SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Northern Everglades River Watershed Research & Water Quality Monitoring Program- Caloosahatchee River Watershed

December 19, 2007

sfwmd.gov

Agenda

- Introduction and Opening Remarks
- Updates
- Revised Outline for the Research and Water Quality Monitoring Plan
- Public Comment Period
- Summary of Water Quality Analysis in the Caloosahatchee River Estuary
- Public Comment Period
- Action items/Next Meeting

Updates

- Integrated Meeting Schedule
- Draft Work Plan and Schedule
- Inventory of Existing Monitoring Projects
- Goals and Objectives of the Plan
- Revised Outline of the Plan

Integrated Meeting Schedule

Florida Keys RAD (FDEP)	Everglades West Coast TMDL (FDEP)	Caloosahatchee River TMDL Meeting (FDEP)	Caloosahatchee Telephone Conference 9:30 AM (Joint)	Caloosahatchee NEEPP Research & Monitoring (SFWMD)	Caloosahatchee NEEPP Watershed Plan (SFWMD)	Charlotte Harbor NEP TAC Meetings (CHNEP)	St. Lucie Basin TMDL & BMAP (FDEP)	St. Lucie NEEPP Research & Monitoring (SFWMD)	St. Lucie NEEPP Watershed Plan (SFWMD)
	Sept 25 PM	Sept 26 AM	Sept12	Sept 26 PM					
Oct 26	Cancelled	Oct 23 PM	Oct 10	No Meeting	Oct 19	Oct. 24 PM	Oct 25 AM	Oct 24 PM	Oct 24 PM
	Cancelled	Cancelled	Nov 7	Cancelled	Nov 20 PM		Nov 9 AM (conf call)	Nov 29 AM	Nov 29
	Dec 18 PM	Dec 19 AM	Dec 5	Dec 19 PM	Dec 20 AM			Dec 20	
2008									
	Jan 22 PM	Jan 23 AM	Jan 9	Jan 23 PM	Jan 17 AM		Jan – date TBD	Jan 15	Jan 15
	Feb 19 PM	Feb 20 AM	Feb 6	Feb 20 PM	Feb 21 AM	Feb 13 AM		Feb 26	Feb 26
	Mar 18 PM	Mar 19 AM	Mar 5	Mar 19 PM	Mar 20 AM			Mar 25	Mar 25
	April 15 PM	April 16 AM	April 2nd	April 16 PM	Apr 17 AM	April 9 AM		Apr 22	Apr 22
	May 20 PM	May 21 AM	May 7	May 21 PM	May 22 AM			May 27	May 27
	June 17 PM	June 18 AM	June 4	June 18 PM	June 19 AM			June 24	June 24
	July 15 PM	July 16 AM	July 2nd	July 16 PM	July 17 AM	July 9		July 22	July 22
	Aug 19 PM	Aug 20 AM	Aug 6	Aug 20 PM	Aug 21 AM			Aug 26	Aug 26
	Sept 16 PM	Sept 17 AM	Sept 3	Sept 17 PM	Sep 18 AM			Sep 23	Sep 23
	Oct 14 PM	Oct 15 AM	Oct 1			Oct 22			
	Nov 18 PM	Nov 19 AM	Nov 5						
	Dec 16 PM	Dec 17 AM	Dec 3						
2009									
	Jan 20 PM	Jan 23 AM	Jan 7						
	Feb 17 PM	Feb 20 AM	Feb 4						
	Mar 17 PM	Mar 19 AM	Mar 4						

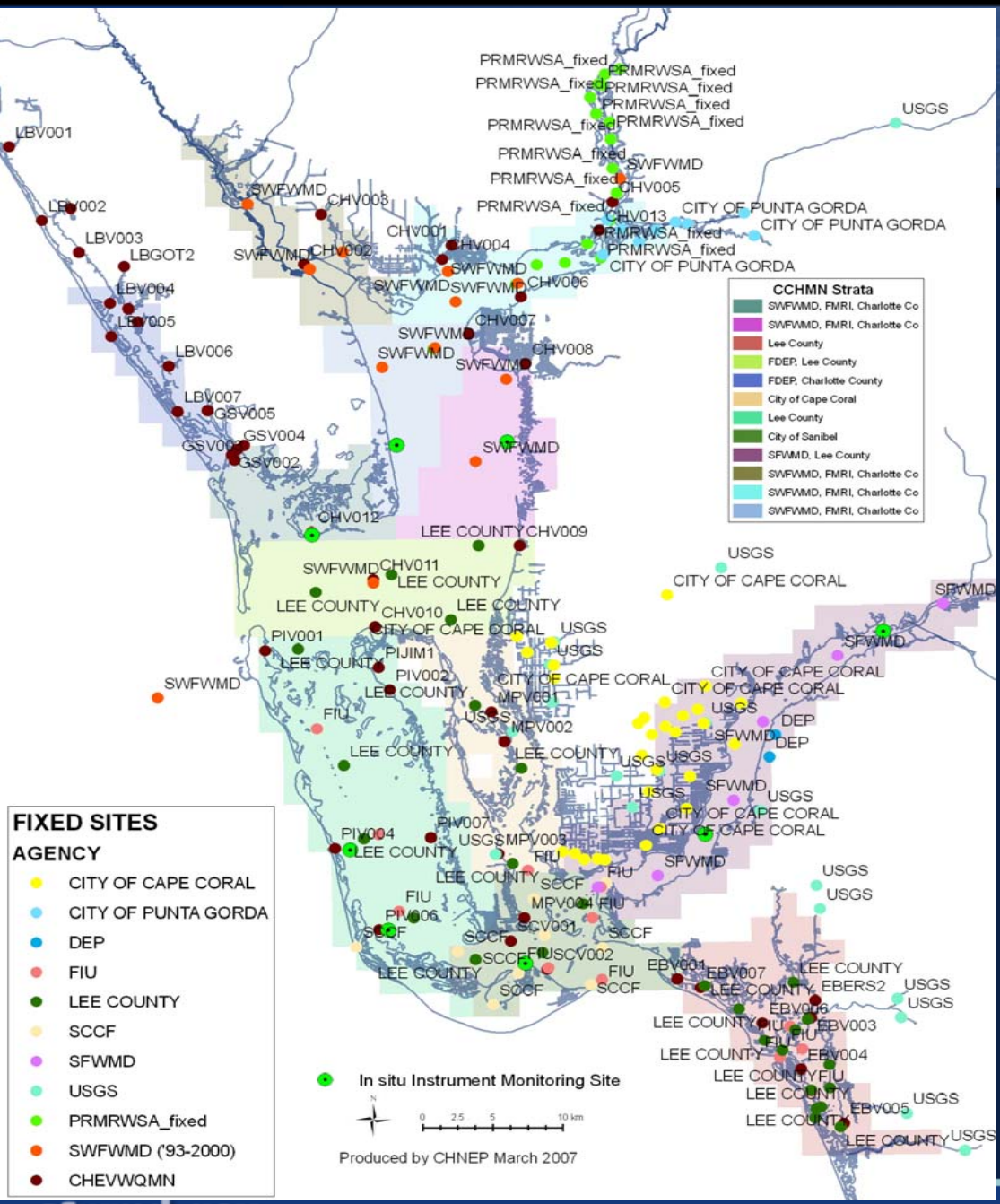
Draft Work Plan Schedule

Caloosahatchee River Watershed Research and Monitoring Plan

		Qtr 1 FY08			Qtr 2 FY08			Qtr 3 FY08			Qtr 4 FY08		
	Sep-07	Oct-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08
Research and Monitoring Plan													
Initiate Caloosahatchee Research and Water Quality Monitoring Plan													
Task 1 –Identify Goals and Objectives of the Plan													
Task 2 – Establish Status, Trends and Targets in Hydrology, Water Quality and Aquatic Habitat													
Task 2.1 Delineation of Study Area													
Task 2.2 Watershed Hydrology and Loading													
Task 2.3 River/estuary salinity, water quality and the related aquatic habitats													
Task 2.4 Salinity Envelopes and Freshwater Inflow Targets													
Task 2.5 Influence of Lake Okeechobee and Watershed Discharge on Delivery to SLRE													
Task 3 –Monitoring on a Regional Scale													
Task 3.1 Define Regional Scale Monitoring													
Task 3.2 Compile Existing Water Quality Monitoring Program													
Task 3.3 Compile Existing Freshwater Inflow Monitoring Program													
Task 3.4 Compile Existing Aquatic Habitat Monitoring Program													
Task 3.5 Conduct Power Analysis- Water Quality and SAV Example													
Task 4 –Monitoring on a ProjectScale													
Task 4.1 Define Project Level Monitoring													
Task 4.2 Summarize Projects Considered in the Plan													
Task 5 –Research for Adaptive Management													
Task 5.1 Identify Research Purpose													
Task 5.2 Summarize Status of Current Research Related to Water Quality													
Task 5.3 Summarize Status of Current Assessment Tools													
Task 6- Develop Recommendations													
Task 7- Internal and External Working Team Meetings													
Task 8- Compilation of Draft Research and Water Quality Monitoring Plan													
Task 9- Final Research and Water Quality Monitoring Plan													
Task 9.1 Incorporate Final Plan into the River Protection Plan													

Inventory of Existing Monitoring

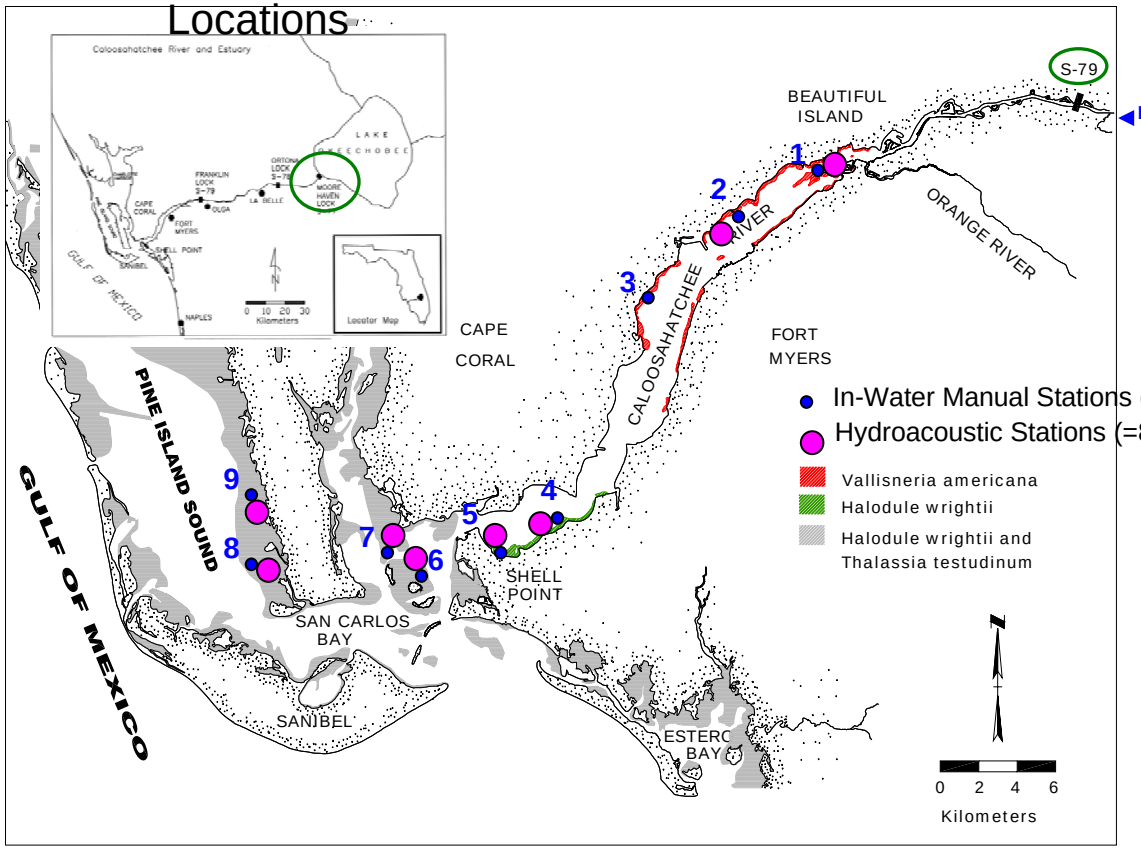
- Revised the inventory
  - In-situ Water Quality Monitoring
    - SFWMD
    - SCCF
  - Discrete Water Quality Monitoring
    - Charlotte Harbor National Estuary Program
    - Florida Department of Environmental Protection South District
    - South Florida Water Management District
    - Lee County
    - City of Cape Coral
    - FIU South Florida Coastal Water Quality Monitoring Network
    - USGS



Water Quality Monitoring Map (CHNEP, 2007) - will be revised for R&WQMP Area

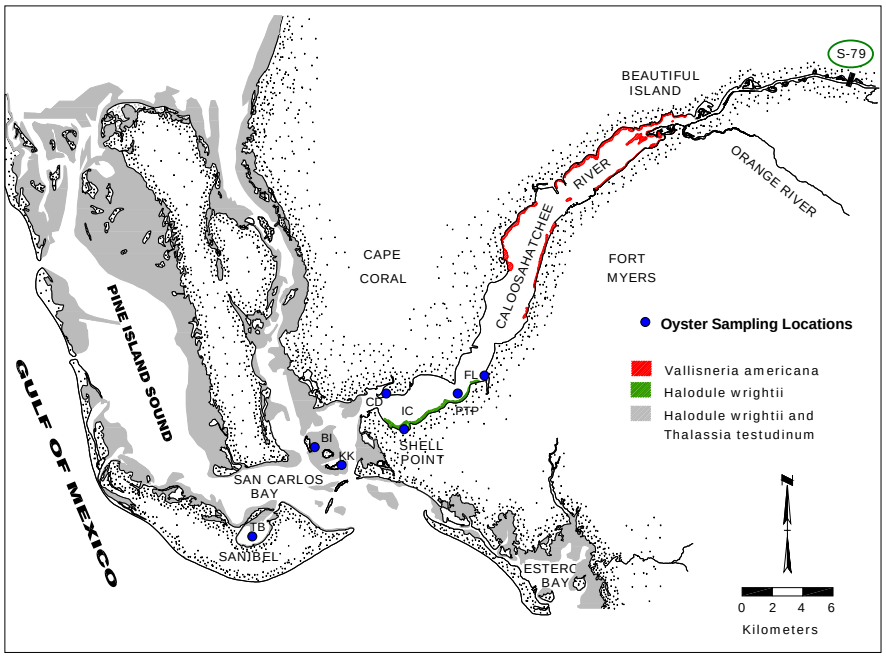
SAV Monitoring

Submerged Aquatic Vegetation and Sampling Locations



- SFWMD
  - 1996 - present
- SCCF
  - 2003- present
- Charlotte Harbor Aquatic Preserve will be added

Oyster Monitoring



- SFWMD
  - 2004- present
  - Monthly

Research and Water Quality Monitoring Program: Objectives

1. Build upon the SFWMD's existing research program
2. Shall be sufficient to carry out, comply with or assess the plans, programs and other responsibilities.
3. The Research Programs must provide for an assessment of the water volumes and timing from Lake Okeechobee and the watersheds and their relative contributions to the timing and volume of water delivered to each estuary. The research program must provide technical information of inflow targets and salinity envelopes for both estuaries based on existing information. To allow for revision of these goals future plans should identify projects that fill information gaps identified during target and envelope development.

Research and Water Quality Monitoring Program: Objectives

4. The research program should provide for the scientific studies that are necessary to support the design of the Caloosahatchee River Watershed Construction Project facilities.
5. To fulfill the requirement to assess plans and programs from a research perspective, predictive empirical and/or numeric modeling tools are needed to predict and evaluate progress towards overall protection program objectives. These tools can be used to evaluate and quantify the nutrient load reduction achieved by construction projects and or operational modifications and progress towards restoration of natural hydrology and targeted water quality.
6. The research program should also provide the empirical data and conceptual understanding of the Caloosahatchee River Watershed and estuarine receiving waters to 1) support and improve predictive models and 2) identify new water quality management measures.

Research and Water Quality Monitoring Program: Original Outline

I. Introduction

- A. Description of Enabling Legislation
- B. Delineation of Study Area and Aquatic Habitats
- C. Status and Trends in Water Quality, Hydrology and Aquatic Habitat

II. Goals and Objectives of Monitoring and Research

- A. Detect Change at the Regional Level
- B. Detect Change at the Project Level
- C. Influence of Lake Okeechobee and Watershed Discharge on Delivery to Estuaries
- D. Establish Salinity Envelopes and Freshwater Inflow Targets
- E. Support Caloosahatchee Project Development*
- F. Develop Predictive/ Assessment Models
- G. Support Annual Reporting

Research and Water Quality Monitoring Program: Original

III. Monitoring on a Regional Scale

- A. Monitoring Required to Meet Objectives
- B. Inventory of Existing Monitoring Programs
- C. Assessment and Identification of Additional Monitoring Needs

IV. Monitoring on the Project Level

V. Research for Adaptive Management

- A. Reduce Uncertainty in Project Design and Function
- B. Reduce Uncertainty of RWPP Benefits at the Regional Scale

VI. Recommendations

* Required under legislation for Caloosahatchee but not St. Lucie.

Research and Water Quality Monitoring Program: Outline Major Changes

I. Introduction

A. Description of Enabling Legislation

B. Delineation of Study Area and Aquatic Habitats (Moved to New Section III)

C. Status and Trends in Water Quality, Hydrology and Aquatic Habitat (Moved to New Section III)

II. Goals and Objectives of Monitoring and Research (REFINED)

A. Detect Change at the Regional Level

B. Detect Change at the Project Level

C. Influence of Lake Okeechobee and Watershed Discharge on Delivery to Estuaries (Moved to New Section III)

D. Establish Salinity Envelopes and Freshwater Inflow Targets (Moved to New Section III)

E. Support Caloosahatchee Project Development*

F. Develop Predictive/ Assessment Models

G. Support Annual Reporting

Research and Water Quality Monitoring Program: Outline Major Changes

III. Monitoring on a Regional Scale

- A. Monitoring Required to Meet Objectives (Combined with C below)
- B. Inventory of Existing Monitoring Programs
- C. Assessment and Identification of Additional Monitoring Needs (Moved to Recommendations)

IV. Monitoring on the Project Level

V. Research for Adaptive Management

- A. Reduce Uncertainty in Project Design and Function
- B. Reduce Uncertainty of RWPP Benefits at the Regional Scale

VI. Recommendations

* Required under legislation for Caloosahatchee but not St. Lucie.

Research and Water Quality Monitoring Program: Revised Outline

I. Introduction

A. Description of Enabling Legislation

B. Document Structure

II. Goals and Objectives of Monitoring and Research

A. Build on SFWMD's Existing Research Program

B. Sufficient to carry out, comply with and assess plans, programs and other responsibilities

C. Scientific studies to support design of Watershed Construction Project Facilities

D. Influence of Lake Okeechobee and watershed discharge on delivery to estuaries

Salinity envelopes and inflow targets

E. Develop predictive empirical and/or numeric modeling tools

F. Provide empirical data to support and improve models and identify new management measures

Research and Water Quality Monitoring Program: Revised Outline

III. The River and its Watershed: Status, Trends and Targets in Hydrology, Water quality and Aquatic Habitat

- A. Delineation of Study Area
- B. Watershed Hydrology and Loading
- C. Estuary
- D. Salinity Envelopes and Flow Targets
- E. Influence of Lake Okeechobee and Watershed Discharge on Freshwater Inflow to Estuaries

IV. Existing Monitoring on the Regional Scale

- A. Definition of regional Scale Monitoring
- B. Water Quality Monitoring Programs
- C. Freshwater Inflow Monitoring Programs
- D. Aquatic Habitat Monitoring Program
- E. Power Analysis

Research and Water Quality Monitoring Program: Revised Outline

V. Monitoring on the Project Scale

- A. Definition of Project Monitoring
- B. Projects Considered in the Plan
- C. Monitoring for Load Reduction – removal efficiency, permit requirements

VI. Current Research for Adaptive Management

- A. Purpose of Research
- B. Status of Current Research related to Water Quality
- C. Status of Current Assessment Tools

VII. Recommendations

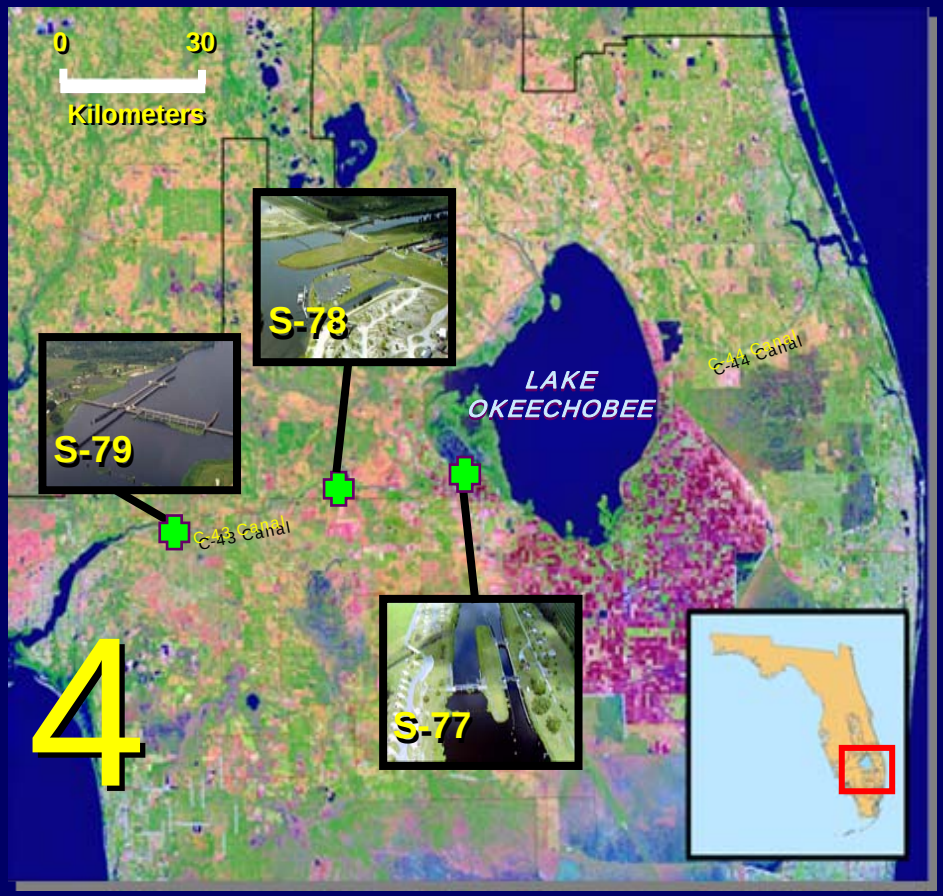
- A. Monitoring Needs at the Regional Scale
- B. Monitoring Needs at the Project Level
- C. Research for Adaptive Management
- D. Modeling Tools for Evaluation/ Assessment

CALOOSAHATCHEE RIVER ESTUARY WATER QUALITY SUMMARY

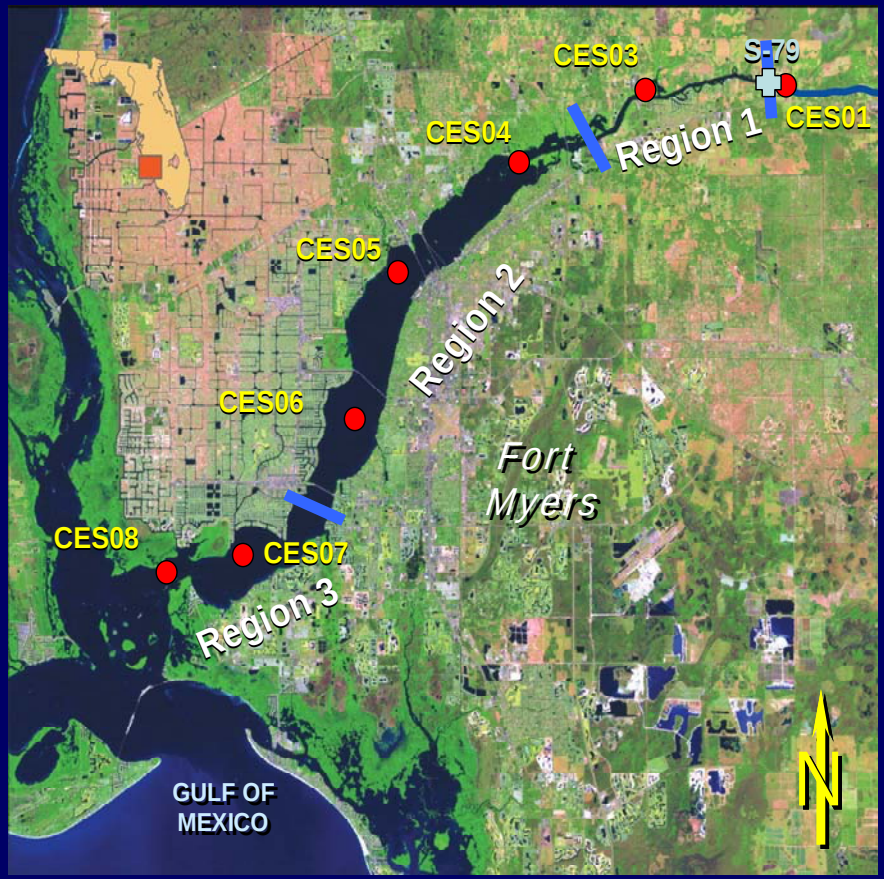
January 1, 1991 – December 31, 2006

Dan Crean

Coastal Ecosystems Division



- The impacts of freshwater flows entering the Caloosahatchee Estuary at S-79 were assessed by examining nutrient and hydraulic loads from (1/1/1993 through 12/31/2006)



- **Surface water monitoring stations within regions and freshwater inflow structure (S-79) on the Caloosahatchee River Estuary**

- **Combined water quality data collected under the CAL and CESWQ projects for the periods 10/1994 – 8/1996 and 4/1999 - 12/2006.**

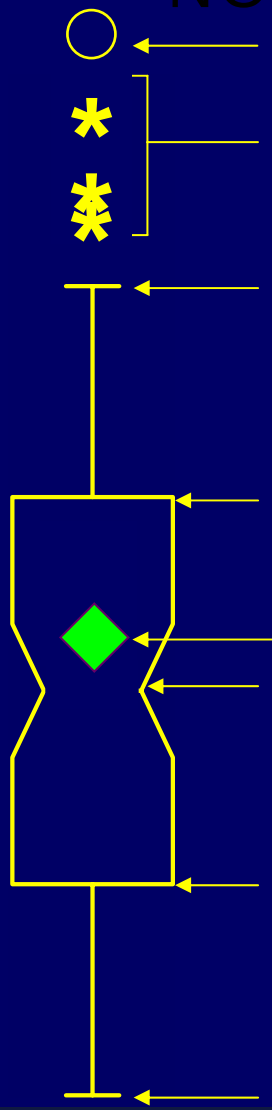
Note: CES01 is located upstream of S-79 in the C-43 canal (freshwater site).

Analyses Performed:

- Monthly flows for the downstream-most structure (S-79) to the Caloosahatchee Estuary were categorized using percentiles (5th, 25th, 75th, 95th and greater than 95th).

- These percentiles were used to group the corresponding monthly water quality data (salinity, total phosphorus, and total nitrogen) for monitoring sites in the estuary to assess water quality conditions for the CRE.

NOTCHED-BOX AND WHISKER PLOTS



Asterisk represents data greater than 4 standard deviations above the median.

Diamond represents data greater than 2 standard deviations above the median.

Upper whisker is maximum data value or highest value not outside +2 standard deviations.

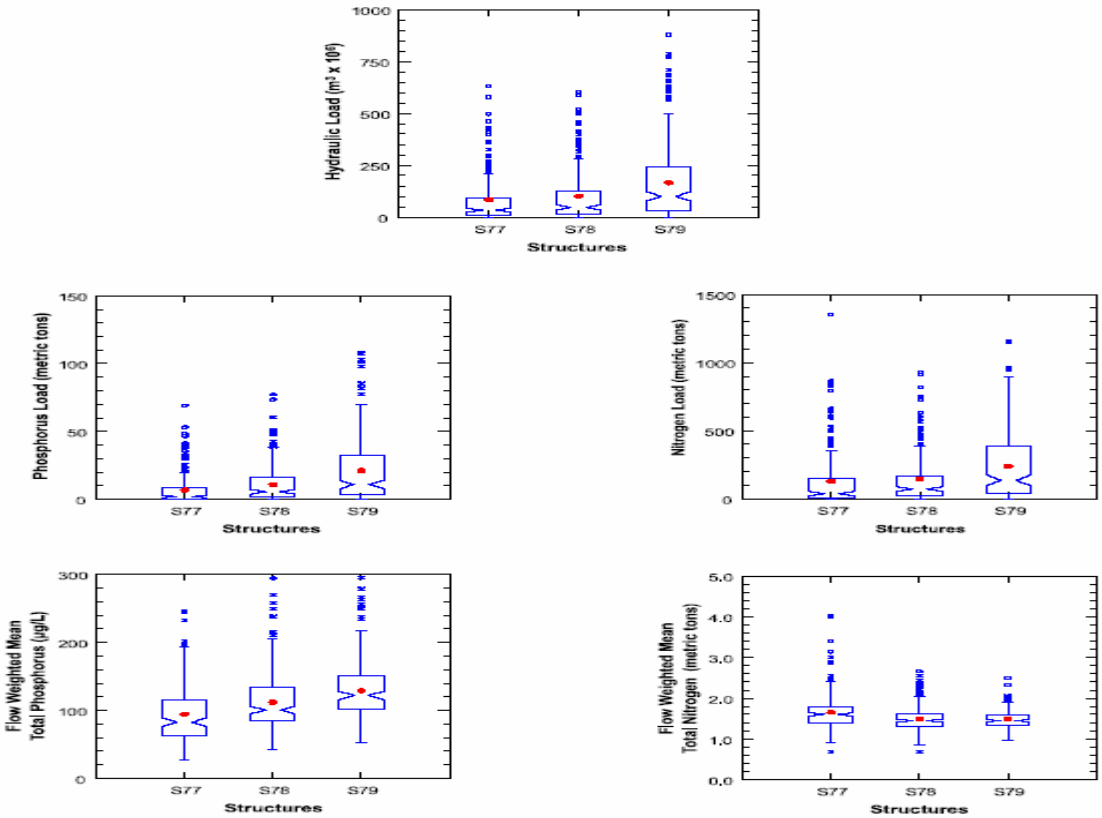
Top of box is the 75th percentile (Q75).

Mean value of data set

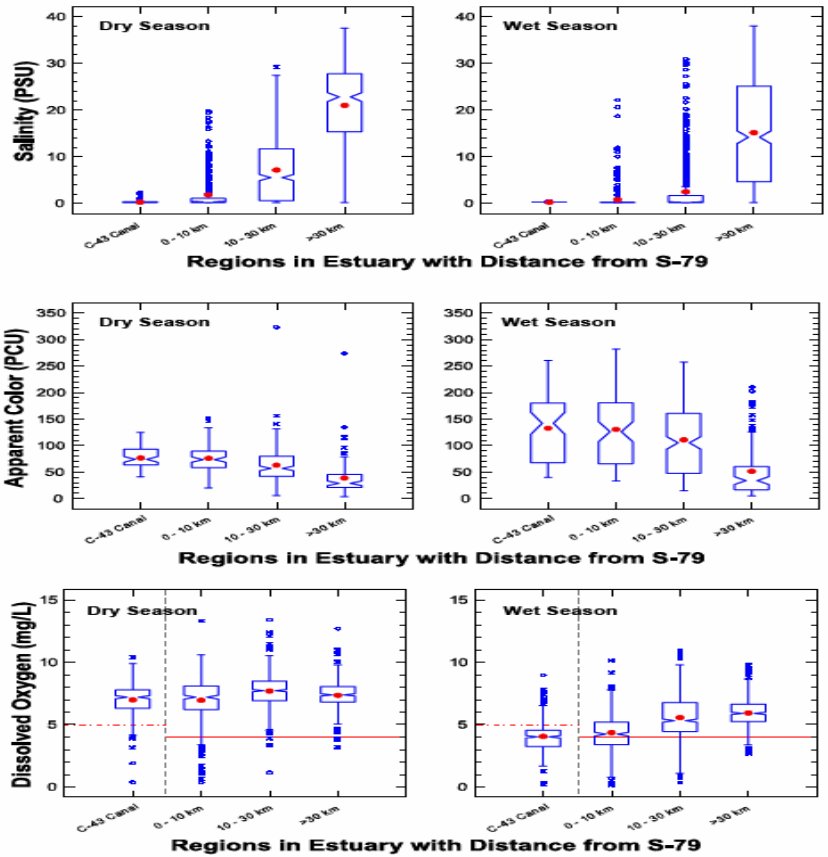
Notch represents the 95% confidence interval for the median.

Bottom of box is the 25th percentile (Q25).

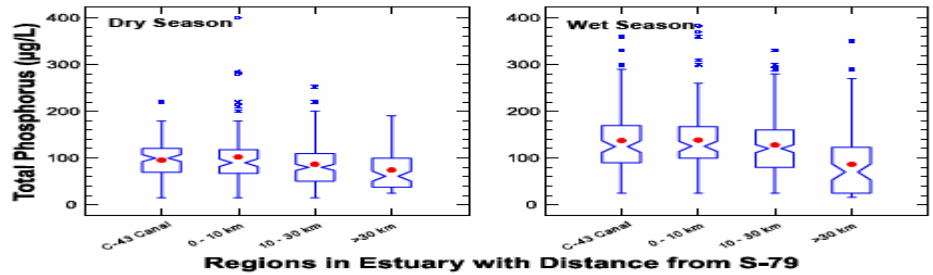
Lower whisker is maximum data value or highest value not outside -2 standard deviations.

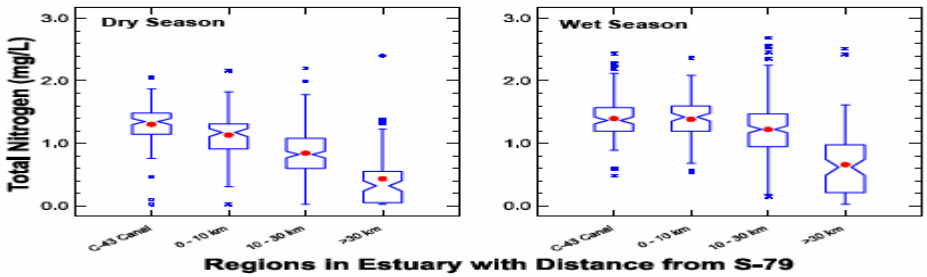


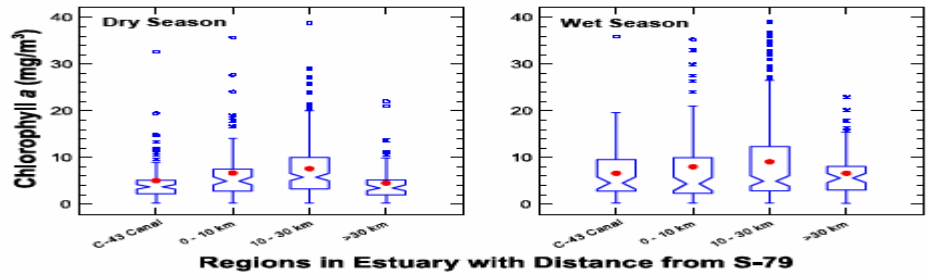
Notched box and whisker plots comparing hydraulic, phosphorus and nitrogen loads and flow weighted mean total phosphorus and total nitrogen concentrations at structures S-77, S-78 and S-79 from January 1991 through December 2006.



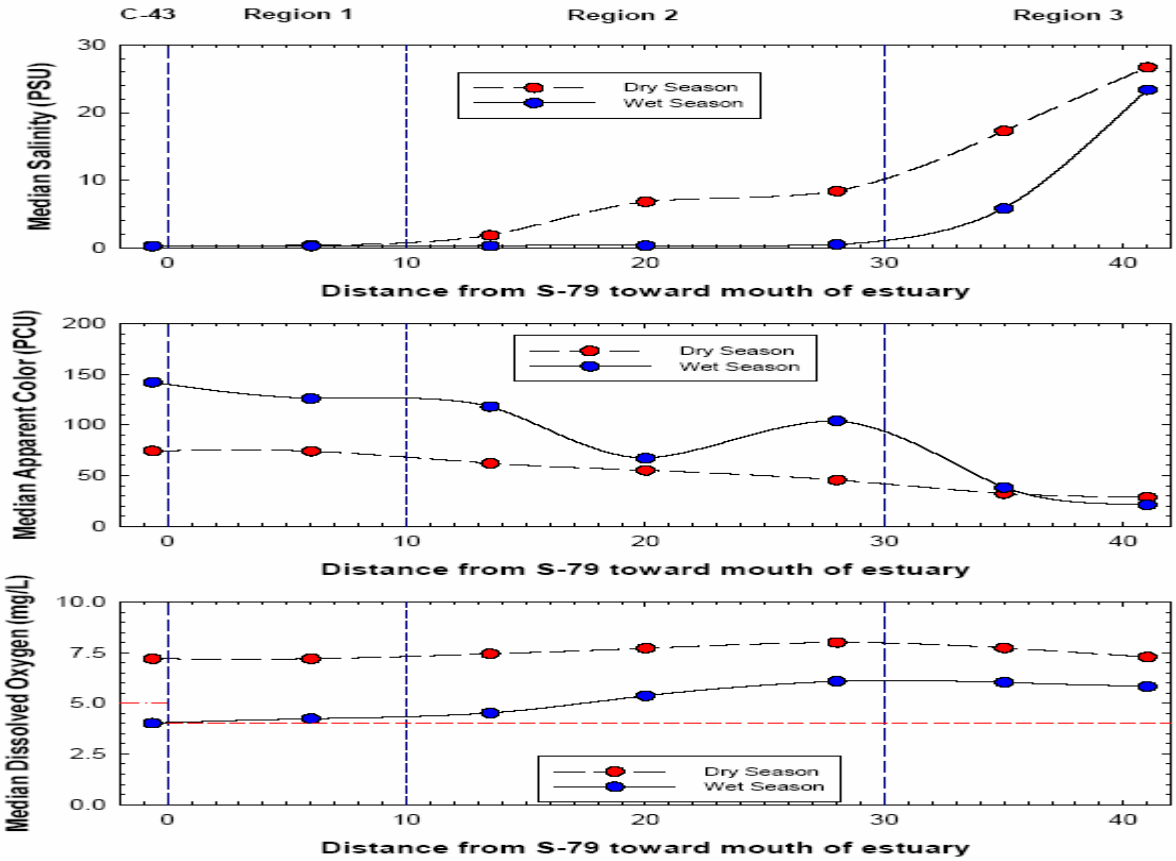
Notched box and whisker plots water quality parameter levels for the dry and wet seasons in three regions of the Caloosahatchee River Estuary for the period from October 1994 through December 2006. C-43 water quality data provided for comparison. Dissolved oxygen graphs contain Class III limits for freshwater (5.0 mg/L) and marine water (4.0 mg/L).



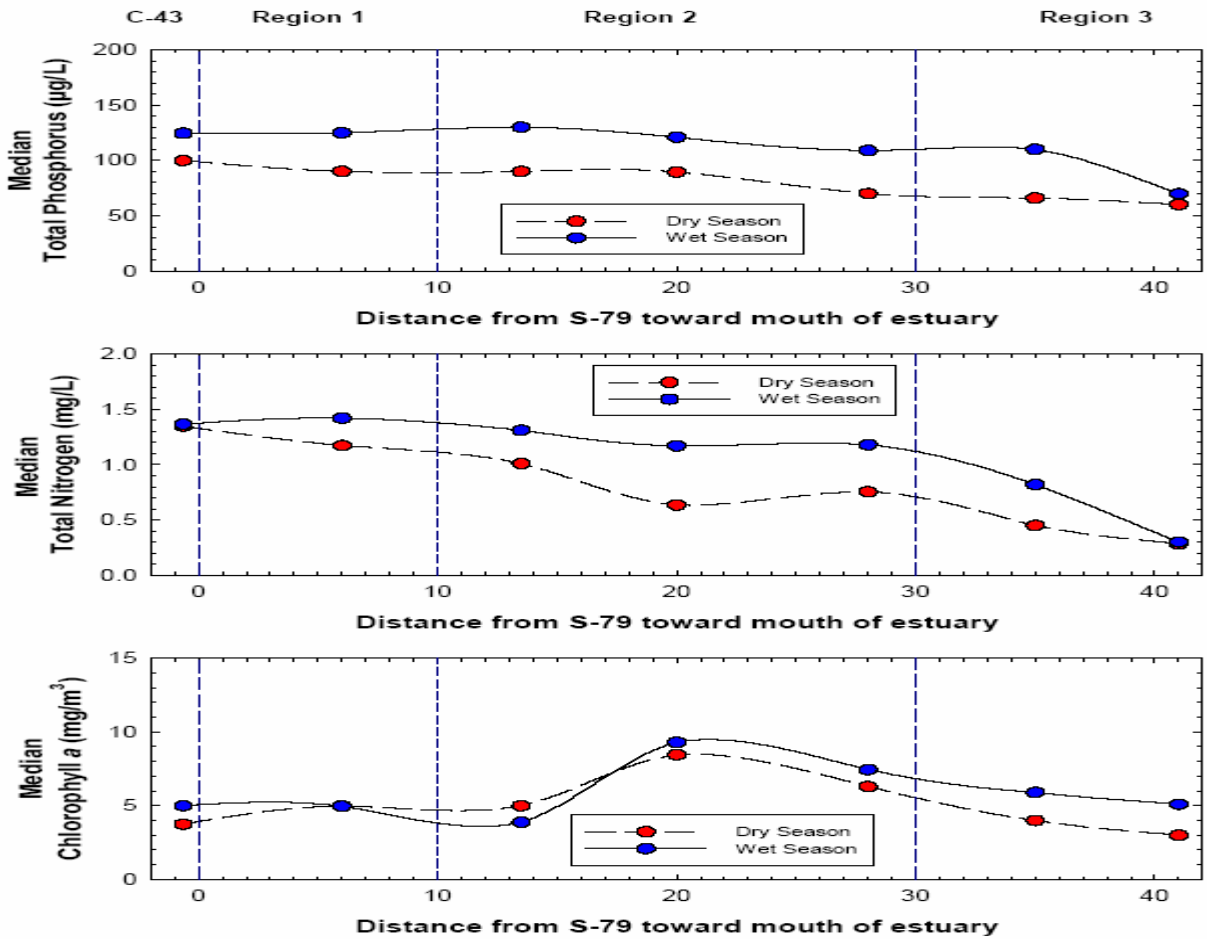




Notched box and whisker plots water quality parameter levels for the dry and wet seasons in three regions of the Caloosahatchee River Estuary for the period from October 1994 through December 2006. C-43 water quality data provided for comparison.



Seasonal median levels in the Caloosahatchee River Estuary with distance from Structure S-79. The vertical lines denote the three regions of the estuary. Data points to the left of the 0 km line show water quality approximately 0.6 km upstream of the S-79 structure. The horizontal lines in the dissolved oxygen graph show the Class III limit of 5.0 mg/L for freshwater and 4.0 mg/L for marine water..



Seasonal median levels in the Caloosahatchee River Estuary with distance from Structure S-79. The vertical lines denote the three regions of the estuary Data points to the left of the 0 km line show water quality approximately 0.6 km upstream of the S-79 structure.

Table 1. Summary of annual freshwater inflows, nutrient loads and flow weighted mean concentrations from S-79 to the Caloosahatchee River Estuary.

Water Year[a]	Inflow Volume	Nutrient Loads (metric tons)		Flow Weighted Mean	
	(m^3 X 10^6)	Phosphorus	Nitrogen	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)
1991	120.9	17.5	208.8	145	1.73
1992	1126	197	1828	175	1.62
1993	1783	445	3064	250	1.72
1994	957.9	139	1968	145	2.05
1995	2815	264	4521	93.6	1.61
1996	3497	274	4097	78.3	1.17
1997	954.3	115	1384	120	1.45
1998	3077	262	4076	85.3	1.32
1999	1105	154	1665	139	1.51
2000	2020	335	3129	166	1.55
2001	593.2	97.1	850.1	164	1.43
2002	1153	245	1852	212	1.61
2003	2232	353	3798	158	1.70
2004	3039	316	4169	104	1.37
2005	2503	279	3303	111	1.32
2006	4331	540	6251	125	1.44

[a] Water year is defined as a 12-month period starting in May and ending in April

Table 2. Summary of water quality for four regions of the Caloosahatchee River Estuary for the period from October 1994 through December 2006. One region is located upstream of S-79 and the other three regions are located in the estuary downstream of S-79.

Parameter	Mean	±	Standard Deviation	Minimum	Percentiles					Maximum
					5th	25th	50th	75th	95th	
Station ~0.6 km upstram of S-79 (C-43)										
Salinity (PSU)	0.3	±	0.1	<0.2	<0.2	<0.2	0.2	0.3	0.5	2.3
Apparent Color (PCU)	103.8	±	53.8	40.0	49.8	64.0	80.4	134.3	213.8	260.0
Dissolved Oxygen (mg/L)	5.6	±	1.9	0.2	2.8	4.1	5.6	7.4	8.4	10.4
Total Phosphorus (µg/L)	115.9	±	57.8	15.0	27.8	77.8	110.0	140.0	230.0	360.0
Total Nitrogen (mg/L)	1.35	±	0.32	<0.05	0.91	1.17	1.36	1.51	1.86	2.43
Chlorophyll *a* (mg/m^3)	8.3	±	13.5	0.3	1.1	2.5	4.2	8.2	32.0	80.7
Stations 0 - 10 km from S-79 (Region1)										
Salinity (PSU)	1.3	±	3.0	<0.2	<0.2	0.2	0.3	0.5	7.2	22.2
Apparent Color (PCU)	103.1	±	57.2	20.4	41.8	60.7	80.2	138.0	221.5	282.0
Dissolved Oxygen (mg/L)	5.6	±	2.1	0.1	2.6	3.9	5.5	7.2	8.7	13.3
Total Phosphorus (µg/L)	125.3	±	83.7	15.0	37.0	72.0	110.0	160.0	280.8	680.0
Total Nitrogen (mg/L)	1.26	±	0.37	<0.05	0.64	1.08	1.26	1.49	1.86	2.36
Chlorophyll *a* (mg/m^3)	8.7	±	10.2	0.3	1.1	2.7	5.0	9.9	33.1	50.0
Stations 10 -30 km from S-79 (Region 2)										
Salinity (PSU)	4.7	±	6.4	<0.2	0.2	0.2	0.8	7.7	18.3	30.9
Apparent Color (PCU)	88.3	±	58.9	6.1	27.0	44.3	67.6	118.0	208.1	379.0
Dissolved Oxygen (mg/L)	6.6	±	1.9	0.4	3.6	5.1	6.8	7.9	9.4	13.4
Total Phosphorus (µg/L)	111.6	±	74.2	15.0	25.0	63.8	100.0	140.0	240.0	730.0
Total Nitrogen (mg/L)	1.04	±	0.47	<0.05	0.30	0.71	1.03	1.33	1.84	2.69
Chlorophyll *a* (mg/m^3)	11.8	±	17.5	0.3	1.5	3.2	5.8	12.4	40.9	119.0
Stations >30 km from S-79 (Region 3)										
Salinity (PSU)	17.9	±	10.6	<0.2	0.6	8.1	19.6	27.0	32.7	38.1
Apparent Color (PCU)	45.3	±	44.1	3.5	8.0	19.0	30.0	53.0	136.2	274.0
Dissolved Oxygen (mg/L)	6.6	±	1.4	2.7	4.1	5.7	6.7	7.6	8.8	12.7
Total Phosphorus (µg/L)	100.4	±	131.2	16.0	25.0	36.0	70.0	120.8	266.5	1130
Total Nitrogen (mg/L)	0.55	±	0.50	<0.05	<0.05	0.16	0.38	0.84	1.40	2.51
Chlorophyll *a* (mg/m^3)	6.1	±	6.7	0.2	0.9	2.6	4.0	7.2	17.3	51.1

SUMMARY

Effect of discharge on estuaries

- **The distribution of water flows, nutrient loads and flow weighted mean concentrations for each of the control structures along the C-43 canal display an increase in flows and loads in a westward directions (i.e., from S-77 to S-79)**
- **On average about 1.53 million acre-feet of water enter the Caloosahatchee at S-79 each year. This discharge carries an average nutrient load of 246 metric tons of P and 2,791 metric tons of N. Of this load 31 % of the P and 55% of the N are discharged from Lake Okeechobee at S-77.**

SUMMARY

- **Conversely Basin loads (between S-77 and S-79) for the C-43 account for 50% of the total hydraulic, 45% of the total nitrogen and 69% of total phosphorus loads to the CRE.**

An Analysis of the Water Quality
In The Caloosahatchee River Estuary

Background/Purpose

The Caloosahatchee River Estuary (CRE) is a large estuarine system where the marine water of the Gulf of Mexico mix with the freshwater inflows from the river, sloughs and overland sheetflow in the basin. The lower reaches are characterized by a shallow bay, extensive seagrass beds and sand flats. Extensive mangrove forests dominate undeveloped areas of the shoreline. Southwest Florida estuaries serve as habitats to more than 40 percent of Florida's rare, endangered and threatened species. The Caloosahatchee River and Estuary extend about 70 miles from Lake Okeechobee to San Carlos Bay on Florida's southwest coast. This watershed includes the East, West and Tidal Caloosahatchee drainage basins as well as the North Coastal, Telegraph Swamp, C-21 and S-236 drainage basins. The freshwater portion of the river has been reconfigured as a canal (C-43), extending 45 miles from the Moore Haven Lock and Dam (S-77) to Franklin Lock and Dam (S-79), to better convey flood water to the Gulf of Mexico. The river and C-43 canal serve as a waterway that links the west coast of Florida with the east coast through Lake Okeechobee (Figure 1).

Two of the major issues affecting the Caloosahatchee River Estuary are salinity variations and nutrient levels. Water quality within the Caloosahatchee River basin is threatened by altered freshwater inputs, nutrient loads from agricultural activities, as well as overall urban growth and development within the watershed. The integrity of riverine and estuarine ecosystems is dependent on water quality. As water quality diminishes, so does the overall quality of the system. The purpose of this report is to summarize the water quality conditions in the CRE from surface water data collected for the period from October 1994 through December 2006. This summary will focus on nutrients and parameters affecting the clarity of the water in the CRE.

Methods

The data analyzed here come from two monitoring programs. The Caloosahatchee Estuary High Flow (CAL) effort sampled monthly at 8 stations from 11/94 to 8/96. Seven stations were located in the estuary and San Carlos Bay, while one was located in freshwater upstream of S-79. The Center for Environmental Studies (CES) program sampled 7 stations in the estuary (S-79 to Shell Point) and one (1) station upstream of S-79 on a monthly basis from 4/1999 to 3/2002. As of 5/2002, the number of stations was reduced to 4, with one upstream of S-79 and the rest in the downstream estuary. This reduced sampling effort continues to the present. CES stations are depicted in Figure 2 are all located in the navigation channel. The corresponding CAL stations were located at the same river-mile but on the flats adjacent to the channel. Since all samples were taken near the surface (0.5 m), and since stations were aggregated into regions, this difference in station location was not considered significant.

All sample collections were conducted in strict accordance with the FDEP approved South Florida Water Management District Comprehensive Quality Assurance Plan number 870166G. In addition, the South Florida Water Management District received a National Environmental Laboratory accreditation Conference (NELAC) certification on May 1, 2002, in accordance with

the FDEP. All samples were collected as close to low tide as possible. *In situ* physical parameters were measured using a Hydrolab Surveyor III multi-parameter metering device. These parameters include temperature, pH, conductivity, and dissolved oxygen which were sampled at half-meter increments from the bottom of the water column to the surface. Conductivity and temperature measurements were used to calculate salinity when salinity measurements were missing using the method described by Millero (1982). Water samples were collected using a Wildco 2.2-liter Van Dorn PVC horizontal sampling bottle (or Niskin sampling bottle) 0.5 meters depth at each sampling site. Samples were analyzed for turbidity, total suspended solids, color, chlorophyll *a*, total phosphorus, total Kjeldahl nitrogen, orthophosphate, nitrate + nitrite, and ammonia. In addition, total nitrogen concentrations were calculated from total Kjeldahl and nitrate + nitrite.

Results

For the purpose of this report a limited number of parameters were used to summarize water quality in the CRE. Those parameters are:

- salinity
- color
- total nitrogen
- dissolved oxygen
- total phosphorus
- chlorophyll *a*

For purposes of summarizing the water quality data, the estuary was divided into three regions, with a freshwater station (CES01) approximately 0.6 km upstream of the S-79 structure for comparison. Region 1 contains a water quality monitoring station located less than 10 km from S-79 (CES03); Region 2 contains stations located from 10 to 30 km from S-79 (CES04, CES05, and CES06); and Region 3 contains stations located beyond 30 km from S-79 (CES07 and CES08). Water quality data from the freshwater station at CES01 were used to represent the water quality of the C-43 canal because these data were collected in conjunction with the other monitoring stations in the CRE.

A summary of annual fresh water inflow and associated nutrient loads to the estuary from the C-43 canal (measured at S-79) is provided in Table 1. This data covers the period from January 1991 through December 2006. On average, the estuary receives $1{,}892 \times 10^6$ m^3 of freshwater and 246 and 2,791 metric tons of phosphorus and nitrogen, respectively.

Notched box and whisker plots presented in Figure 3 show the distribution of flows, nutrient loads and flow weighted mean concentrations for each of the control structures along the C-43 canal. An increase in flows and loads in a westward directions (i.e., from S-77 to S-79) is apparent for all plots in Figure 3. Based on these plots, an average of 31% of the phosphorus load and 55% of the nitrogen load at S-79 is contributed by S-77 (outflow structure from Lake Okeechobee to C-43 canal). In addition to flows and loads increasing in the C-43 canal westward from Lake Okeechobee, the flow weighted mean total phosphorus concentrations also increase (Figure 3). Total nitrogen flow weighted mean concentrations, on the other hand, appear to decrease westward from S-77 (Figure 3). This decrease may be a result of nitrogen removal between S-77 and S-78.

Figures 4a and 4b show notched box and whisker plots of salinity, color, dissolved oxygen, total phosphorus, total nitrogen, and chlorophyll *a* levels in the three regions of the CRE and one station located upstream of S-79. Salinity and dissolved oxygen were the only parameters that exhibited statistically ($p<0.001$) higher concentrations during the dry season compared to the wet season. The remaining parameters exhibited statistically higher levels during the wet season. A strong seasonal signal, with a clear demarcation between the wet season (May through October) and the dry season (November through April), resulting from freshwater inflows and nutrient loads to the estuary is not unexpected in a tropical system.

Dry and wet season median levels for the six parameters of interest were plotted with distance from Structure S-79 (Figures 5a and 5b). Data points located to the left of the 0 km line exhibit water quality at the monitoring station located approximately 0.6 km upstream of the S-79 structure. These plots provide the extent of freshwater impact on the estuary. As was observed with the notched box and whisker plots in Figures 4a and 4b, the six parameters (salinity, color, dissolved oxygen, total phosphorus, total nitrogen and chlorophyll *a*) show the same pattern with salinity and dissolved oxygen concentrations being higher during the dry season, while the other parameters exhibit higher concentrations during the wet season. One interesting observation resulting from the plots in Figures 5a and 5b is that CES05, which is located in Region 2, appears to be influenced by a source of less colored water. During the wet season, the median color level for CES05 (located approximately 20 km downstream of S-79) is lower than the corresponding levels at the nearest upstream stations (CES04) and downstream stations (CES06) (Figure 5a). Median total nitrogen concentrations also appear to be lower at this station for both the dry and wet seasons. In contrast, median chlorophyll *a* levels peak at this location in the CRE during both seasons (Figure 5b). Additional statistical summaries of the water quality data in the three regions of the CRE are provided in Table 2.

Plots of color, total nitrogen, total phosphorus and chlorophyll *a* versus salinity for each region are provided in Appendix A (Figures A.1 and A.2). Color and total nitrogen are the only parameters that appear to exhibit trends with salinity. In both instances, an apparent inverse relationship exists with salinity (e.g., as salinity increases color and total nitrogen decrease).

Discussion

Concentrations of most water quality parameters decreased in a westerly direction from S-79 as a result of nutrient laden freshwater inflows. The increased freshwater inputs observed during the wet season through S-79 tend to contribute to the seasonal variability observed in the CRE.

Hand *et al* (1994) established median water quality standards for four parameters: chlorophyll *a* (9 mg/m^3), total nitrogen (0.8 mg/L), total phosphorus (100 µg/L), and Secchi depth (1.1 m) for Florida Estuaries. The median total nitrogen concentration for the three regions of the CRE ranged from 1.3 mg/L to 0.4 mg/L for Regions 1 through 3, respectively (Table 2). Overall, the CRE exhibited a median total nitrogen concentration of 1.0 mg/L, higher than the 0.8 mg/L limit. Median total phosphorus levels for the CRE (Table 2) were similar the median value for comparable Florida estuarine systems. Slightly higher median total phosphorus concentrations were observed in Region 1 due to its proximity to the freshwater source of S-79. These higher total phosphorus levels can be attributed to the nutrient laden fresh water inflows from the C-43

canal (Chamberlain and Hayward, 1996). Median chlorophyll *a* values ranged from 4.0 mg/m^3 in Region 3 to 5.8- mg/m^3 in Region 2 (Table 2). A median chlorophyll *a* level of 5 mg/m^3 was determined for the entire CRE. This level is below the limit established by Hand *et al.* (1994) for Florida estuaries.

Dissolved oxygen is a critical indicator of the health of an estuarine ecosystem (Engle *et al*, 1999). The CRE has generally maintained median dissolved oxygen values above 4 mg/L in both the wet and dry seasons across the three regions (Figure 4a). Nevertheless, during the warmer wet season a substantial number of samples from region one were under 4 mg/l. Since measurements of dissolved oxygen are performed during optimal photosynthetic conditions, the dissolved oxygen levels can be assumed to be lower during periods of the diel cycle when respiration is optimal.

Literature Cited

Chamberlain, R. and D. Hayward, 1996. Evaluation of Water Quality and Monitoring in the St. Lucie Estuary, Florida. Water Resources Bulletin 32(4): 681-696.

Doering, P. H. 1996. Temporal Variability of Water Quality in the St. Lucie Estuary, South Florida. Journal of the American Resources Association.

Engle, Virginia, D., J. Kevin Summers and John M. Macauley, 1999. Dissolved Oxygen Conditions in Northern Gulf of Mexico Estuaries. Environmental Monitoring and Assessment, 57(1):1-20

Hand, J. J. Col, and E. Grimison, 1994. Southeast and South Florida District Water Quality Assessment 1994 305 (b) Technical appendix, Florida Department Of Environmental Protection.

Millero, Frank., J. 1982. The Thermodynamics of Seawater. Ocean Science and Engineering, 7(4):403-460.

Figures

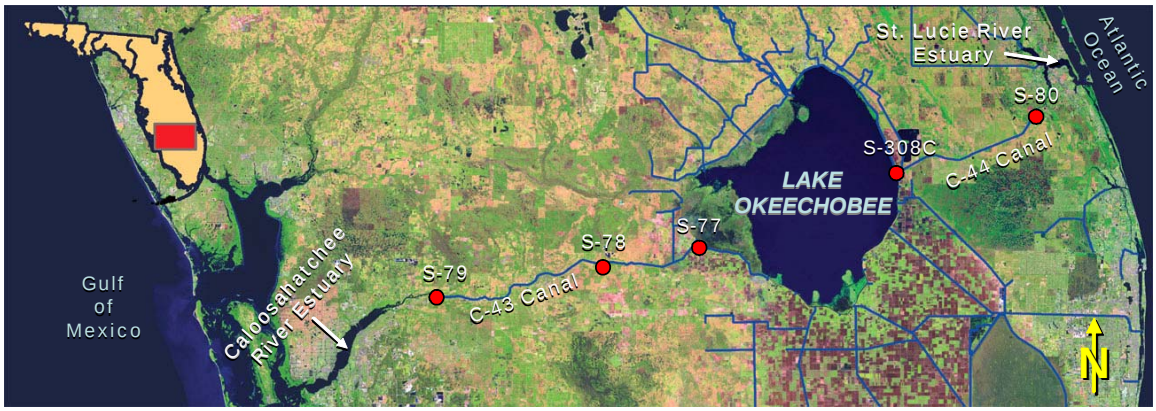


Figure 1. Map of Caloosahatchee (C-43)-Lake Okeechobee-St. Lucie (C-44) waterway.

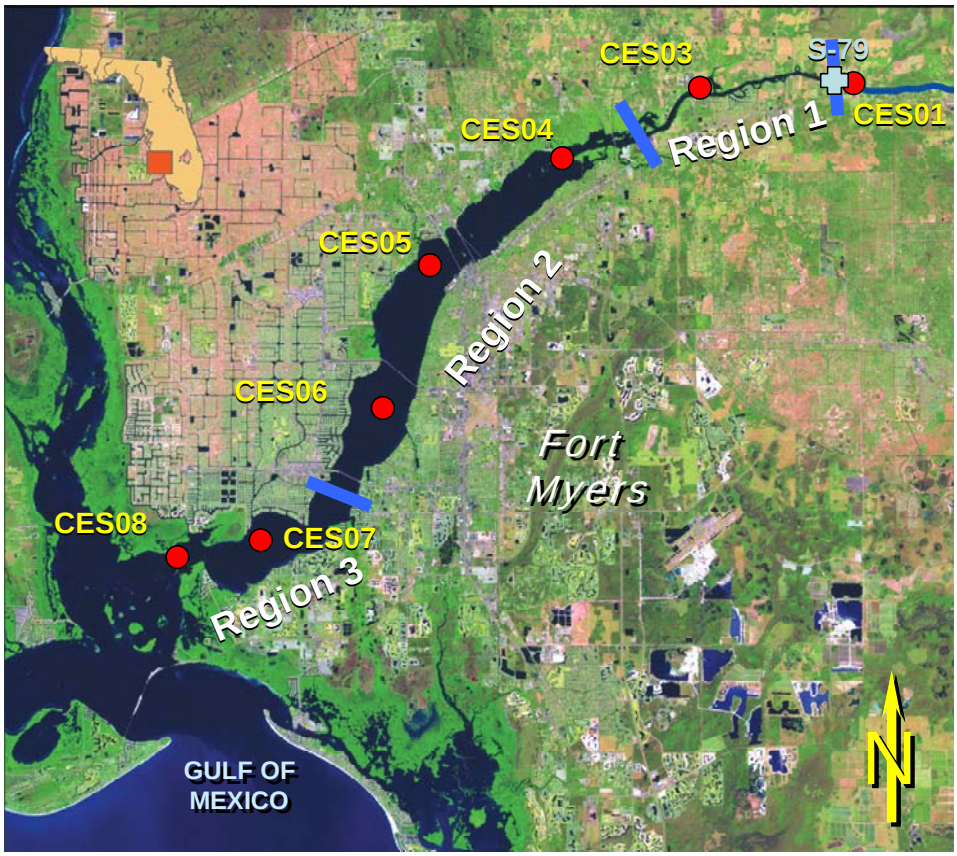


Figure 2. Surface water monitoring stations and freshwater inflow structure on the Caloosahatchee River Estuary.

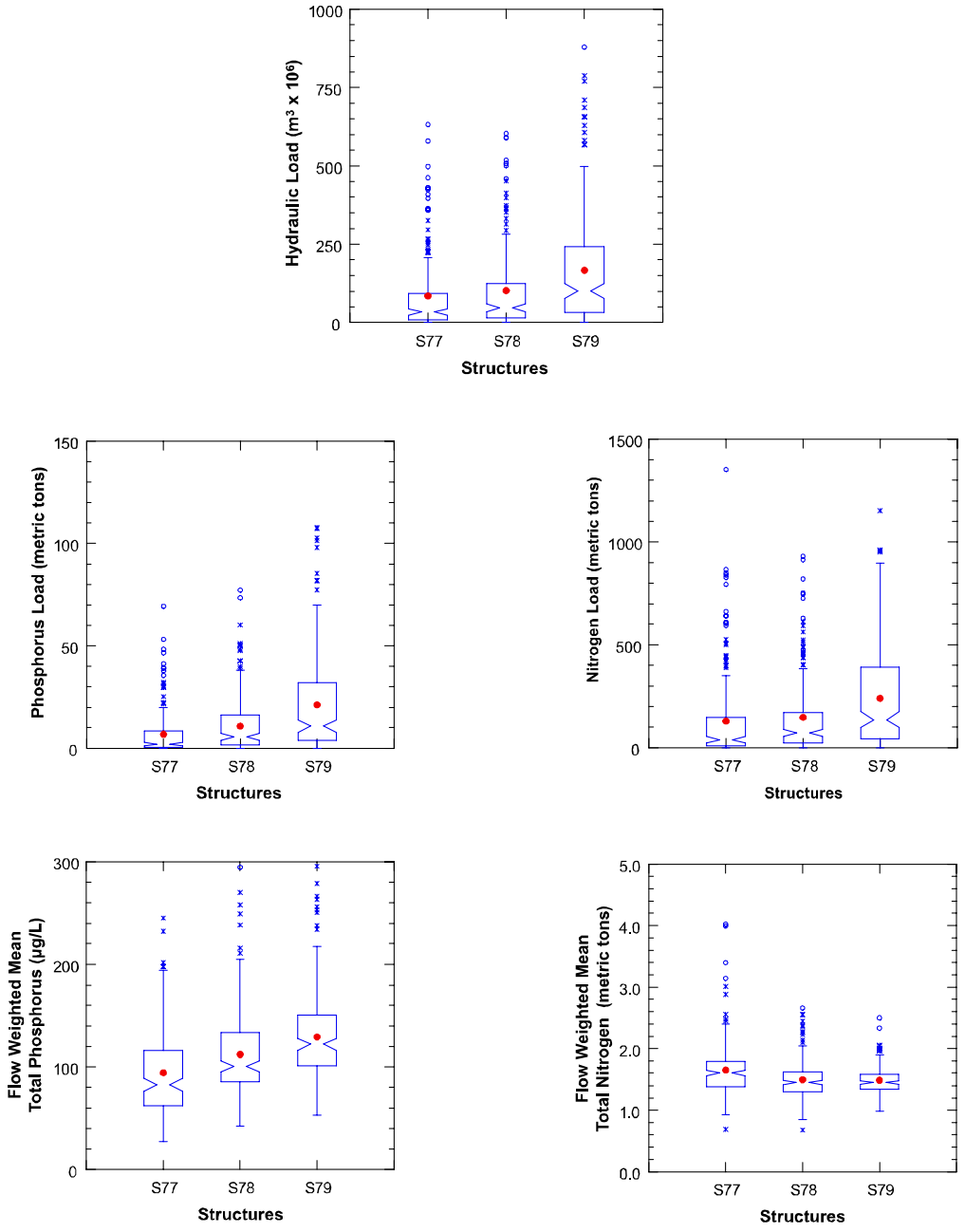


Figure 3. Notched box and whisker plots comparing hydraulic, phosphorus and nitrogen loads and flow weighted mean total phosphorus and total nitrogen concentrations at structures S-77, S-78 and S-79 from January 1991 through December 2006.

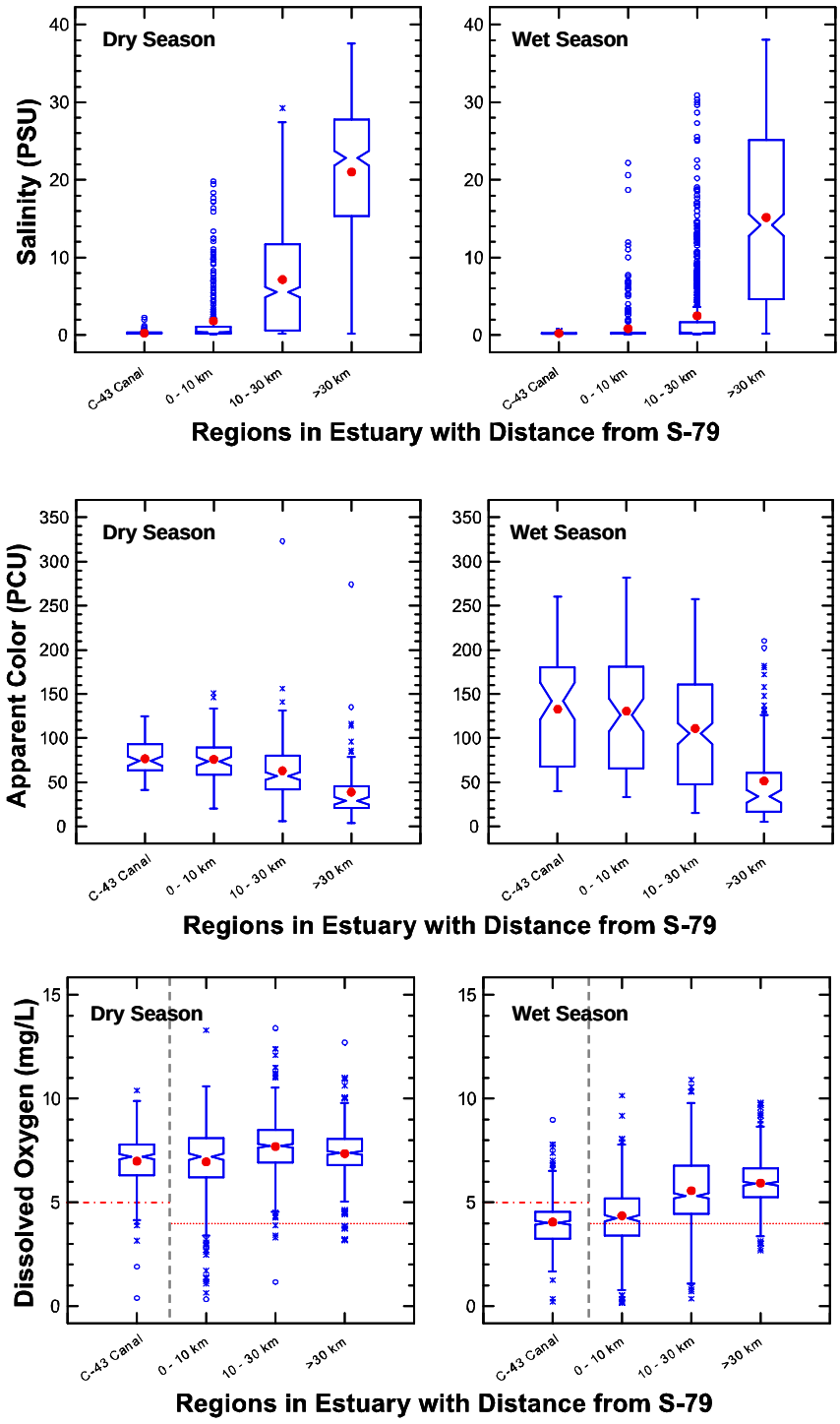


Figure 4a. Notched box and whisker plots water quality parameter levels for the dry and wet seasons in three regions of the Caloosahatchee River Estuary for the period from October 1994 through December 2006. C-43 water quality data provided for comparison. Dissolved oxygen graphs contain Class III limits for freshwater (5.0 mg/L) and marine water (4.0 mg/L).

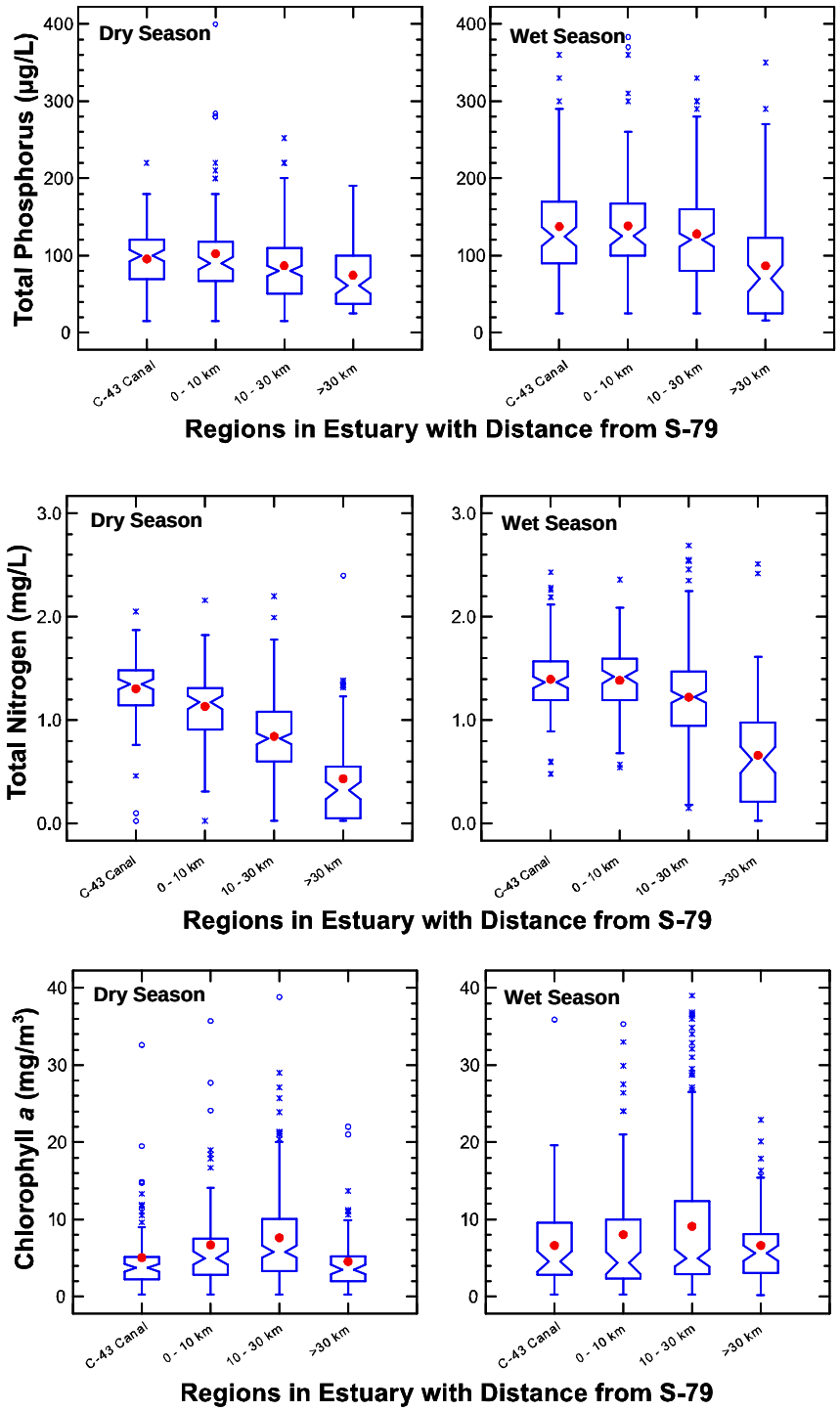


Figure 4b. Notched box and whisker plots water quality parameter levels for the dry and wet seasons in three regions of the Caloosahatchee River Estuary for the period from October 1994 through December 2006. C-43 water quality data provided for comparison.

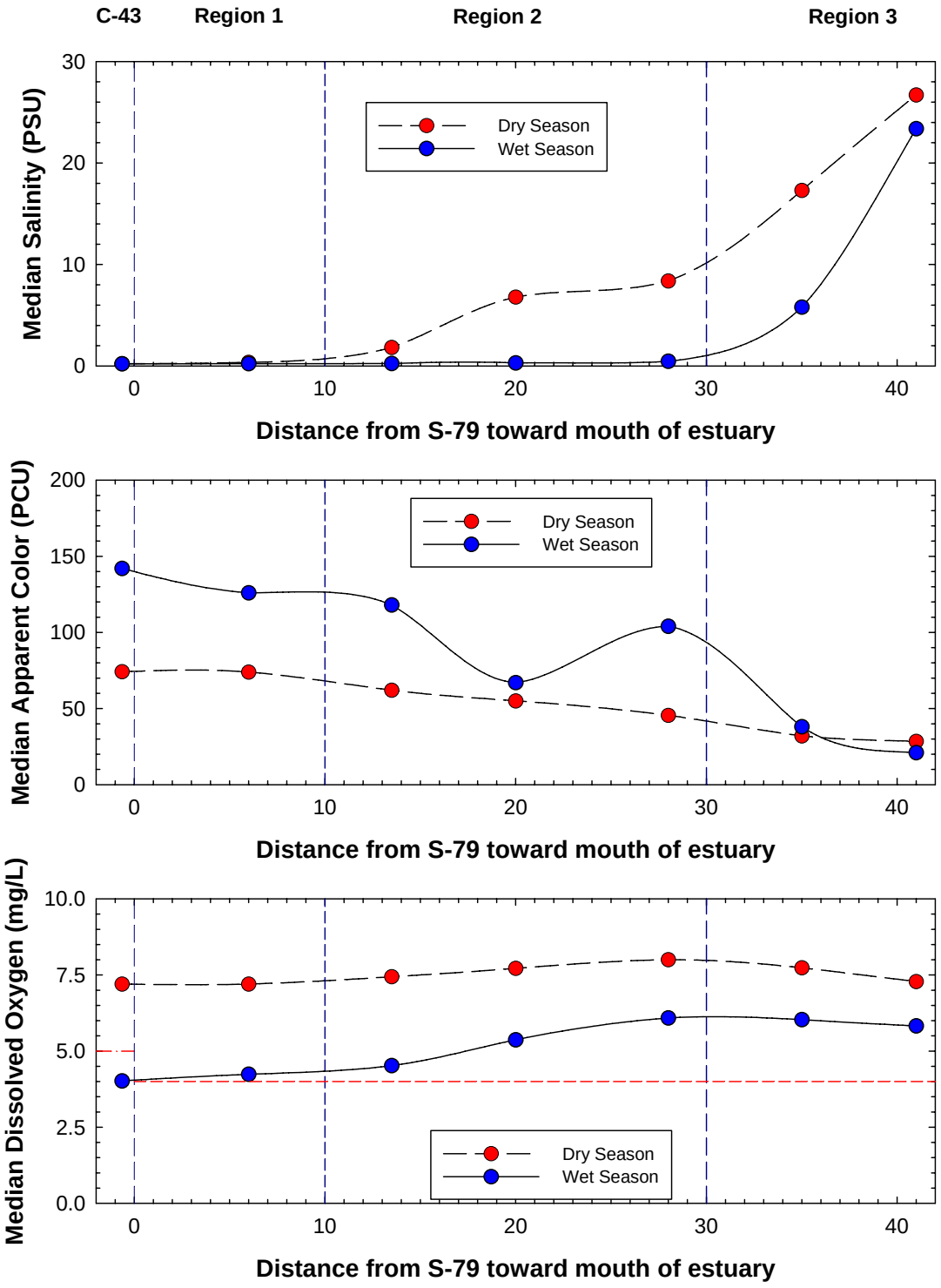


Figure 5a. Seasonal median levels in the Caloosahatchee River Estuary with distance from Structure S-79. The vertical lines denote the three regions of the estuary. Data points to the left of the 0 km line show water quality approximately 0.6 km upstream of the S-79 structure. The horizontal lines in the dissolved oxygen graph show the Class III limit of 5.0 mg/L for freshwater and 4.0 mg/L for marine water..

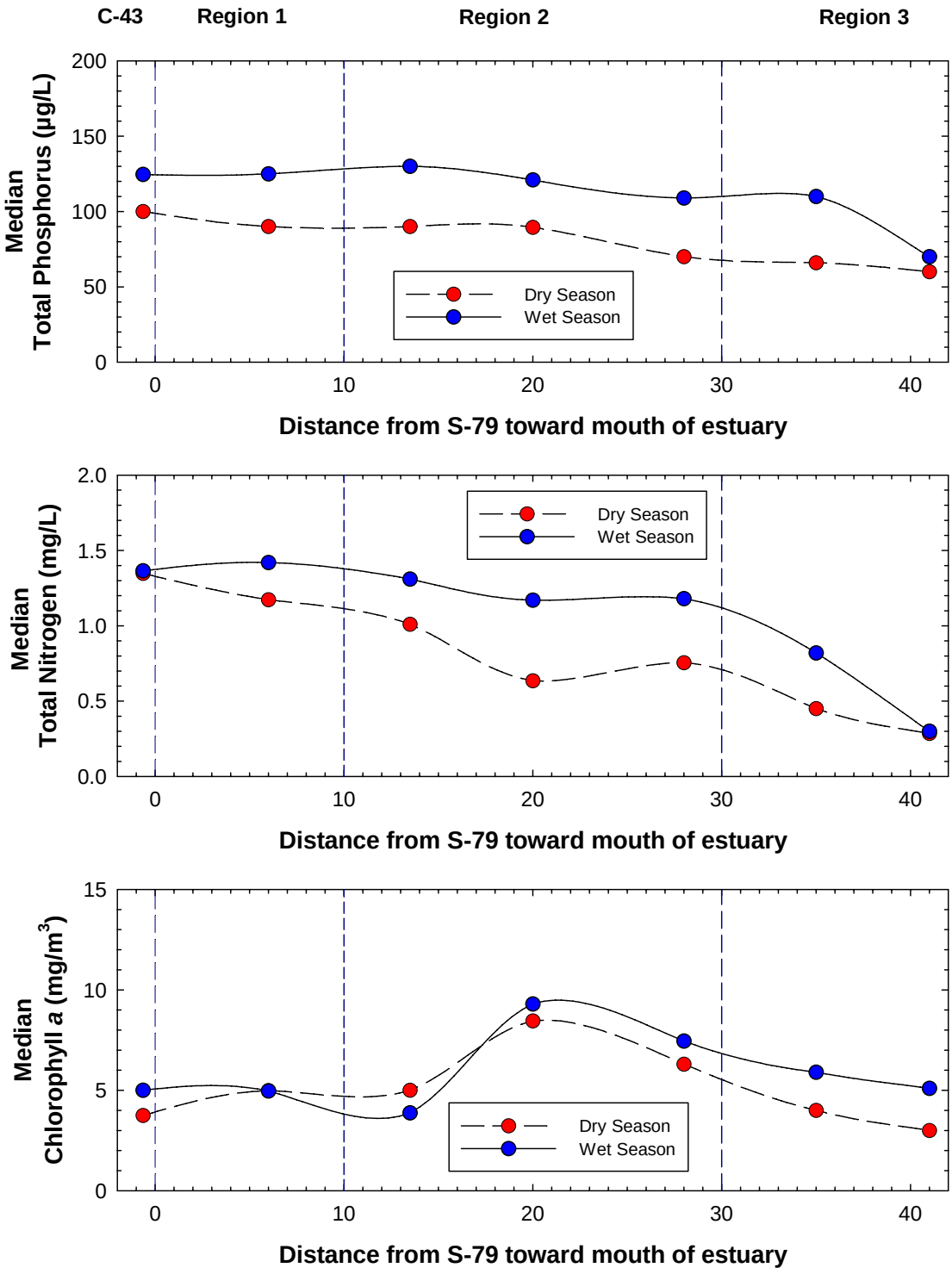


Figure 5b. Seasonal median levels in the Caloosahatchee River Estuary with distance from Structure S-79. The vertical lines denote the three regions of the estuary Data points to the left of the 0 km line show water quality approximately 0.6 km upstream of the S-79 structure.

Tables

Table 1. Summary of annual freshwater inflows, nutrient loads and flow weighted mean concentrations from S-79 to the Caloosahatchee River Estuary.

Water Year[a]	Inflow Volume	Nutrient Loads (metric tons)		Flow Weighted Mean	
	(m^3 X 10^6)	Phosphorus	Nitrogen	Total Phosphorus (µg/L)	Total Nitrogen (mg/L)
1991[b]	120.9	17.5	208.8	145	1.73
1992	1126	197	1828	175	1.62
1993	1783	445	3064	250	1.72
1994	957.9	139	1968	145	2.05
1995	2815	264	4521	93.6	1.61
1996	3497	274	4097	78.3	1.17
1997	954.3	115	1384	120	1.45
1998	3077	262	4076	85.3	1.32
1999	1105	154	1665	139	1.51
2000	2020	335	3129	166	1.55
2001	593.2	97.1	850.1	164	1.43
2002	1153	245	1852	212	1.61
2003	2232	353	3798	158	1.70
2004	3039	316	4169	104	1.37
2005	2503	279	3303	111	1.32
2006	4331	540	6251	125	1.44
2007[b]	856.2	156	1277	182	1.49

[a] Water year is defined as a 12-month period starting in May and ending in April

[b] Contains data for a partial water year

Table 2. Summary of water quality for four regions of the Caloosahatchee River Estuary for the period from October 1994 through December 2006. One region is located upstream of S-79 and the other three regions are located in the estuary downstream of S-79.

Parameter	Mean	±	Standard Deviation	Minimum	Percentiles					Maximum
					5th	25th	50th	75th	95th	
Station ~0.6 km upstram of S-79 (C-43)										
Salinity (PSU)	0.3	±	0.1	<0.2	<0.2	<0.2	0.2	0.3	0.5	2.3
Apparent Color (PCU)	103.8	±	53.8	40.0	49.8	64.0	80.4	134.3	213.8	260.0
Dissolved Oxygen (mg/L)	5.6	±	1.9	0.2	2.8	4.1	5.6	7.4	8.4	10.4
Total Phosphorus (µg/L)	115.9	±	57.8	15.0	27.8	77.8	110.0	140.0	230.0	360.0
Total Nitrogen (mg/L)	1.35	±	0.32	<0.05	0.91	1.17	1.36	1.51	1.86	2.43
Chlorophyll *a* (mg/m^3)	8.3	±	13.5	0.3	1.1	2.5	4.2	8.2	32.0	80.7
Stations 0 - 10 km from S-79 (Region1)										
Salinity (PSU)	1.3	±	3.0	<0.2	<0.2	0.2	0.3	0.5	7.2	22.2
Apparent Color (PCU)	103.1	±	57.2	20.4	41.8	60.7	80.2	138.0	221.5	282.0
Dissolved Oxygen (mg/L)	5.6	±	2.1	0.1	2.6	3.9	5.5	7.2	8.7	13.3
Total Phosphorus (µg/L)	125.3	±	83.7	15.0	37.0	72.0	110.0	160.0	280.8	680.0
Total Nitrogen (mg/L)	1.26	±	0.37	<0.05	0.64	1.08	1.26	1.49	1.86	2.36
Chlorophyll *a* (mg/m^3)	8.7	±	10.2	0.3	1.1	2.7	5.0	9.9	33.1	50.0
Stations 10 -30 km from S-79 (Region 2)										
Salinity (PSU)	4.7	±	6.4	<0.2	0.2	0.2	0.8	7.7	18.3	30.9
Apparent Color (PCU)	88.3	±	58.9	6.1	27.0	44.3	67.6	118.0	208.1	379.0
Dissolved Oxygen (mg/L)	6.6	±	1.9	0.4	3.6	5.1	6.8	7.9	9.4	13.4
Total Phosphorus (µg/L)	111.6	±	74.2	15.0	25.0	63.8	100.0	140.0	240.0	730.0
Total Nitrogen (mg/L)	1.04	±	0.47	<0.05	0.30	0.71	1.03	1.33	1.84	2.69
Chlorophyll *a* (mg/m^3)	11.8	±	17.5	0.3	1.5	3.2	5.8	12.4	40.9	119.0
Stations >30 km from S-79 (Region 3)										
Salinity (PSU)	17.9	±	10.6	<0.2	0.6	8.1	19.6	27.0	32.7	38.1
Apparent Color (PCU)	45.3	±	44.1	3.5	8.0	19.0	30.0	53.0	136.2	274.0
Dissolved Oxygen (mg/L)	6.6	±	1.4	2.7	4.1	5.7	6.7	7.6	8.8	12.7
Total Phosphorus (µg/L)	100.4	±	131.2	16.0	25.0	36.0	70.0	120.8	266.5	1130
Total Nitrogen (mg/L)	0.55	±	0.50	<0.05	<0.05	0.16	0.38	0.84	1.40	2.51
Chlorophyll *a* (mg/m^3)	6.1	±	6.7	0.2	0.9	2.6	4.0	7.2	17.3	51.1

Appendix A

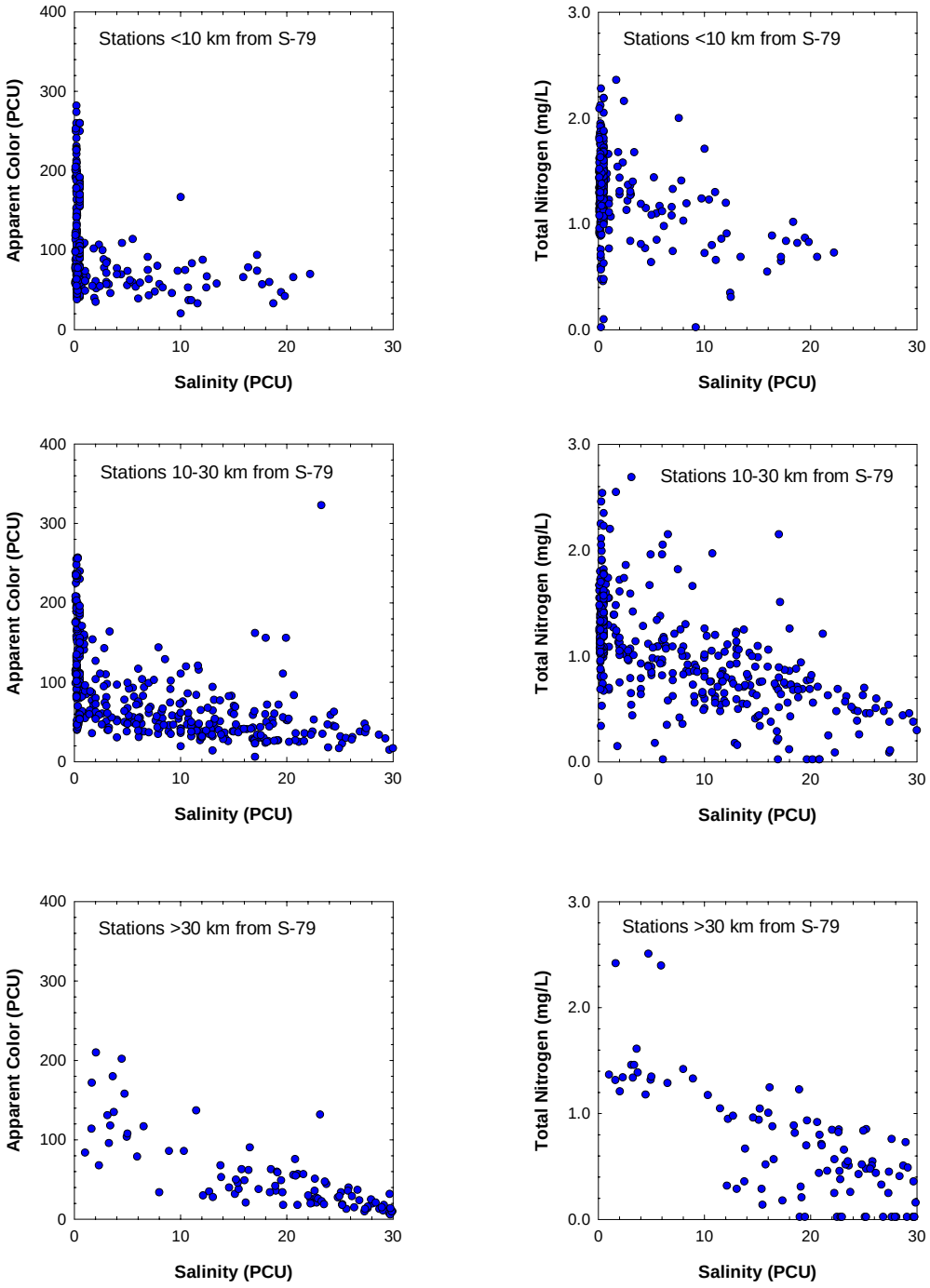


Figure A.1. Plots of color and total nitrogen versus salinity in three regions of the Caloosahatchee River Estuary. Period of record for these plots is October 1994 through December 2006.

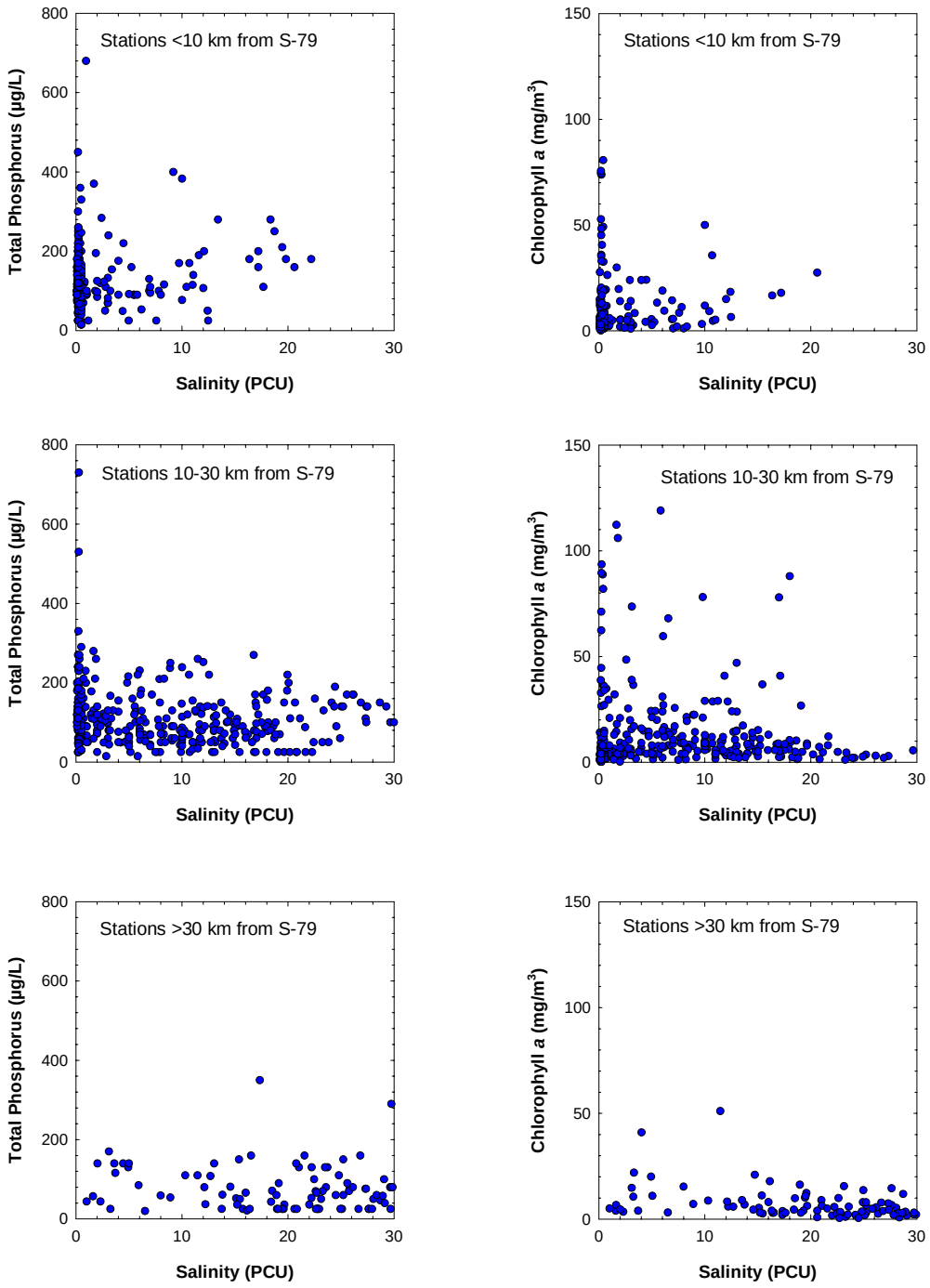


Figure A.2. Plots of total phosphorus and chlorophyll *a* versus salinity in three regions of the Caloosahatchee River Estuary. Period of record for these plots is January 1990(This 1990 date has got to be erroneous) through December 2006.