Tampa Bay Benthic Monitoring Program: Status of Hillsborough Bay: 1993-1998

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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 Hillsborough 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 support for this monitoring program.

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

1- 139 locations (19 to 29 per year) were sampled during late summer/early fall "Index Period" from 1993 to 1998.

2- Near-bottom water temperatures during 1994 were similar to 1997; 1998 and 1996 water temperatures were similar to 1997.

3- Near bottom salinities were generally highest in 1997 and lowest during the 1995 and 1998 sampling periods.

4- Salinities were generally within the polyhaline (18-30 ppt) zone. Mesohaline (5-18 ppt) conditions were observed along the periphery of the bay during 1995 and, to a greater extent, during 1998.

5-Near-bottom dissolved oxygen concentrations were less than 2 parts per million (hypoxia) in more than 30% of samples collected during 1998 and in less than 10% of 1996 samples.

6- Hypoxia was most often observed immediately downstream of the Hillsborough River, between the Interbay peninsula and the Davis Islands.

7- Sediments in Hillsborough Bay were predominantly sandy, although muds are widely distributed in western Hillsborough Bay.

8- At the deeper sites in Hillsborough Bay, the percentage of fine-grained (mud and silt) sediments was higher and dissolved oxygen concentrations lower.

9- A composite index of the chemical contamination of Hillsborough Bay sediments suggested that, in any year surveyed to date, less than 5% of the of the samples had a high likelihood of being toxic to aquatic life. Chemically degraded sediments were found in the upper portions of Hillsborough Bay, including McKay Bay, East Bay, and the Lower Hillsborough River.

10- The percentage of samples "degraded" by metals and hydrocarbons (oils, automotive combustion products, etc.) ranged from 0 to 4.8; the percentage degraded by PCBs ranged from 0 to 3.7% in any year. Additionally, as many as 10% of the samples in any year were likely to be toxic for chlordane.

11- Numerically abundant benthic species included the clam *Mysella planulata,* several segmented worms (*Monticellina dorsobranchialis*, *Carazziella hobsonae, Prionospio perkinsi*), non-segmented worms, and the amphipod crustacean ("scud") *Ampelisca holmesi.*

12-Numerical dominants differed both by year and salinity zone.

13- The variety of animals in any sample varied over years. In 1995, the median numbers of taxa per sample was less than 20 whereas in 1994 it was more than 30. During 1995, almost 20% of the samples contained no living animals.

14- Tampa Bay Benthic Index (a composite measure of the "health" of the communities of bottom dwelling organisms) scores were generally higher during 1993, 1995 and 1996 than during 1997 and 1998. Degraded habitat was found at approximately 30% of the sites sampled during 1995—*vs*. less than 15% of sites in other years. Degraded benthic habitat was generally located immediately downstream of the Lower Hillsborough River, between the Interbay Peninsula and Davis Island, in the northeastern, industrial area of Hillsborough Bay.

15- Benthic Index scores were positively associated with dissolved oxygen and negatively associated with increasing percentages of fine-grained sediments (muds, silts), sediment contaminant level, and depth. The Benthic Index was not affected by salinity.

16- The overall structure of the community of sediment dwelling animals (benthos) was not clearly explained by patterns or trends in physical factors generally shown to be linked to benthic community structure (*e.g*., salinity and sediment type). The linkage between the structure of the benthic community and structure based upon physical (*e.g.,* sample depth, sediment type) and chemical contaminants (*e.g*., metals, pesticides) was generally weak—except when yearly survey averages were considered

17- The benthic community experienced more pronounced shifts in structure from 1996 to 1997 and from 1997 to 1998 than during other years. Three metals (arsenic, cadmium, and chromium) each showed a marked increase in mean concentration from 1996 to 1997. From 1997 to 1998 arsenic concentrations declined approximately 75% while chromium increased almost 5 fold. Benthic organisms which contributed primarily to this shift in community structure from 1996 to 1997 included the clam *Mysella planulata*, the segmented worm *M. dorsobranchialis*, and the "scud" *Ampelisca holmesi*. Shifts in structure from 1997 to 1998 were primarily affected by alterations in the abundance of the segmented worms *M. dorsobranchialis, Prionospio perkinsi*, and the scud *A. holmesi*.

18- Hillsborough Bay appears to be affected more by subnominal dissolved oxygen concentrations than the Louisianian Province (northern Gulf of Mexico south to Tampa Bay) as a whole. Degradation of benthic habitat, however, appears to be markedly higher in the Louisianian Province than in Hillsborough Bay.

19- 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: segmented worms, clams and snails, and one group of amphipods ("scuds"). 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.

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INTRODUCTION

The Environmental Protection Commission of Hillsborough County (EPCHC) has been collecting benthos and sediment samples on an annual basis (late summer to early fall) in Hillsborough Bay since 1993 as part of a bay-wide monitoring program developed by theTampa 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 by evaluating sediment quality by applying Sediment Quality Assessment Guidelines (SQAGs). The Tampa Bay Estuary Program (formerly the Tampa Bay National Estuary Program) and the USEPA have provided partial support for this monitoring program.

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

METHODS

Field Collection and Laboratory Procedures: A total of 139 stations (19 to 29 per year) were sampled during a late summer through early fall "Index Period" from 1993 through 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). Laboratory procedures followed the protocols set forth in Courtney *et al*. (1995).

Figure 1. Young grab sampler 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. Descriptive statistics, the Tampa Bay Benthic Index (TBBI), regression analysis, and the Kolmogorov-Smirnov "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 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) (PRIMER-E Ltd. 2001) was used to examine the resemblance of the Hillsborough Bay sites, by year. Hydrographic (temperature, salinity, dissolved oxygen) and sediment (percent silt+clay [%SC]) variables were normalized prior to anlaysis. 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 & 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 abundances were fourth root transformed n+0.1 and the similarity coefficient 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 evaluated using fourth root transformed n+0.1 abundances (all taxa). Biotic structure was evluated using RIMERhe 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 (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*$e^{-\phi}$ adjusted r^2=0.947). Wentworth size classes for sediments (*cf*. Percival & Lindsay 1997) were then estimated for each %SC value.

* 1993 data were excluded from this analysis because only four samples were collected for chemical contaminants; 1994 samples were excluded because sediment contaminants were not analyzed.

RESULTS

Hydrographic: Table 1 summarizes the surface and bottom water quality measures, as well as sample depth, for the 139 stations sampled. Median sample depth was 2.4-m, although depths ranged to >14-m (Figure 2). The deepest stations (>11 m) were located in the East Bay and Pendola Point areas. The shallowest sites (0.1 m) tended to be located along the eastern shoreline between the Alafia River and Pendola Point.

Table 1. Summary of Mean Physicochemical Variables: Hillsborough Bay, 1993-1998

A. SURFACE

	Temperature (^{o} C)	Salinity (ppt)	Dissolved Oxygen (ppm)	pH (units)
Minimum	25.5	1.8	1.1	6.4
Maximum	36.2	27.6	12.1	8.4
Median	29.2	20.6	6.2	8.0
Mean	29.3	20.1	6.2	7.9

B. BOTTOM

	Depth (meters)	Temperature (^{o} C)	Salinity (ppt)	Dissolved Oxygen (ppm)	pH (units)
Minimum	0.1	25.5	1.8	<0.1	6.8
Maximum	14.7	33.4	28.7	9.5	8.3
Median	2.4	29.0	22.2	4.2	7.8
Mean	2.9	29.1	21.6	4.0	7.7

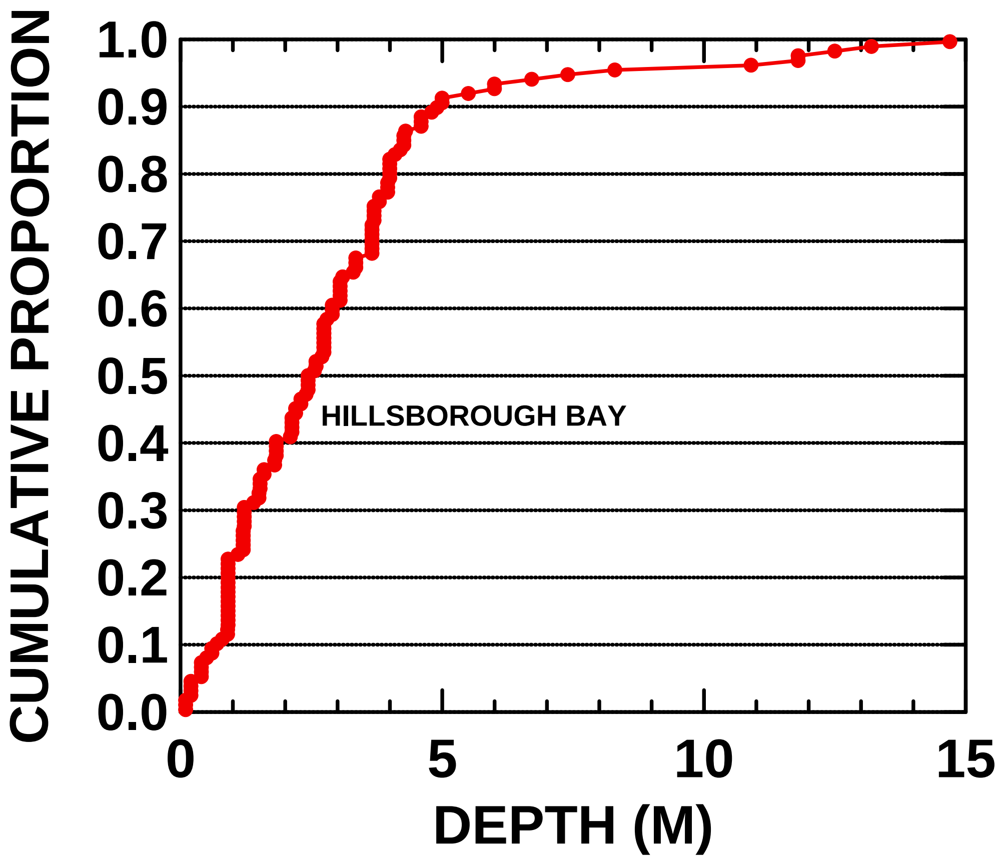

Figure 2. CDF plot of sample depths in Hillsborough Bay, 1993-1998 inclusive.

The temperature-salinity plot suggests that the near-bottom water mass characteristics differed among years (Figure 3). Highest water temperatures were observed during 1995 and in 1993 (Figure 4). The frequency distribution of water temperatures during 1994 were similar to 1997 and 1998; 1996 was similar to 1997 (KS test $p>0.05$). Salinities were generally highest in 1997 and lowest during the 1995 and 1998 sampling periods (Figure 5). The frequency distributions of near-bottom salinities were similar during 1993 and 1996 when polyhaline (>18 ppt) conditions predominated. Salinities were also similar during 1998 and 1995 when mesohaline (5-18 ppt) salinities were established in parts of Hillsborough Bay (KS test $p>0.05$) (Figure 6). Rainfall data (Appendix B) for the area suggested that 1994 and 1995 were the wettest years and 1993 and 1998 were the driest during this study period.

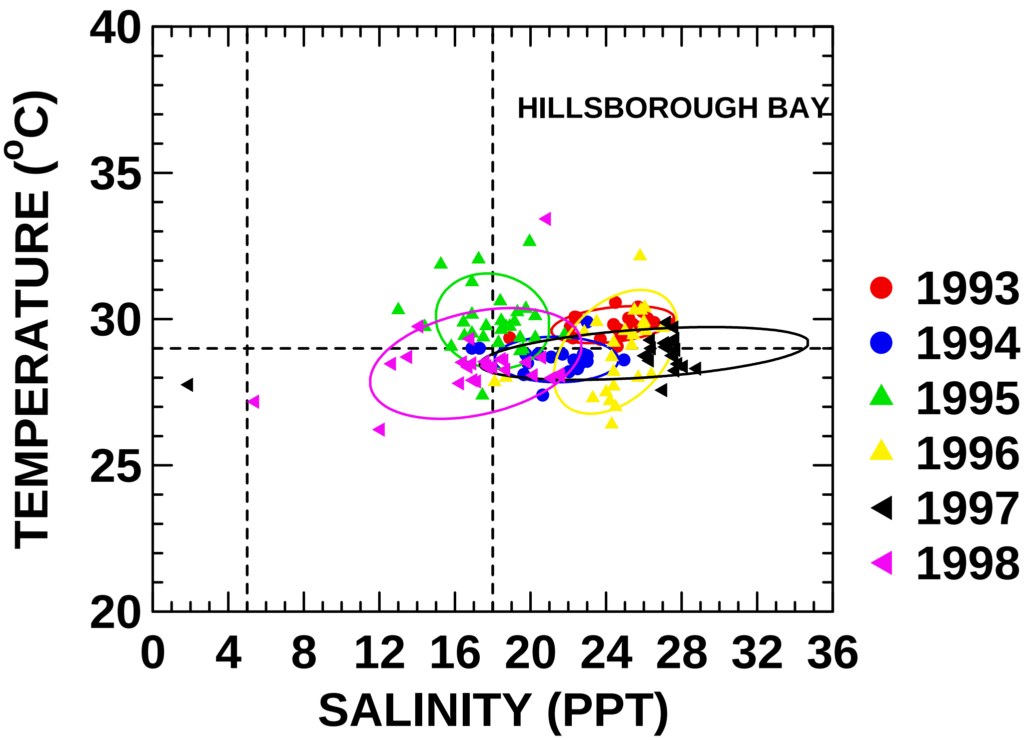

Figure 3. Temperature-salinity plot: Hillsborough Bay 1993-1998. Ellipses embrace ± 1 S.D. within each year.

Near-bottom dissolved oxygen concentrations were hypoxic (<2 ppm) in >30% of samples collected during 1998 and <10% of 1996 samples (Figure 7). Hypoxia was most often observed in the upper portions of Hillsborough Bay (Figure 8). The frequency distribution of near-bottom DO during 1995 differed (generally higher) from that of 1996-1998 (KS test $p<0.05$). (Figure 7).

Sediment Characteristics: Sandy sediments (<25.95 %SC) predominate in Hillsborough Bay (Figure 9). Muddy sediments are more widely distributed in the western parts of Hillsborough Bay; coarser sediments predominate in the southeastern quadrant (Figure 10).

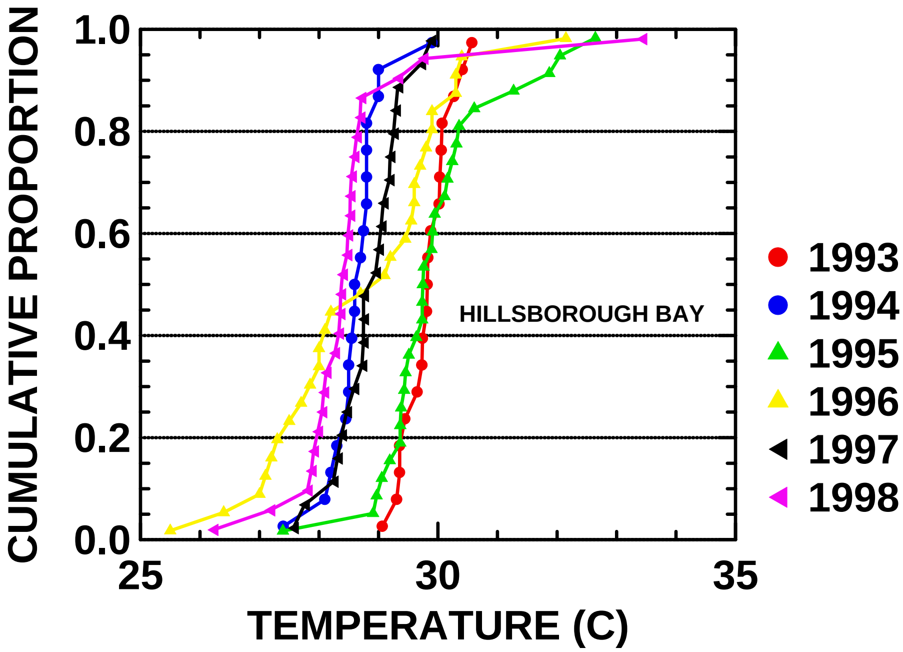

Figure 4. CDF plot of near-bottom temperatures in Hillsborough Bay, by year 1993-1998.

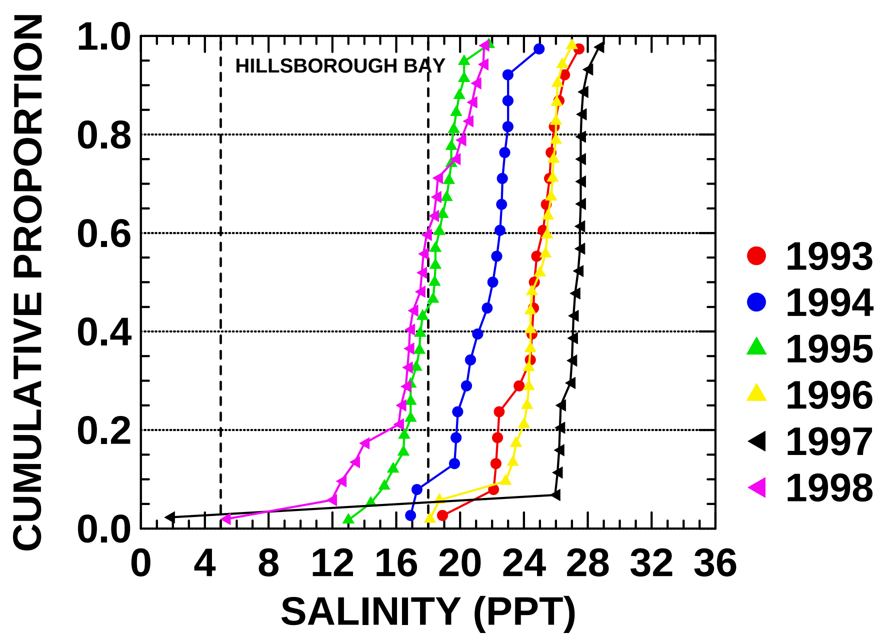

Figure 5. CDF plot of near-bottom salinities in Hillsborough Bay, by year 1993-1998.

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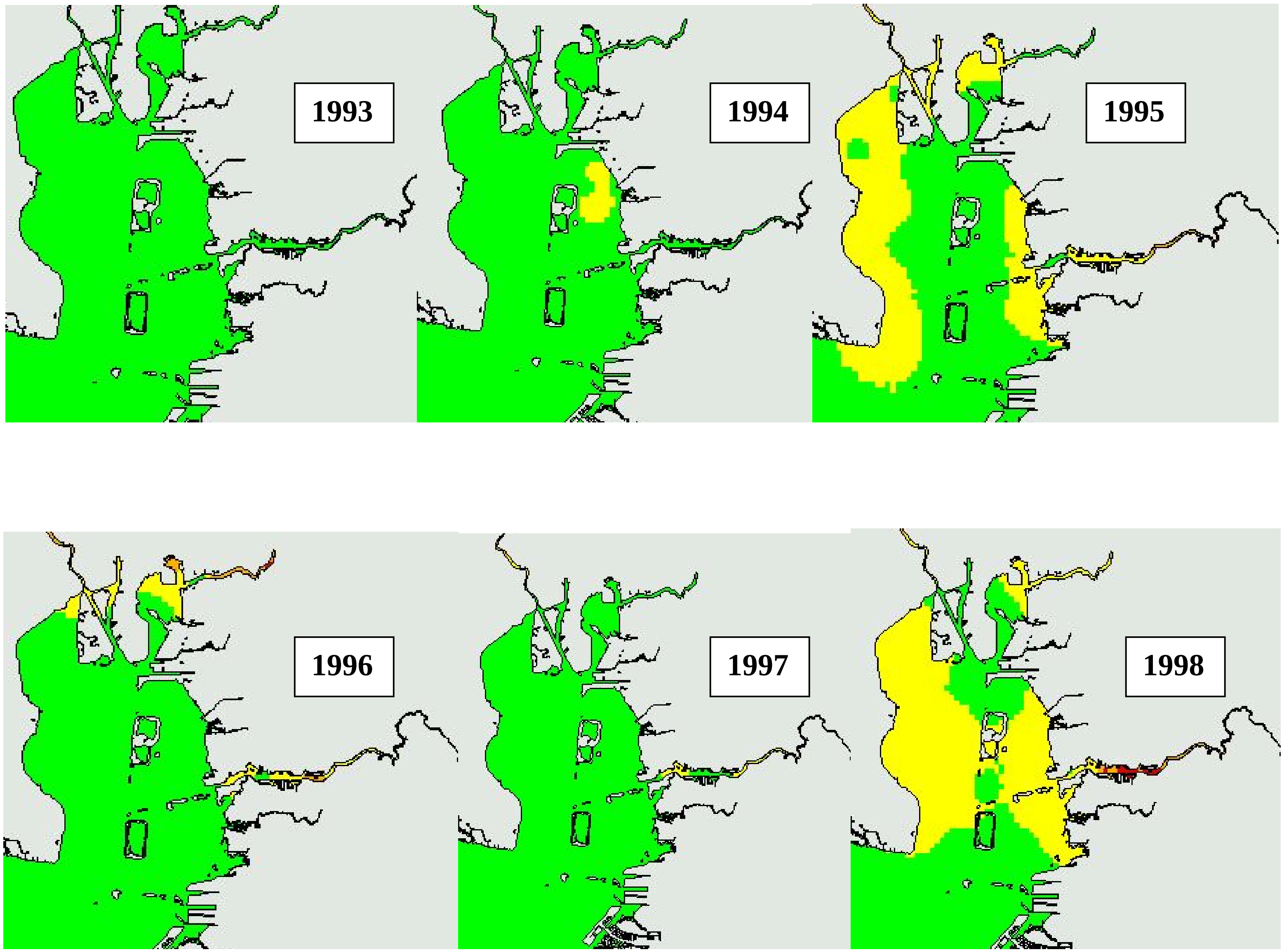

Figure 6. Near-bottom salinity zones in Hillsborough Bay, 1993-1998. Green= polyhaline (18-30 ppt); Yellow=Mesohaline (5-18 ppt); Orange=oligohaline (0.5-5 ppt).

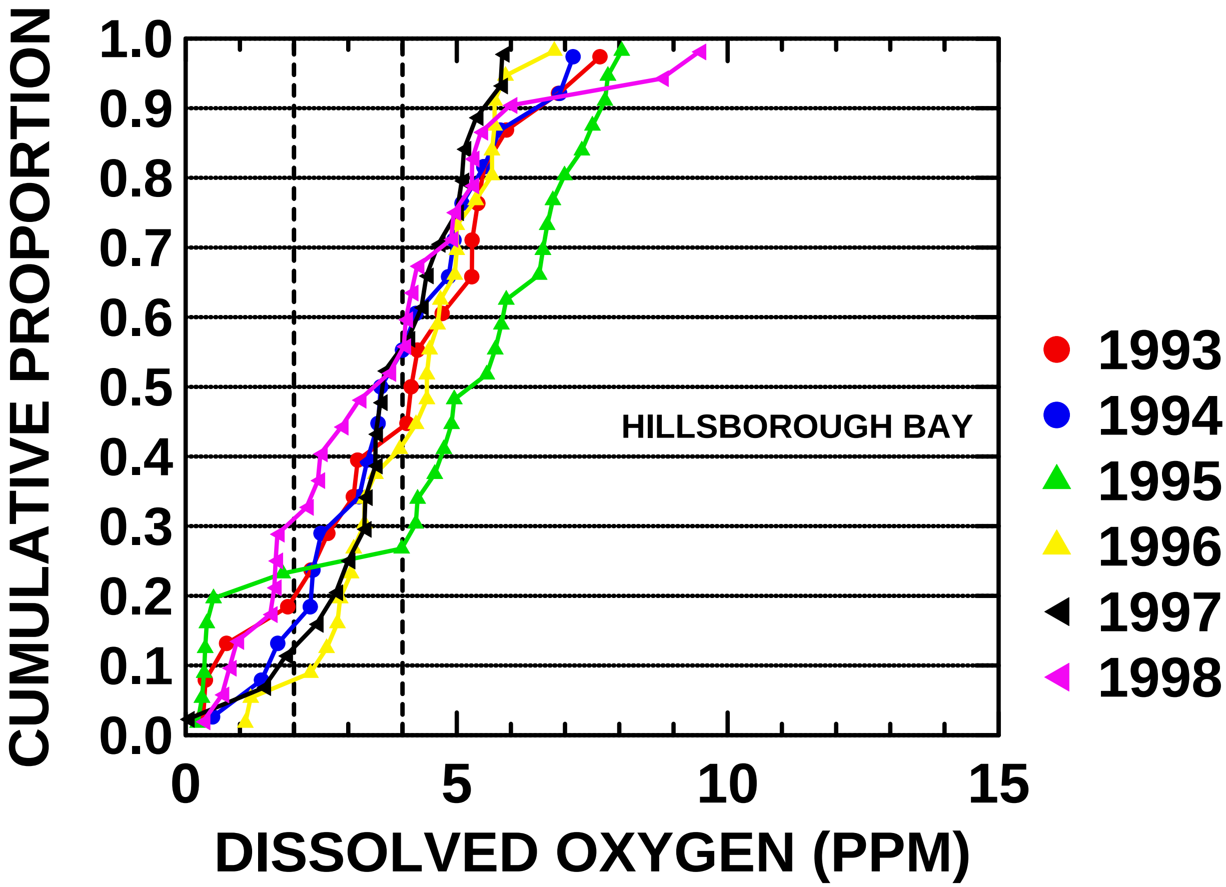

Figure 7. CDF plot of dissolved oxygen concentration in Hillsborough Bay, 1993-1998, by year.

The apparent redox potential discontinuity layer (RPD) ranged from 0 to >100 mm (Figure 11), although in more than half of the samples no RPD was evident. RPD was negatively correlated with %SC (Figure 12) and positively correlated with DO (Figure 13).

Principal Components Analysis [PCA] of Hydrographic and Site Characteristics

PCA showed that the first two PCs explained >60% of the overall variation in Hillsborough Bay hydrography and site characteristics (Table 2). The highest loadings (Table 2-B) in PC1 were for depth, %SC and DO. Temperature had the highest loading in PC2.

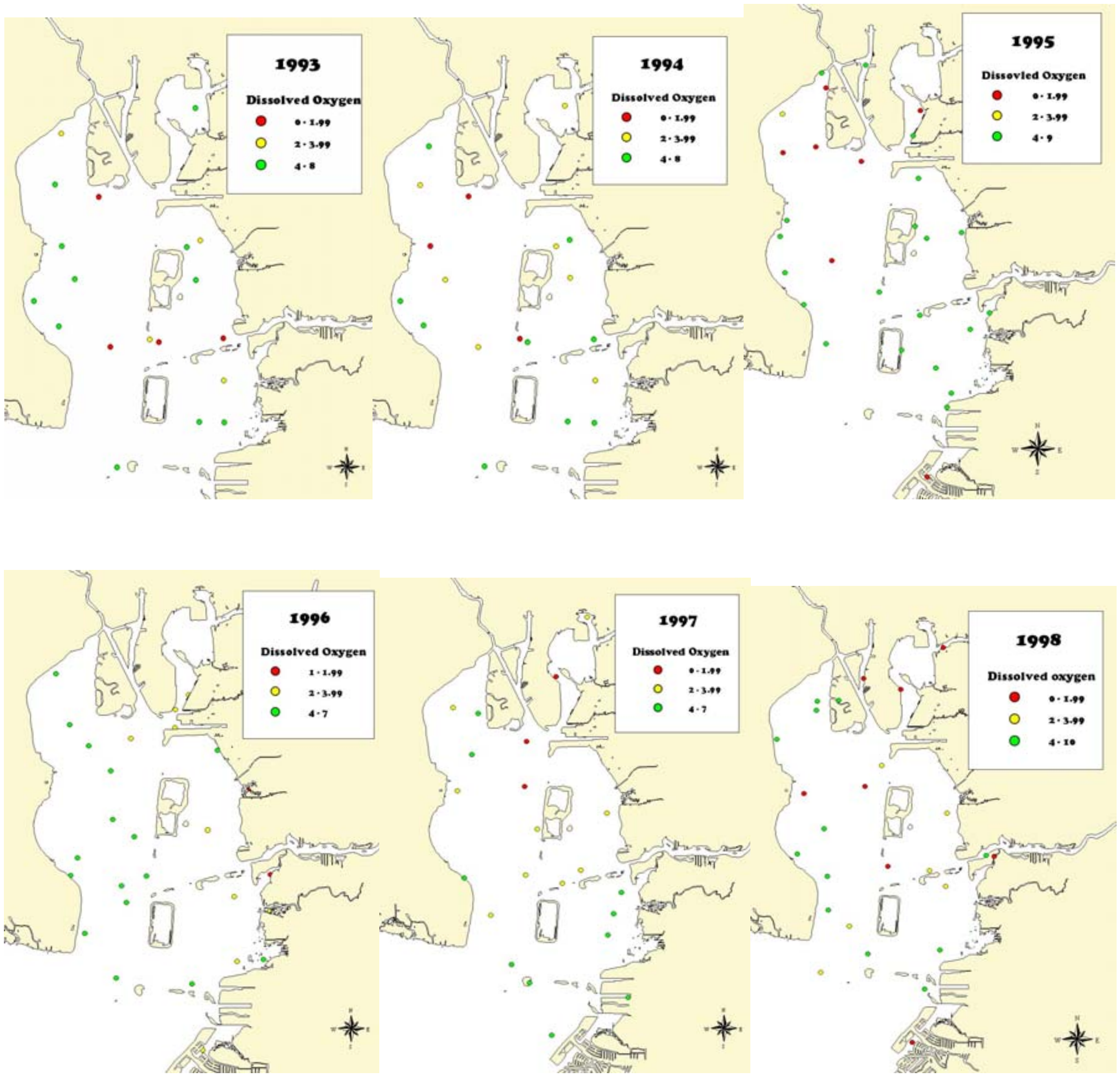

Figure 8. Near-bottom dissolved oxygen concentrations in Hillsborough Bay, 1993-1998. Green:≥4 ppm; Yellow:≥2 <4 ppm; Red:<2 ppm

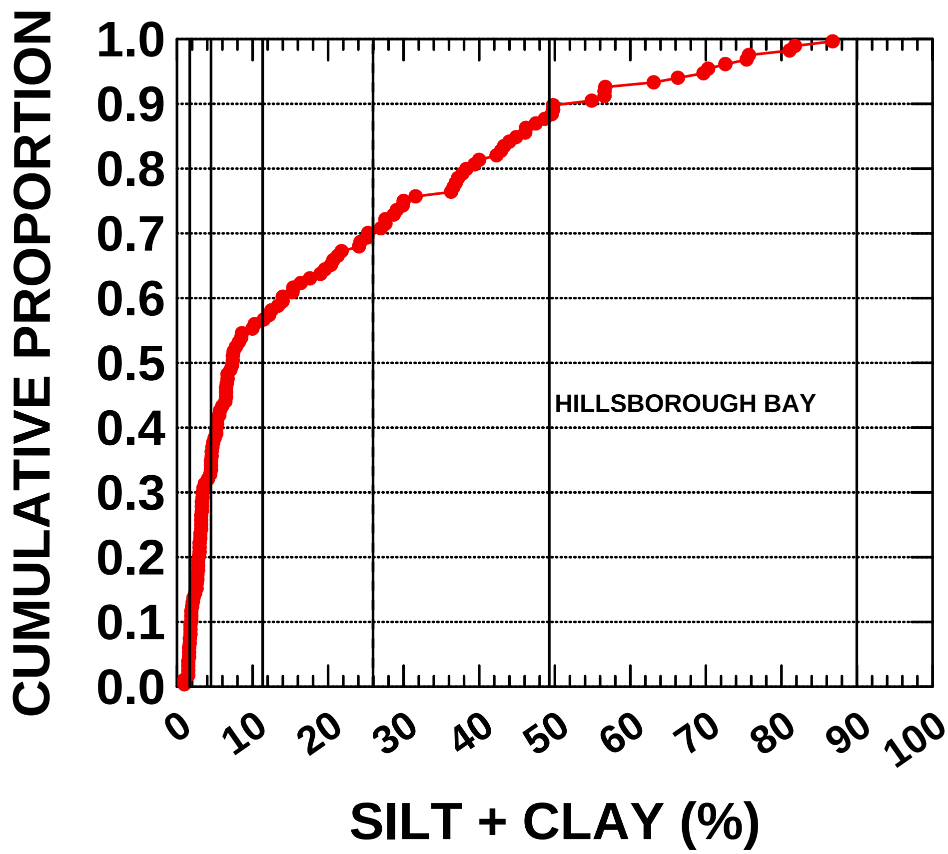

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Figure 9. CDF plot of percent silt+clay in Hillsborough Bay sediments, 1993-1998 inclusive. Vertical lines demarcate sediment types: coarse sand (<1.70% SC), medium sand (1.70 to 4.51 %SC), fine sand (4.51 to 11.35 %SC), very fine sand (11.35 to 25.95 %SC), coarse silt (25.95 to 49.28 %SC), medium silt (42.98 to 89.98 %SC), and fine silt (>89.98 %SC).

The ordination plot and companion "bubble" plots (Figure 14) showed that the deeper sites had higher %SC and DO lower than shallower sites (Pincipal Component 1). Water temperature had the highest loading in Principal Component 2, reflecting interannual differences: cooler in 1998 than in 1993 and 1995 (Figure 14; *cf*. Figure 4).

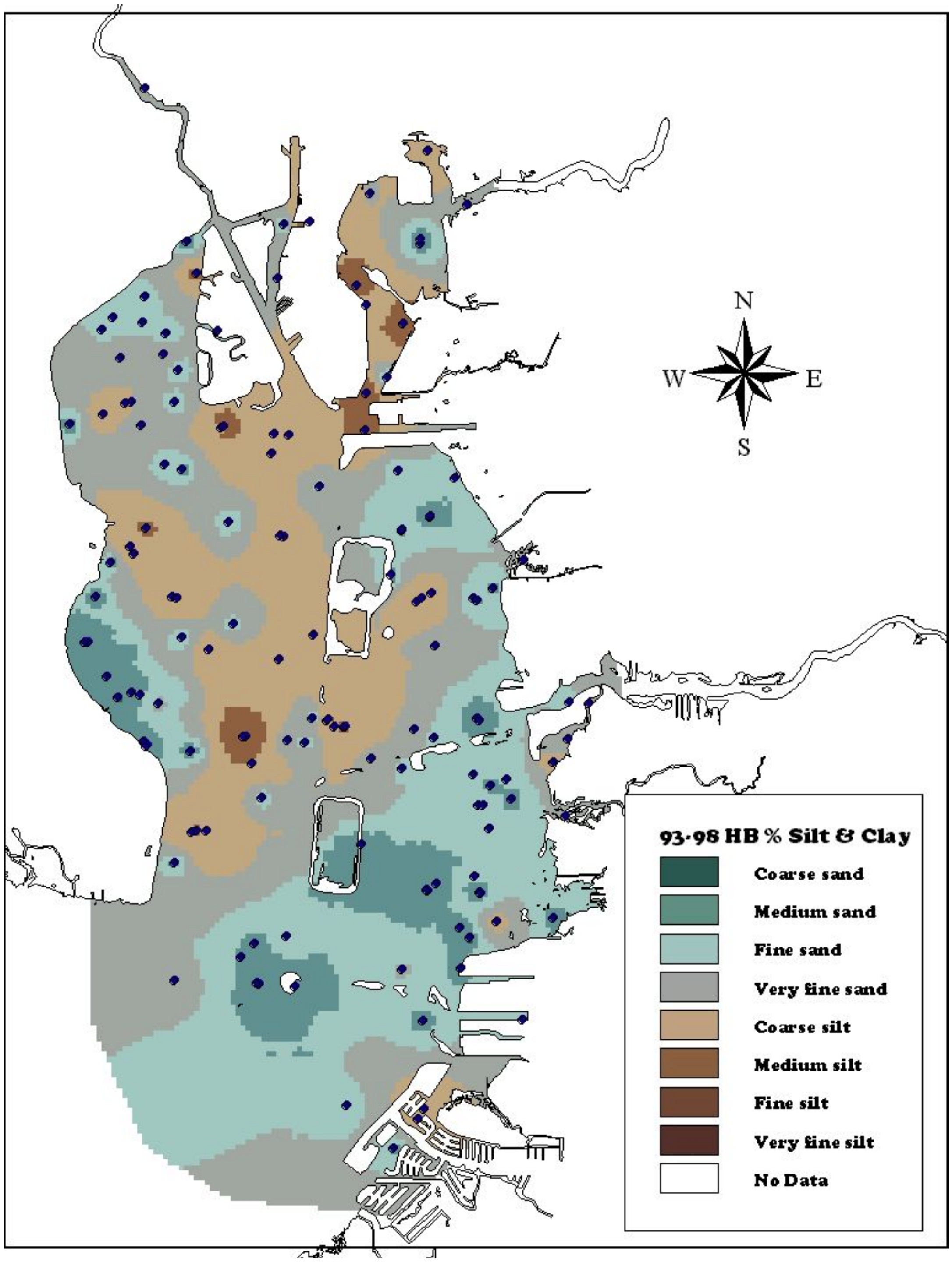

Figure 10. Map depicting the distribution of sediment types in Hillsborough Bay, 1993-1998.

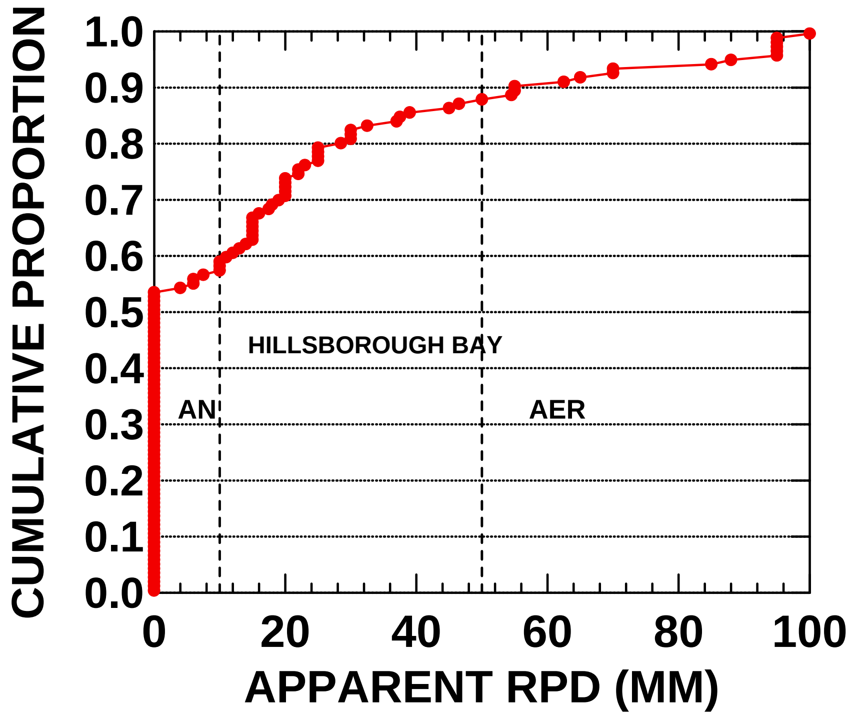

Figure 11. CDF of apparent redox potential discontinuity layer [RPD] in Hillsborough Bay, 1993-1998. Anaerobic [AN] sediments are characterized by an RPD <10-mm and aerobic [AER] sediments are characterized by an RPD>50-mm.

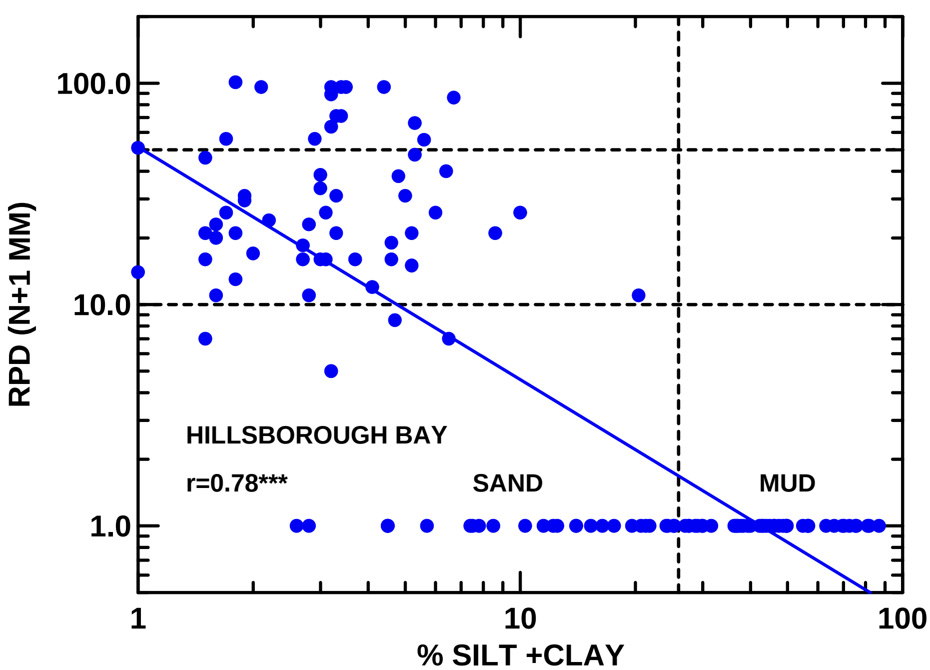

Figure 12. Association between apparent RPD and %SC in Hillsborough Bay, 1993-1998.

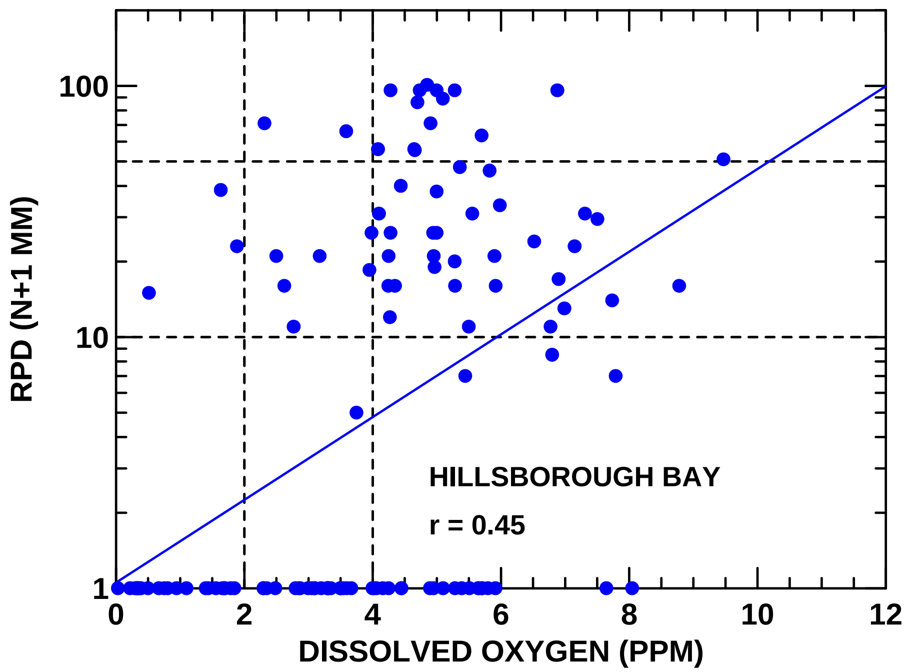

Figure 13. Association between apparent RPD and near-bottom dissolved oxygen, Hillsborough Bay, 1993-1998.

Table 2. Summary of PCA for hydrographic and site variables: Hillsborough Bay 1993-1998

A. EIGENVALUES & VARIANCE EXPLAINED

PC	EIGENVALUE	% VARIANCE EXPLAINED	CUMULATIVE VARIANCE EXPLAINED
1	2.03	40.5	40.5
2	1.05	20.9	61.5
3	0.93	18.5	80.0
4	0.57	11.4	91.4
5	0.43	8.6	100.0

B. EIGENVECTORS

VARIABLE	PC1	PC2	PC3	PC4	PC5
DO	**-0.52**	0.22	-0.27	**0.73**	0.28
% SILT + CLAY	**0.56**	-0.08	0.34	0.28	**0.70**
SALINITY	0.32	0.47	**-0.72**	-0.28	0.27
DEPTH	**-0.56**	0.01	0.19	-0.56	0.58
TEMPERATURE	0.02	**0.85**	0.50	<0.01	-0.16

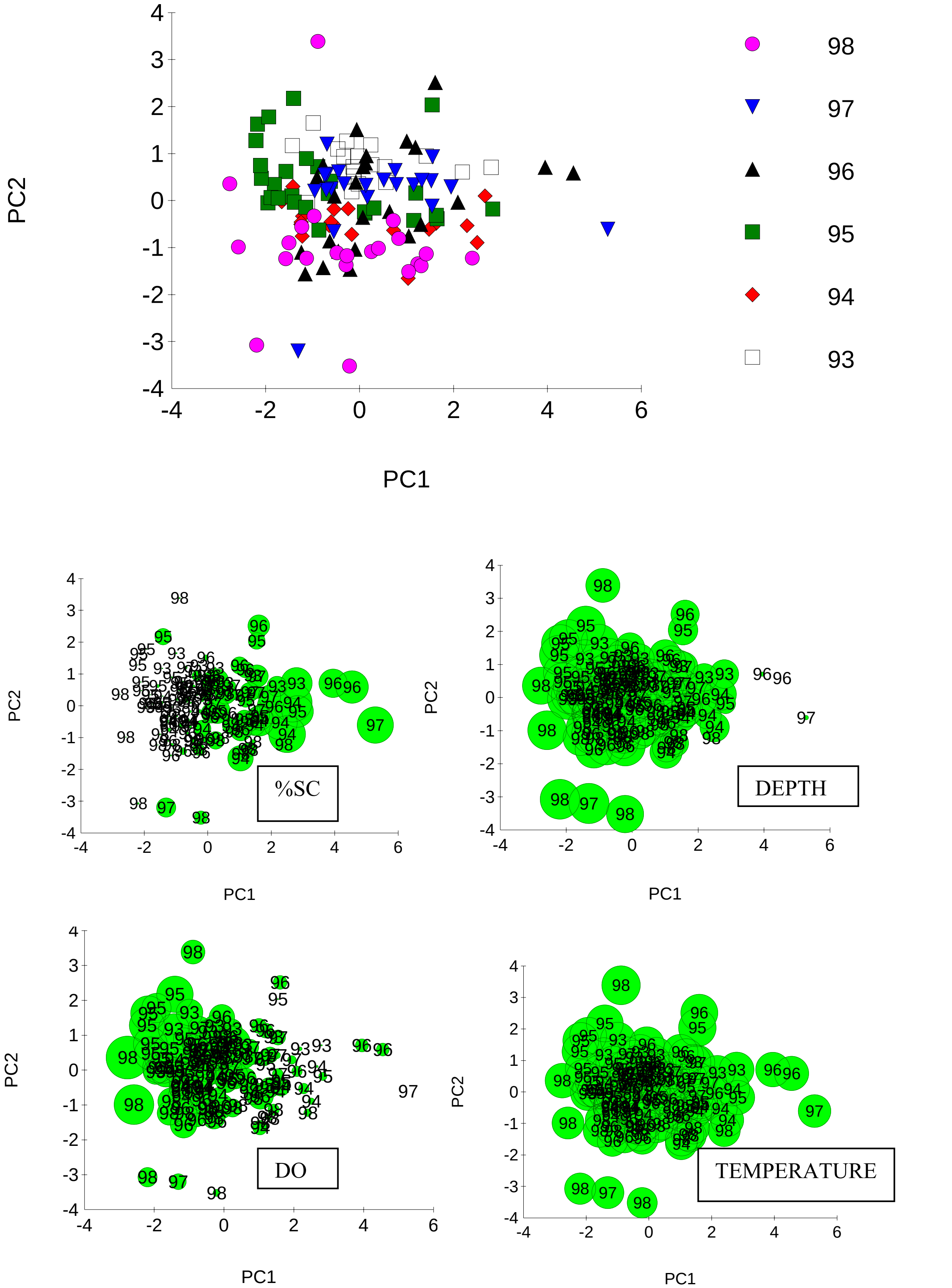

Figure 14. PCA of sample sites in Hillsborough Bay, 1993-1998 and "bubble" plots of %SC, depth, DO, and temperature superimposed on the samples: by year.

Sediment Contaminants: A composite PEL Quotient (Figure 15) suggested that, in any year surveyed to date, <4.8% of the of the sediment samples collected from Hillsborough Bay had a high likelihood of being toxic to aquatic life. Degraded sediments were only found in the upper parts of Hillsborough Bay: McKay Bay, East Bay, and in the Lower Hillsborough River (Figure 16). Frequency distributions of the composite PEL quotient (excluding 1993 when only three samples were collected) showed that only 1997 and 1996 had equivalent (p>0.05) distributions. For metals (Figure 17) and PAHs (Figure 18), the percentage of "degraded" samples also ranged from 0 to 4.8 and for PCBs (Figure 19) the percentage ranged from 0 to 3.7 in any year. Although organochlorine [OCL] pesticides were not included in the computation of the composite PEL quotient, as many as 10% of the samples exceeded the PEL for chlordane in any year (Figure 20) and none of the samples exceeded the PEL for total DDT (Figure 21).

Benthic Community: Table 3 summarizes selected benthic community measures for 1993-1998. At least 315 taxa were identified during this period (Appendix C). Numerically abundant species included the bivalve *Mysella planulata,* several polychaete worms (*Monticellina dorsobranchialis*, *Carazziella hobsonae, Prionospio perkinsi*), tubificid oligochaetes, and the amphipod crustacean *Ampelisca holmesi.*

Numerical dominants differed both by year (Table 4) and salinity zone (Table 5). The bivalve *M. planulata* was ranked either first or second during four of the six years, tubificid oligochaetes were ranked in the top ten during each year, and the polychaete *M. dorsobranchialis* was ranked among the ten dominants during five of the years. Three taxa were ranked in the top ten in both the oligohaline and mesohaline zones and four taxa were ranked in the mesohaline and polyhaline zones.

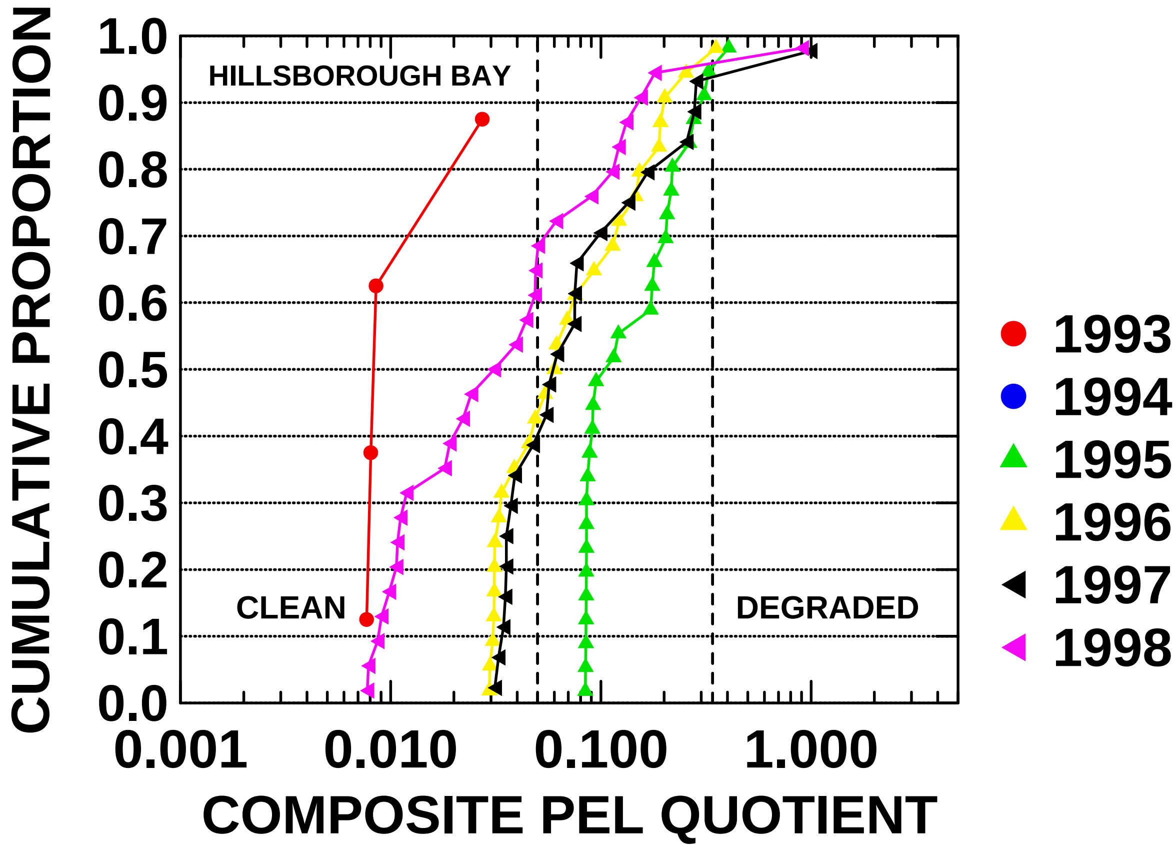

Figure 15. CDF plot of the composite (metals, PAHs, PCBs) PEL quotient for sediment contaminants in Hillsborough Bay, by year. Vertical lines demarcate "clean" (<0.05) and "degraded" (>0.34) sediments.

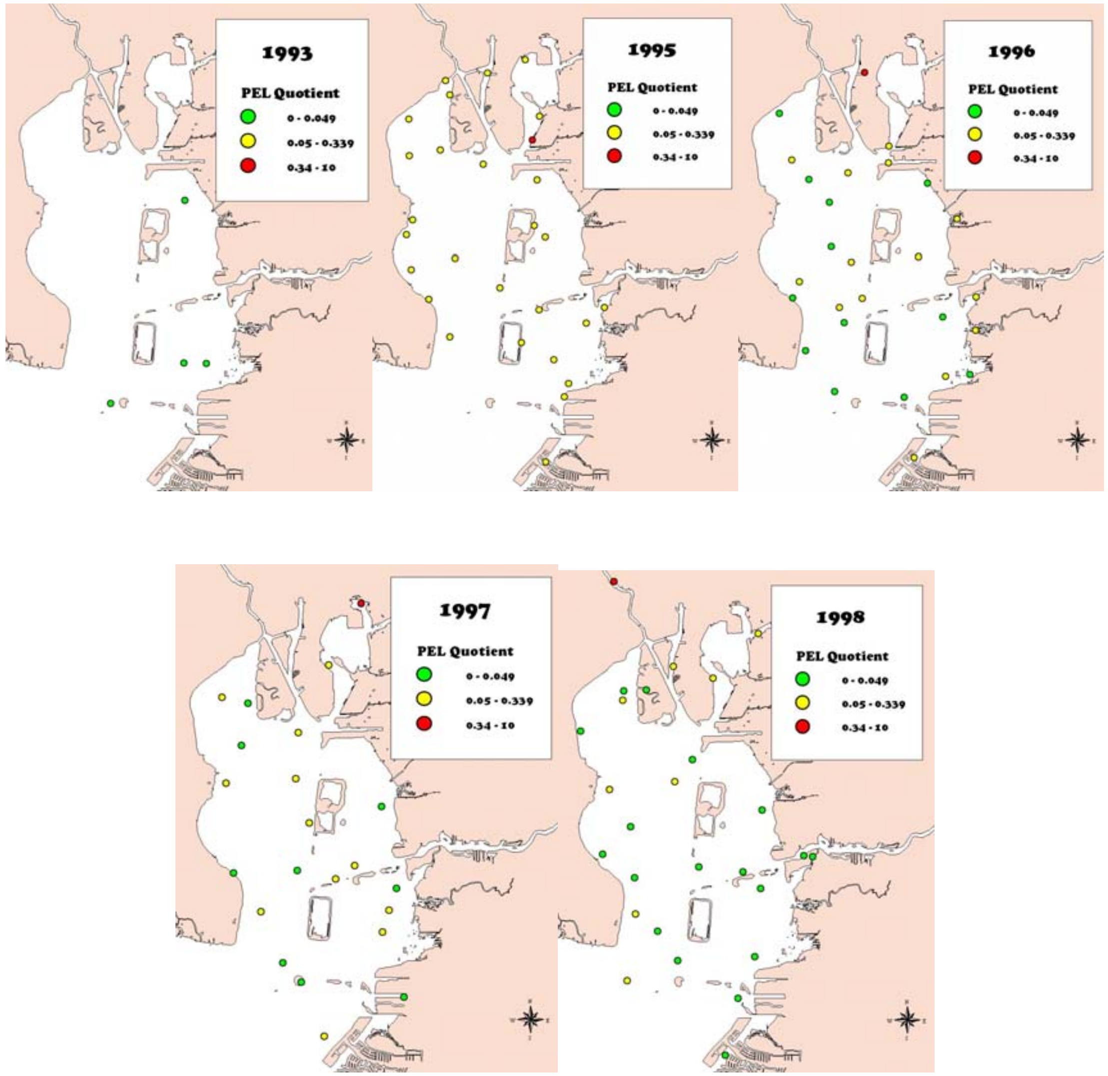

Figure 16. Composite PEL Quotients of Hillsborough Bay sediments, 1993 & 1995-1998. Green:<0.05; Yellow:>=0.05<0.34 ; Red:>0.34

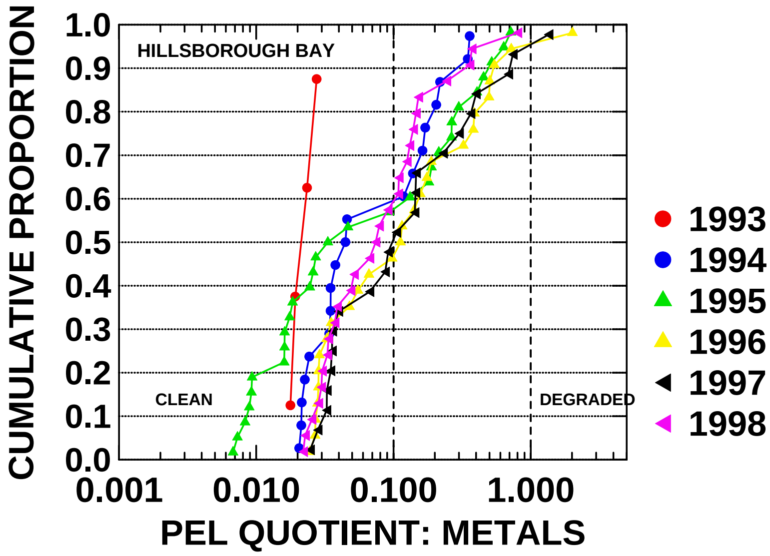

Figure 17. CDF plot of the PEL quotient for metals (composite) in Hillsborough Bay, by year. Vertical lines demarcate "clean" (PEL quotient <0.1) and "degraded" (PEL quotient >1) sediments.

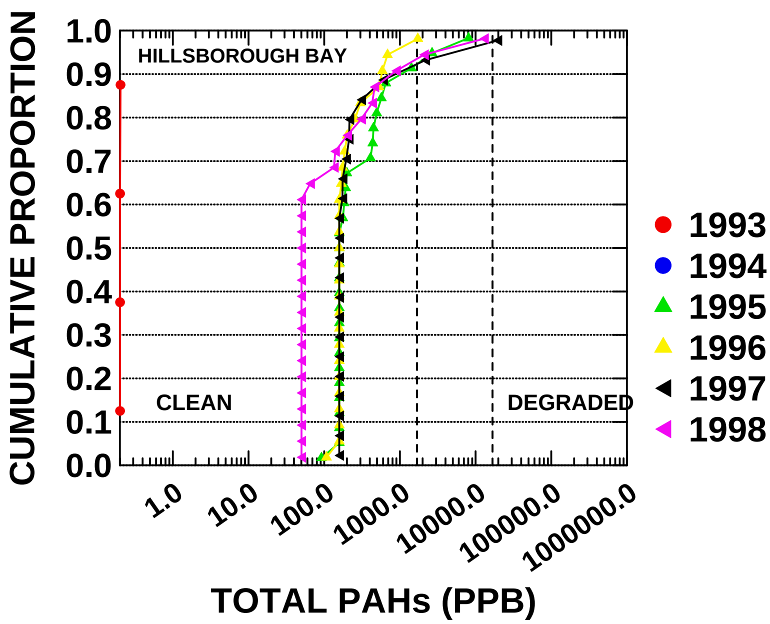

Figure 18. CDF plot of total PAH concentrations in Hillsborough Bay, by year. Vertical lines demarcate TEL (1684) and PEL (16770 ppb).

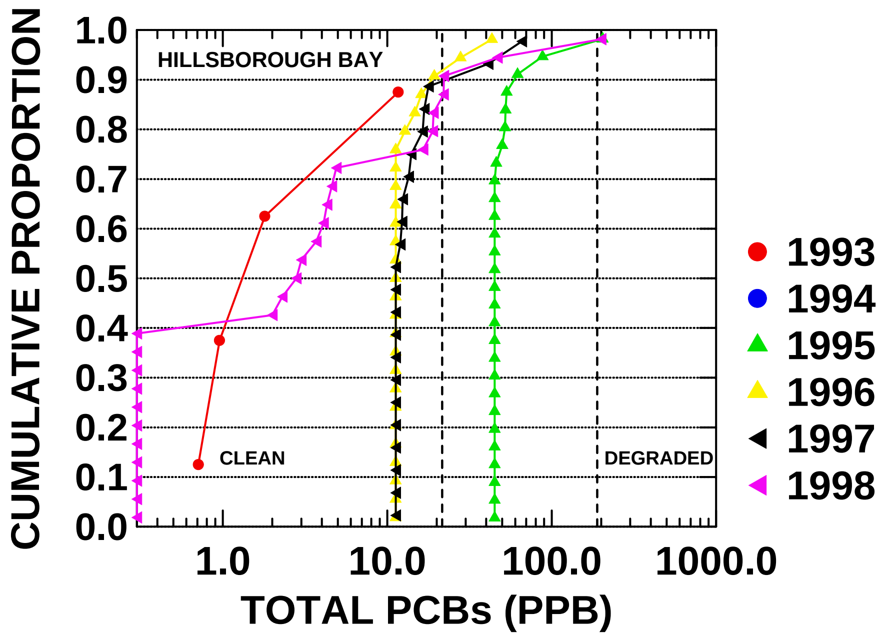

Figure 19. CDF plot of total PCB concentrations in Hillsborough Bay, by year. Vertical lines demarcate TEL (21.6 ppb) and PEL (189 ppb).

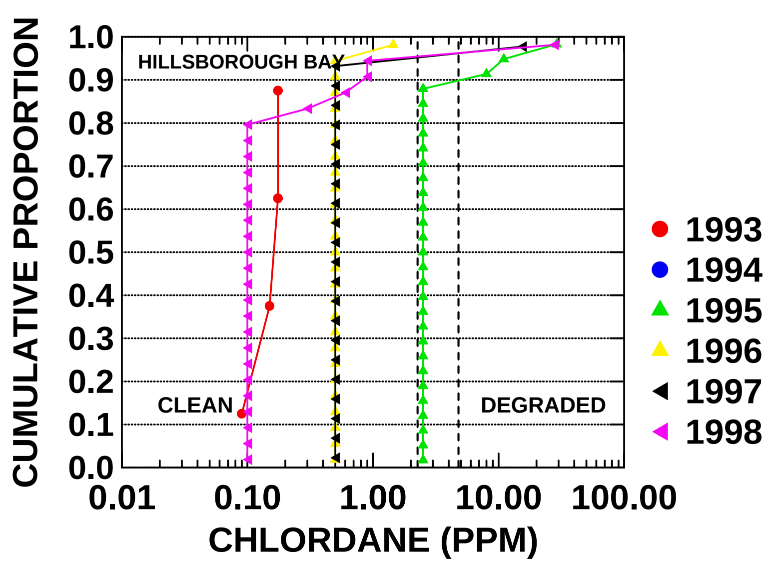

Figure 20. CDF plot of total chlordane concentrations in Hillsborough Bay, by year. Vertical lines demarcate TEL (2.26 ppb) and PEL (4.79 ppb).

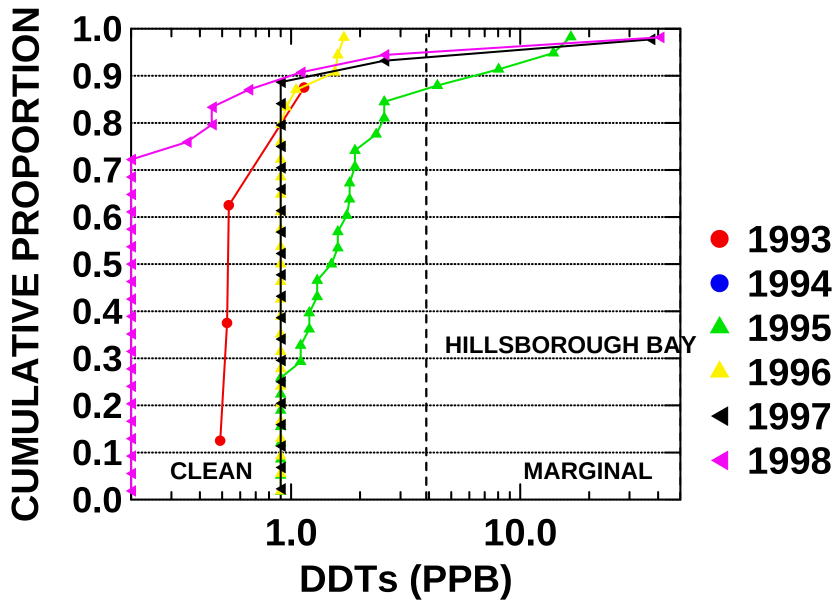

Figure 21. CDF plot of total DDTs concentrations in Hillsborough Bay, by year. Vertical line demarcates the TEL (3.89 ppb).

Table 3. Summary of Benthic Community Measures: Hillsborough Bay, 1993-1998

	Abundance (#/m^2)	Species Richness (S)	Diversity (H')	Evenness (J)	TBBI
Minimum	0	0	0	0.00	-3.0
Maximum	35750	54	4.32	1.00	26.1
Median	4225	23	2.53	0.58	13.0
Mean	6737	22	2.36	0.55	12.7

Numbers of taxa per station were variable over years (Figure 22). During 1995, the median numbers of taxa per m^2 was <20 whereas in 1994 it was >30. During 1995, almost 20% of the samples were devoid of living organisms. The KS test showed that the frequency distribution during 1993 and 1996 a greater proportion of samples had >20 taxa samples than during 1998. In 1995 proportionately more samples had <10 taxa than during 1997.

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

1993	**1994**	**1995**	**1996**	**1997**	**1998**
1.Mediomastus ambiseta (1499)*	*1. M. planulata (599)*	*1. Amygdalum papyrium (541)*	*1. M. planulata (2319)*	*M. planulata (1422)*	*P. perkinsi (808)*
2. Mysella planulata (947)	*2. M. ambiseta (572)*	*2. A. holmesi (537)*	*2. M. dorsobranchialis (578)*	*A. holmesi (1283)*	*M. dorsobranchialis (392)*
3. Carazziella hobsonae (645)	*3. Tubificidae-gen. undet. (571)*	*3. Tubificidae-gen. undet. (354)*	*3. C. hobsonae (458)*	*M. dorsobranchialis (681)*	*Paramphinome sp. B (252)*
4. Ampelisca holmesi (494)	*4. M. dorsobranchialis (451)*	*4. Streblospio gynobranchiata (256)*	*4. A. holmesi (367)*	*R. naglei (605)*	*Pinnixa sp(p). (207)*
5.Tubificidae-gen. undet. (403)	*5. A. holmesi (255)*	*5. P. pinnata (208)*	*5. Laeonereis culveri (365)*	*P. perkinsi (351)*	*Tubificidae-gen. undet. (202)*
6. Branchiostoma floridae (355)	*6. P. perkinsi (222)*	*6. Mulinia lateralis (195)*	*6. A. philbinae (275)*	*Cerapus sp. C (325)*	*C. hobsonae (197)*
7. Paraprionospio pinnata (351)	*7. P. pinnata (209)*	*7. M. planulata (188)*	*7. Rudilemboides naglei (226)*	*P. triquetra (318)*	*Enteropneusta-gen. undet. (171)*
8. Monticellina dorsobranchialis (327)	*8. B. floridae (188)*	*8. Nereis succinea (162)*	*8. Tubificidae-gen. undet. (226)*	*Tubificoides wasselli (317)*	*P. pinnixa (133)*
9. Prionospio perkinsi (295)	*9. Aricidea philbinae (183)*	*9. Parastarte triquetra (141)*	*9. Podarkeopsis laevifuscina (204)*	*C. hobsonae (297)*	*Glottidia pyramidata (131)*
10. Mediomastus sp.(p.) (278)	*10. C. hobsonae (182)*	*10. Enchytraeidae-gen. undet.*	*10. B. floridae (174)*	*B. floridae (285)*	*Gyptis crypta (126)*

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

OLIGOHALINE (0.5-5.0 ppt)	MESOHALINE (5.0-18.0 ppt)	POLYHALINE (18.0-30.0 ppt)
1. Streblospio gynobranchiata (2075)*	*1. A. holmesi (493)*	*1. M. planulata (1179)*
2. Tubificoides brownae (1500)	*2. Amygdalum papyrium (266)*	*2. A. holmesi (523)*
3. Stenoninereis martini (825)	*3. Mulinia lateralis (246)*	*3. M. dorsobranchialis (491)*
4. Cyclaspis cf. varians (800)	*4. S. gynobranchiata (235)*	*4. Mediomastus ambiseta (369)*
5. Tubificidae-gen. undet. (600)	*5. Mysella planulata (182)*	*5. Prionospio perkinsi (365)*
6. Ampelisca holmesi (325)	*6. Monticellina dorsobranchialis (168)*	*6.Carazziella hobsonae (362)*
7. Cerapus sp. C (275)	*7. Parastarte triquetra (138)*	*7. Tubificidae-gen. undet. (350)*
8. Cyathura polita (100)	*8. Paraprionospio pinnata (100)*	*8. Rudilemboides naglei (231)*
9.Ampelisca sp. C (75)	*9. Tubificidae-gen. undet. (88)*	*9. Branchiostoma floridae (218)*
9. Hartmanodes nyei (75)	*10. Aricidea philbinae (62)*	*10. P. pinnata (190)*
9. Ambidexter symmetricus (75)		

Tampa Bay Benthic Index (TBBI) scores were generally higher during 1993, 1995 and 1996 than during 1997 and 1998 (Figure 23); the KS test showed that frequency distributions differed for these two groups of years. TBBI scores <4.6 (degraded habitat) were found at approximately 30% of the sites sampled during 1995, contrasted with <15% of sites in other years. Degraded habitat was generally located immediately south of the Hillsborough River and in the northeastern industrial segment of Hillsborough Bay (Figure 24).

Correlation analysis showed that the TBBI was associated with DO (r=0.54; $p<.001$) (Figure 25), %SC (r=-0.44; $p<.001$) (Figure 26), RPD (r=0.34; $p<.001$) (Figure 27), the composite PEL quotient (r=-0.31; $p<.01$) (Figure 28), and depth (r=-0.27; $p<.001$) (Figure 29), but not with salinity (r=0.04; $p>.05$) (Figure 30).

The stepwise multiple regression (adjusted multiple $r^2 = 0.33$; $p<.001$; n=120) was:

$$\text{TBBI} (\log_{10} n+1) = 0.804 - 0.002*\text{RPD}(\log_{10} n+1) + 0.524*\text{DO}(\log_{10} n+1) - 0.239*\%\text{SC (ASN)}$$

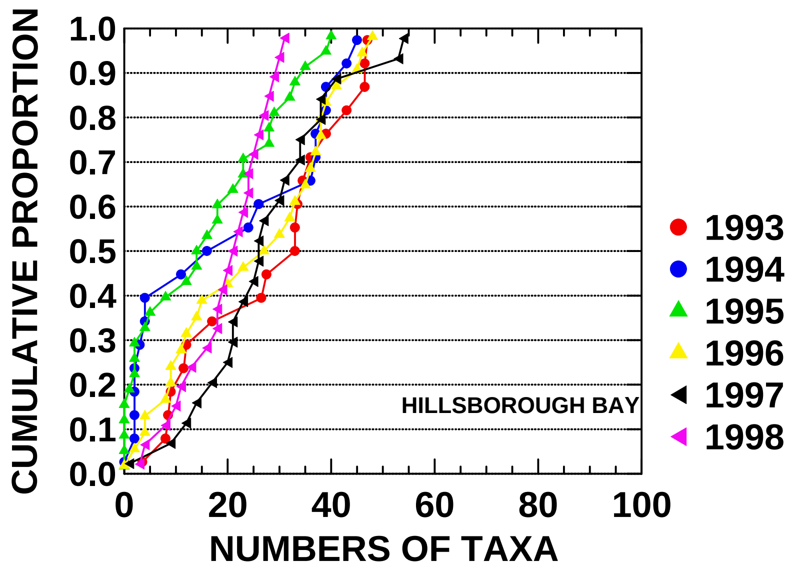

Figure 22. CDF for numbers of taxa in Hillsborough Bay benthos, by year, 1993-1998.

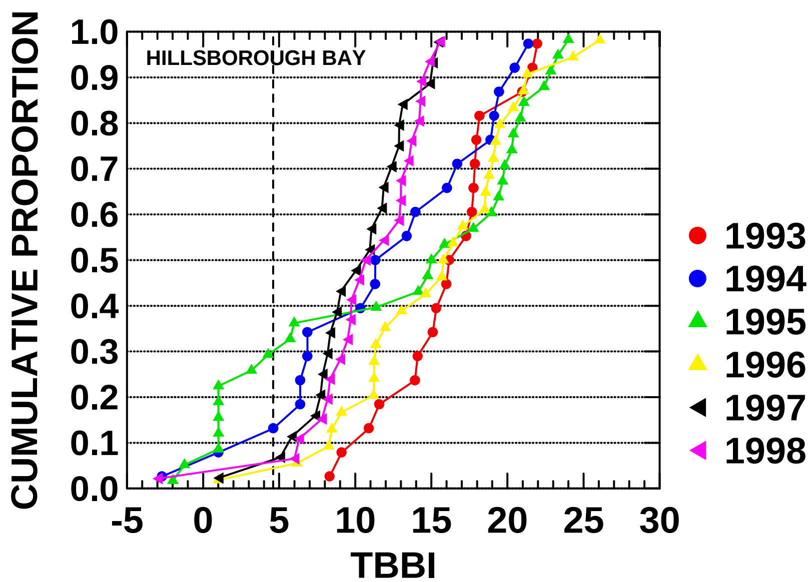

Figure 23. CDF of the Tampa Bay Benthic Index for Hillsborough Bay benthos, by year, 1993-1998. Index scores <4.6 indicate "degraded" benthic habitat and scores ≥4.6 indicate "healthy" benthic habitat.

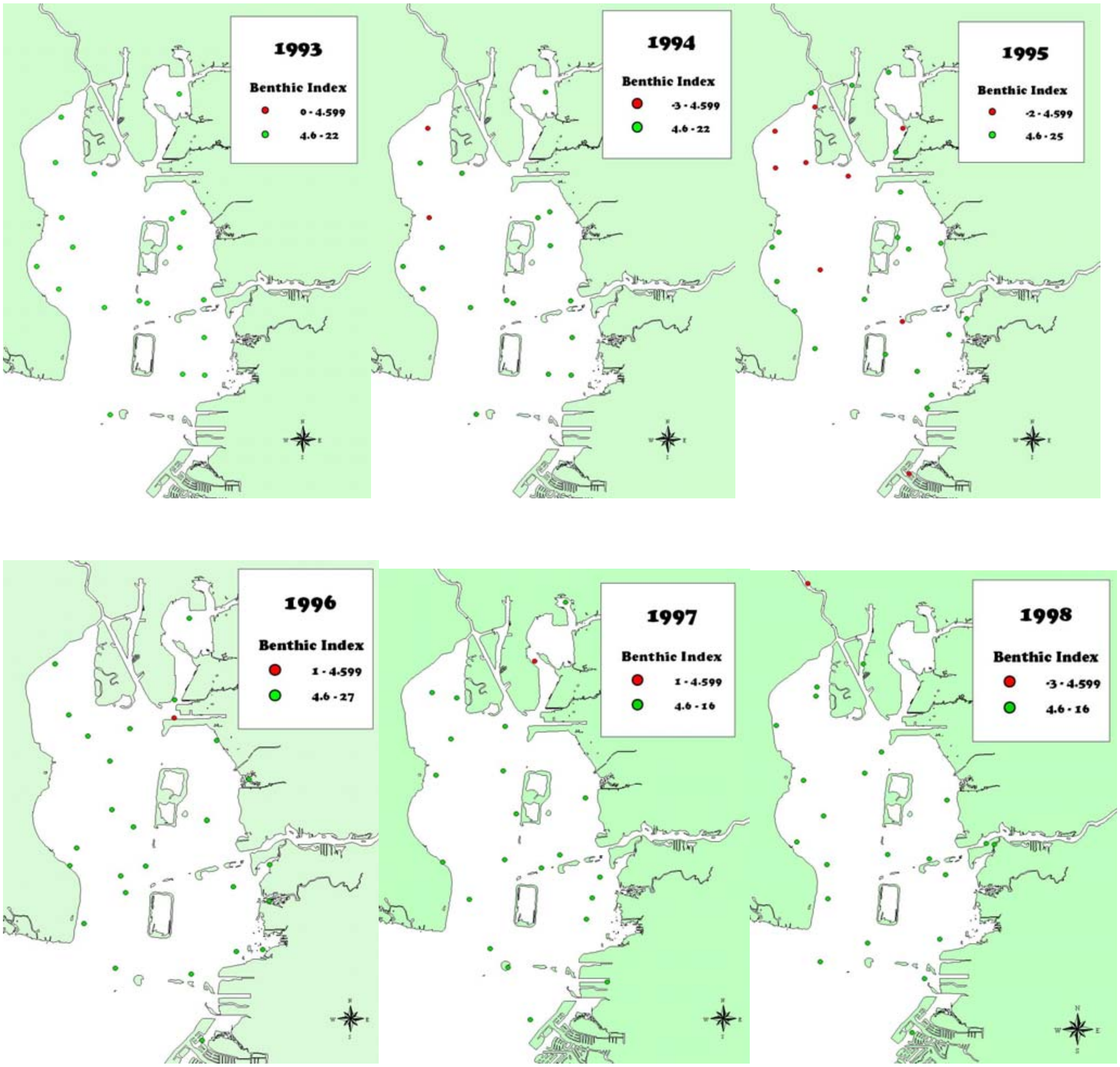

Figure 24 Distribution of "healthy" (green) and "degraded" (red) benthic habitat in Hillsborough Bay, 1993-1998 based upon the Tampa Bay Benthic Index.

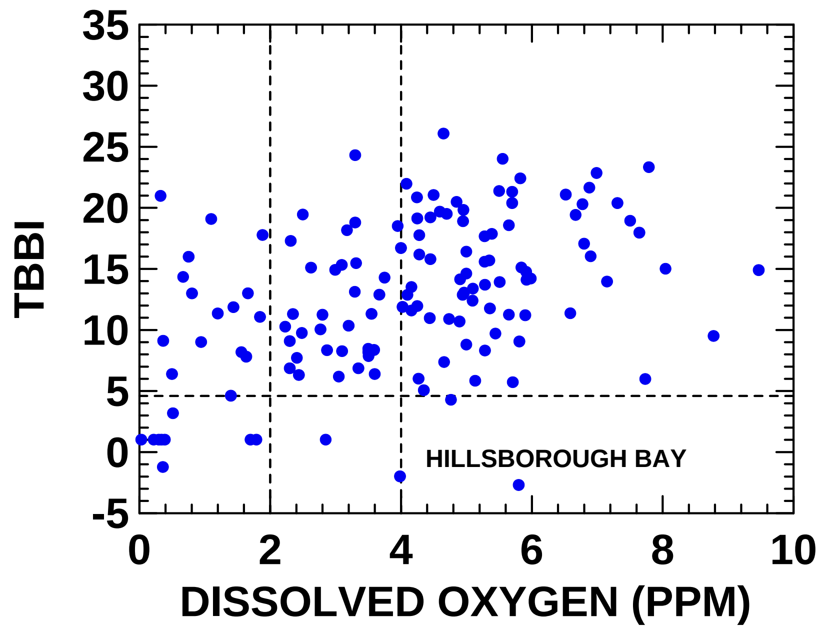

Figure 25. Association between the Tampa Bay Benthic Index and near-bottom dissolved oxygen concentrations in Hillsborough Bay, 1993-1998. TBBI scores <4.6 indicate "degraded" habitat and scores ≥4.6 indicate "healthy" habitat. DO <2.0 ppm indicates "degraded" conditions, ≥2<4 ppm indicates "marginal" conditions, and ≥4 ppm indicates "healthy" conditions.

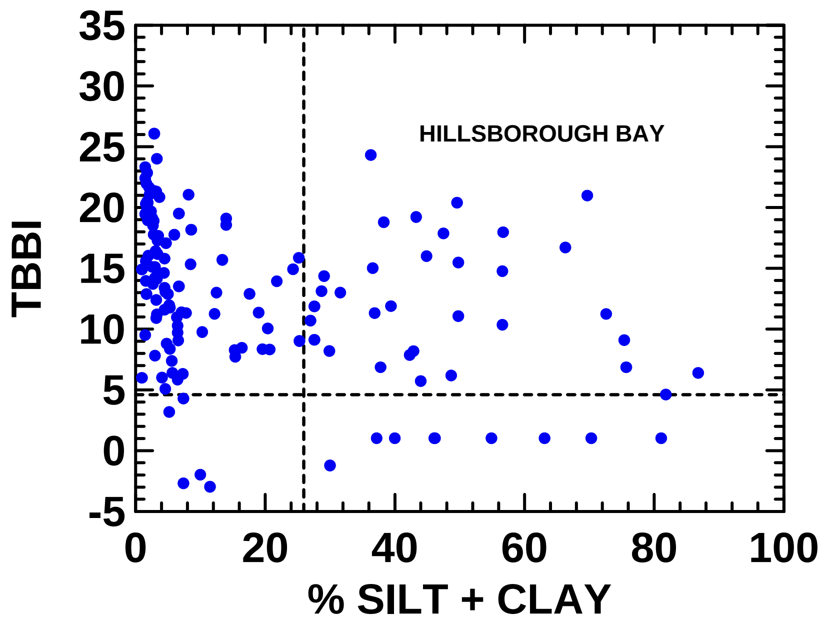

Figure 26. Association between the Tampa Bay Benthic Index and %SC in Hillsborough Bay, 1993-1998. TBBI scores <4.6 indicates "degraded" habitat and scores ≥4.6 indicate "healthy" habitat. Sand and mud fractions are demarcated by 25.95%SC.

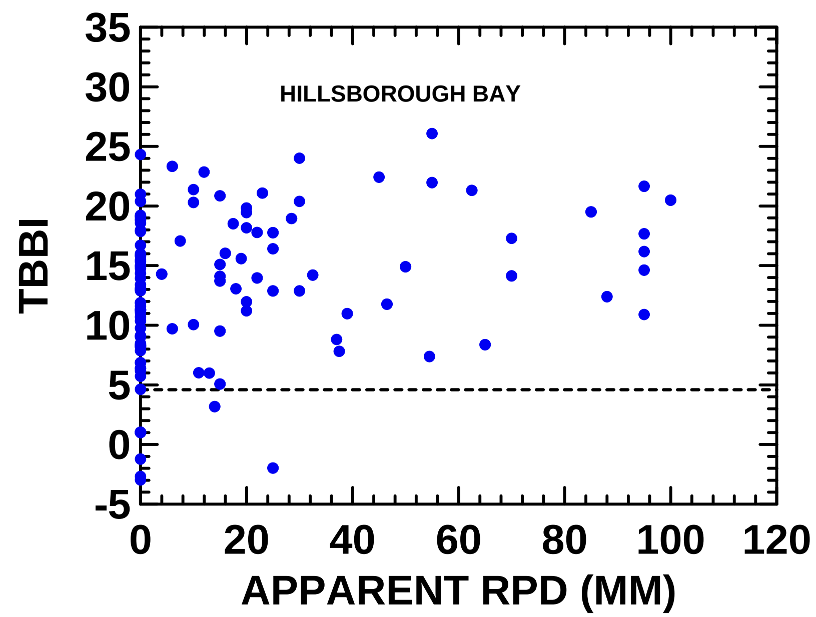

Figure 27. Association between the Tampa Bay Benthic Index and the apparent redox potential discontinuity layer (RPD) in Hillsborough Bay, 1993-1998. TBBI scores <4.6 indicate "degraded" habitat and scores ≥4.6 indicate "healthy" habitat.

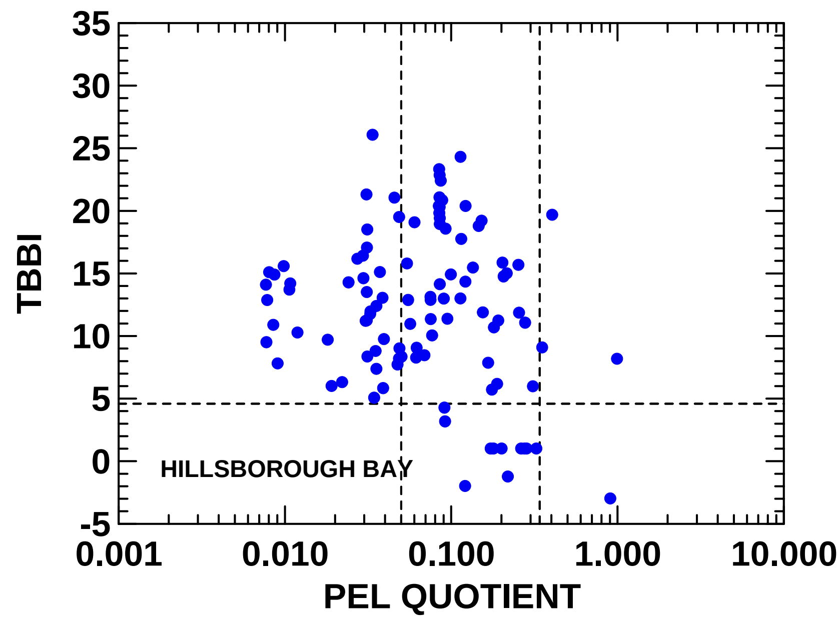

Figure 28. Association between the Tampa Bay Benthic Index and the composite PEL quotient in Hillsborough Bay, 1993-1998. TBBI scores <4.6 and and scores ≥4.6 indicate "healthy" habitat. PEL quotients >0.34 indicate "degraded" sediments and PEL quotients <0.05 indicate "clean" sediments.

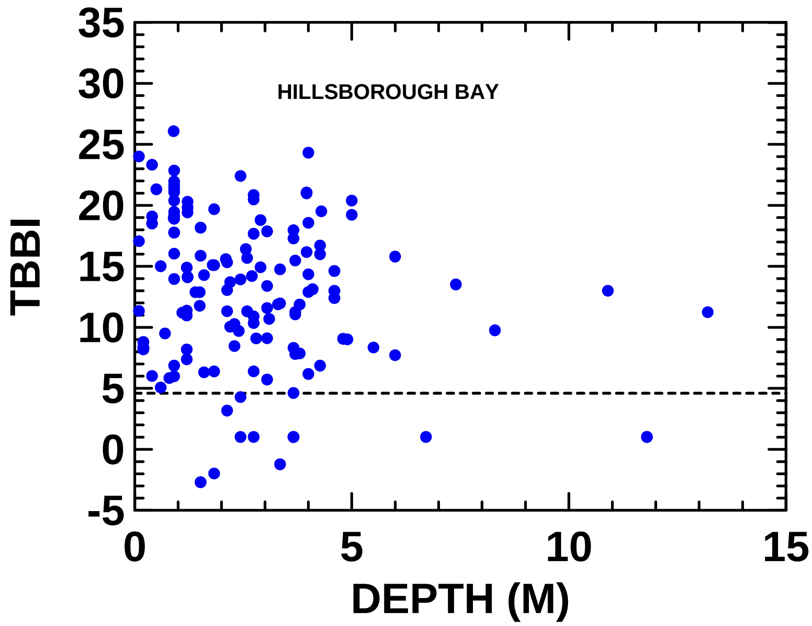

Figure 29. Association between the Tampa Bay Benthic Index and sample depth in Hillsborough Bay, 1993-1998. TBBI scores <4.6 indicate "degraded" habitat and scores ≥4.6 indicate "healthy" habitat.

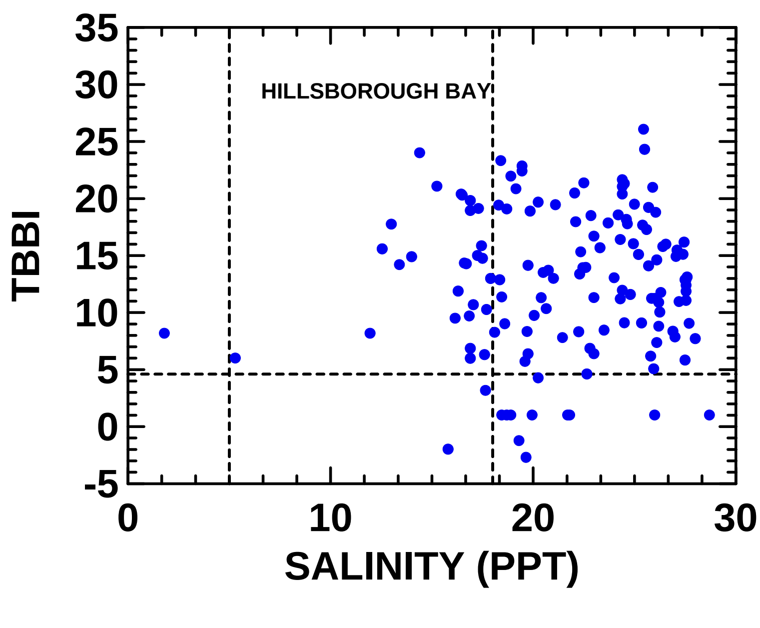

Figure 30. Association between the Tampa Bay Benthic Index and salinity in Hillsborough Bay, 1993-1998. TBBI scores <4.6 indicate "degraded" habitat and scores ≥4.6 indicate "healthy" habitat. Salinity zones are demarcated as: oligohaline (<5 ppt), mesohaline (5-18 ppt), and polyhaline (18-30 ppt).

Benthic Community Structure: Two primary and four secondary "clusters" were identified in the classification analysis of sites (Figure 31) and 9 "clusters" were identified in the classification analysis of taxa (Figure 32). 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 the bivalve mollusc *M. planulata*, tubificid oligochaete worms, the polychaete worm *P. perkinsi* and the amphipod crustacean *A. holmesi* in Cluster B (Table 6 and Appendix D). With the exception of *P. perkinsi*, these taxa were associated with an assemblage of species (Figure 32; Table 7) that also included the polychaetes *Mediomastus ambiseta, Aricidea philbinae*, and *Paraprionospio pinnata*.

These clusters also differed in their site characteristics, including hydrographic and sedimentary characteristics (Table 8). The assemblage characterized by Cluster A was considerably "poorer" biologically and subject to greater environmental stress than Cluster B. Cluster A sites had fewer taxa, a lower TBBI score and considerably lower densities of organisms. The A sites were deeper than the B sites and were characterized by a shallower RPD and higher % SC. The effects of stressors such as DO and sediment contaminants were greater at Cluster A sites as well.

Cluster A could be subdivided into clusters A-1 and A-2. The benthic assemblages at Cluster A-1 sites were especially depauperate (Tables 9 and 10). The stresses from low DO and sediment contaminants appeared to be greater at the A-1 sites as well (Table 10).

Cluster B could be further subdivided into clusters B-1 and B-2 as well. B-1 sites were generally located in shallow waters (Table 11) near the periphery of southern Hillsborough Bay and comprised samples collected during 1996 and 1997. The species contributing most to the dissimilarity between these two clusters included *M. planulata* and two amphipods (*A. holmesi* and *Rudilemboides naglei*), each of which were extremely abundant at B-1 stations relative to B-2 (Table 11). Other species which were especially abundant in B-1 sites included *Parastarte triquetra* (Bivalvia), *Laeonereis culveri* (Polychaeta), *Cerapus* sp. C (Amphipoda) and *Tubificoides wasselli* (Tubificidae) (Table 7). B-2 sites included species in Cluster 5 and Cluster 8 among its numerical dominants. Average total abundance was quite high in B-1 as was the mean numbers of taxa (Table 12). The mean TBBI, however, was higher in B-2-- a consequence of higher diversity and evenness at the B-2 sites. Of the measured stressors, chlordane concentrations were higher at B-2 sites and metals were higher at the B-1 sites.

Table 6. Results of SIMPER analysis comparing the dissimilarity between Hillsborough Bay Clusters A and B. Average dissimilarity = 15.15.

	Avg. abund Cluster A	Avg abund. Cluster B	Contrib. %	Cum. %
Mysella planulata	3	1219	3.3	3.3
TUBIFICIDAE	21	398	3.0	6.3
Prionospio perkinsi	8	375	2.8	9.1
Ampelisca holmesi	3	661	2.8	11.8
Paraprionospio pinnata	14	212	2.4	14.2
Monticellina dorsobranchialis	13	530	2.3	16.5
Carazziella hobsonae	13	367	2.2	18.7
Podarkeopsis levifuscina	7	101	1.9	20.6
Pinnixa spp	4	107	1.8	22.4
Amygdalum papyrium	2	219	1.7	24.1
Sigambra tentaculata	7	80	1.6	25.6

Linking Biotic & Abiotic Variables (1995-1998): PRIMER's (Primer-E Ltd. 2001) 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 33) and the "best fit" for physico-chemical variables (chlordane, PCBs, Al, Cu) (Figure 34) were very weak (<0.08).

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 and from 1997 to 1998 (Figure 35). BIO-ENV analysis using site, hydrographic, and contaminant (metals only; no organic data for 1994) variables showed that the best fit for environmental variables with the biotic data were for As, Cd, and Cr (Spearman r=0.84). As, Cd and Cr each showed a marked increase in mean concentration from 1996 to 1997 (Figure 35). From 1997 to 1998 As concentrations declined approximately 75%and Cr increased almost five fold.

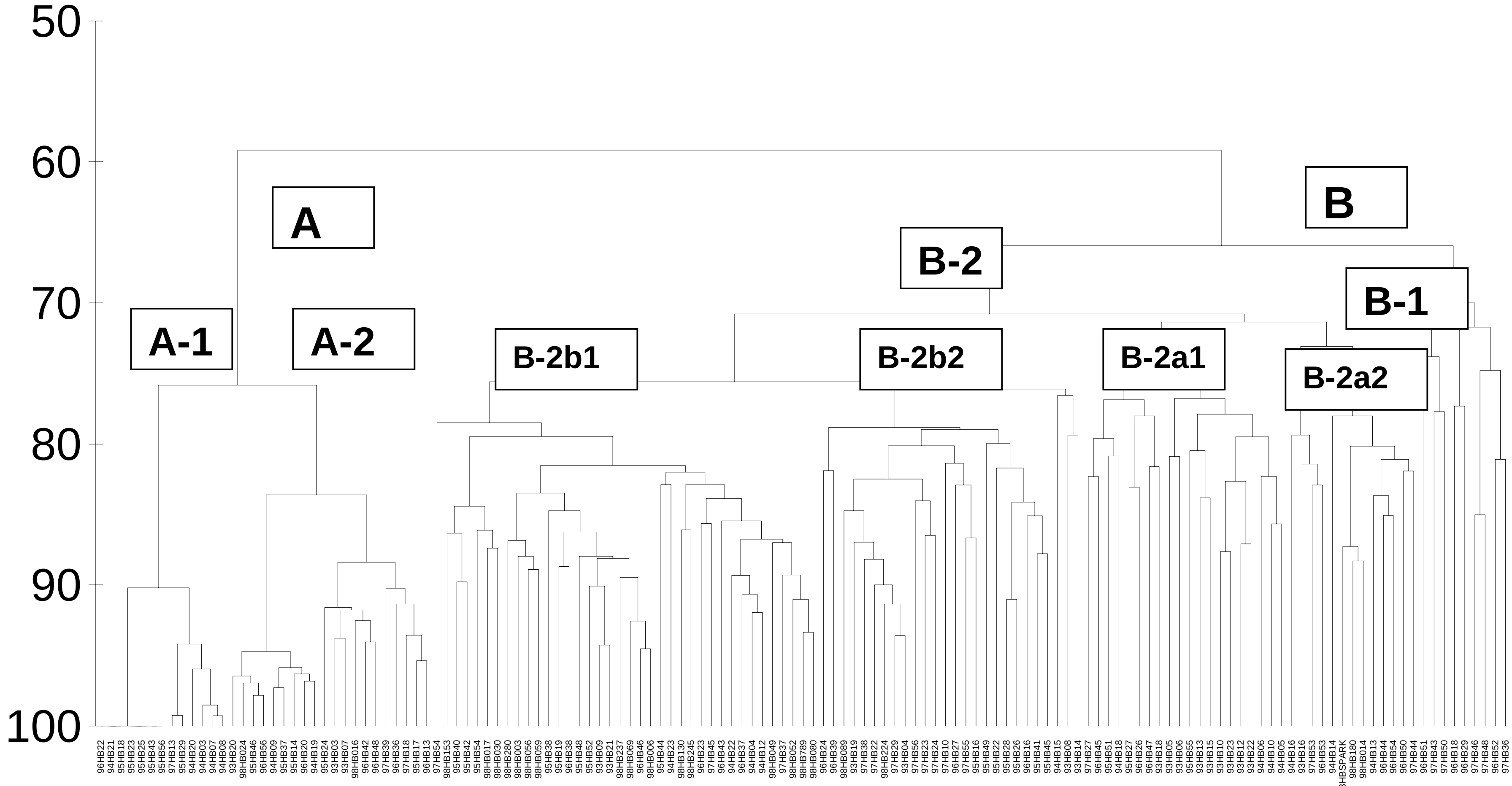

Figure 31. Dendrogram depicting the similarity of sites in Hillsborough Bay 1993-1998 (4th root transformed abundance; Bray-Curtis similarity; Group-average cluster

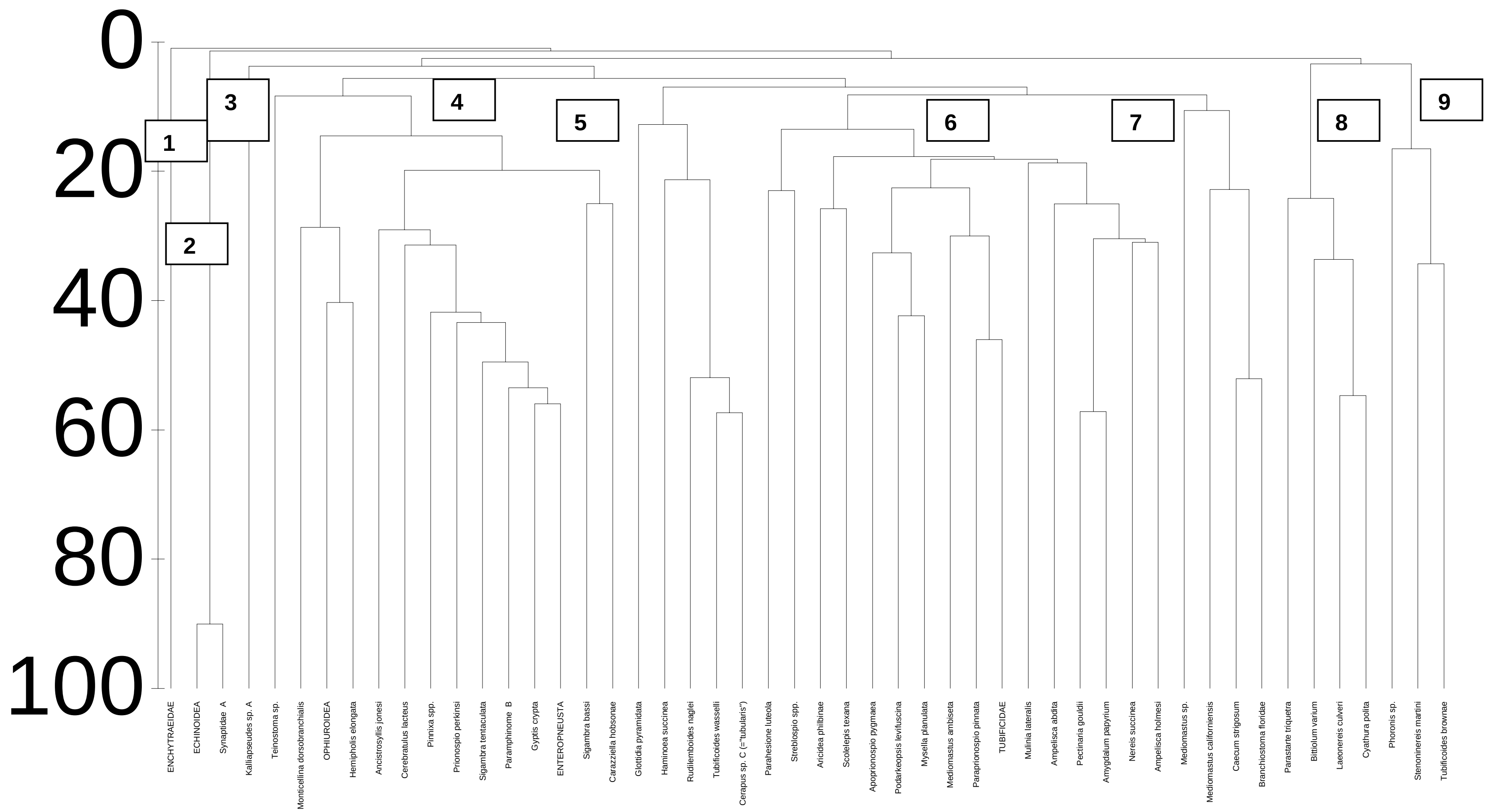

Figure 32. Dendrogram depicting the similarity of 50 most abundant taxa (standardized abundance; Bray-Curtis similarity; Group-average clustering): Hillsborough Bay 1993-1998.

Table 7. Two-way coincidence table (taxa by cluster), Hillsborough Bay benthos, 1993-1998.

TAXA CLUSTER	TAXA	A-1	A-2	B-1	B-2 a1	B-2 a2	B-2 b1	B-2 b2
1	*ENCHYTRAEIDAE*							137
2	*ECHINOIDEA*		5	150			1	
	Synaptidae A			497	3			2
3	*Kalliapseudes sp. A*		4					1
4	*Teinostoma sp.*		14	9		2	39	22
5	*Monticellina dorsobranchialis*	2	20	53	132	2658	53	735
	OPHIUROIDEA			66	34	96	26	78
	Hemipholis elongata		4	297	6	179	14	50
	Ancistrosyllis jonesi		5			23	3	5
	Cerebratulus lacteus					56	23	1
	Pinnixa spp.		7	38	29	375	89	94
	Prionospio perkinsi		13	200	237	1802	108	290
	Sigambra tentaculata		11	103	19	194	61	97
	Paramphinome B	2	14	31	8	350	55	53
	Gyptis crypta		11	19	1	231	36	32
	ENTEROPNEUSTA		32	34	5	350	18	111
	Sigambra bassi		8			27	22	8
	Carazziella hobsonae		21	34	88	1100	191	623
6	*Glottidia pyramidata*			53	4	21	82	23
	Haminoea succinea		1	256	233		26	74
	Rudilemboides naglei		1	2078	369	2	3	3
	Tubificoides wasselli			856			29	42
	Cerapus sp. C (="tubularis")			863	1			11

Table 7 (continued). Two-way coincidence table (taxa by cluster), Hillsborough Bay benthos, 1993-1998.

TAXA CLUSTER	TAXA	A-1	A-2	B-1	B-2 a1	B-2 a2	B-2 b1	B-2 b2
7	*Parahesione luteola*		8		12	8	14	41
	Streblospio gynobranchiata	2	1	3	239	29	51	303
	Aricidea philbinae		1	72	635	13	26	18
	Scolelepis texana			41	84		12	
	Apoprionospio pygmaea	2		34	16	19	2	6
	Podarkeopsis levifuscina		11	313	161	144	33	74
	Mysella planulata		5	7113	1905	69	81	392
	Mediomastus ambiseta			3	1637	263	18	107
	Paraprionospio pinnata	8	18	34	292	292	181	224
	TUBIFICIDAE	4	31	253	390	508	241	637
	Mulinia lateralis		1	78	119	98	126	120
	Ampelisca abdita		45	37.6	68	25	11	11
	Pectinaria gouldii	2		9	92		14	37.6
	Amygdalum papyrium		4	269	813		62	78
	Nereis succinea		4	106	288		17	129
	Ampelisca holmesi		51	3353	1259	8	182	224
8	*Mediomastus sp.*		1	16	278	140	9	25
	Mediomastus californiensis			9	6	29	62	6
	Caecum strigosum		4			669	23	15
	Branchiostoma floridae			263	153	792	168	71
9	*Parastarte triquetra*			1178	283		2	3
	Bittiolum varium			519	6			
	Laeonereis culveri		11	875	230	4	11	120
	Cyathura polita			59	29		10	10
	Phoronis sp.		1	3	1		8	65
	Stenoninereis martini		15				2	61
	Tubificoides brownae		1	9	13	4	15	132

Table 8. Comparison of mean site characteristics, hydrographic conditions, sedimentary contaminants, and biotic variables: Cluster A *vs*. Cluster B (*cf*. Figure 30), Hillsborough Bay, 1993-1998.

VARIABLE	CLUSTER A	CLUSTER B
Depth	3.8	2.4
RPD	2	22
%SC	44.6	11.2
Salinity	21.6	21.7
DO	2.4	4.6
Composite PEL Quotient	0.18	0.10
Metals PEL Quotient	0.33	0.13
PAH PEL Quotient	0.03	0.04
PCB PEL Quotient	0.18	0.12
Chlordane PEL Quotient	0.43	0.35
DDT PEL Quotient	0.04	0.04
# of Taxa	4	27
TBBI	8.4	14.0
Total Abundance	255	8757

Table 9. Results of SIMPER analysis comparing the dissimilarity between Hillsborough Bay Clusters A-1 and A-2. Average dissimilarity = 3.03.

	Avg. abund. Cluster A-1	**Avg abund. Cluster A-2**	**Contrib. %**	**Cum. %**
Ampelisca abdita	<1	45	5.6	5.6
Paraprionospio pinnata	8	18	5.3	10.9
ENTEROPNEUSTA	<1	32	5.0	15.8
Carazziella hobsonae	<1	21	4.6	20.5
Paramphinome B	2	14	4.6	25.0

Table 10. Comparison of mean site characteristics, hydrographic conditions, sedimentary contaminants, and biotic variables: Cluster A-1 *vs*. Cluster A-2 (*cf*. Figure 30), Hillsborough Bay, 1993-1998.

VARIABLE	**CLUSTER A-1**	**CLUSTER A-2**
Depth	4.8	3.2
RPD	0	2
%SC	55.8	38.0
Salinity	21.4	21.7
DO	1.2	3.2
Composite PEL Quotient	0.24	0.15
Metals PEL Quotient	0.41	0.28
PAH PEL Quotient	0.04	0.03
PCB PEL Quotient	0.24	0.14
Chlordane PEL Quotient	0.59	0.35
DDT PEL Quotient	0.05	0.04
# of Taxa	1	6
TBBI	2.2	12.1
Total Abundance	19	397

Table 11. Results of SIMPER analysis comparing the dissimilarity between Hillsborough Bay Clusters B-1 and B-2. Average dissimilarity = 24.92.

	Avg abund Cluster B-1	Avg. Abund. Cluster B-2	Contrib. %	Cum. %
Mysella planulata	7112	737	3.2	3.2
Ampelisca holmesi	3353	441	2.7	5.9
Rudilemboides naglei	2078	78	2.0	7.8
Amygdalum papyrium	269	215	1.5	9.4
Capitella capitata	513	59	1.4	10.8
ONUPHIDAE	272	9	1.4	12.2
Macoma tenta	297	14	1.4	13.6
Cyclaspis cf. varians	397	27	1.4	15.0
Haminoea succinea	256	79	1.4	16.3
Acteocina canaliculata	366	38	1.3	17.7
TUBIFICIDAE	253	410	1.3	19.0
Laeonereis culveri	875	84	1.3	20.3
Monticellina dorsobranchialis	53	569	1.2	21.5
Prionospio perkinsi	200	390	1.2	22.8
Parastarte triquetra	1178	59	1.2	24.0
Branchiostoma floridae	263	214	1.2	25.2

Table 12. Comparison of mean site characteristics, hydrographic conditions, sedimentary contaminants, and biotic variables: Cluster B-1 *vs*. Cluster B-2 (*cf*. Figure 30), Hillsborough Bay, 1993-1998.

VARIABLE	CLUSTER B-1	CLUSTER B-2
Depth	1.6	2.5
RPD	28	22
%SC	9.8	11.3
Salinity	25.6	21.3
DO	4.7	4.5
Composite PEL Quotient	0.08	0.10
Metals PEL Quotient	0.30	0.11
PAH PEL Quotient	0.01	0.04
PCB PEL Quotient	0.06	0.12
Chlordane PEL Quotient	0.10	0.38
DDT PEL Quotient	0.02	0.04
# of Taxa	43	26
TBBI	11.7	14.2
Total Abundance	26161	7142

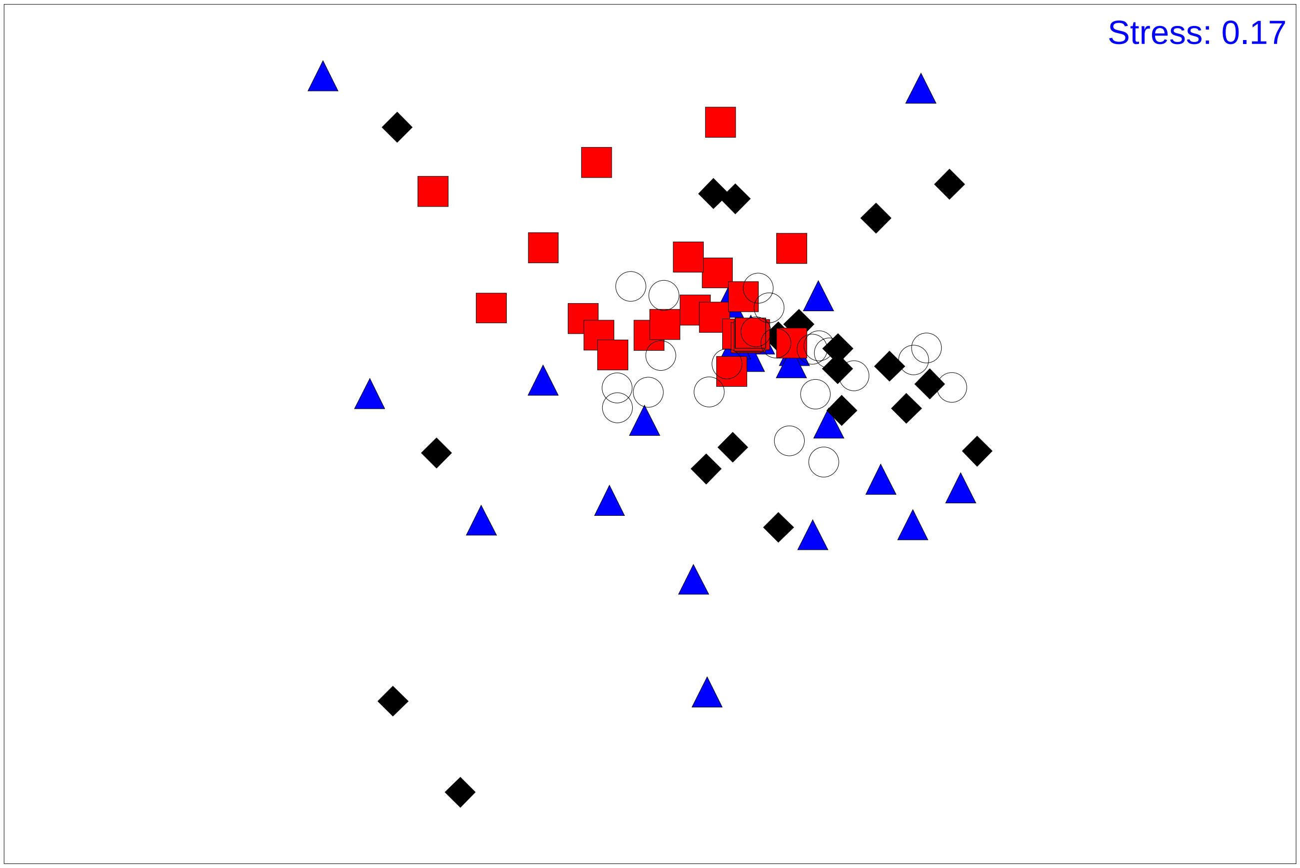

Figure 33. Non-Metric Multi-Dimensional Scaling (MDS) representation of benthic community structure in Hillsborough Bay, 1995-1998, by year

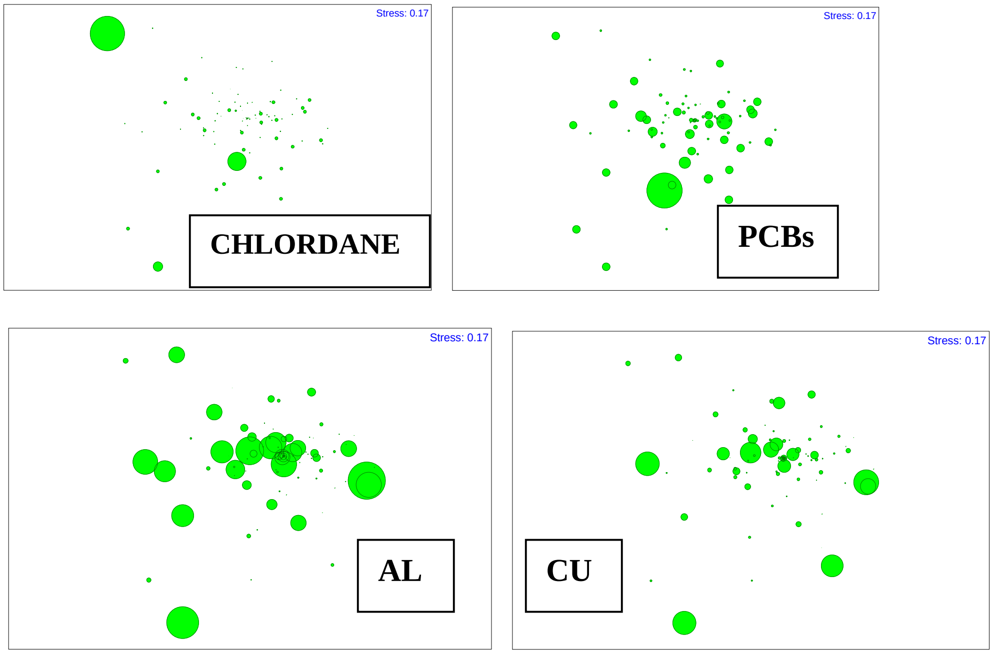

Figure 34. "Bubble" plots of chlordane, PCBs, Al, and Cu concentrations superimposed over the MDS plot depicting benthic community structure, by year, in Hillsborough Bay 1995-1998

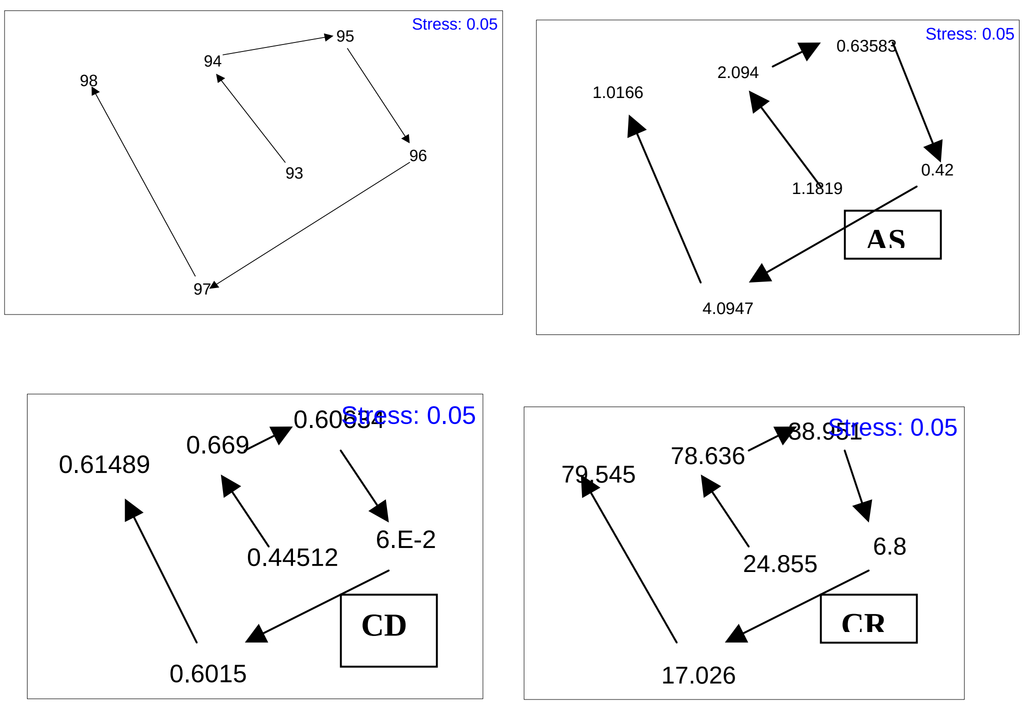

Figure 35. MDS plot of "average" benthic community structure by year and mean concentrations of As, Cd, and Cr by year, Hillsborough Bay, 1993-1998. Lines delineate temporal trend.

Shifts in benthic community structure from 1996 to 1997 were primarily affected by declines in the abundance of *M. planulata* and increases in the abundances of *Prionospio perkinsi* and *A. holmesi* (Appendix E; Figure 36). Taxa which contributed to the shift in benthic community structure from 1997 to 1998 include *M. planulata*, *M. dorsobranchialis*, and *A.holmesi,* each of which underwent a large decline in abundance (Appendix E; Figure 36).

<u>Status of Hillsborough Bay Sediments</u>: Hillsborough Bay appears to be affected more by subnominal DO than the Louisianian Province (northern Gulf of Mexico south to Tampa Bay) as a whole (Table 13). Degradation of benthic habitat, however, appears to be markedly higher in the Louisianian Province than in Hillsborough Bay.

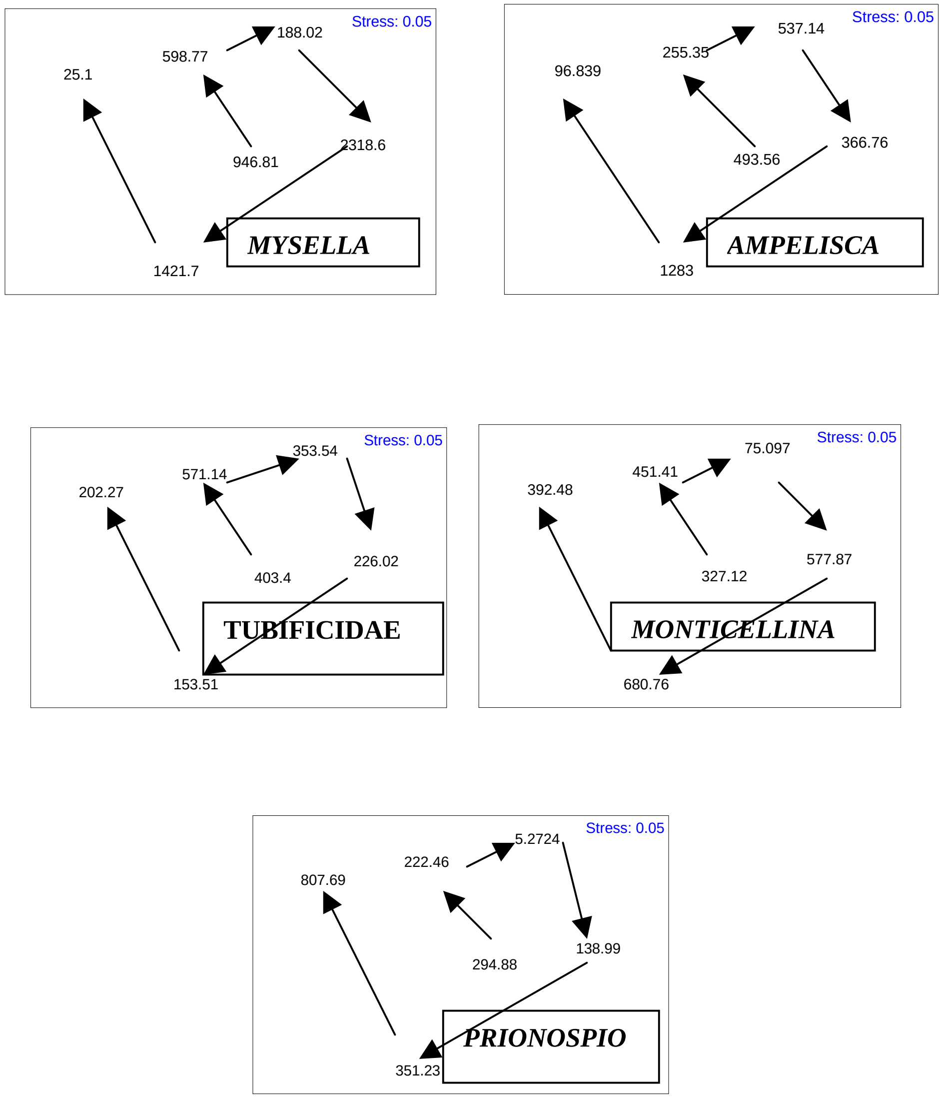

Figure 36. Mean densities (# m^{-2}) concentrations of *Mysella planulata, Ampelisca holmesi*, tubificid oligochaetes (genera undetermined), *Monticellina dorsobranchialis*, and *Prionospio perkinsi*, in Hillsborough Bay, 1993-1998.

Table 13. Comparison of proportions of degraded habitat, by category and study area: Hillsborough Bay, Tampa Bay, Florida (1993-1998) (as % of samples) *vs*. Louisianian Province (as % area).

STUDY AREA	DO	SEDIMENT CHEMISTRY	BENTHOS	DO+ BENTHOS	SEDIMENT CHEMISTRY + BENTHOS	DO + SEDIMENT CHEMISTRY
HILLSBOROUGH BAY (THIS STUDY)	17.3	2.9	10.1	6.5	0.7	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

DISCUSSION

Hillsborough Bay is the most industrialized segment of Tampa Bay as well as one of the most urban segments. Hillsborough Bay's sediments are exposed to nutrients and other contaminant inputs from urban stormwater, industrial and municipal wastewater discharges, thermal discharges and atmospheric deposition from power plants, and the phosphate industry (Estevez 1989). These impacts have been expressed as pervasive algal blooms (FWPCA 1969), subnominal DO, faunal die-offs (Santos & Simon 1980), and contamination of sediments by metals, pesticides, and PAHs (Doyle *et al.* 1989; Long *et al*. 1994; Grabe 1997; Grabe & Barron 2002). Improved treatment of municipal and industrial wastes, increased treatment, retention, and detention of stormwater, and reductions in industrial emissions have all served to ameliorate these problems.

During 1993-1998, 23% of the Hillsborough Bay samples met at least one criterion for "degraded" benthic habitat. DO was subnominal (<2 ppm) at 17%of the sites-- including approximately 30% of the 1995 samples. These areas were generally located downstream of the bay's confluence with the Hillsborough and Alafia rivers. Coincidentally, during 1995 June- August rainfall at sites along the Lower Hillsborough (SWFWMD site 376) and Alafia (SWFWMD site 252) rivers were higher than any year except 1994 and that during 1995 more shallow, inshore sites were sampled than during the other years. The association between rainfall, runoff and stream flow and the dissolved oxygen status of Hillsborough Bay merits more detailed examination.

Based upon the TBBI cutoff of 4.6 (MacDonald *et al*. 2002), the benthic assemblages at 10% of the siteswere also degraded. Degraded benthic assemblages were most often located immediately bayward of the mouth of the Hillsborough River during 1995; a secondary area of degraded benthos was the industrial area of northeastern Hillsborough Bay.

Almost 7% of the samples were subnominal for both DO and benthic structure. Only 3% of the samples were subnominal with respect to sediment contaminants based upon a composite PEL quotient. For metals and PAHs the percentage of "degraded" samples also ranged from 0% to <5% and for PCBs the percentage ranged from 0% to 3.7% in any year.

As many as 10% of the samples exceeded the PEL for chlordane in any year and none of the samples exceeded the PEL for total DDT. The portions of Hillsborough Bay with sediments degraded by chemical contaminants were located in McKay Bay, East Bay, and the lower Hillsborough River.

Correlation analysis showed that the TBBI was positively associated with DO and RPD and negatively associated with %SC, the composite PEL quotient, and depth, but not with salinity. The rank correlations between the biological data and the "best fit" for physico-chemical variables and chemical contaminants (chlordane, PCBs, Al, Cu) were very weak (<0.1).

During the study period, the near-bottom water mass characteristics differed among years. Near-bottom salinities in Hillsborough Bay were generally in the polyhaline (18-30 ppt) zone. Both mesohaline and oligohaline salinities were observed, especially during 1995 and 1998. Salinity patterns did not show any consistent association with rainfall patterns in the near-field. Highest total rainfall during June through August occurred during 1994 (Appendix B) when very little of Hillsborough Bay had salinities <18 ppt. Mesohaline salinities were most prevalent during 1998 when combined rainfall totals for SWFWMD stations in the Lower Hillsborough and Alafia rivers were fourth highest over the six year period (Appendix B). Other variables, such as streamflow, stormwater runoff, and rainfall at other locations in the watershed should be examined to determine their association with salinities in Hillsborough Bay. The averages reported in this survey period (20.1 ppt surface/21.6 bottom) are consistent with the long-term mean (20.9 ppt) reported by Simon (1974).

PCA showed that depth, %SC and DO exerted primary influence on the intra-bay habitat characteristics; salinity was only a minor contributor. %SC was higher and DO was lower at the deeper sites. Temperature exerted a secondary effect, apparently as a surrogate for interannual trends, rather than as an indicator of intra-bay spatial patterns. Sandy sediments predominate in Hillsborough Bay with the coarsest sediments in the southeastern quadrant. Muddy sediments are widely distributed in the western parts of Hillsborough Bay. Doyle *et al*. (1989) and Johansson & Squires (1989), using somewhat different criteria for "mud" *vs*.

“sand”, described a similar distribution using data collected during the 1960s. and 1980s. Although the historical data are sparser than the current data, the location and extents of fine-grained sediments in Hillsborough Bay seems to have remained fairly consistent over the past 40 years.

Within the benthic community, numerically abundant species included *Mysella planulata* (Bivalvia), several polychaete worms (*Monticellina dorsobranchialis*, *Carazziella hobsonae, Prionospio perkinsi*), tubificid oligochaetes, and *Ampelisca holmesi* (Amphipoda). Numerical dominants differed both by year and salinity zone. *Mysella planulata* was ranked either first or second during four of the six years, tubificid oligochaetes were ranked in the top ten during each year, and *M. dorsobranchialis* was ranked during five of the years. Three taxa were ranked in the top ten in both the oligohaline and mesohaline zones and four taxa were ranked in the mesohaline and polyhaline zones.

Data provided by Taylor *et al*. (1970), Taylor (1971), Thoemke (1979), and Santos & Bloom (1980) provide an opportunity to compare the species composition of Hillsborough Bay benthos between 1963-1964, 1975-1977, and 1993-1998. The most frequently occurring mollusks reported by Taylor *et al.* (1970) included *Mulinia lateralis*, *Nassarius vibex*, *Amygdalum papyrium, Tellina versicolor*, and *Macoma tenta*. These were all among the ten most frequently occurring mollusks during the current survey period as well. *Mysella planulata* occurred in >48% of the 1993-1998 samples although it only occurred in 4% of the 1963-1964 samples. *Mysella planulata* was also among the dominants in Hillsborough Bay during the late 1970s (Santos & Simon 1980). *Prunum apicinum* was found in 30% of the samples collected during 1993-1998 but was absent from the 1963-1964 samples.

The most frequently collected polychaetes in Hillsborough Bay during 1963-1964 also differed from the current study. Taylor (1971) found *Spiochaetopterus costarum, Streblospio benedicti* (=*gynobranchiata*) and *Paraprionospio pinnata* in >60% of the samples. In the current database, the common polychaetes included *P. perkinsi* (47% of samples), *P. pinnata* (44%), and *C. hobsonae* (42%). Of the top five most frequently occurring polychaetes in this study only *P. pinnata* was similarly ranked in 1963. *Mediomastus* spp., which was a dominant in 1993 and were also dominants in the late 1970s

(Santos & Bloom 1980), were not reported by Taylor (1971) for any sample in Tampa Bay during 1963-1964.

Uebelacker *et al*. (1984) report that *M. californiensis* ranges up to 25 mm in length by 0.5 mm in width and Hartman (1947) reports that the dimensions of *M. ambiseta* are up to 15 mm by 0.5 mm. Therefore, even though sieve sizes were larger in the 1963 survey (0.7 mm; Taylor 1971) than in the current survey, *Mediomastus* spp. are large enough that some should have been retained by the 0.7 mm were they present in Taylor's samples.

Another apparent difference in species composition since the 1970s to the present is the change in *Ampelisca* spp. populations. Thoemke (1979) described the life history paprameters of *A. abdita* and *A. verrilli* in Hillsborough Bay during 1975-1976. *Ampelisca abdita* was quite abundant relative to *A. "verrilli*". Santos & Bloom (1980) also include these two species in their species list and include *A. abdita* among the numerical dominants. In the present study *A. holmesi* is among the numerical dominants in most years and *A. abdita* is less abundant. *Ampelisca holmesi* was described, by Pearse (1908), from specimens collected in Oyster Bay (near the St. Marks River in northern Florida), with subsequent reports of its occurrence in Charlotte Harbor (Pearse 1912) and Sarasota Bay (Shoemaker 1933. It seems likely that Thoemke's *A. "verrilli"* may be *A. holmesi*. That being the case, the dominance of *A. holmesi* in Hillsborough Bay during the current study period does appear somewhat different from data collected by Thoemke (1979) and Santos & Simon (1980) during the 1970s. However, this may merely reflect interannual trends in the populations of these species.

The benthic community of Hillsborough Bay apparently has changed since the 1960's-1970's--even taking into account interannual variation in composition and abundance.

Spatial and temporal dissimilarities between the biotic assemblages reported in this study in were primarily influenced by differences in the distributions of *M. planulata*, tubificids**,** *P. perkinsi and A. holmesi.* One of the two primary assemblages was considerably "poorer" biologically, perhaps an effect of greater environmental stress than the second primary cluster. Cluster "A" sites had fewer taxa, a lower TBBI score and considerably lower densities of organisms; “A” sites were deeper than the “B” sites and were characterized by a shallower RPD and higher % SC. The effects of stressors such as DO and sediment contaminants were greater at Cluster “A” sites as well

The apparent RPD width demarcates reduced and oxidized sediments (Rosenberg 2001). The depth of the upper, oxidized layer is influenced by bioturbation (Rosenberg 2001;Rosenberg *et al*. 2001). In order for bioturbation to occur, the near-bottom DO regime must be adequate to sustain a diverse benthic assemblage (Nilsson & Rosenberg 2000). Thus, the width of the RPD and DO are correlated (Rosenberg 2001). RPD was, in fact, positively correlated with DO and negatively correlated with %SC in Hillsborough Bay.

Summers *et al*. (1993) suggested that, for Louisianian Province estuaries, an RPD <10mm may be indicative of anaerobic sediments and an RPD>50 mm may represent aerobic sediments. Using these criteria, Hillsborough Bay sediments were considerably more anaerobic than those of the Louisianian Province as a whole. In >50% of the Hillsborough Bay samples the RPD was not detected and in approximately 60% of the Hillsborough Bay samples the RPD was <10 mm, indicative of anaerobic sediments. This compares with 9% of the sediments in the estuaries of the Louisianian Province in 1991 (Summers *et al.*1993) At the Hillsborough Bay sites, however, both DO and %SC varied widely. Rosenberg *et al*. (2001) cautioned that the RPD may vary several centimeters over a short distance, even in hypoxic sediments.

Cluster “A” could be subdivided into two clusters. The benthic assemblages in Cluster “A-1” sites were especially depauperate and stresses from low DO and sediment contaminants were apparently greater at these sites.

Cluster “B” could also be subdivided. “B-1” sites were generally located in shallow waters near the periphery of southern Hillsborough Bay during 1996 and 1997 only. The species contributing most to the dissimilarity between these clusters “B-1” and “B-2” included *M. planulata* and two amphipods (*A. holmesi* and *Rudilemboides naglei*), each of which were extremely abundant at “B-1” stations. The mean TBBI, however, was higher in “B-2”-- a consequence of higher diversity and evenness at the “B-2” sites. Of the measured stressors, chlordane concentrations were higher at "B-2" sites and metals were higher at the "B-1" sites.

The benthic community experienced more pronounced shifts in structure from 1997 to 1997 and from 1997 to 1998 than during other sequential years. The best fit for the *mean* environmental variable data with the *mean* biotic data were for As, Cd, and Cr (Spearman r=0.84). As, Cd, and Cr each showed a marked increase in mean concentration from 1996 to 1997. From 1997 to 1998 As concentrations declined approximately 75% and Cr increased almost 5 fold. Taxa which primarily contributed to the shift in community structure from 1996 to 1997 included *M. planulata*, *M. dorsobranchialis*, and *A.holmesi*. Shifts in structure from 1997 to 1998 were primarily affected by changes in the abundance of *M. dorsobranchialis*, *Prionospio perkinsi*, and *A. holmesi.*

CONCLUSIONS

Soft-sediment habitats in portions of Hillsborough Bay experienced stress from low DO, trace metals, and chlordane. Low DO and subnominal benthic assemblages, were the two primary indicators of degraded benthic habitat. Low DO was more pervasive in Hillsborough Bay than in the Louisianian Province as a whole and subnominal benthic habitat was less pervasive in Hillsborough Bay.

The structure of the benthic community was not clearly explained by patterns or trends in physical factors generally shown to be 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 As, Cd, and Cr 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.

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 Hillsborough Bay. Water temperature, as an indicator of year-to-year changes, was a secondary factor. Salinity was less important in characterizing Hillsborough Bay.

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, and ampeliscid amphipods. 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.

We believe that the historical databases should be more rigorously analyzed in concert with the contemporary data (*cf*. Karlen et al. 1997). Such an approach may shed light on the extent to which the benthic assemblages of Hillsborough Bay have changed concomitant with the documented improvements in water quality.

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APPENDIX A
HILLSBOROUGH BAY SAMPLING LOCATIONS: BY YEAR


94HB18
94HB12
94HB19
94HB20
94HB23
94HB21
94HB22
94HB03
94HB04
94HB05
94HB06
94HB10
94HB08
94HB09
94HB07
94HB13
94HB14
94HB15


95HB19
95HB14
95HB16
95HB18
95HB17
95HB23
95HB22
95HB24
95HB25
95HB29
95HB26
95HB28
95HB40
95HB38
95HB41
95HB27
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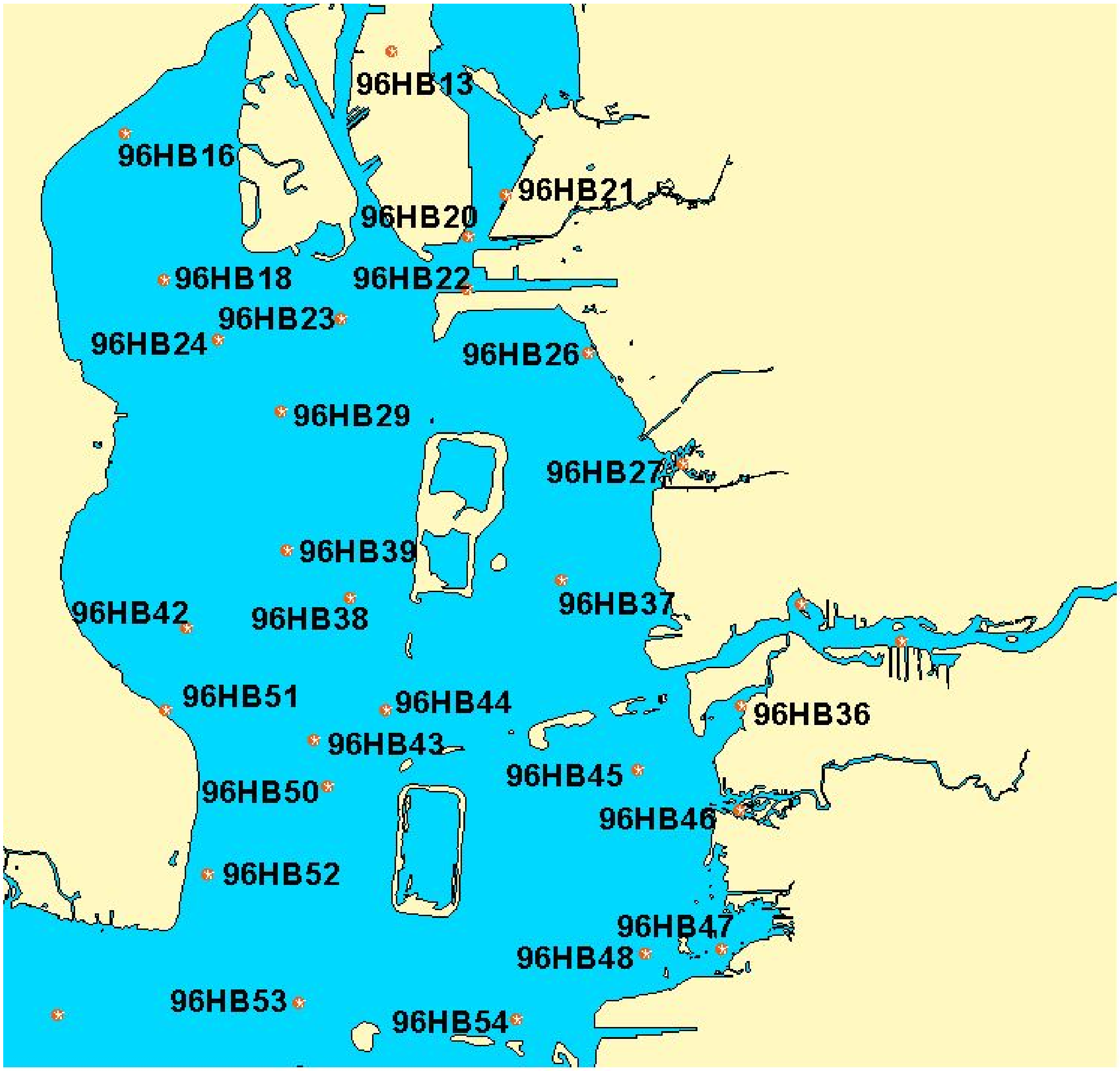
95HB48
95HB54
95HB55


96HB13
96HB16
96HB21
96HB20
96HB18
96HB22
96HB23
96HB24
96HB26
96HB29
96HB27
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96HB42
96HB38
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96HB48
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96HB54


97HB10
97HB13
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97HB22
97HB24
97HB29
97HB39
97HB27
97HB38
97HB43
97HB44
97HB37
97HB45
97HB36
97HB50
97HB46
97MTB02
97HB48
97HB53
97HB54
97HB55


98HR39
98HB171
98HB049
98HB252
98HB016
98HB153
98HB180
98HB052
98HB789
98HB280
98HB059
98HB069
98HB056
98HB014
98HB024
98HB003
98HB130
98HB089
98HB080
98HB174
98HB245
98HB017
98HB224
98HB030
98HB237

APPENDIX B.
MONTHLY RAINFALL (INCHES) AT THREE RAIN GAUGES OPERATED BY THE SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT, JUNE THROUGH AUGUST 1993-1998.

	1993	**1994**	**1995**	**1996**	**1997**	**1998**
ALAFIA (Site 252)						
JUN	4.03	12.21	7.18	8.29	3.43	1.45
JUL	5.59	10.69	9.42	5.40	8.42	8.37
AUG	7.41	8.53	7.96	3.62	9.78	7.32
TOTAL	**17.03**	**31.43**	**24.56**	**17.31**	**21.63**	**17.14**
MACDILL (Site 286)						
JUN	2.78	5.12	5.26	4.74	3.47	-
JUL	4.64	4.23	11.09	5.71	9.57	-
AUG	6.29	8.38	19.41	4.40	1.03	-
TOTAL	13.71	17.73	35.76	14.85	14.07	-
HILLSBOROUGH RIVER (Site 376)						
JUN	3.37	7.38	9.03	10.79	5.49	1.32
JUL	6.13	13.20	9.50	2.48	7.51	12.60
AUG	8.11	8.87	12.25	2.30	7.82	7.62
TOTAL	**17.61**	**29.45**	**30.78**	**15.57**	**20.82**	**21.54**
TOTAL-AR+HR	**34.64**	**60.88**	**55.34**	**32.88**	**42.45**	**38.68**

APPENDIX C
INVENTORY OF BENTHIC MACROINVERTEBRATES COLLECTED FROM HILLSBOROUGH BAY, 1993-1998

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

Tribe Thenaria
Family Actinostolidae
Thenaria A

Phylum Platyhelminthes
Class Turbellaria
Order Polycladida
Turbellaria A
Eustylochus meridianalis

Phylum Nemertea
Nemertea X
Nemertea U
Nemertea T
Nemertea O
Nemertea Q
Nemertea N
Nemertea P
Nemertea L
Nemertea G
Nemertea F
Nemertea E
Nemertea I
Nemertea K
Nemertea B
Nemertea A
Nemertea J

APPENDIX C (CONTINUED)

Class Anopla
Order Paleonemertea
Family Tubulanidae
Tubulanus pellucidus
Tubulanus sp. B

Order Heteronemertea
Family Celebratulidae
Cerebratulus lacteus

Order Heteronemertea
Family Lineidae
Zygeupolia cf. rubens?

Class Enopla
Order Haplonemertea
Family Amphiporidae
Amphiporus bioculatus

Phylum Annelida
Class Polychaeta
Family Polynoidae
Polynoidae A
Malmgreniella maccraryae
Malmgreniella taylori

Family Sigalionidae
Sthenelais A
Family Crysopetalidae
Bhawania heteroseta

Family Amphinomidae
Paramphinome B

Family Phyllodocidae
Phyllodoce longipes
Eteone heteropoda
Eteone foliasa
Nereiphylla castanea
Paranaitis gardineri
Nereiphylla fragilis
Nereiphylla A
Phyllodoce arenae

APPENDIX C (CONTINUED)

Family Hesionidae
Gyptis crypta
Parahesione luteola
Ophiodromus obscura
Podarkeopsis levifuscina

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

Family Syllidae
Pionosyllis sp.
Syllis cornuta
Exogone dispar
Exogone arenosa
Sphaerosyllis sp.
Sphaerosyllis taylori
Sphaerosyllis longicauda
Sphaerosyllis labyrinthophila
Brania wellfleetensis
Brania A
Parapionosyllis longicirrata
Parapionosyllis uelebackerae

Family Nereididae
Nereis succinea
Nereis falsa
Nereis micromma
Nereis lamellosa
Laeonereis culveri
Stenoninereis martini

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

Family Glyceridae
Glycera Americana

Family Goniadidae
Glycinde solitaria
Goniadides carolinae

Family Onuphidae
Onuphis A
Diopatra cuprea
Mooreonuphis cf. nebulosa
Kinbergonuphis simony

Family Oenonidae
Arabella mutans

Family Dorvilleidae
Dorvillea rudolphi
Pettiboneia sp.

Family Orbinidae
Leitoscoloplos robustus
Scoloplos rubra
Scoloplos texana
Leitoscoloplos fragilis

Family Paraonidae
Aricidea suecica
Aricidea cf. catherinae
Aricidea philbinae
Aricidea taylori
Paraonis fulgens
Cirrophorus sp.
Paradoneis cf. lyra

APPENDIX C (CONTINUED)

Family Spionidae
Laonice cirrata
Dipolydora socialis
Polydora cornuta
Prionospio heterobranchia
Prionospio steenstrupi
Apoprionospio pygmaea
Prionospio cristata
Apoprionospio dayi
Prionospio perkinsi
Spio pettiboneae
Spio limnicola
Paraprionospio pinnata
Streblospio spp.
Scolelepis texana
Aonides mayaguezensis
Carazziella hobsonae

Family Magelonidae
Magelona pettiboneae

Family Poecilochaetidae
Poecilochaetus johnsoni

Family Chaetopteridae
Spiochaetopterus costarum

Family Cirratulidae
Caulleriella zetlandica
Caulleriella D
Tharyx sp.
Monticellina dorsobranchialis
Cirriformia A

Family Flabelligeridae
Piromis roberti

Family Ophelidae
Armandia maculata
Travisia hobsonae
Polyopthalmus sp.

APPENDIX C (CONTINUED)

Family Capitellidae
Capitella capitata
Capitella jonesi (=sp. A)
Heteromastus filiformis
Notomastus hemipodus
Notomastus americanus
Notomastus n. sp.?
Mediomastus ambiseta
Mediomastus californiensis
Capitella jonesi

Family Maldanidae
Sabaco americanus
Axiothella mucosa
Axiothella A

Family Pectinariidae
Pectinaria gouldii

Family Ampharetidae
Hobsonia florida
Melinna maculata

Family Terebellidae
Loimia sp.

Family Sabellidae
Megalomma pigmentum
Fabricinuda trilobata

Family Polygordiidae
Polygordius sp.

Class Oligochaeta
Order Tubificida
Family Tubificidae
Limnodriloides monothecus complex
Tubificoides brownae
Tubificoides wasselli
Thalassodrilides gurwitschi

Family Enchytraeidae

APPENDIX C (CONTINUED)

Phylum Mollusca
Class Gastropoda
Family Hydrobiidae

Family Vitrinellidae
Vitrinellidae sp. A
Vitrinella floridana
Teinostoma biscaynense
Teinostoma megastoma

Family Caecidae
Caecum pulchellum
Caecum strigosum

Order Mytiloida
Family Mytilidae
Modulus modulus

Family Cerithiidae
Bittiolum varium

Family Epitoniidae
Epitonium angulatum

Family Eulimidae
Melanella cf. arcuata
Eulima bilineatus
Microeulima hemphilli

Family Naticidae
Tectonatica pusilla

Family Columbellidae
Astyris lunata

Family Melongenidae
Melongena corona

Family Nassaridae
Nassarius vibex

APPENDIX C (CONTINUED)

Family Olividae
Jaspidella blanesi
Olivella floralia
Olivella pusilla
Oliva sayana

Family Marginellidae
Prunum apicinum

Family Conidae
Kurtziella limonitella

Family Pyramidellidae
Fargoa cf. gibbosa
Boonea seminuda
Odostomia laevigata
Odostomia producta
Eulimastoma teres
Sayella fusca
Sayella hemphilli
Turbonilla interrupta
Turbonilla conradi
Turbonilla cf. dalli
Turbonilla hemphilli
Eulimella smithii
Lephalapsidea sp.

Family Acteonidae
Rictaxis punctostriatus

Family Cylichnidae
Acteocina canaliculata
Tornatina inconspicua

Family Haminoeidae
Haminoea succinea
Haminoea antillarum

Class Bivalvia

Family Nuculidae
Nucula crenulata

FamilyArcidae
Anadara transversa

APPENDIX C (CONTINUED)

Family Mytilidae
Brachidontes exustus
Amygdalum papyrium

Family Lucinidae
Parvilucina multilineata

Family Ostreidae
Crassostrea virginica

Family Ungulinidae
Diplodonta semiaspera

Family Lasaeidae
Orobitella floridana
Mysella planulata
Erycina floridana

Family Cardiidae
Laevicardium mortoni

Family Mactridae
Mulinia lateralis

Family Semelidae
Ervilia concentrica

Family Tellinidae
Macoma tenta
Macoma constricta
Tellina iris
Tellina lineata
Tellina versicolor
Tellina alternata
Tellina squamifera
Tellina tampaensis

Family Solecurtidae
Tagelus plebeius
Tagelus divisus

Family Semelidae
Abra aequalis
Semele proficua

APPENDIX C (CONTINUED)

Family Veneridae
Dosinia discus
Mercenaria campechiensis
Pitar sp.
Macrocallista nimbosa
Anomalocardia auberiana
Parastarte triquetra

Family Myidae
Sphenia antillensis

FamilyCorbulidae
Corbula contracta

Family Lyonsiidae
Lyonsia floridana

Family Thraciidae
Asthenothaerus hemphilli

Phylum Arthropoda
Class Malacostraca
Order Leptostraca
Family Nebaliidae
Nebalia

Order Mysidacea
Family Mysidae
Mysidopsis spp.
Bowmaniella sp.
Brasilomysis sp.
Americamysis bahia

Order Cumacea
Family Leuconidae
Leucon americanus

FamilyDiastylidae
Oxyurostylis smithi
Oxyurostylis lecroyae

Family Nannastacidae
Almyracuma proximoculi

APPENDIX C (CONTINUED)

Family Bodotriidae
Cyclaspis cf. varians

Order Tanaidacea
Family Kalliapseudidae
Kalliapseudes sp. A

Family Leptocheliidae
Leptochelia sp.

Order Isopoda
Family Anthuridae
Cyathura polita
Ptilanthura tenuis

Family Hyssuridae
Xenanthura brevitelson
Amakusanthura magnifica

Family Sphaeromatidae
Eurydice personata

Family Idoteidae
Erichsonella attenuata
Edotia triloba

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

Family Ampithoidae
Cymadusa compta

Family Aoridae
Paramicrodeutopus cf. myersi
Rudilemboides naglei
Bemlos sp.

Family Bateidae
Batea catharinensis

APPENDIX C (CONTINUED)

Family Ischyroceridae
Cerapus sp. C
Erichthonius brasiliensis

Family Aoridae
Grandidierella bonnieroides

Family Gammaridae
Elasmopus laevis
Gammarus mucronatus
Melita elongata

Family Haustoriidae
Acanthohaustorius uncinus

Family Corophiidae
Microprotopus shoemakeri

Family Liljeborgiidae
Listriella barnardi

Family Lysianassidae
Shoemakerella lowreyi

Family Oedicerotidae
Hartmanodes nyei

Family Phoxocephalidae
Metharpinia floridana
Eobrolgus spinosus

Family Platyischnopidae
Eudevenopus honduranus

Family Pariambidae
Paracaprella tenuis
Paracaprella pusilla

Order Decapoda
Family Penaeidae
Rimapenaeus constrictus

Family Palaemonidae
Periclimenes americanus

Family Alpheidae
Alpheus sp.
Automate sp.

Family Hippolytidae
Hippolyte sp.

Family Processidae
Processa hemphilli
Ambidexter symmetricus

Family Paguridae
Pagurus longicarpus
Pagurus gymnodactylus
Pagurus maclaughlinae

Family Porcellanidae
Polyonyx gibbesi

Family Upogebiidae
Upogebia affinis

Family Leucosiidae
Persephona mediterranea

Family Panopeidae
Hexapanopeus angustifrons
Panopeus bermudensis
Rhithropanopeus harrisii
Dyspanopeus texanus

Family Pinnotheridae
Pinnixa chaetopterana
Pinnixa cf. pearsei
Pinnixa A
Pinnixa D

Phylum Sipuncula
Sipuncula sp. A

Phylum Phoronida
Phoronis ?architecta

Phylum Brachipoda
Glottidia pyramidata

APPENDIX C (CONTINUED)

Phylum Echinodermata
Class Ophiuroidea
Family Ophiactidae
Hemipholis elongata

Family Amphiuridae
Amphiodia nr. riisei
Amphipholis squamata
Amphipholis gracillima
Ophiophragmus filograneus
Amphioplus abditus
Amphioplus thrombodes
Amphioplus A
Micropholis sp.
Amphipholis atra

Class Echinoidea
Mellita tenuis

Class Holothuroidea
Holothuroidea C

Family Synaptidae
Synaptidae A
Synaptidae C
Leptosynapta

Phylum Hemichordata
Class Enteropneusta
Enteropneusta B

Family Harrimaniidae
Stereobalanus canadensis

Class Cephalochordata
Order Amphioxi
Family Branchiostomidae
Branchiostoma floridae

APPENDIX D
SIMPER ANALYSES:
COMPARISONS OF HILLSBOROUGH BAY CLUSTERS, 1993-1998
(TAXA EXPLAINING 25% OF DISSIMILARITY)

Groups B1 & B2a1

Average dissimilarity = 25.23

	Group B1	Group B2a1				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mediomastus ambiseta	3.23	1636.98	0.53	1.20	2.09	2.09
Rudilemboides naglei	2078.19	368.86	0.50	1.18	1.97	4.06
Mysella planulata	7112.53	1905.07	0.50	1.31	1.97	6.02
Aricidea philbinae	71.98	635.09	0.38	1.22	1.52	7.54
Ampelisca holmesi	3353.19	1258.86	0.37	1.21	1.46	9.00
Parastarte triquetra	1178.20	283	0.36	0.81	1.43	10.43
Capitella capitata	512.58	170.10	0.36	1.28	1.41	11.84
Laeonereis culveri	875.08	230.10	0.34	0.89	1.36	13.20
Macoma tenta	296.96	1.98	0.33	1.19	1.33	14.53
Haminoea succinea	256.34	232.59	0.32	1.35	1.29	15.82
ONUPHIDAE	271.98	41.98	0.32	1.21	1.28	17.10
Paraprionospio pinnata	34.48	292.00	0.32	1.35	1.25	18.35
Branchiostoma floridae	262.59	153.23	0.31	1.33	1.25	19.59
Amygdalum papyrium	268.84	813.22	0.30	1.27	1.18	20.77
Nereis succinea	106	288.25	0.29	1.27	1.17	21.94
Magelona pettiboneae	18.85	171.98	0.29	1.64	1.17	23.10
TUBIFICIDAE	253.23	390.12	0.29	1.32	1.15	24.26

Groups B1 & B2b1

Average dissimilarity = 23.97

	Group B1	Group B2b1				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	7112.53	80.55	0.92	1.66	3.84	3.84
Ampelisca holmesi	3353.19	181.50	0.74	1.54	3.08	6.92
Rudilemboides naglei	2078.19	3.31	0.50	0.88	2.09	9.01
Amygdalum papyrium	268.84	61.64	0.41	1.90	1.70	10.71
Cyclaspis cf. varians	396.95	8.43	0.38	1.24	1.57	12.28
Capitella capitata	512.58	20.61	0.37	0.97	1.54	13.82
ONUPHIDAE	271.98	0.10	0.37	1.17	1.53	15.36
Macoma tenta	296.96	3.63	0.37	1.22	1.53	16.89
Acteocina canaliculata	365.71	7.79	0.36	1.23	1.52	18.41
TUBIFICIDAE	253.23	241.44	0.35	1.45	1.46	19.87
Haminoea succinea	256.34	26.38	0.35	1.36	1.46	21.33
Podarkeopsis levifuscina	312.59	33.11	0.33	1.23	1.40	22.73
Laeonereis culveri	875.08	11.00	0.32	0.70	1.32	24.05
Parastarte triquetra	1178.20	2.02	0.30	0.59	1.27	25.32

Groups B2a1 & B2b1

Average dissimilarity = 21.70

Species	*Group B2a1 Av.Abund*	*Group B2b1 Av.Abund*	*Av.Diss*	*Diss/SD*	*Contrib%*	*Cum.%*
Mysella planulata	*1905.07*	*80.55*	*0.69*	*1.94*	*3.17*	*3.17*
Mediomastus ambiseta	*1636.98*	*18.05*	*0.60*	*1.20*	*2.78*	*5.96*
Ampelisca holmesi	*1258.86*	*181.50*	*0.59*	*1.69*	*2.71*	*8.67*
Amygdalum papyrium	*813.22*	*61.64*	*0.45*	*1.23*	*2.08*	*10.75*
Aricidea philbinae	*635.09*	*25.74*	*0.44*	*1.22*	*2.01*	*12.76*
Scoloplos rubra	*156.98*	*5.87*	*0.40*	*2.20*	*1.82*	*14.58*
Nereis succinea	*288.25*	*16.77*	*0.40*	*1.44*	*1.82*	*16.41*
TUBIFICIDAE	*390.12*	*241.44*	*0.39*	*1.37*	*1.80*	*18.20*
Magelona pettiboneae	*171.98*	*22.54*	*0.35*	*1.73*	*1.63*	*19.84*
Acteocina canaliculata	*147.60*	*7.79*	*0.35*	*1.46*	*1.59*	*21.43*
Paraprionospio pinnata	*292.00*	*180.55*	*0.34*	*1.31*	*1.59*	*23.02*
Nemertea F	*192.62*	*4.91*	*0.34*	*1.33*	*1.56*	*24.58*
Branchiostoma floridae	*153.23*	*168.05*	*0.33*	*1.26*	*1.52*	*26.09*

Groups B1 & B2a2

Average dissimilarity = 27.58

Species	*Group B1 Av.Abund*	*Group B2a2 Av.Abund*	*Av.Diss*	*Diss/SD*	*Contrib%*	*Cum.%*
Mysella planulata	*7112.53*	*68.85*	*0.86*	*1.66*	*3.14*	*3.14*
Ampelisca holmesi	*3353.19*	*8.43*	*0.78*	*1.88*	*2.83*	*5.97*
Monticellina dorsobranchialis	*53.23*	*2658.38*	*0.64*	*1.43*	*2.32*	*8.29*
Carazziella hobsonae	*34.48*	*1100.08*	*0.48*	*1.44*	*1.74*	*10.03*
Rudilemboides naglei	*2078.19*	*2.18*	*0.47*	*0.88*	*1.69*	*11.71*
Amygdalum papyrium	*268.84*	*0.10*	*0.44*	*2.58*	*1.60*	*13.32*
Prionospio perkinsi	*200.10*	*1802.14*	*0.43*	*1.33*	*1.56*	*14.88*
Branchiostoma floridae	*262.59*	*791.74*	*0.38*	*0.95*	*1.37*	*16.25*
Haminoea succinea	*256.34*	*0.10*	*0.35*	*1.38*	*1.27*	*17.52*
Acteocina canaliculata	*365.71*	*0.10*	*0.35*	*1.25*	*1.26*	*18.78*
ONUPHIDAE	*271.98*	*0.10*	*0.34*	*1.17*	*1.24*	*20.02*
Capitella capitata	*512.58*	*0.10*	*0.34*	*0.86*	*1.23*	*21.25*
Macoma tenta	*296.96*	*18.85*	*0.33*	*1.23*	*1.20*	*22.44*
Hemipholis elongata	*296.96*	*179.26*	*0.32*	*1.05*	*1.15*	*23.59*
Cyclaspis cf. varians	*396.95*	*10.52*	*0.31*	*1.16*	*1.14*	*24.73*
ENTEROPNEUSTA	*34.48*	*350.09*	*0.31*	*0.95*	*1.13*	*25.86*

Groups B2a1 & B2a2

Average dissimilarity = 26.34

	Group B2a1	Group B2a2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Monticellina dorsobranchialis	132.00	2658.38	0.66	1.44	2.50	2.50
Mysella planulata	1905.07	68.85	0.65	2.00	2.48	4.98
Ampelisca holmesi	1258.86	8.43	0.63	2.16	2.37	7.35
Mediomastus ambiseta	1636.98	262.58	0.54	1.22	2.07	9.41
Prionospio perkinsi	237.02	1802.14	0.51	1.43	1.93	11.34
Carazziella hobsonae	88.23	1100.08	0.49	1.40	1.85	13.19
Amygdalum papyrium	813.22	0.10	0.45	1.28	1.72	14.92
Aricidea philbinae	635.09	12.60	0.42	1.22	1.58	16.50
Branchiostoma floridae	153.23	791.74	0.41	1.33	1.55	18.04
Scoloplos rubra	156.98	0.10	0.40	2.61	1.52	19.57
Nereis succinea	288.25	0.10	0.39	1.48	1.48	21.05
Magelona pettiboneae	171.98	2.18	0.38	2.14	1.44	22.49
Paraprionospio pinnata	292.00	291.75	0.36	1.27	1.37	23.86
TUBIFICIDAE	390.12	508.43	0.35	1.40	1.34	25.19

Groups B2b1 & B2a2

Average dissimilarity = 19.50

	Group B2b1	Group B2a2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Monticellina dorsobranchialis	52.98	2658.38	0.74	1.45	3.82	3.82
Prionospio perkinsi	108.11	1802.14	0.62	1.59	3.20	7.02
Carazziella hobsonae	191.44	1100.08	0.51	1.39	2.64	9.66
Pinnixa spp.	88.56	375.09	0.40	1.35	2.03	11.69
TUBIFICIDAE	241.44	508.43	0.40	1.25	2.03	13.72
Branchiostoma floridae	168.05	791.74	0.38	0.82	1.95	15.66
Paraprionospio pinnata	180.55	291.75	0.38	1.27	1.93	17.60
ENTEROPNEUSTA	18.37	350.09	0.36	1.05	1.83	19.42
Gyptis crypta	35.68	231.34	0.35	1.20	1.78	21.20
Sigambra tentaculata	61.00	193.85	0.33	1.40	1.70	22.91
Caecum strigosum	22.86	668.83	0.32	0.72	1.66	24.56
Podarkeopsis levifuscina	33.11	143.85	0.32	1.55	1.64	26.20

Groups B1 & B2b2

Average dissimilarity = 24.91

	Group B1	Group B2b2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	7112.53	392.40	0.83	1.51	3.33	3.33
Ampelisca holmesi	3353.19	224.13	0.73	1.61	2.94	6.27
Rudilemboides naglei	2078.19	3.47	0.48	0.89	1.94	8.21
Monticellina dorsobranchialis	53.23	735.19	0.41	1.17	1.64	9.85
Capitella capitata	512.58	47.70	0.36	0.97	1.45	11.30
Amygdalum papyrium	268.84	78.47	0.36	1.69	1.44	12.74
ONUPHIDAE	271.98	1.06	0.35	1.18	1.41	14.16
Cyclaspis cf. varians	396.95	38.08	0.35	1.22	1.40	15.56
Haminoea succinea	256.34	74.14	0.34	1.36	1.37	16.92
TUBIFICIDAE	253.23	636.62	0.34	1.32	1.35	18.28
Acteocina canaliculata	365.71	11.64	0.34	1.20	1.35	19.62
Macoma tenta	296.96	35.68	0.33	1.25	1.34	20.96
Carazziella hobsonae	34.48	623.20	0.33	0.89	1.31	22.27
Laeonereis culveri	875.08	120.29	0.33	0.73	1.31	23.57

Podarkeopsis levifuscina	312.59	74.14	0.30	1.25	1.20	24.78
Prionospio perkinsi	200.10	290.47	0.30	1.31	1.20	25.98

Groups B2a1 & B2b2

Average dissimilarity = 22.51

Species	Group B2a1 Av.Abund	Group B2b2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	1905.07	392.40	0.61	1.67	2.71	2.71
Ampelisca holmesi	1258.86	224.13	0.59	1.77	2.61	5.31
Mediomastus ambiseta	1636.98	106.85	0.57	1.20	2.55	7.87
Monticellina dorsobranchialis	132.00	735.19	0.43	1.18	1.92	9.78
Aricidea philbinae	635.09	18.37	0.43	1.22	1.91	11.69
Amygdalum papyrium	813.22	78.47	0.41	1.21	1.84	13.53
TUBIFICIDAE	390.12	636.62	0.39	1.31	1.71	15.24
Nereis succinea	288.25	128.94	0.36	1.39	1.59	16.83
Scoloplos rubra	156.98	17.89	0.35	1.86	1.57	18.40
Carazziella hobsonae	88.23	623.20	0.35	0.92	1.55	19.95
Paraprionospio pinnata	292.00	223.65	0.34	1.36	1.53	21.48
Prionospio perkinsi	237.02	290.47	0.33	1.29	1.47	22.95
Magelona pettiboneae	171.98	87.60	0.33	1.60	1.45	24.39
Streblospio spp.	239.47	303.45	0.32	0.95	1.43	25.82

Groups B2b1 & B2b2

Average dissimilarity = 16.65

Species	Group B2b1 Av.Abund	Group B2b2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Monticellina dorsobranchialis	52.98	735.19	0.48	1.16	2.86	2.86
TUBIFICIDAE	241.44	636.62	0.47	1.35	2.82	5.67
Carazziella hobsonae	191.44	623.20	0.42	1.02	2.53	8.20
Mysella planulata	80.55	392.40	0.37	1.13	2.21	10.41
Prionospio perkinsi	108.11	290.47	0.35	1.26	2.12	12.53
Paraprionospio pinnata	180.55	223.65	0.35	1.27	2.12	14.65
Ampelisca holmesi	181.50	224.13	0.34	0.99	2.06	16.71
Pinnixa spp.	88.56	94.33	0.29	1.21	1.74	18.44
Sigambra tentaculata	61.00	96.73	0.28	1.13	1.66	20.11
Streblospio spp.	51.38	303.45	0.27	0.71	1.60	21.70
Podarkeopsis levifuscina	33.11	74.14	0.26	1.21	1.56	23.26
ENTEROPNEUSTA	18.37	111.15	0.26	1.01	1.55	24.81
Branchiostoma floridae	168.05	71.25	0.24	0.82	1.46	26.27

Groups B2a2 & B2b2

Average dissimilarity = 20.60

Species	Group B2a2 Av.Abund	Group B2b2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Monticellina dorsobranchialis	2658.38	735.19	0.61	1.41	2.98	2.98
Carazziella hobsonae	1100.08	623.20	0.54	1.47	2.64	5.62
Prionospio perkinsi	1802.14	290.47	0.52	1.44	2.54	8.16
TUBIFICIDAE	508.43	636.62	0.40	1.35	1.93	10.10
Branchiostoma floridae	791.74	71.25	0.37	0.87	1.79	11.88
Paraprionospio pinnata	291.75	223.65	0.37	1.26	1.79	13.67
ENTEROPNEUSTA	350.09	111.15	0.36	1.17	1.74	15.41
Pinnixa spp.	375.09	94.33	0.35	1.33	1.70	17.11
Mysella planulata	68.85	392.40	0.34	1.09	1.63	18.75
Sigambra tentaculata	193.85	96.73	0.34	1.41	1.63	20.37
Gyptis crypta	231.34	32.31	0.33	1.20	1.62	22.00

Caecum strigosum	668.83	15.48	0.30	0.68	1.47	23.47
Paramphinome B	350.08	52.98	0.30	0.84	1.45	24.91
Erycina floridana	189.68	15.48	0.28	0.95	1.38	26.29

Groups B1 & A2

Average dissimilarity = 23.34

	Group B1	Group A2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	7112.53	5.10	1.12	1.80	4.79	4.79
Ampelisca holmesi	3353.19	5.10	0.94	1.99	4.02	8.81
Rudilemboides naglei	2078.19	1.35	0.53	0.87	2.27	11.08
Amygdalum papyrium	268.84	3.85	0.47	2.24	2.03	13.11
TUBIFICIDAE	253.23	31.35	0.45	1.74	1.93	15.05
Cyclaspis cf. varians	396.95	1.35	0.40	1.24	1.71	16.76
Macoma tenta	296.96	2.60	0.39	1.19	1.68	18.44
Haminoea succinea	256.34	1.35	0.39	1.38	1.68	20.12
ONUPHIDAE	271.98	0.10	0.39	1.17	1.67	21.79
Acteocina canaliculata	365.71	1.35	0.39	1.24	1.67	23.45
Capitella capitata	512.58	1.35	0.39	0.88	1.66	25.11

Groups B2a1 & A2

Average dissimilarity = 21.25

	Group B2a1	Group A2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	1905.07	5.10	0.92	2.95	4.35	4.35
Ampelisca holmesi	1258.86	5.10	0.76	2.39	3.60	7.95
Mediomastus ambiseta	1636.98	0.10	0.64	1.19	3.03	10.98
Amygdalum papyrium	813.22	3.85	0.50	1.25	2.36	13.34
Aricidea philbinae	635.09	1.35	0.49	1.23	2.33	15.67
Scoloplos rubra	156.98	0.10	0.46	2.62	2.16	17.82
TUBIFICIDAE	390.12	31.35	0.45	1.32	2.14	19.96
Magelona pettiboneae	171.98	0.10	0.45	2.32	2.13	22.09
Nereis succinea	288.25	3.85	0.43	1.48	2.02	24.12
Paraprionospio pinnata	292.00	17.60	0.40	1.31	1.88	26.00

Groups B2b1 & A2

Average dissimilarity = 10.69

	Group B2b1	Group A2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Paraprionospio pinnata	180.55	17.60	0.38	1.20	3.56	3.56
TUBIFICIDAE	241.44	31.35	0.36	0.94	3.35	6.91
Carazziella hobsonae	191.44	21.35	0.32	0.95	2.95	9.86
Prionospio perkinsi	108.11	12.60	0.31	1.13	2.92	12.78
Ampelisca holmesi	181.50	5.10	0.29	0.83	2.72	15.50
Mysella planulata	80.55	5.10	0.26	0.92	2.47	17.97
Sigambra tentaculata	61.00	11.35	0.25	1.02	2.34	20.31
Pinnixa spp.	88.56	6.98	0.24	0.87	2.26	22.57
Paramphinome B	54.91	13.85	0.22	0.88	2.02	24.59
Podarkeopsis levifuscina	33.11	11.35	0.20	0.92	1.92	26.50

Groups B2a2 & A2

Average dissimilarity = 17.95

Species	Group B2a2 Av.Abund	Group A2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Prionospio perkinsi	1802.14	12.60	0.86	2.30	4.77	4.77
Monticellina dorsobranchialis	2658.38	20.10	0.82	1.47	4.58	9.35
Carazziella hobsonae	1100.08	21.35	0.61	1.47	3.37	12.72
TUBIFICIDAE	508.43	31.35	0.50	1.41	2.77	15.49
Pinnixa spp.	375.09	6.98	0.48	1.46	2.68	18.18
Sigambra tentaculata	193.85	11.35	0.40	1.47	2.22	20.40
ENTEROPNEUSTA	350.09	31.98	0.38	1.03	2.12	22.52
Gyptis crypta	231.34	10.73	0.38	1.19	2.11	24.62
Podarkeopsis levifuscina	143.85	11.35	0.38	1.76	2.10	26.73

Groups B2b2 & A2

Average dissimilarity = 14.28

Species	Group B2b2 Av.Abund	Group A2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
TUBIFICIDAE	636.62	31.35	0.58	1.38	4.05	4.05
Monticellina dorsobranchialis	735.19	20.10	0.51	1.14	3.60	7.65
Prionospio perkinsi	290.47	12.60	0.41	1.22	2.86	10.51
Carazziella hobsonae	623.20	21.35	0.39	0.84	2.75	13.26
Mysella planulata	392.40	5.10	0.38	0.93	2.64	15.90
Paraprionospio pinnata	223.65	17.60	0.36	1.11	2.52	18.42
Pinnixa spp.	94.33	6.98	0.29	1.12	2.02	20.44
ENTEROPNEUSTA	111.15	31.98	0.28	1.02	1.99	22.43
Podarkeopsis levifuscina	74.14	11.35	0.27	1.18	1.92	24.35
Ampelisca holmesi	224.13	5.10	0.26	0.76	1.85	26.20

Groups B1 & B2

Average dissimilarity = 23.55

Species	Group B1 Av.Abund	Group B2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	7112.53	20000.00	0.69	1.27	2.94	2.94
Shoemakerella lowreyi	21.98	725.10	0.61	3.74	2.59	5.54
Aricidea philbinae	71.98	450.10	0.46	1.93	1.94	7.47
Prionospio heterobranchia	40.73	450.10	0.45	2.19	1.91	9.38
Rudilemboides naglei	2078.19	0.10	0.45	0.81	1.90	11.29
Tubificoides wasselli	856.33	100.10	0.44	3.95	1.85	13.14
Ampelisca vadorum	3.23	175.10	0.41	4.69	1.75	14.88
Ampelisca holmesi	3353.19	5050.00	0.41	1.66	1.73	16.61
Capitella capitata	512.58	350.10	0.39	2.36	1.67	18.28
Oxyurostylis smithi	59.48	375.10	0.39	1.79	1.66	19.95
Odostomia producta	12.60	150.10	0.37	2.81	1.59	21.54
Dyspanopeus texanus	0.10	100.10	0.37	22.57	1.58	23.12
Grandidierella bonnieroides	0.10	100.10	0.37	22.57	1.58	24.70
Cyclaspis cf. varians	396.95	625.10	0.37	2.02	1.58	26.28

Groups B2a1 & B2

Average dissimilarity = 22.24

Species	*Group B2a1 Av.Abund*	*Group B2 Av.Abund*	*Av.Diss*	*Diss/SD*	*Contrib%*	*Cum.%*
Mysella planulata	*1905.07*	*20000.00*	*0.87*	*3.21*	*3.91*	*3.91*
Shoemakerella lowreyi	*1.35*	*725.10*	*0.67*	*10.36*	*3.00*	*6.91*
Mediomastus ambiseta	*1636.98*	*0.10*	*0.54*	*1.16*	*2.45*	*9.35*
Cyclaspis cf. varians	*28.23*	*625.10*	*0.50*	*2.85*	*2.26*	*11.61*
Oxyurostylis smithi	*28.85*	*375.10*	*0.48*	*2.78*	*2.14*	*13.76*
Ampelisca holmesi	*1258.86*	*5050.00*	*0.47*	*1.78*	*2.13*	*15.88*
Nemertea J	*5.10*	*225.10*	*0.47*	*5.38*	*2.10*	*17.98*
Odostomia producta	*0.10*	*150.10*	*0.43*	*23.06*	*1.94*	*19.92*
Ampelisca vadorum	*6.98*	*175.10*	*0.42*	*3.88*	*1.89*	*21.81*
Dyspanopeus texanus	*0.10*	*100.10*	*0.38*	*23.06*	*1.72*	*23.52*
Tubificoides wasselli	*0.10*	*100.10*	*0.38*	*23.06*	*1.72*	*25.24*

Groups B2b1 & B2

Average dissimilarity = 22.55

Species	*Group B2b1 Av.Abund*	*Group B2 Av.Abund*	*Av.Diss*	*Diss/SD*	*Contrib%*	*Cum.%*
Mysella planulata	*80.55*	*20000.00*	*1.64*	*6.01*	*7.26*	*7.26*
Ampelisca holmesi	*181.50*	*5050.00*	*1.06*	*3.21*	*4.68*	*11.94*
Shoemakerella lowreyi	*0.10*	*725.10*	*0.76*	*30.93*	*3.36*	*15.30*
Cyclaspis cf. varians	*8.43*	*625.10*	*0.70*	*5.87*	*3.09*	*18.39*
Prionospio heterobranchia	*2.98*	*450.10*	*0.64*	*7.08*	*2.84*	*21.22*
Oxyurostylis smithi	*5.23*	*375.10*	*0.58*	*5.05*	*2.59*	*23.81*
Aricidea philbinae	*25.74*	*450.10*	*0.56*	*2.98*	*2.49*	*26.30*

Groups B2a2 & B2

Average dissimilarity = 27.97

Species	*Group B2a2 Av.Abund*	*Group B2 Av.Abund*	*Av.Diss*	*Diss/SD*	*Contrib%*	*Cum.%*
Mysella planulata	*68.85*	*20000.00*	*1.53*	*6.17*	*5.49*	*5.49*
Ampelisca holmesi	*8.43*	*5050.00*	*1.11*	*8.45*	*3.96*	*9.45*
Monticellina dorsobranchialis	*2658.38*	*0.10*	*0.73*	*1.43*	*2.60*	*12.05*
Shoemakerella lowreyi	*0.10*	*725.10*	*0.70*	*48.40*	*2.51*	*14.55*
Prionospio heterobranchia	*0.10*	*450.10*	*0.61*	*48.40*	*2.19*	*16.75*
Cyclaspis cf. varians	*10.52*	*625.10*	*0.58*	*4.26*	*2.09*	*18.83*
Oxyurostylis smithi	*0.10*	*375.10*	*0.58*	*48.40*	*2.08*	*20.91*
Amygdalum papyrium	*0.10*	*375.10*	*0.58*	*48.40*	*2.08*	*22.99*
Capitella capitata	*0.10*	*350.10*	*0.57*	*48.40*	*2.04*	*25.03*

Groups B2b2 & B2

Average dissimilarity = 23.85

Species	Group B2b2 Av.Abund	Group B2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	392.40	20000.00	1.47	3.75	6.17	6.17
Ampelisca holmesi	224.13	5050.00	1.03	3.14	4.33	10.50
Shoemakerella lowreyi	0.10	725.10	0.73	28.35	3.06	13.56
Cyclaspis cf. varians	38.08	625.10	0.62	3.60	2.60	16.17
Prionospio heterobranchia	7.79	450.10	0.59	4.78	2.47	18.64
Oxyurostylis smithi	1.54	375.10	0.59	8.32	2.46	21.10
Aricidea philbinae	18.37	450.10	0.57	3.55	2.37	23.48
Capitella capitata	47.70	350.10	0.50	2.58	2.11	25.59

Groups A2 & B2

Average dissimilarity = 22.05

Species	Group A2 Av.Abund	Group B2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	5.10	20000.00	1.94	18.23	8.80	8.80
Ampelisca holmesi	5.10	5050.00	1.32	11.35	5.97	14.77
Shoemakerella lowreyi	0.10	725.10	0.80	76.16	3.63	18.40
Cyclaspis cf. varians	1.35	625.10	0.75	11.34	3.42	21.82
Prionospio heterobranchia	0.10	450.10	0.70	76.16	3.18	25.00

Groups B1 & A1

Average dissimilarity = 23.06

Species	Group B1 Av.Abund	Group A1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	7112.53	0.10	1.16	1.81	5.02	5.02
Ampelisca holmesi	3353.19	0.10	1.01	2.14	4.36	9.38
Rudilemboides naglei	2078.19	0.10	0.54	0.86	2.34	11.71
Amygdalum papyrium	268.84	0.10	0.51	2.59	2.23	13.94
TUBIFICIDAE	253.23	3.95	0.45	1.72	1.94	15.89
Prionospio perkinsi	200.10	0.10	0.43	1.53	1.85	17.74
Cyclaspis cf. varians	396.95	0.10	0.41	1.25	1.79	19.53
Podarkeopsis levifuscina	312.59	0.10	0.41	1.24	1.79	21.32
Haminoea succinea	256.34	0.10	0.41	1.39	1.76	23.08
Macoma tenta	296.96	0.10	0.40	1.18	1.76	24.84
Acteocina canaliculata	365.71	0.10	0.40	1.25	1.75	26.59

Groups B2a1 & A1

Average dissimilarity = 20.73

Species	Group B2a1 Av.Abund	Group A1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	1905.07	0.10	0.96	3.15	4.66	4.66
Ampelisca holmesi	1258.86	0.10	0.83	2.71	4.00	8.65
Mediomastus ambiseta	1636.98	0.10	0.66	1.19	3.17	11.83
Amygdalum papyrium	813.22	0.10	0.53	1.28	2.55	14.38
Aricidea philbinae	635.09	0.10	0.51	1.23	2.47	16.85
Scoloplos rubra	156.98	0.10	0.47	2.62	2.26	19.11
Magelona pettiboneae	171.98	0.10	0.46	2.32	2.23	21.34
TUBIFICIDAE	390.12	3.95	0.46	1.34	2.20	23.54
Nereis succinea	288.25	0.10	0.45	1.48	2.19	25.73

Groups B2b1 & A1

Average dissimilarity = 9.58

Species	Group B2b1 Av.Abund	Group A1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Paraprionospio pinnata	180.55	7.79	0.39	1.21	4.03	4.03
TUBIFICIDAE	241.44	3.95	0.35	0.93	3.66	7.69
Prionospio perkinsi	108.11	0.10	0.33	1.07	3.45	11.14
Carazziella hobsonae	191.44	0.10	0.31	0.83	3.26	14.40
Ampelisca holmesi	181.50	0.10	0.29	0.75	2.98	17.39
Mysella planulata	80.55	0.10	0.27	0.91	2.79	20.18
Sigambra tentaculata	61.00	0.10	0.25	0.92	2.61	22.79
Pinnixa spp.	88.56	0.10	0.24	0.80	2.48	25.27

Groups B2a2 & A1

Average dissimilarity = 17.66

Species	Group B2a2 Av.Abund	Group A1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Prionospio perkinsi	1802.14	0.10	0.97	2.83	5.47	5.47
Monticellina dorsobranchialis	2658.38	2.02	0.87	1.48	4.94	10.41
Carazziella hobsonae	1100.08	0.10	0.69	1.57	3.92	14.33
Pinnixa spp.	375.09	0.10	0.52	1.52	2.96	17.29
TUBIFICIDAE	508.43	3.95	0.49	1.37	2.79	20.08
Podarkeopsis levifuscina	143.85	0.10	0.46	2.37	2.59	22.66
Sigambra tentaculata	193.85	0.10	0.45	1.54	2.56	25.22

Groups B2b2 & A1

Average dissimilarity = 13.54

Species	Group B2b2 Av.Abund	Group A1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
TUBIFICIDAE	636.62	3.95	0.58	1.38	4.32	4.32
Monticellina dorsobranchialis	735.19	2.02	0.54	1.11	3.96	8.28
Prionospio perkinsi	290.47	0.10	0.46	1.25	3.36	11.64
Mysella planulata	392.40	0.10	0.39	0.91	2.84	14.48
Carazziella hobsonae	623.20	0.10	0.38	0.71	2.78	17.26
Paraprionospio pinnata	223.65	7.79	0.36	1.09	2.66	19.93
Pinnixa spp.	94.33	0.10	0.30	1.09	2.23	22.16
Podarkeopsis levifuscina	74.14	0.10	0.30	1.16	2.19	24.35
ENTEROPNEUSTA	111.15	0.10	0.27	0.87	2.00	26

Groups A2 & A1

Average dissimilarity = 3.03

Species	*Group A2 Av.Abund*	*Group A1 Av.Abund*	*Av.Diss*	*Diss/SD*	*Contrib%*	*Cum.%*
Ampelisca abdita	*45.10*	*0.10*	*0.17*	*0.63*	*5.57*	*5.57*
Paraprionospio pinnata	*17.60*	*7.79*	*0.16*	*0.72*	*5.29*	*10.86*
ENTEROPNEUSTA	*31.98*	*0.10*	*0.15*	*0.60*	*4.97*	*15.83*
Carazziella hobsonae	*21.35*	*0.10*	*0.14*	*0.62*	*4.64*	*20.47*
Paramphinome B	*13.85*	*2.02*	*0.14*	*0.70*	*4.56*	*25.04*

Groups B2 & A1

Average dissimilarity = 21.56

Species	*Group B2 Av.Abund*	*Group A1 Av.Abund*	*Av.Diss*	*Diss/SD*	*Contrib%*	*Cum.%*
Mysella planulata	*20000.00*	*0.10*	*2.00*	*353.17*	*9.29*	*9.29*
Ampelisca holmesi	*5050.00*	*0.10*	*1.39*	*353.17*	*6.45*	*15.74*
Shoemakerella lowreyi	*725.10*	*0.10*	*0.82*	*353.17*	*3.79*	*19.54*
Cyclaspis cf. varians	*625.10*	*0.10*	*0.78*	*353.17*	*3.64*	*23.18*
Prionospio heterobranchia	*450.10*	*0.10*	*0.71*	*353.17*	*3.32*	*26.50*

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

Groups 94 & 93
Average dissimilarity = 18.74

Species	Group 94 Av.Abund	Group 93 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mediomastus ambiseta	572.44	1499.48	0.56	1.23	2.99	2.99
Mysella planulata	598.77	946.81	0.51	1.27	2.70	5.68
TUBIFICIDAE	571.14	403.40	0.45	1.18	2.38	8.06
Carazziella hobsonae	181.67	644.88	0.43	1.10	2.30	10.36

Groups 95 & 94
Average dissimilarity = 13.81

Species	Group 95 Av.Abund	Group 94 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
TUBIFICIDAE	353.54	571.14	0.47	1.05	3.37	3.37
Ampelisca holmesi	537.14	255.35	0.44	1.00	3.18	6.55
Mysella planulata	188.02	598.77	0.44	1.08	3.16	9.71
Mediomastus ambiseta	0.10	572.44	0.40	0.90	2.92	12.63

Groups 96 & 95
Average dissimilarity = 16.06

Species	Group 96 Av.Abund	Group 95 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	2318.59	188.02	0.54	1.03	3.39	3.39
Ampelisca holmesi	366.76	537.14	0.45	1.12	2.81	6.20
TUBIFICIDAE	226.02	353.54	0.40	1.07	2.48	8.68
Amygdalum papyrium	101.02	541.47	0.35	0.95	2.21	10.89

Appendix E- (continued)

Groups 96 & 97
Average dissimilarity = 20.04

Species	Group 96 Av.Abund	Group 97 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Mysella planulata	2318.59	1421.67	0.58	1.12	2.88	2.88
Monticellina dorsobranchialis	577.87	680.76	0.47	1.04	2.33	5.21
Ampelisca holmesi	366.76	1283.04	0.45	1.01	2.24	7.45
Carazziella hobsonae	458.43	296.68	0.39	1.04	1.94	9.39
Prionospio perkinsi	138.99	351.23	0.37	1.25	1.86	11.25

Groups 97 & 98
Average dissimilarity = 17.83

Species	Group 97 Av.Abund	Group 98 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Monticellina dorsobranchialis	680.76	392.48	0.47	1.11	2.63	2.63
Prionospio perkinsi	351.23	807.69	0.44	1.31	2.46	5.09
Ampelisca holmesi	1283.04	96.84	0.42	0.94	2.35	7.43
Mysella planulata	1421.67	25.10	0.42	0.91	2.35	9.78
Carazziella hobsonae	296.68	196.83	0.36	1.19	2.00	11.79