

Profile of Benthic Macroinvertebrates in the Loxahatchee River Estuary

**Richard C. Dent, Lorene R. Bachman and Mary S. Ridler
Loxahatchee River District**

January 1998

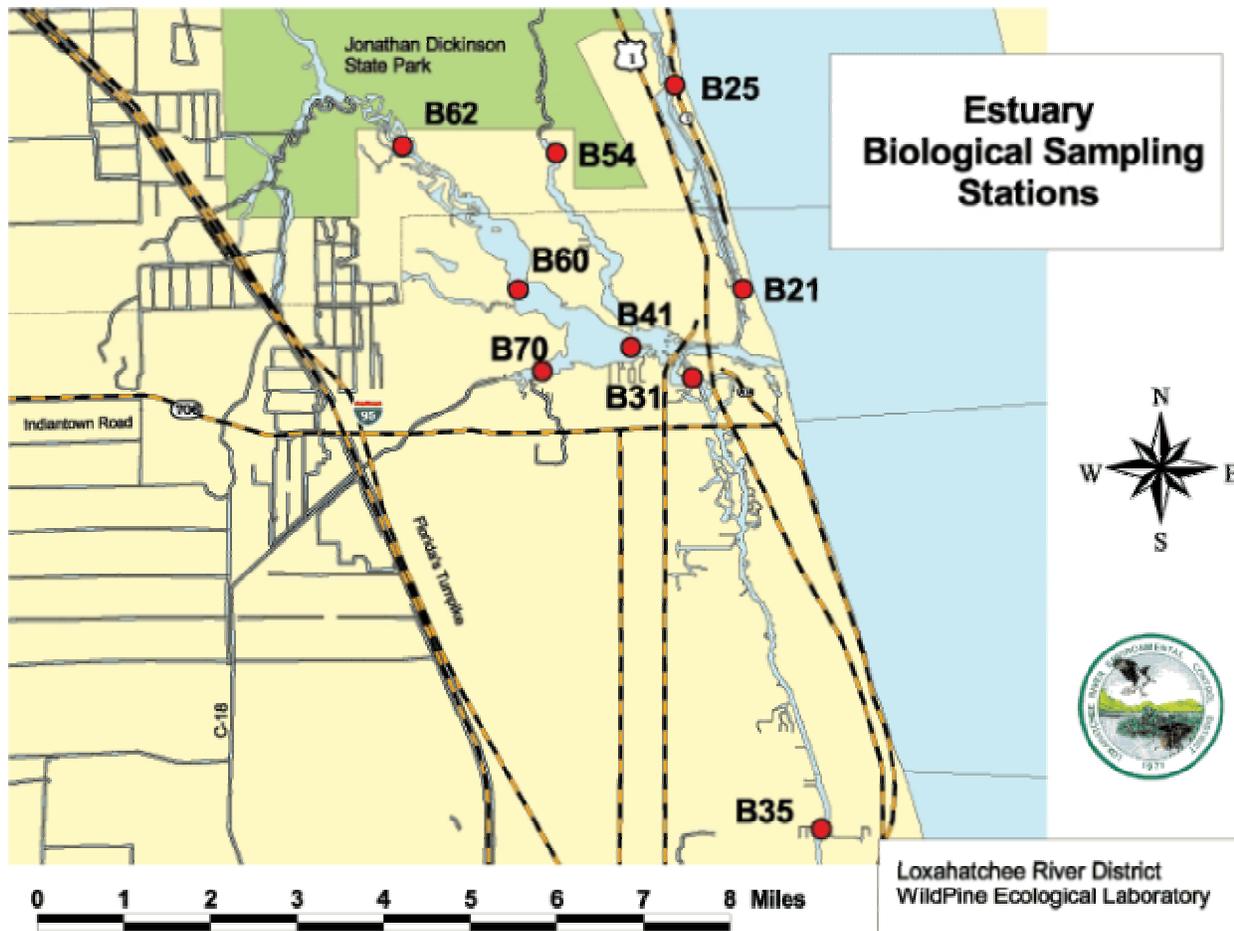
Introduction

The study area is shown on Figure #1 and incorporates the Loxahatchee River estuary and portions of the Atlantic Intracoastal Waterway. The estuary of the Loxahatchee River, situated at the very southern end of the Indian River Lagoon, is relatively small, encompassing only a few square miles, and drains a watershed of approximately 200 square miles located in northern Palm Beach and southern Martin counties. The estuary consists of a main body and three arms that reach up to meet the major freshwater tributaries of the basin. The northern arm of the estuary extends several miles up the north prong of the river to accept waters drained from urban land uses and preserved lands in Jonathan Dickinson State Park. The southwest fork of the estuary receives discharges from several small tributary creeks and from the C-18 drainage basin during times of discharge through a South Florida Water Management District control structure designated S-46. The northwest fork of the Loxahatchee River is the only federally designated Wild and Scenic river in Florida and it flows into the central arm of the estuary. The entire estuary has received a number of designations and environmental protections. It is a Manatee Protection Area, an Outstanding Florida Water, a State Class II designation and shares two designations as an Aquatic Preserve.

The area of study also incorporates the Intracoastal Waterway for a distance of approximately five miles both north and south of the Jupiter Inlet. South of the inlet, the Intracoastal Waterway is designated as the Lake Worth Creek Aquatic Preserve. North of the inlet, the Intracoastal Waterway joins the Loxahatchee estuary as a part of the Indian River Lagoon Aquatic Preserve that has both state and federal recognition's.

Historically, the inlet at Jupiter had closed and opened based on natural occurrences. Over the past 50 years, however, the inlet has been maintained open allowing a relatively constant exchange of tidal ocean waters with the freshwaters from the uplands. Other major hydrologic changes include a reduction of the watershed size and the channelization and structural control of major sub-basins. The impact of urban, recreational and agricultural development within the watershed has also adjusted the water quality and other conditions within the estuary. While not well documented over the years, it is believed that the general habitat within the Loxahatchee estuary differs

substantially from conditions present in the first half of this century. Further, with the loss of wetlands and their attendant buffering effects during wet weather conditions, the discharge of stormwaters during major events can have a significant effect on the character of the estuary.



The environmental conditions within the estuary have been monitored since 1970 by a sampling program emphasizing water quality. This information is presently housed in a large data base and is analyzed to develop information valuable to environmental decision makers. Water quality data alone, however, can be limited in its application to a given ecosystem and related studies are often useful. Benthic invertebrates, small animals inhabiting the substratum or bottom materials of the waters of the study area can be used as indicators of environmental status and trends. The reason is that benthic organisms are generally limited in mobility and can not avoid changing environmental conditions. Therefore, benthic invertebrates tend to reflect the local environmental conditions and serve as an indicator of the health of the aquatic environment. Stress to the environment, resultant from natural or anthropogenic sources, may escape periodic water quality monitoring, but be detected by a study of the benthic community.

The objective of this study is to develop an extensive data base on the benthic community structure throughout the estuarine portions of the Loxahatchee River and attendant reaches of the Intracoastal Waterway. To achieve this goal, five years of data, recorded from 1992 through 1997, is presented. Further, this report provides the format to communicate this new information by providing summations of the data in a form that can be easily used and understood by those faced with making environmentally important decisions. The summations and findings from the data will be developed by the establishment of acceptable standards and metrics and the development of trends and other comparative analyses.

Description of the Sampling Sites

In addition to describing the study area, Figure #1 identifies the nine biological sampling stations employed in the five year study of benthic macroinvertebrates. Two stations (#21 & #25) were placed in the Indian River Lagoon portion of the Intracoastal Waterway and two stations (#31 & #35) were located within the Lake Worth Creek portion of the Intracoastal Waterway south of the Jupiter Inlet. A central embayment station (#41), two stations (#60 & #62) in the lower northwest fork of the Loxahatchee River and one station each in the rivers' north prong (#54) and southwest fork (#70) were sampled. The following paragraphs provide a brief overview of the habitat, general water quality and other environmental conditions characterizing each of the sites.

Station #21

Station #21 is located east of channel marker 59 in the Intracoastal Waterway north of the State Road 707 bridge and approximately 1.1 miles north of the Jupiter Inlet. The main channel of the Intracoastal Waterway in this area is approximately five meters in depth but slopes sharply up to shallower flats averaging less than two meters in depth. These flats typically consist of a sandbar shoreward of the channel then a depressional area that slopes gradually to the shoreline. The biological sampling station is located easterly of the main channel and some 400 meters north of the bridge and approximately 15 meters from the mangrove and Australian pine vegetated shoreline. At low tide, the water depth at the station is slightly greater than one meter. The bottom materials at the site consist predominantly of clean very fine sands containing modest amounts of fine grain sediment and silt.

Figure #2 summarizes the observed water quality at all biological sampling stations and, specific to Station #21, shows the quality of water is typically very good, often exhibiting the highest quality found within the entire watershed. On an incoming tide, a substantial portion of the seawater entering the Jupiter Inlet is diverted northerly several miles up the Indian River Lagoon. Therefore, the biological site at Station #21 is bathed twice daily with clear saline waters. Based on observations between 1991 and 1996, salinity at this station averaged 33 ppt with a minimum reading of 27 ppt. Turbidity and color were consistently low, temperature varied seasonally, pH was consistently high and total alkalinity ranged little. Dissolved oxygen concentrations were high with no observations below 5.6 mg/l and nutrients were present at this site in relatively low concentrations

when compared to other sampling stations within the Loxahatchee watershed. Fecal coliform readings were consistently low and always below fishing and recreational standards set by the state of Florida. The Florida Water Quality Index (FWQI) is a composite of clarity, oxygen, organic demand, nutrients, bacteria and biological integrity commonly used to compare stations statewide. Index values range from 0 to 90 with lower values reflecting superior qualitative conditions. The index for this site is exceptional at 17.

An assessment of the general biological characteristics of the substrate at the site shows that the flora is predominated by an approximate 75 percent cover of turtle grass, Thalassia testudium and the shoal grass Halodule wrightii. The macroinvertebrate community is typically very diverse, rich and abundant and provides a food source for a large and varied population of fishes and other vertebrates.

Station #25

Station #25 is located in a dense seagrass bed on the side of a sand bar that extends from the western side of the Intracoastal Waterway approximately 4.0 miles north of Station #21 near channel marker 44. In many respects, this biological sampling station mirrors the conditions at Station #21. Approximately 1.0 meter of water at low tide covers this site that is about 15 meters from the mangrove and Australian pine shoreline. The site exhibits a predominantly medium grained sand bottom containing minimal organics within the substrate or deposited on the sand. Seagrasses, frequently covering 85 percent of the site, are present and support a very rich and diverse macroinvertebrate community. Based on the Shannon-Wiener Index of diversity for macroinvertebrates, Station #25 ranked the highest in the watershed for biological diversity.

Water quality is very good at this highly saline station that experiences only occasional salinity drops below 20 ppt with an average approaching 32 ppt. Clarity is very good but somewhat more turbid with a lower transparency than Station #21. Dissolved oxygen concentrations and pH values are high, and low levels of nutrients and very low bacteria counts were recorded. The overall Florida Water Quality Index (FWQI) number was calculated to be 21, which is very good and represents the top 21 percent of sampling stations statewide. This station is more remote and experiences less recreational activity than the other sampling stations.

Figure 2: Water Quality Paramteres for the Loxahatchee River Biological Stations

	21	25	31	35	41	60	70	62	54
Temperature (degree C)	25.2	25	25.6	26.1	25.5	25.5	25.6	25.1	25.2
pH (standard units)	7.98	7.78	7.8	7.64	7.86	7.73	7.56	7.5	7.22
Alkalinity (mg/l)	114	116	116	118	112	113	117	117	85
Turbidity (mg/l)	2.1	2.5	2.3	2.6	2.3	1.9	3	1.8	2.4
Transparency (meters)	2.6	1.7	1.5	1.7	1.3	1.3	1.1	1.3	0.8
Color (pt/Co units)	<25	<25	36	37	43	52	61	63	142
Salinity (ppt)	33.3	31.9	27.5	26.1	28.5	23.6	21.5	10.4	14
Conductivity (umhos/cm)	50.7	48.8	42.7	42.4	44.4	37.4	33.9	17	22.6
Dissolved Oxygen (mg/l)	6.99	6.46	6.43	6.16	6.77	5.86	5.82	5.57	5.07
% Dis. Oxy. Saturation (%)	83.5	76.7	77.1	74.4	81.7	70.3	69.9	66	60.1
B.O.D. (mg/l)	0.9	1.2	1.5	1.5	1.2	1.6	1.9	1.6	1.9
Total Nitrogen (mg/l)	0.82	0.8	1.01	1.01	0.91	1.32	1.25	1.16	1.18
Total Phosphorus (mg/l)	0.04	0.03	0.05	0.04	0.04	0.05	0.06	0.06	0.05
Fecal Coli. Bacteria (#/100ml)	8	6	28	104	23	68	193	110	218
Biol. Diversity SWD Index	3.4	3.72	3.3	3.4	2.92	3.34	3.17	2.96	2.32
Florida Water Quality Index	17	21	30	35	26	37	45	41	51

Station #31

The general character of the Intracoastal Waterway changes somewhat south of the Jupiter Inlet. The two stations located in this Lake Worth Creek reach of the Intracoastal Waterway have a less extensive tidal exchange with seawater and are therefore slightly less saline and exhibit higher levels of color, organics, nutrients and bacteria. In terms of overall water quality, as expressed by the Florida Water Quality Index, the numbers are still well within the good range.

Station #31 is located on a sandbar off the tip of a mangrove and Australian pine island on the west side of the Intracoastal Waterway. The site is a little more than one-half mile north of the S.R. 706 bridge and across from the county boat ramp. One meter of water at low tide covers the predominantly fine and medium sand bottom that is moderately covered with snag, leaf litter and vegetation to the extent that organics and other depositional materials are typically present at 25 percent of the site.

Water quality is good and the average FWQ Index for the site is 30. Salinity, pH and alkalinity are all high and experience only moderate changes. The turbidity is similar to the stations in the Indian River Lagoon portion of the Intracoastal Waterway, but the transparency is slightly lower due to higher color values in the water column. Dissolved oxygen is consistently high, but organic demand, as expressed by biochemical oxygen demand (B.O.D.), averages 1.5 mg/l. Nutrient levels are 25 percent higher than those recorded at Station #21 and #25 and fecal coliform bacteria counts are still quite low. Vegetation in the form of grasses is absent from this mud flat; yet, the general diversity of the macroinvertebrate community is very good.

Station #35

Approximately 4.5 miles south of Station #31, Station #35 is situated on a sandbar some 5 meters off shore from the northeast side of the Donald Ross Road bridge. The bottom contour slopes from a mangrove and pine shoreline to the site in 1.1 meters of water at low tide and exhibiting a medium sand bottom with an approximate 50 percent cover of organic depositional materials.

Salinity, clarity, dissolved oxygen, nutrients and most other chemical parameters are present in concentrations very similar to those recorded at Station #31. The one major variance is fecal coliform bacteria with counts at Station #35 averaging over 100 count per 100 ml. or 4 fold the levels observed closer to the inlet. In reaction to the higher coliform levels, the FWQ Index for the site is 35, still in the good range. Based on composite index results, the biological diversity at Station #35 is high.

Station #41

Station #41 is located in the central embayment of the Loxahatchee estuary west of a mangrove island and approximately 1/2 mile west of the F.E.C. railroad bridge. The land use surrounding the central embayment site is over 95 percent residential with restricted riparian vegetation containing some mangrove as the only native. The site is in close proximity to a mangrove island and contains silted sand smothering approximately one-half of the bottom. Snags and leaf litter, interspersed with emergent vegetation, are also present over approximately 15 percent of this relatively barren site.

Water chemistry is similar to the Intracoastal Waterway sites but tends to fluctuate more, reflecting marine conditions on incoming tides and upstream conditions on the ebb tide and after significant rain events. For example, salinity is found to range from 0 ppt to over 30 ppt. On average, salinity, pH, alkalinity and dissolved oxygen are high with nutrients and counts of fecal coliform bacteria low.

The general biological character of the benthic community within the Loxahatchee estuary has been quite dynamic over the past 15 years of observation. Seagrass beds shift, expand and contract in response to the surrounding conditions. For most of the sample runs over the period of record for this study, the bottom at Station #41 did not

support significant seagrass growth and benthic macroinvertebrates were present in densities and diversities noticeably lower than the Intracoastal stations.

Station #70

The remaining four stations, #60, #70, #62 and #54, are located further upstream and generally exhibit salinities near or below two-thirds that of ocean water. In certain respects, these stations can be grouped and considered estuarine in nature as compared to the more marine nature of the other five stations.

Station #70 is located in the southwest fork of the Loxahatchee River downstream of the confluence of the channelized saline portion of the C-18 canal, Sims Creek and the Jupiter River (Jones Creek) and approximately 3 miles from the inlet. The site is 50 meters off shore in an area where the water depth at low tide is approximately 1.5 meters. The bottom at site #70 is composed of a mixture of very fine and fine sands that, for the first portion of the study period, were covered with four or more inches of loose sand and decomposing organic materials. Rains in the winter of 1994 and 1995, and the attendant discharges from the spillway on the C-18 Canal, flushed these materials out of the area leaving a more compact, sandy bottom with less than 20 percent coverage of loose depositional materials.

The pH value at Station #70 averages below 7.6, turbidity and color are relatively high causing transparency to average just under one meter. Dissolved oxygen is typically below 6 mg/l and B.O.D. is high at this station. Likewise, nitrogen, phosphorus and ammonia values and counts of fecal coliform bacteria are among the highest of the nine sampling stations incorporated into the study. The FWQ Index number of 45 for this station approaches the fair category. It is important to emphasize that the chemical quality and biological community make-up at this site vary substantially.

Station #60

Station #60 is upstream from the Jupiter Inlet a distance of 3.2 miles and is located on a sandbar in less than 1.0 meter of water at low tide near the eastern shore of the northwest fork of the Loxahatchee River. The entire shoreline has given way to residential development and only a few remnant mangrove persist. The bar is composed of medium sands combined with a moderate amount of organic material. The sandbar is typically half covered with loose deposited materials and supports little rooted vegetation.

Water quality is good, displaying a mean FWQ Index of 37. Total nitrogen here is found in concentrations higher than at the upstream and other estuarine stations, fecal coliform bacteria counts are moderate as are the BOD concentrations, color and transparency. The dissolved oxygen levels are near 6 mg/l and fairly stable and the general macroinvertebrate community is of good health. Average salinity concentrations are near 23 ppt; however conditions of less than 10 ppt prevail during much of the time.

Station #62

Approximately 2.1 miles upstream of Station #60 is the least saline of the nine stations, Station #62. The site is located off the eastern tip of a mangrove island upstream of the Island Way Road bridge and downstream from Jonathan Dickinson State Park. Seventy-five percent of the medium and fine sand bottom of the site was covered by snags, leaf and oyster shells and decomposing matter. However, this habitat was modified after heavy rains in 1994 and 1995 converted the northwest fork to entirely freshwater for periods exceeding 30 days on each occasion. The oyster shell became more smothered by wood and other organic detritus deposited on the bar.

Water quality at Station #62 is good, averaging a FWQ Index of 41, but subject to variance, especially as relates to a broad divergence from the salinity mean of 10 ppt. On average, relatively low turbidities are combined with slightly elevated color to create only moderate transparency levels. Total nitrogen is present in the lowest concentrations for the four estuarine stations, dissolved oxygen is present in a range above and below 5.5 mg/l and counts of fecal coliform bacteria are moderate in relation to other stations. The general character of the biological community was quite good prior to the major rain events and declined subsequent to the habitat modification.

Station #54

The final station is in the north prong of the river approximately 4.6 miles up river from the inlet. Station #54 is located in 0.8 meters of water at low tide on a mudflat south of a grouping of small oyster bars, 1/2 mile north of the Palm Beach - Martin County line and 1 1/2 miles north of the Tequesta Drive bridge. Residential development along both shorelines has limited the riparian vegetation, yet some mangrove remain. Interspersed with the primarily fine sands of the site are relatively high contents of organics and clays. The bottom is substantially smothered with organic materials and vegetation, snags, etc. cover only a slight portion of the site.

Station #54 is characterized by the poorest water quality of the nine stations analyzed in this study. Alkalinity and pH were relatively low, the averages for turbidity and color were among the highest recorded resulting in the lowest level of light penetration. Salinity fluctuated moderately and averaged 14 ppt. While dissolved oxygen also varied from basin low mean of 5 mg/l, nutrient concentrations were only moderately high and fecal coliform counts of above 200 were recorded. Biological diversity was also the poorest of all sites and the FWQ Index number of 51 reflects water quality only in the fair range.

Methodology and Analytical Protocol

The period of record for this study on benthic invertebrates was originally established to be four years in order to correspond to the major time blocks that have been employed in water quality analyses over the past two decades. Atypical hydrologic conditions in the late Fall of the third and fourth years however, prompted an extension of the study for an additional 18 months.

The sampling frequency was designed for two sample runs per year to capture the seasonal differences that exist in south Florida. Samples were taken in February or March of each year to represent dry season or winter conditions and additional samples were taken in September, October or November of each year to capture summertime or wet season conditions. To assure that hydrologic conditions typical to the desired season were present during the sampling, rainfall in advance of the sampling event was observed. Rainfall in the 20 day period preceding the six dry season runs averaged 1.7 inches and ranged from 0.8 inches to 3.0 inches. In contrast, the five wet season sample runs occurred after 20 days when rainfall averaged nearly 9 inches. This figure was skewed by two large, late season storm events in November of 1994 and October of 1995 when 10.3 inches and 16.5 inches of rain fell in the 20 days prior to the biological collection. However, all wet season sampling events followed a period of 4.9 inches or more of rainfall.

The sample collection procedure followed for this study is outlined in the 18th Edition of Standard Methods for the Examination of Water and Wastewater, method # 10500-B, Benthic Macroinvertebrates - Sample Collection. The specific equipment used was a square diver core that was 12.5 cm per side and a sieve bucket with U.S. Standard No. 30 mesh sieve (0.595-mm openings). All samples were taken in shallow water, with a depth of approximately one meter at low tide. Four cores were pulled and sieved at each site with the sieved sample from each core placed in a one-liter jar with 900 ml of site water and 100ml formaldehyde with rose bengal.

Method #10500-C of the Standard Methods is Sample Processing and Analysis. This method generally outlines the manner in which the macroinvertebrates are sorted and identified. The preserved samples were sent to laboratories with expert taxonomists for analysis. The laboratories have detailed methods, using dichotomous keys, that are specific to each sorted group or subgroup. The laboratories contributing to this study were Mote Marine and The Center for Systemics and Taxonomy, both in Sarasota, Florida and Toxikon Environmental Sciences and Toxicology in Jupiter, Florida.

The methods for taxonomic and numeric evaluations also followed acceptable procedures. The macrobenthic invertebrates were categorically identified and enumerated by utilizing a series of procedures. The identification process began with the sorting of the animals from the associated substrates in the sample. Animals were initially grouped together by common characteristics; for example, the presence or absence of a shell, a chitinous carapace, or the number of or lack of appendages. Typically, this step did not require the use of a dissecting scope and tended to lump the animals into phyla and perhaps class or order categories. With the aid of a dissecting scope, a finer sorting process followed. The animals were grouped into family, genera, and possibly species groupings. Certain animals from each group were selected by the presence of key characteristics and were identified with a taxonomic dichotomous key. Some animals, such as crustacea required dissection in order to identify them to genus or species. Many annelid species could only be distinguished by first mounting the

animal on a slide with CMC 10 mounting media and then proceeding with a detailed evaluation using the dichotomous references.

Once an animal or group of animals had been identified, the other animals within that grouping were matched against the identified individuals. If they were of the same genus or species, then they were counted and recorded as such. If they did not match, then these animals would be identified as a different genus or species. Many animals within a sample were found to be either damaged or did not display certain key characteristics from which an accurate identification could be made. Also, many juvenile animals did not have all of the same adult characteristics and therefore could not be keyed out to a genus or species. In each case, the animals were categorized by the lowest practical taxonomic level.

Data from each sample station was entered into a biological analyzing program called Bio-10: Software for Macroinvertebrate Biology, that was developed by the Florida Department of Environmental Protection. The Bio-10 program calculated Total Taxa, Percent Dominant Taxon, Shannon-Weiner Diversity Index and Evenness for all replicates and the overall collection event for all dates. The data were also entered into Microsoft Excel to allow for manipulation and graphical presentation.

A complete list of all animals identified during the study period is included as Appendix "A" of this report.

The station by station results of the taxonomic identification process are presented on a series of tables entitled "Macroinvertebrate Taxa by Major Faunal Group" and included in this study as Appendix "B".

The use of biological metrics can be a beneficial method to convert a large taxonomic data base into useable information. Dozens of metrics have been established and they tend to fall into one of four major categories: measures of richness, composition, tolerance and trophic status. This report concentrates on the measures of richness and composition, selecting specific metrics from each category. It is believed that the inclusion of tolerance metrics such as the Florida or Marine Index may prove to be helpful and is encouraged for future updates.

Richness is a measure of the relative diversity or variety of the aquatic macroinvertebrates at a given site. The number of Total Taxa is a common richness measure of the overall variety of macroinvertebrates and typically responds positively to improved biological conditions. Composition measures offer information on the types of organisms present in the biological community and the contribution made by certain populations to the total macroinvertebrate community. The most common composition metric is the Shannon-Weiner Diversity Index that incorporates both richness and evenness in its formula. This index increases as the biological condition improves. The other popular composition measure used in this report is the Percent Dominant Taxon. This metric measures the dominance of the three most abundant taxon. Typically, the values for Percent Dominant Taxon decline in response to improvement in the overall

biological condition. These metric expressions will be used in the following sections of this report to help recognize trends and make other comparative observations.

Findings and Results

Gross Taxonomy

The benthic macroinvertebrate community found within the study area is generally very healthy. As shown in Appendix 'A', the five year study identified 410 individual animals residing in the aquatic substrate of the Loxahatchee estuary and associated waters of the Intracoastal Waterway.

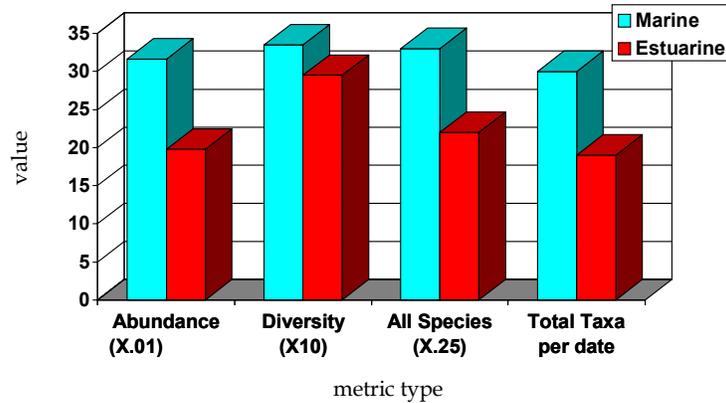
Figure #3 provides a synopsis of the gross taxonomic composition found during the study. It incorporates average results over the five year study period for categories and metrics relating to abundance, relative presence by phyla, total numbers of taxa, total taxa, diversity, percentage of the three dominant taxon and a listing of the five most dominant taxon. Information on each of these categories is provided by station. In order to develop a working understanding of the values expressed by the metrics and for the purpose of comparison in subsequent sections of this report, the ranges for the lowest one-third, the typical one-third and the highest one-third of all values for each of the three selected metrics are presented in the following sentences. Low, or poorer, values for the Total Taxa metric are recorded at less than 15, values from 15 to 32 are found to be typical and high values are those above 32. Values for the Shannon-Weiner Diversity Index range from 1.0 to nearly 5 with values greater than 3.8 considered high, values from 2.5 to 3.8 representing typical findings and values below 2.5 considered low. As relates to the Percent Dominant Taxon, in which lower values are good, a value of less than 19 is rated high with more typical values ranging from 19 to 42 and the lowest one-third of the values recorded as greater than 42.

A general observation is that the benthic macroinvertebrate community residing at the more saline 'marine' stations (#21, #25, #31, #35 & #41) tends to be more abundant, more diverse, containing more total species and Total Taxa when compared to the more 'estuarine' stations (#70, #60, #62 & #54). Figure #4 provides a simplified comparison between the 'marine' and 'estuarine' station groups.

**Figure # 3: Synopsis of General
Taxonomic Composition 1992-1997**

Station	Abundance Total Mean	Gross Composition				Total # of Species	Dominant Taxa	Genus species	Mean Total Taxa	Mean Diversity Shannon-Weiner	Mean % Dominant
		Annelid	Crust.	Mollusc.	Other						
21	3181	69	15	11	7	199	OLIGOCHAETA OLIGOCHAETA POLYCHAETA ISOPODA POLYCHAETA	Limnodriloides sp. Limnodriloidinae unid. Streblospio benedicti Xenanthura brevitelson Prionospio cristata	34	3.82	46.71
25	2390	59	20	9	12	149	SIPUNCULIDA OLIGOCHAETA POLYCHAETA POLYCHAETA POLYCHAETA POLYCHAETA	Sipunculida unid. Limnodriloides sp. Prionospio heterobranchia Capitella capitata Capitellides jonesi Prionospio sp.	31	4.06	43.03
31	4048	74	20	5	1	154	POLYCHAETA POLYCHAETA POLYCHAETA TANAIDACEA POLYCHAETA	Polydora socialis Aricidea philbinae Capitella capitata Hargeria repax Scolelepis texana	36	3.76	52.14
35	3362	34	59	4	3	89	TANAIDACEA TANAIDACEA AMPHIPODA POLYCHAETA POLYCHAETA	Halmyrapseudes bahamensis Hargeria repax Corophium lacustre Capitella capitata Scolelepis texana	25	3.4	55.26
41	2812	54	36	6	4	73	PELECYPODA POLYCHAETA OLIGOCHAETA POLYCHAETA POLYCHAETA	Macominae unid. Prionospio sp. Tubificidae unid. Polydora socialis Scolelepis texana	23	2.92	60.96
60	1599	39	41	15	5	85	TANAIDACEA POLYCHAETA NEMERTINEA POLYCHAETA GASTROPODA	Hargeria repax Capitella capitata Nemertea unid. Scolelepis texana Caecum pulchellum	18	3.34	52.94
70	2795	61	22	11	6	113	POLYCHAETA POLYCHAETA POLYCHAETA AMPHIPODA POLYCHAETA	Streblospio benedicti Capitella capitata Branchiomma sp. Grandidierella bonnieroides Lumbrineris verilli	26	3.63	77.75
62	1913	17	48	13	22	76	ISOPODA DIPTERA AMPHIPODA TANAIDACEA TANAIDACEA	Cyanthura polita Polypedilum scalaenum group Grandidierella bonnieroides Halmyrapseudes bahamensis Hargeria repax	19	3.44	52.81
54	1605	44	42	4	10	66	POLYCHAETA AMPHIPODA TANAIDACEA AMPHIPODA NEMERTINEA	Streblospio benedicti Grandidierella bonnieroides Halmyrapseudes bahamensis Ampelisca vadorum Nemertea unid.	13	2.32	48.62
All Stations	2461	53	30	10	7	114			25	3.41	54.47

Figure #4 : Relative Comparison of Selected Metrics for 'Marine' vs. 'Estuarine' Stations



Further, the gross comparison of benthic invertebrates shows variance in composition between the two groups of stations. Figure #5 presents a breakout of the major faunal groups from the 'marine' stations and shows that Annelids make up the greatest percentage of the gross composition of animals living at the more saline sampling stations, with 30% of the composition made up of crustaceans, 7% molluscs and 5% other classifications. Conversely, the sampling stations subject to lower salinity and more salinity variations support populations that express a taxonomic composition similar to that shown on Figure #6. This graphic shows that crustaceans make up 44% of the total abundance of animals, 33% are annelids, 12% other invertebrates, including insect larvae, and molluscs comprise 11% of the total macroinvertebrate population. In addition, lower total abundance and diversity and a typically lower number of species and total taxa are characteristics of the more 'estuarine' stations.

When reviewing all stations in relation to one another, Stations #21, #25 and #31 rate in the upper third for most of the composition categories presented. Stations #54 and #62, the freshest water stations and those most subject to variations in salinity, rank in the lower third for most categories. The remaining four stations range between the two extremes.

Figure # 5 : Overall Percentage of Taxonomic Groups for all Marine Stations (#21, #25, #31, #35 & #40)

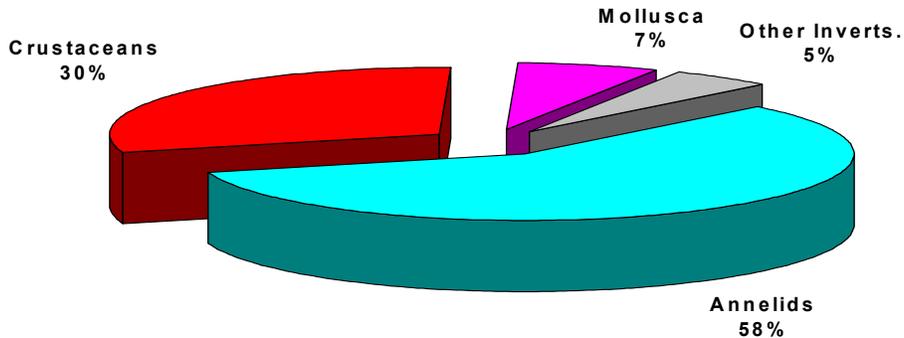
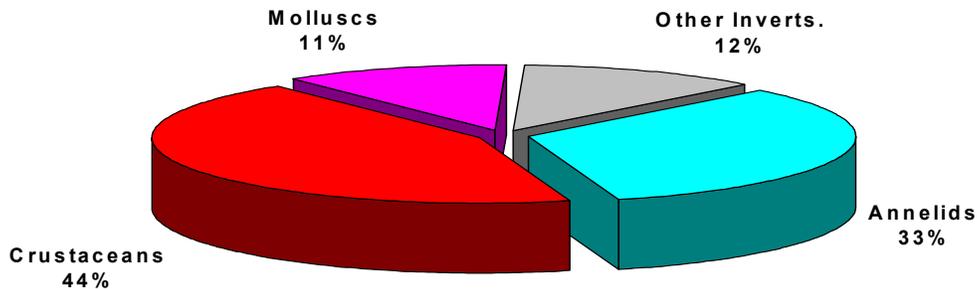


Figure 6 : Overall Percentage of Taxonomic Groups for Selected Estuarine Stations (#60, #62 & # 54)



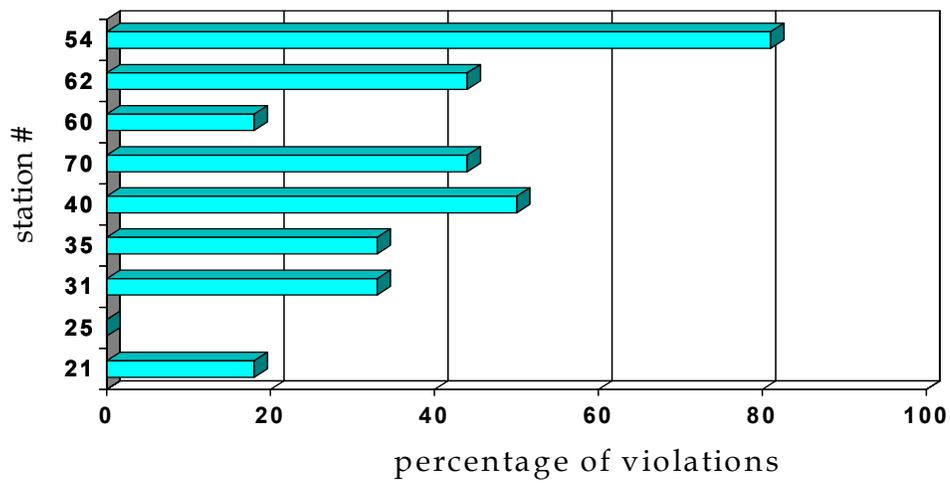
State Criteria for Biological Integrity

One approach used in this study was to apply the 'biological integrity' standard of the Florida Administrative Code (FAC). Chapter 62-302 of the FAC adopts the Shannon-Weiner diversity, H', as the metric for 'biological integrity' for Class II - Shellfish Harvesting and Class III - Recreation and Propagation of Fish and Wildlife waters. To meet the designated use class for a water body, the diversity at a given location on a given date can not be less than 75 percent of that of a suitable reference location. To adopt this standard to the design for this study, Station #25 was determined to be an

acceptable reference site. Station #25 is the most remotely located station, experiences less man induced stress from runoff, recreation, etc. and continually ranked high in all chemical and biological parameters evaluated. The mean Shannon-Weiner Diversity Index at Station #25 for the five year study period was 3.72; therefore, a value of 2.79 or lower would fail to meet the 'biological integrity' standard of the FAC.

Application of the diversity standard to all sample runs at all stations over the full period of record results in approximately two-thirds of the values of the Shannon-Weiner Diversity Index meeting the standard and one-third falling short of the value of 2.79. By station, it is observed that Station #21 recorded a violation on only two occasions, in October of 1994 and November of 1995. The two stations in the Lake Worth Creek section of the Intracoastal Waterway, Station #31 and Station #35, each fell below the standard about one-third of the time, including the October of 1994 and November of 1995 dates. Station #41 failed to meet the standard on one half of the sampling dates as did Station #70 that recorded lower values for four straight monitoring events in 1994 and 1995. Of the stations located within the main embayment and the three arms of the Loxahatchee estuary, Station #60, in the northwest fork showed the greatest tendency to meet the diversity standard. The value fell below the 2.79 standard at this location on only two of eleven occasions, in September of 1992 and again in November of 1995. The north prong station was found to be in violation on 80 percent of the sample runs including five continuous sample dates starting in October of 1994. It should be noted that nearly one-half of the observed violations occurred on sample dates in 1994 and 1995 immediately after the two most significant rainfall events recorded during the period of record. Figure #7 summarizes the violations of the State of Florida biological integrity standard that were observed during the study.

Figure #7 : Frequency of Biological Integrity Violations by Station



Comparison of Sampling Stations

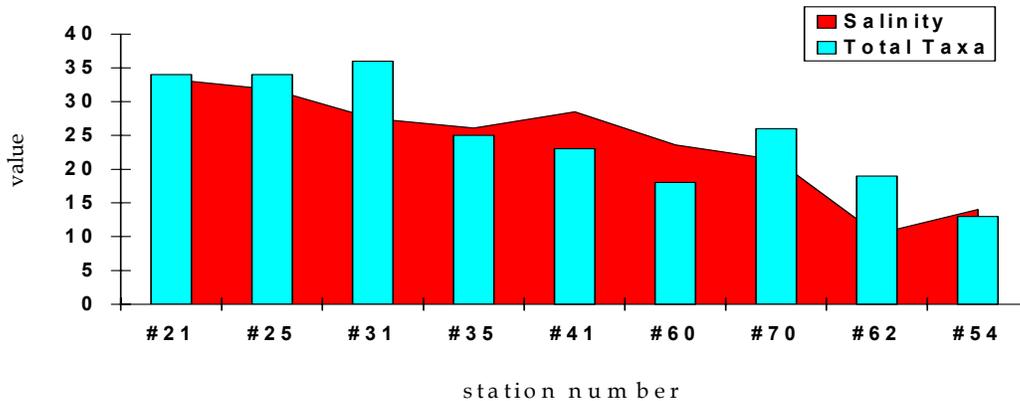
A comparative analysis of the benthic invertebrate communities resident at each of the nine stations was one of the primary purposes of the study. With the known habitat types and water quality profiles described in an earlier section, spatial differences were anticipated, but the extent and character of the perceived variances were not known.

During the study, it was observed that the biological monitoring stations tended to divide into two general groups. Stations #21, #25, #31, #35 and #41 made up the 'marine' group of stations and rated high for biological metrics like Total Taxa, abundance and diversity. Conversely, lower ratings were usually observed for these metrics at the stations comprising the 'estuarine' group, Stations #60, #62, #70 and #54. For example, the estuarine stations had no dates for which the Total Taxa was observed over 25, while the marine stations recorded Total Taxa in excess of 25 on 73 % of the sampling occasions. Although several exceptions were observed, such as in March of 1993, the two sets of stations tended to have similar patterns of variation, usually with the marine stations exhibiting a higher biological condition. For instance, November of 1995 was the date when both Total Taxa and Shannon-Weiner diversity were the lowest recorded during the entire study period for both sets of stations.

The environmental character of each individual biological sampling station was found to be significantly unique from the other stations. While sometimes subtle, differences in substrate conditions, vegetation and water quality were apparent. In response to the different habitat conditions, the composition of the macroinvertebrate community was also found to vary from station to station. Throughout most of the study, a relative 'hierarchy' of the biological conditions found at the various stations was formed and remained fairly consistent from one collection date to another. The overall condition within the study area would be observed to fluctuate with time, but the ranking of a given station did not vary substantially. Given the unique character and relative hierarchy of each station, a spatial extrapolation of the findings for a specific station to other portions of the study area could be made; however, results should only be viewed in very general terms.

For the purpose of this report, the only water quality parameter that was looked at in any detail for relationships to biological integrity was salinity. The reason for choosing salinity was that ample data were available and it demonstrated the most variance between stations. Figure #8 shows the mean salinity readings at each station as compared to Total Taxa. A fairly significant correlation is drawn. Similar correlations may be drawn for other water quality parameters, like clarity, nutrients, dissolved oxygen and others, but were not examined in the scope of this report. The scope of future investigations should consider an appraisal of other relationships.

Figure # 8 : Comparison of Mean Total Taxa at All Stations to Mean Salinity



Comparison with Previous Studies

Previous studies on the macroinvertebrate communities of the study area were conducted by the Florida Department of Environmental Protection (DEP) during the decade of the 1980's. The findings of these in depth evaluations can be found in two reports, A Macroinvertebrate Study of the Loxahatchee River by Harvey Rudolph and The Benthic Macroinvertebrates of the Estuarine Portion of the Loxahatchee River by Donald Deis and Harvey Rudolph. The reports concentrated on the estuary and focused on four stations, three of which were adopted for the current effort. It should be noted that a different sampling technique was used by the DEP researchers and that only one replicate sample was taken at each station during each sampling collection event. Therefore, while comparisons can be made, the results of these comparisons must be viewed with caution.

Figures #9 and #10 provide a gross comparison of the Shannon-Weiner Diversity Index and the Total Taxa observed at two of the stations monitored in each of the studies. The early 1980's and late 1980's are taken from the DEP research and the two time periods for the 1990's are taken from the current study. An evaluation of the overall trend at Station #60 shows that diversity, as measured by Shannon-Weiner, has remained relatively constant from the early 1980's until the present. However, Total Taxa appears to have changed with the average number of organisms currently present at the site being below 20 whereas readings ranging to 35 were observed in the initial D.E.P. study. In contrast, an evaluation of the overall trend at Station #70 shows little or no significant changes between the research in the 1980's and the current work. It is of interest that the 1982 sampling conducted by the DEP scientists occurred shortly after a significant rainfall period.

More extensive evaluation of these two studies is needed to determine if any meaningful trends or relationships can be established.

Figure #9 : Temporal Evaluation for Selected Metrics at Station #60

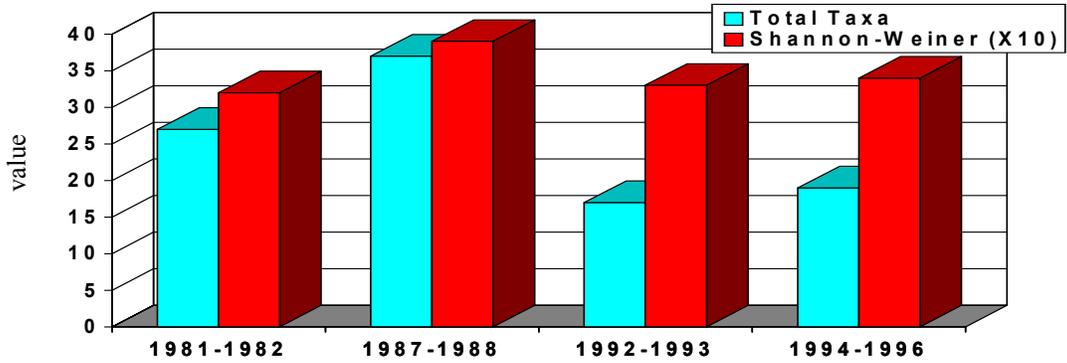
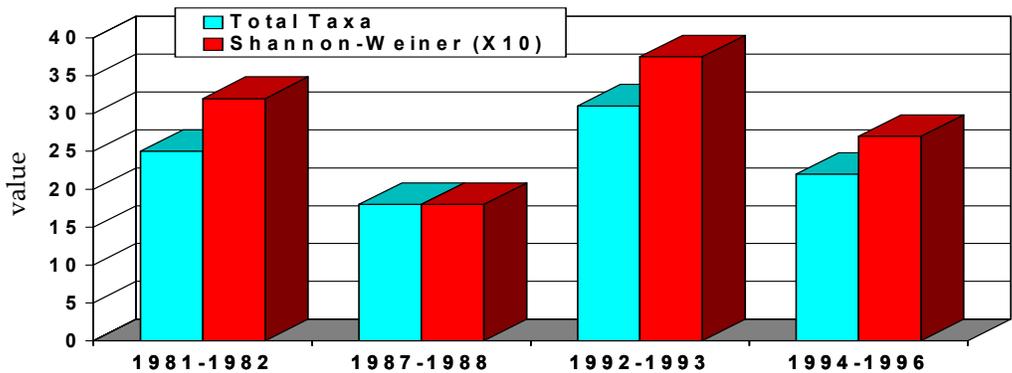


Figure #10 : Temporal Evaluation for Selected Metrics at Station #70



In light of the limitations outlined, only a few selected results of the trend analyses are presented for review. Figure #11 relates to the marine stations and shows the composited results for Total Taxa and Shannon-Weiner Diversity Index from each sample date. Figure #12 provides similar information from the composite of the estuarine stations. The observed variations in each graphic do not demonstrate any easily detectable trend. The marine stations show a dip in both Total Taxa and diversity during the middle of the study period. Both measurements, however, recover by the 1996-97 time frame. In a very similar fashion, the temporal analysis of the stations within the estuary indicates a mid study dip in both metrics. The Shannon-Weiner Diversity Index

appears to have recovered toward the end of the study period. A recovery of the Total Taxa does not appear to have occurred through the 1997 collection date.

Evaluations of the individual stations produced temporal changes that indicate, without statistical verification, variances or trends. As an example, Figure #13 shows the Total Taxa and Shannon-Weiner Diversity Index results for each sampling date at Station #70 located in the southwest fork of the Loxahatchee River. The findings of the first eight collection periods present a continuously declining trend, especially as relates to the diversity of organisms. The February 1996 results, however, appear to reverse the four year long trend and help to instill a note of caution when interpreting five year duration data sets. Figure #13 offers a second example. The biological condition at Station #54 in the north prong of the estuary has been shown to be the poorest of the nine sites evaluated in the study. It can be reasoned that long term and continuous degradation would first be observed at this location. All three metrics presented on Figure #14 show a degradation in the health of the benthic macroinvertebrate community at this site.

A more in depth evaluation of the data collected during this study is recommended as is the acquisition of new data to extend the period of record for which temporal variations and trends might be observed.

Figure #11 : Temporal Trend Analysis for Selected Metrics at Marine Stations

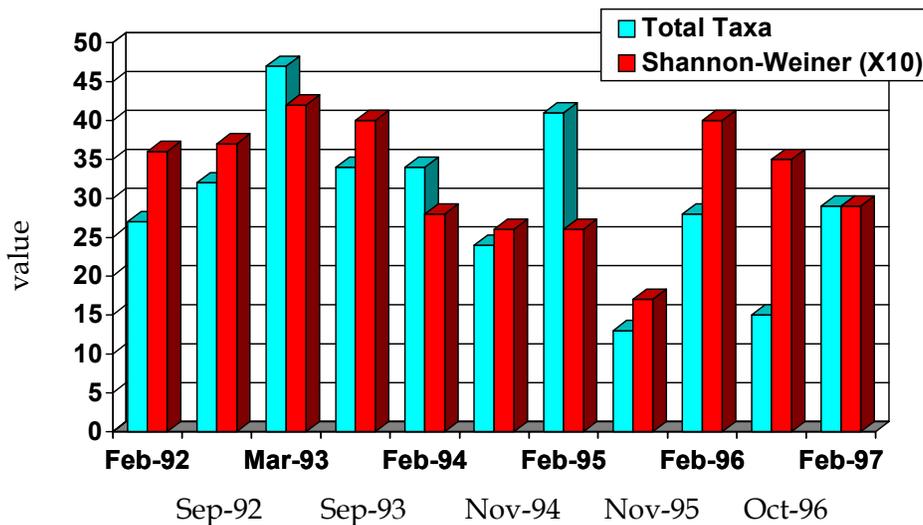


Figure #12 : Temporal Trend Analysis for Selected Metrics at Estuarine Stations

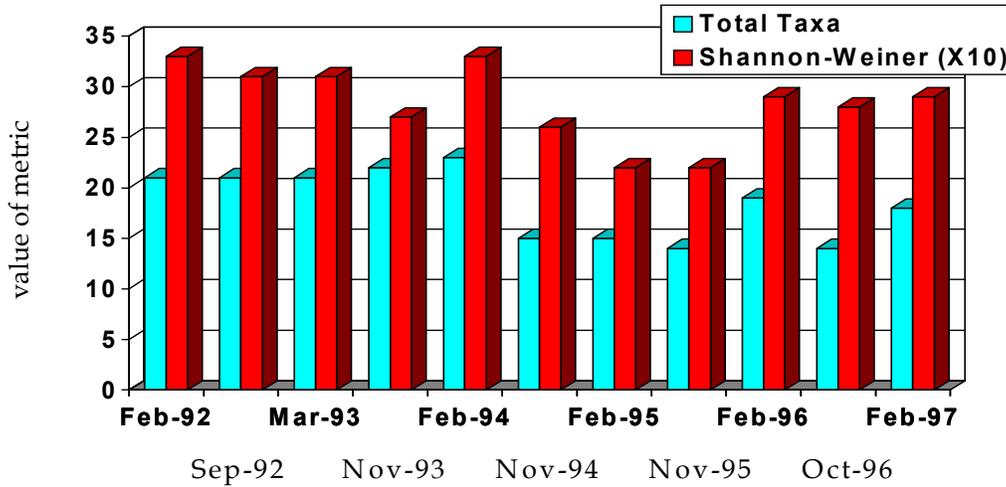


Figure #13 : A Declining Trend at Station #70 May be Reversing

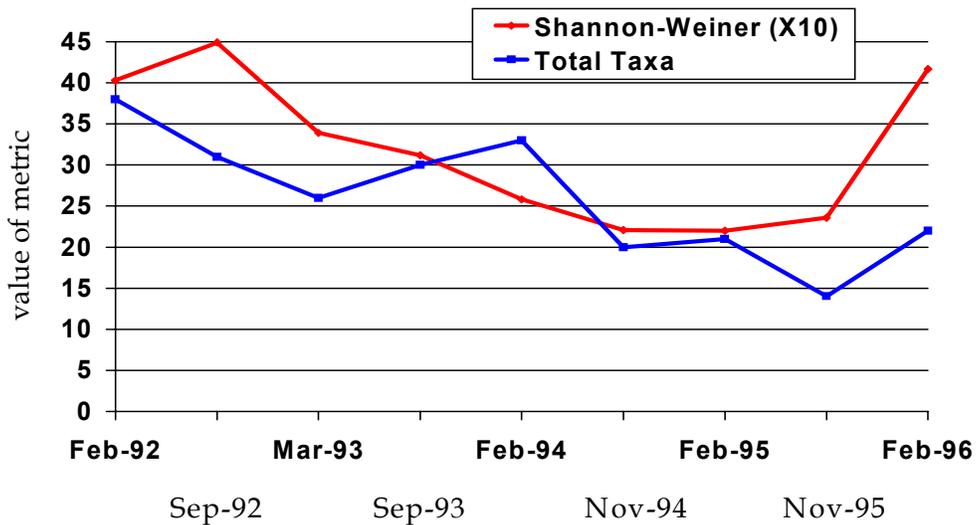
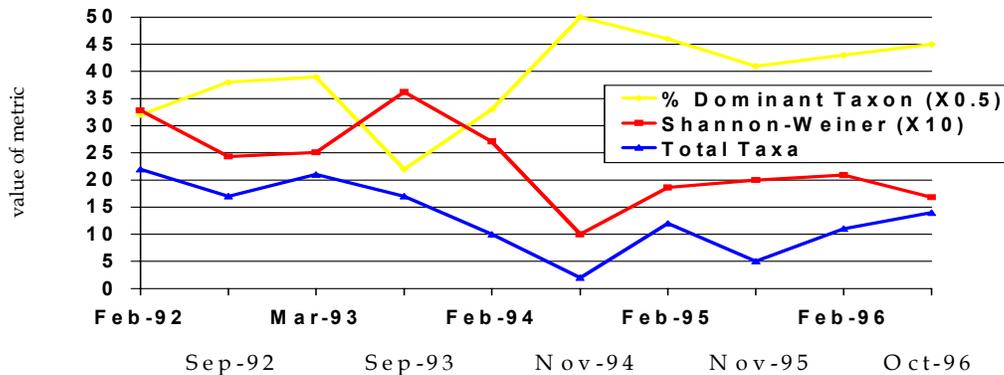


Figure # 14 : The Biological Condition at Station #54 Appears to be in Decline



Seasonal Variations

One of the design elements of the study entailed an evaluation of seasonality. With two very distinct rainfall seasons in South Florida, the summer-fall wet season and the winter-spring dry season, the twice per year sample runs during the study were timed to coincide with the varying conditions experienced by the macroinvertebrate community. Rainfall was monitored prior to the monitoring events so that dry season collections were preceded by a 20 day period of less than 3.0 inches of rainfall and wet season collections at all stations occurred only after rainfall of 4.9 inches or greater in the preceding 20 days. It is believed that this procedure provided the benthic community of macroinvertebrates to assimilate to the varying fresh water - salt water mix.

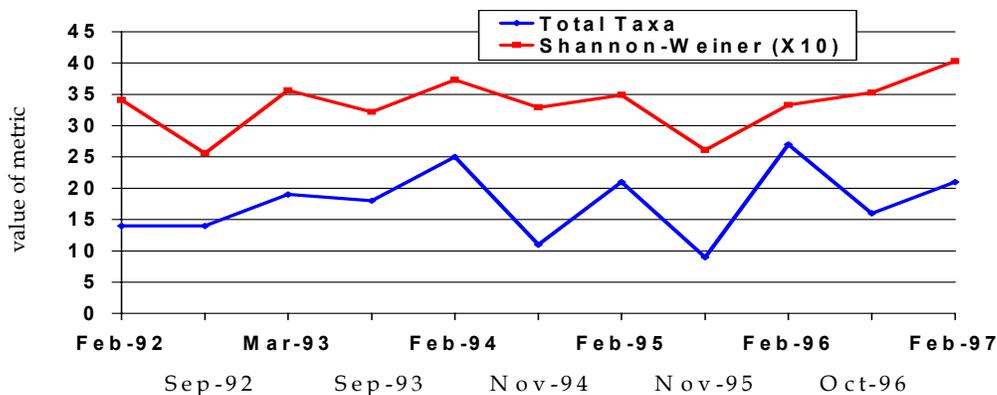
Based on long term water quality monitoring, seasonal variations in salinity have been found to typically vary by less than 5 ppt in the more marine stations and by a much wider range at stations within the forks of the estuary. This difference was even more pronounced in the dry season - wet season samples taken in the final two years of the study.

Figure #15 shows how the macroinvertebrate community at one station responded to the seasonal differences. It should be noted that other water quality measurements, such as water clarity and temperature, effect the general biological composition. Further, not all stations reflected the seasonal variations as clearly as the example shown. An overall observation, however, is that most of the examined metrics at most of the sampling stations responded to seasonal differences. Generally, abundance, total taxa and diversity, as calculated by Shannon-Weiner, were all higher and the Percent Dominant Taxon was lower during dry season monitoring events. While, during the wet season sampling runs, the Percent Dominant Taxon increased and lower abundance, Total Taxa

and diversity were observed. Further evaluation, directed to the macroinvertebrates present during each season and to the reasons for variance, is needed.

As presented in an earlier section, the seasonal differences observed were not verifiable by strict statistical examination. It was further observed that the seasonal 'pulse' was interrupted in the latter portion of the period of record due to atypically wet events in the fall of 1994 and 1995. This observation will be discussed further in the next section of this report.

Figure #15 : Seasonal Variations in Certain Biological Measurements were Evident at Station #60



Impact of Significant Rainfall Events

The study was originally designed to conclude in early 1995 after four years and four samples each in the dry and wet seasons. However, high rainfall periods in late 1994 and 1995, each resulting in freshwater runoff and discharges from the system in amounts not previously monitored, offered a unique opportunity and the study period was extended.

Specifically, in the middle of November, 1994, ten inches of rain fell on the watershed of the Loxahatchee River. Flooding was severe and runoff continuous, perhaps greater than anytime since 1982. During the following month, salinity levels within the study area were extremely low.

The wet season of 1995 was even more atypical. In the third week of October, over 16 inches of rain fell. Flooding was severe and runoff continuous. Although the water quality monitoring devices became clogged with vegetation transported from upriver and precise salinity readings were not available, it is believed that the entire estuary remained essentially fresh for at least three weeks after the rain. In order to capture the impact that these events had on the macroinvertebrate community, the study was extended through

the spring of 1997. Wet season collection of macroinvertebrates in 1994 took place in late November and the wet season collections for 1995 were taken in the first week of November. Both were within three weeks of the preceding major rainfall events.

Figure #16 and Figure #17 show the representative impacts on the benthic macroinvertebrate community of the major hydrologic events of 1994 and 1995 for a marine and estuarine site respectively. Visual observations made at the time of the sampling indicate that significant habitat modification had occurred. At several marine stations, the seagrass coverage was reduced to a fraction of that recorded in the earlier years of the study. The more inland stations were also effected, with organic muck layers being swept away, as was observed at Station #70, to the covering of oyster bars by woody materials as was the case at Station #62.

The macroinvertebrate community responded negatively to the alterations in the water column above it and to the changes in habitat. These responses were not short lived, but appeared to prevail for an extended time period. The post event reduction in abundance, Total Taxa and diversity and the increase in the Percent Dominant Taxon metric continued into the following spring dry season. The integrity of the biological community remained low through the 1996 wet season and was observed at some stations only to improve in the spring of 1997 when collection for this study was completed. Subsequent analyses of the benthic macroinvertebrate community will address the extent of the recovery of the system.

Figure #16 : Significant Rainfall Events Impact Certain Biological Metrics at Station #31

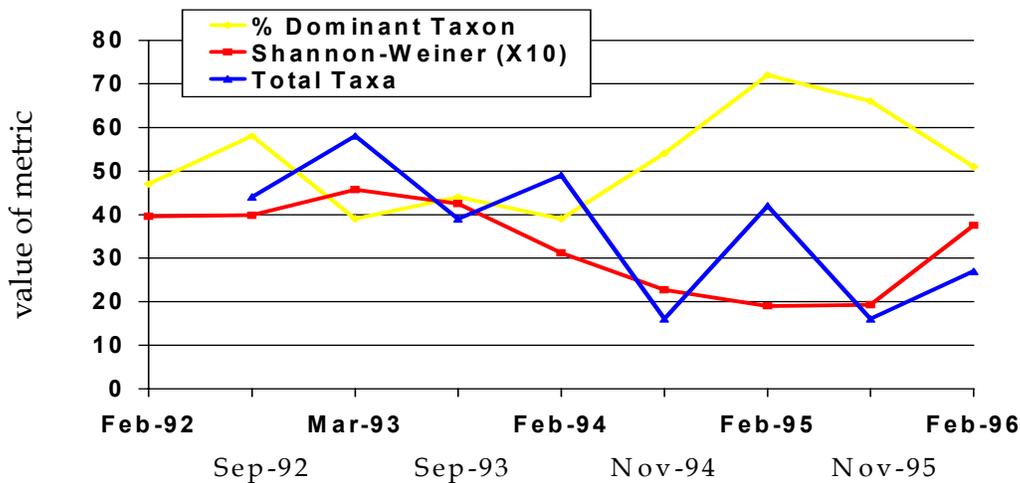
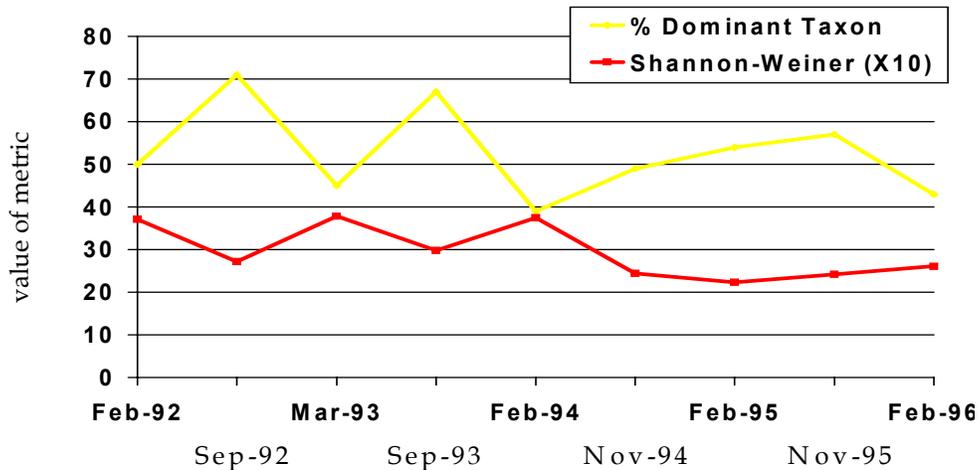


Figure #17 : Seasonal Variations at Station #62 were Modified by Significant Rainfall Events



Comments

The five year study and this report on the findings are believed to have fulfilled the initial design considerations and met the principle project objective. In addition, the study met several secondary objectives, provided information on several fronts and, like most initiatives of this sort, raised further questions. The comments listed below are provided to summarize the major findings of the study, to provoke thought and to invite further evaluation and research on the benthic macroinvertebrates of the Loxahatchee Estuary and the southernmost portion of the Indian River Lagoon.

- * The primary objective of the study was to develop an extensive data base on the benthic macroinvertebrate community structure throughout the study area. This objective was achieved and the results are organized and presented in the appendices.
- * The number and location of the biological sampling stations were designed to produce a representative overview of the study area; and, this element is believed to have been accomplished.
- * Likewise, the sampling frequency, designed for twice per year to capture seasonality, is believed to have been successful. The extended duration of the study was reasonable in that it allowed for the incorporation of data from atypical wet conditions.
- * The methods of collection, preservation, identification and data management were consistently maintained and conducted in accordance with accepted standards.

- * The overall results of the taxonomic composition analysis indicate a healthy biological condition existing through most of the study area. A mean abundance near 2,500 individuals per square meter, 410 different animals identified during the 5 year study, an average of 25 Total Taxa found per station per sampling event and an overall Shannon-Weiner Diversity Index of over 3.0 all speak to the quality of the macroinvertebrate community.
- * The study established that the selected sampling stations fell into one of two broad groups: a 'marine' group that exhibited superior biological conditions in an environment of relatively high and stable salinity; and, an 'estuarine' group that exhibited relatively lower biological conditions in a lower salinity environment that was subjected to greater variances in salinity.
- * The study selected only three biological metrics to define the biological condition. While the measurement types selected are commonly used and useful in biological work, several other metrics are available and the further development of this data to produce other metrics is encouraged. The development of the Florida Marine Index is specifically recommended.
- * The establishment of an overall index number to express the combination of various metrics was desired but not completed within the context of the report. The State of Florida, through the Department of Environmental Protection, has produced reports aimed at creating such an Index. It is believed that additional development may be needed for strict application to estuaries, but the results would be beneficial.
- * The overall species list should be further analyzed to identify organisms common to a given site, important indicator species and taxa important to the development of the Florida Marine Index. In addition, individual animals, such as certain bivalves within the estuary, could be specifically studied and documented.
- * Statistical analysis of the study data was only minimally undertaken. Variables produced by the observed seasonality and the impact of major storm events hampered the use of statistics as a tool. A more thorough examination of the data and the development of a means to apply statistical methods are recommended.
- * Station #25, located in the Indian River Lagoon north of the Jupiter Inlet, was appropriately selected as the reference site as defined in the Florida Administrative Code. Long standing and extensive seagrass coverage, a clean sand bottom, excellent water quality, the presence of a relatively natural riparian shoreline and minimal recreational pressure all contribute to the designation. Now that this site is well documented, it may be useful in comparison with other biological sites located further north in the Indian River Lagoon.
- * Application of the Florida State 'biological integrity' standard to the study area is appropriate. It is recommended that all future results of Shannon-Weiner Diversity Index

calculations be compared against the standard set by this report and submitted to the Florida Department of Environmental Protection for consideration.

* The previous macroinvertebrate work by the Department of Environmental Protection is valuable and a greater emphasis should be placed on evaluating the results of the two studies and searching for significant similarities and variances. This comparison could be aided by filtering out certain variables, such as seasonality, and looking for long term tendencies that are not currently apparent.

* It remains important to investigate and record the character and condition of the sampling sites during each collection period. Any significant habitat alteration may have an impact on the composition of the biological community.

* The modified habitats at Station #62 and Station #70 should continue to be observed in conjunction with future changes in the biological condition.

* Recruitment, extreme predation and other short term or cyclic biological phenomenon can effect the results of monitoring for benthic macroinvertebrates. An example was observed at Station #35 when an atypically large number of crustaceans were recorded from samples taken in February of 1994. The data set established through this study provides a sufficient background against which future results can be compared.

* The relatively low number of molluscs, as reflected in the percent of total abundance, was not anticipated. Bivalves were a staple food source for the Native Americans living within the watershed of the Loxahatchee River and the early pioneers to the Jupiter area used shell for a number of tasks such as road building. Changing conditions are known to have reduced and replaced, up river, a remnant of the historic shellfish population; however, the presence of oysters and other bivalves seemed low.

* The study was able to document seasonal variations in most metrics at most stations during most of the sampling dates. Typical results in the dry season did not equate to typical results for the wet season. This observation is important for two reasons. First, it points out the adaptability of the biological community to changing conditions resulting from naturally occurring seasonal fluctuations. Second, recognition of the seasonal differences is helpful in comparing data from separate collections events. Future collection in a typical or extreme dry condition will likely produce results that are superior when compared to an overall data base consisting of all seasons or against a set of wet season data.

* The portion of the study intended to identify temporal differences was hampered by the strong seasonal and runoff induced variances. A means to filter out the seasonal component will be helpful in recognizing trends.

* The correlation of mean salinity to certain biological metrics was significant. A need remains, however, to examine other water quality conditions, most notable clarity and dissolved oxygen, to see if additional correlations can be drawn.

- * The seepage of groundwater into the estuary and Intracoastal Waterway is a known phenomenon. Measurements near certain of the estuarine stations suggest flow rates of one to two gallons per square foot per day. The consequence of this input of freshwater has not been considered in this or other known water quality or biological studies on the Loxahatchee system. Subsequent studies of the benthos should consider this freshwater source.
- * Large rainfall events or atypically wet periods, and the attendant runoff and alterations in the waters of the study area appear to have significant and longer term impacts on the macroinvertebrate community and the habitat in which it resides. The significance of the changes and the time extent of the impact seem to be more acute for those stations located within the estuary and thus more subject to the effects of runoff.
- * A comparison of the results of this study with other estuaries in Florida or along the gulf and southeast Atlantic coastlines was not undertaken. It is believed that the Loxahatchee Estuary and the southern Indian River Lagoon could compare favorably and the need to examine the results of this study in light of other research is important.
- * The results of the study are believed to be representative of the southern tip of the Indian River Lagoon and the compilation of this information with other biological data generated from elsewhere in the Lagoon is encouraged.

**Appendix A and Species List are located in the
Biology Data Folder of this CD.**