

# **Trophic State of the Loxahatchee River Estuary**

**Richard C. Dent  
Loxahatchee River District**

**January 2001**

## **Introduction**

The estuarine waters inside the Jupiter Inlet have, for centuries, provided an extremely productive and aesthetically desirable aquatic environment. The diverse array of fish life, supported by seagrass and mangrove habitats and complemented by vast oyster and other shellfish populations, sustained Native American societies and the European colonization that followed. Although several physical changes have been made to the waterway in the past half century, including the relocation and permanent maintenance of an open inlet, the channelization of the Lake Worth and Jupiter Sound creeks into the Intercoastal Waterway (ICWW), the removal of historic oyster bars and the drainage of the uplands, the inland waters remain of high quality and a signature feature of the area.

Maintaining a quality environment in light of the pressures of human development has been more successful in the Loxahatchee River/Jupiter Inlet area than in certain other coastal areas. Many estuaries in Florida and elsewhere have displayed significant changes resultant from the increased presence of man. A major change observed in other estuaries has been the enrichment of waters by nutrients, a process termed eutrophication. In such cases, discharges of stormwater and wastewater from uplands developed for urban and agricultural uses, combined with physical alterations to the waterways, have served to pollute historically good water quality and degrade the biological productivity of the estuary. One purpose of this paper is to evaluate the degree to which the waters inland of the Jupiter Inlet have undergone a change in enrichment or trophic state.

A water body can be classified as one of three general trophic states, oligotrophic, meaning low nutrient levels and high clarity, or mesotrophic, a moderate elevation in nutrient concentrations resulting in lower clarity and a reduction in desirable biological habitats or the most enriched state, eutrophic, which can result in significant loss of environmental qualities. Under natural, undisturbed conditions, most estuaries, including the Loxahatchee, would exist in the pristine or oligotrophic state, exhibiting low nutrients, high clarity and minimal growth of algae. With the introduction of pollutants, predominantly nutrients such as nitrogen and phosphorus, the condition of the estuary would degrade to a mesotrophic or eutrophic condition. Water clarity would diminish and the critical habitats supporting the productive estuary, like the seagrass beds and oyster communities, would decline. In order to evaluate the trophic condition of a study area consisting of the Loxahatchee Estuary and the associated reaches of the ICWW

extending north and south of the Inlet, this paper employs water quality data compiled over the past thirty years and applies that information to a composite measurement.

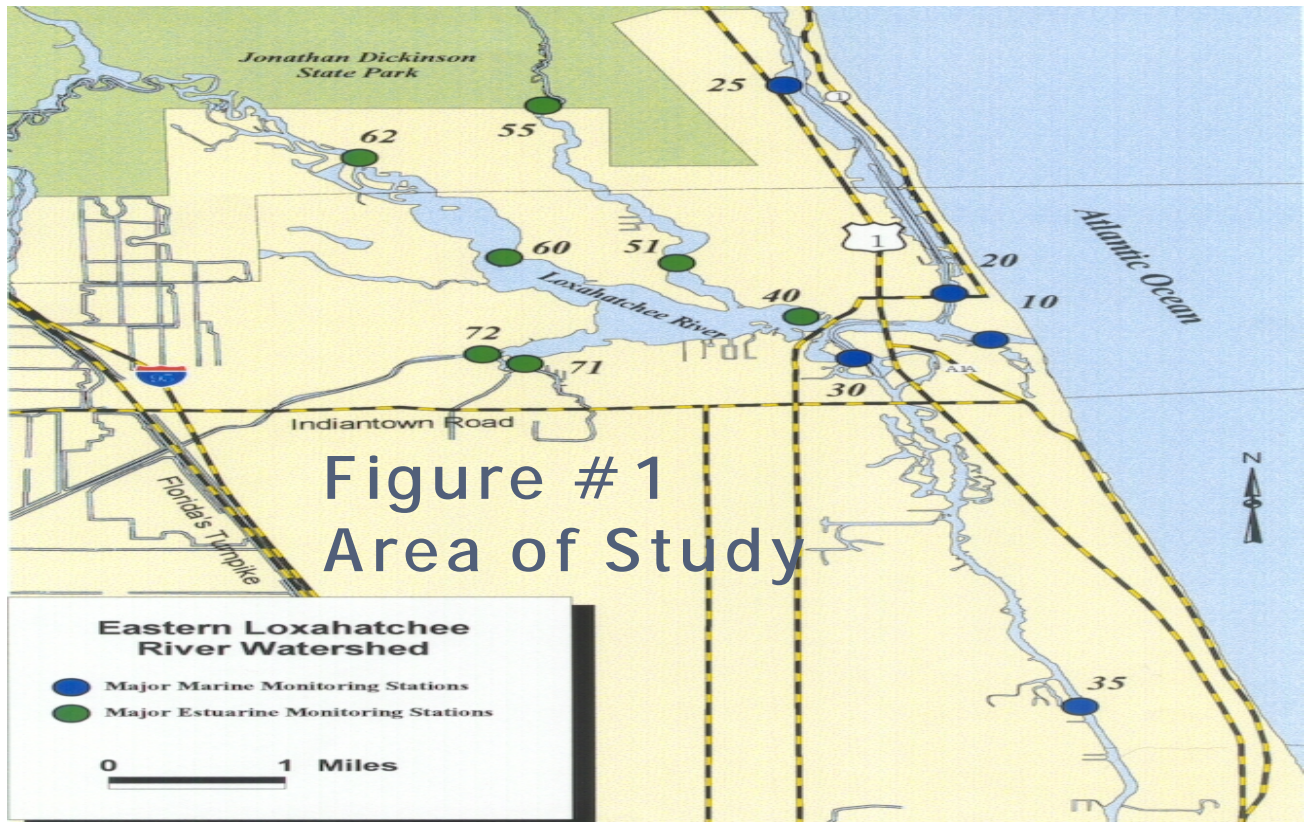
The study area is shown on Figure #1 and encompasses the Jupiter Inlet, approximate five-mile reaches of the ICWW north and south of the inlet, the major embayment of the Loxahatchee Estuary and the mouths of each of the three main branches of the Loxahatchee River. Water quality data, compiled from twelve long-term monitoring stations over time periods ranging from three decades to the past seven years, are examined. The five stations located in the inlet and along the ICWW have consistently shown salinity levels above 25 ppt. as an annual average. The other seven stations exhibit annual mean salinity ranges of 11 ppt. to 25 ppt. Given the different salinity conditions, two subgroups, 'marine' and 'estuarine', were created and analyzed separately for much of the evaluation.

### **The Trophic State Index**

The Florida Trophic State Index (TSI) is a composite measurement used in evaluating the level of enrichment to the waters of the study area. The TSI was developed in the 1980's by the Florida Department of Environmental Protection (FDEP) through contractual arrangement with the University of Florida and is intended to provide a relative expression of the trophic state or level of enrichment of lakes and estuaries in the State. The index provides an effective method of classifying trophic status (oligotrophic, mesotrophic or eutrophic) in lakes and estuaries based on nitrogen and phosphorus concentrations, the concentration of chlorophyll and the water clarity as measured by secchi disc depth. Originally established for Florida lakes, the index was modified to accommodate estuaries using these four components and establishing a scale of zero to 100. The grading scale applied to Florida's estuaries established overall TSI values as follows.

Value of less than 50=	Condition rated 'good' or oligotrophic (not enriched)
Value of 50 to less than 60 =	Condition rated 'fair' or mesotrophic (some enrichment)
Value of 60 or above=	Condition rated 'poor' or eutrophic (enriched)

The calculation of the TSI requires water quality data for total nitrogen, total phosphorus, chlorophyll 'a' and secchi disc depth. The Loxahatchee River District and others have compiled nitrogen and phosphorus data for thirty years. While some secchi disc measurements were recorded in the 1980's, it wasn't until the early 1990's that consistent data were compiled. Chlorophyll 'a' monitoring did not become standard in the study area until 1996. The majority of the evaluations presented in this report concentrate on the seven-year period of record from 1994 through 2000. For long-term comparative purposes, certain evaluations incorporate a full thirty-year period of record and employ only those parameters for which information was available. While reducing the level of accuracy, this process is acceptable under the TSI protocol. It should also be noted that only data secured under acceptable monitoring and analytical standards of the federal Environmental Protection Agency were used in the evaluations.



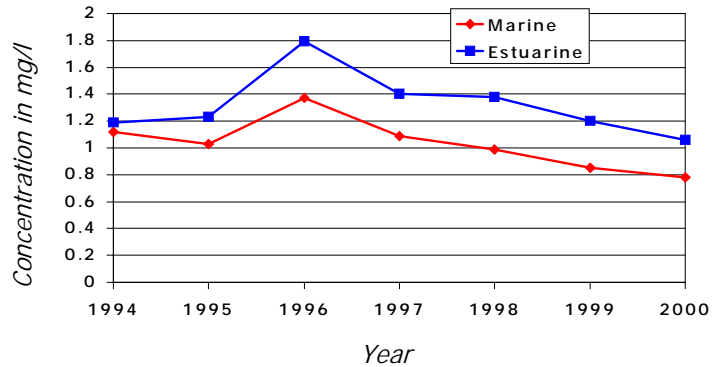
**Figure # 2      Mean Values for  
Key Parameters and TSI Index**

Monitoring Station		T.S.I. Component Parameter				TSI Index
No.	Location	Secchi	Chl a	Total N	Total P	# Value
10	Inlet	1.5	2.4	1.03	0.027	40
20	ICWW @ 707 bridge	2.4	2.0	0.99	0.025	34
25	ICWW @ MM	1.7	3.6	1.05	0.028	41
30	ICWW @ 706 bridge	1.6	4.8	1.20	0.038	45
35	ICWW @ Donald Ross	1.8	4.8	1.22	0.035	43
40	Central Bay	1.5	2.7	1.11	0.030	41
51	Lower North Prong	1.4	4.0	1.17	0.036	45
55	Upper North Prong	0.8	5.3	1.36	0.045	53
60	NW Fork - Mouth	1.4	4.1	1.38	0.046	46
62	NW Fork - Island Way	1.4	4.1	1.45	0.058	49
71	Jones Creek	1.1	7.2	1.43	0.060	54
72	SW Fork - Lox Riv Rd	1.2	7.6	1.58	0.054	53

Figure #2 presents the mean results, by monitoring station, for each of the parameters used in the TSI for the 1994-2000 time frame. The following paragraphs present a brief synopsis of each parameter and the findings.

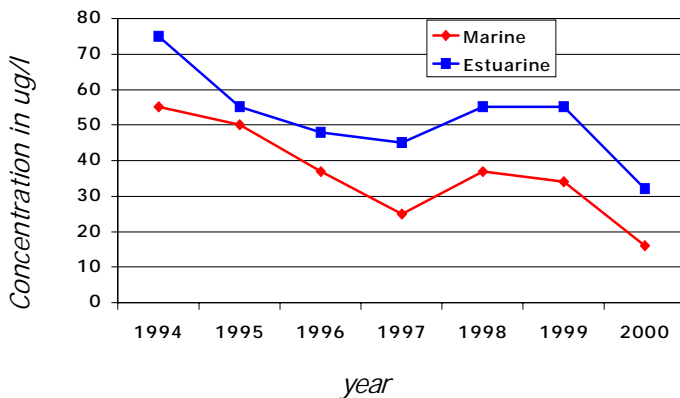
The total nitrogen concentrations for 1994-2000 are shown on Figure #3. The results of the five 'marine' stations and the seven 'estuarine' stations are shown separately. As is observed, the mean annual total nitrogen concentrations for the 'marine' stations ranges from approximately 0.8 to 1.4 mg/l. The annual mean for the 'estuarine' stations shows a higher range of 1.0 to 1.8 mg/l. The trend over the seven-year period indicates a short-term improvement for each set of stations. It should be noted, however, that total nitrogen in the decade of the 1970's was significantly lower, averaging 0.6 and 0.7 mg/l for the 'marine' and 'estuarine' stations, respectively. By way of comparison, the statewide averages for total nitrogen in estuarine waters is 1.2 mg/l and therefore, the concentration of total nitrogen in the waters inland of the Jupiter Inlet is comparable to or slightly higher than the norm when considering the past seven years.

Figure #3 Total Nitrogen Concentrations



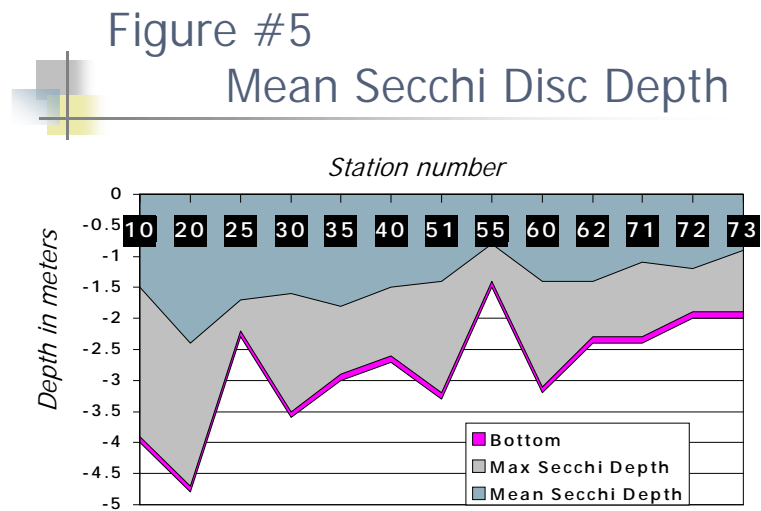
The mean annual total phosphorus concentrations are shown on Figure #4. As with total nitrogen, the apparent short-term trend is toward lower concentrations or improvement.

Figure #4 Total Phosphorus Concentrations



From 1994 through 2000, the 'marine' stations exhibited annual average concentrations ranging from less than 20 to 55 ppb. Annual average total phosphorus concentrations for the 'estuarine' stations ranged higher at 31 to 75 ppb. These recent levels are similar to concentrations observed prior to the 1990 time period. Unlike total nitrogen, the total phosphorus concentrations recorded in the surface waters of the study area are lower than the statewide average which is 80 ppb for the 1990 to 1998 time period.

Secchi disc depth is a water quality measurement evaluating clarity. In a generic sense, it can be considered to combine light restricting constituents such as total suspended solids, turbidity and color. Figure #5 shows the mean secchi disc depth at each station along with maximum secchi disc depths and bottom depth at each monitoring site. As shown, the mean secchi depth ranges from 0.8 to 2.4 meters and the maximum secchi disc depth at each station has been recorded as 'clear to the bottom'. Other estuaries in the state of Florida show varying results for secchi disc measurements, but the average depth, established by the FDEP is 1.1 meters.



Chlorophyll 'a' is a measurement of the single cell plant matter or algal biomass in the water column. Typically resultant from nutrient enrichment, suspended algae, and the associated concentrations of chlorophyll, increase the presence of chlorophyll 'a' in polluted waters. Figure #6 is provided to show the concentrations of chlorophyll 'a' found during monitoring over the past three and one-half years. Although variable, the 'marine' stations in the study area exhibit annual mean values ranging from approximately 2 ug/l to 8 ug/l and the annual means for the 'estuarine' stations range from approximately 2 ug/l to 11 ug/l. As relates to other estuaries in Florida the median value of chlorophyll 'a' has been recorded as 9 ug/l by the FDEP.

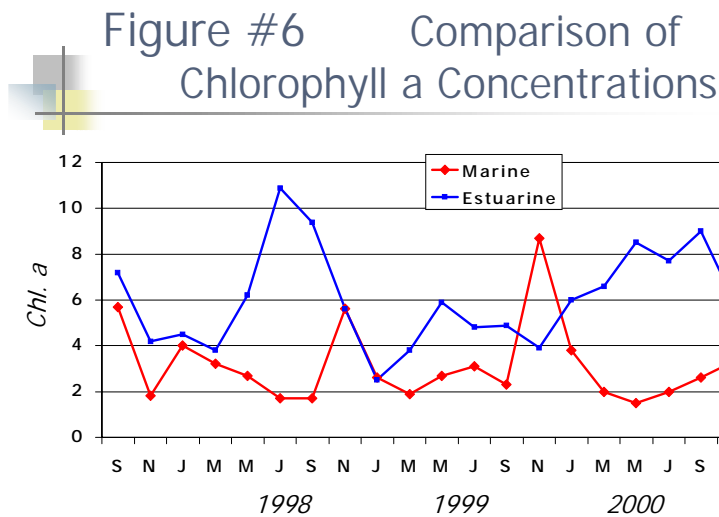


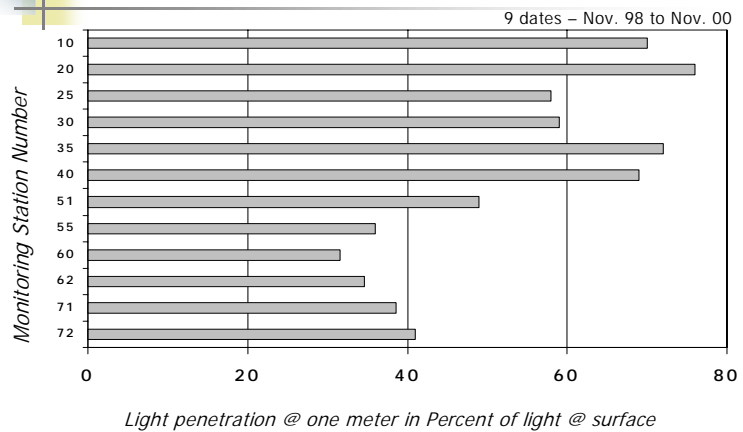
Figure #6 is provided to show the concentrations of chlorophyll 'a' found during monitoring over the past three and one-half years. Although variable, the 'marine' stations in the study area exhibit annual mean values ranging from approximately 2 ug/l to 8 ug/l and the annual means for the 'estuarine' stations range from approximately 2 ug/l to 11 ug/l. As relates to other estuaries in Florida the median value of chlorophyll 'a' has been recorded as 9 ug/l by the FDEP.

While the four-parameter TSI method has been used in Florida for nearly twenty years, it should be noted that other methods of evaluating the trophic condition of an estuary have been developed and are in use. In these indices, other parameters, such as dissolved oxygen, percent dissolved oxygen saturation, biochemical oxygen demand and other measurements of light penetration, are incorporated along with those used in the TSI.



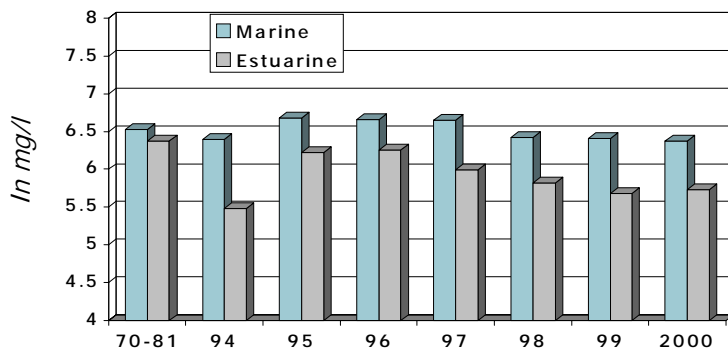
Figure #7 exhibits the results of the first two years of an ongoing evaluation of light penetration at key water quality monitoring stations. The value measured is percent of surface light present at the depth of one meter (the percent of light present at two meters is also monitored) and, like the secchi disc depth, offers a composite measure of light reducing parameters including turbidity, total suspended solids and color. Consistent with other measurements, the light penetration observed at the 'marine' stations is superior to that observed at the 'estuarine' stations.

Figure #7 Percent of Light Penetration at One Meter



Dissolved oxygen and the percent saturation of dissolved oxygen have also been measured over time. Figure #8 shows the mean annual concentrations of dissolved oxygen for the time period 1994 through 2000 for the 'marine' and 'estuarine' groups of stations. Mean annual dissolved oxygen concentrations vary from 6.38 mg/l to 6.68 mg/l for the 'marine' stations and from 5.48 mg/l to 6.26 mg/l for the 'estuarine' group of stations. For comparison purposes, the mean dissolved oxygen concentrations during the 1970 through 1981 time frame are included on the graphic and were 6.53 mg/l for the 'marine' stations and 6.38 mg/l for the 'estuarine' stations. While the 'marine' stations showed little change over time, a decline in the concentration of dissolved oxygen for the 'estuarine' stations is evident. Overall however, the waters of the study area, when tested in daylight hours during the period of study, show relatively high and uniform levels of dissolved oxygen.

Figure #8 Mean Annual Dissolved Oxygen Concentrations



The percent saturation of dissolved oxygen is a measurement that accounts for variables such as water temperature and can be used separately or in concert with dissolved oxygen. The percent saturation for the 'marine' stations is consistently above 90%. A lower and more variable percent saturation of dissolved oxygen is observed in the estuary with typical values ranging around 80%.

## Observed Variations in Trophic State

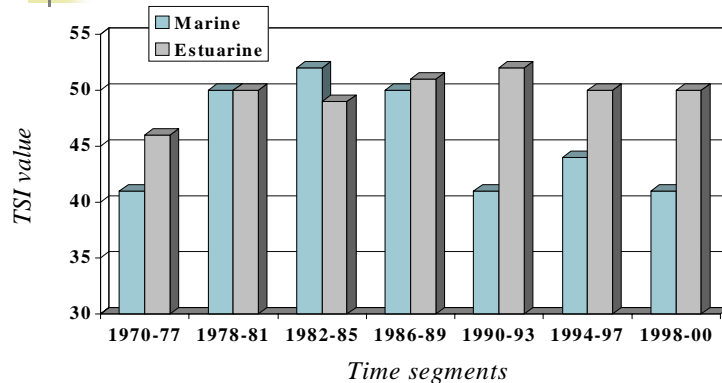
Relative comparisons of the TSI values calculated for the surface waters in the study area are presented in three ways: spatial differences by station, changes over the years for the 'marine' and 'estuarine' station groups and seasonal variations.

As relates to the TSI variances among the twelve water quality monitoring stations within the study area, Figure #2 provides a tabular comparison for the 1994-2000 time period. All 'marine' stations (#10, #20, #25, #30, & #35) exhibit a TSI value in the 'good' or oligotrophic range. Station #40, located in the main embayment of the Loxahatchee estuary, stations #60 and #62, placed in the mouth and lower reach of the the river's northwest fork and station #51 in the lower portion of the north prong, also average a TSI value in the 'good' range. TSI values in the low 50's, indications of 'fair' or mesotrophic states, are evident at three of the 'estuarine' stations; station #55 in the north prong and stations # 71 and #72 located in Jones Creek and the southwest fork.

The long-term temporal evaluation of the study area is presented in Figure #9 which examines 'marine' and 'estuarine' stations over seven time groupings covering the past thirty years. The 'marine' stations exhibit a greater than expected variance with 'good' TSI values in the early and mid 1970's and from 1990 to the present interrupted by twelve years of higher (poorer) values. No rationale for this variance can be forwarded at this time. An initial negative trend that flattens out over the past seven years is shown for the 'estuarine' group of stations. Extensive urban development on the upland surrounding the major embayment may account for the rise in TSI and the improvements to stormwater and wastewater systems may help explain the apparent stabilization of TSI values over recent years.

The significant variance in rainfall over south Florida's typical summer-wet and winter-dry seasons was evaluated as causal components in variation of TSI. Increased freshwater flows from the urban land uses surrounding the study area and rural and agricultural land uses to the west are believed to have resulted in higher TSI values in the wet season. From 1994 through 2000, a minimum of six water quality sampling runs were conducted each year incorporating all twelve monitoring stations used in this report. Data from sampling conducted in January, February and March of a given year was composited to provide TSI values representative of the dry season and data from sampling events conducted in July, August and September of a given year were composited to provide TSI values representative of the wet season. Data from the April, May and June and October, November and December time periods was not

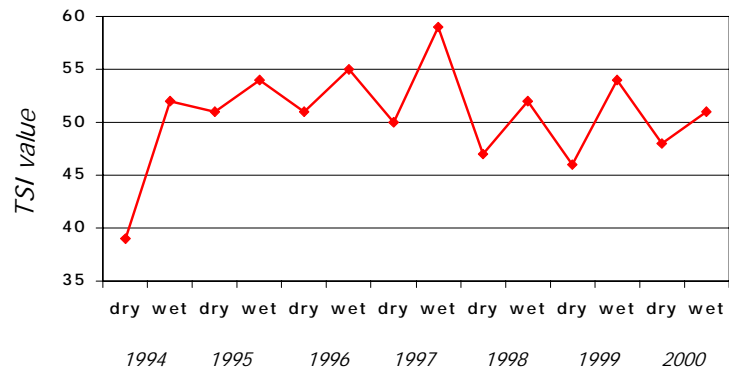
Figure #9  
Changes in TSI Over Time



included in this analysis in that rainfall in these transition periods exhibits a greater variability from the established seasonal norms. Wet season and dry season results are shown on Figure #10.

For the five 'marine' stations, minimal wet season to dry season variation was observed. While individual years exhibit some variance, the mean TSI values over the seven years was 43 for the dry season sampling and 43 for the wet season sampling. These stations typically had salinity values in excess of 25 ppt and the extensive flushing from tidal action through the Jupiter Inlet is believed to have moderated any seasonal fluctuations.

Figure #10 Loxahatchee River Estuary, Seasonal Variation in TSI



The seven 'estuarine' stations, where salinity concentrations were lower, salinity variances greater and tidal flushing less pronounced, did show seasonal change in TSI values. Summer-wet season values fall into the 'fair' range with a mean of 53 while the winter-dry season values remain 'good' at mean TSI value of 46. Certain monitoring stations, typically those most remote from the inlet, tend to experience greater seasonal TSI value variances; however, specific examinations on a site-by-site basis have not been extensively evaluated.

Also unknown at this time is relative contribution to the observed variations by each of the four components used in the TSI computation. Over the seven-year period of record for this evaluation, total nitrogen and total phosphorus concentrations were higher by approximately 15% and 30%, respectively, during the wet season sampling events. Further, a review of Figure #6 indicates seasonal variances in chlorophyll 'a', especially as relates to the 'estuarine' group of monitoring stations. Additional evaluation of these and other relationships is encouraged.

### **Summary and Comments**

This paper has reviewed the Trophic State Index (TSI), a composite measurement of surface water enrichment employed in Florida, and shown how it can be effectively applied to the waters inshore of the Jupiter Inlet. By using data from individual sampling stations, groups of stations or the full compliment of twelve stations monitored for the study, spatial and temporal comparisons have been drawn.

The more saline 'marine' stations of the Jupiter Inlet and ICWW tend to display lower (better) TSI values than the stations located within the estuary of the Loxahatchee River.



Over the seven-year study period, 1994 through 2000, nine of the stations showed an average trophic condition of 'good' or oligotrophic and three stations rated 'fair' or mesotrophic. Therefore, the local waters are believed to compare favorably with other Florida estuaries. Seasonal variations in TSI are observed for the 'estuarine' stations, but not evident for the 'marine' stations. Long-term comparisons of TSI values, evaluating approximately thirty years of data, show mixed results, with 'marine' stations in the 'good' TSI value range prior to 1978, followed by twelve years of TSI values approaching or entering the 'fair' category, followed by twelve years consistently exhibiting 'good' TSI values. The 'estuarine' stations had 'good' TSI values prior to 1978 but near or above the threshold for 'fair' values over the past 23 years.

The component parameters used in the TSI calculations, secchi disc depth and concentrations of chlorophyll 'a', total nitrogen and total phosphorus, have been examined over periods of record for which data are available. Continued monitoring and specific evaluations of the relative effect of each component on the overall TSI is encouraged. Further, examination and incorporation of other parameters reviewed in this report, such as dissolved oxygen, percent dissolved oxygen saturation and light penetration are also encouraged. Of special interest is examination of diurnal fluctuations in dissolved oxygen and light penetration to a depth of two meters, a depth considered important to seagrass propagation. Relative productivity studies, based on one of several accepted analytical techniques, will also be beneficial to understanding the trophic condition of the study area.

One final observation relates to the relationship between total nitrogen and total phosphorus. The Florida TSI method recognizes a long-standing limnological principle that one of these two nutrients may be limiting to the growth of algae in the water column or other plant growth in a specific water body. In very general terms, if the total nitrogen concentration exceeds the total phosphorus concentration by a factor of ten or less, nitrogen is more likely to be the limiting nutrient. And, if the concentration of total nitrogen exceeds the total phosphorus concentration by a factor of thirty or more, then total phosphorus can be considered to be the limiting nutrient. Some estuaries in Florida, like Sarasota Bay on the Gulf Coast, are believed to be nitrogen limited. The nutrient data generated from long-term monitoring stations in the Loxahatchee River estuary however, frequently have total nitrogen vs. total phosphorus relationships of greater than thirty. Additional study is needed to further examine the potential 'key' role that total phosphorus plays in the enrichment of the surface waters of the Loxahatchee River estuary.

The Loxahatchee River District, through its research team housed in the WildPine Ecological Laboratory in Jupiter, will continue to monitor the surface waters of the study area with a minimum frequency of six times annually. Water quality data resultant from these sampling events will continue to be used in calculating the TSI for the established monitoring stations and comparisons with the information presented in this report will be developed.