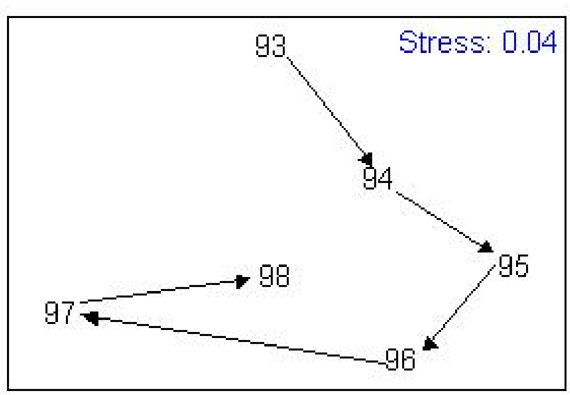


**Figure 34. MDS plot, "average" benthic community structure by year and mean concentrations of by year, Middle Tampa Bay, 1993-1998. Lines delineate temporal trend.**

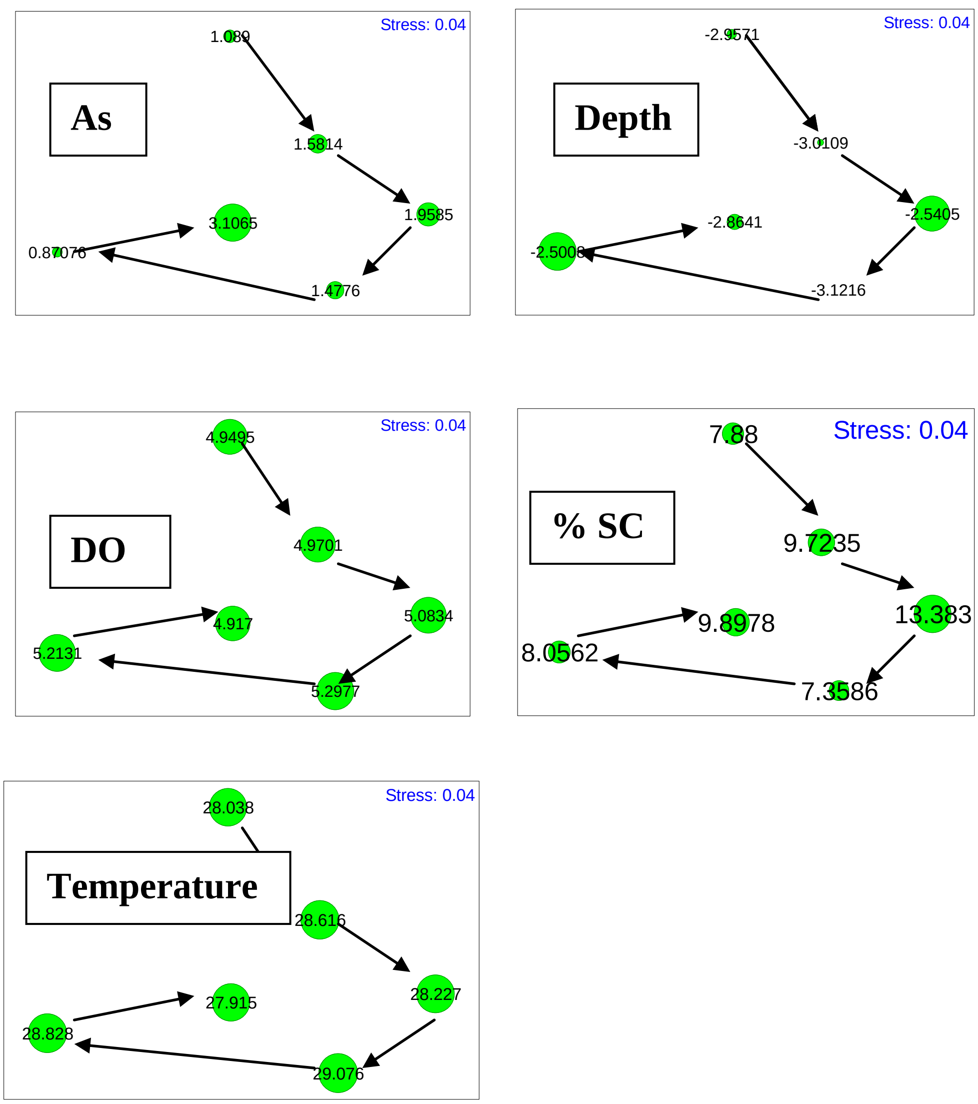


**Figure 35. Bubble plots depicting mean annual Arsenic, sample depth, DO, %SC, and temperature in Middle Tampa Bay, 1993-1998.**

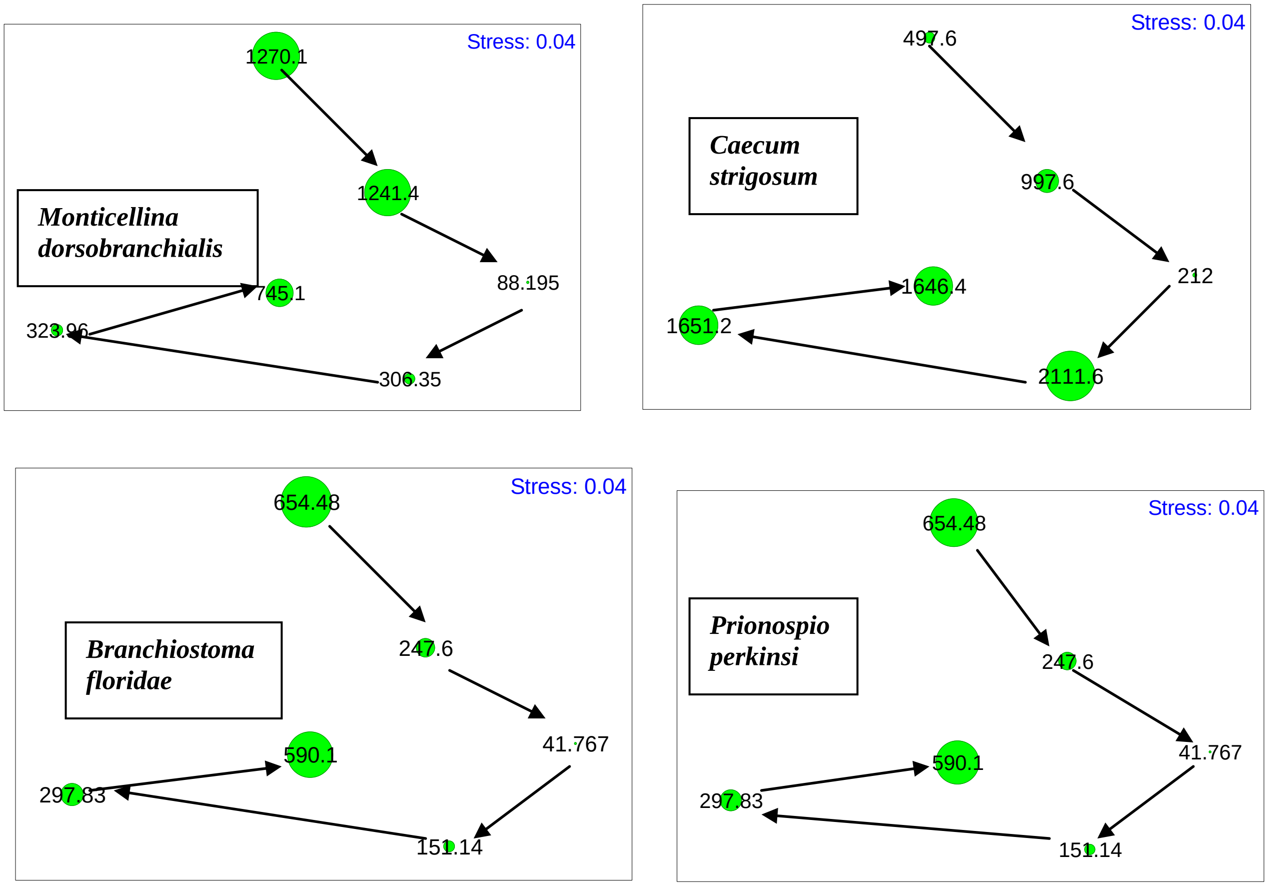


**Figure 36. Bubble plots depicting yearly mean densities (# m$^{-2}$) of *Monticellina dorsobranchialis, Caecum strigosum, Branchiostoma floridae, and Prionospio perkinsi* in Middle Tampa Bay, 1993-1998.**

**Table 13. Comparison of proportions of degraded habitat, by category and study area: southeastern US and Gulf of Mexico**.

| STUDY AREA | DO | SEDIMENT CHEMISTRY | BENTHOS | DO+ BENTHOS | SEDIMENT CHEMISTRY + BENTHOS | DO + SEDIMENT CHEMISTRY |
|---|---|---|---|---|---|---|
| **THIS STUDY (as % of samples)** | 2.4 | 0.0 | 1.6 | 1.6 | 1.9 | 1.6 |
| | | | | | | |
| **LOUISIANIAN PROVINCE 1991[a] (as % area)** | 6.1 | | 31.7 | | | |
| **LOUISIANIAN PROVINCE 1992[b]** | 5.0 | | 27.0 | | | |
| **LOUISIANIAN PROVINCE 1993[c]** | 7.0 | | 35.0 | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

[a] Summers *et al*. 1993 [b]. Macauley *et al*. 1994 [c] Macauley *et al*. 1995

# DISCUSSION

Middle Tampa Bay is one of the more diverse bay segments in terms of land use. Northeastern and southeastern Middle Tampa Bay are somewhat industrialized, with the Big Bend Generating Station and Port Manatee. The central portion of eastern Middle Tampa Bay is somewhat residential and the Little Manatee River has been designated as an "Outstanding Florida Water". Western Middle Tampa Bay is almost wholly urban residential. Middle Tampa Bay sediments are exposed to impacts from urban stormwater, thermal discharges, and atmospheric deposition from power plants (Estevez 1989), but less subject to industrial inputs than Hillsborough Bay.

During the 1993-1998 study period, the near-bottom water mass characteristics differed among years. Salinities in Middle Tampa Bay were generally in the polyhaline (18-30 ppt) zone and only rarely in the mesohaline and oligohaline zones.

PCA showed that %SC and depth exerted primary influence on the intra-bay habitat characteristics and salinity and DO exerted secondary influences. %SC was higher at the deeper sites and DO was higher at the more saline sites.

Sandy sediments predominate in Middle Tampa Bay with mud-sized sediments found at only two sites. This spatial pattern differed somewhat from historical data (1963-1992). Data collected by Taylor (1971) in the early 1960s showed that mud-sized sediments were often encountered in Middle Tampa Bay on a transect running approximately from Apollo Beach west to Snell Isle. This transect does appear to overlay the shipping channels in northern Middle Tampa Bay, which may explain the deposition of mud-sized sediments.

Data collected by Doyle *et al*. (1989) and Long *et al*. (1994) found some evidence of mud-sized sediments in this area, but they were not as prevalent as in the 1960s. Data collected under the current monitoring program has found fine sand-sized sediments prevalent in upper Middle Tampa Bay, but no mud-sized sediments. Few, if any of these samples were collected from actual shipping channels. The apparent differences in sediment composition may be due to actual changes within MiddleTampa Bay or they could merely be an artifact of the different study designs.

During 1993-1998 barely 2% of the Middle Tampa Bay samples met at least one criterion for “degraded” habitat. DO was subnominal (<2 ppm) at 2.4% of the sites; “degraded” benthic habitat (based on the TBBI) was detected at 1.6% of the sites. These percentages are considerably lower than those for the Louisianian Province as a whole.

Correlation analysis showed that the TBBI was positively associated with %SC in Middle Tampa Bay but not with other variables including a composite index of sediment contamination, DO, salinity, or sample depth. The rank correlations between benthic community structure and the “best fit” for physico-variables (arsenic and copper) were very weak (<0.1).

Within the benthic community, numerically abundant species included the lancelet *B. floridae*, the gastropod *Caecum strigosum*, and several polychaete worms. Numerical dominants differed by year and salinity zone—although few samples were, in fact collected from mesohaline and oligohaline waters.

The benthic community of Middle Tampa Bay may have changed since the 1960’s-1970’s--even taking into account interannual variation in composition and abundance. The most frequently collected mollusks and polychaetes in Middle Tampa Bay during 1963-1964 were not among the numerical dominants in the current study. Karlen *et al.* (1997) showed that the polychaete fauna in Middle Tampa Bay during 1963 was only 29% similar (presence-absence of species) to that observed in this study during 1993. Taylor (1971) reported that the most frequently occurring polychaetes were *Neanthes succinea, Pyllodoce arenae, Glycinde solitaria*, and S*piochaetopterus costarum* were each detected in >50% of the samples. The most abundant species in the current study (*M. dorsobranchialis* and *P. perkinsi*) were not even among the ten most frequently occurring in Taylor’s study. Although Leverone *et al*. (1991) showed that *Paraprionospio pinnata* was a dominant in the Big Bend area during the 1970s and 1980s, it was not particularly abundant in Middle Tampa Bay as a whole in this study.

The species composition of the mollusk fauna was only 33% between 1963 and 1993-1994 (Karlen *et al*. 1997). The most commonly occurring species (>30% of the samples) in 1963 were *Nucula crenulata, Tellina versicolor, Mercenaria* sp., and *Crepidula plana* (Taylor and Salomon 1969). Leverone *et al*. (1991) observed that *Mulinia lateralis* was a dominant near Big Bend in the 1970s and 1980s. In the current study, *C. strigosum* was the dominant. Its absence from the 1963 ranking may, however, have been due to the larger mesh size (0.7 mm) employed by Taylor and Salomon (1969). *Macoma tenta* and *M. lateralis* were also relatively abundant and among the 50 most frequently occurring species in the current study but not ranked by Taylor and Salomon (1969).

Spatial and temporal dissimilarities between the biotic assemblages reported in this study in were primarily influenced by differences in the distributions of sand-sized sediments, as measured by %SC, and depth—consistent with the results of the PCA. Interannual variations were also important in characterizing some groups of sites. Temperature, salinity and DO were variables which helped explain more subtler trends.

BIO-ENV analyses revealed only weak correlations between the overall structure of the benthic community and the suite of measured physical and chemical variables. The effects of the El Nino-Southern Osciillation (ENSO) on the benthic community, seen in both Hillsborough and Old Tampa bays during 1997-1998 (Grabe *et al*. 2003 and 2002), was not evident in Middle Tampa Bay. Schmidt and Luther (2002) showed that, unlike Hillsborough and Old Tampa bays, salinity in Middle Tampa Bay is more affected by winds and tides than by freshwater inflows. Thus, the ENSO would be expected to exert lesser impacts to the biota as distance from the major sources of freshwater increases.

The species most often contributing to the dissimilarity ion community structure included *C. strigosum* and *B. floridae* (common in coarser sand-sized sediments in “deeper” waters), *M. californiensis* and *E. honduranus* (characteristic of shallower sites), tubificid oligochaetes and *A. philbinae* (shallow, peripheral areas of Middle Tampa Bay), and *M. dorsobranchialis*, *E. floridana*, and *P. perkinsi* (characteristic of deeper areas of northeastern and central Middle Tampa Bay. There was also some evience of interannual variation affecting benthic structure.

The benthic community experienced more pronounced shifts in structure from 1996 to 1997 than during other year sequences in Middle Tampa Bay. The best fit for the *mean* environmental variable data with the *mean* biotic data over the 1993-1998 study period were for a combination of the variables arsenic, depth, DO, %SC, and temperature. However, the Spearman rank correlation coefficient was <0.5 and none of these variables demonstrated a profound change from 1996 to 1997. Differences in the mean abundance of selected species, including *B. floridae* and *C. strigosum*, helped explain the dissimilarities in the benthic assemblages of Middle Tampa Bay in 1996 and 1997.

## CONCLUSIONS

Analysis of hydrographic (temperature, salinity) and habitat variables (depth, %SC, DO) suggested that %SC and sample depth were primary determinants, and salinity and DO secondary determinants of the physico-chemical "structure" of Middle Tampa Bay.

Soft-sediment habitats in portions of Middle Tampa Bay experienced little stress from low DO and sediment contaminants. Degraded benthic habitat was also rarely detected. Subnominal habitat, based upon DO, sediment contaminants, or benthic status, was less pervasive in Middle Tampa Bay than in the Louisianian Province as a whole.

The structure of the benthic community was affected primarily by sediment type and depth and secondarily by DO, salinity, temperature. The linkage between biotic and abiotic structure was generally weak.

The composition of the benthos appears to have undergone changes since the 1960s and 1970s. Changes were observed in the most frequently occurring species within three taxonomic groups: polychaete worms, mollusks. Although interannual variations in population size andlocation could explain some of these differences, the differences could indicate changes in habitat quality over the past 30 years.

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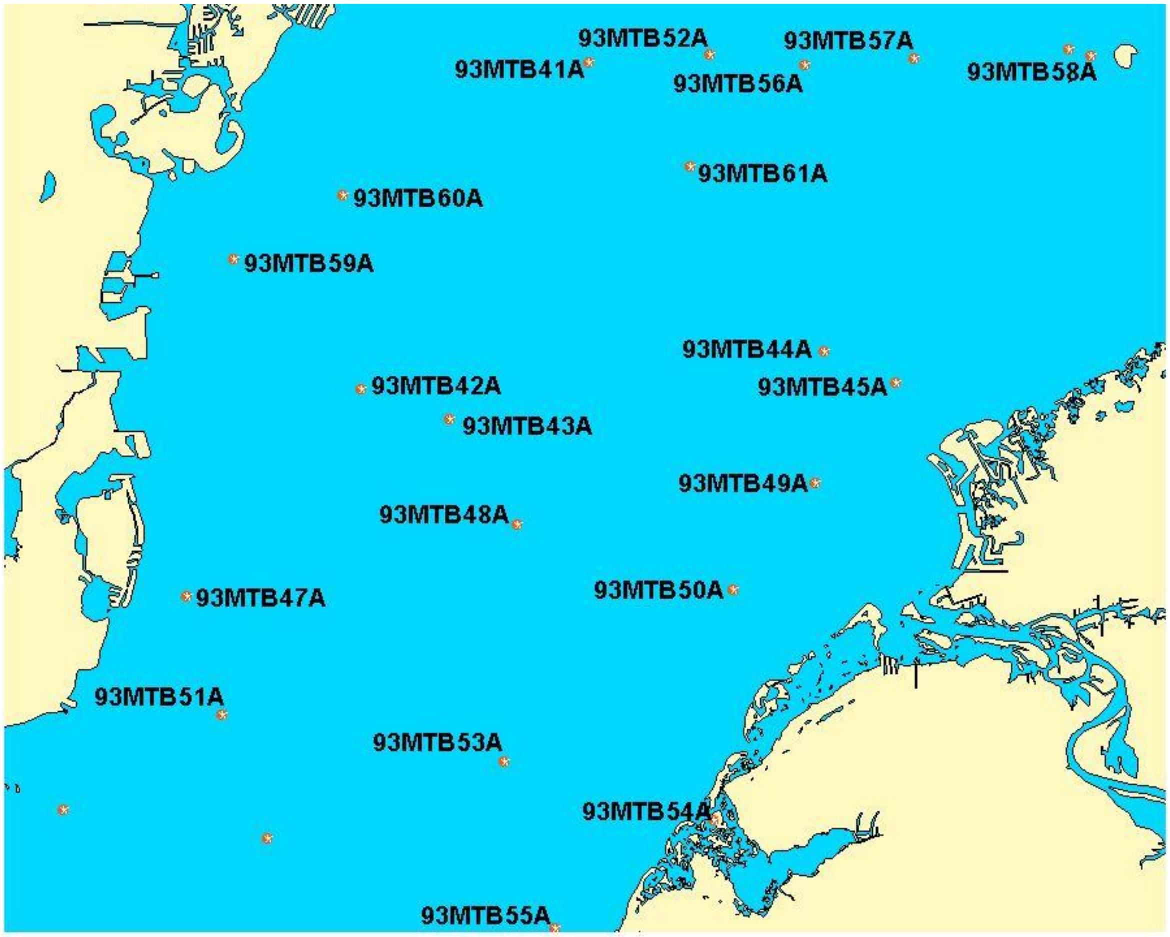
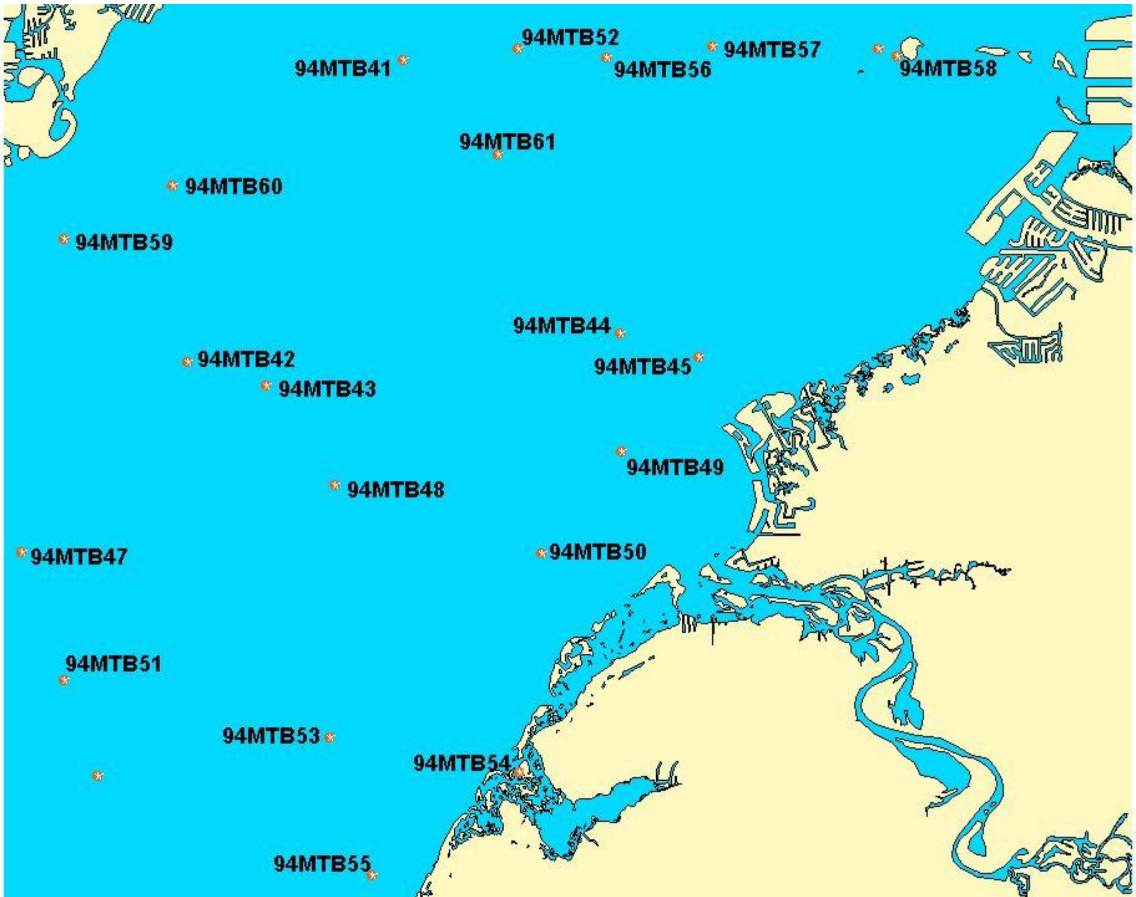
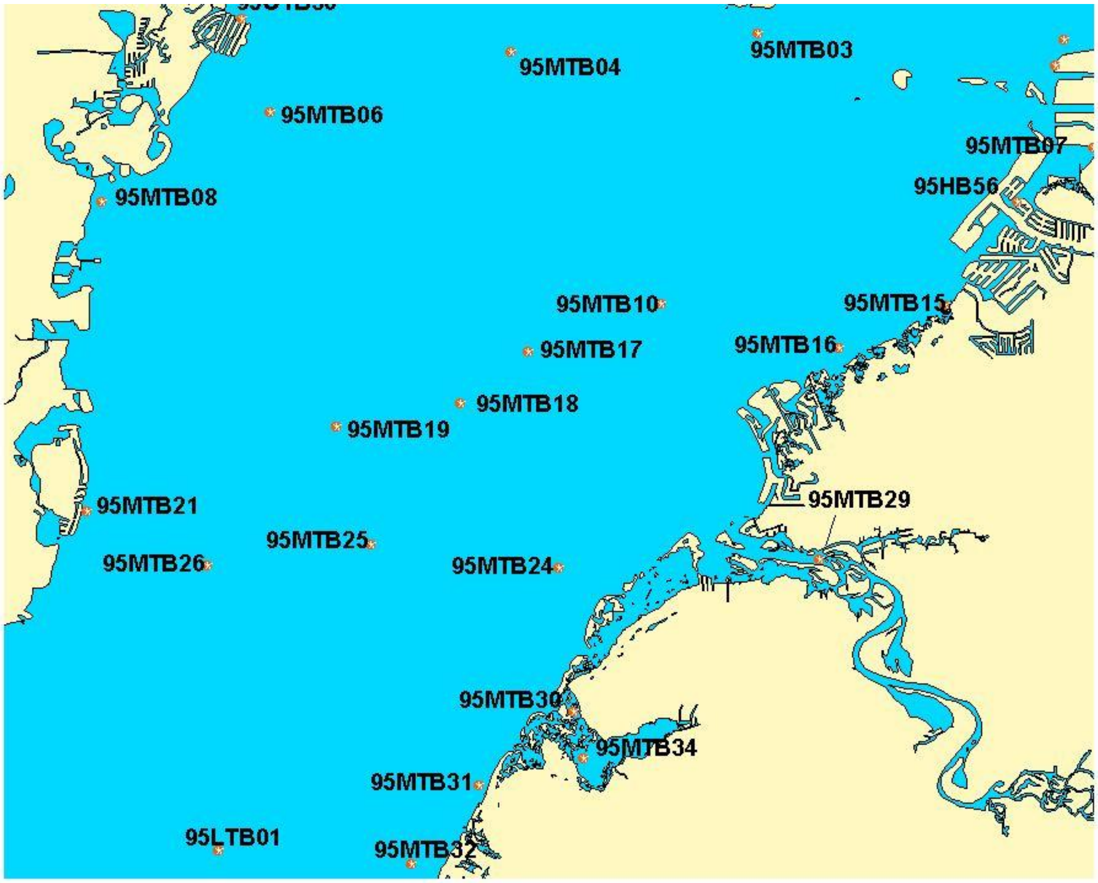
# APPENDIX A
# MIDDLE TAMPA BAY SAMPLING LOCATIONS: BY YEAR



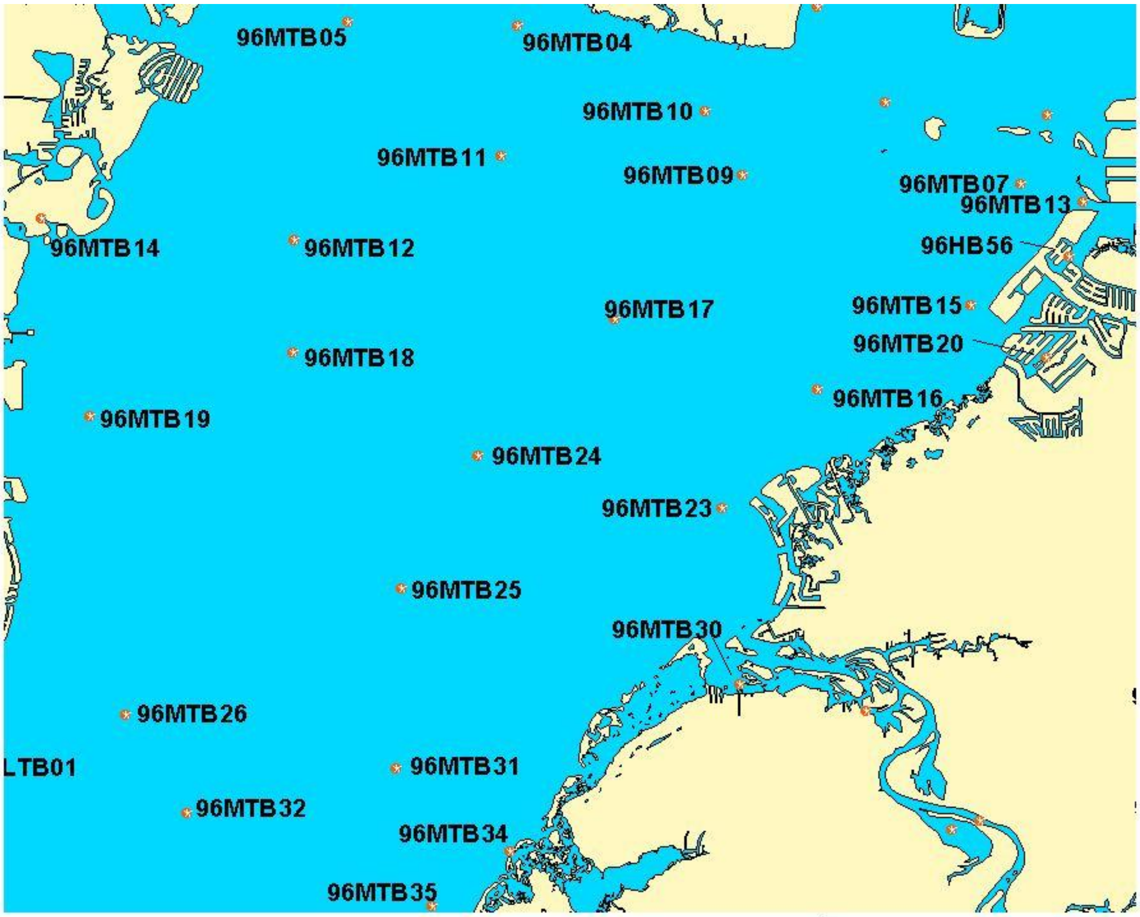

1993 Middle Tampa Bay Stations




1994 Middle Tampa Bay Stations




1995 Middle Tampa Bay Stations

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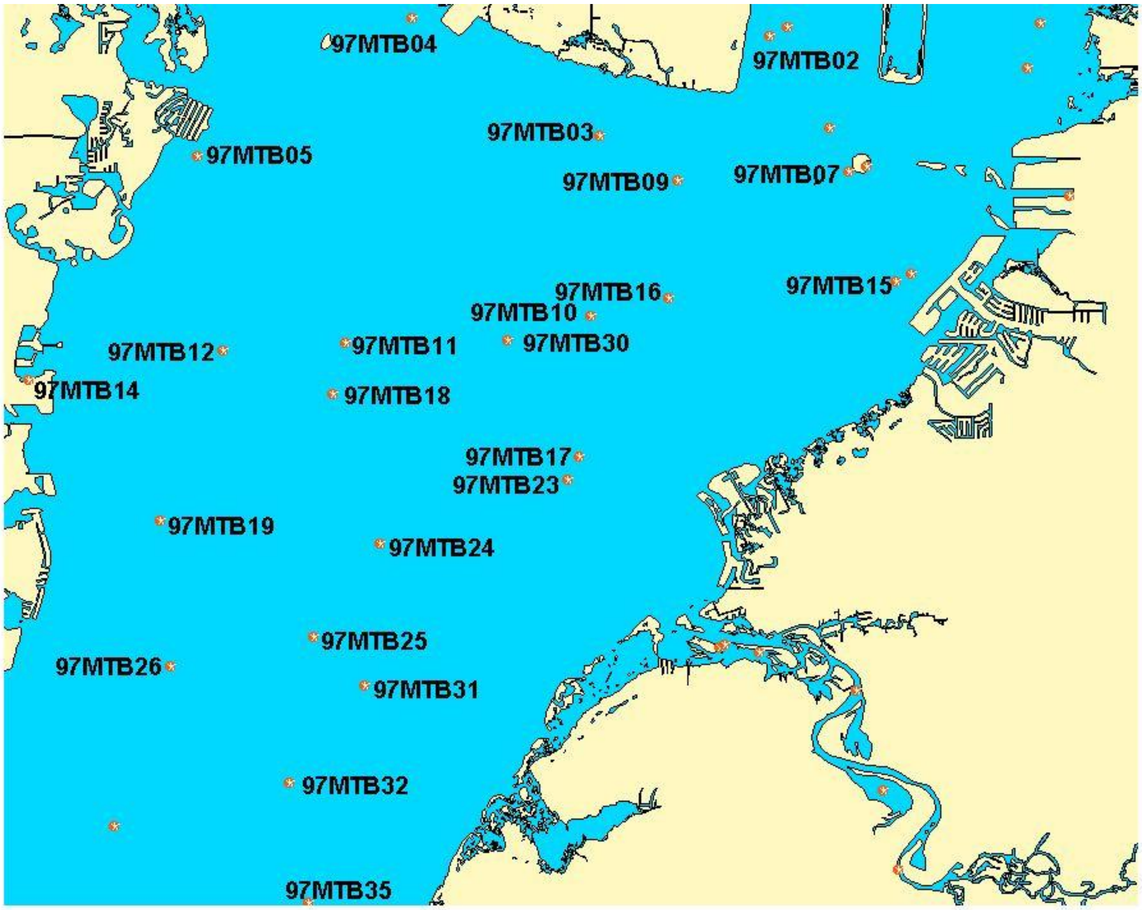
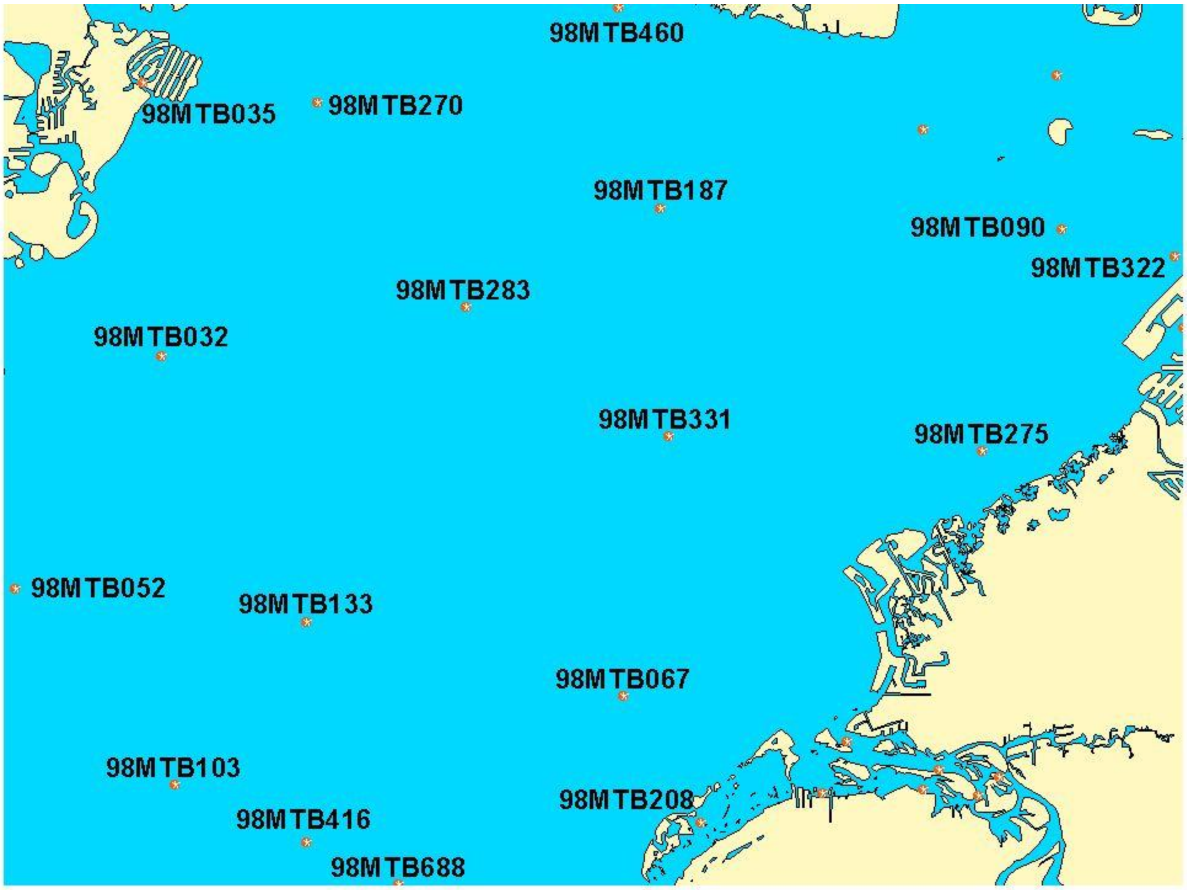



1997 Middle Tampa Bay Stations




1998 Middle Tampa Bay Stations

# APPENDIX B
# TAXONOMIC INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM MIDDLT TAMPA BAY ,1993-1998

***Phylum Cnidaria***
**Order Actinaria**
**Class Anthozoa**
*Anthozoa*
*Gorgonacea sp.*
*Actiniaria*

**Tribe Thenaria**
**Family Actinostolidae**
*Athenaria*
*Thenaria*
*Thenaria A*
*Thenaria B*

***Phylum Platyhelminthes***
**Class Turbellaria**
**Order Polycladida**
*Turbellaria A*
*Eustylochus meridianalis*
*Stylochoplana floridana*

## APPENDIX B (continued)

***Phylum Nemertea***
*Nemertea Y*
*Nemertea X*
*Prostoma sp.*
*Nemertea V*
*Nemertea U*
*Nemertea T*
*Nemertea R*
*Nemertea Q*
*Nemertea N*
*Nemertea L*
*Nemertea G*
*Nemertea F*
*Nemertea I*
*Nemertea K*
*Nemertea B*
*Nemertea A*
*Nemertea J*

**Class Anopla**
**Order Archinemertea**
*Archinemertea sp. A*

**Order Paleonemertea**
**Family Tubulanidae**
*Tubulanus pellucidus*

**Order Heteronemertea**
**Family Celebratulidae**
*Cerebratulus lacteus*

**Class Enopla**
**Order Hoplonemertea**
**Family Amphiporidae**
*Amphiporus bioculatus*
*Amphiporus cf. caecus*

## APPENDIX B (continued)

***Phylum Annelida***
**Class Polychaeta**
**Order Phyllodocida**
**Family Polynoidae**
*Harmothoe sp.*
*Malmgreniella maccraryae*
*Malmgreniella taylori*
*Polynoidae- genus undet.*

**Family Eulepethidae**
*Grubeulepis mexicana*

**Family Sigalionidae**
*Sigalion A*
*Sigalion B*
*Sthenelais sp.*
*Sthenelais sp. A*

**Family Chrysopetalidae**
*Bhawania heteroseta*

**Order Amphinomida**
**Family Amphinomidae**
*Paramphinome B*

**Order Phyllodocida**
**Family Phyllodocidae**
*Eteone heteropoda*
*Eteone foliasa*
*Paranaitis gardineri*
*Nereiphylla fragilis*
*Phyllodoce arenae*

**Family Hesionidae**
*Gyptis crypta*
*Parahesione luteola*
*Ophiodromus obscura*
*Podarkeopsis levifuscina*

# APPENDIX B (continued)

**Family Pilargidae**
*Ancistrosyllis hartmanae*
*Ancistrosyllis jonesi*
*Sigambra tentaculata*
*Sigambra bassi*
*Cabira incerta*
*Synelmis ewingi*
*Litocorsa antennata*
*Litocorsa A*

**Family Syllidae**
*Dentatisyllis carolinae*
*Syllis gracilis*
*Syllis cornuta*
*Trypanosyllis coeliaca*
*Syllis alternata*
*Syllis (Typosyllis) corallicola*
*Syllis (Typosyllis) alosa*
*Exogone dispar*
*Exogone lourei*
*Exogone arenosa*
*Exogone breviantennata*
*Sphaerosyllis aciculata*
*Sphaerosyllis glandulata*
*Sphaerosyllis taylori*
*Sphaerosyllis bilobata*
*Sphaerosyllis piriferopsis*
*Sphaerosyllis labyrinthophila*
*Grubeosyllis clavata*
*Brania wellfleetensis*
*Grubeosyllis nitidula*
*Grubeosyllis mediodentata*
*Grubeosyllis rugulosa*
*Brania A*
*Syllides floridanus*
*Streptosyllis pettiboneae*
*Parapionosyllis longicirrata*
*Parapionosyllis uelebackerae*

## APPENDIX B (continued)

**Family Nereididae**
*Kinberginereis ?sp.*
*Nereis acuminata*
*Nereis succinea*
*Nereis falsa*
*Nereis micromma*
*Nereis lamellose*
*Platynereis dumerilii*
*Laeonereis culveri*
*Stenoninereis martini*

**Family Nephtyidae**
*Nephtys cf. hombergii*
*Nephtys picta*
*Nephtys incisa*
*Nephtys cryptomma*
*Aglaophamus verrilli*

**Family Glyceridae**
*Glycera Americana*
*Hemipodus roseus*
*Glycinde solitaria*

**Family Goniadidae**
*Goniadides carolinae*

**Order Eunicida**
**Family Onuphidae**
*Diopatra cuprea*
*Mooreonuphis cf. nebulosa*
*Kinbergonuphis simony*

**Family Eunicidae**
*Marphysa sanguinea?*
*Nematonereis hebes*

**Family Lumbrineridae**
*Lumbrineris tenuis*
*Lumbrineris D*
*Lumbrineris B*

**Family Oenonidae**
*Arabella mutans*

# APPENDIX B (continued)

**Family Dorvilleidae**
*Dorvillea Rudolphi*
*Pettiboneia duofurca*
*Pettiboneia sp. A*

**Order Orbinida**
**Family Orbinidae**
*Leitoscoloplos robustus*
*Scoloplos rubra*
*Scoloplos texana*
*Orbinia riseri*
*Leitoscoloplos fragilis*

**Order Cirratulida**
**Family Paraonidae**
*Aricidea suecica*
*Aricidea fragilis*
*Aricidea philbinae*
*Aricidea taylori*
*Paraonis fulgens*
*Paradoneis cf. lyra*
*Cirrophorus perkinsi*
*Aricidea currutii*

**Order Spionida**
**Family Spionidae**
*Dipolydora socialis*
*Polydora cornuta*
*Prionospio multibranchiata*
*Prionospio heterobranchia*
*Prionospio steenstrupi*
*Apoprionospio pygmaea*
*Prionospio cristata*
*Prionospio perkinsi*
*Spio pettiboneae*
*Spiophanes bombyx*
*Paraprionospio pinnata*
*Paraprionospio A*
*Streblospio spp.*
*Scolelepis texana*
*Scolelepis cf. quadridenta*
*Microspio pigmentata*
*Carazziella hobsonae*

# APPENDIX B (continued)

**Order Magelonida**
**Family Magelonidae**
*Magelona pettiboneae*
*Magelona H*
*Magelona I*
*Magelona C*
*Boguea enigmatica*

**Order Spionida**
**Family Poecilochaetidae**
*Poecilochaetus johnsoni*

**Order Chaetopterida**
**Family Chaetopteridae**
*Chaetopterus pergamentaceus*
*Mesochaetopterus sp.*
*Spiochaetopterus costarum*

**Order Cirratulida**
**Family Cirratulidae**
*Caulleriella zetlandica*
*Caulleriella C*
*Caulleriella D*
*Tharyx acutus*
*Monticellina dorsobranchialis*
*Tharyx sp. A*
*Tharyx sp. E*
*Chaetozone B*
*Chaetozone A*
*Cirratulus sp.*
*Cirriformia sp. 1*
*Cirriformia cf. sp. B of Wolf, 1984*
*Cirriformia A*

**Order Ophelia**
**Family Ophelidae**
*Ophelina cylindricaudata*
*Armandia agilis*
*Armandia maculata*
*Travisia hobsonae*

## APPENDIX B (continued)

**Order Capitellida**
**Family Capitellidae**
*Capitella capitata*
*Heteromastus filiformis*
*Notomastus cf. tenuis*
*Notomastus hemipodus*
*Notomastus americanus*
*Notomastus n. sp.?*
*Mediomastus ambiseta*
*Mediomastus californiensis*
*Capitella jonesi*
*Capitomastus sp.*

**Family Arenicolidae**
*Arenicola cristata*

**Family Maldanidae**
*Sabaco americanus*
*Clymenella torquata*
*Axiothella mucosa*
*Axiothella A*

**Order Oweniida**
**Family Owenida**
*Owenia sp. A*
*Owenia fusiformis*
*Galathowenia oculata*

**Order Terebellida**
**Family Pectinariidae**
*Pectinaria gouldii*

**Family Sabellariidae**
*Sabellaria A*

**Family Ampharetidae**
*Amphicteis gunneri*
*Hobsonia florida*
*Melinna maculata*
*Isolda pulchella*

## APPENDIX B (continued)

**Family Terebellidae**
*Polycirrus hematodes*
*Polycirrus plumose*
*Polycirrus D*
*Polycirrus C*
*Lysilla sp. ?(alba)*
*Loimia medusa*
*Loimia viridis*
*Streblosoma hartmanae*

**Order Sabellida**
**Family Sabellidae**
*Chone sp.*
*Megalomma pigmentum*
*Fabricinuda trilobata*

**Family Serpulidae**
*Pomatoceros americanus*

**Family Spirorbidae**
*Janua (Dexiospira) steueri*

**Order Polygordiida**
**Family Polygordiidae**
*Polygordius sp.*

**Class Oligochaeta**
**Order Tubificidae**

**Family Enchytraeidae**
*Grania sp.*

**Family Tubificidae**
*Tubificoides motei*
*Tubificoides B*
*Tubificoides A*
*Limnodriloides anxius*
*Tubificoides brownae*
*Tubificoides wasselli*
*Thalassodrilides eneri*
*Heterodrilus bulbiporus*
*Heterodrilus occidentalis*
*Heterodrilus pentcheffi*
*Heterodrilus A*
*Bathydrilus ingens*
*Bathydrilus adriaticus*
*Bathydrilus A*
*Inandrilus bulbosus*
*Inanidrilus sp. A*
*Pectinodrilus molestus*
*Tectidrilus squalidus*
*Phallodrilinae*

***Phylum Mollusca***
**Class Gastropoda**

**Order Archaeogastropoda**
**Family Turbinidae**
*Didianema pauli*

**Order Heterostropha**
**Family Pyramidellidae**
*Sayella sp.*

**Order Neotaenioglossa**
**Family Vitrinellidae**
*Vitrinella floridana*
*Teinostoma sp.*
*Cyclostremiscus ?pentagonus*
*Solariorbis infracarinata*

## APPENDIX B (continued)

**Family Caecidae**
*Caecum pulchellum*
*Caecum imbricatum*
*Caecum johnsoni*
*Caecum nitidum*
*Caecum strigosum*

**Family Cerithiidae**
*Bittiolum varium*
*Cerithium lutosum*
*Cerithium muscarum*

**Family Epitoniidae**
*Epitonium angulatum*

**Family Eulimidae**
*Melanella B*
*Melanella ?intermedia*
*Melanella cf. arcuata*
*Melanella gracilis*
*Melanella A*
*Eulima bilineatus*
*Microeulima hemphilli*
*Eulima bifasciatus*
*Eulima auricincta*
*Polygireulima sp A*
*Vitreolina arcuata*

**Family Calyptraeidae**
*Calyptraea centralis*
*Crepidula fornicata*
*Crepidula convexa*
*Crepidula plana*
*Crepidula maculosa*

**Family Naticidae**
*Tectonatica pusilla*
*Sinum perspectivum*

# APPENDIX B (continued)

**Order Neogastropoda**
**Family Columbellidae**
*Astyris lunata*
*Parvanachis obesa*
*Costoanachis semiplicata*

**Family Nassaridae**
*Nassarius vibex*

**Family Olividae**
*Jaspidella blanesi*
*Olivella pusilla*
*Olivella nivea*
*Oliva sayana*

**Family Cystiscidae**
*Granulina hadria*
*Gibberula lavalleenana*

**Family Marginellidae**
*Dentimargo aureocinctus*
*Prunum apicinum*

**Family Terebridae**
*Terebra dislocata*

**Family Conidae**
*Kurtziella atrostyla*
*Pyrgocythara plicosa*

**Order Heterostropha**
**Family Pyramidellidae**
*Fargoa cf. gibbosa*
*Odostomia laevigata*
*Eulimastoma teres*
*Turbonilla interrupta*
*Turbonilla conradi*
*Turbonilla cf. dalli*
*Turbonilla hemphilli*
*Houbricka cf. incisa*
*Eulimastoma sp.*
*Turbonilla viridaria*
*Boonea impressa*

**Order Cephalaspidea**
*Lephalapsidea sp.*

**Order Unknown**
**Family Acteonidae**
*Rictaxis punctostriatus*

**Order Cephalaspidea**
**Family Cylichidae**
*Acteocinidae sp. A*
*Acteocina canaliculata*
*Acteocina ?atriata*
*Acteocina bidentata*
*Tornatina inconspicua*

**Family Bullidae**
*Bulla striata*

**Family Haminoeidae**
*Haminoea succinea*
*Haminoea antillarum*

**Order Anaspidea**
**Family Aplysiidae**
*Aplysia sp.*

**Order Nudibranchia**

**Class Bivalvia**

**Order Solemyoida**
**Family Solemyidae**
*Solemya occidentalis*

**Order Nuculoida**
**Family Nuculidae**
*Nucula crenulata*

**Order Arcoida**
**Family Arcidae**
*Anadara transversa*

## APPENDIX B (continued)

**Order Mytiloida**
**Family Mytilidae**
*Crenella decussata*
*Musculus lateralis*
*Brachidontes exustus*
*Amygdalum papyrium*

**Order Pterioida**
**Family Isognomonidae**
*Isognomon radiatus*

**Order Ostreoida**
**Family Anomiidae**
*Anomia simplex*

**Family Ostreidae**
*Crassostrea virginica*

**Order Veneroida**
**Family Lucinidae**
*Parvilucina multilineata*
*Lucinoma filosa*

**Family Ungulinidae**
*Diplodonta semiaspera*

**Family Lasaeidae**
*Orobitella floridana*
*Orobitella limpida*
*Mysella planulata*
*Erycina floridana*

**Family Carditidae**
*Pteromeris perplanna*
*Pleuromeris tridentata*
*Carditamera floridana*

**Family Crassatellidae**
*Crassinella lunulata*

**Family Cardiidae**
*Laevicardium mortoni*

## APPENDIX B (continued)

**Family Mactridae**
*Mulinia lateralis*
*Mactrotoma fragilis*

**Family Pharidae**
*Ensis minor*

**Family Tellinidae**
*Macoma tenta*
*Macoma constricta*
*Tellina iris*
*Tellina lineata*
*Tellina versicolor*
*Tellina alternata*
*Tellina texana*
*Tellina tampaensis*
*Tellina tenella*
*Tellidora cristata*

**Family Solecurtidae**
*Tagelus plebeius*
*Tagelus divisus*

**Family Semelidae**
*Abra aequalis*

**Family Veneridae**
*Transennella conradina*
*Dosinia discus*
*Dosinia eleganis*
*Pitar sp.*
*Chione cancellata*
*Macrocallista nimbosa*
*Anomalocardia auberiana*
*Parastarte triquetra*

**Order Myoida**
**Family Myidae**
*Sphenia antillensis*

**Family Corbulidae**
*Corbula contracta*
*Corbula swiftiana*

# APPENDIX B (continued)

**Order Pholadomyoida**
**Family Lyonsiidae**
*Lyonsia floridana*

**Family Periplomatidae**
*Periploma margaritaceum*

**Family Thraciidae**
*Asthenothaerus sp. A*
*Asthenothaerus sp. B*

***Phylum Arthropoda***
*Limulus polyphemus*

**Class Malacostraca**
**Order Leptostraca**
**Family Nebaliidae**
*Nebalia*

**Order Mysidacea**
**Family Mysidae**
*Bowmaniella floridana*
*Americamysis bigelowi*
*Americamysis bahia*
*Americamysis stucki*
*Brasilomysis sp.*
*Mysidopsis furca*

**Order Cumacea**
**Family Leuconidae**
*Leucon americanus*

**Family Diastylidae**
*Oxyurostylis smithi*
*Oxyurostylis lecroyae*

**Order Cumacea**
**Family Bodotriidae**
*Cyclaspis pustulata*
*Cyclaspis cf. varians*
*Cyclaspis sp. B*

**Family Nannastacidae**
*Cummella cf. garrityi*

# APPENDIX B (continued)

**Order Tanaidacea**
**Family Kalliapseudidae**
*Kalliapseudes sp. A*

**Family Leptocheliidae**
*Leptochelia sp.*

**Order Isopoda**
**Family Anthuridae**
*Cyathura polita*
*Amakusanthura magnifica*

**Family Hyssuridae**
*Xenanthura brevitelson*
*Neophyssura irpex*

**Order Amphipoda**
**Family Cirolanidae**
*Euridice personata*

**Family Sphaeromatidae**
*Paracerceis caudata*
*Harrieta faxoni*

**Family Serolidae**
*Serolis mgrayi*

**Family Idoteidae**
*Erichsonella attenuata*
*Edotia triloba*
*Cleantioides planicauda*

**Family Ampeliscidae**
*Ampelisca abdita*
*Ampelisca vadorum*
*Ampelisca agassizi*
*Ampelisca holmesi*
*Ampelisca bicarinata*
*Ampelisca sp. C*
*Ampelisca sp. A*

**Family Amphilochidae**
*Amphilocus neopolitanus*

## APPENDIX B (continued)

**Family Ampithoidae**
*Cymadusa compta*

**Family Aoridae**
*Globosolembos smithi*
*Bemlos brunneamaculatus*
*Bemlos setosus*
*Paramicrodeutopus cf. myersi*
*Rudilemboides naglei*
*Bemlos rectangulatus*

**Family Argissidae**
*Argissa hamatipes*

**Family Bateidae**
*Batea catharinensis*

**Family Ischyroceridae**
*Cerapus sp. C*
*Cerapus sp. D*
*Cerapus sp. A*

**Family Corophiidae**
*Apocorophium louisianum*
*Erichthonius brasiliensis*

**Family Aoridae**
*Grandidierella bonnieroides*

**Family Eusiridae**
*Pontogeneia bartschi*

**Family Gammaridae**
*Elasmopus laevis*
*Elasmopus procellimanus*

**Family Haustoriidae**
*Acanthohaustorius uncinus*

**Family Corophiidae**
*Microprotopus raneyi*

**Family Liljeborgiidae**
*Listriella barnardi*

# APPENDIX B (continued)

**Family Lysianassidae**
*Shoemakerella cubensis*
*Lysianassidae Genus C*

**Family Megaluropidae**
*Gibberosus cf. myersi*

**Family Oedicerotidae**
*Hartmanodes nyei*

**Family Phoxoxephalidae**
*Metharpinia floridana*
*Eobrolgus spinosus*

**Family Platyischnopidae**
*Eudevenopus honduranus*

**Family Stenothoidae**
*Parametopella sp.*
*Stenothoe minuta*
*Stenothoe sp. A*

**Family Synopiidae**
*Tiron triocellatus*

**Family Pariambidae**
*Deutella incerta*
*Paracaprella tenuis*
*Paracaprella pusilla*
*Hemiaegina minuta*

**Order Decapoda**
**Family Penaeidae**

**Family Sicyoniidae**
*Sicyonia typica*

**Family Pasiphaeidae**
*Leptochela serratorbita*
*Leptochela bermudensis*

**Family Palaemonidae**
*Periclimenes americanus*

## APPENDIX B (continued)

**Family Alpheoidea**
*Alpheus normanni*
*Automate evermanni*
*Automate rectifrons*
*Automate dolicognatha*

**Family Ogyrididae**
*Ogyrides alphaerostris*

**Family Hippolytidae**
*Hippolyte zostericola*
*Latreutes parvulus*

**Family Processidae**
*Processa hemphilli*
*Processa vicina*
*Nikoides schmitti*
*Ambidexter symmetricus*

**Subfamily Callichirinae**

**Superfamily Paguroidea**
**Family Paguridae**
*Paguristes hummi*
*Pagurus gymnodactylus*
*Pagurus maclaughlinae*

**Family Porcellanidae**
*Euceramus praelongus*
*Polyonyx gibbesi*

**Family Albuneidae**
*Albunea paretii*

**Family Upogebiidae**
*Upogebia affinis*

**Superorder Brachyura**
**Family Leucoriidae**
*Persephona mediterranea*

**Family Leucosiidae**
*Iliacantha subglobosa*

## APPENDIX B (continued)

**Family Majidae**
*Libinia dubia*
*Pitho sp.*

**Family Parthenopidae**
*Heterocrypta granulata*

**Family Panopeidae**
*Hexapanopeus angustifrons*
*Panopeus herbstii*
*Rhithropanopeus harrisii*
*Dyspanopeus texanus*

**Family Pinnotheridae**
*Dissodactylus mellitae*
*Tumidotheres maculatus*
*Pinnixa chaetopterana*
*Pinnixa cf. pearsei*
*Pinnixa cf. floridana*
*Pinnixa A*

**Class Insecta**
**Order Diptera**
**Family Chironomidae**
*Dicrotendipes simpsoni*

***Phylum Sipuncula***
**Family Golfingiidae**
*Phascolion cryptum*
*Phascolion strombi*
*Phascolion cf. caupo*

**Family Aspidosiphonidae**
*Aspidosiphon muelleri*

**Phylum Phoronida**
*Phoronis ?architecta*

# APPENDIX B (continued)

**Phylum Bryozoa**
*Bryozoa I*
*Bryozoa H*
*Bryozoa E*
*Bryozoa D*
*Membranipora*
*Discoporella sp.*

***Phylum Brachiopoda***
**Class Inarticulata**
**Order Lingulidae**
**Family Lingulidae**
*Glottidia pyramidata*

***Phylum Echinodermata***
**Class Ophiuroidea**
**Order Ophiurida**

**Family Ophiodermatidae**
*Ophioderma brevispinum*

**Family Ophiactidae**
*Hemipholis elongata*

**Class Amphiuroidea**
**Family Amphiuridae**
*Amphiodia sp.*
*Amphipholis squamata*
*Amphipholis gracillima*
*Ophiophragmus wurdemanii*
*Ophiophragmus filograneus*
*Amphioplus abditus*
*Amphioplus thrombodes*
*Amphioplus sepultus*
*Micropholis sp.*
*Amphipholis atra*

**Class Echinoidea**
**Family Mellitidae**
*Mellita tenuis*

# APPENDIX B (continued)

**Order Apodida**
**Family Synaptidae**
*Synaptidae  A*
*Synaptidae C*
*Leptosynapta sp.*

***Phylum Hemichordata***
**Family Harrimaniidae**
*Stereobalanus canadensis*

**Class Cephalochordata**
**Order Amphioxi**
**Family Branchiostomidae**
*Branchiostoma floridae*

# APPENDIX C
# SIMPER ANALYSES:
# COMPARISONS OF MIDDLE TAMPA BAY BENTHIC ASSEMBLAGES, BY YEAR- 1993-1998
# (TAXA EXPLAINING ≥10% OF DISSIMILARITY)

*Groups 94 and 93*

Average dissimilarity = 16.18

| Species | Group 94 Av.Abund | Group 93 Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| Caecum strigosum | 997.60 | 497.60 | 0.33 | 1.14 | 2.05 | 2.05 |
| Monticellina dorsobranchialis | 1241.35 | 1270.10 | 0.33 | 0.92 | 2.03 | 4.08 |
| Branchiostoma floridae | 576.35 | 716.35 | 0.28 | 1.36 | 1.71 | 5.79 |
| Prionospio perkinsi | 247.60 | 654.48 | 0.26 | 1.34 | 1.59 | 7.37 |
| Erycina floridana | 151.35 | 292.60 | 0.22 | 0.96 | 1.35 | 8.73 |
| Mediomastus californiensis | 235.10 | 366.35 | 0.22 | 0.88 | 1.34 | 10.06 |

*Groups 94 and 95*

Average dissimilarity = 15.43

| Species | Group 94 Av.Abund | Group 95 Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| Caecum strigosum | 997.60 | 212.00 | 0.33 | 1.07 | 2.13 | 2.13 |
| Branchiostoma floridae | 576.35 | 339.39 | 0.30 | 1.42 | 1.94 | 4.07 |
| Tellina sp. | 181.35 | 241.77 | 0.24 | 1.21 | 1.59 | 5.66 |
| Prionospio perkinsi | 247.60 | 41.77 | 0.24 | 1.35 | 1.56 | 7.22 |
| TUBIFICIDAE | 232.60 | 119.15 | 0.23 | 1.16 | 1.46 | 8.69 |
| Nucula crenulata | 237.60 | 66.77 | 0.23 | 1.22 | 1.46 | 10.15 |

*Groups 96 and 95*

Average dissimilarity = 16.59

| Species | Group 96 Av.Abund | Group 95 Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| Caecum strigosum | 2111.56 | 212.00 | 0.32 | 0.83 | 1.92 | 1.92 |
| Branchiostoma floridae | 470.93 | 339.39 | 0.28 | 1.16 | 1.67 | 3.59 |
| Rudilemboides naglei | 1116.77 | 46.53 | 0.26 | 0.85 | 1.59 | 5.18 |
| Pinnixa spp. | 256.35 | 17.96 | 0.25 | 1.56 | 1.49 | 6.67 |
| Metharpinia floridana | 387.60 | 122.72 | 0.24 | 0.98 | 1.46 | 8.13 |
| Ampelisca sp. C | 296.98 | 34.62 | 0.22 | 1.12 | 1.34 | 9.47 |
| Ampelisca holmesi | 282.39 | 116.77 | 0.22 | 1.03 | 1.34 | 10.81 |

*Groups 96 and 97*

Average dissimilarity = 19.10

| Species | Group 96 Av.Abund | Group 97 Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| Branchiostoma floridae | 470.93 | 2953.51 | 0.41 | 1.22 | 2.15 | 2.15 |
| Caecum strigosum | 2111.56 | 1651.24 | 0.38 | 1.01 | 1.99 | 4.14 |
| Rudilemboides naglei | 1116.77 | 97.83 | 0.25 | 0.76 | 1.30 | 5.44 |
| Monticellina dorsobranchialis | 306.35 | 323.96 | 0.24 | 1.11 | 1.28 | 6.72 |
| TUBIFICIDAE | 267.81 | 469.42 | 0.24 | 1.08 | 1.27 | 7.99 |
| Metharpinia floridana | 387.60 | 141.01 | 0.23 | 1.03 | 1.23 | 9.22 |
| Nucula crenulata | 188.64 | 238.74 | 0.22 | 1.28 | 1.16 | 10.38 |

*Groups 98 and 97*

Average dissimilarity = 18.81

| Species | Group 98 Av.Abund | Group 97 Av.Abund | Av.Diss | Diss/SD | Contrib% | Cum.% |
|---|---|---|---|---|---|---|
| Branchiostoma floridae | 1312.60 | 2953.51 | 0.41 | 1.31 | 2.20 | 2.20 |
| Caecum strigosum | 1646.35 | 1651.24 | 0.37 | 1.06 | 1.99 | 4.19 |
| TUBIFICIDAE | 327.60 | 469.42 | 0.26 | 1.26 | 1.40 | 5.59 |
| Prionospio perkinsi | 590.10 | 297.83 | 0.26 | 1.30 | 1.38 | 6.97 |
| Monticellina dorsobranchialis | 745.10 | 323.96 | 0.25 | 1.01 | 1.35 | 8.33 |
| Tellina versicolor | 3.85 | 362.60 | 0.22 | 1.04 | 1.17 | 9.49 |
| Mediomastus sp. | 242.60 | 68.28 | 0.20 | 1.22 | 1.09 | 10.58 |