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

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# Environmental Protection Commission of Hillsborough County

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# EXECUTIVE SUMMARY

The Environmental Protection Commission of Hillsborough County (EPCHC) has been collecting sediment samples on an annual (summer) basis in Old Tampa Bay since 1993 as part of a bay-wide monitoring program developed by the Tampa Bay National Estuary Program. These samples are analyzed for the composition and abundance of the animals living in and on the sediments ("benthos") as well as for chemical contaminants (metals, pesticides *etc.*). The original objectives of this program were to discern the "health" or "status" of the bay's sediments based upon both chemistry and biology.

The Tampa Bay Estuary Program (formerly the Tampa Bay National Estuary Program) and the USEPA have provided partial funding for this monitoring program.

This report summarizes data collected during 1993-1998 from the Old Tampa Bay segment of Tampa Bay. Among the major findings are that:

1- 104 locations (15 to 23 per year) were sampled during late summer/early fall "Index Period" from 1993 to 1998.

2- Near-bottom water temperatures were highest during 1996 and lowest during 1997.

3- Near-bottom salinities were generally highest in 1993 and lowest during the 1995 and 1998 sampling periods. Salinities were generally within the polyhaline (18-30 ppt) zone.

4-Near-bottom dissolved oxygen concentrations were less than 2 parts per million (hypoxia) in only 3 of the >100 sites sampled. "Marginal" (>2≤4 ppm) conditions for dissolved oxygen generally occurred in less than 20% of the samples in any year.

5- Sediments in Old Tampa Bay were predominantly medium and coarse sands. There appears to be a transition near the Howard Frankland Bridge (I-275) between a coarse-medium sand habitat to the south and a fine-very fine sand habitat to the north.

6- A composite index of the chemical contamination, based upon metals, PCBs, and hydrocarbons, of Old Tampa Bay sediments suggested that at only a single site in Culbreath Bayou was there a high likelihood that sediments could be toxic to aquatic life. Contaminants of concern at this site included the metals chromium, nickel and lead as well as the pesticide chlordane. There has been no evidence of hydrocarbon contamination in the samples collected to date from Old Tampa Bay.

7- Numerically abundant benthic species included the clam *Mysella planulata,* the lancelet *Branchiostoma floridae*, and the amphipods *Rudilemboides naglei* and *Metharpinia floridana*. Numerical dominants differed both by year and salinity zone.

8- The variety of animals (numbers of species) in any sample ranged widely within each year, but was generally similar from year to year.

9- Tampa Bay Benthic Index (a composite measure of the "health" of the communities of bottom dwelling organisms primarily driven by Shannon-wiener diversity) scores were generally indicative of a "healthy" benthic habitat. At only two sites were Index scores suggestive of "degraded" conditions.

10- Benthic Index scores were associated with the apparent redox potential discontinuity layer (a measure of the depth of aerobic sediments), percent of silt+clay in the sediments, and dissolved oxygen. The Benthic Index was not associated with salinity, an index of sediment contamination and sample depth.

11- The overall structure of the *community* of sediment dwelling animals, based on multivariate analyses of community structure, appeared to be related to the transition in sediment type in the vicinity of the Howard Frankland bridge. Associations between benthic community structure and measured physical and chemical variables was, however, generally weak.

12- The benthic community experienced more pronounced shifts in structure from 1994 to 1995 and from 1997 to 1998 than during other years. These time periods reflected a shift from a higher salinity regime to a lower salinity regime influenced by El Niño-Southern Oscillation events. The association between(multivariate) benthic community structure and measured physical and chemical variables was, again, fairly weak. Benthic organisms which contributed primarily to this shift in community structure from 1994 to 1995 and again from 1997 to 1998 included the clam *Mysella planulata*, which increased in abundance during El Niño years, and the lancelet *Branchiostom,a floridae* and the amphipod crustacean *Metharpinia floridana*, which declined in abundance.

13- Old Tampa Bay appears to be proportionately less affected by subnominal dissolved oxygen concentrations (<2 ppm) and degraded benthic habitat than the Louisianian Province (northern Gulf of Mexico south to Tampa Bay) as a whole.

14- The taxonomic composition of the benthos appears to have undergone changes since the 1960s and 1970s. Changes were primarily observed among the mollusks. Although interannual variations in population size and differences in sampling locations could explain some of these differences, such differences may also reflect changes in habitat quality over the past 30 years. At this point no determination has been made as to whether these changes represent either an improvement or a deterioration in the status of benthic habitat in Old Tampa Bay.

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# I. INTRODUCTION

The Environmental Protection Commission of Hillsborough County (EPCHC) has been collecting sediment samples in Old Tampa Bay since 1993. These are part of a bay-wide monitoring program for sediment contaminants and benthic macroinvertebrates. The purpose of the monitoring program was to evaluate trends in habitat status with respect to the goals and objectives of the Comprehensive Conservation and Management Plan for Tampa Bay (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 and to assess sediment quality by means of Sediment Quality Assessment Guidelines (SQAGs) (MacDonald Environmental Sciences Ltd. 1994). The Tampa Bay Estuary Program has provided partial funding for this monitoring program.

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

# II. METHODS

***Field Collection and Laboratory Procedures***: A total of 104 stations (15 to 23 per year) were sampled during a 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 (Figure 1) following the field protocols outlined in Courtney *et al*. (1993). Sediment samples were collected for sediment contaminants, benthic macroinvertebrates, and sediment types (as percent silt+clay). The sample collected for silt+clay analysis was also examined for the presence and width of the "apparent redox potential discontinuity layer" (RPD). The width of the RPD demarcates oxidized and reduced sediments (Rosenberg 2001). Field measurements included hydrographic profiles for temperature, salinity, dissolved oxygen, and pH, Laboratory procedures followed the protocols set forth in Courtney *et al*. (1995).

**Figure 1. Young grab sampler (stainless steel; 0.04 m$^2$ sampling area) used to collect sediment and benthic samples.**

***Data Analysis***: Species richness, Shannon-Wiener diversity, and Evenness were calculated using PISCES Conservation Ltd.'s (2001) "Species Diversity and Richness II" software. The Tampa Bay Benthic Index (TBBI) was developed by Coastal Environmental, Inc. (1995) for the TBEP as a tool for discerning the "status" of benthic habitat in Tampa Bay. Variables used in the construction of the TBBI include Shannon-Wiener diversity and the abundance of capitellid polychaetes, tubificid oligochaetes, gastropods, and amphipods.

Descriptive statistics, the Tampa Bay Benthic Index (TBBI), regression analysis, and the Kolmogorov-Smirnov (KS) "two-sample" test (used to compare frequency distributions by year), and graphs were generated using SYSTAT 10 (SSPS Inc. 2000). Sediment status was assessed by comparing measured contaminant 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; organochlorine pesticides were excluded) >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) (PRIMER-E Ltd. 2001) was used to examine the resemblance of the Old Tampa Bay sites, by year. Hydrographic (temperature, salinity, dissolved oxygen) and sediment (percent silt+clay; %SC) variables were normalized to a mean = 0 and s.d.=1 prior to analysis. The objective of this ordination is to reduce the multiple variables into a lower dimensional (2-D) "map" based upon the percentage of the total variance explained (principal component) (Clarke & 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 principal component (PC); Johnson & 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 & Warwick 2001). In these analyses, taxa densities were transformed (n+0.1; fourth root) and the similarity coefficient used was Bray-Curtis (PRIMER-E Ltd. 2001). “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 (PRIMER-E Ltd. 2001) was used to investigate the structure of the benthic community (site x year and taxa). The site x year structure was examined using fourth root transformed n+0.1 abundances (all taxa). Biotic structure was evaluated using the 50 most abundant taxa (standardized densities). The similarity measure was Bray-Curtis and the clustering algorithm was “group average”. PRIMER’s SIMPER (PRIMER-E Ltd. 2001) program was used to rank the various taxa’s contribution to the dissimilarity between identified clusters.
PRIMER’s BIO-ENV (PRIMER-E Ltd. 2001) 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 36 physical, hydrographic, and contaminant variables ($\text{Log}_{10}$ (x+1)) transformed and standardized; normalized Euclidean distance) for the 1995-1998 data[*] (Clarke & Ainsworth 1993).

Sediment type (*e.g.*, sand, silt) was determined by regressing %SC vs. mean grain (ϕ) size for Tampa Bay data collected by Long *et al.* (1994) using TableCurve 2D (AISN Software, 2000). These data were used to develop a relationship between %SC and mean grain size:

$$\%SC= 1/(0.0097+1.575*e^{-\phi}\text{adjusted } r^2=0.947).$$

Wentworth size classes for sediments (*cf.* Percival & Lindsay 1997) were then estimated for each %SC value.

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[*] 1994 samples were excluded because sediment contaminants were not analyzed. In 1993 only four samples were collected from Hillsborough Bay. In order to make all bay segment assessments in this series comparable, 1993 data were deleted from this analysis for Old Tampa Bay as well.

# III. RESULTS

***Hydrographic***: Table 1 summarizes the surface and bottom water quality measures, including temperature, salinity and dissolved oxygen (DO), as well as sample depth for the 104 stations sampled. Median sample depth was 2.2 m, although depths ranged to >7 m (Figure 2). The deepest stations (>5 m) were located in southern Old Tampa Bay between Papys' Point (Pinellas County) and Picnic Island (Hillsborough County).

**Table 1. Summary of Mean Physicochemical Variables, by Relative Depth: Old Tampa Bay, 1993-1998**

| SURFACE | Temperature ($^o$ C) | Salinity (ppt) | Dissolved Oxygen (ppm) |
|---|---|---|---|
| **Minimum** | 25.8 | 0.0 | 2.4 |
| **Maximum** | 31.8 | 26.8 | 11.0 |
| **Median** | 29.1 | 21.8 | 6.1 |
| **Mean** | 29.1 | 21.1 | 6.2 |

| BOTTOM | Depth (meters) | Temperature ($^o$C) | Salinity (ppt) | Dissolved Oxygen (ppm) |
|---|---|---|---|---|
| **Minimum** | 0.1 | 26.0 | 0.0 | 0.2 |
| **Maximum** | 7.5 | 31.2 | 26.8 | 11.0 |
| **Median** | 2.2 | 29.0 | 22.3 | 5.6 |
| **Mean** | 2.4 | 28.9 | 21.4 | 5.4 |

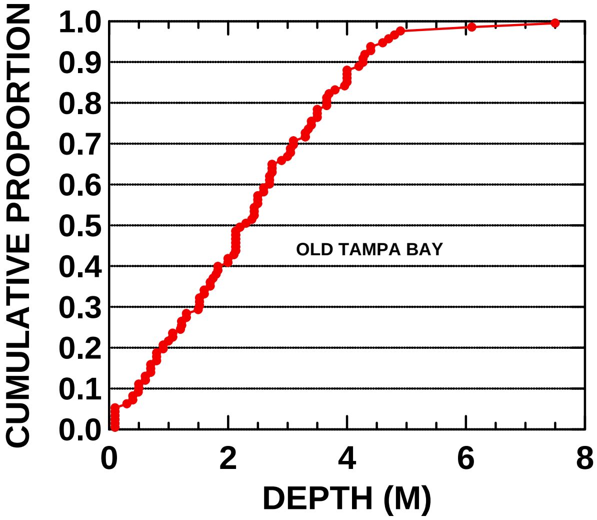

**Figure 2. CDF plot of sample depths in Old Tampa Bay, 1993-1998 inclusive.**

The temperature-salinity plot suggests that the near-bottom water mass characteristics differed among years (Figure 3). Highest water temperatures were observed during 1996 and lowest during 1995 (Figure 4). The frequency distribution of water temperatures during 1993 was similar to 1994, 1997 and 1998; 1994 and 1997 were also similar (KS test *p*>0.05). Salinities were generally highest in 1993 and 1997 and lowest during the 1995 and 1998 sampling periods (Figure 5). The frequency distributions of near-bottom salinity were similar during 1993 and 1997, during 1994 and 1996, and during 1995 and 1998 (KS test *p*>0.05). Salinities were generally within the polyhaline (18-30 ppt) zone (Figure 5). During 1994 to 1997 and again from 1997 to 1998 median salinities declined by >5 ppt—the largest changes observed over consecutive years.

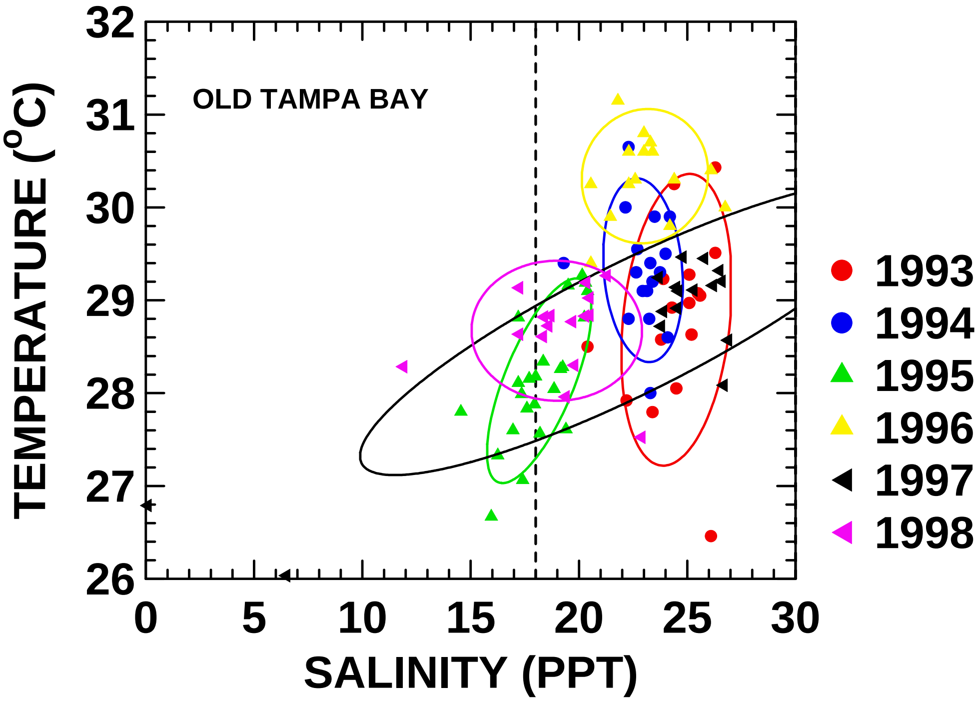

**Figure 3. Temperature-salinity plot, by year, Old Tampa Bay 1993-1998. Ellipses embrace ±. S.D within each year**.

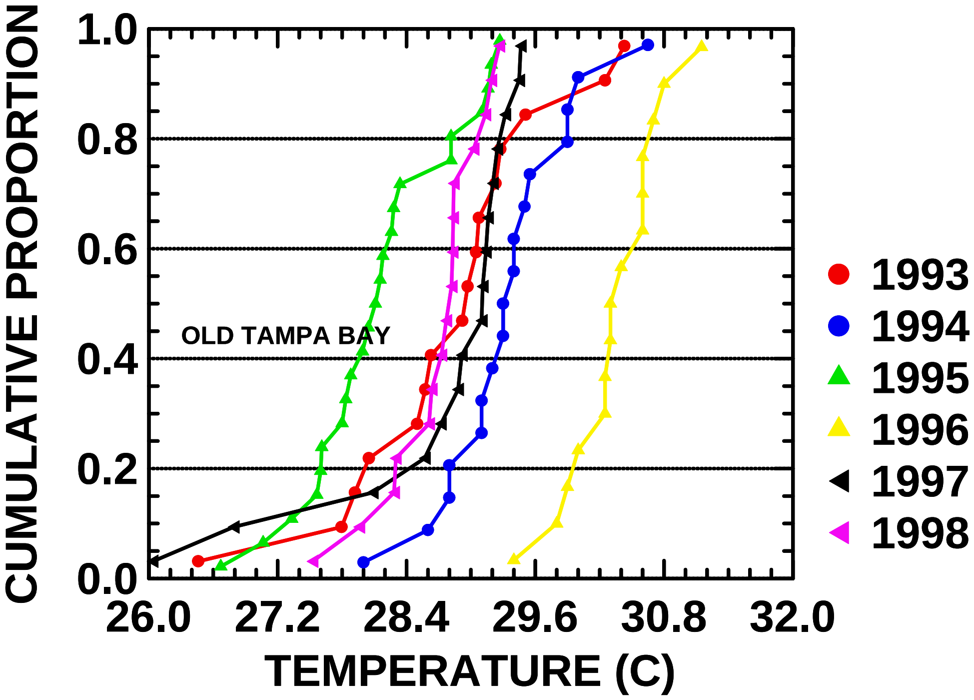

Figure 4. CDF plot of near-bottom temperatures in Old Tampa Bay, by year 1993-1998.

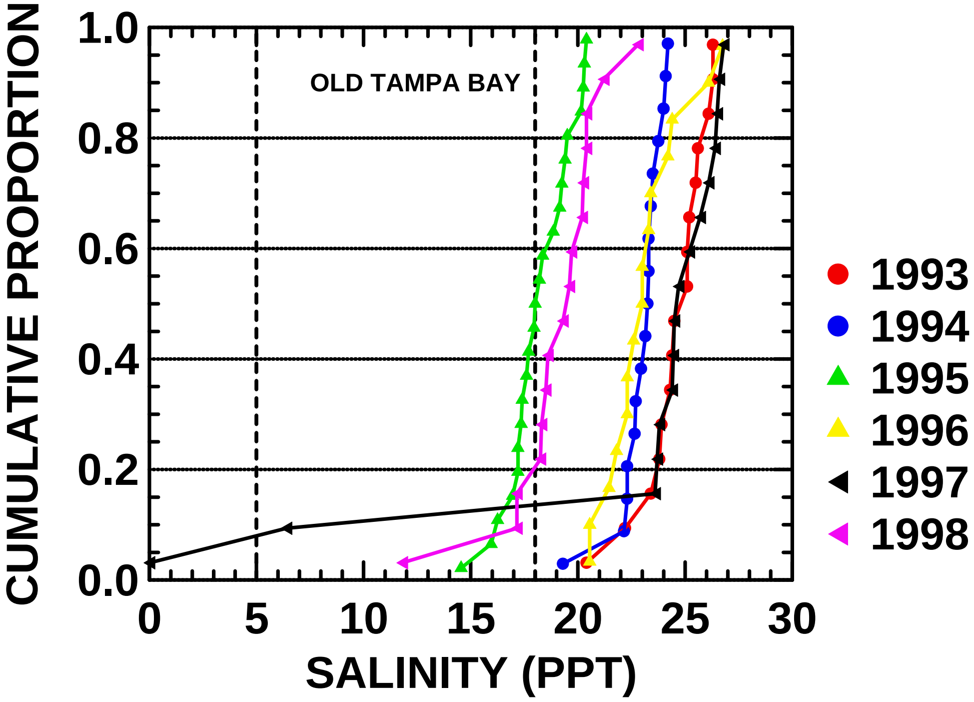

Figure 5. CDF plot of near-bottom salinities in Old Tampa Bay, by year 1993-1998.

Near-bottom dissolved oxygen concentrations were “subnominal” (<2 ppm=hypoxic) in only three samples (Figure 6). Hypoxia was observed at two sites near the Courtney Campbell Causeway and a third site near the entrance to Lake Tarpon (Figure 7). The frequency distribution of near-bottom DO (Figure 6) during 1996 and 1997 differed from that of 1993-1995 (KS test $p<0.05$). “Marginal” DO (≥2<4 ppm) was primarily observed in the northwestern portion of Old Tampa Bay (Figure 7).

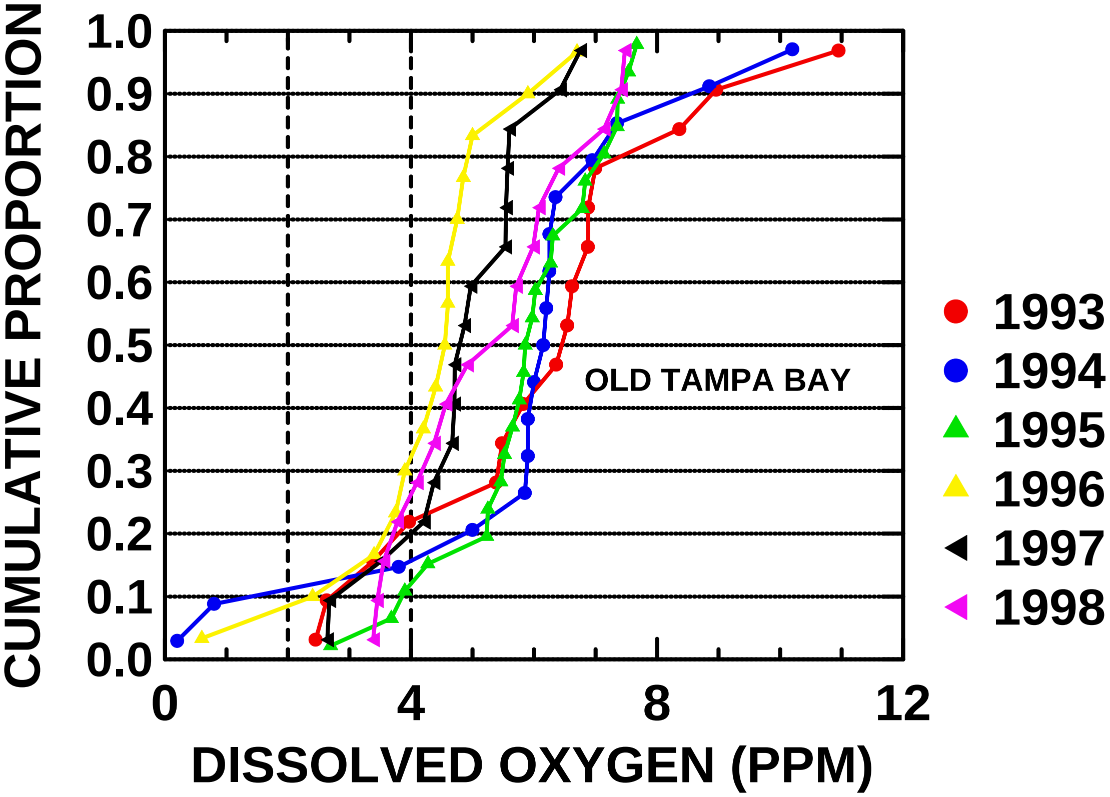

**Figure 6. CDF plot of dissolved oxygen concentration in Old Tampa Bay, 1993-1998: by year. (Hypoxia is defined as DO<2 ppm; the standard for Class III waters in Florida is 4 ppm).**

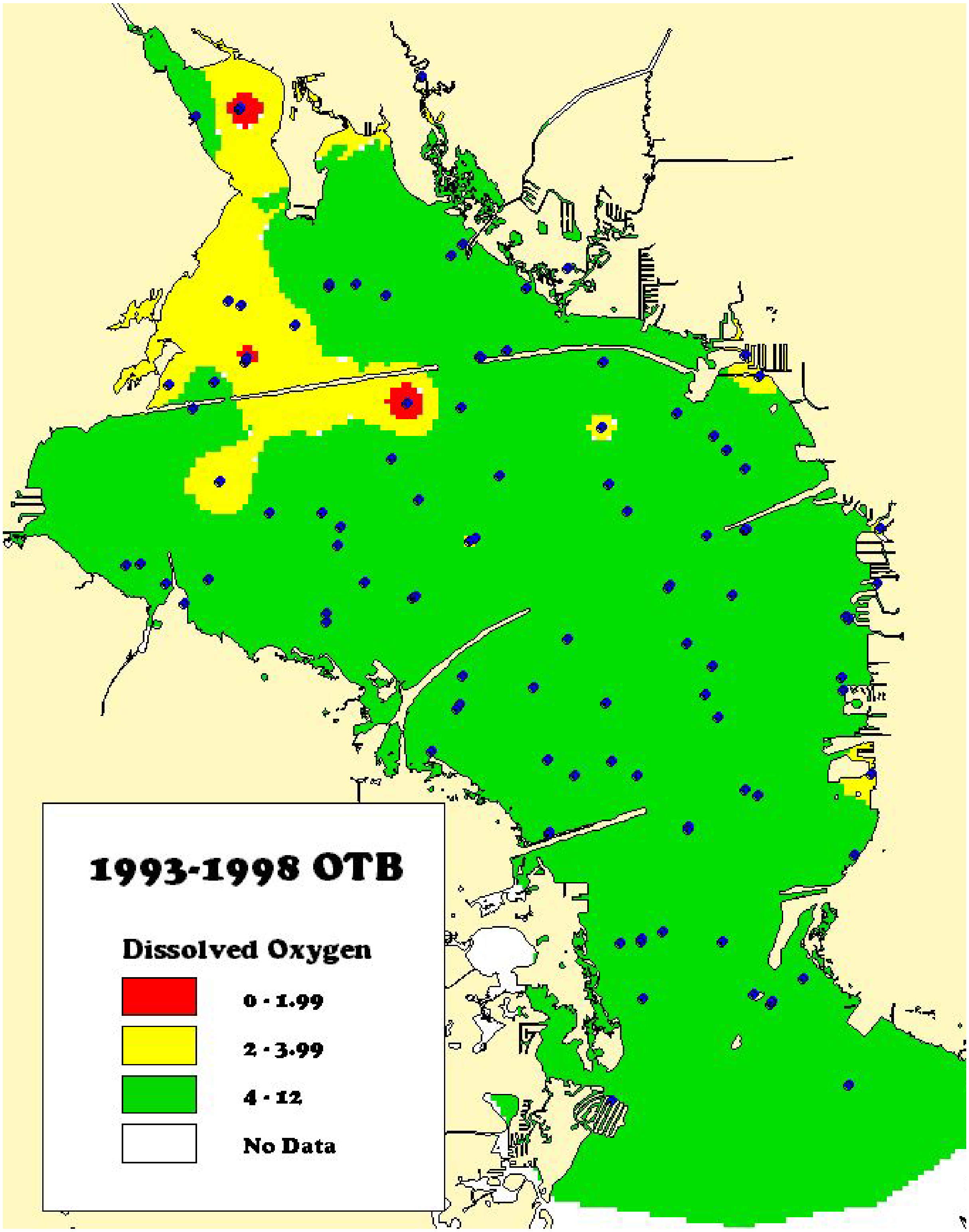

**Figure 7. Map depicting the distribution of near-bottom dissolved oxygen concentrations in Old Tampa Bay, 1993-1998.**

***Sediment Characteristics***: Old Tampa Bay sediments are predominantly sandy (<25.95 %SC)--primarily medium and coarse sands (<4.51%SC) (Figures 8 and 9). The finest grained sediments are located in the Safety Harbor and Culbreath Isles areas (Figure 9). There also appears to be a demarcation between a medium-coarse sand environment south of the Howard Frankland Bridge (I-275) and a fine to very fine sand environment to the north.

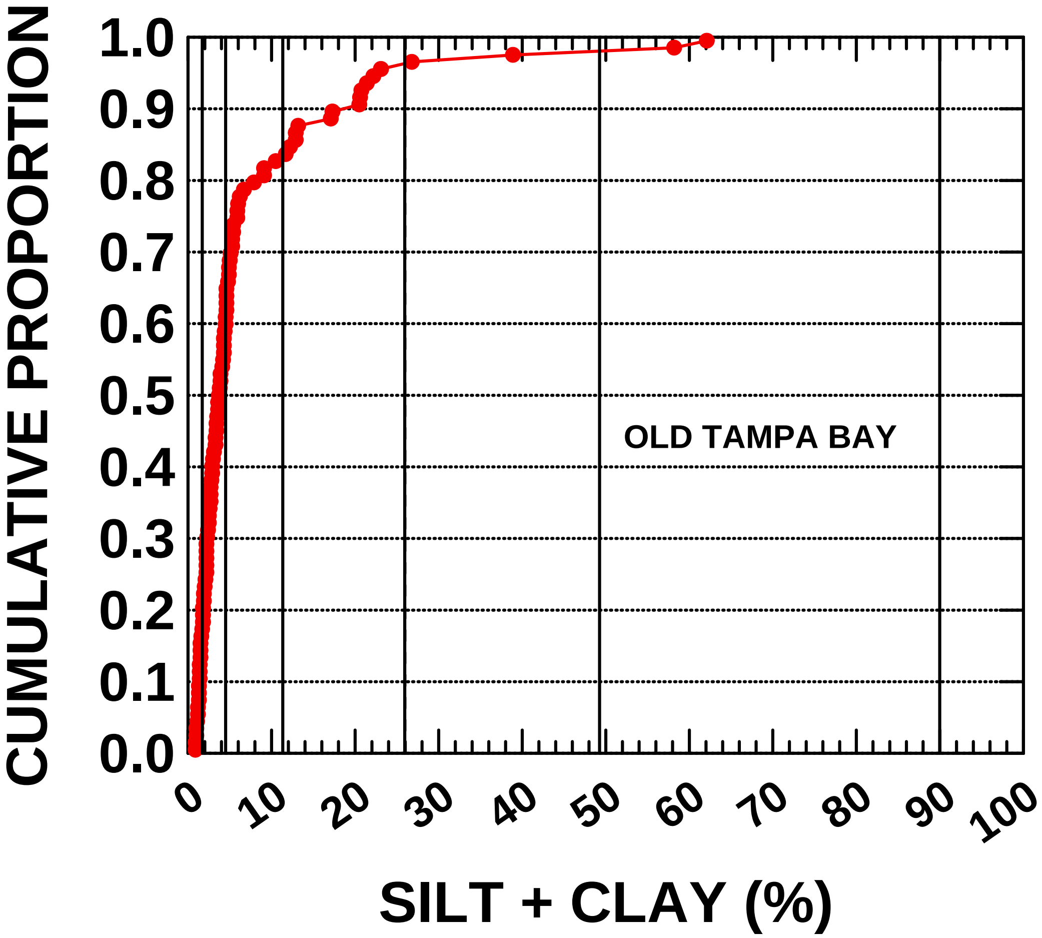

**Figure 8. CDF plot of %SC in Old Tampa Bay sediments, 1993-1998. Vertical lines demarcate sediment types: coarse sand (<1.70% SC), medium sand (1.70 to 4.51 %SC), fine sand (4.51 to 11.35 %SC), very fine sand (11.35 to 25.95 %SC), coarse silt (25.95 to 49.28 %SC), medium silt (42.98 to 89.98 %SC), and fine silt (>89.98 %SC).**

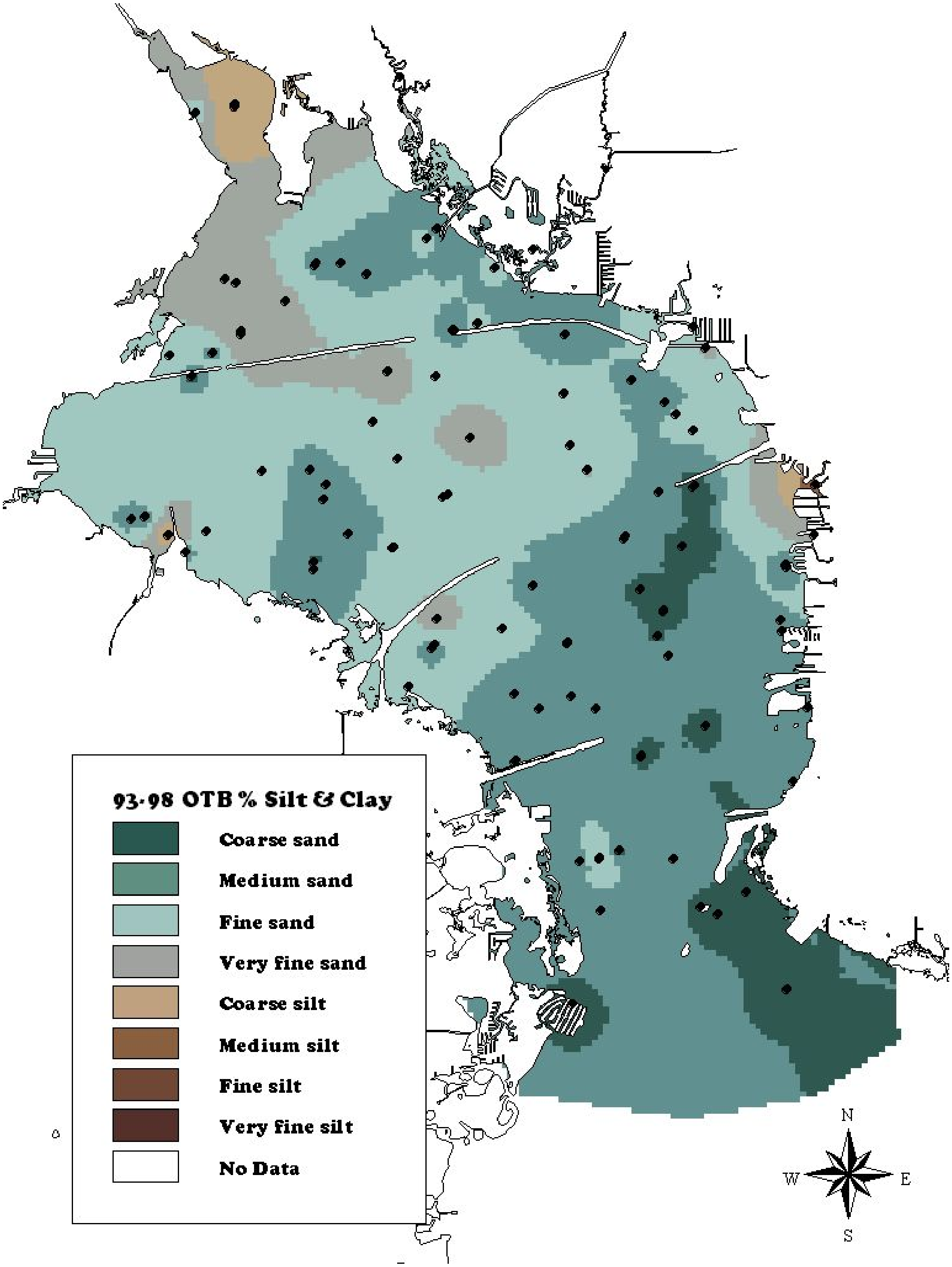

**Figure 9. Map depicting distribution of sediment types in Old Tampa Bay, 1993-1998.**

The apparent RPD ranged from 0 to >100 mm (Figure 10), with aerobic conditions (RPD>50-mm; Summers *et al*.1993) evident in >35% of the samples. Approximately 35% of the samples also had an RPD<10-mm, suggestive of anaerobic sediments (Summers *et al*. 1993). The width of the RPD layer was negatively correlated with %SC (Figure 11) and positively correlated with DO (Figure 12).

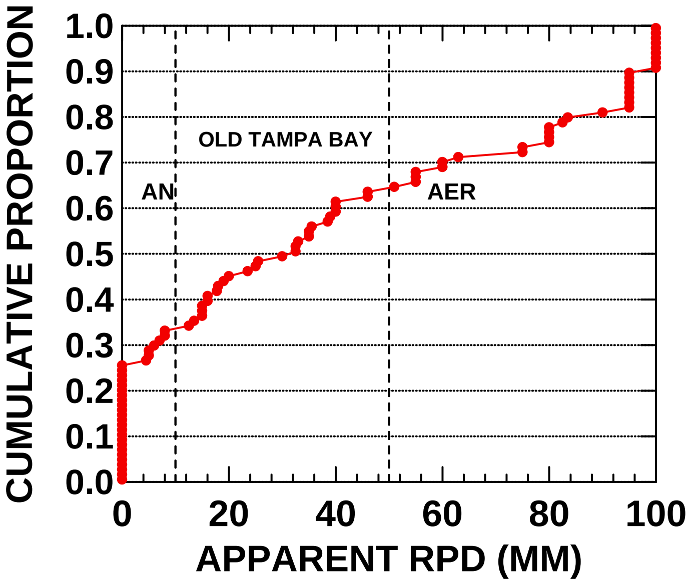

**Figure 10. CDF of apparent RPD in Old Tampa Bay, 1993-1998. Anaerobic (AN) sediments are characterized by an RPD <10-mm and aerobic (AER) sediments are characterized by an RPD>50-mm.**

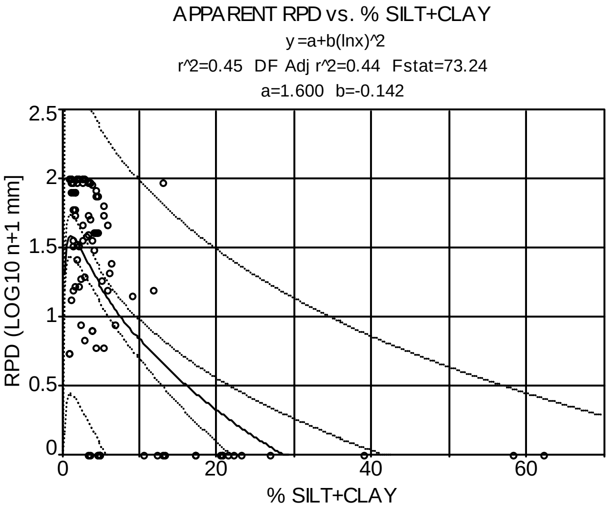

**Figure 11. Association between apparent RPD and %SC in Old Tampa Bay, 1993-1998.**

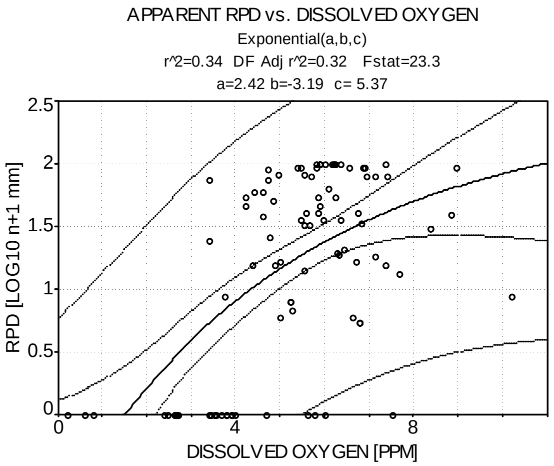

**Figure 12. Association between apparent RPD and near-bottom dissolved oxygen, Old Tampa Bay, 1993-1998.**

***Principal Components Analysis (PCA)of Hydrographic and Site Characteristics***: PCA showed that the first two principal components (PC) explained almost 70% of the overall variation in Old Tampa Bay hydrography and site characteristics (Table 2). The highest loadings (Table 2-B) in PC1 were for salinity, temperature, and sample depth. Salinities tended to be highest at the deepest, warmest sites (Figure 13). PC2 reflected the inverse association between DO and %SC (Figure 13).

***Sediment Contaminants***: Based upon the composite PEL Quotient (Figure 14), few of the sediment samples collected from Old Tampa Bay had a high likelihood of being toxic to aquatic life. Sediments of "marginal" quality accounted for <20% of the samples in any year except 1995—when high MDLs increased the composite PEL quotient. One site in Culbreath Bayou (95OTB15; *cf.* Appendix A) had a higher likelihood of being toxic to aquatic life. At this location the PEL quotient for metals was close to one (Figure 15); concentrations of chromium, nickel, and lead exceeded the PEL and zinc concentrations approached the PEL. Old Tampa Bay sediments were "clean" with respect to contamination by PAHs (Figure 16) and PCBs (Figure 17).

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

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

| | **DO** | **% SILT+CLAY** | **SALINITY** | **DEPTH** |
|---|---|---|---|---|
| **DO** | -- | | | |
| **% SILT + CLAY** | 0.53 (<0.001) | -- | | |
| **SALINITY** | 0.11 (0.29) | -0.12 (0.23) | -- | |
| **DEPTH** | 0.22 (0.02) | -0.05 (0.64) | -0.27 (<0.01) | -- |
| **TEMPERATURE** | -0.03 (0.76) | 0.03 (0.77) | 0.54 (<0.001) | -0.39 (<0.001) |

### B EIGENVALUES & % VARIANCE EXPLAINED

| **PC** | **EIGENVALUE** | **% VARIANCE EXPLAINED** | **CUMULATIVE VARIANCE EXPLAINED** |
|---|---|---|---|
| **1** | 1.84 | 36.8 | 36.8 |
| **2** | 1.59 | 31.9 | 68.5 |
| **3** | 0.71 | 14.1 | 82.8 |
| **4** | 0.44 | 8.9 | 91.7 |
| **5** | 0.42 | 8.3 | 100.0 |

### C. EIGENVECTORS

| **VARIABLE** | **PC1** | **PC2** | **PC3** | **PC4** | **PC5** |
|---|---|---|---|---|---|
| **DO** | 0.12 | -0.68 | -0.08 | -0.67 | 0.25 |
| **% SILT + CLAY** | -0.04 | 0.67 | -0.42 | -0.51 | 0.34 |
| **SALINITY** | -0.56 | -0.26 | -0.42 | 0.41 | 0.52 |
| **DEPTH** | -0.52 | 0.14 | 0.76 | -0.22 | 0.28 |
| **TEMPERATURE** | -0.53 | -0.06 | -0.24 | -0.27 | -0.58 |

Although organochlorine (OCL) pesticides were not included in the computation of the composite PEL quotient, the 1995 sample in Culbreath Bayou also had unusually high concentrations of chlordane (Figure 18) and total DDT (>90% as DDE) (Figure 19).

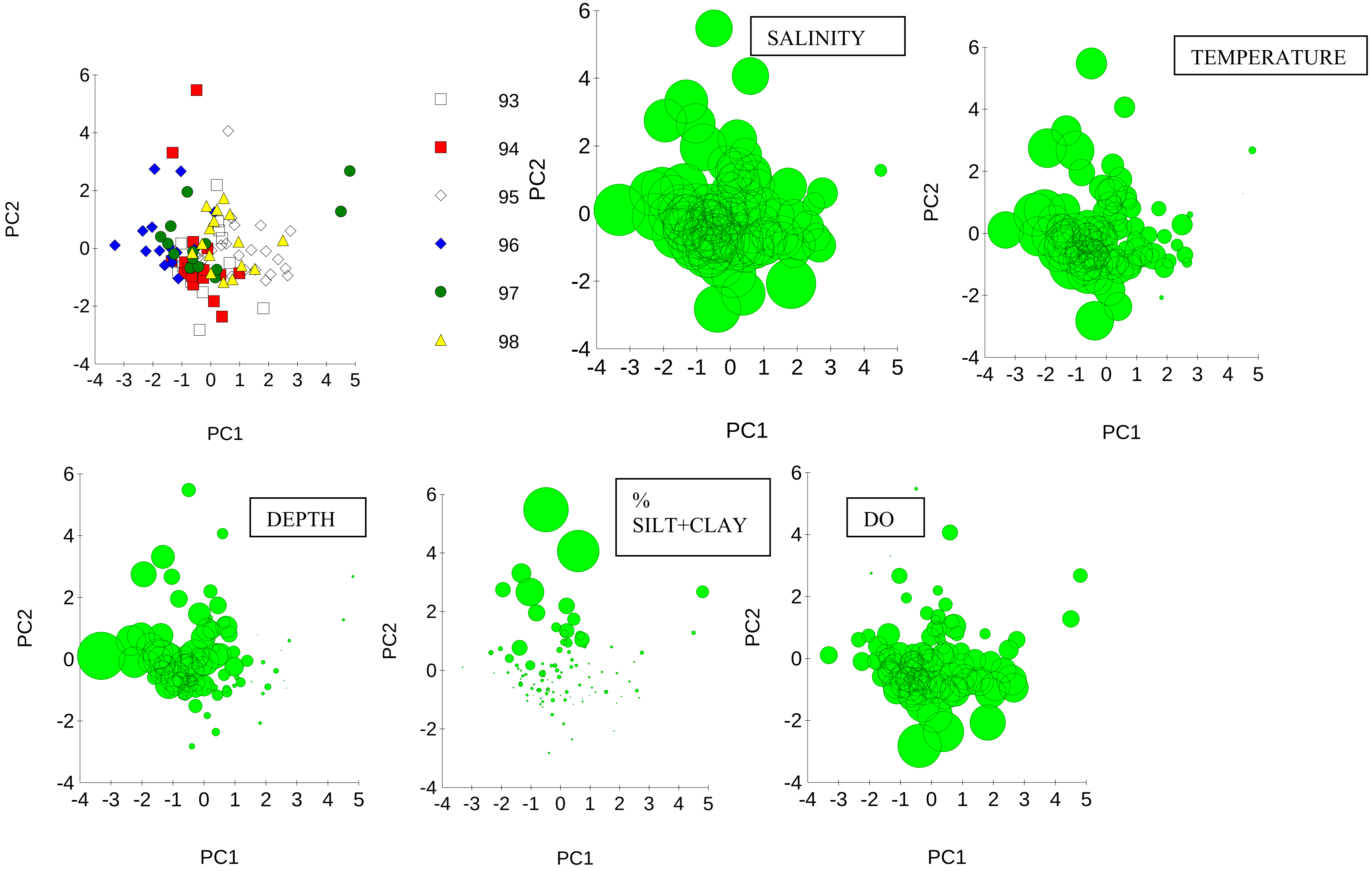

**Figure 13. PCA of sample sites in Old Tampa Bay, 1993-1998 and “bubble” plots of salinity, temperature, depth, %SC and DO superimposed on the samples: by year.**

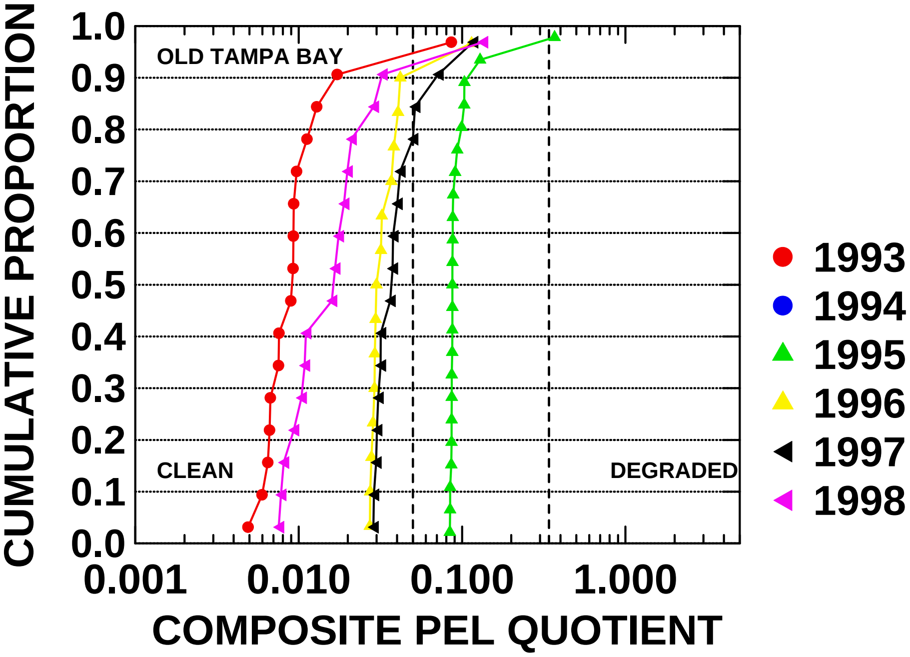

Figure 14. CDF plot of the composite (metals, PAHs, PCBs) PEL quotient for sediment contaminants in Old Tampa Bay, by year. Vertical lines demarcate "clean" (<0.05) and "degraded" (>0.34) sediments.

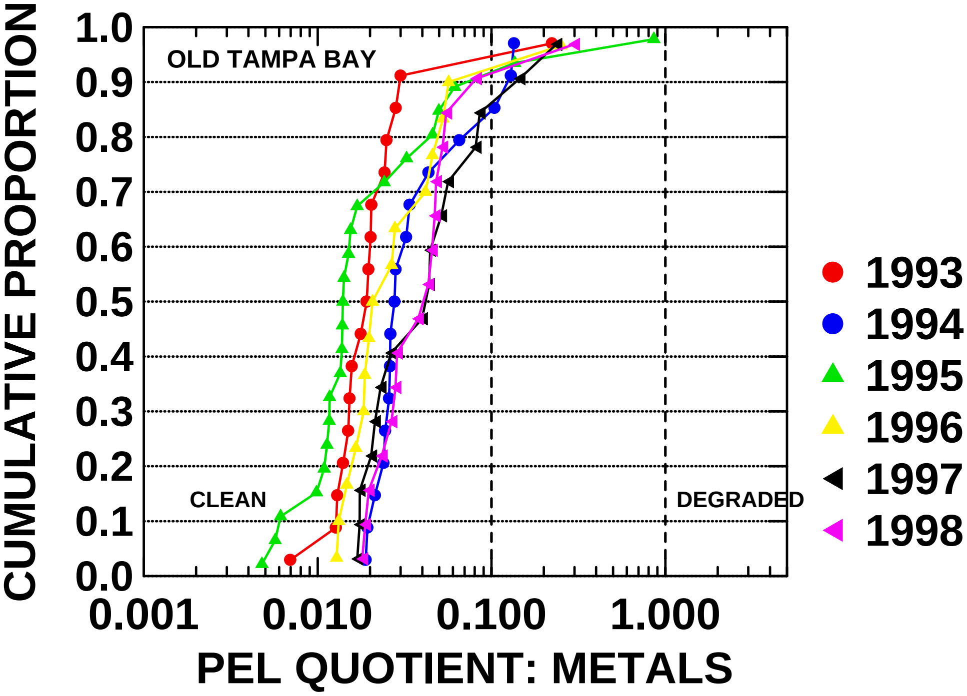

Figure 15. CDF plot of the PEL quotient for metals (composite) in Old Tampa Bay, by year. Vertical lines demarcate "clean" (PEL quotient <0.1) and "degraded" (PEL quotient >1) sediments.

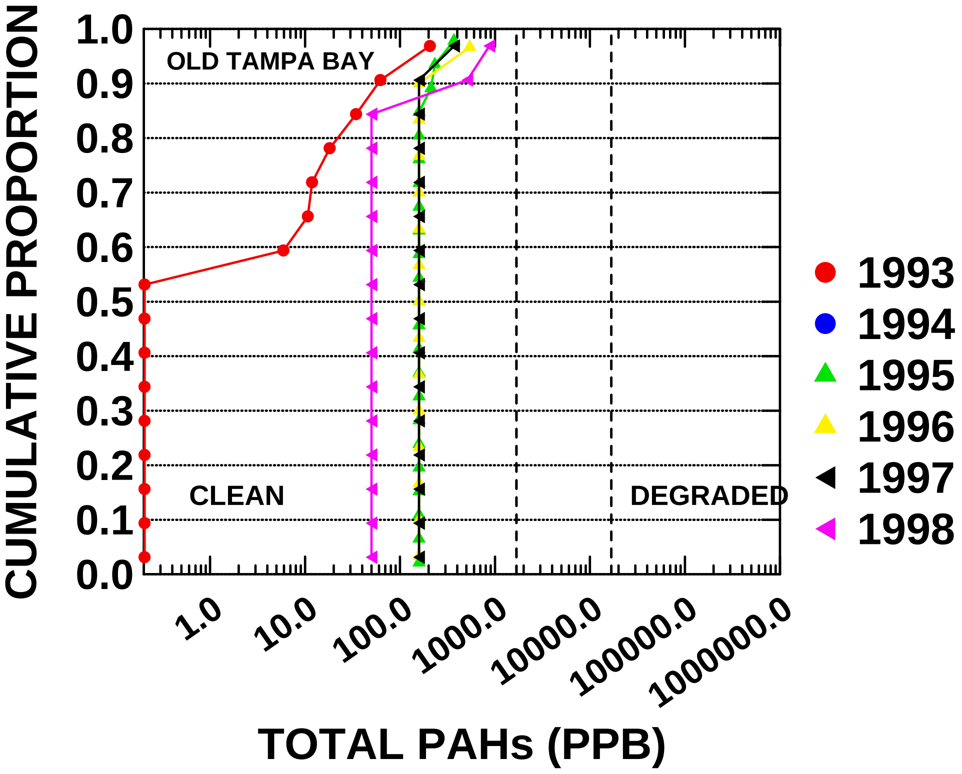

Figure 16. CDF plot of total PAH concentrations in Old Tampa Bay, by year. Vertical lines demarcate TEL (1684 ppb) and PEL (16770 ppb).

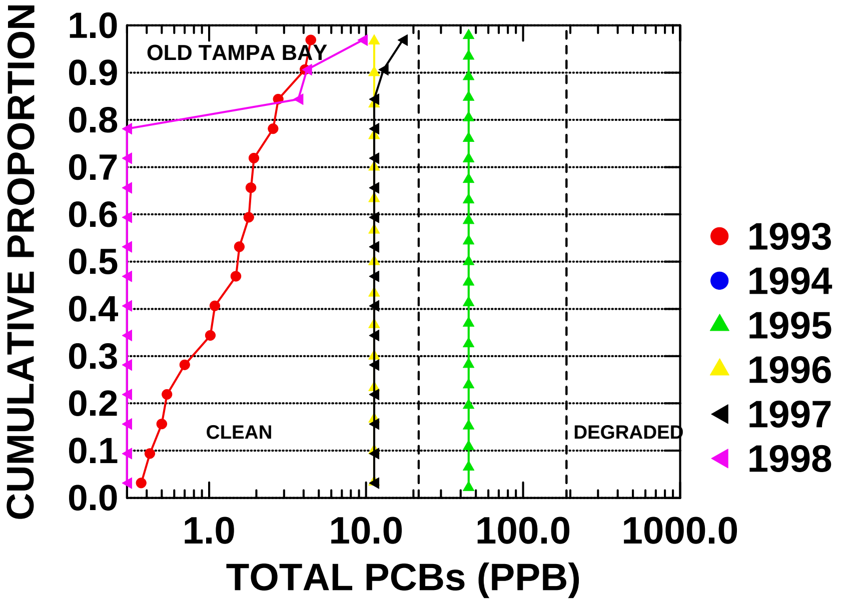

Figure 17. CDF plot of total PCB concentrations in Old Tampa Bay, by year. Vertical lines demarcate TEL (21.6 ppb) and PEL (189 ppb).

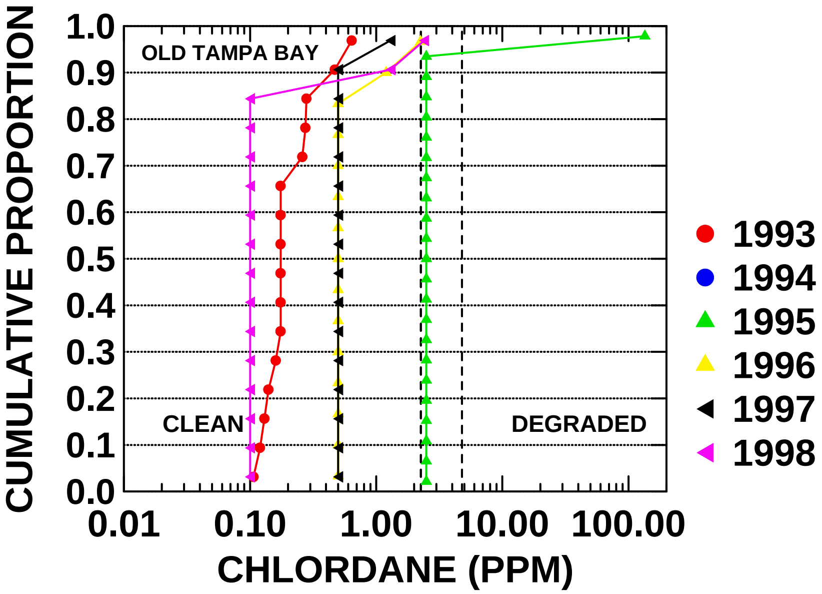

Figure 18. CDF plot of total chlordane concentrations in Old Tampa Bay, by year. Vertical lines demarcate TEL (2.26 ppb) and PEL (4.79 ppb).

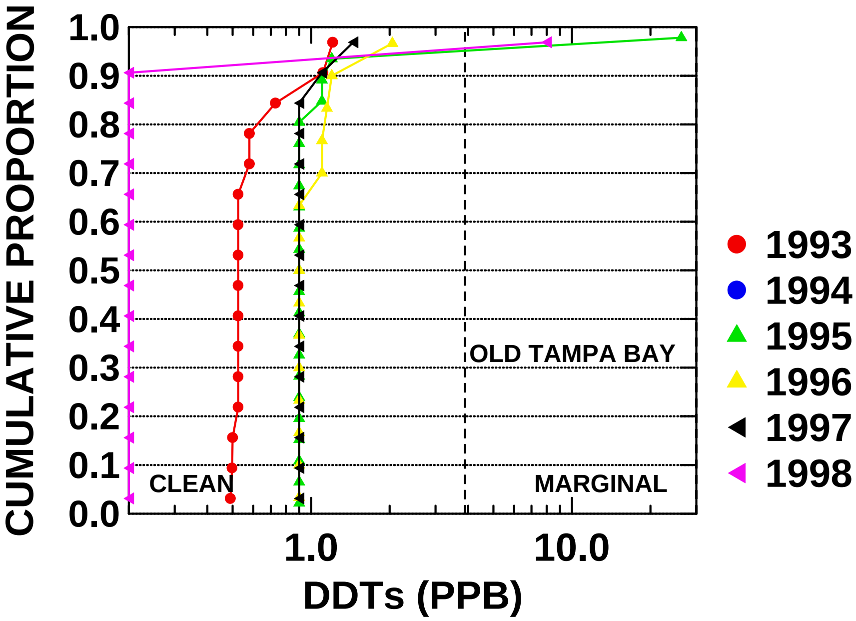

Figure 19. CDF plot of total DDTs concentrations in Old Tampa Bay, by year. Vertical line demarcates the TEL (3.89 ppb).

***Benthic Community***: Table 3 summarizes selected benthic community measures for 1993-1998. More than 330 taxa were identified during this period (Appendix B). The lancelet *Branchiostoma floridae* and the amphipod crustaceans *Rudilemboides naglei* and *Metharpinia floridana* were each ranked among the ten most abundant taxa in five of the six years; the amphipods *Eudevenopus honduranus* and *Ampelisca* sp. C were ranked in the top ten during four of the six years (Table 4).

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

| | **Abundance (numbers m$^{-2}$)** | **Species Richness (S)** | **Diversity (H')** | **Evenness (J)** | **TBBI** |
|---|---|---|---|---|---|
| **Minimum** | 400 | 2 | 0.1 | 0.02 | -3.3 |
| **Maximum** | 44,500 | 64 | 4.88 | 0.87 | 29.4 |
| **Median** | 7,912 | 34 | 3.14 | 0.65 | 18.8 |
| **Mean** | 9,900 | 33 | 3.08 | 0.60 | 17.3 |

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

| **1993** | **1994** | **1995** | **1996** | **1997** | **1998** |
|---|---|---|---|---|---|
| *Branchiostoma floridae (1,578)* | *B. floridae (1,088)* | *Caecum strigosum (672)* | *M. planulata (2,497)* | *R. naglei (1,852)* | *M. planulata (2,134)* |
| *Rudilemboides naglei (1,097)* | *M. floridana (628)* | *Mysella planulata (465)* | *A. holmesi (998)* | *B. floridae (1,432)* | *Mulinia lateralis (1,315)* |
| *Prionospio perkinsi (561)* | *P. perkinsi (552)* | *Polygordius sp. (390)* | *R. naglei (968)* | *Glottidia pyramidata* | *Amygdalum papyrium (940)* |
| *Nucula proxima (449)* | *E. honduranus (537)* | *R. naglei (317)* | *Leitoscoloplos robustus* | *C. strigosum (895)* | *M. dorsobranchialis* |
| *Cerapus sp. C (418)* | *Acanthohaustorius uncinus (512)* | *B. floridae (306)* | *Ampelisca sp. C (668)* | *M. planulata (800)* | *B. floridae (438)* |
| *Eudevenopus honduranus (393)* | *R. naglei (490)* | *Tellina sp. (241)* | *B. floridae (458)* | *Shoemakerella lowreyi (600)* | *A. holmesi (305)* |
| *Ampelisca sp. C (381)* | *Mediomastus californiensis* | *A. holmesi (191)* | *Tubificidae-gen. undet.* | *Monticellina dorsobranchialis* | *G. pyramidata (255)* |
| *Metharpinia floridana* | *Ampelisca sp. C (312)* | *Amakusanthura magnifica* | *M. floridana (378)* | *Tubificidae-gen. undet. (333)* | *C. hobsonae (210)* |
| *A. holmesi (317)* | *N. proxima (291)* | *M. floridana (179)* | *E. honduranus* | *Ampelisca. sp. C (332)* | *Tubificidae-gen. undet. (188)* |
| *Carazziella hobsonae* | *Athenaria-gen undet. (280)* | *E. honduranus (154)* | *A. magnifica (273)* | *M. floridana (317)* | *C. strigosum (185)* |

Numerical dominants also differed by salinity zone (Table 5). The bivalve mollusc *Mysella planulata* was ranked first in mean abundance in both mesohaline and polyhaline habitats. *Branchiostoma floridae* and the four most abundant amphipods were ranked in the top ten only in the polyhaline zone.

**Table 5. Ten Most Abundant Macroinvertebrate Taxa in Old Tampa Bay, 1993-1998: By Salinity Zone (Venice System; *cf*. Remane 1934). (mean numbers m$^{-2}$)**

| **TIDAL FRESHWATER (<0.5 PPT) (N=1)** | **MESOHALINE (5.0-18.0 ppt) (N=15)** | **POLYHALINE (18.0-30.0 ppt) (N=87)** |
|---|---|---|
| *Tubificidae-gen. undet. (2,075)* | *Mysella planulata (1,119)* | *M. planulata (961)* |
| *Capitella capitata (150)* | *Nereis succinea (242)* | *Branchiostoma floridae (891)* |
| *Tanypus clavatus (100)* | *Tellina spp. (235)* | *Rudilemboides naglei (811)* |
| *Laeonereis culveri (25)* | *Ampelisca holmesi (202)* | *Caecum strigosum (413)* |
| *Streblospio gynobranchiata (25)* | *Mulinia lateralis (189)* | *A. holmesi (382)* |
| *Polypedilum scalaneum grp. (25)* | Tubificidae-*gen. undet. (189)* | *Metharpinia floridana (338)* |
| | *Amygdalum papyrium (181)* | *Prionospio perkinsi (326)* |
| | *A. abdita* (179) | *Eudevenopus honduranus* (324) |
| | *L. culveri* (175) | *Ampelisca* sp. C (301) |
| | *T. versicolor* (162) | *Glottidia pyramidata* (240) |

Numbers of taxa per station were not especially variable over years—although there was a wide range within years (Figure 20). The KS test showed that the frequency distributions between any pair of years were not significantly different (*p*>0.05).

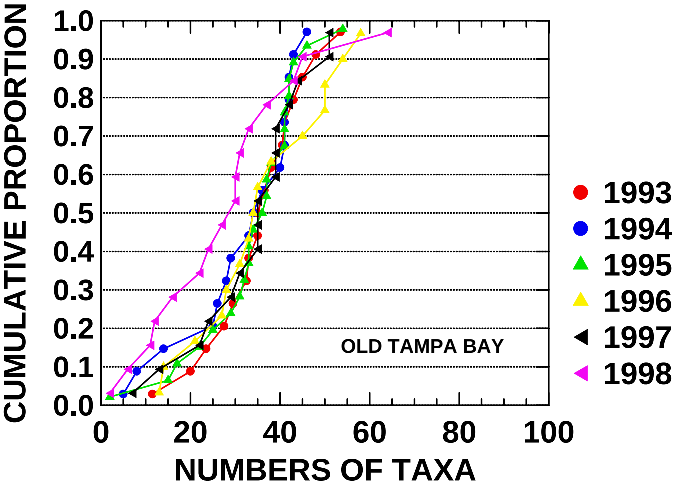

**Figure 20. CDF plot for numbers of taxa in Old Tampa Bay benthos, by year, 1993-1998.**

Tampa Bay Benthic Index (TBBI) scores were generally lowest during 1997 and 1998 (Figure 21) and the KS test (*p*<0.05) showed that frequency distributions in 1997 and 1998 differed from all other years. Only two sites had TBBI scores <4.6 (degraded habitat): a 1997 sample in Double Branch Creek north of Hillsborough Avenue and a 1998 sample near West San Miguel Street in the Westshore area of Tampa (Figure 22). The former site was a tidal freshwater habitat with low H' and S. There was no evidence of sediment contamination and DO concentrations within the "marginal" range. The latter site had sediment contaminant concentrations of chlordane and the metals arsenic, cadmium, chromium, and lead >TEL (of "marginal" quality).

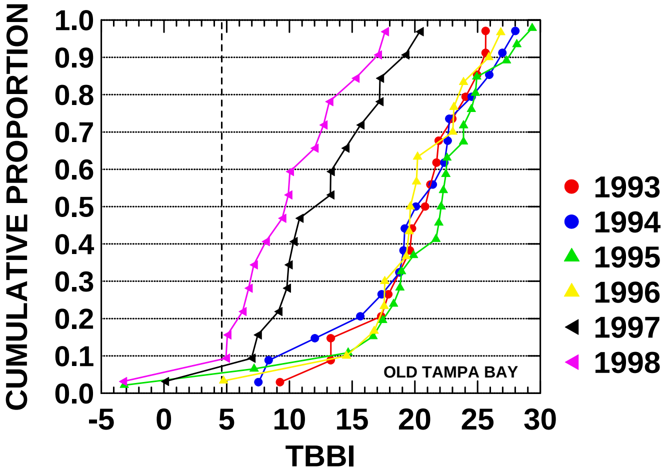

**Figure 21. CDF plot of the Tampa Bay Benthic Index for Old Tampa Bay benthos, by year, 1993-1998. Scores <4.6 indicate "degraded" benthic habitat.**

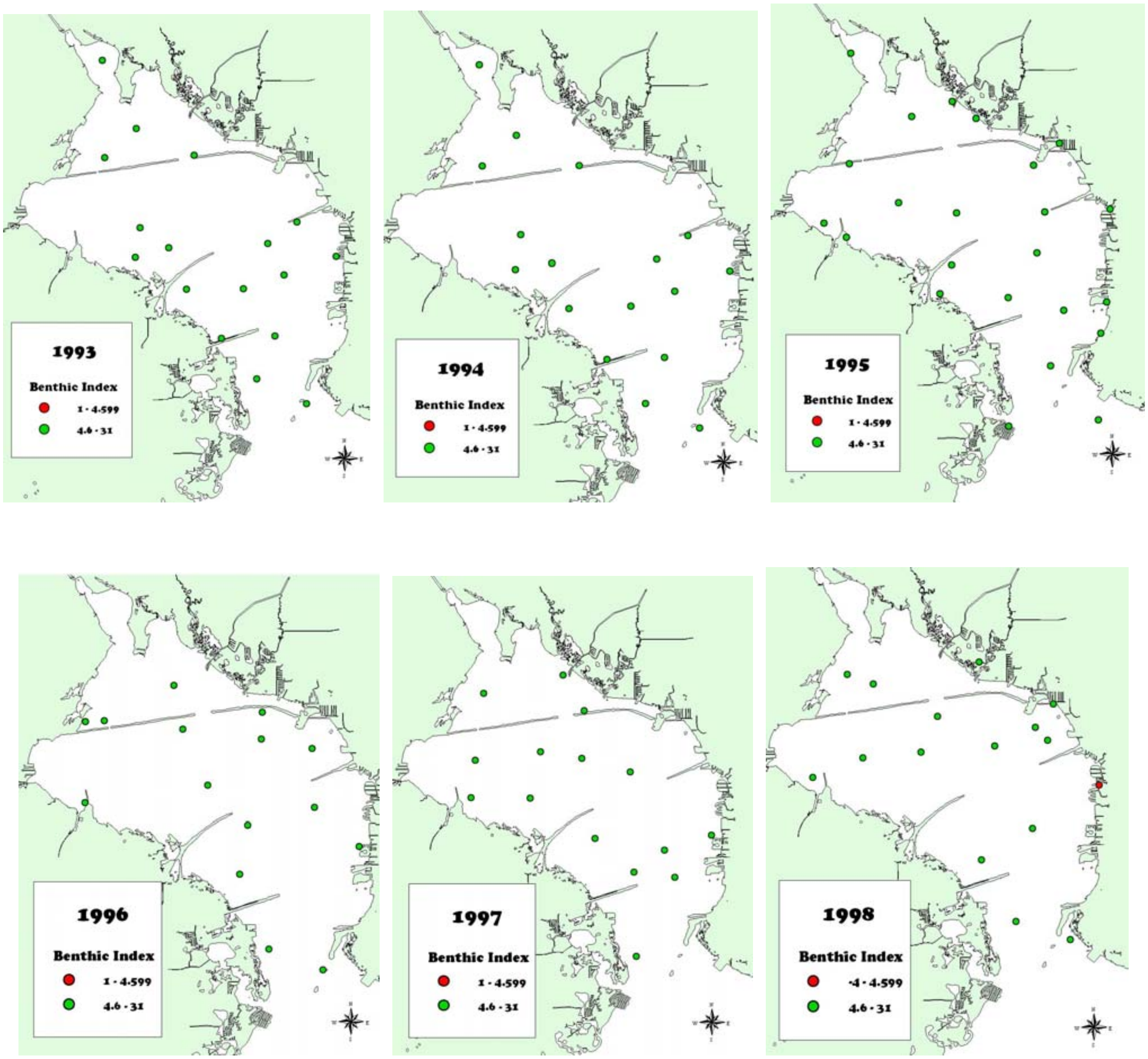

**Figure 22. Distribution of "healthy" (green) and "degraded" (red) benthic habitat in Old Tampa Bay, 1993-1998 based upon the Tampa Bay Benthic Index**

Correlation analysis, using transformed variables, showed that the TBBI was significantly (*p*<0.05) associated with RPD (Figure 23), %SC (Figure 24), and DO (Figure 25), but not with salinity (Figure 26), sample depth (Figure 27) or the composite PEL quotient (Figure 28). Stepwise multiple regression (adjusted multiple $r^2 = 0.53$; $p<0.001$; n=72) yielded the following relationship:

TBBI ($\log_{10}$n+1) =0.1159+0.07*RPD ($\log_{10}$n+1)+0.73*Salinity ($\log_{10}$n+1)–1.04*%SC (ASN)+2.15 PELQ

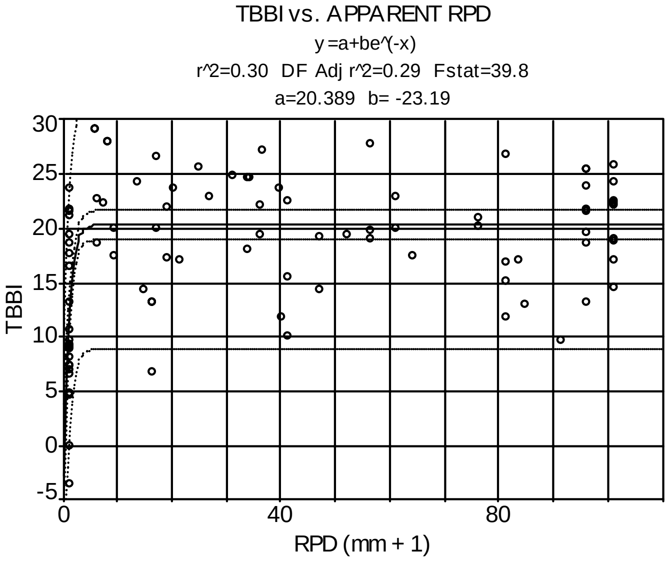

**Figure 23. Association between the Tampa Bay Benthic Index and the apparent redox potential discontinuity layer (RPD) in Old Tampa Bay, 1993-1998.**

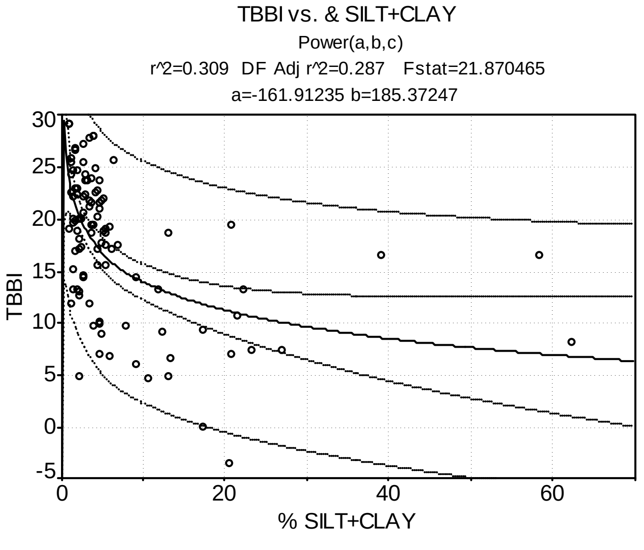

**Figure 24. Association between the Tampa Bay Benthic Index and %SC in Old Tampa Bay, 1993-1998.**

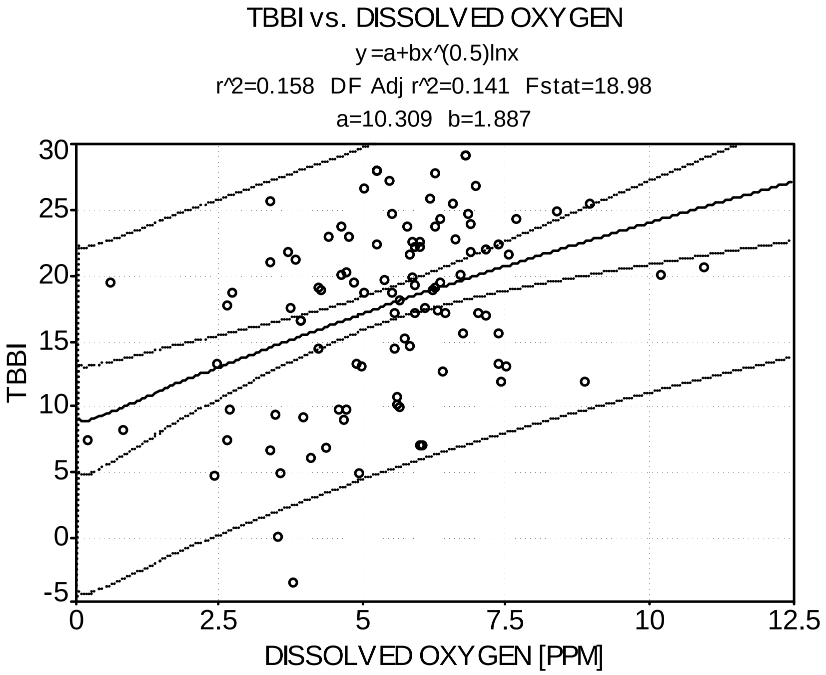

**Figure 25. Association between the Tampa Bay Benthic Index and near-bottom dissolved oxygen concentrations in Old Tampa Bay, 1993-1998**

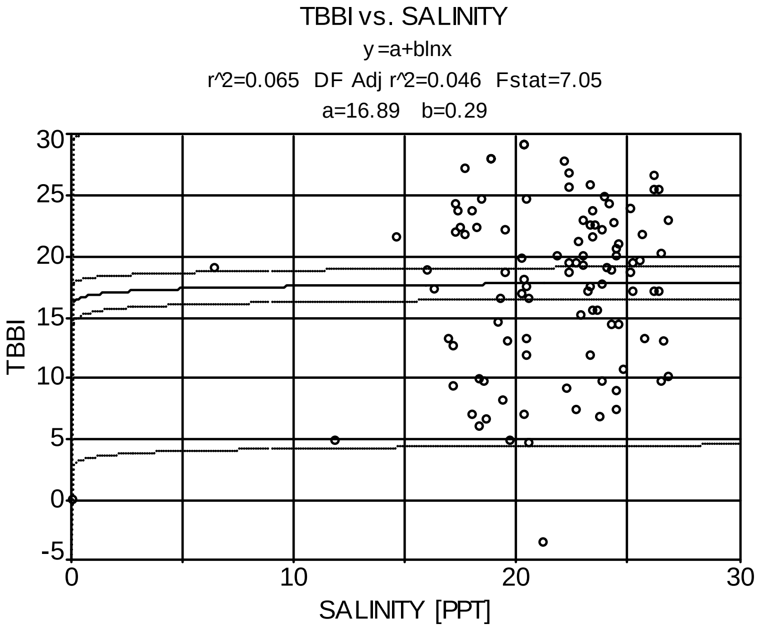

**Figure 26. Association between the Tampa Bay Benthic Index and salinity in Old Tampa Bay, 1993-1998.**

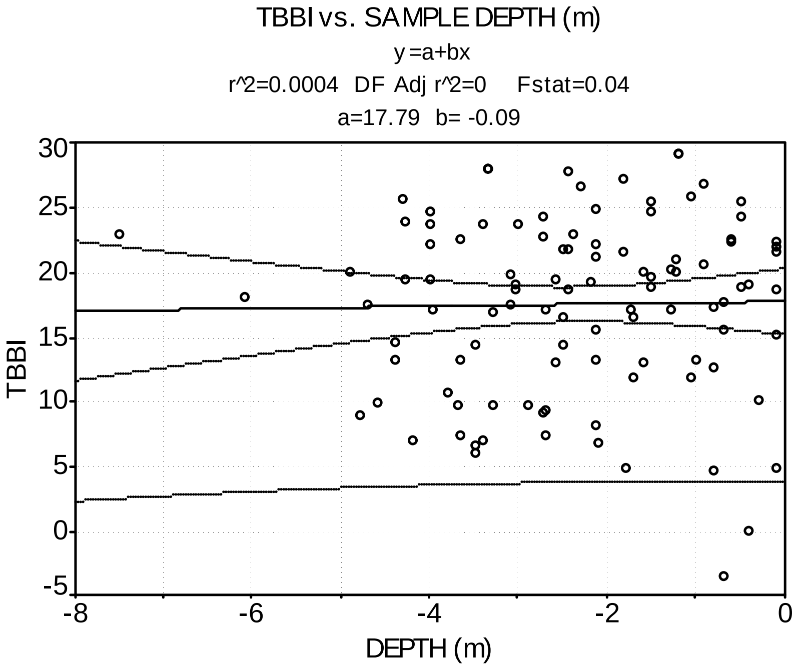

**Figure 27. Association between the Tampa Bay Benthic Index and sample depth in Old Tampa Bay, 1993-1998.**

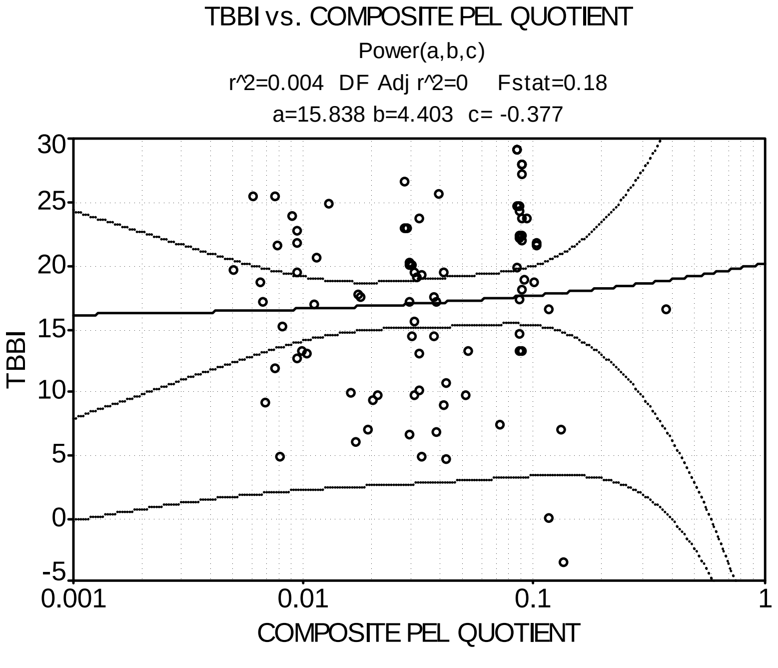

**Figure 28. Association between the Tampa Bay Benthic Index and the composite PEL quotient in Old Tampa Bay, 1993-1998.**

*Benthic Community Structure*: Two “primary” and four “secondary” “clusters” were identified in the classification analysis of sites (Appendix Figure C). Clusters A, B-1 and B-2 A were essentially “outliers” from the majority of the Old Tampa Bay stations, which formed clusters B2B1 and B2B2. Twelve “primary” and two “secondary” “clusters” were identified in the taxa classification (Appendix Figure D).

SIMPER analyses (Clarke & Warwick 2001) showed that dissimilarities between the biotic assemblages in Clusters A and B were primarily influenced by the higher densities of *M. planulata, Amygdalum papyrium* and *Mulinia lateralis* in Cluster A and higher densities of *Rudilemboides naglei* and *B. floridae* in Cluster B (Table 6). Cluster A sites also had a higher mean density and higher mean S than B sites (Table 7).

These clusters differed little in their site characteristics, including hydrographic and sedimentary characteristics (Table 7). Mean %SC was relatively low in both groups; mean sediment contaminant levels were higher at cluster B sites, although all values, except for chlordane at one site, were not likely to to be toxic to aquatic life.

Cluster B could be subdivided into clusters B-1 and B-2. B-1 sites were generally located in shallow waters on the west side of Old Tampa Bay between the Howard Frankland and Gandy bridges. %SC was somewhat higher at the B-1 sites (Table 9). Four polychaete worms, the isopod *Ericsonella attenuata*, and tubificid oligochaetes were more abundant at the B-1 sites (Table 10).

The two largest clusters, B2B1 and B2B2, showed considerable overlap in location, although B2B1 sites tended to be north of the Howard Frankland Bridge and the B2B2 sites tended to range more to the south (Figure 29). The clusters differed in sediment characteristics (finer sediments, shallower RPD at B2B1) and salinity (lower at B2B1 sites) (Table 12). The faunal assemblages of the B2B2 sites tended to have much higher densities of *B. floridae* and *R. naglei* than the more northern assemblage (Table 13).

**Table 6. Two-way coincidence table (taxa by cluster), Old Tampa Bay benthos, 1993-1998.**

| TAXA CLUSTER | TAXA | A | B1 | B2A | B2B1 | B2B2 |
|---|---|---|---|---|---|---|
| **1** | *Cerithium muscarum* | 0 | 140 | 0 | 0 | 0 |
| **2** | *Pinnixa D* | 0 | 0 | 0 | 45 | 2 |
| **3** | *Synaptidae A* | 0 | 79 | 0 | 1 | 0 |
| | *Laeonereis culveri* | 0 | 63 | 0 | 42 | 14 |
| | *Xenanthura brevitelson* | 0 | 0 | 0 | 13 | 0 |
| **4** | *ENCHYTRAEIDAE* | 13 | 0 | 0 | 8 | 3 |
| **5** | *Polygordius sp.* | 0 | 0 | 0 | 0 | 180 |
| | *Mediomastus californiensis* | 13 | 4 | 916 | 4 | 142 |
| | *Athenaria* | 0 | 0 | 1188 | 0 | 26 |
| | *Limnodriloides sp.* | 0 | 2 | 444 | 14 | 10 |
| **6** | *Parastarte triquetra* | 0 | 21 | 0 | 36 | 1 |
| | *Turbellaria* | 0 | 296 | 3 | 3 | 3 |
| | *Leitoscoloplos robustus* | 0 | 33 | 0 | 260 | 2 |
| | *Prionospio heterobranchia* | 25 | 838 | 44 | 16 | 56 |
| | *Capitella capitata* | 75 | 242 | 3 | 29 | 13 |
| | *Aricidea philbinae* | 500 | 825 | 0 | 44 | 32 |
| | *TUBIFICIDAE* | 288 | 821 | 66 | 273 | 76 |
| **7** | *Mediomastus ambiseta* | 0 | 0 | 25 | 9 | 13 |
| | *Pinnixa cf. pearsei* | 0 | 0 | 166 | 16 | 13 |
| **8** | *Ampelisca abdita* | 0 | 4 | 0 | 19 | 58 |
| | *Streblospio spp.* | 25 | 8 | 0 | 64 | 8 |
| **9** | *Paramphinome B* | 0 | 0 | 3 | 55 | 0 |
| | *Monticellina dorsobranchialis* | 0 | 13 | 13 | 327 | 102 |
| | *Carazziella hobsonae* | 13 | 2 | 0 | 349 | 4 |
| | *Paraprionospio pinnata* | 138 | 4 | 0 | 117 | 42 |
| | *Tubificoides wasselli* | 188 | 125 | 0 | 39 | 91 |
| **10** | *Cerapus sp. C (="tubularis")* | 0 | 308 | 1719 | 4 | 141 |
| | *Microprotopus raneyi* | 0 | 0 | 0 | 0 | 68 |
| **11A** | *Caecum strigosum* | 13 | 4 | 0 | 74 | 694 |
| | *Acanthohaustorius uncinus* | 0 | 0 | 6 | 33 | 339 |
| | *Rudilemboides naglei* | 325 | 4 | 2850 | 81 | 1224 |
| | *Travisia hobsonae* | 0 | 0 | 131 | 27 | 159 |
| | *Branchiostoma floridae* | 38 | 15 | 1678 | 182 | 1473 |
| | *Ampelisca sp. C* | 0 | 0 | 1041 | 2 | 457 |
| | *Metharpinia floridana* | 0 | 8 | 506 | 35 | 550 |
| | *Eudevenopus honduranus* | 13 | 0 | 509 | 14 | 536 |

**Table 6 (continued). Two-way coincidence table (taxa by cluster), Old Tampa Bay benthos, 1993-1998.**

| TAXA CLUSTER | TAXA | A | B1 | B2A | B2B1 | B2B2 |
|---|---|---|---|---|---|---|
| **11B** | *Tellina sp.* | 13 | 13 | 34 | 91 | 107 |
| | *Shoemakerella lowreyi* | 13 | 17 | 681 | 22 | 288 |
| | *Eobrolgus spinosus* | 13 | 0 | 281 | 9 | 167 |
| | *Pinnixa spp.* | 50 | 4 | 56 | 68 | 100 |
| | *Tellina versicolor* | 25 | 4 | 100 | 87 | 150 |
| | *Prionospio perkinsi* | 150 | 8 | 1288 | 185 | 326 |
| | *Nucula proxima* | 25 | 6 | 1703 | 18 | 245 |
| **12** | *Glottidia pyramidata* | 50 | 0 | 0 | 110 | 335 |
| | *Nereis succinea* | 350 | 100 | 28 | 111 | 21 |
| | *Mysella planulata* | 11575 | 188 | 19 | 733 | 899 |
| | *Ampelisca holmesi* | 2163 | 104 | 97 | 251 | 415 |
| | *Haminoea succinea* | 263 | 19 | 0 | 21 | 32 |
| | *Amygdalum papyrium* | 5938 | 21 | 0 | 184 | 19 |
| | *Mulinia lateralis* | 4825 | 8 | 0 | 316 | 7 |

**Table 7. Comparison of mean site characteristics, hydrographic conditions, sedimentary contaminants, and biotic variables: Cluster A *vs*. Cluster B (*cf*. Appendix Figure C), Old Tampa Bay, 1993-1998.**

| VARIABLE | CLUSTER A (N=2) | CLUSTER B (N=102) |
|---|---|---|
| **Depth** | 2.0 | 2.4 |
| **RPD** | 25 | 39 |
| **%SC** | 2.6 | 7.0 |
| | | |
| **Salinity** | 20.4 | 21.5 |
| **DO** | 4.5 | 5.4 |
| | | |
| **Composite PEL Quotient** | 0.02 | 0.05 |
| **Metals PEL Quotient** | 0.02 | 0.05 |
| **PAH PEL Quotient** | <0.01 | 0.01 |
| **PCB PEL Quotient** | 0.03 | 0.09 |
| **Chlordane PEL Quotient** | 0.06 | 0.54 |
| **DDT PEL Quotient** | 0.01 | 0.02 |
| | | |
| **# of Taxa** | 61 | 32 |
| **TBBI** | 12.8 | 17.4 |
| **Total Abundance** | 33,900 | 9,429 |

**Table 8. Results of SIMPER analysis comparing the dissimilarity between Old Tampa Bay Clusters A and B. Average dissimilarity =26.77.**

| | **Avg abund. Cluster A** | **Avg. abund. Cluster B** | **Contrib. %** | **Cum. %** |
|---|---|---|---|---|
| ***Mysella planulata*** | 11,575 | 7,54 | 3.8 | 3.8 |
| ***Amygdalum papyrium*** | 5,938 | 87 | 3.6 | 7.4 |
| ***Mulinia lateralis*** | 4,825 | 134 | 2.3 | 9.6 |
| ***Ampelisca holmesi*** | 2,163 | 316 | 2.1 | 11.8 |

**Table 9 Comparison of mean site characteristics, hydrographic conditions, sedimentary contaminants, and biotic variables: Cluster B-1 *vs*. Cluster B-2 (*cf*. Appendix Figure C), Old Tampa Bay, 1993-1998.**

| VARIABLE | **CLUSTER B-1(N=6)** | **CLUSTER B-2(N=96)** |
|---|---|---|
| **Depth** | 0.6 | 2.5 |
| **RPD** | 25 | 40 |
| **%SC** | 4.0 | 7.2 |
| | | |
| **Salinity** | 21.4 | 21.5 |
| **DO** | 4.8 | 5.4 |
| | | |
| **Composite PEL Quotient** | 0.06 | 0.05 |
| **Metals PEL Quotient** | 0.03 | 0.05 |
| **PAH PEL Quotient** | 0.01 | 0.01 |
| **PCB PEL Quotient** | 0.16 | 0.09 |
| **Chlordane PEL Quotient** | 0.34 | 0.55 |
| **DDT PEL Quotient** | 0.02 | 0.02 |
| | | |
| **# of Taxa** | 40 | 32 |
| **TBBI** | 14.5 | 17.4 |
| **Total Abundance** | 37,045 | 9,503 |

**Table 10. Results of SIMPER analysis comparing the dissimilarity between Old Tampa Bay Clusters B1 and B2. Average dissimilarity = 25.08.**

| | **Avg. Abund. Cluster B1** | **Avg abund Cluster B2** | **Contrib. %** | **Cum. %** |
|---|---|---|---|---|
| ***Prionospio heterobranchia*** | 838 | 38 | 2.3 | 2.3 |
| TUBIFICIDAE | 821 | 162 | 1.8 | 4.1 |
| ***Aricidea philbinae*** | 825 | 36 | 1.7 | 5.8 |
| ***Capitella capitata*** | 242 | 20 | 1.5 | 7.2 |
| ***Magelona pettiboneae*** | 238 | 6 | 1.5 | 8.7 |
| ***Erichsonella attenuata*** | 188 | 1 | 1.4 | 10.2 |

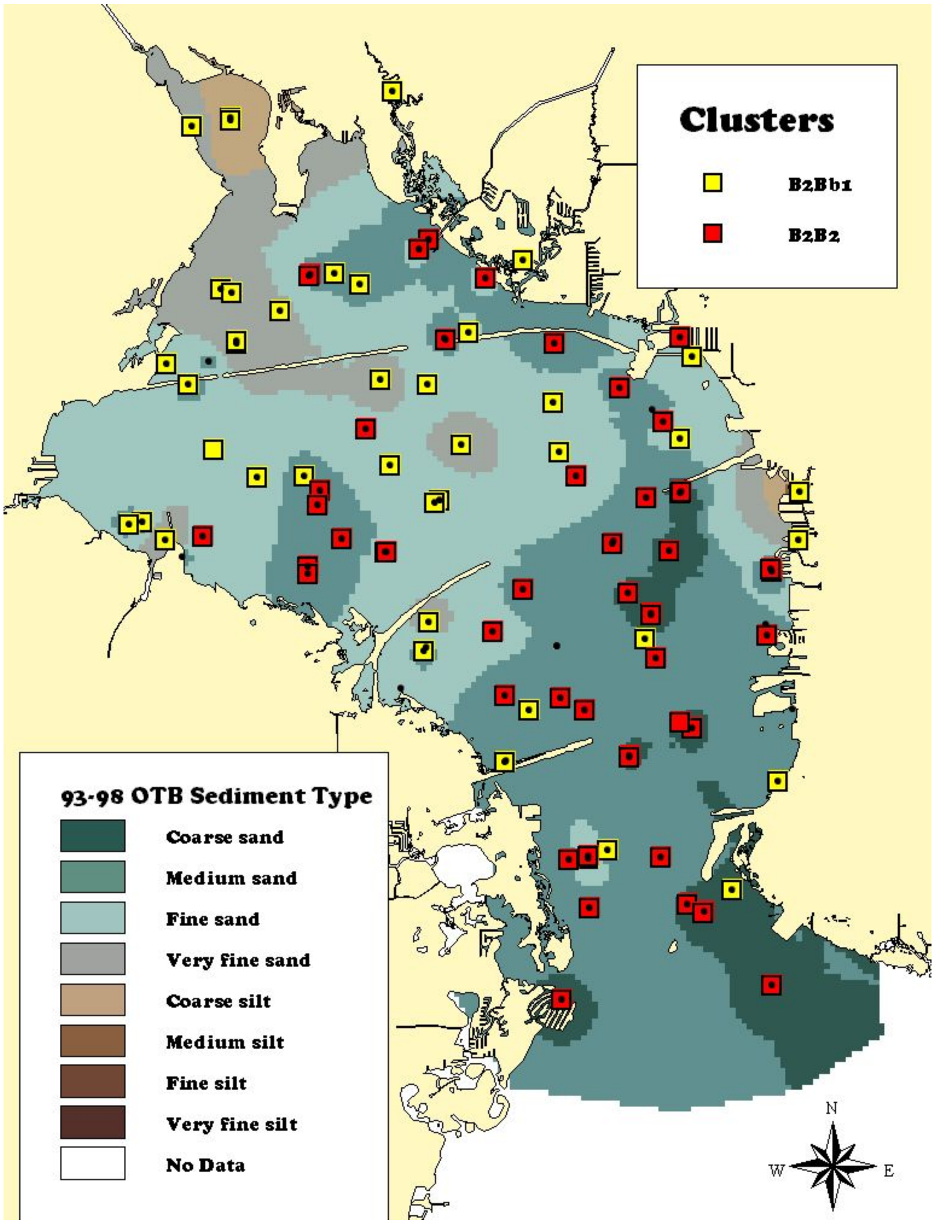

**Figure 29. The location of stations in clusters B2B1 and B2B2 overlaying the map depicting sediment type in Old Tampa Bay 1993-1998**

**Table 11. Comparison of mean site characteristics, hydrographic conditions, sedimentary contaminants, and biotic variables: Cluster B2A *vs*. Cluster B2B (*cf*. Appendix Figure C), Old Tampa Bay, 1993-1998.**

| VARIABLE | CLUSTER B2A(4) | CLUSTER B2B(92) |
|---|---|---|
| **Depth** | 3.3 | 2.4 |
| **RPD** | 75 | 39 |
| **%SC** | 4.0 | 7.4 |
| | | |
| **Salinity** | 24.8 | 21.3 |
| **DO** | 6.9 | 5.4 |
| | | |
| **Composite PEL Quotient** | 0.01 | 0.05 |
| **Metals PEL Quotient** | 0.02 | 0.05 |
| **PAH PEL Quotient** | <0.01 | 0.01 |
| **PCB PEL Quotient** | <0.01 | 0.09 |
| **Chlordane PEL Quotient** | 0.06 | 0.57 |
| **DDT PEL Quotient** | 0.01 | 0.02 |
| | | |
| **# of Taxa** | 45 | 31 |
| **TBBI** | 20.3 | 17.2 |
| **Total Abundance** | 21,091 | 8,999 |

**Table 12. Results of SIMPER analysis comparing the dissimilarity between Old Tampa Bay Clusters B2A and B2B. Average dissimilarity = 24.90.**

| | Avg. Abund. Cluster B2A | Avg abund Cluster B2B | Contrib. % | Cum. % |
|---|---|---|---|---|
| ***Cerapus sp. C*** | 2,288 | 78 | 2.3 | 2.3 |
| ***Rudilemboides naglei*** | 2,871 | 724 | 2.3 | 4.6 |
| ***Nucula proxima*** | 1,913 | 152 | 2.2 | 6.8 |
| ***Branchiostoma floridae*** | 1,425 | 900 | 2.0 | 8.8 |
| ***Shoemakerella lowreyi*** | 813 | 168 | 1.8 | 10.6 |

**Table 13. Comparison of mean site characteristics, hydrographic conditions, sedimentary contaminants, and biotic variables: Cluster B2B1 vs. Cluster B2B2 (*cf*. Appendix Figure C), Old Tampa Bay, 1993-1998.**

| VARIABLE | CLUSTER B2B1(N=42) | CLUSTER B2B2(N=50) |
|---|---|---|
| **Depth** | 2.4 | 2.5 |
| **RPD** | 21 | 53 |
| **%SC** | 11.9 | 3.4 |
| | | |
| **Salinity** | 19.6 | 22.8 |
| **DO** | 4.9 | 5.8 |
| | | |
| **Composite PEL Quotient** | 0.06 | 0.04 |
| **Metals PEL Quotient** | 0.09 | 0.02 |
| **PAH PEL Quotient** | 0.01 | 0.01 |
| **PCB PEL Quotient** | 0.08 | 0.10 |
| **Chlordane PEL Quotient** | 0.94 | 0.21 |
| **DDT PEL Quotient** | 0.03 | 0.02 |
| | | |
| **# of Taxa** | 23 | 38 |
| **TBBI** | 13.5 | 20.4 |
| **Total Abundance** | 5,455 | 1,1976 |

Species richness, TBBI, and overall abundance were also lower in this more northern assemblage of sites. Taxa that were more characteristic of B2B1 sites included the polychaetes *Carazziella hobsonae*, *M. dorsobranchialis* and the bivalve mollusk *Mulinia lateralis* (Table 14).

**Table 14. Results of SIMPER analysis comparing the dissimilarity between Old Tampa Bay Clusters B2B1 and B2B2. Average dissimilarity =62.36.**

| | Avg. Abund. Cluster B2B1 | Avg abund Cluster B2B2 | Contrib. % | Cum. % |
|---|---|---|---|---|
| ***Branchiostoma floridae*** | 182 | 1,473 | 4.4 | 4.4 |
| ***Rudilemboides naglei*** | 81 | 1,224 | 3.6 | 7.9 |
| ***Mysella planulata*** | 733 | 899 | 3.2 | 11.1 |

***<u>Linkage of Biotic & Abiotic Variables ( 1995-1998):</u>*** 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 rank correlations between the biological data (Figure 30) and the "best fit" for physico-variables (PCBs, chlordane, nickel, tin) (Figure 31) were very weak (-0.036).

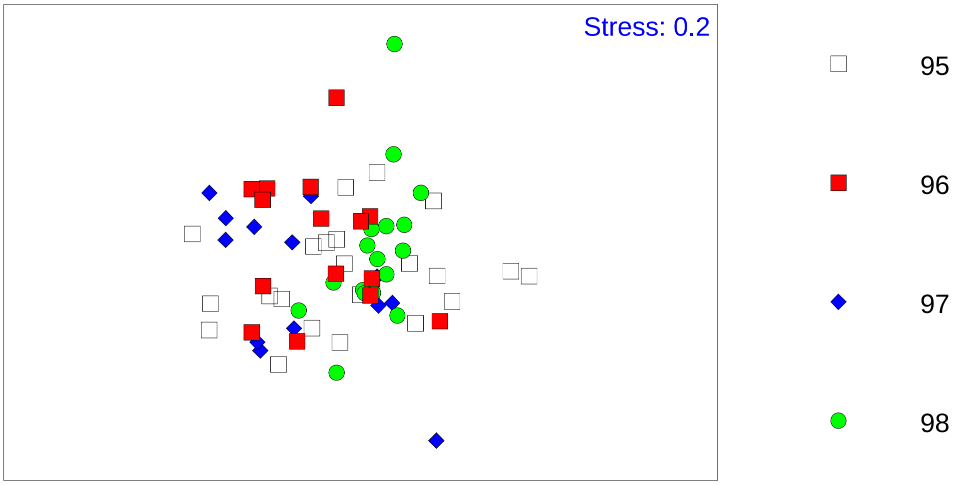

**Figure 30. MDS representation of benthic community structure in Old Tampa Bay, 1995-1998, by year**.

***<u>Interannual Trends</u>***: MDS of average abundance of all benthic taxa, by year, show that the benthic community experienced more pronounced shifts in structure from 1994 to 1995 and from 1997 to 1998 (Figure 32). BIO-ENV analysis using mean site, hydrographic, and sediment contaminant (metals only; no organic data for 1994) variables showed that the best fit for environmental variables with the biotic data were for aluminum, arsenic, cadmium, copper, tin, DO, and temperature (Spearman r=-0.25) (Figure 33). The mean concentrations of aluminum (increased approximately 50%) and tin (increased more than an order of magnitude) showed the greatest changes from 1994 to 1995. Mean concentrations of aluminum (decreased >80%), tin (drecreased 50%) and DO (decreased >25%) showed the greatest relative changes from 1997 to 1998. Mean near-bottom water temperatures increased slightly from 1994 to 1995 and again from 1997 to 1998.

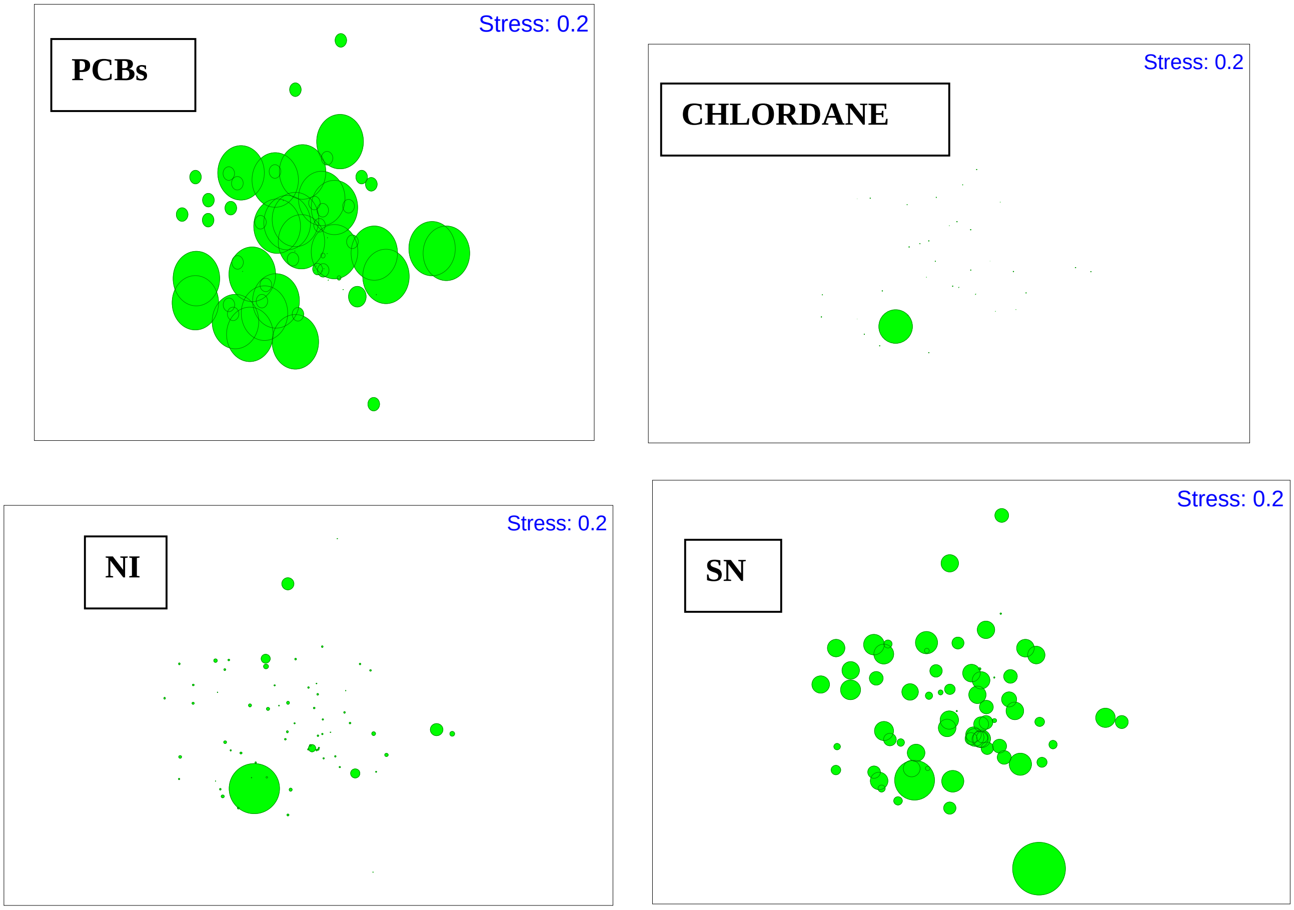

**Figure 31. “Bubble” plots of chlordane, PCBs, Ni, and Sn superimposed over the MDS plot depicting benthic community structure, by year, in Old Tampa Bay 1995-1998.**

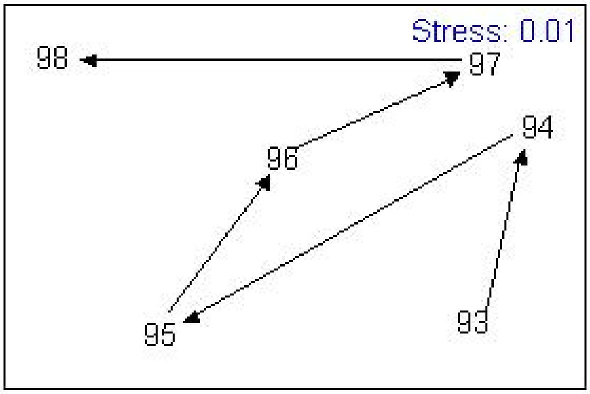

**Figure 32. MDS plot, “average” benthic community structure by year , Old Tampa Bay, 1993-1998 Lines delineate temporal trend.**

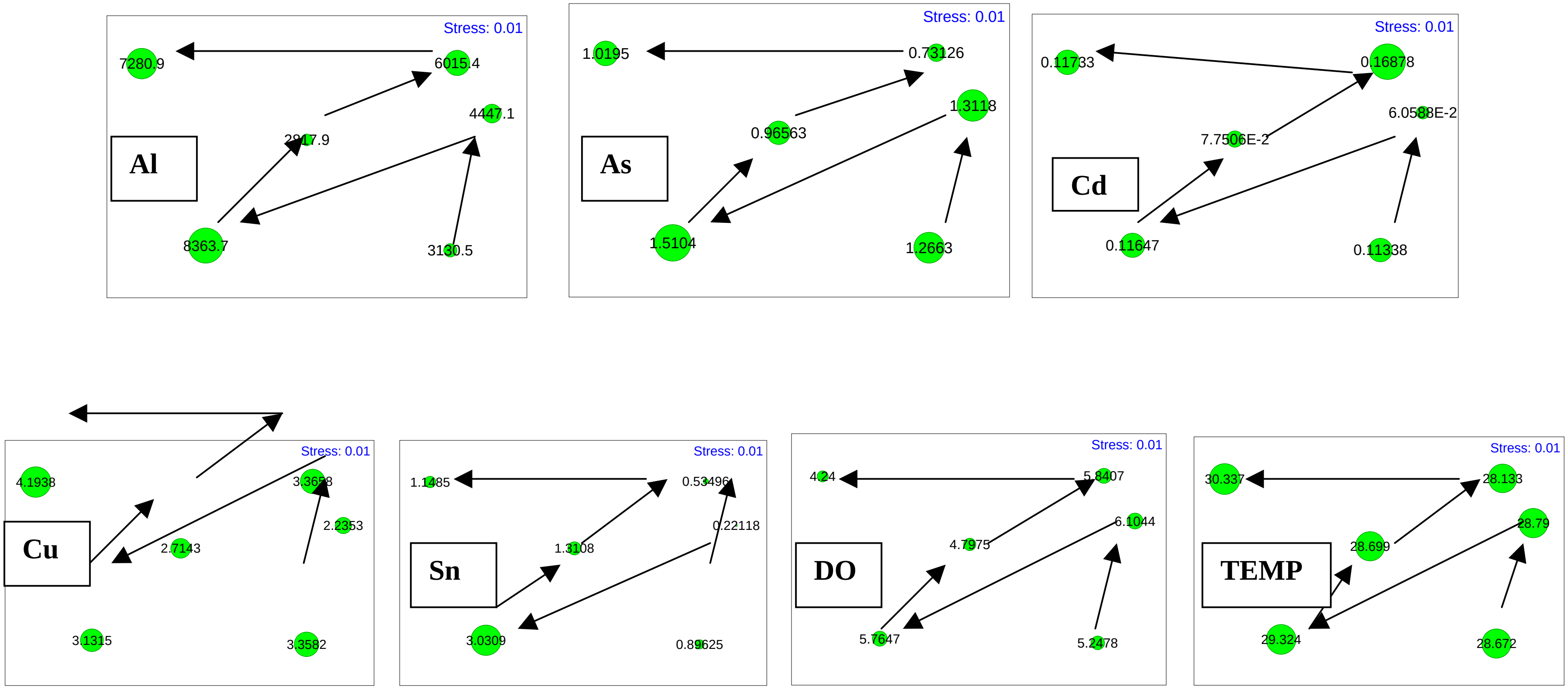

**Figure 33. MDS plot of "average" benthic community structure by year and mean concentrations of Al, As, Cd, Cu, Sn, DO and temperature by year, Old Tampa Bay, 1993-1998. Lines delineate temporal trend.**

Three taxa were most closely linked to interannual changes in community structure (Figure 34; Appendix E). With respect to the 1994-1995 shift, both *M. floridana* and *B. floridae* experienced declines in mean density >70% and *M. planulata* density increased 375%. From 1997 to 1998, mean density of *M. planulata* increased >250% whereas decreases were evident for both *B. floridae* (30%) and *M. floridana* (20%).

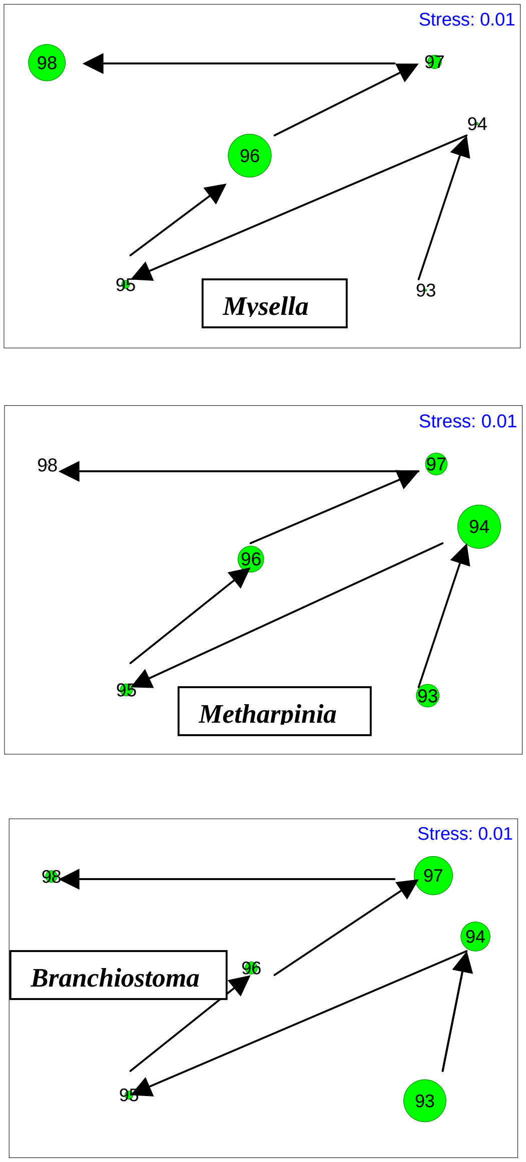

**Figure 34. MDS plot of "average" benthic community structure by year and "bubble" plots of mean densities of *Mysella planulata, Metharpinia floridana*, and *Branchiostoma floridae* by year, Old Tampa Bay, 1993-1998. Lines delineate temporal trend.**

***Status of Old Tampa Bay Sediments***: Old Tampa Bay appears to be much less affected by subnominal DO levels and degraded benthic habitat than the Louisianian Province (northern Gulf of Mexico south to Tampa Bay) as a whole (Table 15).

**Table 15. Comparison of proportions of degraded habitat, by category and study area: Old Tampa Bay (as percent of samples) *vs*. Louisianian Province (as percent area)**.

| STUDY AREA | HYPOXIA (DO<2 ppm) | SEDIMENT CHEMISTRY | BENTHOS | DO+ BENTHOS | BENTHOS + SED CHEM | DO + SED CHEM |
|---|---|---|---|---|---|---|
| **THIS STUDY** | 2.9 | 1.2 | 1.9 | 0.0 | 1.2 | 0.0 |
| | | | | | | |
| **LOUISIANIAN PROVINCE 1991[a]** | 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

# IV. DISCUSSION

Old Tampa Bay is the third largest (200 $km^2$) of the seven primary segments of Tampa Bay, encompassing approximately 19% of its surface area (Clark & Macauley 1989). The average depth of Old Tampa Bay is 2.8 m, shallower than the average for the bay as a whole (3.7 to 4.1 m; Lewis and Estevez 1988). Smaller creeks and streams (*e.g.*, Rocky Creek, Allen's Creek, Double Branch Creek, Lake Tarpon outfall), rather than larger rivers, are the primary sources of freshwater inflow to Old Tampa Bay. This segment is home to some industrial sites including the Bartow Generating Station on the southwestern shore and petrochemical storage areas along the southeastern shore.

During the study period, the near-bottom water mass characteristics differed among years. Salinities in Old Tampa Bay were generally in the polyhaline (18-30 ppt) zone. PCA showed that salinity, temperature and depth exerted primary influence on the intra-bay habitat characteristics. Salinities tended to be highest at the deepest, warmest sites.

Medium and coarse sandy sediments currently predominate in Old Tampa Bay. The finest grained sediments tended to be located in the northwestern portion of Old Tampa Bay—below the Lake Tarpon outfall, and near Culbreath Bayou along the eastern shore. This pattern seems somewhat different from that observed in 1963 (Taylor & Saloman 1969) when fine-grained sediments were located southwest of the Courtney Campbell Causeway (completed in 1934). There was, however, a trend of finer sands located north of the Howard Frankland Bridge (completed in 1960) and coarser sands located to the south (Figure 35). The construction of a barrier separating Lake Tarpon from Old Tampa Bay (an earthen dam was completed in 1967, which was replaced by a culvert system in 1971; Coastal Environmental/PBS&J, Inc. 1998) would also have a likely effect on sediment distribution patterns in northern Old Tampa Bay.

By 1987-1992 (Schoellhamer 1991; Long *et al.* 1994) muddy sediments were found downstream of the Lake Tarpon outfall and on both the east and west sides of Old Tampa Bay south of the Howard Frankland Bridge (Figure 35). Fine to very fine sand size sediments appeared to prevail between the Howard Frankland Bridge and the Courtney Campbell Causeway. The 1987-1992 data are sparse south of the Howard Frankland. It may be that the construction of the Howard Frankland Bridge has affected recent sedimentation in Old Tampa Bay more than the Gandy Bridge, which was completed in 1924. Old Tampa Bay sediments may have reached a fairly stable distribution with respect to the earlier bridge, causeway, and culvert construction--which may again have been affected by construction of the Howard Frankland. More data would, however, be required to verify whether this is, in fact, the case.

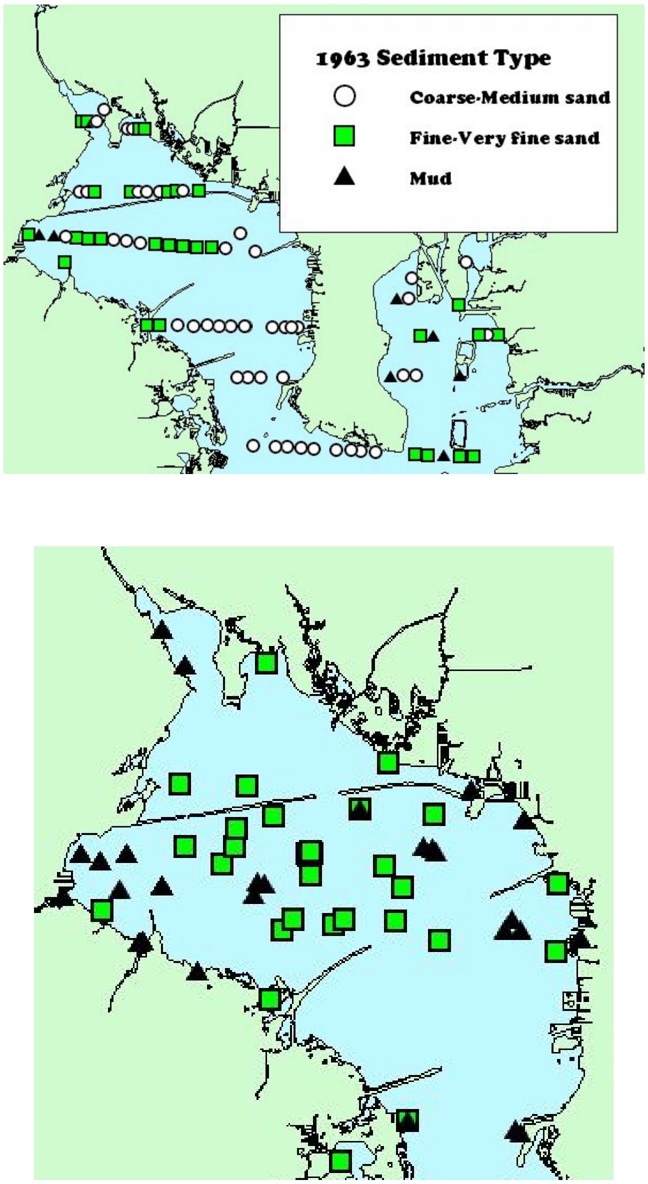

**Figure 35. Sediment types in Old Tampa Bay 1963 (top) and 1987-1992 (bottom) (after Taylor & Saloman 1969, Schoellhamer 1991 and Long *et al*. 1994).**

The benthic community shows a similar pattern: the benthic assemblage to the north (cluster group B2B1), where sediments are finer grained, differs from that located more to the south (cluster group B2B2). The primary distinctions between these two site groups are the higher densities of the lancelet *Branchiostoma floridae* and the amphipod *Rudilemboides naglei* at the coarser grained sites to the south.

For this bay segment as a whole, the lancelet *Branchiostoma floridae* and the amphipod crustaceans *Rudilemboides naglei* and *Metharpinia floridana, Eudevenopus honduranus* and *Ampelisca* sp. C were among the ranked numerical dominant species.

Data provided by Taylor (1971) (summarized in Karlen *et al*. 1997), Bloom *et al*. (1972), Simon & Dauer (1977), and Dauer (1980) provide an opportunity to compare the species composition of Old Tampa Bay benthos between 1963-1964, 1968, 1973 and 1993-1998. The most frequently occurring molluscs reported by Taylor *et al.* (1970) included the gastropod mollusc *Nassarius vibex*, and the bivalve molluscs *Tellina versicolor*, and *Macoma tenta*. In this current survey period *T. versicolor* was the sixth most frequently occurring mollusc and *N. vibex* was ranked seventh. Six of the eight most frequently occurring molluscs in 1993-1998 were not ranked among the six most frequently occurring molluscs in 1963. Rather, *Parvilucina multilineata* (24% of samples), *Olivella pusilla* (23%), and *Abra aequalis* (20%) were the only molluscs to occur in >20% of the 1963 samples. The polychaete (segmented worms) assemblages were more similarly ranked: five of the eight most frequently occurring polychaete species listed in 1963 were also among those ranked for 1993-1998. *Paraprionospio pinnata* was the most frequently occurring polychaete in 1963, followed by *Glycera americana* and *Glycinde solitaria* (Karlen *et al*. 1997). During the current study, *Phyllodoce areneae*, *G. americana*, and *G. solitaria* ranked one through three and each occurred in >20% of the samples.

Bloom *et al*. (1972) sampled intertidally along the south side of the Courtney Campbell Causeway during September 1968. The most abundant species were *Branchiostoma* “*caribaeum*”, *Acanthohaustorius* sp., the polychaete *Onuphis eremita oculata*, the razor clam *Tagelus divisus* (intertidal), and the gastropod *Bittiolium varium*.

Simon & Dauer (1977) studied four sites in proximity to one another south of the Courtney Campbell Causeway. During July 1973 the most abundant taxa were the bivalve mollusc *Tellina* sp., the amphipod *Acanthohaustorius* sp., the brachiopod *Glottidia pyramidata*, and the polychaete *Travisia* sp.

For the 1993-1998 period, the lancelet *Branchiostoma floridae*, the gastropod mollusc *Caecum strigosum*, the bivalve mollusc *Mysella planulata*, and amphipods other than *A. uncinus (e.g., M. floridana, R. naglei, Eudevenopus honduranus, Ampelisca holmesi*, and *A.* sp. C) were generally among the most abundant taxa in Old Tampa Bay as a whole.

The benthic community of Old Tampa Bay may have undergone some shifts in the species composition of the fauna since the 1960's and 1970's. The available data suggest that the mollusc assemblage may have changed more than the polychaete assemblage. Comparisons with Bloom *et al*. (1972), Simon & Dauer's (1977) and Dauer's (1980) results are complicated by the paucity of sites investigated during 1973 and different sampling methods. It would be more appropriate to parse out those sites more or less common to all of the studies and examine them more closely.

Another biotic characteristic of Old Tampa Bay that merits some discussion is the prevalence of *Branchiostoma floridae*. Pierce (1965) surveyed Florida's coasts for *Branchiostoma* and found the highest densities in Old Tampa Bay on sand bars. Stokes (1996) studied life history characteristics of this population during 1992-1994. During Stokes' (1996) study, the maximum density observed was 1200 m$^{-2}$. This compares favorably with the bay segment means observed in our survey (*cf*. Table 4).

There has been little evidence of degraded sedimentary habitat in Old Tampa Bay during this study period. No more than three of the >100 sediment and hydrographic samples met at least one criterion for "degraded" habitat. Based upon the most current iteration of the TBBI, the benthic assemblages at <2% of the sites, were "degraded". Near-bottom hypoxia was evident at <3% of the sites, although some impairment (DO<4 ppm) was observed in northwestern Old Tampa Bay. The percentages of "degraded" habitat (benthos and DO) are lower than those reported for the Louisianian Province as a whole (Summers *et al.* 1993; Macauley *et al.* 1994; Macauley *et al.* 1995).

Only one site, located in the vicinity of Culbreath Bayou (eastern Old Tampa Bay), showed evidence of severe sediment contamination. Concentrations of chlordane (135 ppb; PEL Quotient >28), DDT (>26 ppb; >TEL), and chromium, lead, and nickel concentrations (>PEL) were each high enough to be of ecological concern.

Old Tampa Bay sediments were considerably more anaerobic (>30% of samples), based upon the width of the RPD, than those of the Louisianian Province as a whole in 1991 (9%; Summers *et al.*1993) At the Old Tampa Bay sites, both DO and %SC varied widely for any measured RPD (*cf.* Rosenberg *et al*. 2001).

Correlation analysis showed that the TBBI was positively associated with DO and RPD and negatively associated with %SC. The associations with salinity, the composite PEL quotient, and depth were not statistically significant. Multiple regression analysis, however, did produce a statistically significant association between the TBBI and the RPD, salinity, %SC, and the PEL quotient. The *rank* correlations between the overall structure of the benthic community and the "best fit" for physico-variables 1995-1998 data (PCBs, chlordane, nickel, tin) were very weak (-0.036).

Examining the data for trends (means for each Index Period), the benthic community experienced more pronounced shifts in structure from 1994 to 1995 and from 1997 to 1998 than during other sequential years. The best fit for the (mean) environmental variables with the biotic data were for aluminum, arsenic, cadmium, copper, tin, DO, and temperature, although the Spearman rank correlation coefficient was only -0.25. The mean concentrations of aluminum and tin increased markedly from 1994 to 1995. Mean concentrations of aluminum, tin, and DO decreased considerably from 1997 to 1998.

With respect to the benthic community, shifts in the densities of three species were primarily responsible for the magnitude of the shifts in structure from 1994 to 1995 and from 1997 to 1998. Both *Metharpinia floridana* and *Branchiostoma floridae* each experienced marked declines in abundance during each of these time periods, when salinities generally declined >5 ppt. Mean density of *Mysella planulata* increased during these periods.

One factor not considered in this analysis—and which merits further evaluation--- was the possible effects of the El Niño-Southern Oscillation (ENSO). The summer-fall 1994 to winter 1995 and the spring 1997 to summer 1998 periods were both El Niños and the summer-fall of 1998 was a La Niña (www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.html; Schmidt *et al*. 2001). These regional influences on the timing and amount of rainfall, manifested as marked changes in the salinity regimes, could certainly have affected benthic community structure in Tampa Bay (*cf*. Gutierrez *et al*. 2000 and Poulin *et al*. 2002).

# V. CONCLUSIONS

*Soft-sediment habitats in Old Tampa Bay experienced little stress from either low DO or sediment contaminants and the benthic community could generally be considered "healthy".* Hypoxia was less pervasive in Old Tampa Bay than in the Louisianian Province as a whole and subnominal benthic habitat was less pervasive in Old Tampa Bay.

The *structure of the benthic community* was not clearly explained by patterns or trends in physical factors generally linked to benthic community structure (*e.g.*, salinity and sediment type). The linkage between biotic and abiotic structure was generally weak—except when yearly survey averages were considered. In the interannual trend analysis, changes in the *average* concentrations of the metals arsenic, cadmium, and chromium were linked to changes in the *average* composition of the benthic community. The TBBI was, however, associated with several of the measured variables, including DO, RPD, depth, %SC, and a composite index of sediment contaminants.

As noted, shifts in *benthic community structure* did not appear to be associated with salinity *per se*. The observed variations in benthic community structure from 1994 to 1995 and again from 1997 to 1998 were, however, associated with the occurrence of an El Nino event and a >5 ppt change in median salinities.

Analysis of hydrographic (temperature, salinity) and habitat variables (depth, %SC, DO) suggested that sample depth, DO and %SC were primary determinants of the *physico-chemical "structure"* of Old Tampa Bay. Water temperature, as an indicator of interannual changes, was a secondary factor. Salinity was less important in characterizing Old Tampa Bay.

*The composition of the benthos appears to have undergone changes since the 1960s and 1970s.* Changes were observed in the rank order of the most frequently occurring mollusc species. Alterations in the composition of polychaete worms were less evident and crustaceans could not be evaluated. Although interannual variations in population size and location could explain some of these differences—and should be examined on a bay-wide basis, the differences could also reflect changes in habitat quality over the past 30 years.

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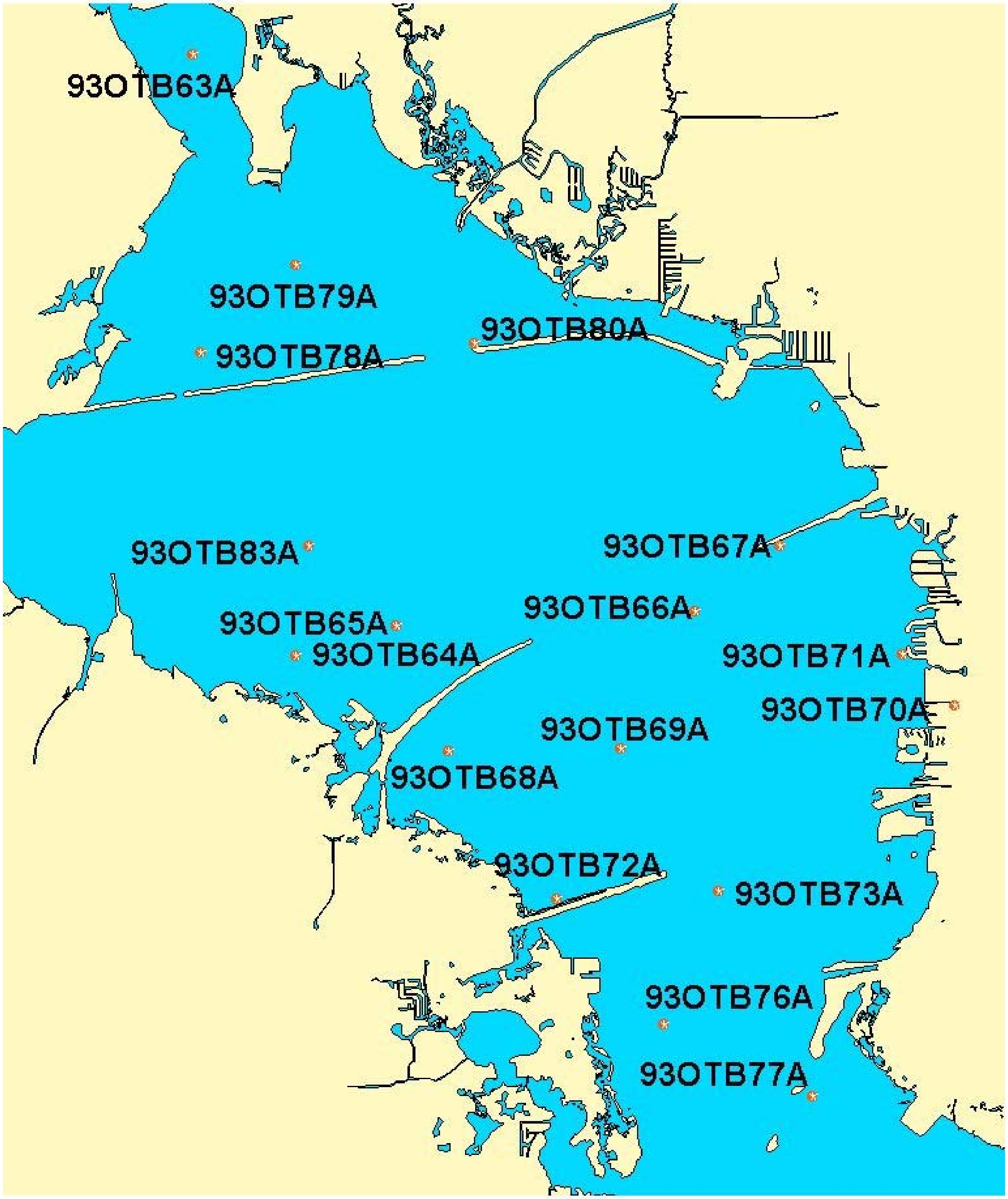
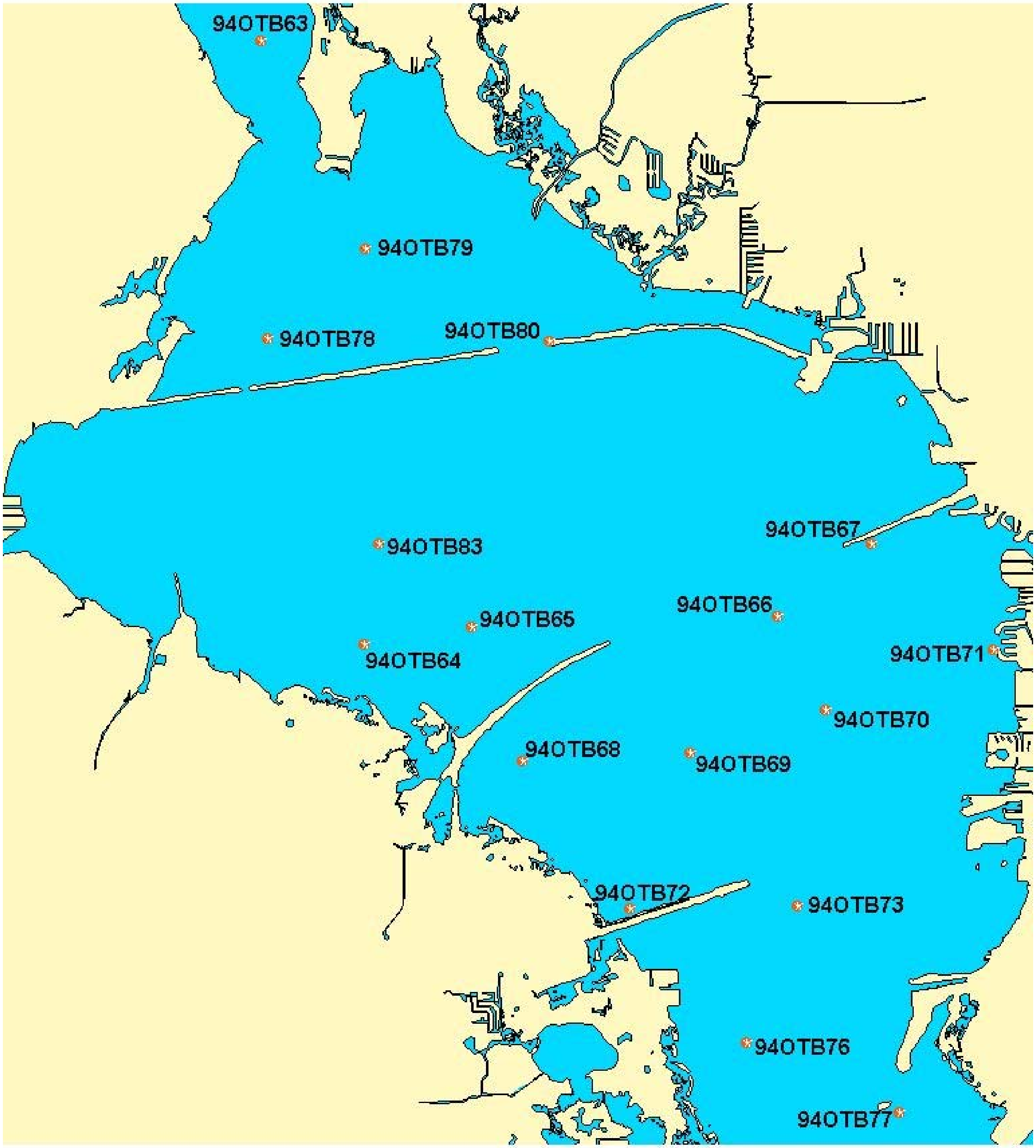
# VIII. APPENDICES

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



1993 Old Tampa Bay Stations



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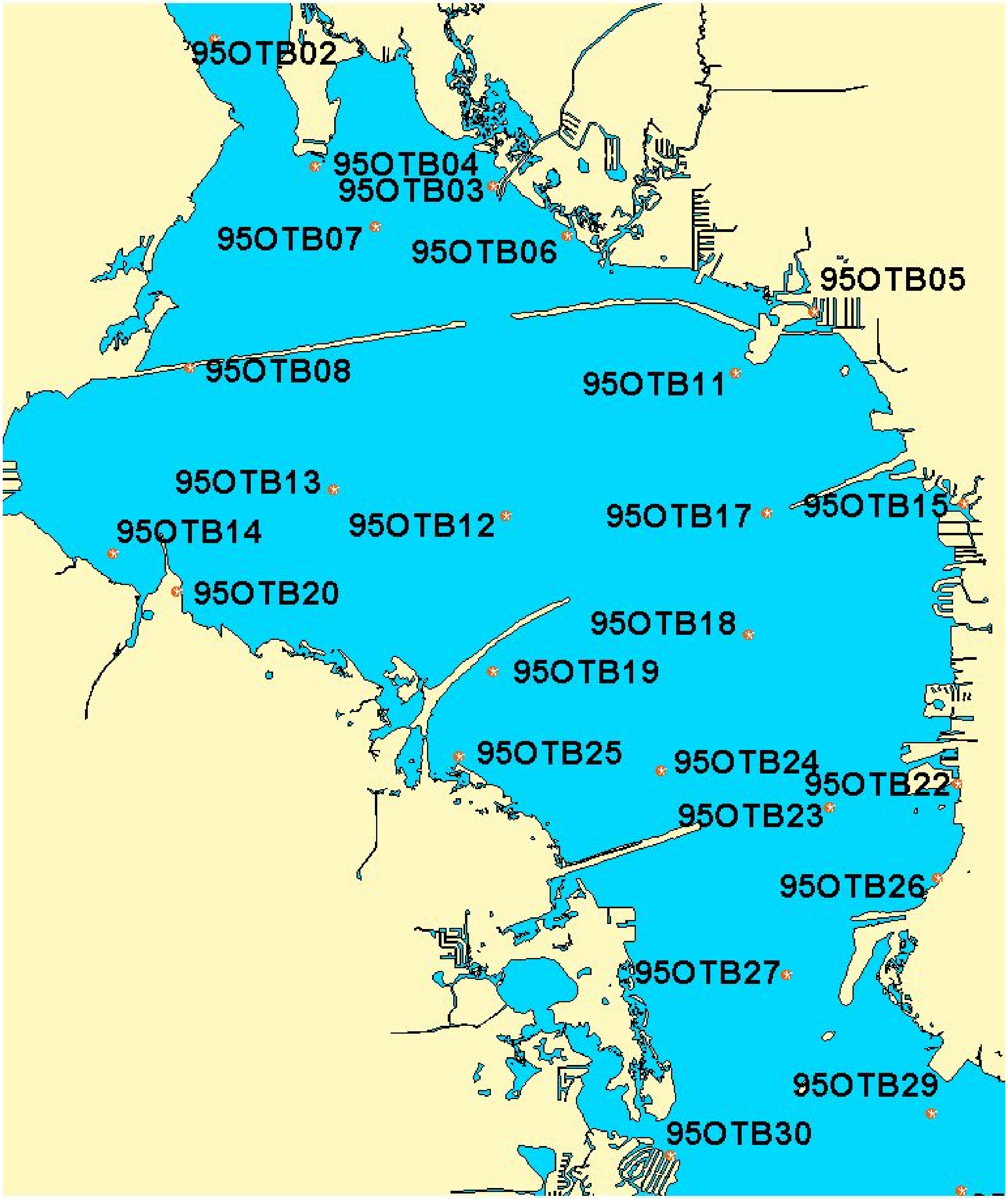

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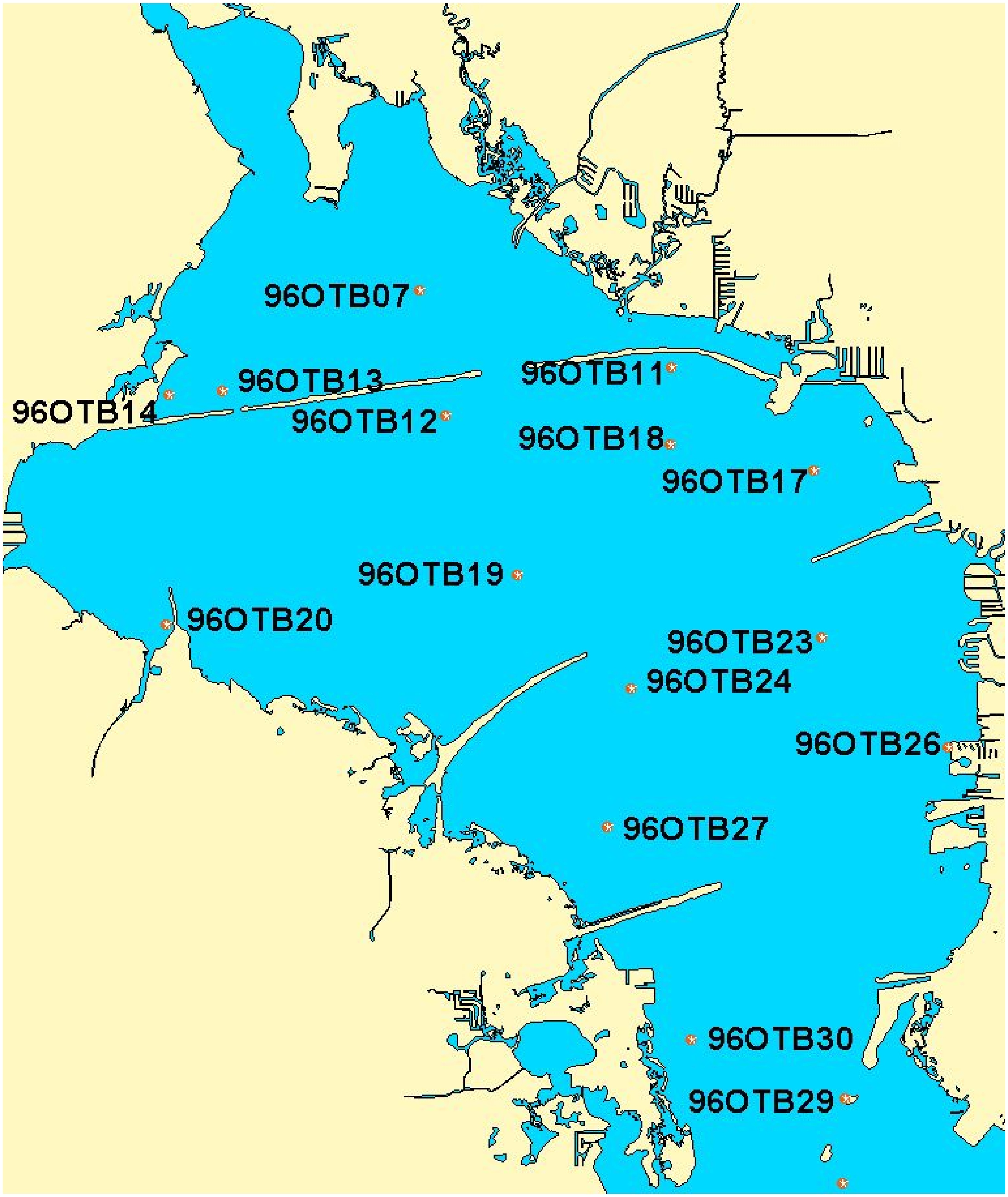
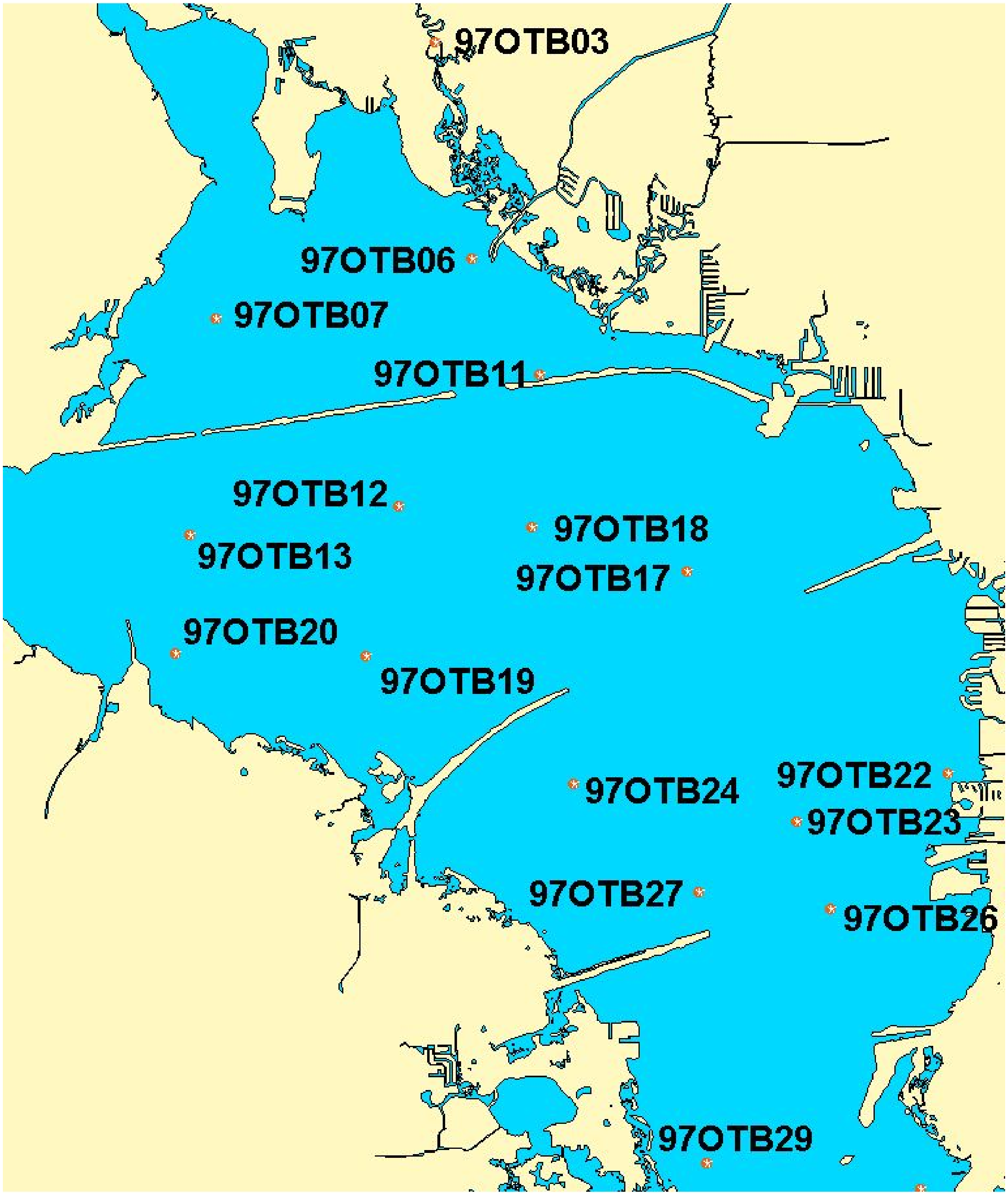
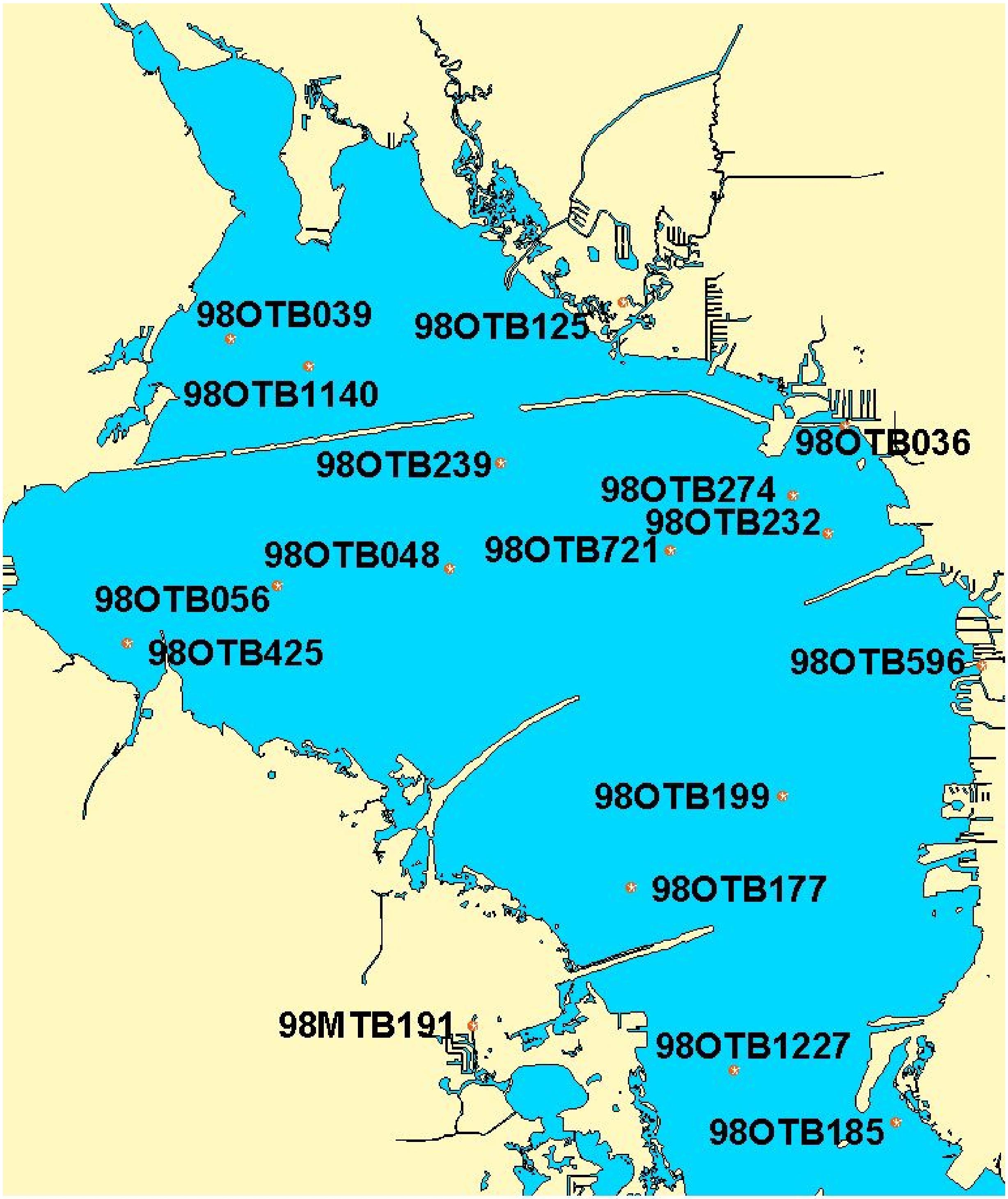


1996 Old Tampa Bay Stations



1997 Old Tampa Bay Stations



1998 Old Tampa Bay Stations

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

***Phylum Porifera***
*Porifera sp. E*
*Porifera sp. D*
*Porifera sp. C*

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

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

***Phylum Platyhelminthes***
**Class Turbellaria**
**Order Polycladida**
*Turbellaria A*
*Stylochus sp.*
*Eustylochus meridianalis*

***Phylum Nemertea***
*Nemertea Y*
*Nemertea X*
*Nemertea U*
*Nemertea R*
*Nemertea O*
*Nemertea Q*
*Nemertea N*
*Nemertea P*
*Nemertea G*
*Nemertea F*
*Nemertea I*
*Nemertea K*
*Nemertea B*
*Nemertea J*

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Class Anopla**
**Order Paleonemertea**
**Family Tubulanidae**
*Tubulanus pellucidus*

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

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

**Family Tetrastemmatidae**
*Tetrastemma candidum*

***Phylum Annelida***
**Class Polychaeta**
**Order Phyllodocida**
**Family Polynoidae**
*Malmgreniella maccraryae*
*Malmgreniella taylori*
*Polynoidae Genus D*

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

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

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Order Phyllodocida**
**Family Phyllodocidae**
*Eteone heteropoda*
*Eteone foliasa*
*Nereiphylla castanea*
*Paranaitis gardineri*
*Nereiphylla sp. A*
*Phyllodoce arenae*

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

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

**Family Syllidae**
*Syllis gracilis*
*Syllis cornuta*
*Exogone dispar*
*Sphaerosyllis taylori*
*Sphaerosyllis longicauda*
*Sphaerosyllis labyrinthophila*
*Grubeosyllis clavata*
*Brania wellfleetensis*
*Brania sp. A*
*Parapionosyllis longicirrata*
*Parapionosyllis uelebackerae*

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Family Nereididae**
*Nereis acuminata*
*Nereis succinea*
*Platynereis dumerilii*
*Laeonereis culveri*
*Stenoninereis martini*

**Family Nephtyidae**
*Nephtys cryptomma*
*Aglaophamus verrilli*

**Family Glyceridae**
*Glycera americana*
*Glycinde solitaria*

**Family Goniadidae**
*Goniadides carolinae*

**Order Eunicida**
**Family Onuphidae**
*Diopatra cuprea*
*Kinbergonuphis simony*

**Family Lumbrineridae**
*Lumbrineris tenuis*

**Family Oenonidae**
*Drilonereis magna*
*Drilonereis E*
*Arabella iricolor*
*Arabella mutans*

**Family Dorvilleidae**
*Ophryotrocha n. sp.*
*Dorvillea rudolphi*

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

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

**Order Cirratulida**
**Family Paraonidae**
*Aricidea suecica*
*Aricidea philbinae*
*Aricidea taylori*
*Paraonis fulgens*

**Order Spionida**
**Family Spionidae**
*Polydora cornuta*
*Prionospio multibranchiata*
*Prionospio heterobranchia*
*Prionospio steenstrupi*
*Apoprionospio pygmaea*
*Prionospio cristata*
*Prionospio perkinsi*
*Spio setosa*
*Spio pettiboneae*
*Spiophanes bombyx*
*Paraprionospio pinnata*
*Streblospio gynobranchiata*
*Scolelepis texana*
*Minuspio (Prionospio) sp.*
*Carazziella hobsonae*

**Order Magelonida**
**Family Magelonidae**
*Magelona pettiboneae*

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

## APPENDIX B (continued)
## INVENTORY OF BENTHIC MACROINVERTEBRATES
## COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Order Chaetopterida**
**Family Chaetopteridae**
*Spiochaetopterus costarum*

**Order Cirratulida**
**Family Cirratulidae**
*Caulleriella zetlandica*
*Monticellina dorsobranchialis*

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

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

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Family Ampharetidae**
*Hobsonia florida*
*Melinna maculata*

**Family Terebellidae**
*Loimia medusa*
*Loimia viridis*

**Order Sabellida**
**Family Sabellidae**
*Chone cf. americana*
*Fabricinuda trilobata*

**Family Serpulidae**

**Family Spirorbidae**

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

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

**Family Enchytraeidae**
*Grania monospermatheca*

**Family Tubificidae**
*Tubificoides B*
*Tubificoides A*
*Limnodriloides sp.*
*Tubificoides brownae*
*Tubificoides wasselli*
*Thalassodrilides eneri*
*Heterodrilus bulbiporus*
*Heterodrilus A*
*Inanidrilus sp. A*

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

***Phylum Mollusca***
**Class Gastropoda**
**Order Heterostropha**
**Family Pyramidellidae**
*Sayella fusca*

**Order Neotaenioglossa**
**Family Vitrinellidae**
*Vitrinella floridana*
*Teinostoma sp.*

**Family Caecidae**
*Caecum pulchellum*
*Caecum imbricatum*
*Caecum strigosum*

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

**Family Epitoniidae**
*Epitonium angulatum*
*Epitonium tollini*

**Family Eulimidae**
*Melanella cf. arcuata*
*Eulima bilineatus*
*Microeulima hemphilli*
*Eulima bifasciatus*

**Family Calyptraeidae**
*Crepidula fornicata*
*Crepidula plana*
*Crepidula maculosa*

**Family Naticidae**
*Tectonatica pusilla*

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

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Family Melongenidae**
*Melongena corona*

**Family Nassaridae**
*Nassarius vibex*

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

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

**Family Marginellidae**
*Prunum apicinum*

**Order Heterostropha**
**Family Pyramidellidae**
*Fargoa cf. gibbosa*
*Odostomia laevigata*
*Odostomia producta*
*Odostomia virginica*
*Eulimastoma weberi*
*Eulimastoma teres*
*Eulimastoma engonium*
*Eulimastoma ergonia?*
*Turbonilla interrupta*
*Turbonilla conradi*
*Turbonilla hemphilli*
*Turbonilla constricta*
*Turbonilla (Pyrigiscus) sp. C*
*Pyramidella sp.*
*Boonea impressa*

**Order Cephalaspidea**
*Lephalapsidea sp.*

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

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Order Cephalaspidea**
**Family Cylichidae**
*Acteocina canaliculata*
*Acteocina bidentata*
*Tornatina inconspicua*

**Family Bullidae**
*Bulla striata*

**Family Haminoeidae**
*Haminoea succinea*

**Order Nudibranchia**
**Family Dorididae**
*Doris verrucosa*

**Class Bivalvia**
**Order Nuculoida**
**Family Nuculidae**
*Nucula crenulata*

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

**Order Mytiloida**
**Family Mytilidae**
*Brachidontes exustus*
*Amygdalum papyrium*

**Order Veneroida**
**Family Lucinidae**
*Parvilucina multilineata*

**Family Ungulinidae**
*Diplodonta semiaspera*

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

## APPENDIX B (continued)
## INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Family Crassatellidae**
*Crassinella lunulata*

**Family Cardiidae**
*Laevicardium sp.*
*Laevicardium mortoni*

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

**Family Semelidae**
*Ervilia concentrica*

**Family Pharidae**
*Ensis minor*

**Family Tellinidae**
*Macoma tenta*
*Macoma constricta*
*Macoma phenax*
*Tellina iris*
*Tellina lineata*
*Tellina versicolor*
*Tellina alternata*
*Tellina tampaensis*
*Tellina tenella*

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

**Family Semelidae**
*Abra aequalis*

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Family Veneridae**
*Transennella conradina*
*Dosinia discus*
*Cyclinella tenuis*
*Chione cancellata*
*Macrocallista nimbosa*
*Callista eucymata*
*Parastarte triquetra*

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

**Family Corbulidae**
*Corbula contracta*

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

**Family Thraciidae**
*Asthenothaerus hemphilli*

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

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

**Order Mysidacea**
**Family Mysidae**
*Bowmaniella floridana*

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

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

**Family Bodotriidae**
*Cyclaspis pustulata*
*Cyclaspis cf. varians*

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

**Family Leptocheliidae**
*Leptochelia sp.*

**Order Isopoda**
**Family Anthuridae**
*Cyathura polita*

**Family Hyssuridae**
*Xenanthura brevitelson*
*Amakusanthura magnifica*

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

**Family Idoteidae**
*Erichsonella attenuata*
*Edotia triloba*

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

**Family Amphilochidae**
*Amphilocus cf. casahoya*
*Gitanopsis laguna*

**Family Ampithoidae**
*Cymadusa compta*

## APPENDIX B (continued)
## INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Family Aoridae**
*Bemlos spinicarpus*
*Paramicrodeutopus cf. myersi*
*Rudilemboides naglei*

**Family Argissidae**
*Argissa hamatipes*

**Family Bateidae**
*Batea catharinensis*

**Family Ischyroceridae**
*Cerapus sp. C (="tubularis")*
*Cerapus sp. A*

**Family Corophiidae**
*Americorophium ellisi*
*Erichthonius brasiliensis*

**Family Aoridae**
*Grandidierella bonnieroides*

**Family Gammaridae**
*Ceradocus sp. A*
*Elasmopus laevis*
*Gammarus mucronatus*
*Melita elongata*

**Family Haustoriidae**
*Acanthohaustorius uncinus*

**Family Corophiidae**
*Microprotopus raneyi*

**Family Liljeborgiidae**
*Listriella barnardi*

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

## APPENDIX B (continued)
## INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

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

**Family Oedicerotidae**
*Hartmanodes nyei*

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

**Family Platyischnopidae**
*Eudevenopus honduranus*

**Family Stenothoidae**
*Parametopella texensis*
*Parametopella sp. A*

**Family Synopiidae**
*Tiron triocellatus*

**Family Pariambidae**
*Deutella incerta*
*Paracaprella tenuis*

**Order Decapoda**
**Family Penaeidae**
*Farfantepenaeus duorarum*
*Rimapenaeus constrictus*

**Family Palaemonidae**
*Periclimenes americanus*

**Family Ogyrididae**
*Ogyrides alphaerostris*

**Family Hippolytidae**
*Hippolyte zostericola*

**Family Processidae**
*Processa hemphilli*
*Ambidexter symmetricus*

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Family Paguridae**
*Pagurus gymnodactylus*
*Pagurus maclaughlinae*

**Family Upogebiidae**
*Upogebia affinis*

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

**Family Parthenopidae**
*Heterocrypta granulata*

**Family Panopeidae**
*Eurypanopeus sp.*
*Hexapanopeus angustifrons*
*Panopeus sp.*
*Rhithropanopeus harrisii*
*Dyspanopeus texanus*

**Family Pinnotheridae**
*Tumidotheres maculatus*
*Pinnixa chaetopterana*
*Pinnixa cf. pearsei*
*Pinnixa A*
*Pinnixa D*

**Class Insecta**
**Order Diptera**
**Family Chironomidae**
*Tanypus clavatus*
*Polypedilum scalaneum group*

***Phylum Sipuncula***
**Family Golfingiidae**
*Phascolion cryptum*

# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

**Family Aspidosiphonidae**
*Aspidosiphonidae*

***Phylum Phoronida***
*Phoronis ?architecta*
*Phoronida B*

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

***Phylum Echinodermata***
**Class Ophiuroidea**
**Order Ophiurida**
**Family Ophiactidae**
*Hemipholis elongata*

**Class Amphiuroidea**
**Family Amphiuridae**
*Amphipholis gracillima*
*Ophiophragmus wurdemanii*
*Ophiophragmus filograneus*
*Amphioplus abditus*
*Amphioplus thrombodes*
*Amphioplus sepultus*
*Amphioplus cuneatus*
*Amphipholis atra*
*Amphipholis sp. A*

**Class Echinoidea**

**Class Holothuroidea**
*Holothuroidea B*

**Family Synaptidae**
*Synaptidae A*

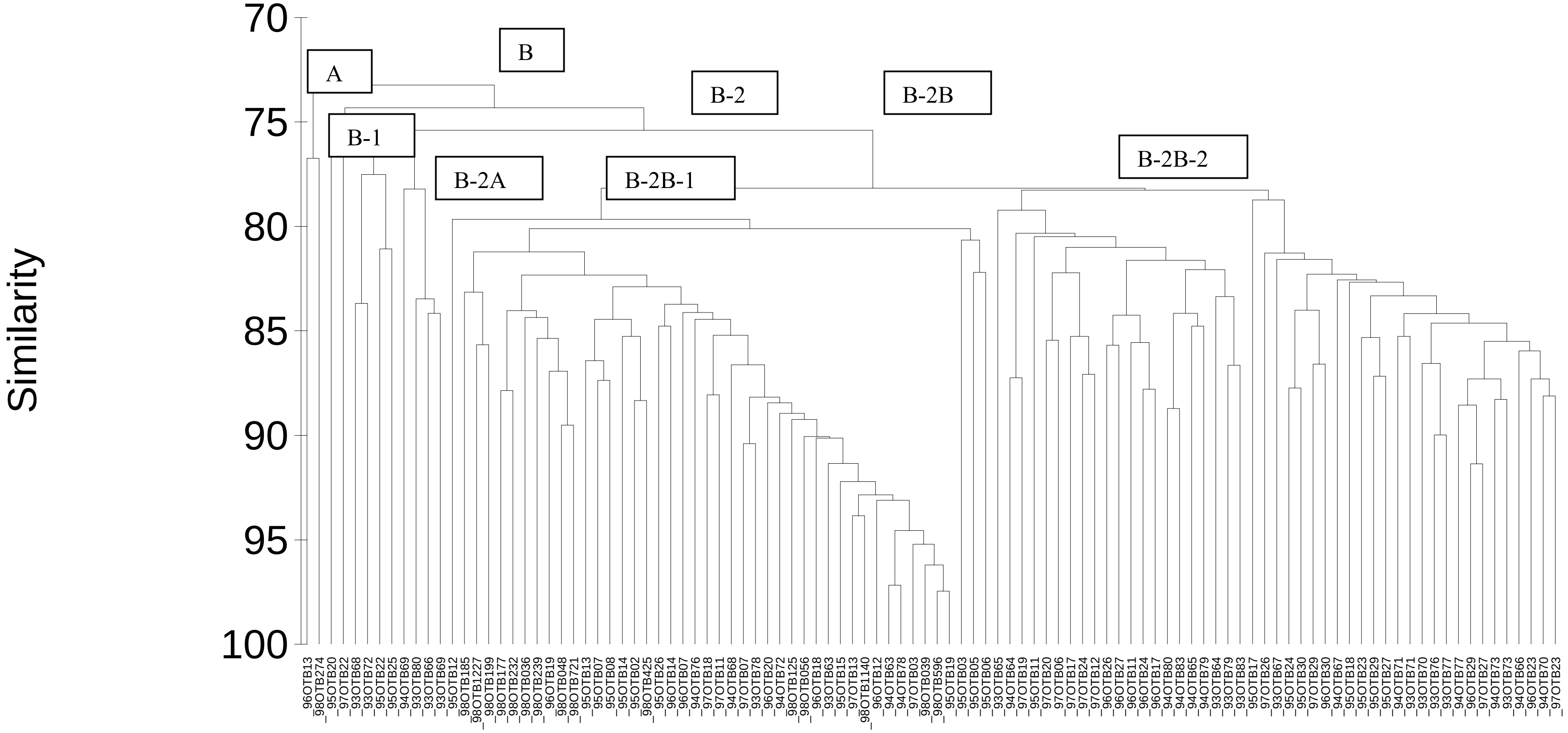
# APPENDIX B (continued)
# INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM OLD TAMPA BAY, 1993-1998

***Phylum Hemichordata***
**Class Enteropneusta**
*Enteropneusta B*

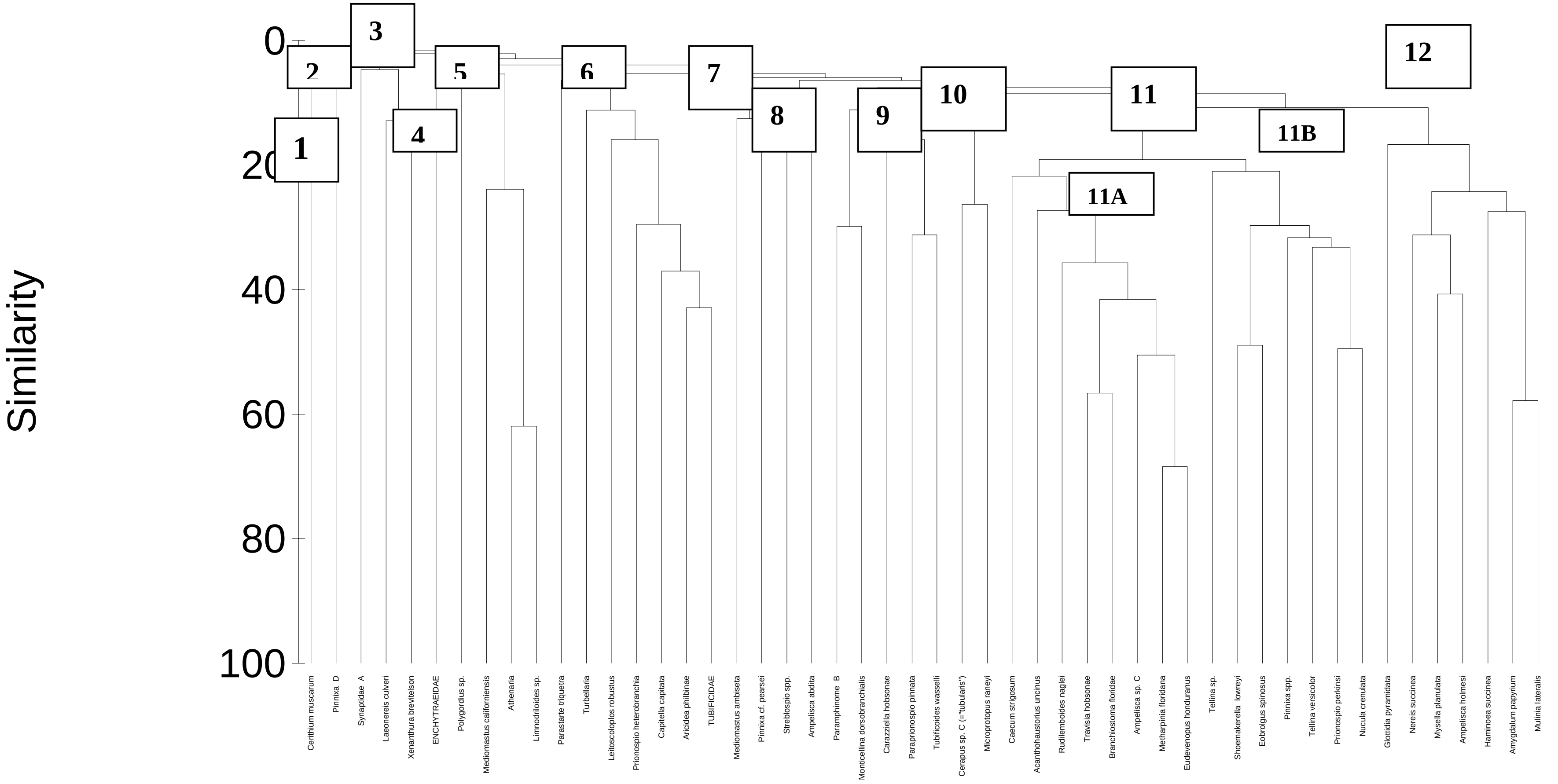
**Family Harrimaniidae**
*Stereobalanus canadensis*

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

# Appendix C.
# Dendrogram depicting the similarity of sites in Old Tampa Bay 1993-1998
# (4th root transformed abundance; Bray-Curtis similarity; group-average clustering).



# APPENDIX D
## Dendrogram depicting the similarity of the 50 most abundant taxa, Old Tampa Bay 1993-1998 (standardized abundance; Bray-Curtis similarity; group-average clustering)



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

**Groups 94  &  93**
**Average dissimilarity = 21.19**

```
                              Group 94  Group 93
Species                       Av.Abund  Av.Abund  Av.Diss  Diss/SD  Contrib%  Cum.%
Branchiostoma floridae         1088.34   1578.04     0.48     1.34      2.27   2.27
Rudilemboides naglei            489.81   1097.16     0.42     1.38      1.96   4.23
Metharpinia floridana           628.04    333.19     0.38     1.33      1.78   6.01
Eudevenopus honduranus          536.86    393.48     0.35     1.33      1.65   7.66
Prionospio perkinsi             551.57    561.13     0.35     1.34      1.64   9.30
Ampelisca sp. C                 311.86    380.98     0.32     1.30      1.53  10.83
```

**Groups 94  &  95**
**Average dissimilarity = 21.16**

```
                            Group 94  Group 95
Species                     Av.Abund  Av.Abund  Av.Diss  Diss/SD  Contrib%  Cum.%
Branchiostoma floridae       1088.34    305.53     0.45     1.29      2.14   2.14
Mysella planulata             123.63    465.32     0.43     1.52      2.02   4.16
Metharpinia floridana         628.04    179.45     0.40     1.26      1.90   6.06
Eudevenopus honduranus        536.86    154.45     0.40     1.38      1.88   7.94
Rudilemboides naglei          489.81    317.49     0.39     1.30      1.83   9.76
Prionospio perkinsi           551.57     83.80     0.36     1.34      1.71  11.48
```

**Groups 95  &  96**
**Average dissimilarity = 20.92**

```
                         Group 95  Group 96
Species                  Av.Abund  Av.Abund  Av.Diss  Diss/SD  Contrib%  Cum.%
Mysella planulata          465.32   2496.77     0.48     1.38      2.28   2.28
Rudilemboides naglei       317.49    968.43     0.44     1.28      2.11   4.39
Ampelisca holmesi          191.40    998.43     0.42     1.39      1.99   6.37
Branchiostoma floridae     305.53    458.43     0.36     1.03      1.71   8.08
Metharpinia floridana      179.45    378.43     0.34     1.10      1.63   9.70
Eudevenopus honduranus     154.45    373.43     0.33     1.10      1.60  11.31
```

**Groups 97  &  96**
**Average dissimilarity = 20.85**

```
                               Group 97  Group 96
Species                        Av.Abund  Av.Abund  Av.Diss  Diss/SD  Contrib%  Cum.%
Mysella planulata                800.10   2496.77     0.56     1.40      2.68   2.68
Rudilemboides naglei            1851.77    968.43     0.49     1.29      2.34   5.02
Branchiostoma floridae          1431.77    458.43     0.44     1.01      2.13   7.15
Ampelisca holmesi                315.10    998.43     0.43     1.33      2.07   9.22
Metharpinia floridana            316.77    378.43     0.36     1.17      1.74  10.96
```

**Groups 97  &  98**
**Average dissimilarity = 21.16**

```
                               Group 97  Group 98
Species                        Av.Abund  Av.Abund  Av.Diss  Diss/SD  Contrib%  Cum.%
Mysella planulata                800.10   2133.92     0.54     1.36      2.57   2.57
Mulinia lateralis                  0.10   1314.81     0.46     1.02      2.18   4.75
Rudilemboides naglei            1851.77      4.51     0.46     1.01      2.17   6.92
Branchiostoma floridae          1431.77    438.34     0.45     0.99      2.15   9.07
Monticellina dorsobranchialis    555.10    461.86     0.40     1.13      1.89  10.96
```