BENTHIC HABITAT STATUS OF THE LOWER HILLSBOROUGH, PALM, ALAFIA AND LITTLE MANATEE RIVERS: 1995-2000

Stephen A. Grabe, David J. Karlen, Lucia Gutierrez-Antrim,

Christina M. Holden, & Barbara Goetting

Environmental Protection Commission of Hillsborough County

Prepared For:
Southwest Florida Water Management District

March 2002

Environmental Protection Commission of Hillsborough County

Dr. Richard Garrity

Executive Director

Christopher A. Dunn

Director, Water Management Division

Tom Cardinale

Assistant Director, Water Management Division

Environmental Monitoring and Analysis

-ACKNOWLEDGEMENTS

Funding was provided by the Southwest Florida Water Management District (SWFWMD), Alafia River and Hillsborough River Basin Boards, the Hillsborough County Board of County Commissioners, and the Environmental Protection Commission of Hillsborough County. Tom Ash, Glenn Lockwood, and Richard Boler assisted with field collections and instrument calibration. Shanin Shapiro prepared the maps for this report. Sara Markham, Janna Otto, and Briane Wright-Weber assisted with sample processing. Amy Remly (SWFWMD) reviewed an earlier draft.

EXECUTIVE SUMMARY

In 1993 the Environmental Protection Commission of Hillsborough County (EPCHC) began participating in a bay-wide benthic/sediment contaminant monitoring program initiated under the auspices of the Tampa Bay National Estuary Program (1996). The original objectives of this program were to discern the “health”—or “status”-- of the bay’s sediments by monitoring both sediment contaminants as well as the assemblage of animals (benthic macroinvertebrates) which inhabit these sediments. The Lower Hillsborough, Palm, and Alafia rivers were added to the bay-wide monitoring program, as separate strata, in 1995. This was in anticipation of these tributaries being exploited for their water resources; the Little Manatee River was added in 1996. This report summarizes data collected during the period 1995- 2000 sampling period.

During 2000, the salinities of the near-bottom waters were generally the highest of the years studied due to the regional drought. Palm River salinities were the highest of the four tributaries. Both the Palm and Lower Hillsborough rivers show evidence of stress from low dissolved oxygen.

Sediment contamination was widespread in the Lower Hillsborough and Palm rivers with some contaminants detected at concentrations likely to be toxic to aquatic life. These include polycyclic aromatic hydrocarbons, the pesticide chlordane, and zinc in the Lower Hillsborough River and PCBs in the Palm River. To date, the Little Manatee River shows little evidence of sediment contamination.

Benthic communities differed by tributary with respect to numbers and types of animals. The two tributaries with the highest densities of organisms and greatest diversity differed markedly in species composition: polychaete worms predominated in the Lower Hillsborough River and crustaceans (*e.g.*, shrimps, crabs, amphipods) predominated in the Little Manatee River. Low dissolved oxygen conditions contributed to a high frequency of Palm River benthic samples being devoid of animals.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

I. INTRODUCTION

In 1993 the Environmental Protection Commission of Hillsborough County (EPCHC) began participating in a bay-wide benthic/sediment contaminant monitoring program initiated under the auspices of the Tampa Bay National Estuary Program (1996). The original objectives of this program were to discern the “health”—or “status”-- of the bay’s sediments by monitoring both sediment contaminants as well as the assemblage of macroinvertebrates which inhabit these sediments.

The Lower Hillsborough, Palm, and Alafia rivers were added to the bay-wide monitoring program, as separate strata, in 1995. This was in anticipation of these tributaries being exploited for their water resources; the Little Manatee River was added in 1996. Since 1998, partial support for this monitoring was provided by the Southwest Florida Water Management District (SWFWMD).

In late 1998, Tampa Bay Water (TBW) developed a Master Water Plan (Tampa Bay Water 1998) to provide additional water resources for the Tampa Bay region. An element of this plan includes the withdrawal of up to 10% of the surface water flow over 80 mgd (8 mgd to a maximum of 51.7 mgd) from the Alafia River at Bell Shoals Road (PBS&J 1999). The diverted water will be pumped to a surface reservoir in southern Hillsborough County. This proposal would, in effect, reduce the flow of freshwater to the lower Alafia River during periods of high flow. Additionally, flow over the Hillsborough River dam and Structure 160 in the Palm River/Tampa By-Pass Canal could also be reduced, thereby retaining more water for human consumption as well.

In response to TBW’s plan, the Hillsborough County Board of County Commissioners requested that the Hillsborough County Water Resource Team and EPCHC staff develop a monitoring program independent of TBW’s permit requirements. The EPCHC proposed enhanced sampling of benthic macroinvertebrates in the Lower Hillsborough, Palm, and Alafia rivers during the three “wet seasons” preceding the initiation of withdrawals. This pre-diversion sampling would then be followed by at least three years of post-diversion sampling. The Little Manatee River was added as a “reference” estuary. The inclusion of this reference location, unaffected by freshwater diversions/withdrawals, may facilitate interpretation of trends in the biota of the affected tributaries. This report summarizes data collected during the period 1995- 2000 sampling period.

II. METHODS

II.1 Field Collection and Laboratory Procedures

A total of 269 samples were collected for benthic macroinvertebrates and 130 samples were collected for sediment chemistry during the six year period (Figures 1-4; Table 1). Sample locations were randomly selected from computer- generated coordinates provided by Janicki Environmental, Inc. (St. Petersburg, FL). Benthic and sediment samples were collected using a Young grab sampler following the field protocols outlined in Courtney *et. al*. (1993). Laboratory procedures followed the protocols set forth in Courtney *et. al*. (1995).

Table 1. Number of benthic and sediment chemistry samples collected: by tributary and year.

TRIBUTARY	HILLSBOROUGH RIVER	PALM RIVER	ALAFIA RIVER	LITTLE MANATEE RIVER
BENTHIC MACROINVERTEBRATES				
1995	3	3	5	0
1996	5	3	5	4
1997	5	5	7	5
1998	8	5	5	6
1999	19	20	40	20
2000	19	21	38	18
TOTAL	59	57	100	53
SEDIMENT CHEMISTRY				
1995	3	3	5	0
1996	5	3	5	4
1997	5	5	7	6
1998	7	5	5	6
1999	11	6	9	8
2000	5	5	7	5
TOTAL	36	27	38	29

II.2 Data Analysis

Species richness (S), Shannon-Wiener diversity (H'), and Evenness (J) (Pielou 1975) were calculated using PISCES Conservation Ltd.'s (2000) "Species Diversity and Richness II" software.

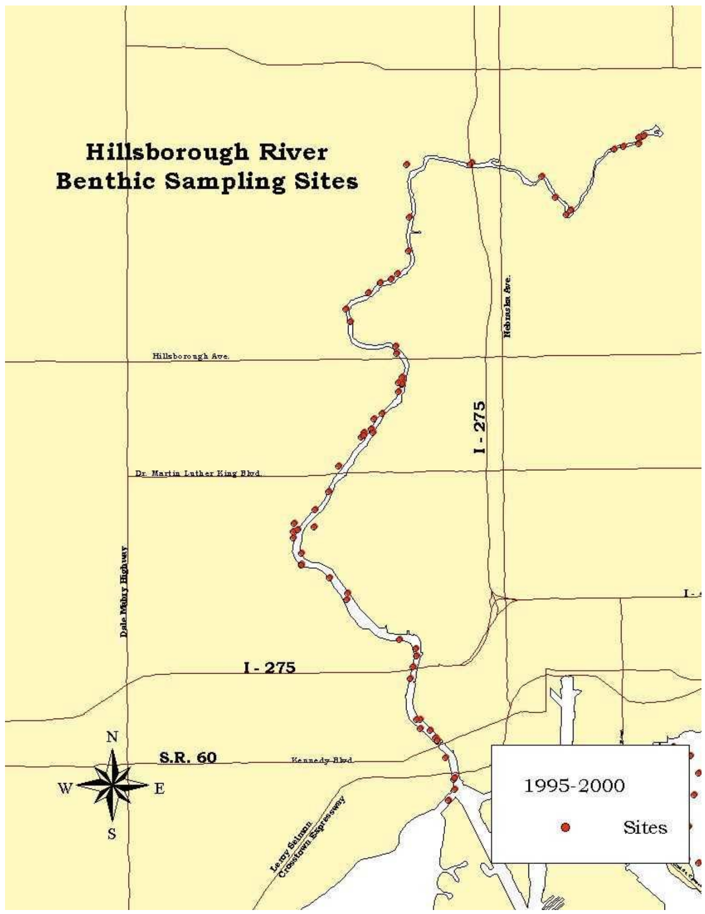

Figure 1. Location of sampling stations in the Lower Hillsborough River, 1995-2000.

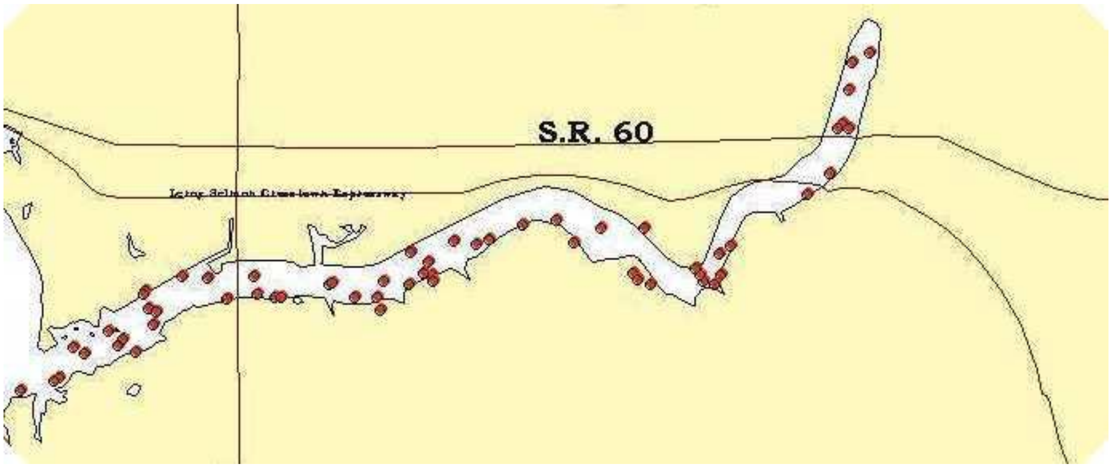

Figure 2. Location of sampling stations in the Palm River, 1995-2000.

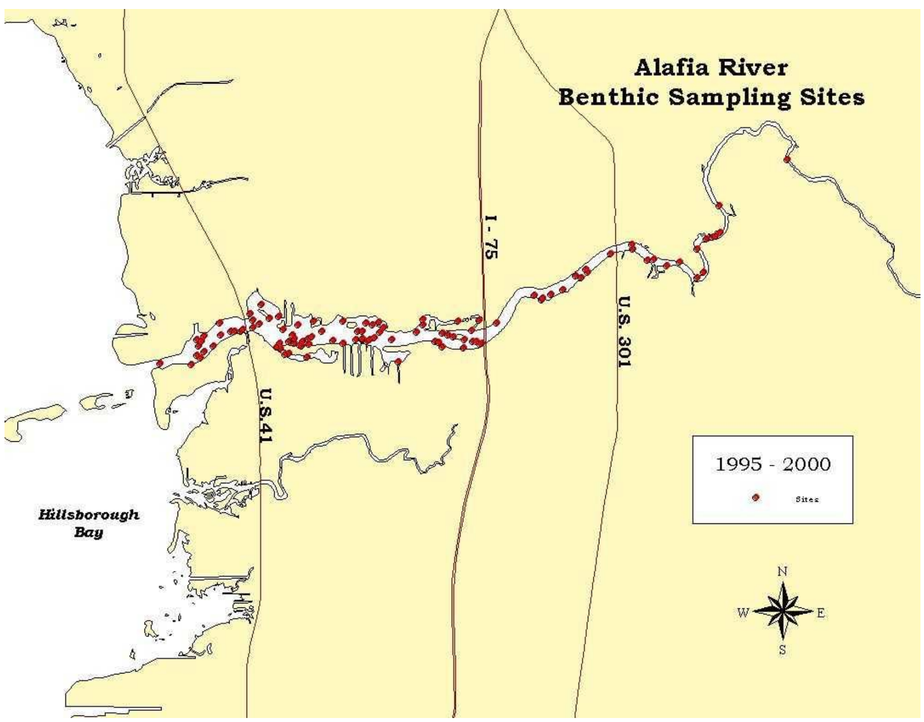

Figure 3. Location of sampling stations in the Alafia River, 1995-2000.

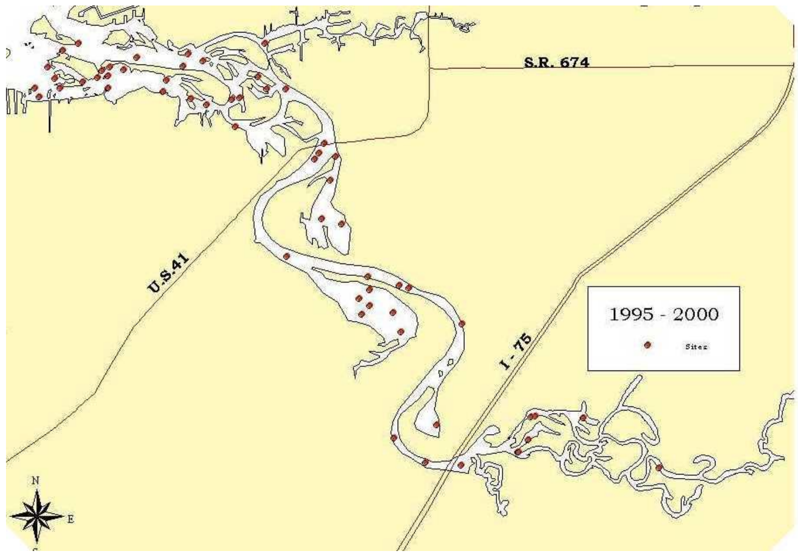

Figure 4. Location of sampling stations in the Little Manatee River, 1996-2000.

To examine whether the temperature-salinity signatures differed between tributaries and years, multivariate analysis of variance (MANOVA) was used (Johnson & Wichern 1988) with $\log_{10}$ n+1 transformed variables (*cf*. Sokal & Rohlf 1981). Where significant effects were found in MANOVA, univariate analysis of variance (ANOVA) were used to determine which effect is significant and then an *a posteriori* test for equality of means (Bonferroni comparison; Neter *et al*. 1985) was applied.

Association/regression analyses were used to examine relationships between the Tampa Bay Benthic Index (TBBI) (Coastal Environmental Services, Inc. 1995) and measured physico-chemical variables. The association between the TBBI and depth in the Palm River was evaluated using piecewise regression (SPSS Inc. 2000).

Equality of frequency distributions (untransformed data) was tested by the Kolmogorov-Smirnov two-sample test (KS) (Sokal & Rohlf 1981).

Descriptive statistics, ANOVA, MANOVA, association/regression analysis, Kolmogorov-Smirnov two-sample test and graphs of hydrographic and biological data were generated using SYSTAT 10 (SSPS Inc. 2000). Maps were generated using GIS Arcview ver. 3.2 (ESRI 1999).

III. RESULTS

III.1 <u>Hydrographic</u>

Table 2 summarizes the surface and bottom hydrographic data for 1995-2000 for the four tributaries.

MANOVA showed that the temperature-salinity characteristics of near-bottom waters differed by tributary (Wilkes' Lambda $_{6,536}$=0.87; *p*<0.001) (Figure 5). Univariate tests showed that mean near-bottom water temperatures differed by tributary ($F_{3,269}$=12.3; *p*<0.001) although mean near-bottom salinities were not significantly different (*p*=0.87). Water temperatures in the Lower Hillsborough River and Palm River were higher than those in the Alafia and Little Manatee rivers (Figure 6). The frequency distributions of near-bottom water temperatures were significantly different among the four rivers (KS test *p*<.001-0.019; Figure 7). The frequency distributions of salinity were similar (KS test *p*>0.05) in the Little Manatee and Hillsborough rivers, where mesohaline salinities (5-18 ppt) predominated; the Palm River was predominantly polyhaline (18-30 ppt) (Figures 8 and 9).

MANOVA also showed that there were differences in temperature-salinity characteristics between years (Wilkes' Lambda $_{10,536}$=0.56; *p*<0.001) (Figure 10). Both salinities ($F_{5,269}$=3.2;*p*<0.01) and temperatures ($F_{5,269}$=37;*p*<0.001) differed between years. Highest temperatures were recorded during 1999 and 2000 and temperatures were lowest during 1997 (Figure 6). Mean salinities differed between years ($F_{5,280}$=13.6; *p*<0.001), with highest salinities during 2000 and 1996 and lowest salinities recorded during 1997, 1995, and 1998 (Figure 9).

Table 2. Summary of physico-chemical variables in four tributaries to Tampa Bay: 1995-2000.

SURFACE

	TEMPERATURE					SALINITY					DISSOLVED OXYGEN					PH			
	HR	PR	AR	LMR		HR	PR	AR	LMR		HR	PR	AR	LMR		HR	PR	AR	LMR
MIN	25.4	25.5	25.3	25.5		0.0	0.3	0.0	0.0		2.0	0.4	1.9	3.0		6.81	6.52	6.68	6.15
MAX	31.2	32.2	31.4	30.0		19.2	26.4	24.7	23.6		7.0	10.3	7.7	10.3		7.98	8.28	8.12	8.52
MEDIAN	28.5	30.3	28.1	27.7		2.2	18.4	6.1	6.1		4.7	4.8	4.4	5.1		7.20	7.70	7.35	7.40
MEAN	28.4	29.8	28.1	27.6		4.3	16.6	6.6	7.8		4.4	5.0	4.6	5.5		7.23	7.60	7.39	7.32

BOTTOM

	TEMPERATURE					SALINITY					DISSOLVED OXYGEN					PH			
	HR	PR	AR	LMR		HR	PR	AR	LMR		HR	PR	AR	LMR		HR	PR	AR	LMR
MIN	25.5	25.5	25.3	25.5		0.0	0.4	0.0	0.0		<0.1	<0.1	0.2	0.6		6.76	6.52	6.59	6.14
MAX	31.1	31.1	30.7	30.9		28.3	28.1	29.5	25.8		6.9	8.9	6.1	8.4		7.98	8.12	8.03	8.22
MEDIAN	29.1	30.4	28.7	27.7		9.2	24.6	17.0	7.2		1.9	0.6	2.0	4.3		7.12	7.49	7.44	7.32
MEAN	28.9	29.8	28.5	27.9		11.1	22.3	14.9	9.1		2.7	1.5	2.5	4.5		7.18	7.44	7.44	7.31

HR= Lower Hillsborough River; PR=Palm River; AR= Alafia River; LMR=Little Manatee River (1996-2000)

Mean dissolved oxygen concentrations were lowest in the Palm and Lower Hillsborough rivers and highest in the Little Manatee River ($F_{3,274}$=23.0; p<0.001; Figure 11). More than 75% of the Palm River samples and approximately 50% of the Lower Hillsborough and Alafia river samples near- bottom DO measurements were indicative of hypoxia (DO<2

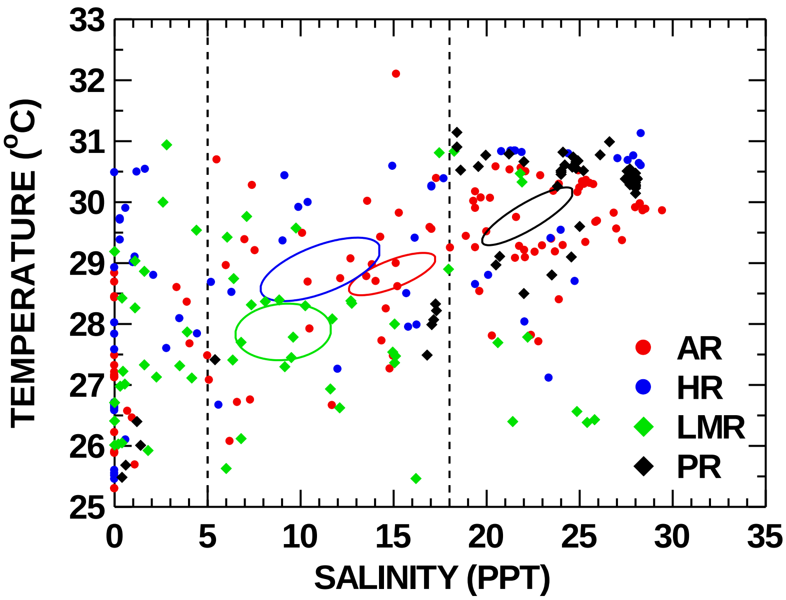

Figure 5. Temperature-salinity plot (near-bottom) of stations sampled for benthos: by tributary, 1995-2000. Ellipses demarcate standard deviations around the mean and the orientation represents the Pearson correlation between temperature and salinity.

ppm) (Figure 12). The KS test showed that the distributions of DO in the Alafia and Hillsborough rivers were similar (p>0.05; Figure 12). Figures 13-34 show the spatial extents, by survey period, of dissolved oxygen conditions in each tributary.

Mean DO also differed among salinity zones ($F_{3,274}$=50.6; p<0.001). Highest mean DO concentrations were found in tidal freshwaters and the lowest mean DO was found in polyhaline waters (Figure 11). DO concentrations were similar among years ($F_{5,274}$=2.0;p>0.07)

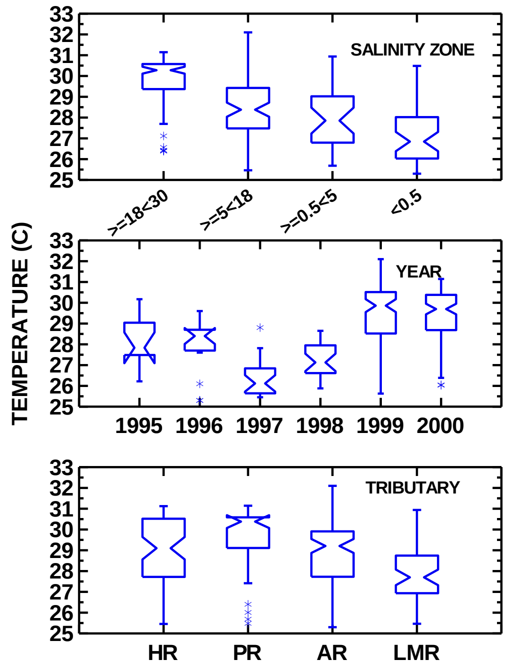

Figure 6. Notched box plot of median and 95% confidence limits of near-bottom water temperature by salinity zone, year, and tributary.

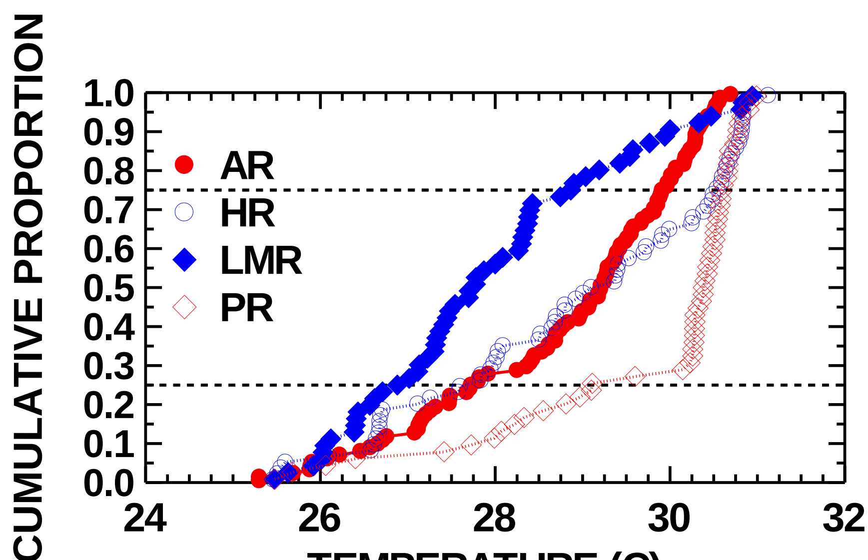

Figure 7. Cumulative distribution function plot of near-bottom water temperatures: by tributary, 1995-2000.

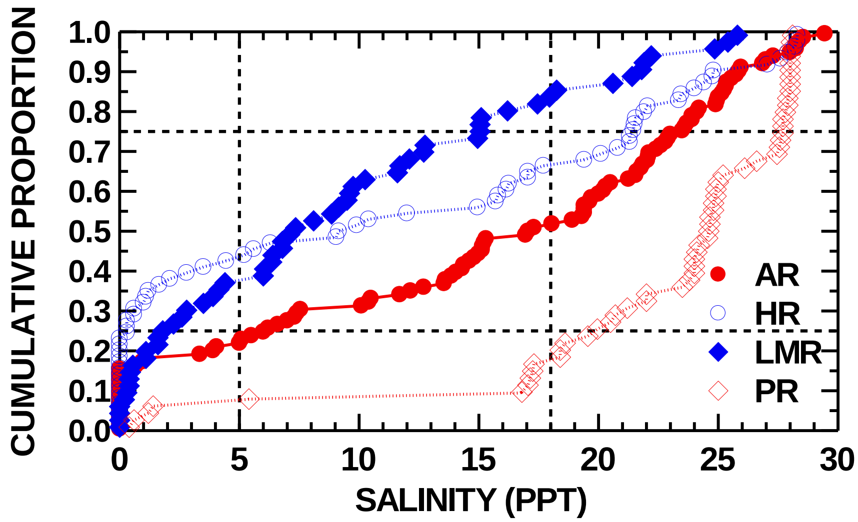

Figure 8. Cumulative distribution function plot of near-bottom salinities: by tributary, 1995-2000.

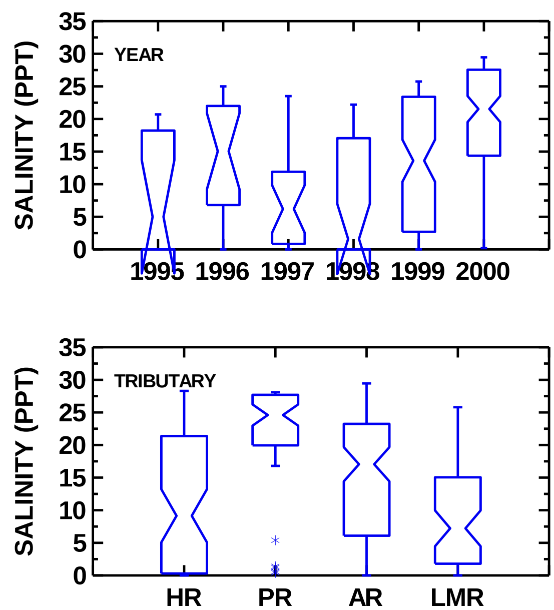

Figure 9. Notched box plot of median and 95% confidence limits of near-bottom salinity by year and tributary.

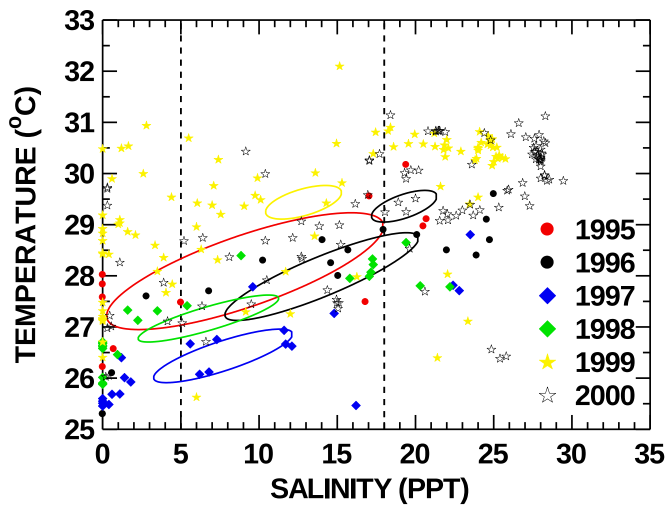

Figure 10. Temperature-salinity plot of stations sampled for benthos: by year, 1995-2000. Ellipses demarcate standard deviations around the mean and the orientation represents the Pearson correlation between temperature and salinity.

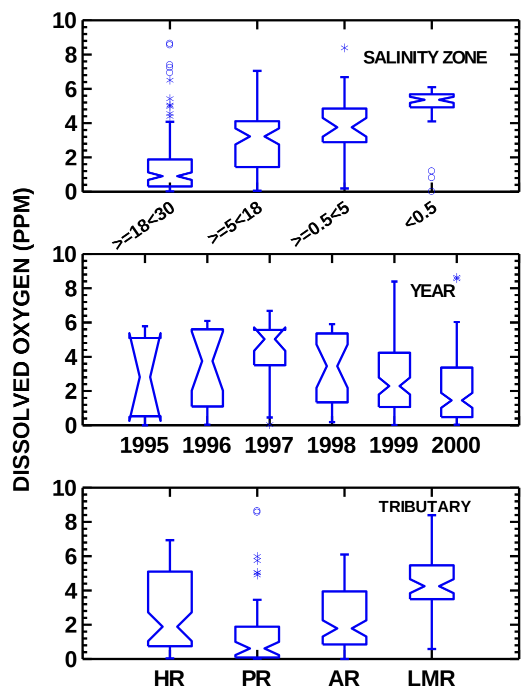

Figure 11. Notched box plot of median and 95% confidence limits of near-bottom dissolved oxygen by salinity zone, year, and tributary.

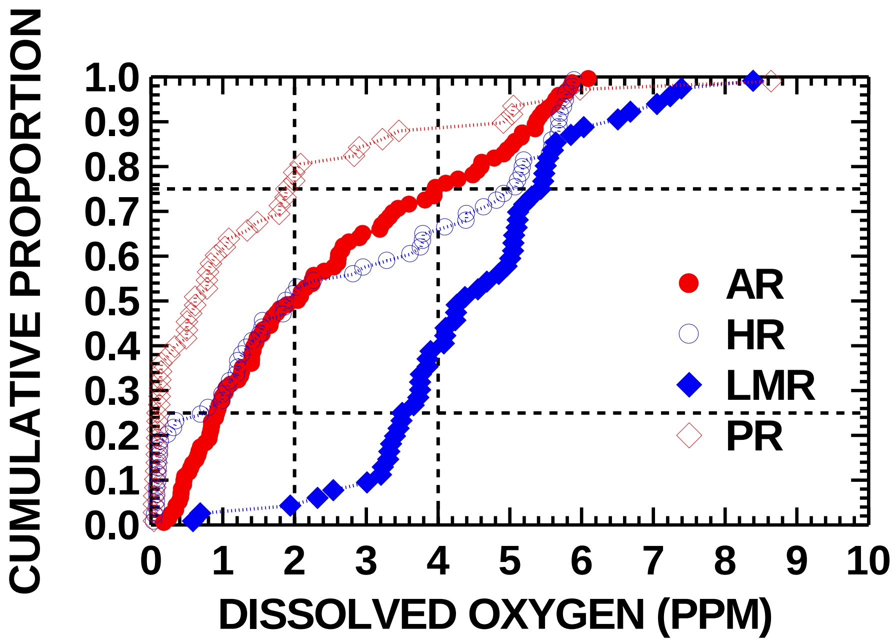

Figure 12. Cumulative distribution function plot of near-bottom dissolved oxygen: by tributary, 1995-2000.

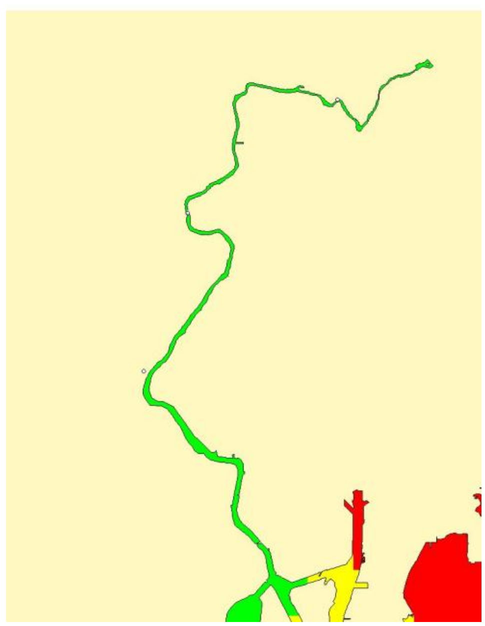

Figure 13. Near-bottom dissolved oxygen concentration strata in the Lower Hillsborough River, 1995. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

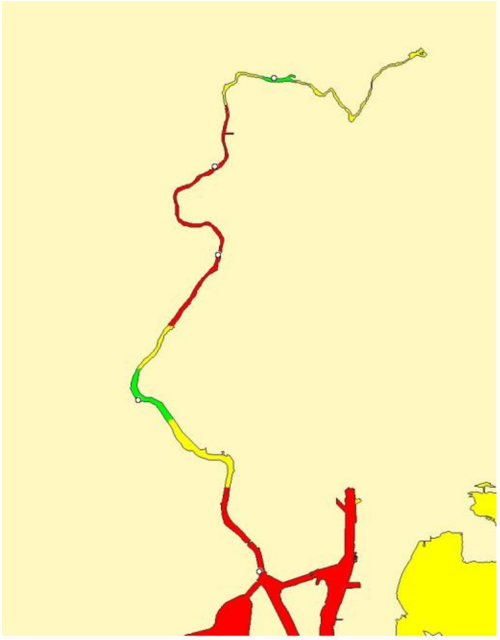

Figure 14. Near-bottom dissolved oxygen concentration strata in the Lower Hillsborough River, 1996. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

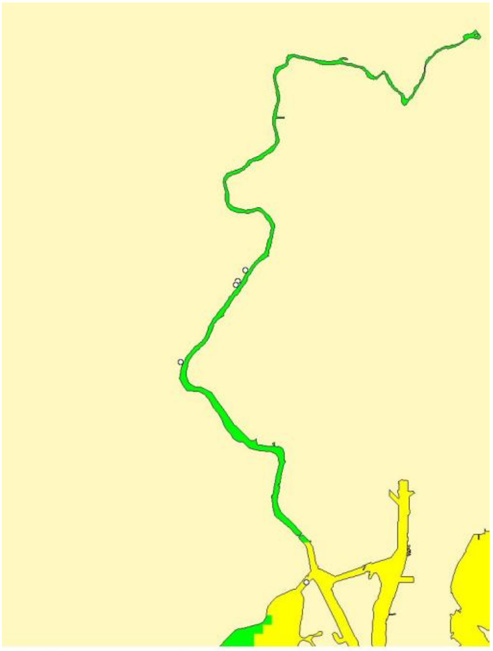

Figure 15. Near-bottom dissolved oxygen concentration strata in the Lower Hillsborough River, 1997. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

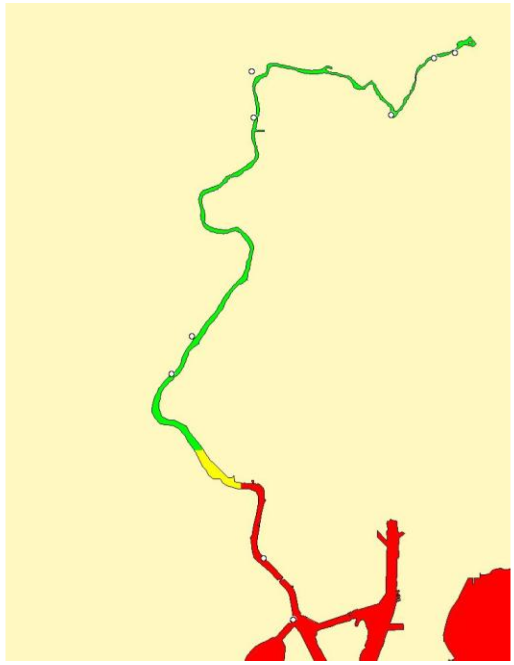

Figure 16. Near-bottom dissolved oxygen concentration strata in the Lower Hillsborough River, 1998. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

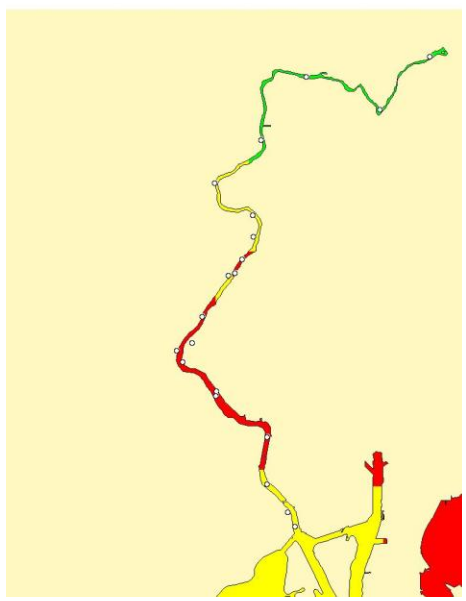

Figure 17. Near-bottom dissolved oxygen concentration strata in the Lower Hillsborough River, 1999. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

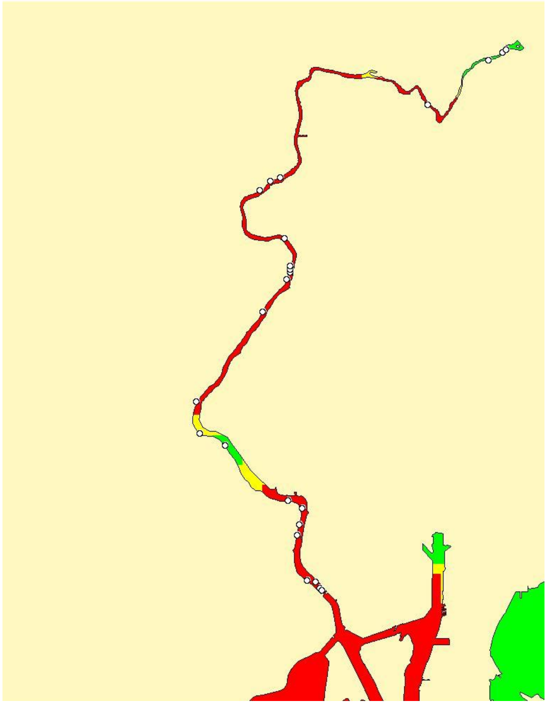

Figure 18. Near-bottom dissolved oxygen concentration strata in the Lower Hillsborough River, 2000. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

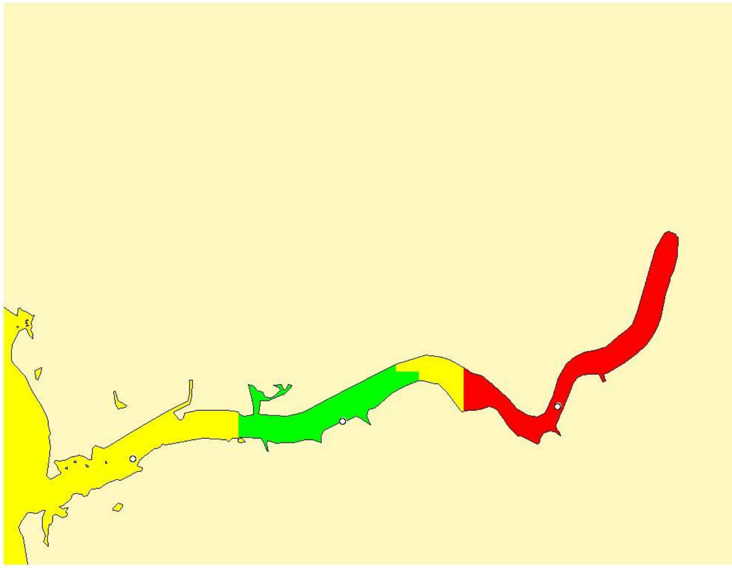

Figure 19. Near-bottom dissolved oxygen concentration strata in the Palm River, 1996. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

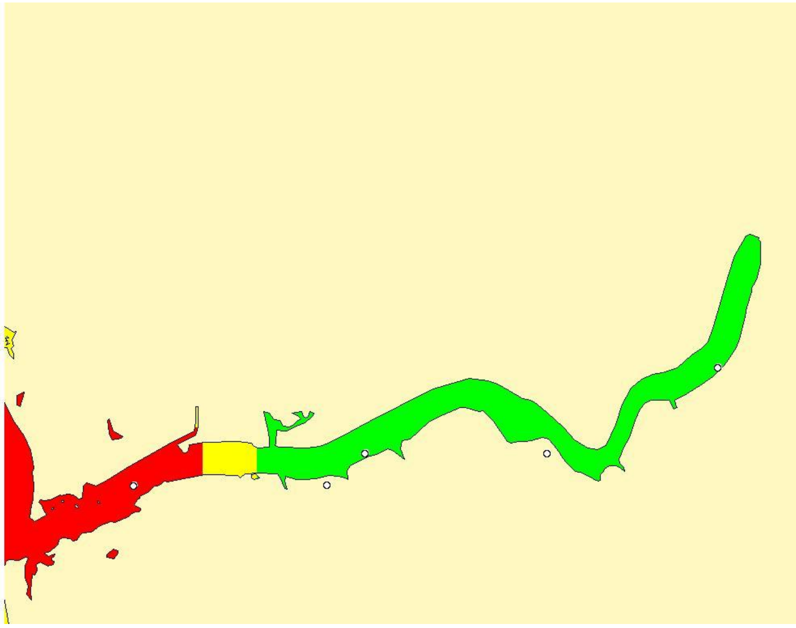

Figure 20. Near-bottom dissolved oxygen concentration strata in the Palm River, 1997. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

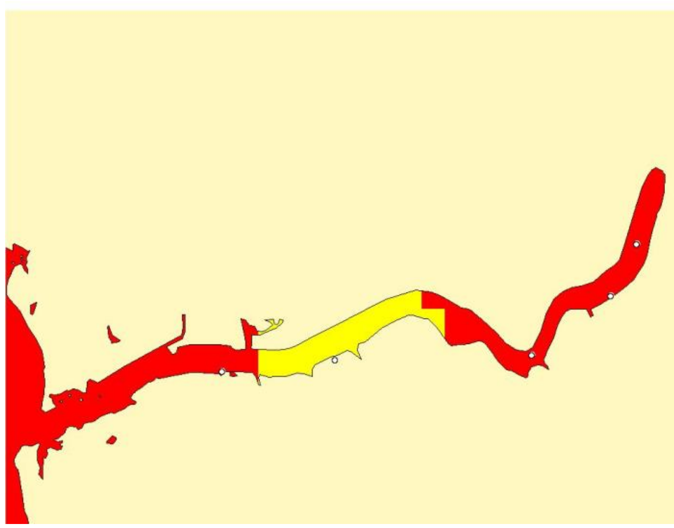

Figure 21. Near-bottom dissolved oxygen concentration strata in the Palm River, 1998. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

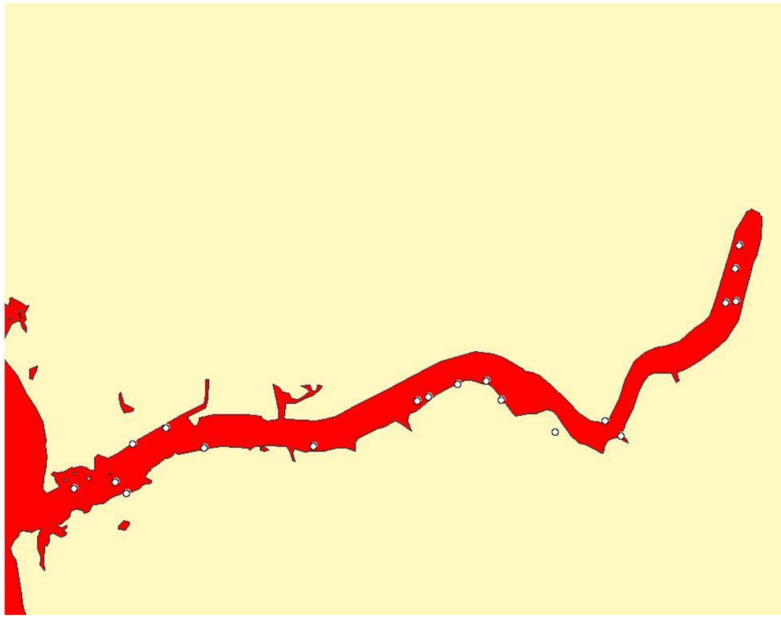

Figure 22. Near-bottom dissolved oxygen concentration strata in the Palm River, 1999. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

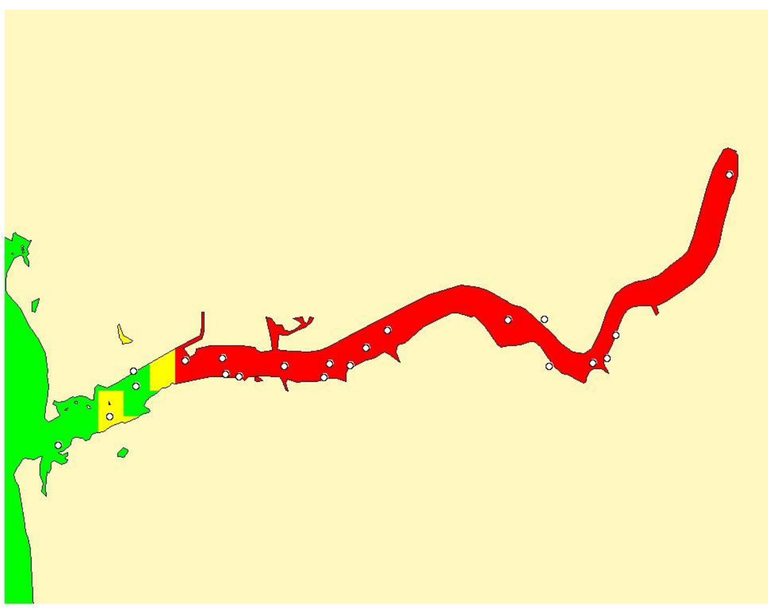

Figure 23. Near-bottom dissolved oxygen concentration strata in the Palm River, 2000. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

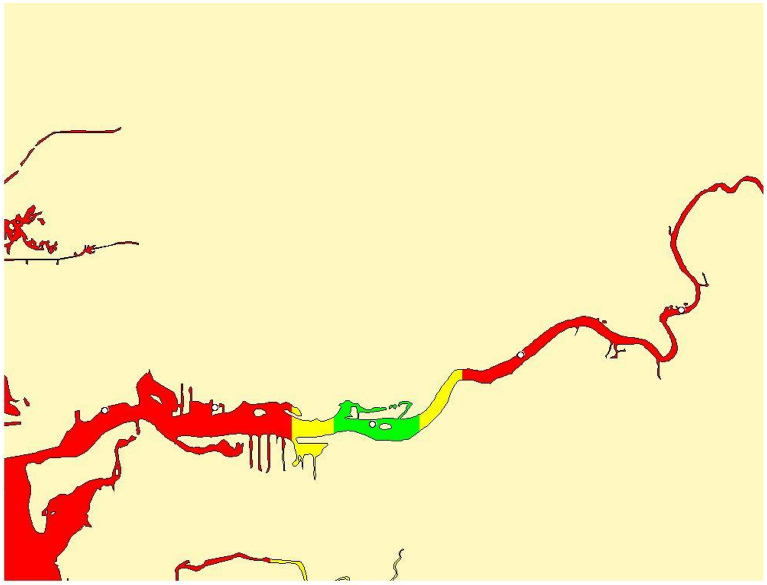

Figure 24. Near-bottom dissolved oxygen concentration strata in the Alafia River, 1995. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

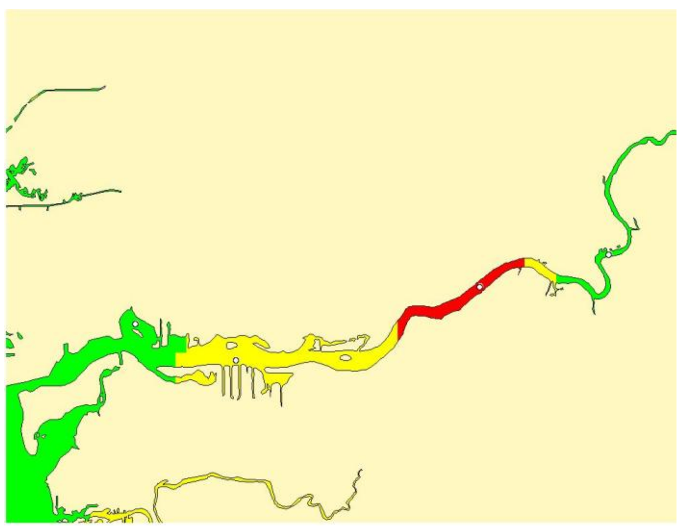

Figure 25. Near-bottom dissolved oxygen concentration strata in the Alafia River, 1996. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

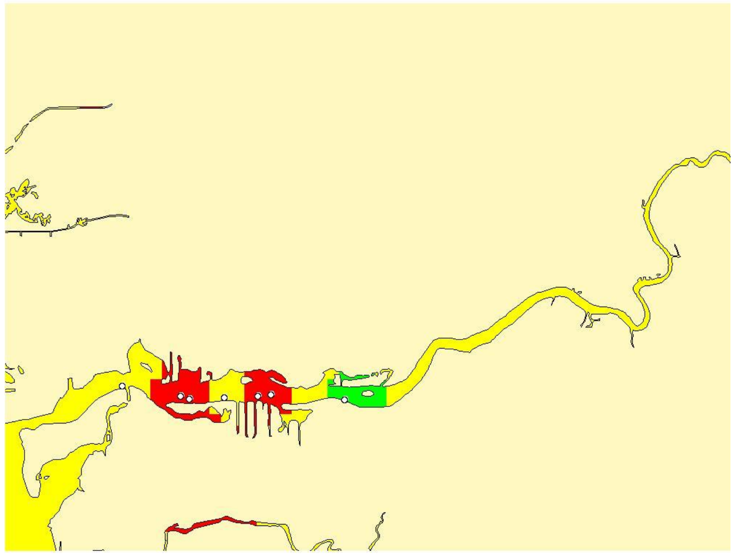

Figure 26. Near-bottom dissolved oxygen concentration strata in the Alafia River, 1997. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

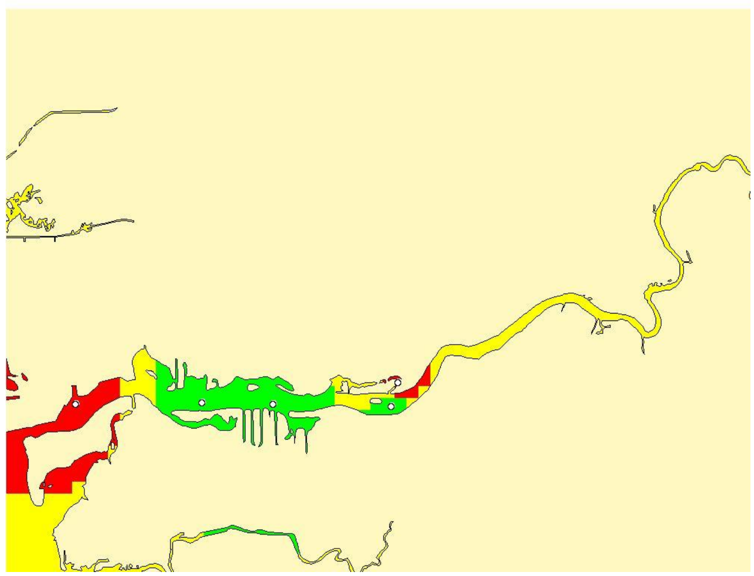

Figure 27. Near-bottom dissolved oxygen concentration strata in the Alafia River, 1998. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

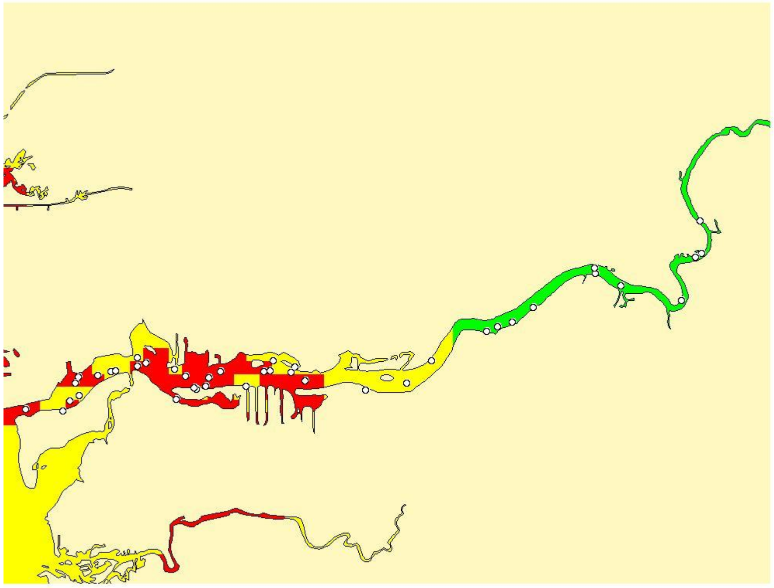

Figure 28. Near-bottom dissolved oxygen concentration strata in the Alafia River, 1999. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

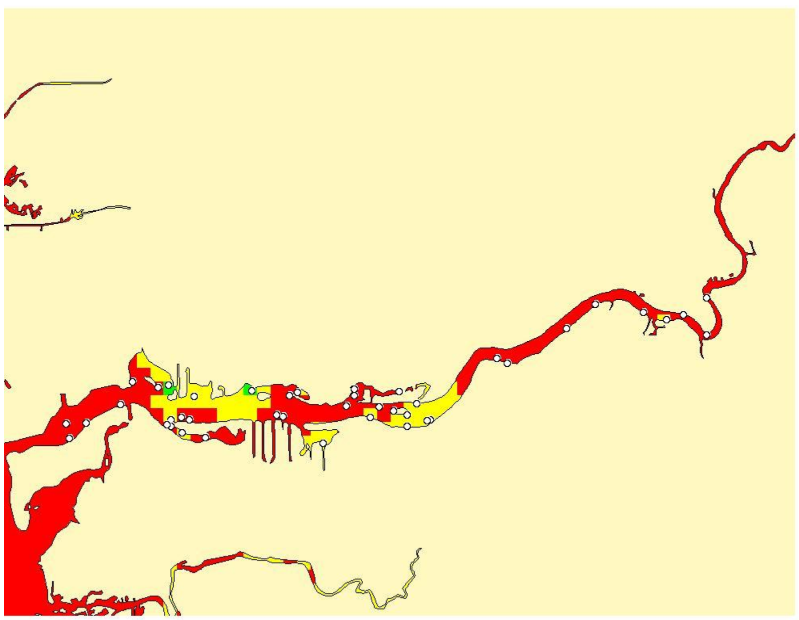

Figure 29. Near-bottom dissolved oxygen concentration strata in the Alafia River, 2000. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

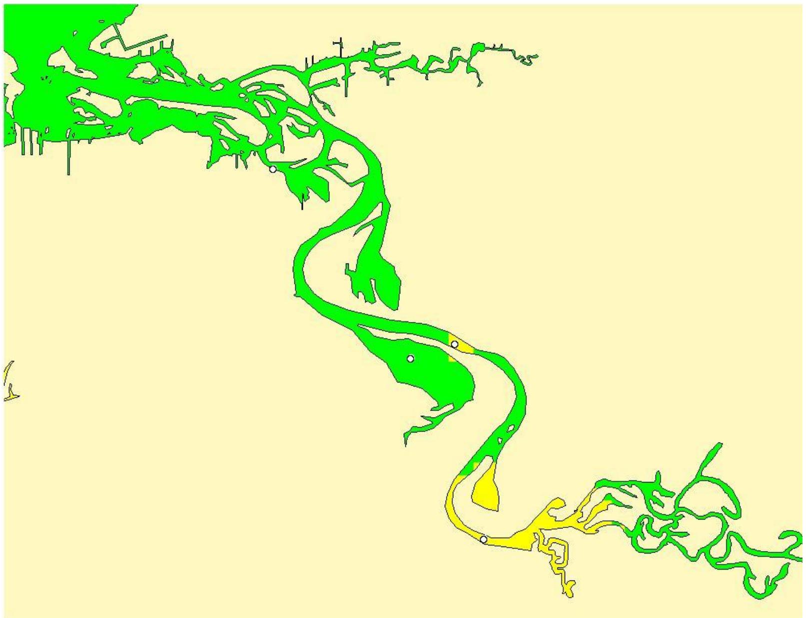

Figure 30. Near-bottom dissolved oxygen concentration strata in the Little Manatee River, 1996. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

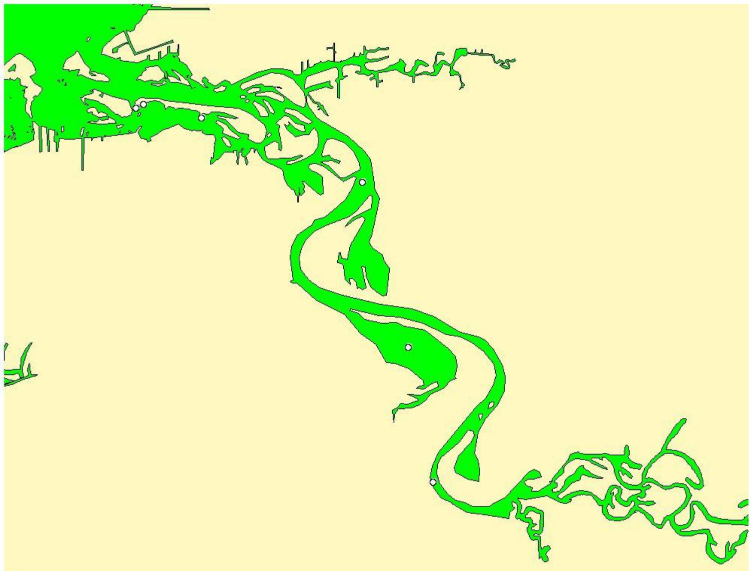

Figure 31. Near-bottom dissolved oxygen concentration strata in the Little Manatee River, 1997. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

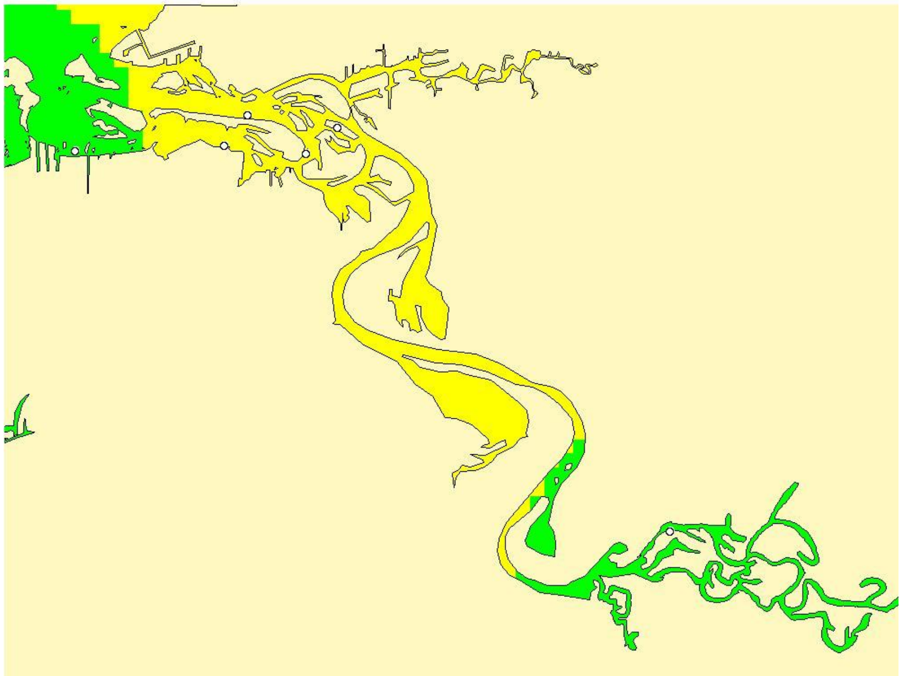

Figure 32. Near-bottom dissolved oxygen concentration strata in the Little Manatee River, 1998. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

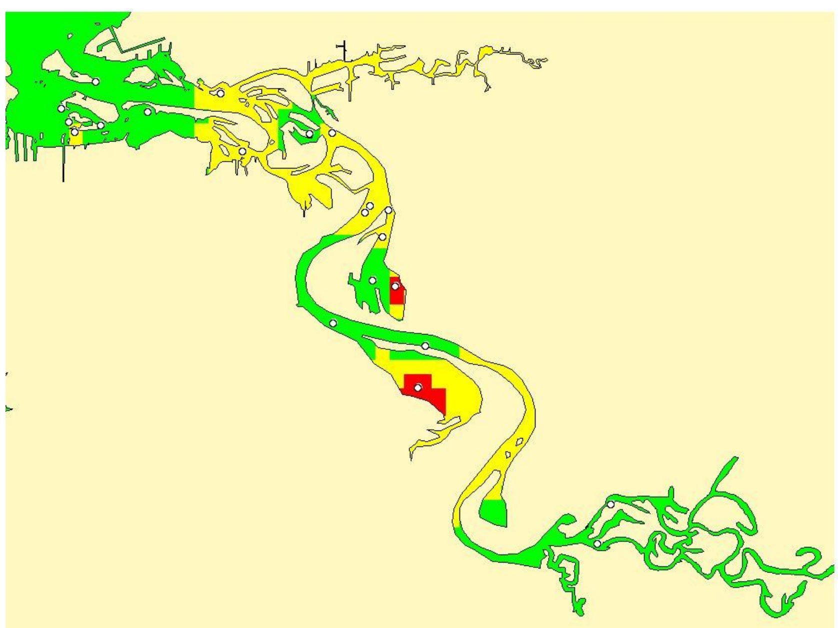

Figure 33. Near-bottom dissolved oxygen concentration strata in the Little Manatee River, 1999. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

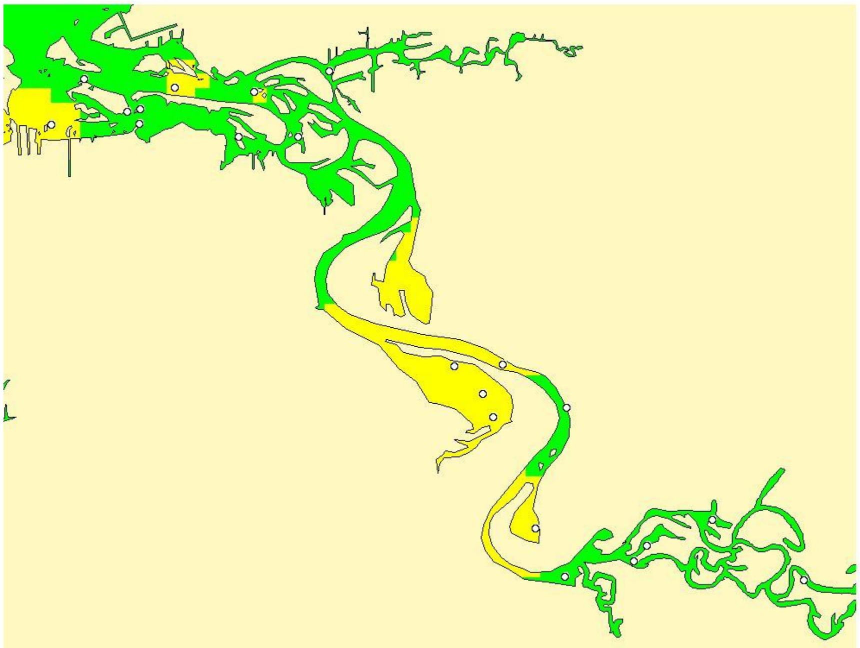

Figure 34. Near-bottom dissolved oxygen concentration strata in the Little Manatee River, 2000. Red=DO<2 ppm;Yellow=DO>2<4 ppm; Green=DO>4 ppm.

III.2 <u>Sample Depths and Sediment Characteristics</u>

Mean sample depths differed between tributaries ($F_{3,276}$=20.9; p<0.001) and mean sample depth was greatest in the Palm and Lower Hillsborough rivers (Figure 35). The KS test, however, showed that all frequency distributions were equivalent (Figure 36). Sample depths also differed among salinity zones ($F_{3,276}$=11.0;p<0.001); sample depths were greater in polyhaline waters than in oligohaline (0.5-5 ppt) and mesohaline waters (Figure 35). ANOVA showed that mean depths differed by year as well ($F_{5,276}$=2.5; p<0.05) (Figure 35), although the Bonferoni comparisons were not significant.

Mean percent silt+clay (%SC) differed between tributaries ($F_{3,268}$=18.0; p<0.001) and mean %SC was greatest in the Palm River (Figure 37). The KS test, showed that, with the exception of the Alafia and Lower Hillsborough rivers, the frequency distributions differed among tributaries as well (Figure 38). Mean %SC differed among salinity zones

($F_{3,268}$=;p<0.001) and %SC was greatest in salinities of 18-30 ppt. ANOVA showed that mean %SC did not differ by year ($F_{5,266}$=1.47;p=*0.2*). Figures 39-42 show the spatial distribution of %SC in each of the tributaries (all survey periods combined).

III.3 Sediment Contaminants

III.3.1 Trace Metals: Trace metal concentrations were generally highest in the Lower Hillsborough River and lowest in the Little Manatee River (Figures 43-50). KS tests showed that the frequency distributions of silver, arsenic, cadmium. chromium, nickel, and lead concentrations in the Little Manatee River differed (p<0.05) from the other tributaries. The frequency distribution of copper in the Hillsborough River differed from the other tributaries (Figure 46) and the distribution of lead in the Hillsborough River differed from that of the Alafia River (Figure 47).

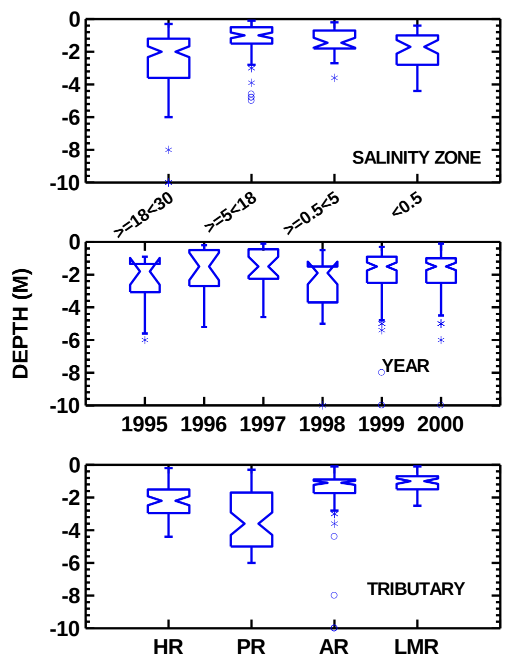

Figure 35. Notched box plot of median and 95% confidence limits of station depth by salinity zone, year, and tributary.

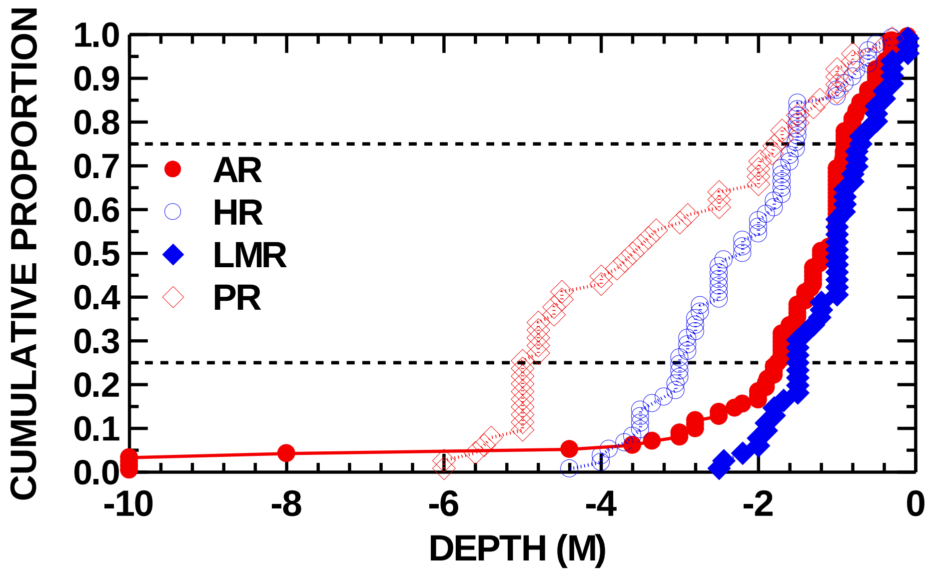

Figure 36. Cumulative distribution function plot of station depth: by tributary, 1995-2000.

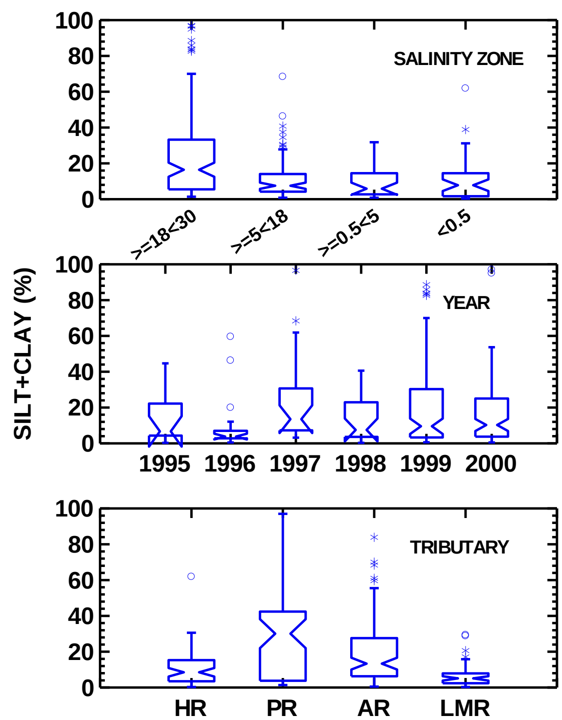

Figure 37. Notched box plot of median and 95% confidence limits of % silt+clay by salinity zone, year, and tributary.

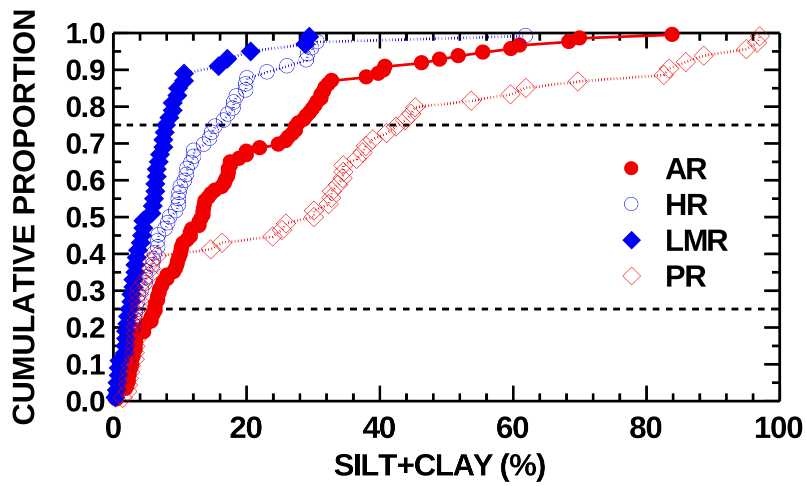

Figure 38. Cumulative distribution function plot of % silt+clay: by tributary, 1995-2000

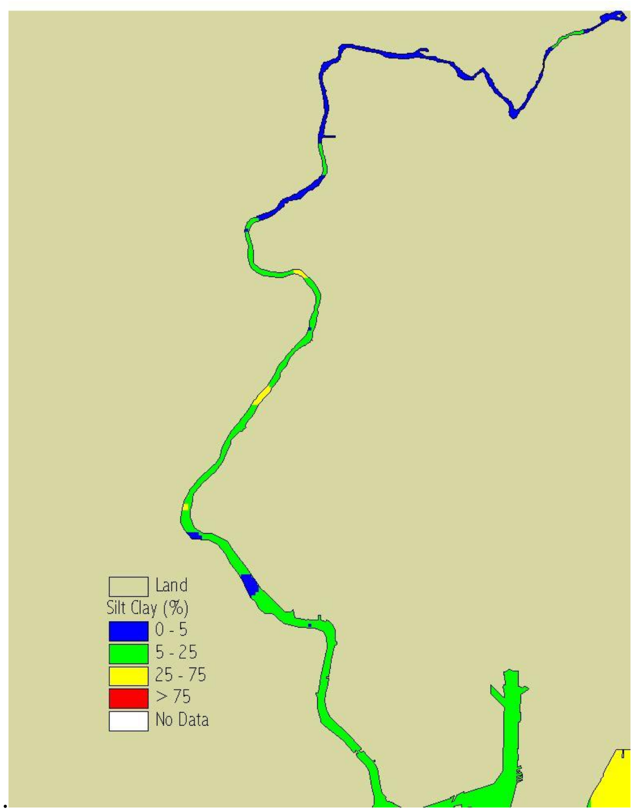

Figure 39. Spatial distribution of sediment type (as % silt+clay) in the Lower Hillsborough River, 1995-2000.

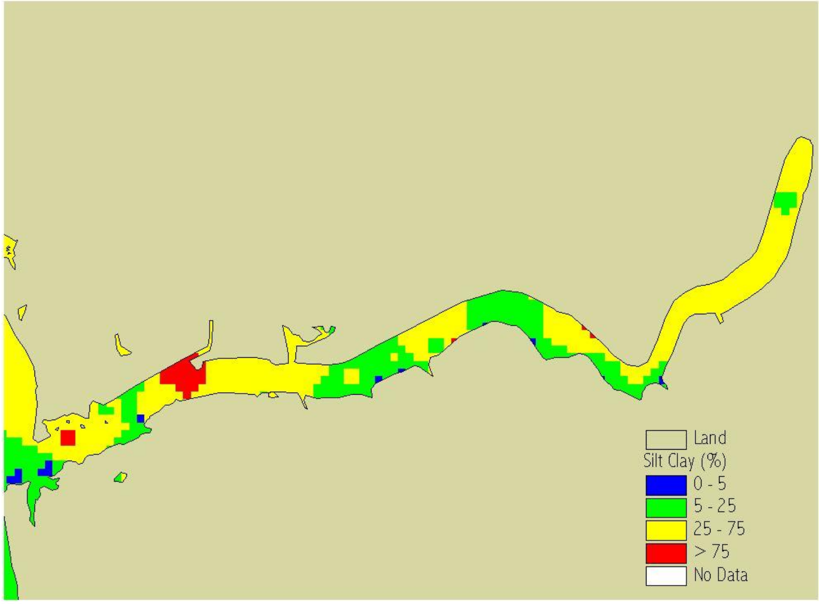

Figure 40. Spatial distribution of sediment type (as % silt+clay) in the Palm River, 1995-2000.

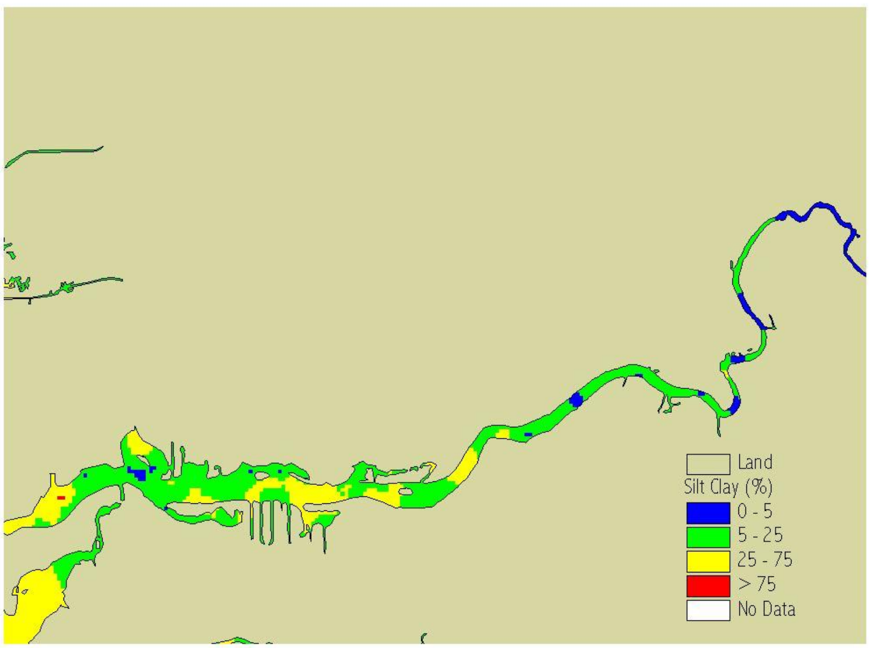

Figure 41. Spatial distribution of sediment type (as % silt+clay) in the Alafia River, 1995-2000.

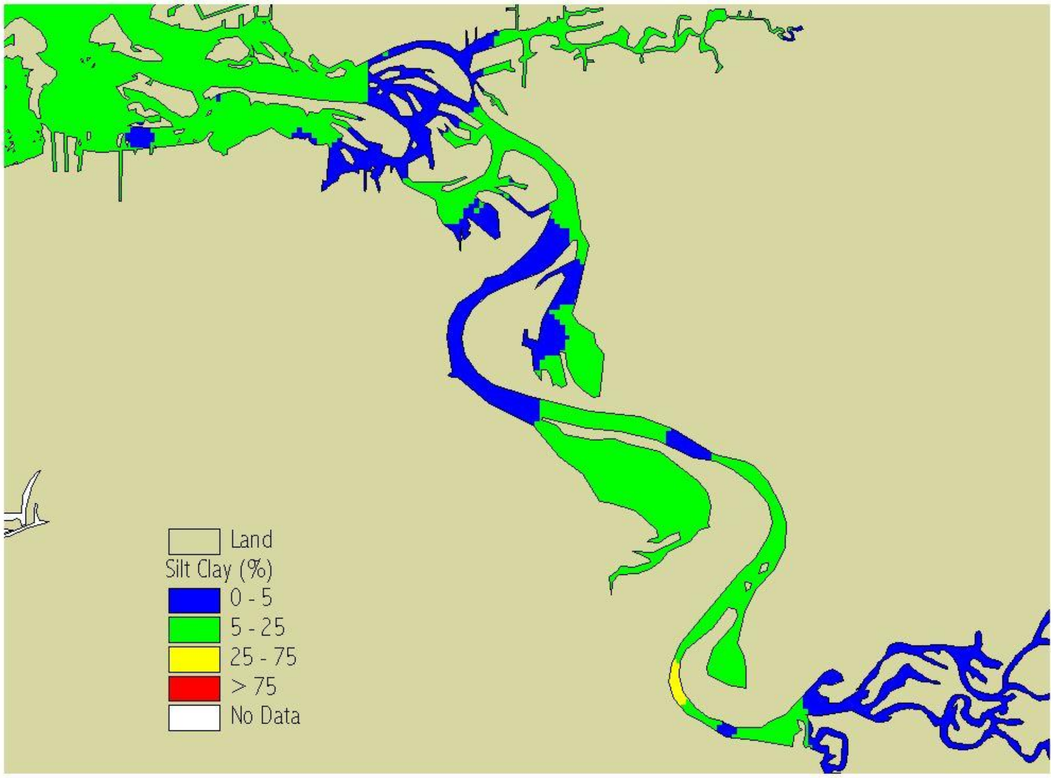

Figure 42. Spatial distribution of sediment type (as % silt+clay) in the Little Manatee River, 1996-2000.

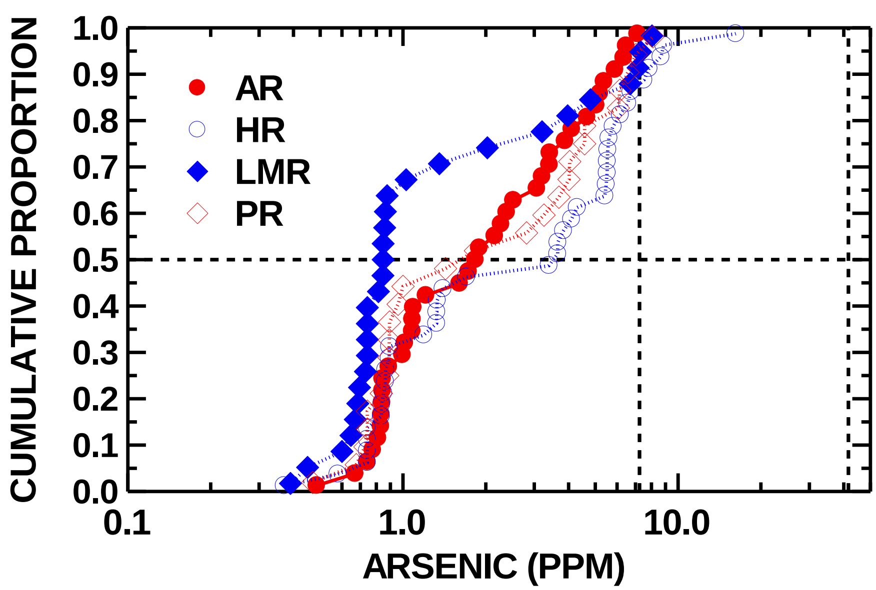

Figure 43. Cumulative distribution function plot of arsenic (ppm) in sediments: by tributary, 1995-2000.Vertical lines demarcate the TEL (7.2) and PEL (41.6).

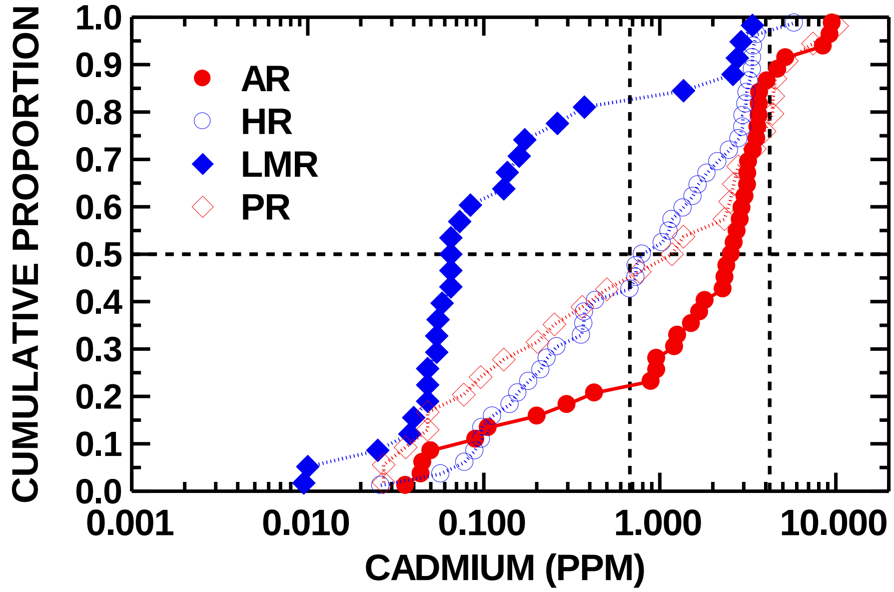

Figure 44. Cumulative distribution function plot of cadmium (ppm) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (0.68) and PEL (4.2).

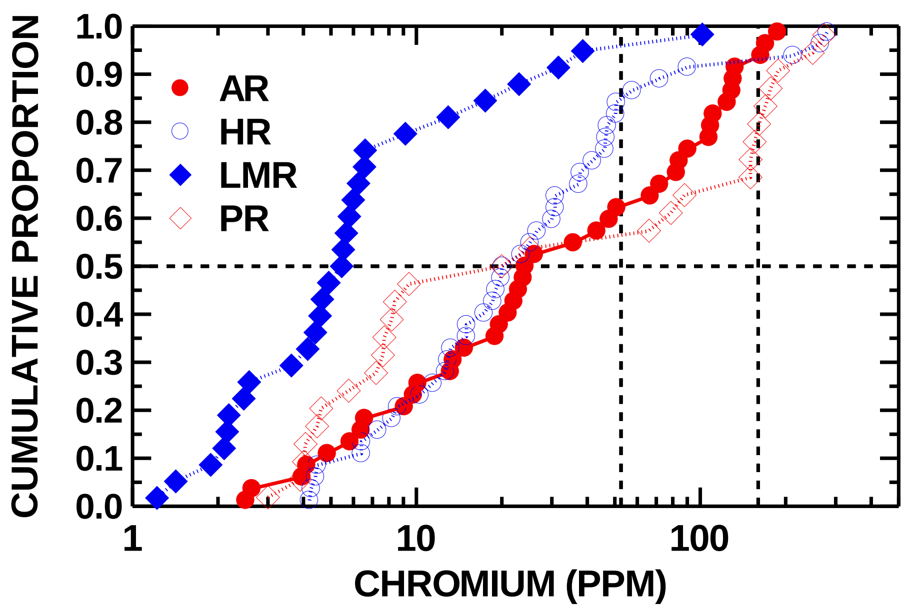

Figure45. Cumulative distribution function plot of chromium (ppm) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (52.3) and PEL (160).

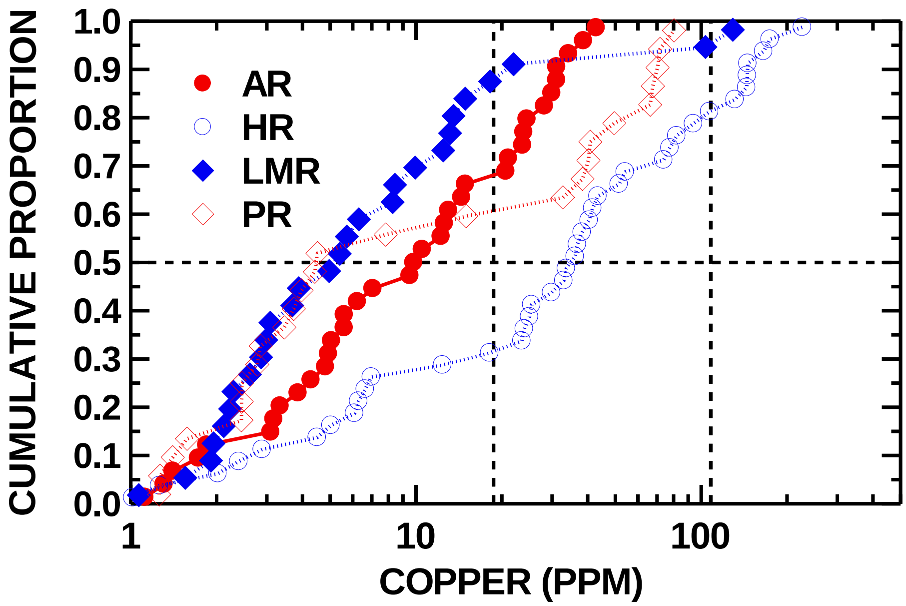

Figure 46. Cumulative distribution function plot of copper (ppm) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (18.7) and PEL (108).

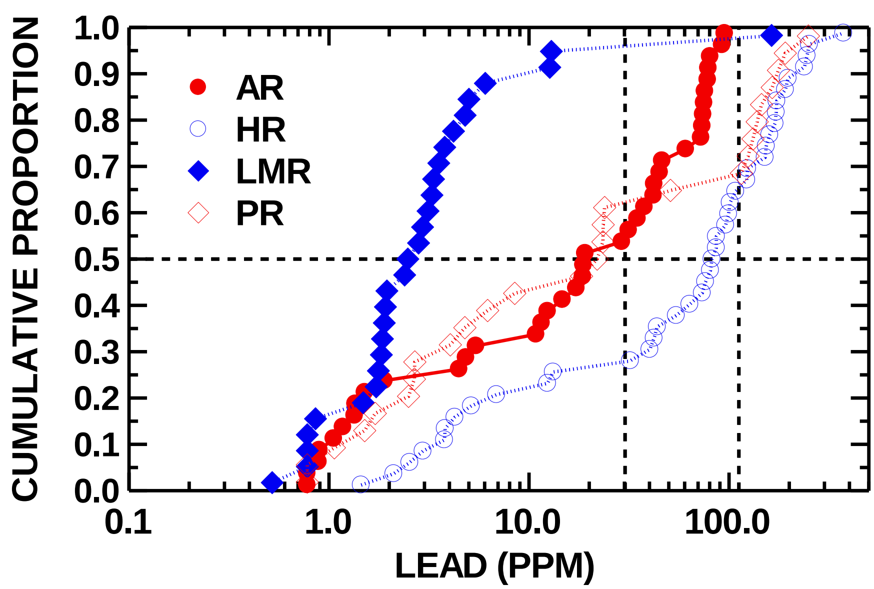

Figure 47. Cumulative distribution function plot of lead (ppm) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (30.2) and PEL (112).

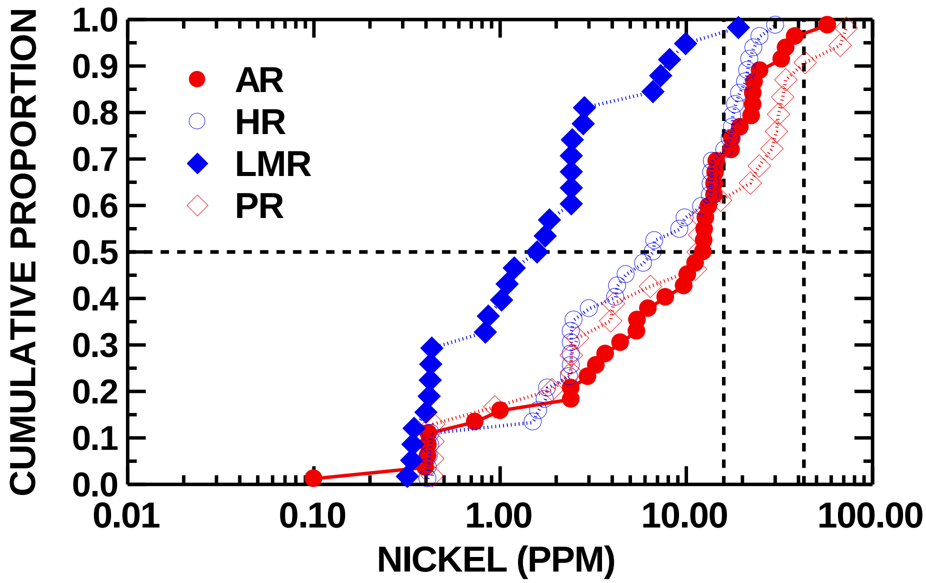

Figure 48. Cumulative distribution function plot of nickel (ppm) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (15.9) and PEL (42.8).

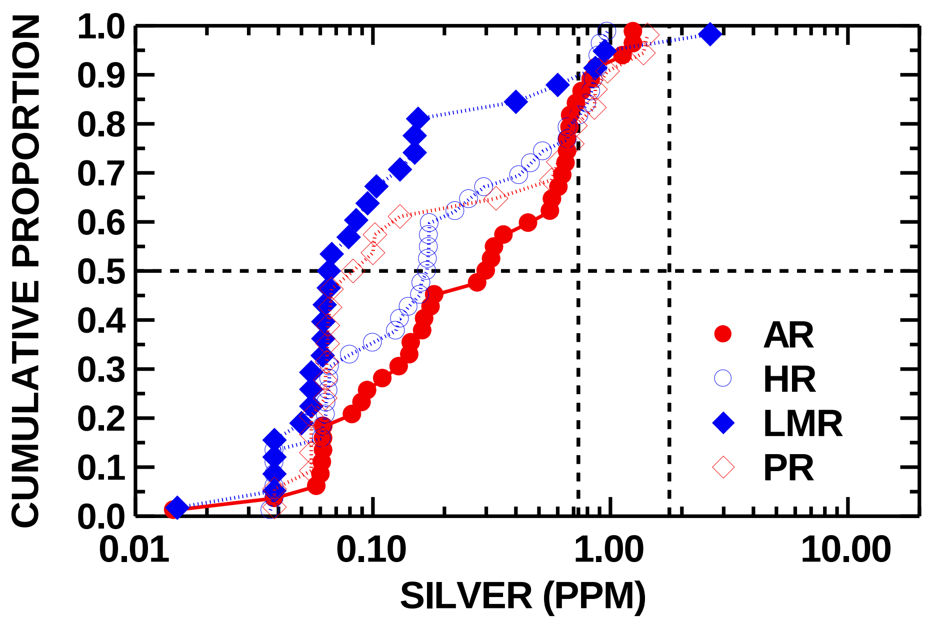

Figure 49. Cumulative distribution function plot of silver (ppm) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (0.73) and PEL (1.77).

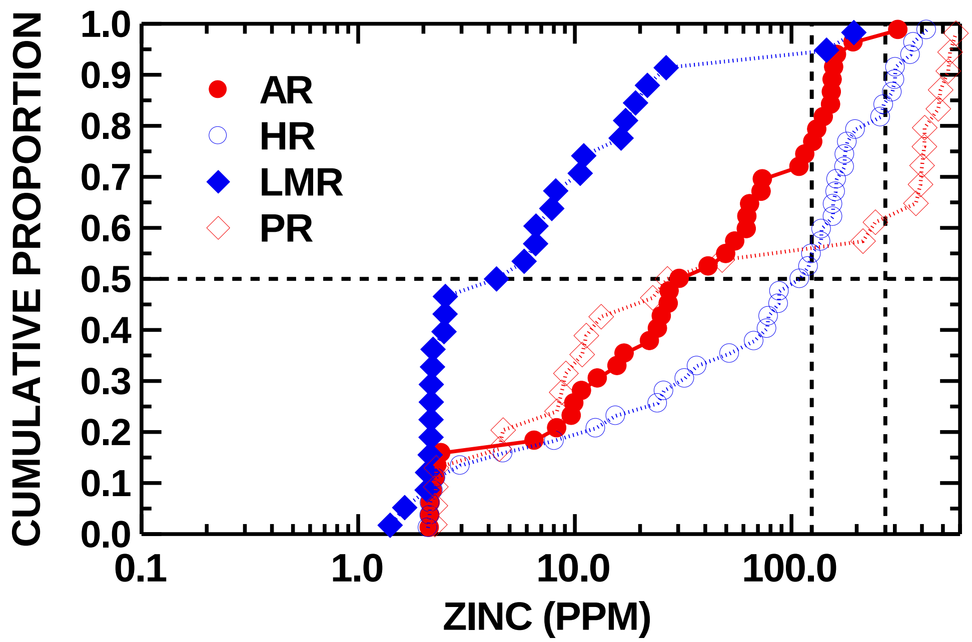

Figure 50. Cumulative distribution function plot of zinc (ppm) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (124) and PEL (271).

Concentrations of metals above the Probable Effects Level (PEL) (MacDonald Environmental Sciences, Ltd. 1994)—the concentration above which a contaminant has a high (>50%) likelihood of being toxic to aquatic life—were most frequently observed in the Hillsborough River—especially for copper, lead, and zinc (Figures 46, 47, 50-52); lead and zinc concentrations were also above the PEL in >30% of the Palm River samples (Figures 50 & 53).

III.3.2 Polycyclic Aromatic Hydrocarbons (PAHs): Total PAH concentrations were highest in the Lower Hillsborough and generally less than the laboratory's method detection limit (MDL) in the Little Manatee River (Figure 54). KS tests showed the distributions differed ($p<0.05$) among the four rivers. Approximately 50% of the Hillsborough River samples exceeded the PEL (Figures 54 & 55) and approximately 50% of the Palm River samples exceeded the Threshold Effects Level (TEL) (MacDonald Environmental Sciences, Ltd. 1994) (Figure 54), a concentration that is indicative of moderate levels of contamination.

III.3.3 Organochlorine Pesticides: Total chlordane concentrations were highest in the Lower Hillsborough River and the frequency distribution of chlordane in the Lower Hillsborough River differed from the other rivers (Figures 56 & 57)**.** Approximately 80% of the Hillsborough River samples exceeded the PEL and none of the Little Manatee River samples exceeded the TEL.

Total DDTs also were highest in the Lower Hillsborough River and the frequency distributions were similar (KS test $p>0.05$) among the Alafia, Palm, and Little Manatee rivers (Figure 58). Approximately 80% of the Hillsborough River samples exceeded the TEL (Figure 58 & 59) and none of the Little Manatee and Alafia river samples exceeded the TEL.

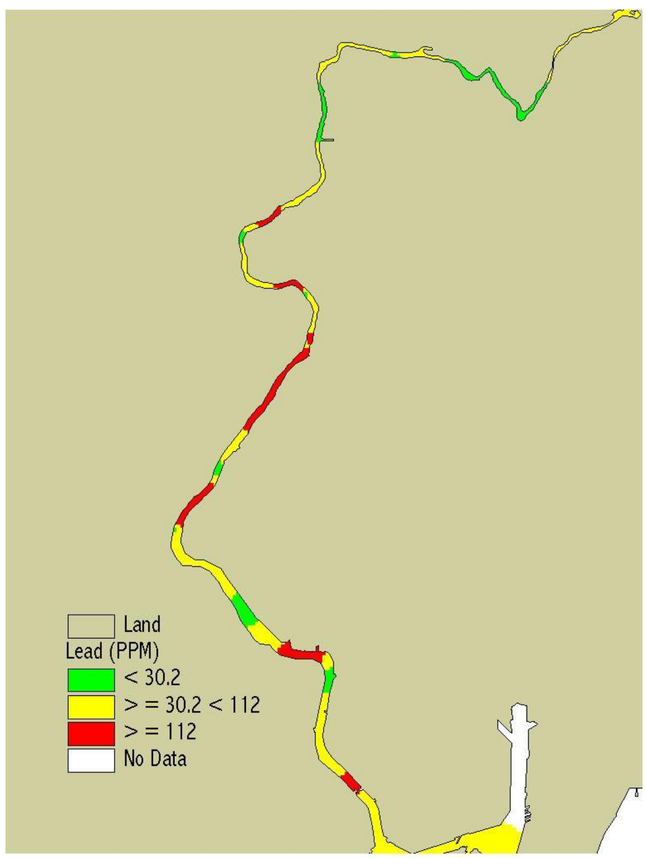

Figure 51. Spatial distribution of lead in the Lower Hillsborough River, 1995-2000. Green<TEL; Yellow>=TEL<PEL; Red>=PEL.

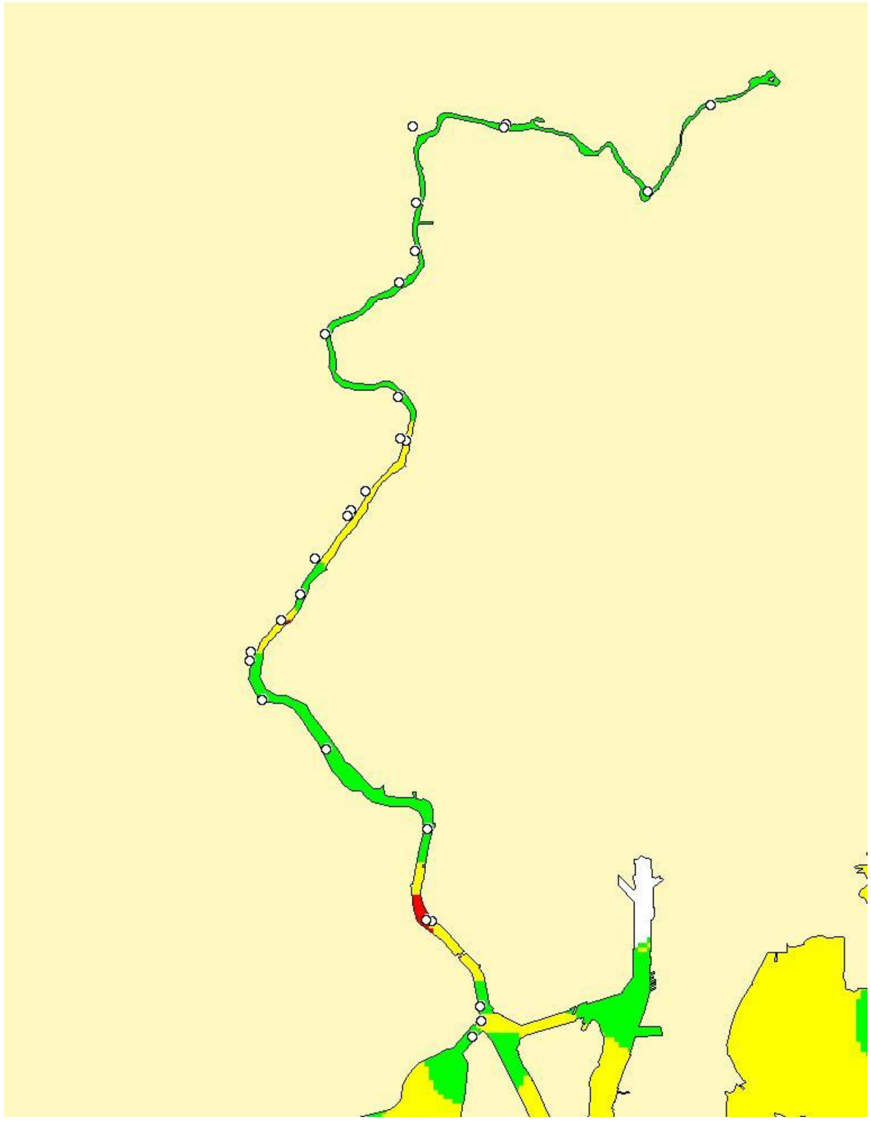

Figure 52. Spatial distribution of zinc in the Lower Hillsborough River, 1995-2000.Green<TEL; Yellow>=TEL<PEL;Red>=PEL.

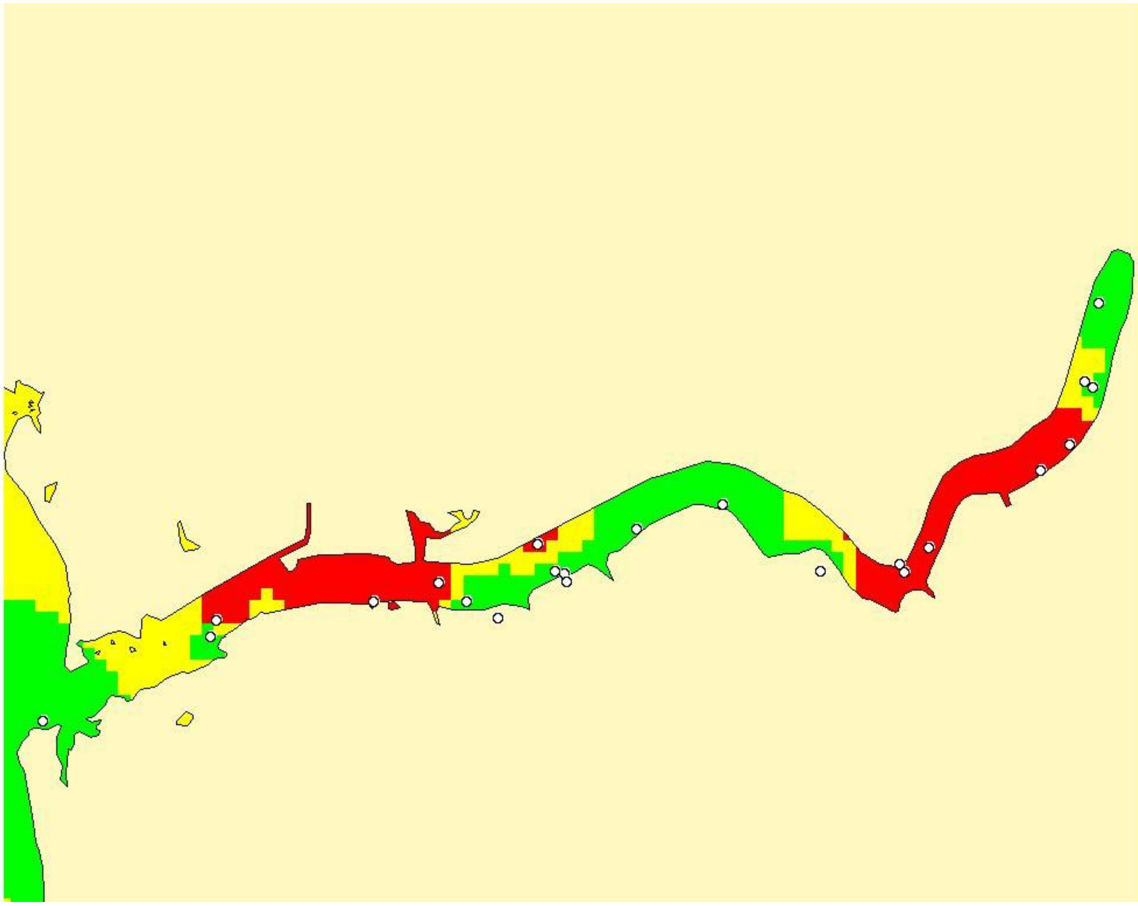

**Figure 53. Spatial distribution of zinc in the Palm River, 1995-2000.
Green<TEL; Yellow>=TEL<PEL;Red>=PEL.**

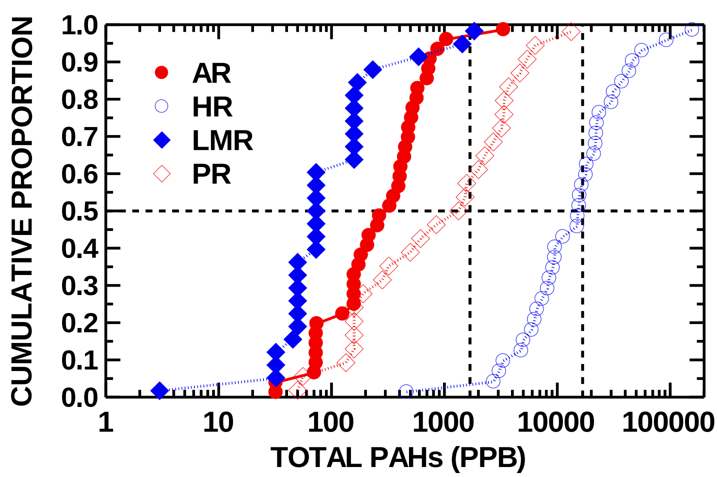

Figure 54. Cumulative distribution function plot of total PAHs (ppb) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (1684) and PEL (16770).

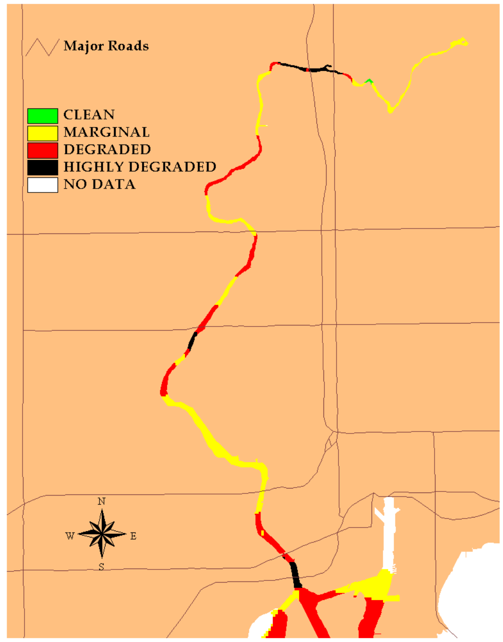

Figure 55. Spatial distribution of total PAHs in the Hillsborough River, 1995-2000. Green<TEL; Yellow>=TEL<PEL; Red>=PEL.; Black>3xs PEL

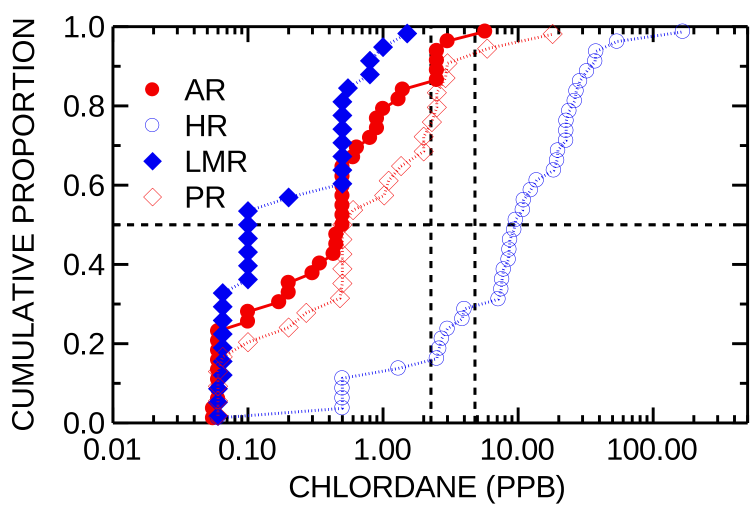

Figure 56. Cumulative distribution function plot of total chlordane (ppb) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (2.26) and PEL (4.79).

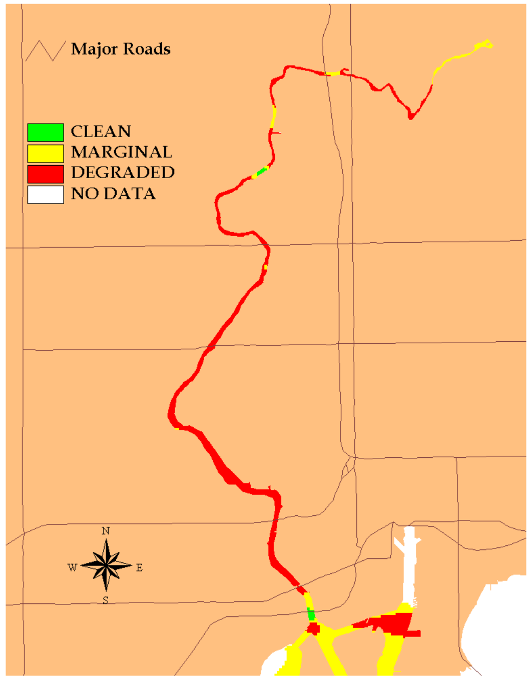

Figure 57. Spatial distribution of total chlordane in the Hillsborough River, 1995-2000. Green<TEL; Yellow>=TEL<PEL; Red>=PEL.

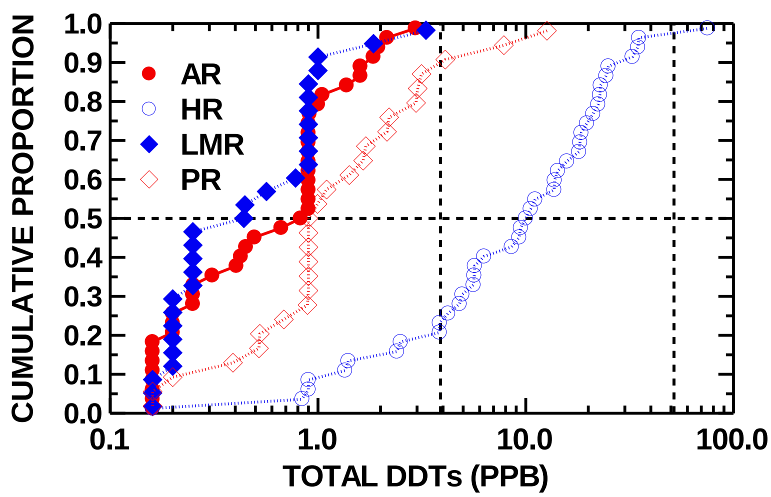

Figure 58. Cumulative distribution function plot of total DDTs (ppb)in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (3.89) and PEL (51.7).

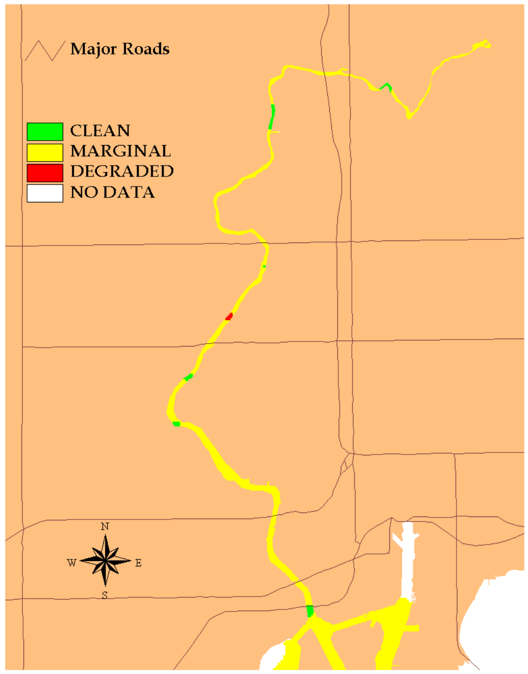

Figure 59. Spatial distribution of total DDTs in the Hillsborough River, 1995-2000. Green<TEL; Yellow>=TEL<PEL; Red>=PEL.

III.3.4 Polychlorinated Biphenyls (PCBs): PCB concentrations were generally highest in the Palm and Hillsborough rivers (Figures 60-62), although the frequency distributions for all tributaries were similar (KS test; $p>0.05$) . Lowest (generally <MDL) PCB concentrations were found in the Little Manatee River.

III.4 Benthic Community

III.4.1. Benthic Abundances: The highest overall densities of benthic macroinvertebrates were ($F_{3,250}=9.2$;$p<0.001$) found in the Little Manatee and Lower Hillsborough rivers (Table 3; Figure 63). The frequency distribution of total benthic abundance showed that the Palm River differed from other tributaries (KS test $p<0.05$) and the distribution of the Little Manatee River differed from that of the Alafia River (Figure 64). The Palm River was characterized by the prevalence of azoic samples (Figure 64). Although ANOVA showed that mean total abundance differed among years ($F_{5,,250}=1.4$;$p<0.001$), the Bonferroni test was unable to detect these differences.

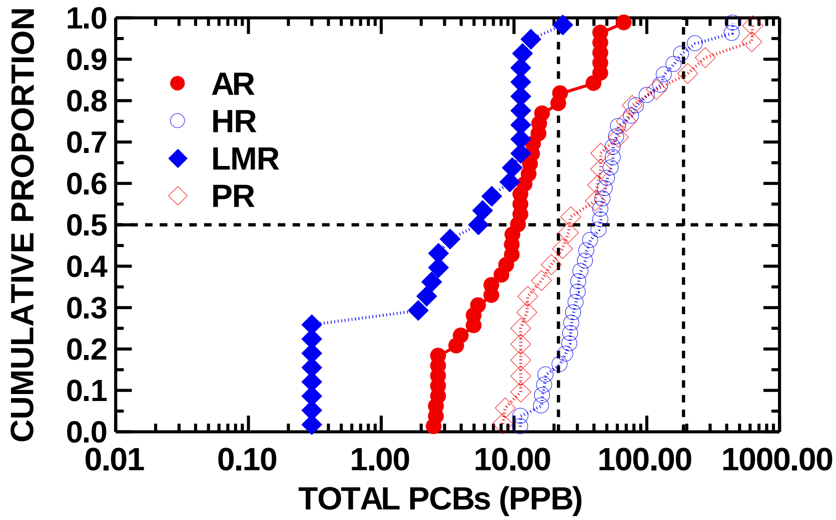

Figure 60. Cumulative distribution function plot of total PCBs (ppb) in sediments: by tributary, 1995-2000. Vertical lines demarcate the TEL (21.6) and PEL (189).

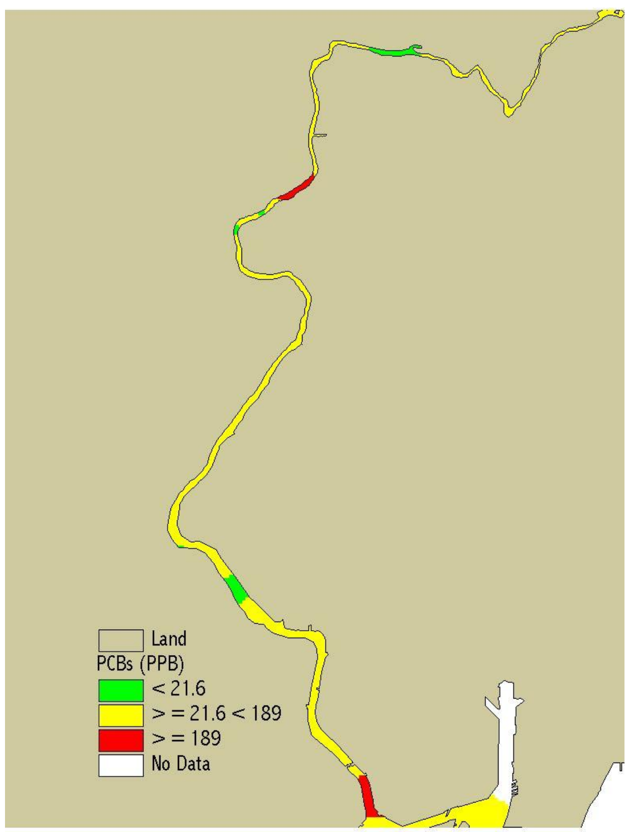

Figure 61. Spatial distribution of total PCBs in the Hillsborough River, 1995-2000. Green<TEL; Yellow>=TEL<PEL; Red>=PEL.

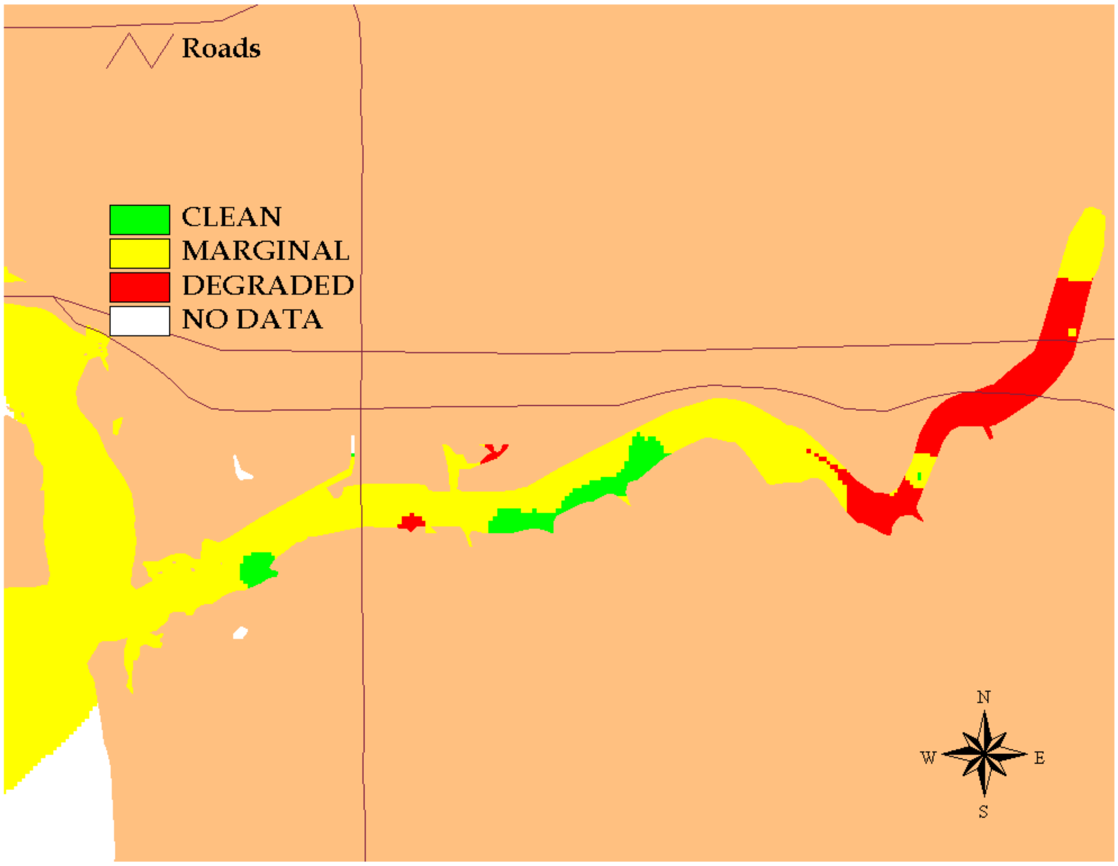

Figure 62 Spatial distribution of total PCBs in the Palm River, 1995-2000. Green<TEL; Yellow>=TEL<PEL; Red>=PEL.

Table 3. Summary of benthic community measures: total abundance (number m^{-3}), species richness, diversity, and evenness.

	ABUNDANCE					SPECIES RICHNESS					DIVERSITY					EVENNESS			
	HR	PR	AR	LMR		HR	PR	AR	LMR		HR	PR	AR	LMR		HR	PR	AR	LMR
MIN	0	0	0	75		0	0	0	1		0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
MAX	50225	13325	21475	69650		54	35	47	59		3.1	3.6	4.1	4.1		0.9	0.9	1.0	1.0
MEDIAN	2975	25	1050	2650		7	1	8	13		1.7	0.0	1.4	2.2		0.5	0.0	0.4	0.5
MEAN	6510	1349	3639	5952		13	6	11	16		1.6	0.8	1.5	2.1		0.5	0.2	0.4	0.5

HR= Lower Hillsborough River; PR=Palm River; AR= Alafia River; LMR=Little Manatee River

Table 4. Number (percent) of benthic macroinvertebrate taxa identified from the Lower Hillsborough , Palm, Alafia, and Little Manatee rivers, 1995-2000.

GROUP	HILLSBOROUGH RIVER (59)	PALM RIVER (57)	ALAFIA RIVER (100)	LITTLE MANATEE RIVER (53)	TOTAL (269)
Nemertea	9 (5.3)	5 (5.2)	11 (6.0)	11 (5.6)	14 (4.2)
Polychaeta	68 (39.8)	34 (35.1)	59 (32.0)	56 (28.4)	99 (29.9)
Gastropoda	24 (14.0)	14 (14.4)	23 (12.5)	23 11.7)	42 (12.7)
Bivalvia	17 (9.9)	11 (11.3)	20 (10.9)	32 (16.2)	39 (11.8)
Crustacea	28 (16.4)	17 (17.5)	26 (14.1)	39 (19.8)	57 (17.2)
Insecta	14 (8.2)	9 (9.3)	27 (14.7)	16 (8.1)	43 (13.0)
Ophiuroidea	2 (1.2)	1(1.0)	6 (3.3)	5 (2.5)	6 (1.8)
Other Taxa	11 (6.4)	7 (7.2)	18 (9.8)	20 (10.2)	37 (11.2)
Estuarine Taxa	153 (88.3)	88 (89.7)	155 (81.0)	175 (86.3)	275 (83.1)
Freshwater Taxa	20 (11.7)	10 (10.3)	35 (19.0)	27 (13.7)	56 (16.9)
TOTAL TAXA	**173**	**98**	**190**	**202**	**331**

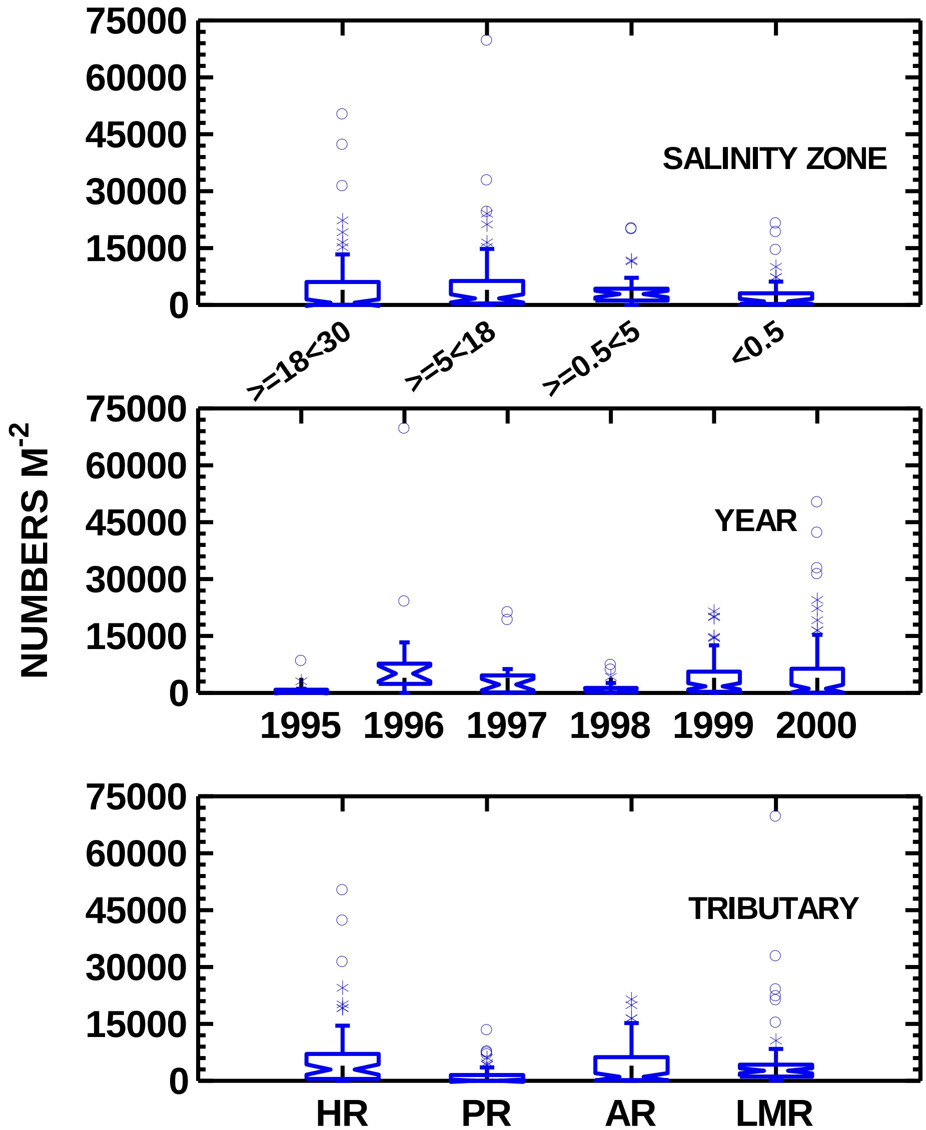

Figure 63. Notched box plot of median and 95% confidence limits of total benthic abundance by tributary, year, and salinity zone.

There were no significant differences in mean total abundance either by depth strata or salinity zone (Figure 64).

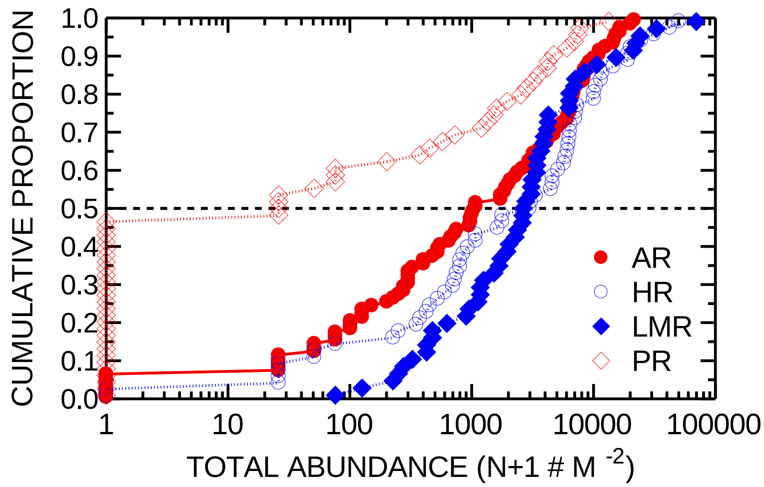

Figure 64. Cumulative distribution function plot of total abundance of benthic macroinvertebrates: by tributary, 1995-2000.

III.4.2. Species Richness, Diversity, and Evenness: Species richness (numbers of taxa), diversity, and evenness were generally highest in both the Little Manatee and Lower Hillsborough rivers (Table 3).

III.4.3 Taxonomic Composition: At least 331 taxa were identified from the four tributaries during 1995-2000 (Appendix A). Sixty-one taxa were common to the four tributaries; the percentage of taxa identified from only a single tributary ranged from 13.4% (Palm River) to 25.0% (Alafia River). Although almost 200 taxa have been identified from 53 Little Manatee River samples, <100 have been identified from 57 Palm River samples. Approximately 30% of the taxa were polychaete worms and >17% were Crustacea. The Lower Hillsborough River had proportionately more species of polychaetes than did the other tributaries and the Little Manatee River had proportionately more crustaceans (Table 4). Approximately 17% of the taxa identified from all of the tributaries can be considered as primarily "freshwater" species with the highest proportion found in the Alafia river and lowest in the Palm River (Table 4).

The Lower Hillsborough River was dominated primarily by polychaete species (especially *Monticellina dorsobranchialis*) and tubificid oligochaetes (Table 5). Polychaetes were the most abundant and most speciose group during each year except 1995 (Figures 65 & 66). Subdominants varied from year to year and included bivalves, gastropods, tubificid oligochaetes, and, during 1998, insect larvae (Table 6).

The Palm River was also dominanted primarily by polychaete worms (especially *Streblospio gynobranchiata*) and bivalves (especially *Mysella planulata* and *Mytilopsis leucophaeata*) (Tables 7 & 8). Amphipod Crustacea were less important and insect larvae were among the subdominants only during 1997 (Figures 67 & 68).

Tubificid oligochaetes, a spionid polychaete *(S. gynobranchiata*.) and an amphipod (*Ampelisca abdita*) were the dominant taxa in the Alafia River (Table 9). There were interannual differences in the abundant (Figure 69) and dominant (Table 10) taxa: gastropods in 1995, crustaceans in 1996, oligochaetes in 1997 polychaetes in 1998 and 2000, and bivalves in 1999. Polychaetes were the most speciose group during each year except 1996 when insect larvae contributed considerably to the species inventory (Figure 70).

The dominant taxa in the Little Manatee River were primarily amphipod crustaceans and tubificid oligochaetes (Tables 11 & 12). Amphipod crustaceans were the most abundant taxa during each year (Figure 72). With respect to taxonomic composition, polychaetes, crustaceans, and bivalves were generally the most speciose groups, although aquatic insect larvae represent approximately 15% of the taxa during 1997 (Figure 71).

III.4.4. The Tampa Bay Benthic Index (TBBI). Mean TBBI scores were similar (p>0.05) among tributaries (Figure 73). Frequency distributions, however, differed by tributary. The frequency distributions within the Palm River, with its high frequency of azoic samples, and Little Manatee River differed significantly (KS test; p<0.05) from that of the other tributaries (Figure 74).

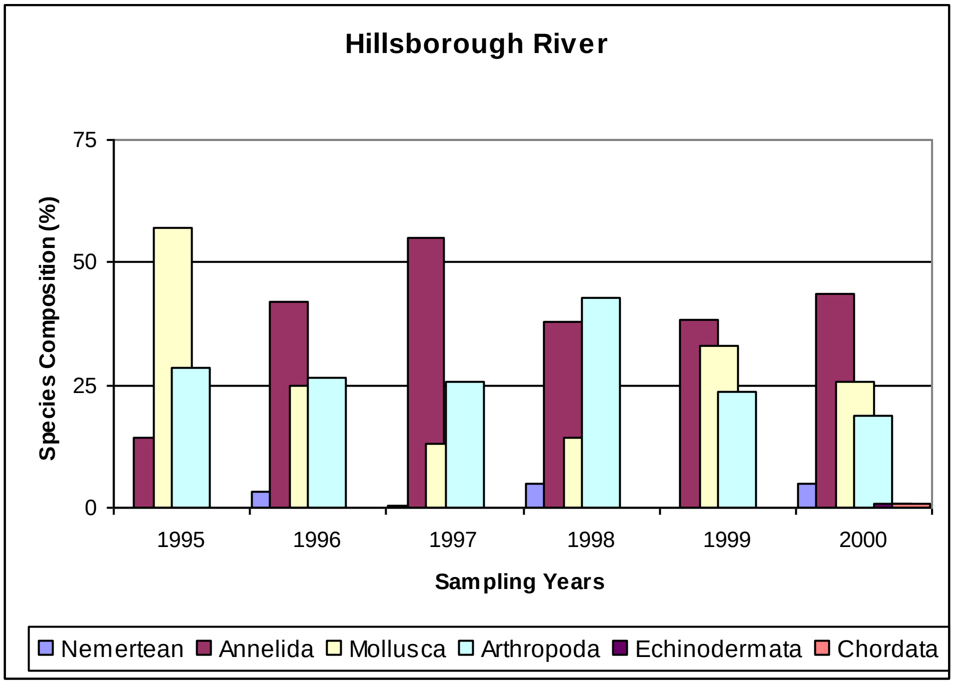

Figure 65. Species composition (as % of total taxa), Lower Hillsborough River benthos, 1995-2000.

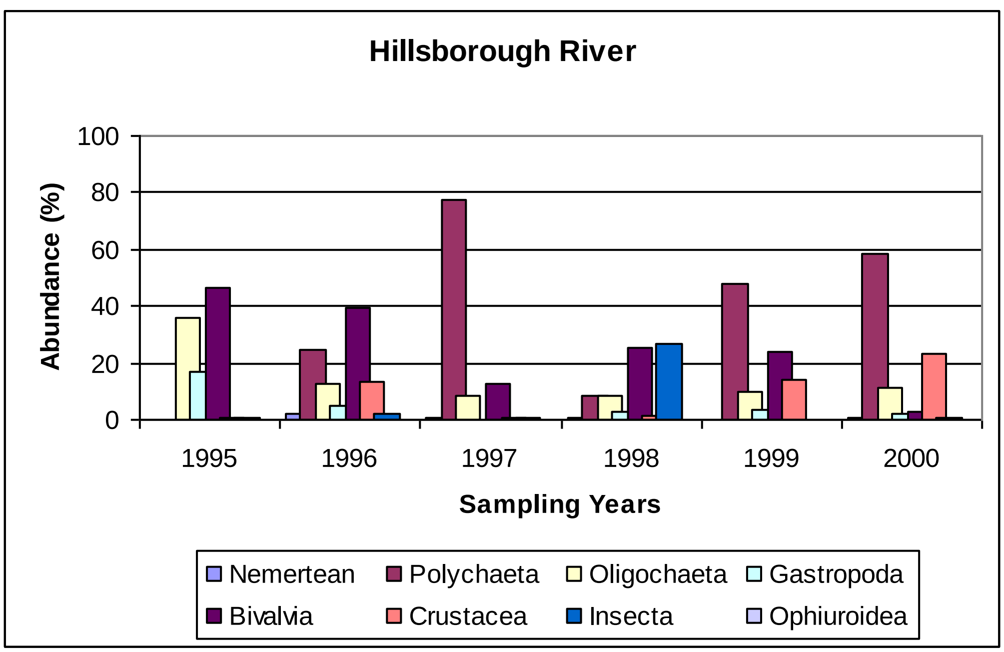

Figure 66. Percent composition of benthic macroinvertebrates, Lower Hillsborough River, 1995-2000

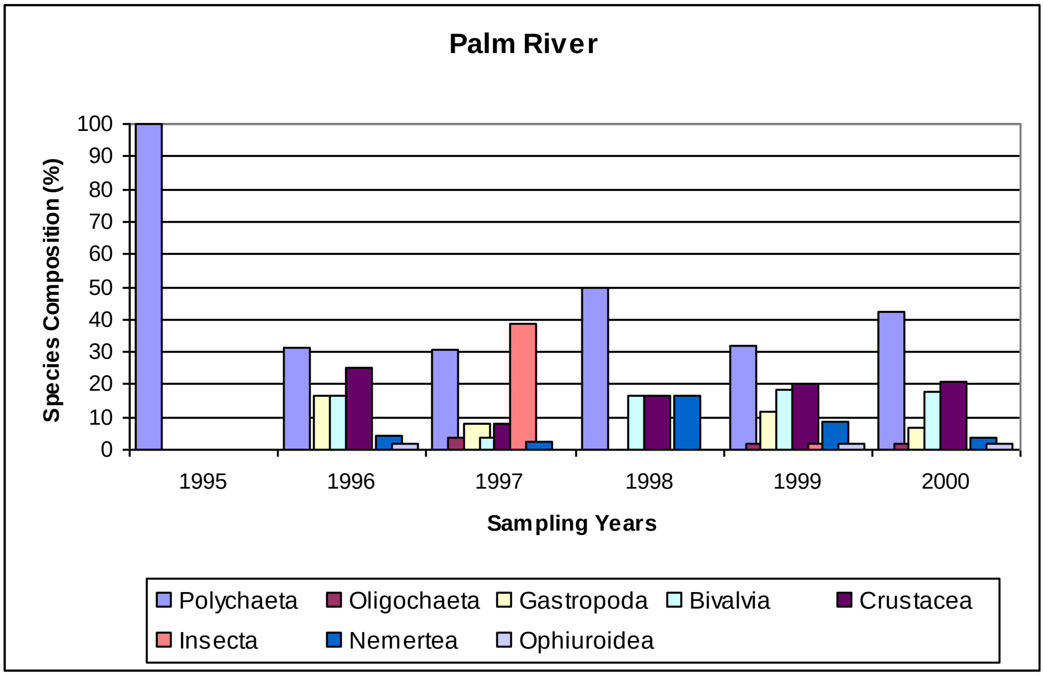

Figure 67.Species composition (as % of total taxa), Palm River benthos, 1995-2000.

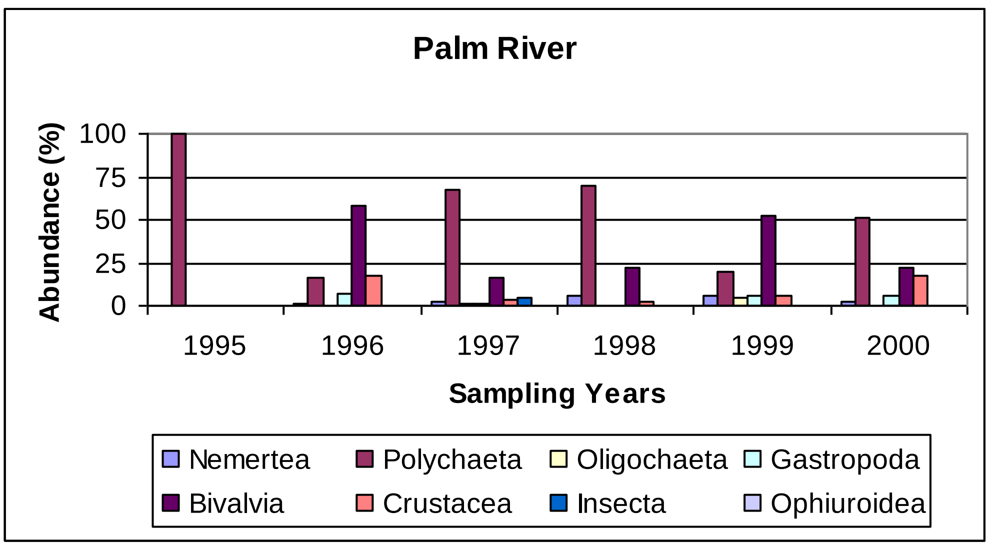

Figure 68. Percent composition of benthic macroinvertebrates, Palm River, 1995-2000

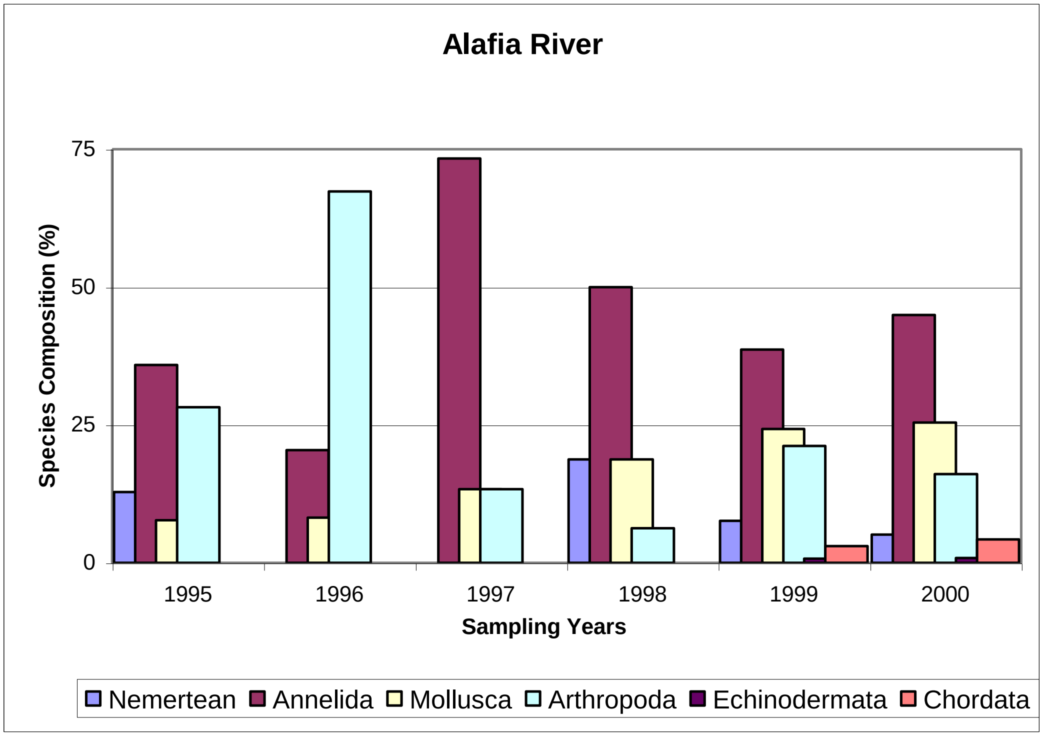

Figure 69.Species composition (as % of total taxa),Alafia River benthos ,1995-2000.

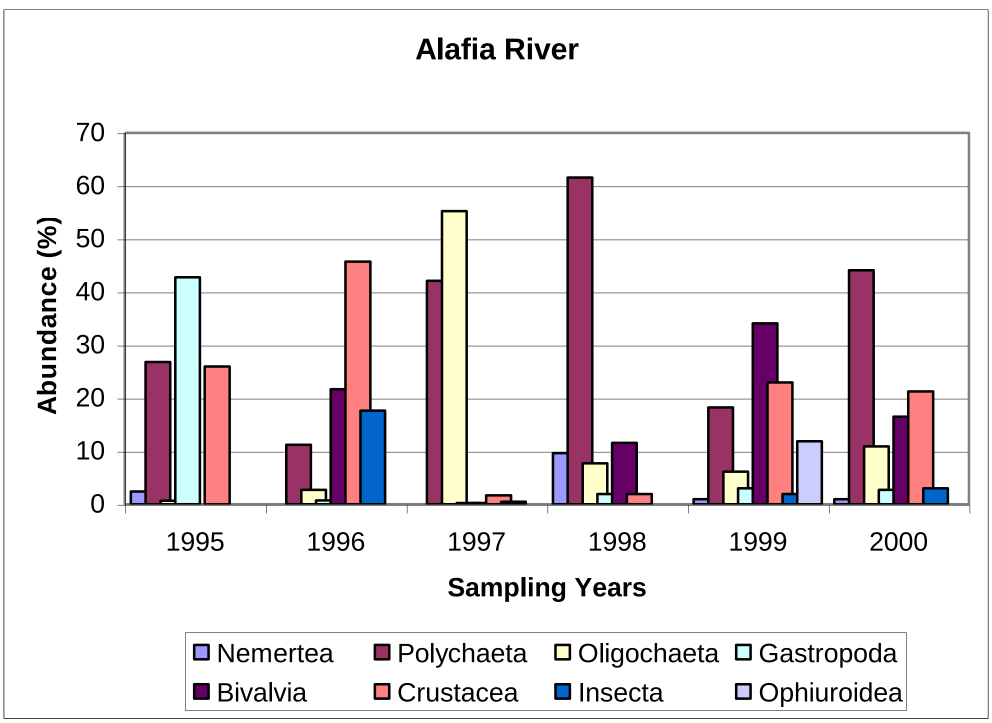

Figure 70. Percent composition of benthic macroinvertebrates, Alafia River, 1995-2000

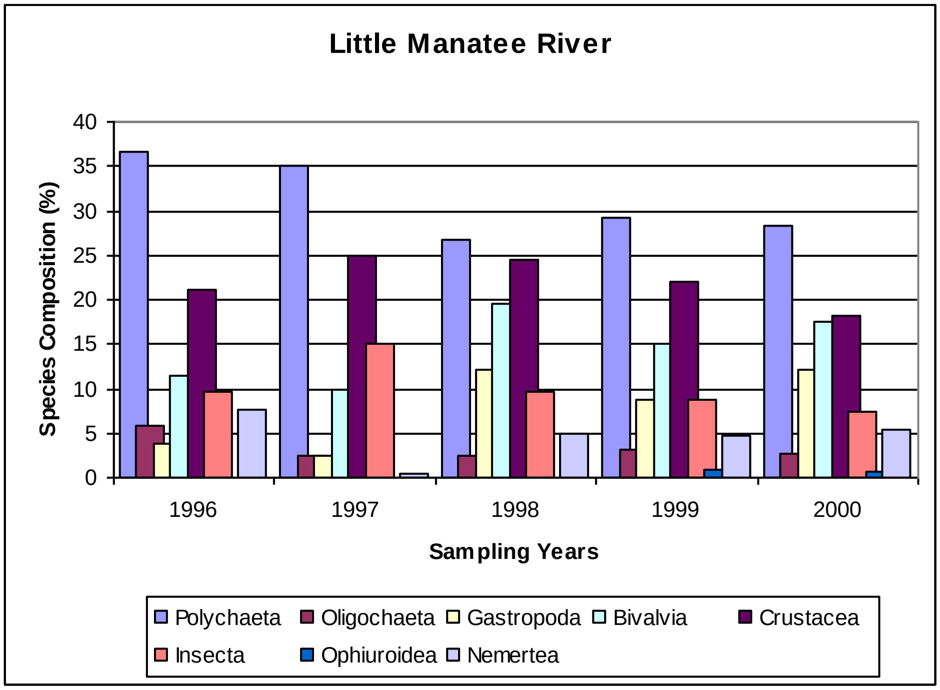

Figure 71.Species composition (as %of total taxa), Little Manatee River benthos, 1996-2000.

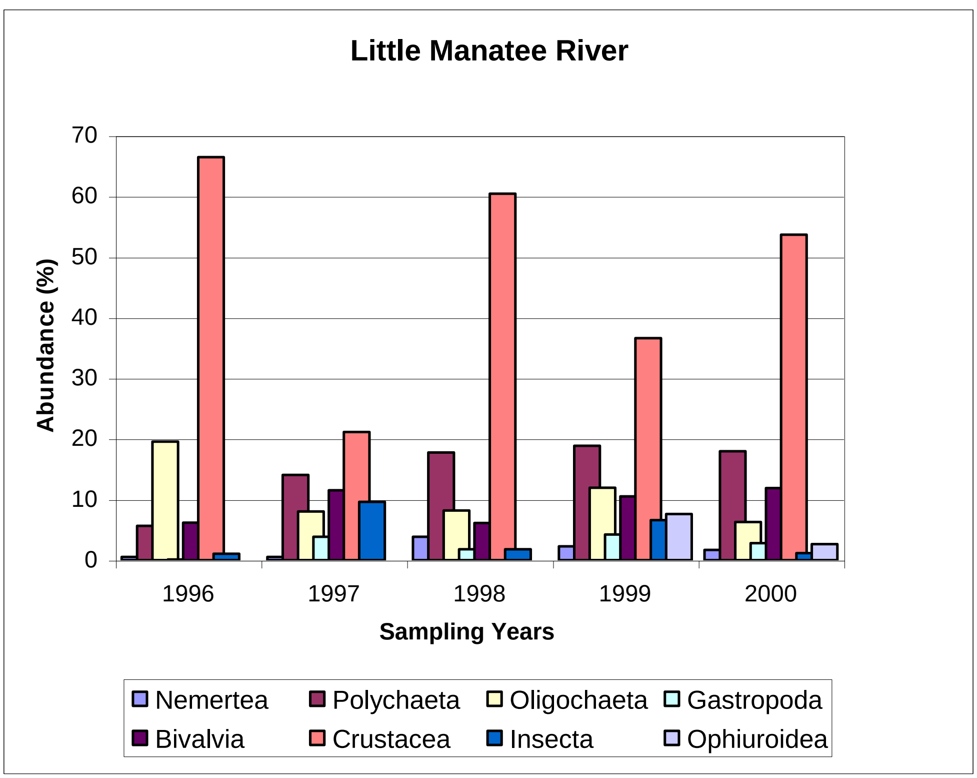

Figure 72. Percent composition of benthic macroinvertebrates, Little Manatee River, 1996-2000

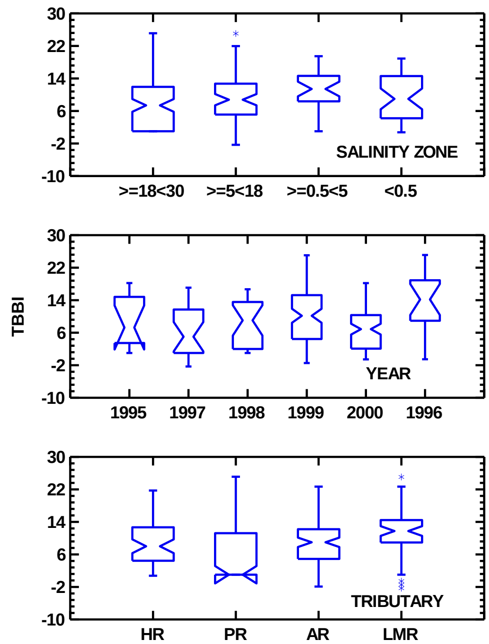

Figure 73. Notched box plot of median and 95% confidence limits of The Tampa Bay Benthic Index (TBBI) by salinity zone, year, and tributary.

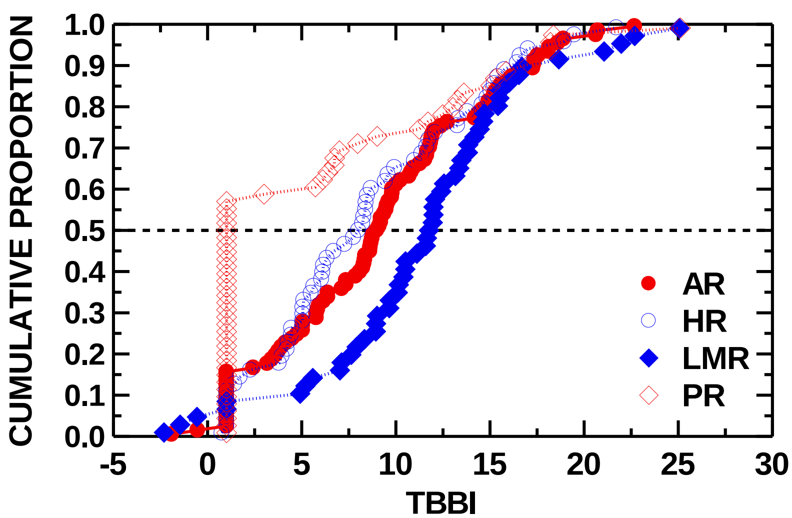

Figure 74. Cumulative distribution function plot of the Tampa Bay Benthic Index (TBBI): by tributary, 1995-2000.

Interannual differences in mean TBBI was observed (p<0.001); scores were lower in 1997 than during all other years with the exception of 1995 and 2000 (Figure 73). TBBI scores were also higher in the mesohaline zone than in the polyhaline zone (Figure 73).

Table 5. Dominant* macroinvertebrate taxa: Lower Hillsborough River, 1995- 2000

RANK	TAXA	% ABUNDANCE	% OCCURRENCE	DOMINANCE SCORE
1	*Monticellina dorsobranchialis (P)*	24.65	23.64	24.1
2	Tubificidae*(O)*	8.64	49.09	20.6
3	*Laeonereis culveri (P)*	9.92	38.18	19.5
4	*Stenoninereis martini (P)*	9.79	34.54	18.4
5	*Mytilopsis leucophaeata (B)*	7.29	43.64	17.8
6	*Grandidierella bonneroides (A)*	3.67	41.82	12.4
7	*Ampelisca abdita (A)*	3.70	36.36	11.6
8	*Ampelisca holmesi (A)*	4.06	20.00	9.0
9	*Aricidea taylori (P)*	1.76	23.64	6.4
10	*Capitella capitata (P)*	1.69	20.00	5.8
11	*Cyclaspis cf. varians (C)*	1.05	16.36	4.1
12	*Rhithropanopeus harrisii (B)*	0.53	30.91	4.1
13	*Littoridinops palustris (G)*	0.70	16.36	3.4
14	*Paraprionospio pinnata (P)*	0.47	20.00	3.1
15	*Amphiporus bioculatus (N)*	0.51	18.18	3.0
16	*Mulinia lateralis (B)*	0.56	14.54	2.9
17	*Streblospio gynobranchiata. (P)*	0.26	29.09	2.75
18	*Scoloplos rubra (P)*	0.34	21.82	2.7
19	*Podarkeopsis levifuscina (P)*	0.41	16.36	2.6
20	*Prionospio perkinsi (P)*	0.46	14.54	2.6

A= Amphipoda; B=Bivalvia; C=Cumacea; D=Decapoda; G=Gastropoda; I=Isopoda; In=Insecta; N=Nemertea; O=Oligochaeta; P=Polychaeta; T=Tanaidacea

* $(\% \text{ Abundance} * \% \text{ Occurrence})^{0.5}$

Table 6. Five dominant macroinvertebrate taxa: by year. Lower Hillsborough River

TAXA	1995-1998	1999	2000
Monticellina dorsobranchialis (P)		21.5	35.0
Tubificidae*(O)*	29.4	22.5	18.2
Laeonereis culveri (P)		32.3	17.2
Stenoninereis martini (P)	48.8	27.1	
Mytilopsis leucophaeata (B)	28.4	29.3	
Grandidierella bonneroides (A)	10.6		
Ampelisca holmesi (A)			16.2
Ampelisca abdita (A)			14.4
Corbicula fluminea (B)	12.9		

A= Amphipoda; B=Bivalvia; O=Oligochaeta; P=Polychaeta;

Table 7. Dominant macroinvertebrate taxa: Palm River, 1995- 2000

RANK	TAXA	% ABUNDANCE	% OCCURRENCE	DOMINANCE SCORE
1	*Streblospio gynobranchiata.(P)*	12.32	24.56	17.4
2	*Mysella planulata (B)*	14.30	19.29	16.6
3	*Mytilopsis leucophaeata (B)*	11.05	24.56	16.57
4	*Tagelus plebius (B)*	7.25	15.79	10.7
5	*Ampelisca abdita (A)*	4.26	17.54	8.6
6	*Stenoninereis martini (P)*	4.03	17.54	8.4
7	*Paraprionospio pinnata (P)*	3.32	21.05	8.4
8	*Mulinia lateralis (M)*	3.67	14.04	7.2
9	*Ampelisca holmesi (Ai*	3.19	12.28	6.3
10	*Acteocina canaliculata (G)*	2.47	10.53	5.1
11	Tubificidae-*(O)*	2.02	12.28	5.0
12	*Podarkeopsis levifuscina (P)*	1.46	15.79	4.8
13	*Nereis succinea (P)*	1.56	12.28	4.4
14	*Haminoea succinea (P)*	1.43	8.77	3.5
15	*Capitella capitata (P)*	0.88	14.04	3.5
16	*Laeonereis culveri (P)*	0.84	14.04	3.4
17	*Tellina versicolor (B)*	1.11	10.53	3.4
18	*Amphiporus bioculatus (N)*	1.04	10.53	3.3
19	*Nemertea sp. F (N)*	0.94	10.53	3.2
20	*Xenanthura brevitelson (I)*	0.88	10.53	3.0

A= Amphipoda; B=Bivalvia; C=Cumacea; D=Decapoda; G=Gastropoda; I=Isopoda; In=Insecta; N=Nemertea ;O=Oligochaeta; P=Polychaeta; T=Tanaidacea

Table 8. Five dominant macroinvertebrate taxa: by year. Palm River

TAXA	1995-1998	1999	2000
Streblospio sp.(P)	16.2	18.2	19.5
Mysella planulata (B)	20.0	10.0	
Mytilopsis leucophaeata (B)	10.2	26.3	
Tagelus plebius (B)		23.2	
Ampelisca abdita (A)	10.6		
Stenoninereis martini (P)	10.7		12.9
Paraprionospio pinnata (P)			20.9
Mulinia lateralis (M)			12.7
Ampelisca holmesi (A)I			11.5
Acteocina canaliculata (G)			
Tubificidae-(O)			
Macoma constricta (B)		7.1	

A= Amphipoda; B=Bivalvia; G=Gastropoda;O=Oligochaeta; P=Polychaeta

Table 9. Dominant macroinvertebrate taxa: Alafia River, 1995- 2000

RANK	TAXA	% ABUNDANCE	% OCCURRENCE	DOMINANCE SCORE
1	Tubificidae- *(O)*	4.90	48.39	15.4
2	*Streblospio gynobranchiata. (P)*	5.24	44.09	15.2
3	*Ampelisca abdita (A)*	4.91	40.86	14.2
4	*Mytilopsis leucophaeata (B)*	3.71	29.03	10.4
5	*Stenoninereis martini (P)*	2.60	35.48	9.6
6	*Pinnixa sp.(p) (D)*	2.64	29.03	8.8
7	*Glottidia pyramidata (Br)*	3.06	24.73	8.7
8	*Paraprionospio pinnata (P)*	2.50	30.11	8.7
9	*Paramphinome sp. B (P)*	2.38	27.96	8.2
10	*Ampelisca holmesi (A)*	2.46	24.73	7.8
11	*Prionospio perkinsi (P)*	2.49	24.73	7.8
12	*Grandidierella bonneroides (A)*	2.12	23.66	7.1
13	*Edotia triloba (I)*	1.78	20.43	6.0
14	*Laeonereis culveri (P)*	1.77	20.43	6.0
15	*Podarkeopsis levifuscina (P)*	1.56	22.58	5.9
16	*Amygdalum papyrium (B)*	1.64	18.28	5.5
17	*Mulinia lateralis (B)*	1.76	16.84	5.4
18	*Monticellina dorsobranchialis (P)*	1.58	16.84	5.2
19	*Melinna maculata (P)*	1.46	18.28	5.2
20	*Mysella planulata (B)*	1.40	18.28	5.1

A= Amphipoda; B=Bivalvia; Br=Brachiopoda; C=Cumacea; D=Decapoda; G=Gastropoda; I=Isopoda; In=Insecta; N=Nemertea;O=Oligochaeta; P=Polychaeta; T=Tanaidacea

Table 10. Five dominant macroinvertebrate taxa: by year. Alafia River

TAXA	1995-1998	1999	2000
Tubificidae- *(O)*		14.2	22.0
Streblospio gynobranchiata (P)	23.3	9.9	34.6
Ampelisca abdita(A)	12.2	26.3	21.0
Mytilopsis leucophaeata (B)	21.8	27.2	
Glottidia pyramidata (Br)		18.6	
Prionospio perkinsi (P)			13.2
Grandidierella bonneroides (A)	17.7		
Laeonereis culveri (P)	10.8		
Mulinia lateralis (B)			15.6

A= Amphipoda; B=Bivalvia; Br=Brachiopoda;O=Oligochaeta; P=Polychaeta

Table 11. Dominant macroinvertebrate taxa: Little Manatee River, 1996- 2000

RANK	TAXA	% ABUNDANCE	% OCCURRENCE	DOMINANCE SCORE
1	*Grandidierella bonneroides (A)*	18.51	49.06	30.1
2	Tubificidae- *(O)*	10.40	49.06	22.6
3	*Apocorophium louisianum (A)*	9.99	26.42	16.9
4	*Cyathura polita (I)*	6.05	41.51	15.8
5	*Ampelisca holmesi (A)*	7.39	33.96	15.8
6	*Ampelisca abdita (A)*	2.16	41.51	9.5
7	*Xenanthura brevitelson (I)*	2.39	35.85	9.3
8	*Aricidea philbinae (P)*	2.08	30.19	7.9
9	*Monticellina dorsobranchialis (P)*	2.59	20.75	7.3
10	*Glottidia pyramidata (Br)*	2.20	22.64	7.1
11	*Laeonereis culveri (P)*	1.04	41.51	6.6
12	*Mytilopsis leucophaeata (B)*	1.97	16.98	5.8
13	*Mysella planulata (B)*	1.74	16.98	5.4
14	*Streblospio gynobranchiata .(P)*	1.15	24.53	5.3
15	*Polypedilum scalaneum group (In)*	1.00	26.42	5.1
16	*Mulinia lateralis (B)*	1.23	16.98	4.6
17	*Heteromastus filiformis (P)*	0.78	26.42	4.5
18	*Amygdalum papyrium (B)*	0.78	22.64	4.2
19	*Leptochelia sp. (T)*	0.64	24.53	4.0
20	*Rhithropanopeus harrisii (D)*	0.45	33.96	3.9

A= Amphipoda; B=Bivalvia; Br=Brachiopoda; C=Cumacea; D=Decapoda; G=Gastropoda; I=Isopoda; In=Insecta; N=Nemertea ;O=Oligochaeta; P=Polychaeta; T=Tanaidacea

Table 12. Five dominant macroinvertebrate taxa: by year. Little Manatee River

TAXA	1996-1998	1999	2000
Grandidierella bonneroides (A)	50.2	.	17.0
Tubificidae- *(O)*	39.7	26.4	16.0
Apocorophium louisianum (A)	33.9	.	.
Cyathura polita (I)	30.3	17.3	.
Ampelisca holmesi (A)	.	.	23.4
Ampelisca abdita (A)	.	17.9	11.4
Xenanthura brevitelson (I)	.	17.3	.
Monticellina dorsobranchialis (P)	.	.	11.4
Glottidia pyramidata (Br)	.	16.3	.
Mytilopsis leucophaeata (B)	11.5	.	.
Cerapus sp. C (A)	.	.	25.6

A= Amphipoda; B=Bivalvia; Br=Brachiopoda; I=Isopoda; ;O=Oligochaeta; P=Polychaeta

III.4.5. TBBI and Physico-Chemical Variables: Pearson correlation coefficients for the association between the TBBI for the Lower Hillsborough River (untransformed) and the variables DO, salinity, and %SC were not significant ($p>0.05$); there was evidence of an increased TBBI as river depth decreased ($p<0.05$) (Figure 75).

Within the Palm River the TBBI was positively associated ($p<0.001$) with near-bottom DO ($r^2=0.4$) and decreasing sample depth ($r^2=0.6$) and negatively associated with both %SC ($r^2=0.4$), and salinity ($r^2=0.1$) (Figure 76). At depths down to approximately 2 meters the TBBI was not significantly associated with depth ($r^2=<0.001$); at stations deeper than 2-m the TBBI and depths were positively associated ($r^2=0.24$; $p<0.01$) (Figure76).

In the Alafia and Little Manatee rivers, Pearson correlation coefficients (untransformed data) were generally not associated with the TBBI ($p>0.05$). TheTBBI was associated ($p<0.05$) with %SC in the Alafia River ($r^2=0.07$) (Figure 77) and with DO in the Little Manatee River ($r^2=0.08$) (Figure 78).

III.4.6. TBBI and Sediment Contaminants: Pearson correlation coefficients for the association between the Lower Hillsborough River TBBI (untransformed) and the PEL quotients for PAHs, organochlorine pesticides, and PCBs were not significant ($p>0.05$) (Figure 79), there was a negative association with the PEL quotient for metals ($r^2=0.24$). Within the Palm River the TBBI was negatively associated ($p<0.05$) with both PAHs ($r^2=0.23$) and metals ($r^2=0.3$) (Figure 80). Within the Alafia River the TBBI was negatively associated ($p<0.05$) with metals ($r^2=0.14$) (Figure 81). Within the Little Manatee River the TBBI was negatively associated ($p<0.05$) with PCBs ($r^2=0.2$) (Figure 82).

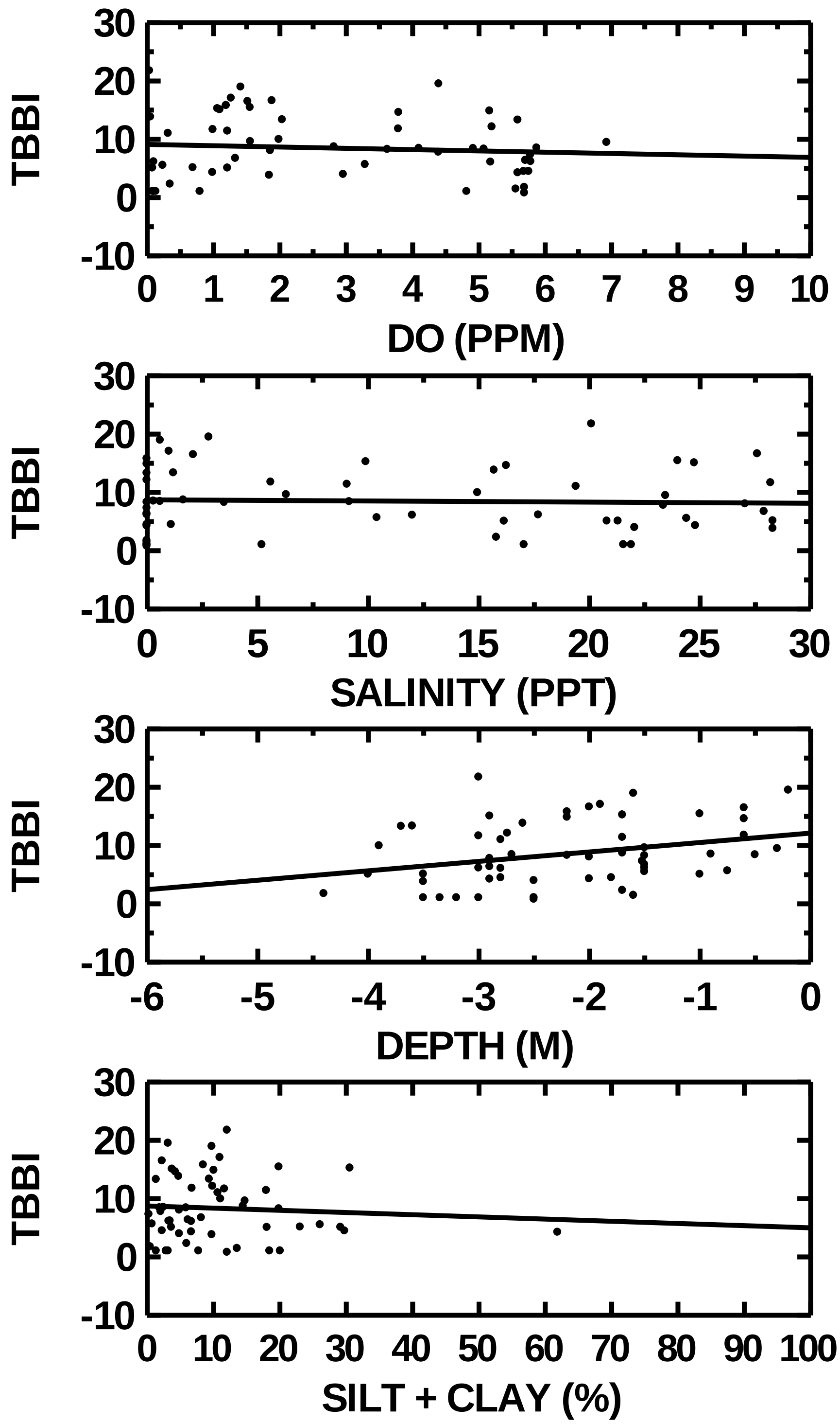

Figure 75. Scatter plot and linear regression line showing the association between the TBBI and DO, salinity, depth, and %SC, Lower Hillsborough River, 1995-2000.

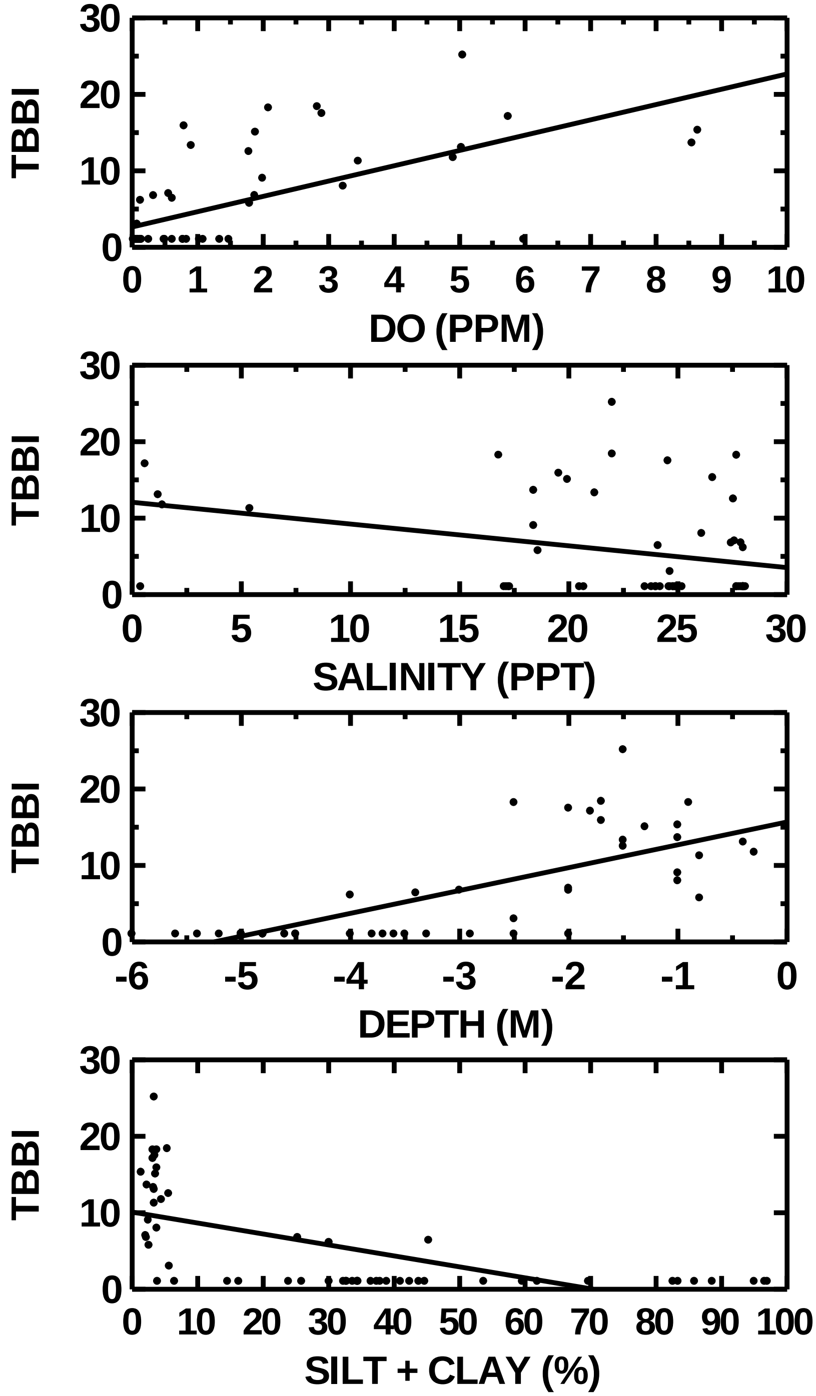

Figure 76. Scatter plot and linear regression line showing the association between the TBBI and DO, salinity, depth, and %SC, Palm River, 1995-2000.

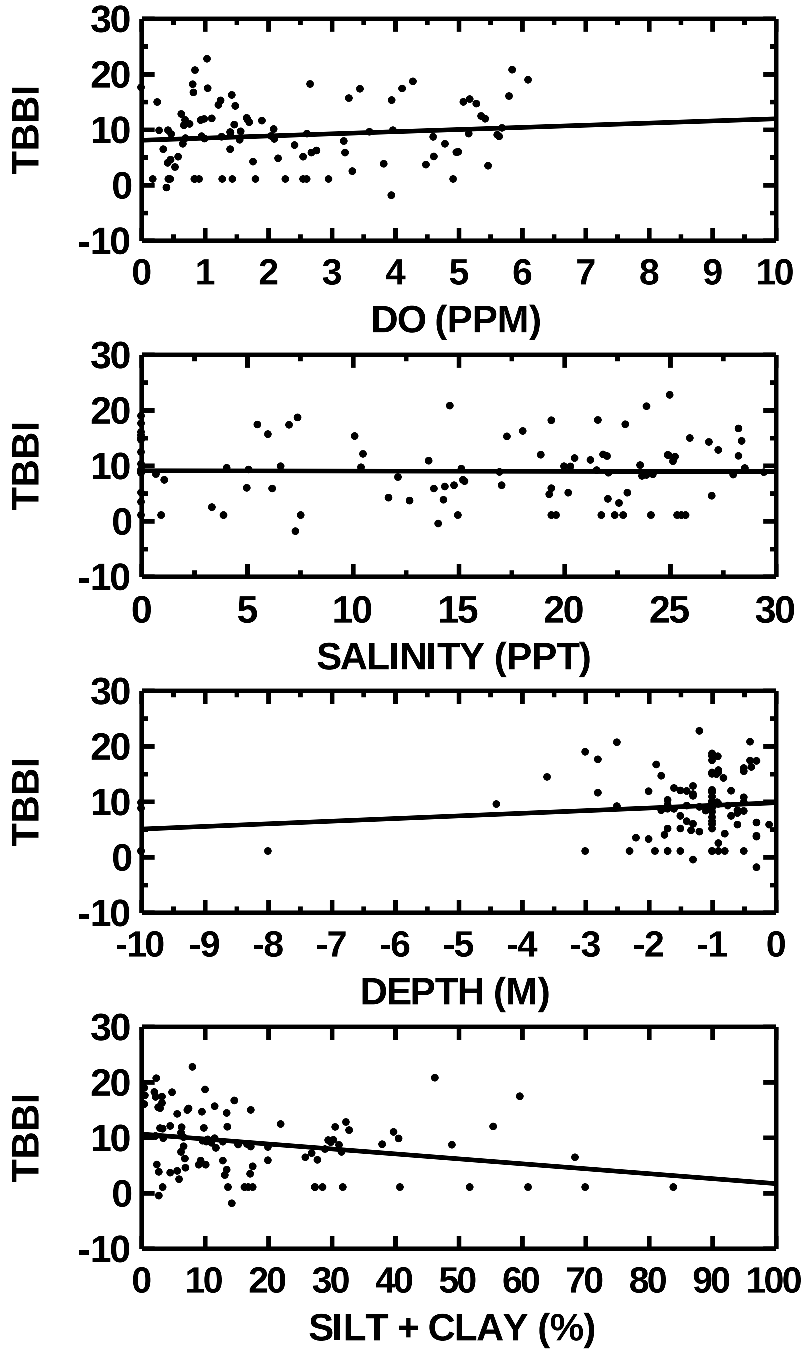

Figure 77. Scatter plot and linear regression line showing the association between the TBBI and DO, salinity, depth, and %SC, Alafia River, 1995-2000.

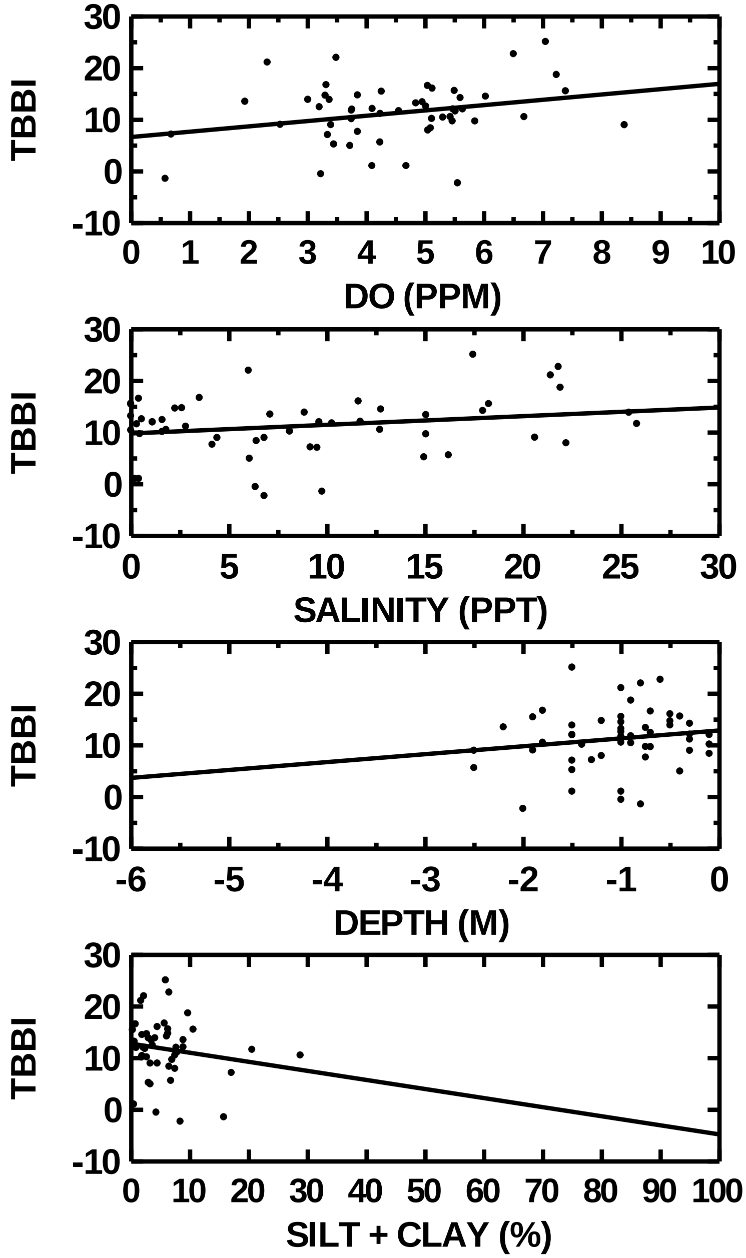

Figure 78. Scatter plot and linear regression line showing the association between the TBBI and DO, salinity, depth, and %SC, Little Manatee River, 1996-2000.

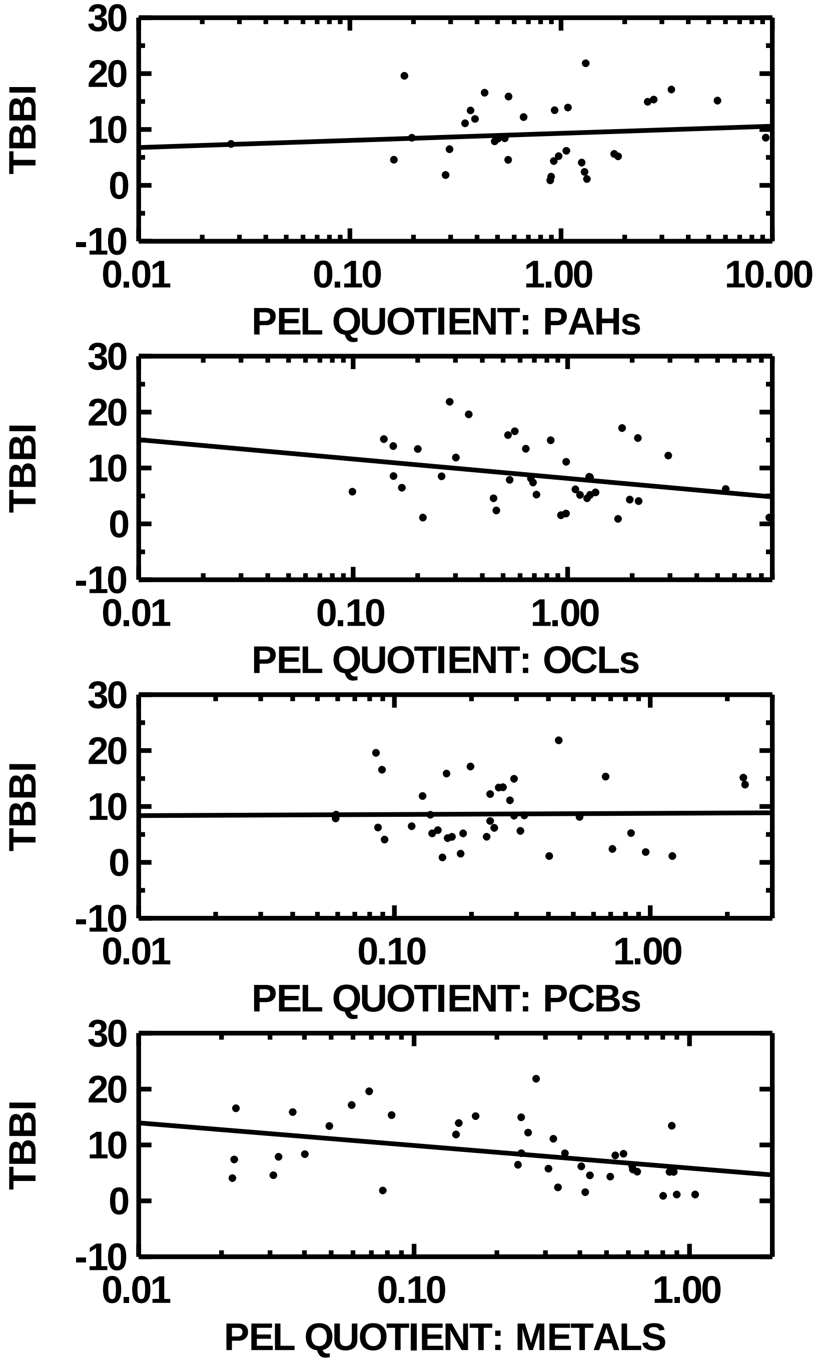

Figure 79. Scatter plot and linear regression line showing the association between the TBBI and PEL quotients for PAHs, organochlorine pesticides [OCLs], PCBs, and metals. Lower Hillsborough River, 1995-2000.

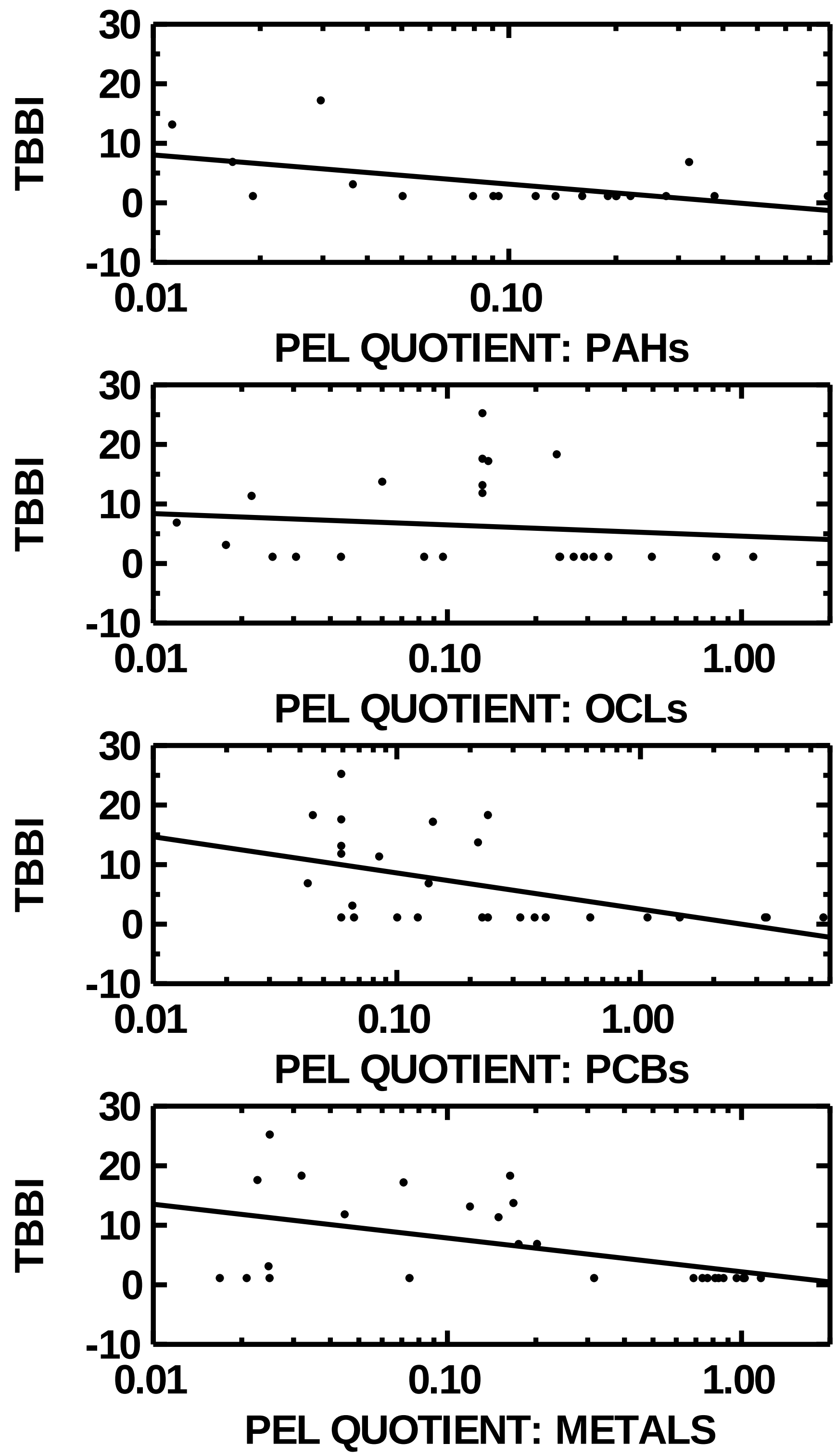

Figure 80. Scatter plot and linear regression line showing the association between the TBBI and PEL quotients for PAHs, organochlorine pesticides [OCLs], PCBs, and metals. Palm River, 1995-2000.

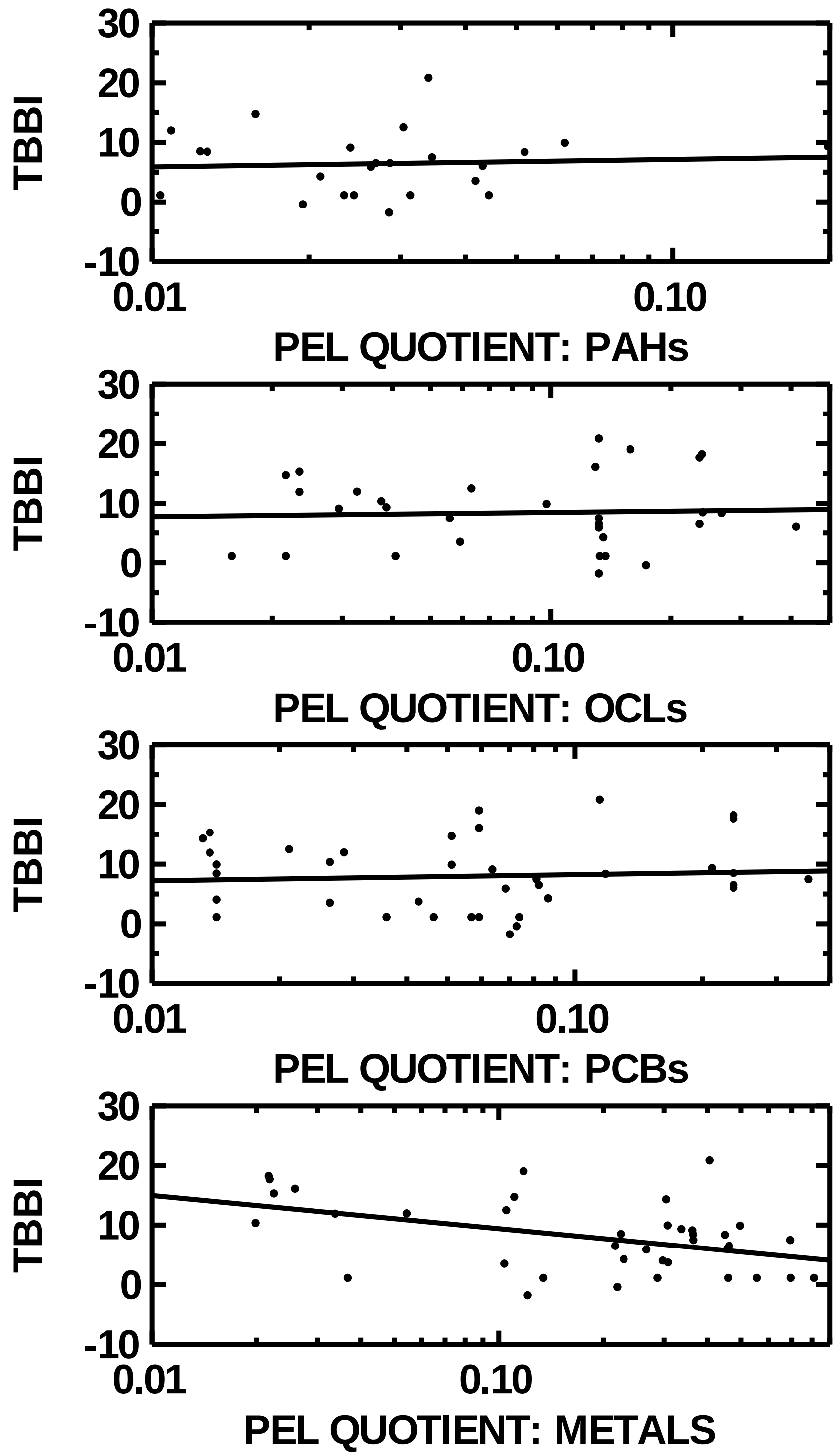

Figure 81. Scatter plot and linear regression line showing the association between the TBBI and PEL quotients for PAHs, organochlorine pesticides [OCLs], PCBs, and metals. Alafia River, 1995-2000.

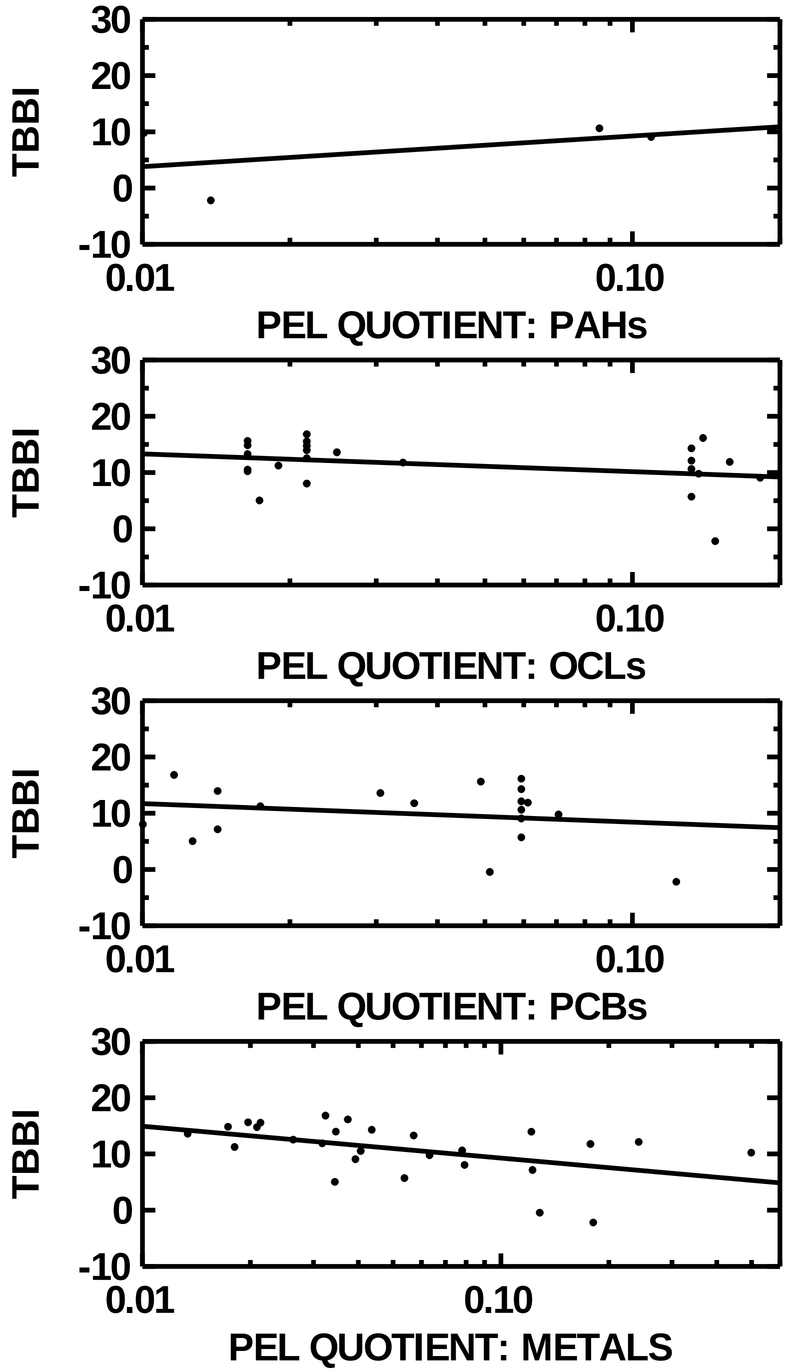

Figure 82. Scatter plot and linear regression line showing the association between the TBBI and PEL quotients for PAHs, organochlorine pesticides [OCLs], PCBs, and metals. Little Manatee River, 1996-2000.

IV. DISCUSSION

A bay-wide benthic and sediment contaminant monitoring program for Tampa Bay has been in effect since 1993. The original study design was such that there was a low probability that sampling locations would be located in the smaller tributaries to the bay. To address this deficit, targeted sampling of three tributaries to Tampa Bay (The Lower Hillsborough, Palm, and Alafia rivers) was added to the bay-wide program in 1995; the Little Manatee River was added in 1996. These early efforts (1995-1996) were intended as pilot studies.

A more formal design was implemented in 1997 with the intent of collecting approximately 20 samples per tributary over a four year period. Support for this modification was provided, in part, by the SWFWMD and two of its Basin Boards. Beginning in 1999 this design became considerably more robust (20-40+ samples per tributary). Hillsborough County's Board of County Commissioners requested that EPCHC develop a monitoring program capable of evaluating possible impacts from the implementation of Tampa Bay Water's "Master Water Plan" (1998) independent of the SWFWMD's monitoring requirements of the utility.

Each of these four tributaries has been modified to some extent by anthropogenic activities. These modifications are manifest as alterations (i.e., reductions) in freshwater inflow, agricultural/industrial/residential/urban development, increased sedimentation, and lowered dissolved oxygen. The data collected during the period 1995-2000 in these tributaries show degradation of the sediments and sedimentary biota in each system. The extent and types of impacts differ by tributary.

The Lower Hillsborough River is essentially an urban estuary impacted by stormwater discharges and reduction of freshwater inflow (Mote Marine Laboratory 1984; Water & Air Research Inc. 1993; Water & Air Research & SDI Environmental Services, Inc. 1994). The Public Interest Research Group (PIRG 2001) does not include the Lower Hillsborough River in their assessment of contamination of Florida waterways. A consequence of these manmade modifications to this system has been increased salinity, the accumulation of fine-grained sediments and associated contaminants, as well as lowered DO levels.

The Palm River system has also been affected by stormwater discharges, reduction of freshwater inflow, and diminished flushing (HDR Engineering, Inc. 1994). The results, similar to those reported from the Lower Hillsborough River include increased salinity, accumulation of fine-grained sediments, and lowered DO levels. The northern shoreline of the Palm River has had several industrial facilities whereas the southern shoreline is more residential.

Whereas the Alafia River system has been heavily impacted by residential development in the lower reaches, agriculture and phosphate mining have affected the upper reaches. Impacts from the latter industries can be detected downstream (Dames & Moore, Inc., 1975; PIRG 2001; SWFWMD 2001). PIRG's (2001) data suggest that contamination of sediments by metals, endocrine disruptors, and carcinogens such as PAHs, appears minimal.

The Alafia is subject to surface water withdrawals to help meet agricultural and industrial needs (SWFWMD 2001). These withdrawals are augmented, in part, by surface water discharges into the Alafia River from phosphate industry related activities upstream of the estuary (SWFWMD 2001). By the fall of 2001 the SWFWMD is scheduled to adopt minimum flows for the Alafia "to establish limits to withdrawals that will not cause significant harm to the water resources or ecology of the area" (SWFWMD 2001).

The Little Manatee River has been the least impacted of these four tributaries, although the watershed has been modified. The portion of the river below I-75 is suburban/urban (especially Marsh Branch & Ruskin Inlet) and farther upstream there are agricultural (pastureland, citrus, tomatoes) and phosphate mining activities (Fernandez 1985; PBS&J 2001).

Near-bottom salinities differed by year (for the “Index Period”) and among tributaries. Tributary salinities generally increased from 1997-2000, a consequence of regional drought conditions. Within the tributaries, salinities were generally highest in the Palm River, which has limited freshwater inflow over Structure 160 of the Tampa Bay-Pass Canal. The Palm River also demonstrated the lowest proportion of low salinity (<5 ppt) observations. By contrast, >40% of the salinity measurements in the lower Hillsborough River were <5 ppt. Flow over the Hillsborough River dam and inflow from Sulphur Springs contributed to these lower salinities.

Mean near-bottom DO values were similar between the years sampled for this study. However, DO varied spatially within individual tributaries as areas of low DO. Proportionally, the Palm River was most affected (>75% of measurements)—especially at depths greater than 2-m. These low DO conditions were exacerbated by the presence of a sill near US41 which affects flushing and exchange. The lower Hillsborough River also exhibited extensive hypoxia which can be attributed to the modifications described above.

The silt+clay content of the sediments differed by tributary. Sedimentation, low flow, and the presence of the sill were factors that contributed to sediments in the Palm River having the highest mean silt+clay content.

Sediment contamination was generally highest in the lower Hillsborough River (metals, pesticides, PAHs) and lowest in the Little Manatee River. Runoff from urban and residential properties as well as major roadways proximal to the Lower Hillsborough River were the most likely sources of these contaminants. Several locations in the Palm River had sediments with inordinately high PCB levels. Putative sources of PCBs to the Palm River could be roadway runoff (*e.g.*, Selmon Expressway and SR 60) and an abandoned landfill on the north shore.

Benthic community structure differed among tributaries. Benthic standing crop (as numbers of organisms), mean diversity, and mean numbers of taxa were highest in the Little Manatee and lower Hillsborough rivers. However, the taxa contributing to these metrics differed considerably. Hillsborough river benthos was characterized by high numbers of polychaete worms whereas crustaceans predominated in the Little Manatee. The Palm River had a relatively high frequency of "empty" samples—a consequence of the DO stress within this tributary.

Approximately 20% of the >300 taxa identified to date from these tributaries during this monitoring program comprised a "core group" of taxa found in each of the four tributaries. Although low salinity habitat was most frequently encountered in the lower Hillsborough River, freshwater species were proportionately more common in the Alafia River—a tributary which still exhibits a longitudinal salinity gradient. The Palm River, which had the lowest proportion of low salinity measurements, had the lowest proportion of freshwater species.

Although the Tampa Bay Benthic Index [TBBI] was developed to assess the status of higher salinity habitats, some observations are instructive. TBBI scores were associated with depth (Palm and Hillsborough), DO (Palm and Little Manatee), %SC (Palm and Alafia), salinity (Palm), metals (Hillsborough, Palm, Alafia), PAHs (Palm), and PCBs (Little Manatee). Associations with sediment contaminants are based upon a subset of the database and should be reassessed as the sample sizes increase over time using more rigorous statistical tools.

V. CONCLUSIONS

Tampa Bay Water plans to commence withholding additional freshwater flow from the Lower Hillsborough and Palm rivers, and diverting flow from the Alafia river by the fall of 2002. The 1999 and 2000 sampling periods represent the first two years of baseline data collection for Hillsborough County's "Independent Monitoring Program" (HIMP). The HIMP is a tool for Hillsborough County's Water Resource Team to monitor these tributaries for ecological changes coincident with implementation of TBW's "Master Water Plan" (1998). Additionally, these tributaries are scheduled to have minimum flows established by 2015 (SWFWMD 2002).

Salinities in 2000 were generally the highest of the years studied due to the extreme drought conditions throughout the region; mean values have steadily increased since 1997. Palm River salinities were the highest of the four tributaries.

Both the Palm and Lower Hillsborough rivers show evidence of stress from low dissolved oxygen. Extremely low dissolved oxygen concentrations are particularly common in waters deeper than two meters in the Palm River because of low flow and density stratification.

Sediment contamination was widespread in the Lower Hillsborough and Palm rivers and some contaminants were detected at concentrations likely to be toxic to aquatic life. These include PAHs, Chlordane, and Zinc in the Hillsborough and PCBs in the Palm River. The Little Manatee River shows little evidence of sediment contamination.

Benthic communities differed by tributary with respect to abundance, numbers of species, and composition. The two tributaries with the highest densities of organisms and greatest diversity differed markedly in species composition: polychaetes predominated in the lower Hillsborough and crustaceans predominated in the Little Manatee. Hypoxia and anoxia contributed to the prevalence of samples devoid of benthic organisms in the Palm River.

VI. REFERENCES CITED

Coastal Environmental, Inc. 1995. *Statistical Analysis of theTampa Bay National Estuary Program 1993 Benthic Survey*. Prep. for TBNEP, St. Petersburg.

Courtney, C.M., R. Brown, & D. Heimbuch. 1993. *Environmental Monitoring and Assessment Program Estuaries-West Indian Province: Volume I. Introduction, Methods and Materials, and Quality Assurance Field and Laboratory Operations Manual for a Synoptic Survey of Benthic Macroinvertebrates of the Tampa Bay Estuaries*. Environmental Protection Commission of Hillsborough County, Tampa, FL

Courtney, C.M., S.A. Grabe, D.J. Karlen, R. Brown, & D. Heimbuch. 1995. *Laboratory Operations Manual for a Synoptic Survey of Benthic Macroinvertebrates of the Tampa Bay Estuaries*. Environmental Protection Commission of Hillsborough County, Tampa, FL. [DRAFT]

Dames & Moore, Inc. 1975. *Hydrobiologic Assessment of the Palm and Little Manatee River Basins*. Prepared for: Southwest Florida Water Management District Palm River Basin Board.

ESRI, Inc. 1999. *ARCVIEW®* ver. 3.2. Redlands, CA.

Fernandez, M. 1985. *Salinity Characteristics and Distributuiion and effects of alternative Plans for Freshwater Withdrawal,Llittle Manatee River Estuary and Adjacent Areas of Tampa Bay, Florida*. USGS Water Resources Investigations Report 84-4301. USGS. Tallahassee. 45 pp.

HDR Engineering, Inc. 1994. *Environmental Assessment of the Palm River, Tampa/Hillsborough County, Florida*. Prep. for Palm River Management Committee. 73p.

Johnson, R.A. & D.W. Wichern. 1988. *Applied Multivariate Statistical Analysis*. 2nd Ed. Prentice Hall. NJ. 607p.

MacDonald Environmental Services Ltd. 1994. *Approach to the Assessment of Sediment Quality in Florida Coastal Waters. Volume 1. Development and Evaluation of Sediment Quality Assessment Guidelines*. Prep. for FDEP. MacDonald Environmental Sciences Ltd. Ladysmith, B.C., Canada. 126 p.

Mote Marine Laboratory. 1984. *Biological and Chemical Studies on the Impact of Stormwater Runoff upon the Biological Community on the Hillsborough Rriver, Tampa, Florida*. Prep. For City of Tampa, Stormwater Management Division.

PBS&J, Inc. 2001. *Little Manatee River Watershed Management Plan*.[DRAFT] Prep. for Hillsborough County Board of County Commissioners.

REFERENCES CITED (continued)

PBS&J, Inc. 1999. *Tampa Bay-pass Canal/Lower Hillsborough River Water Supply Projects Hydrobiological Monitoring Program*. Prep. for TBW.

Pielou, E.C. 1975. *Ecological Diversity*. Wiley-Interscience. N.Y. 165 p.

PISCES Conservation Ltd 2000. *Species Diversity and Richness II*. Lymington, England.

Public Interest Research Group. 2001. *Poisoning Our Water: How the Government Permits Pollution*. 24 pp+Appendices

Sokal, R.R. & F.J. Rohlf. 1981. *Biometry*. 2nd Ed. W.H. Freeman & C0. San Francisco. 859 p.

SPSS, Inc. 2000. *SYSTAT®* 10. Chicago, IL.

Southwest Florida Water Management District. 2001. *Alafia River Comprehensive Watershed Management Plan*. Brooksville.

Southwest Florida Water Management District. 2002. *Publication of Approved Priority List and Schedule for the Establishment of Minimum Flows and Levels*. Brooksville.

Tampa Bay National Estuary Program. 1996. *Charting the Course: The Comprehensive Conservation and Management Plan for Tampa Bay*. St. Petersburg.

Tampa Bay Water. 1998. *Master Water Plan*. Clearwater, FL.

Water & Air Research, Inc. 1993. *First Progress Report: Tampa Bypass Canal and Hillsborough River Biological Assessment & Monitoring Program*. Prepared for West Coast Regional Water Supply Authority. Clearwater.

Water & Air Research, Inc. & SDI Environmental Services Inc. 1994. *Second Interpretive Report Tampa Bypass Canal and Hillsborough River Monitoring Program*. Prepared for West Coast Regional Water Supply Authority. Clearwater.

APPENDIX A

Inventory of Benthic Macroinvertebrates Identified from the Lower Hillsborough River, Palm River, Alafia River, and Little Manatee River, 1995-2000.