Attachment 4 – FDEP Site Specific Information
Wacassassa Bay 2010

Site-Specific Information in Support of Establishing Numeric Nutrient Criteria in Suwannee Estuary/Suwannee Sound/Cedar Keys, Waccasassa Bay, and Withlacoochee Bay

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Executive Summary

This report was prepared by the Florida Department of Environmental Protection (FDEP), in cooperation with local scientists, to support the development of numeric nutrient criteria for the Suwannee, Waccasassa, and Withlacoochee Estuaries. The primary purpose of the proposed numeric nutrient criteria is to protect healthy, well-balanced natural populations of flora and fauna from the effects of excess nutrient enrichment.

The Suwannee, Waccasassa, and Withlacoochee Estuaries are open, shallow estuaries in Florida's Big Bend. These estuaries are fed by rivers with a high percentage of wetlands in their watersheds, so color and organic matter concentrations are high, which suppresses algal productivity in the rivers but naturally fuels it in the estuary. This portion of Florida's coast contains many conservation lands, therefore wide expanses of swamps and coastal marshes remain intact to support the ecosystem and provide a filter between uplands and the coastal areas.

The Suwannee Estuary is a dynamic system because it is dominated by river flow, and the biological communities in the estuary are highly influenced by these freshwater inputs. During high river flow, swamp water (originating from the Okeefenokee Swamp) dominates, and color and organic nutrient concentrations are relatively high, but inorganic nutrient concentrations are very low. Color and non-chlorophyll particulates are the major contributors to light limitation, except at times of very low river flow. During low flow periods, the river is dominated by Floridan Aquifer spring flow, and water clarity and anthropogenic nitrate concentrations are high.

Submersed aquatic vegetation (SAV) beds are abundant along this part of the coast, but not quite as dense when compared with adjacent regions such as Apalachee Bay. Reductions in SAV have been observed north of the Suwannee River mouth and have been linked to high river flows during years of abnormally high rainfall (1998, 2004–05). The reduction in light is strongly influenced by water color, turbidity, and chlorophyll *a*, and it is unclear which of these factors may be linked to SAV loss and if that loss is to be expected after extreme high-flow periods. The Suwannee River is impaired for excess nitrate concentrations, but data indicate that the nitrate is diminished to background levels at the estuary interface. Some increased benthic algal growth was observed during very low river flow periods, possibly related to the excess nitrate. Phytoplankton, zooplankton, and fish communities are healthy, as determined by qualitative interpretation of research studies. Concentrations of total nitrogen and total phosphorus are strongly linked to salinity in this system.

Waccasassa Bay has the highest nutrient and chlorophyll *a* concentrations of the region, despite the extremely minimal anthropogenic activity in the basin. The nutrient inputs are associated with the high percentage of wetlands in the watershed and the shallow nature of the estuary, which results in frequent resuspension of estuarine sediments. With the high color inputs from the extensive swamp systems, Waccasassa Bay naturally has lower water clarity than coastal areas to the north and to the south; therefore the SAV communities are not as well developed or as well studied. However, evidence gathered shows that conditions have not changed in this estuary since the 1960s, when there was nearly no development and no point source discharges into the basin, so it follows that the existing condition protects the aquatic life use in the estuary.

The Withlacoochee Estuary has been hydrologically modified by the Inglis Dam, the Cross Florida Barge Canal, and the Crystal River Power Plant. The Withlacoochee River, which originates in the Green Swamp, experiences low levels of disturbance and has been used by FDEP and EPA as a minimally disturbed reference system for freshwater nutrient criteria development. It is possible that the Inglis dam actually prevents some of the natural nutrient loading from reaching the estuary by holding back much of the natural flow. The discharge from the Crystal River Power Plant does not contribute an additional nutrient load to the estuary, but has dikes that alter the exchange of water in the estuary. No nutrient data are available from before dam construction, which occurred in 1969. TN and chlorophyll *a* concentrations have not changed in this estuary since the 1980s, and there is no evidence of other impairment in the estuary. There is a strong relationship between nutrient concentrations and salinity due to the dominance of the Withlacoochee River in the estuary.

The evidence gathered by FDEP and presented in this document shows that aquatic life use in the Waccasassa and Withlacoochee estuaries is fully supported, and will be fully supported in the Suwannee estuary pursuant to the Suwannee River TMDL implementation. FDEP therefore proposes that the numeric nutrient criteria be crafted to maintain the existing nutrient regime, except for reduction in total nitrate loading into the Suwannee Estuary, commensurate with the established TMDL for nitrate in the Suwannee River.

Contributors to this report include:

Thomas K. Frazer, University of Florida, Paul Carlson, FWCC, Melissa Charbonneau, Big Bend Seagrasses and St. Martin Marsh Aquatic Preserves, Erin Quinlan, (UF) Georgia Gwinnett College, Jason Hale, Pandion Technology, Ltd., Robbie McKinney, SRWMD, and Nia Wellendorf, FDEP.

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Table 1a. Checklist of nutrient enrichment symptoms in the Suwannee, Waccasassa, and Withlacoochee Estuaries

Response Variable	Observed Historically or Currently?	Explanation	Source
Low DO (hypoxia/anoxia)	No	No impairments for dissolved oxygen in this region. One researcher noted low oxygen in the early morning hours when there was abundant macroalgal growth on oyster beds in the Suwannee Estuary during a period of low water.	Quinlan 2010
Reduced clarity	No	There is reduced water clarity in this region when high rainfall causes colored water discharge from the rivers (especially the Suwannee) to be high. This colored water can extend from Horseshoe Cove and down the Springs Coast, and is a natural phenomenon.	Carlson *et al.* 2010; Jolliff *et al.* 2004
Increased chlorophyll *a* concentrations	Yes	The Suwannee Estuary is on the 303(d) list for increase in chlorophyll *a* compared to historic concentrations. This effect was localized to the mouth of the river, and is addressed through the Suwannee River TMDL. Chlorophyll *a* values vary through time, but the FDEP analysis in this report did not indicate an upward trend.	Hallas and Magley 2008
Phytoplankton blooms (nuisance or toxic)	No	-	-
Problematic epiphyte growth	No	-	-
Problematic macroalgal growth	No	One researcher documented increased seasonal macroalgal growth on the oyster beds in Suwannee Sound during low river flow period, but it was temporary and there is no indication that it was problematic.	Quinlan 2010
SAV community changes or loss	Yes	Some SAV loss north of the Suwannee River, and some SAV community change in the deep edge of SAV beds south of this region, both after record rainfall years. Reduced water clarity is the likely cause in both cases, and evidence suggests that color (of natural origin) is the agent.	Carlson *et al.* 2010; Hale *et al.* 2004; Quinlan 2003
Emergent or shoreline vegetation community changes or loss	No	-	-
Coral/hardbottom community changes or loss	N/A	No confirmed record of hardbottom communities in this region.	-
Impacts to benthic community	Yes	Very little information on benthic community, but one researcher documented a “plume” of benthic algae that followed the Suwannee River plume, during very low-flow conditions.	Quinlan 2010
Fish kills	No		-

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Table 1b. Checklist of additional factors for the Suwannee, Waccasassa, and Withlacoochee Estuaries

- = Empty cell/no data

Nutrient Factors	Observed?	Explanation	Source
Increased nutrient loading or concentrations	Yes	Increased nitrate loading has been documented for the Suwannee River, and a TMDL has been established for nitrate in the river to address the negative biological responses. Phosphorus loading has significantly decreased. Some increased concentrations during the wet season were detected over time by Jacoby et al. (2008) for some Withlacoochee sites.	Hallas and Magley 2008; Jacoby *et al.* 2008
Difference between nearshore and offshore levels	Yes	These river-dominated estuaries show strong negative relationships between salinity and TN and salinity and TP.	Figures 46 and 47
Mitigating factors that could prevent nutrient expression	Yes	High color suppresses phytoplankton growth in the Suwannee and Waccasassa systems	Quinlan 2003; Putnam 1967
Other significant stressors to biological communities	No	-	-
Natural high nutrient episodes (e.g., seasonal or event driven)	Yes	Nutrient concentrations increase with increases in rainfall and river flow.	-

Geographic and Physical Description

The Suwannee, Waccasassa, and Withlacoochee (south) rivers are all large, tannin-stained rivers that drain watersheds containing a high percentage of wetlands. They are considered together in this document because of the similar water chemistry of their estuaries. Figure 1 shows the extent of their watersheds (the Florida portion of the Suwannee). Table 1 contains land use information for the watersheds, and Table 2 contains physical descriptions of the estuaries.

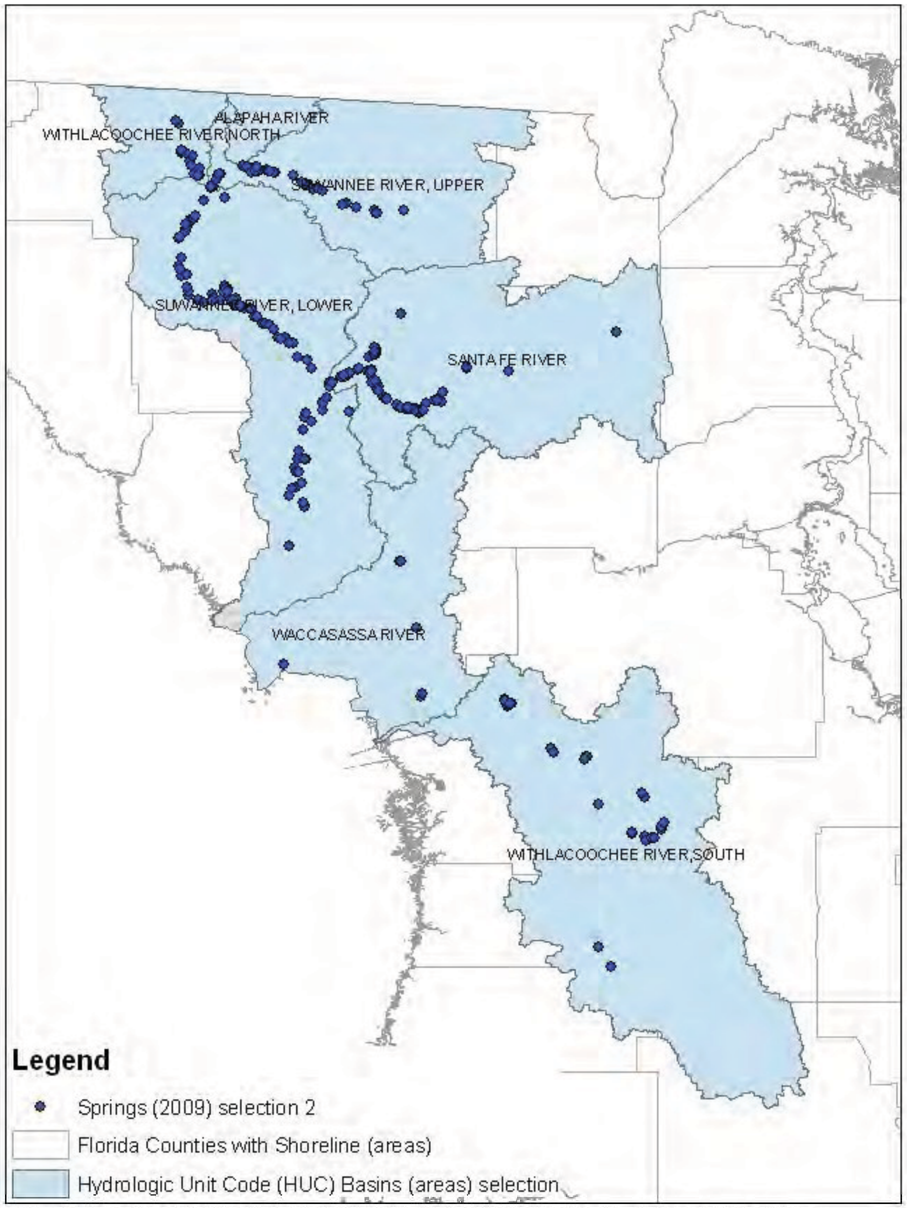

Figure 1. Study area of the Suwannee, Waccasassa, and Withlacoochee (South) watersheds. This region has numerous karst features, and here the springs are noted as blue points.

Suwannee Watershed

The Suwannee River arises in the Okefenokee Swamp, emerging at Fargo, Georgia. It flows southwest into Florida, dropping in elevation through limestone and marine clay layers (Hawthorne Formation), resulting in Class II whitewater rapids, which are rare in Florida. The river then turns west near White Springs, Florida, receiving the waters of the Alapaha and Withlacoochee (north) Rivers, which together drain portions of south-central Georgia. The watershed contains a rich assortment of rivers and streams, springs, cypress ponds, swamps, and estuaries. The Florida portion of the watershed is divided into units of the Upper and Lower Suwannee, and tributaries (Figure 1) (www.protectingourwater.org and Charbonneau 2010). The Gulf of Mexico lies along the southwestern edge of the watershed.

Because of the region's flat topography, the entire low-energy shoreline is one large estuarine complex composed of river and tidal systems. Extensive seagrass beds stretch from these estuaries for miles into the open Gulf.

Although lakes are scattered throughout the watershed, the region contains fewer lakes than other areas of the state, but wetlands are plentiful. There are 98 known springs that discharge within the Suwannee River coastal drainage area; 4 are 1st magnitude and 39 are 2nd magnitude. The River flow is highly influenced by springs during periods of low rainfall. During normal to high flows, the Suwannee is typically a highly colored river. River flow and discharge is heavily influenced by wetlands during high rainfall periods, resulting in an extensive plume of colored water into the Gulf during much of the year (Figure 5).

Growth and development along the watershed's rivers has been limited, largely because of floodplain management ordinances, land use plans, and land acquisition programs at state, regional, and local levels. To the west of the Suwannee River, the dominant land uses are silviculture and agriculture (Table 1). Large timber companies, following applicable forestry Best Management Practices, hold most of the coastal lowlands in large tracts of planted pine. Vast tracts of timber are also found in the wet flatwoods to the east of the Alapaha River and uppermost Suwannee River. East of the Suwannee River, silviculture and agriculture continue to dominate, but the amount of urbanized land is markedly greater than west of the river. The watershed has farms that combine row crops with livestock, large corporate dairies, and irrigated row crop and forage operations. Other land uses include poultry production, phosphate mining, and aquaculture. Phosphate mining in southeastern Hamilton County has altered a large part of the original landscape.

Table 1. Land use distribution in the Suwannee, Waccasassa, and Withlacoochee Coastal Drainage Areas, based on 2004 land uses. Parks and zoos were included in the upland forest classification rather than in urban, and pastures were included in shrub, range, and pasture rather than agriculture.

Sources: Information for the Suwannee and Waccasassa from land use coverages in FDEP GIS system; information for Withlacoochee from SWFWMD.

Land Use	Suwannee (lower basin only, HUC 25)	Waccasassa (HUC 32)	Withlacoochee (HUC 34)
Urban	7%	6%	20%
Agriculture	12%	6%	5%
Shrub, range, and pasture	16%	10%	25%
Upland forests	48%	45%	23%
Water	1%	2%	2%
Wetlands	15%	30%	23%
Other	1%	1%	2%

Table 2. Physical properties of the estuaries of the Suwannee, Waccasassa, and Withlacoochee Rivers.

CDA = Coastal drainage area, defined by NOAA.

Property	Suwannee	Waccasassa	Withlacoochee	Source
Estuarine surface area (km^2)	Suwannee Sound – 70 km^2 Horseshoe Cove – 140 km^2	40 km^2 (EPA), 49,749 acres or 201 km^2 (DACS)	52,000 acres (DACS report)	Carlson *et al.* 2010
Watershed area (km^2)	26,000 km^2 Coastal drainage area (Lower Suwannee HUC)- 4568 km^2 and includes Levy, Dixie, Taylor, Gilchrist, Columbia, Suwannee, Madison Counties	CDA =2,128 km^2 and includes Gilchrist, Alachua, Levy, and Marion Counties	CDA = watershed = 5133 km^2 and includes Citrus, Sumter, Marion, Hernando, Polk, and Lake Counties.	NOAA 2007 Charbonneau
HUC Area (km^2)	Lower Suwannee HUC = 4,088	2,334	5,332	FDEP ArcGIS HUC coverage
Mean depth (m)	2.24 m	1.69 m	2.24 m	Project COAST sampling, UF
Tidal range (m)	1.8 m – tides are mixed semidiurnal and typically two unequal high and low tides each day.	Average 3.5 ft. Tides are mixed and semi-diurnal, typically with two unequal high and two unequal low tides occurring each day.	average 3.5 ft./ 1.0668 m - semidiurnal, two tide cycles	Charbonneau presentation
Tidal freshwater inflow (cfs)	Average Daily Freshwater Inflow USGS station – 02323592 = 7599 cfs	Average Daily Freshwater Inflow USGS station 02313700 = 250.52 cfs	By Pass Channel Average - 423 cfs Withlacoochee Inglis Dam Average – 1020.86 cfs	USGS
Mean water residence time (days)	0.5 (50% of volume is exchanged twice daily)	0.5 (50% of volume is exchanged twice daily)	0.5 (50% of volume is exchanged twice daily)	DACS

The landscape development intensity index (LDI) is an index that was developed to estimate the intensity of human land use based on nonrenewable energy flow (Brown and Vivas 2004). For the LDI, each land use was assigned a coefficient of energy use associated with that land use (Table 3). The agricultural land uses in the Suwannee Basin appear as widespread yellow areas, with urban centers in orange and red (Figure 2).

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Table 3. Energy coefficients associated with land uses, as described for the LDI (Brown and Vivas 2004). Higher values indicate greater intensity of human land use.

Land use	LDI value
Natural Open water	1.00
Pine Plantation	1.58
Woodland Pasture	2.02
Pasture	2.77
Recreational / Open Space (Low-intensity)	2.77
Low Intensity Pasture (with livestock)	3.41
Citrus	3.68
High Intensity Pasture (with livestock)	3.74
Row crops	4.54
Single Family Residential (Low-density)	6.79
Recreational / Open Space (High-intensity)	6.92
High Intensity Agriculture	7.00
Single Family Residential (Med-density)	7.47
Single Family Residential (High-density)	7.55
Low Intensity Highway	7.81
Low Intensity Commercial	8.00
Institutional	8.07
High Intensity Highway	8.28
Industrial	8.32
Low Intensity Multi-family residential	8.66
High intensity commercial	9.18
High Intensity Multi-family residential	9.19
Low Intensity Central Business District	9.42
High Intensity Central Business District	10.00

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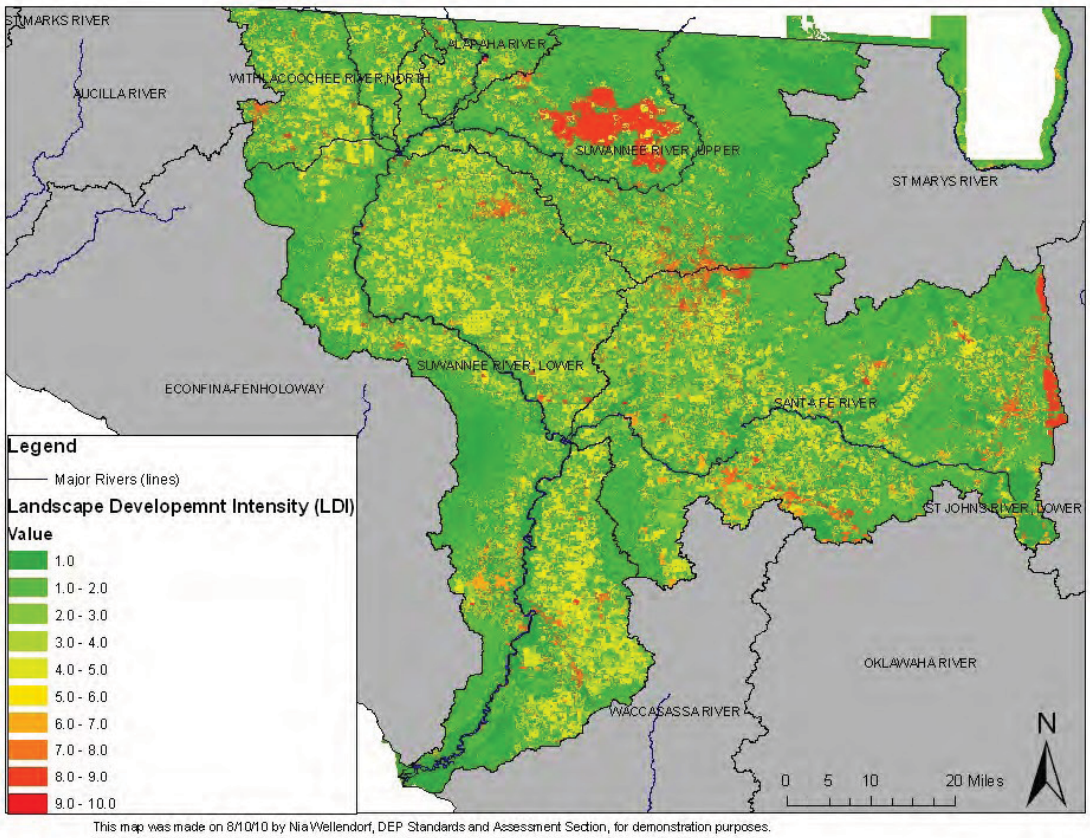

Figure 2. Landscape Development Intensity coefficients of land uses within the Florida portion of the Suwannee Watershed, based on 2005-2008 aerial photos. LDI coefficients as in Table 3.

Suwannee Estuary

During the spring/summer season, prevailing southeasterly winds bring warm humid air onshore from the Gulf, resulting in frequent summer convection storms. These thunderstorms are typically of high intensity, short duration, and limited aerial extent. In winter, prevailing northwesterly winds frequently propel frontal systems through the area. Suwannee Sound, an area of low energy Gulf Coast, is about six miles wide and 15 miles long, covering approximately 80 square miles. The broad shallow submerged shelf off the coast (up to 160 km wide), coupled with prevailing storm winds from the north and east, results in low wave and wind energy effects on the shoreline. The average depth of the Sound is about 6 feet, and the maximum depths are associated with the river channels (to about 24 feet). There are no barrier islands or peninsulas stretching from the mainland to form an embayment. Shoals and oyster bars, many of which are exposed at low tide, act as permeable barriers and create a bay-like system. The estuary is formed by freshwater from the Suwannee River and numerous creeks mixing with Gulf water over a shallow limerock shelf (description from Kuhman 2007).

While the Suwannee River contributes the majority of freshwater inflow to Suwannee Sound, several other watersheds drain into coastal creeks along the shore. These include the California Swamp, Barnett Creek and the Black Point Swamp watersheds. Hydrography, with respect to tidal range, is complex. Daily tidal amplitude in the estuary may vary during a 30-day period from one to four feet, with a maximum range of over four feet and a mean range of 3.0 feet. The mean tidal prism results in an exchange of 50% of the areas volume twice daily (Kuhman 2007).

The Cedar Keys are located south of the Suwannee River in Levy County. They provide important fishing grounds and shellfish production grounds for this region, and the town of Cedar Key has become a popular tourist destination. Coastal waters surrounding Cedar Keys are heavily influenced by the freshwater content and volume of flow from the Suwannee River.

A major feature of the watershed is its many protected natural areas, which include three national wildlife refuges, ten state parks or preserves, other public lands, and the Big Bend Seagrasses Aquatic Preserve. The preserve, the largest in Florida, includes about 450,000 acres of seagrass beds and salt marsh that extend southward and eastward from the St. Marks River to the south Withlacoochee River. The Big Bend Seagrasses Aquatic Preserve is the second largest contiguous area of seagrass habitat in the eastern Gulf of Mexico, making it an important resource not only to Florida but also nationally and internationally. The Big Bend area is also designated as an Outstanding Florida Water (OFW) and a U.S. Environmental Protection Agency Gulf Ecological Management Site (GEMS). Other preserved areas in this region include the 53,000 acre Lower Suwannee National Wildlife Refuge, the 10,000 acre Jena Unit Big Bend Wildlife Management Area, and the Cedar Keys National Wildlife Refuge (Figure 3).

Aquaculture is increasing along the coast, particularly in Levy County (the Cedar Key area), following a reduction in other fisheries resulting from the constitutional ban of gill nets. Submerged leases offshore from Cedar Key are used to raise littleneck clams for local, national, and international markets.

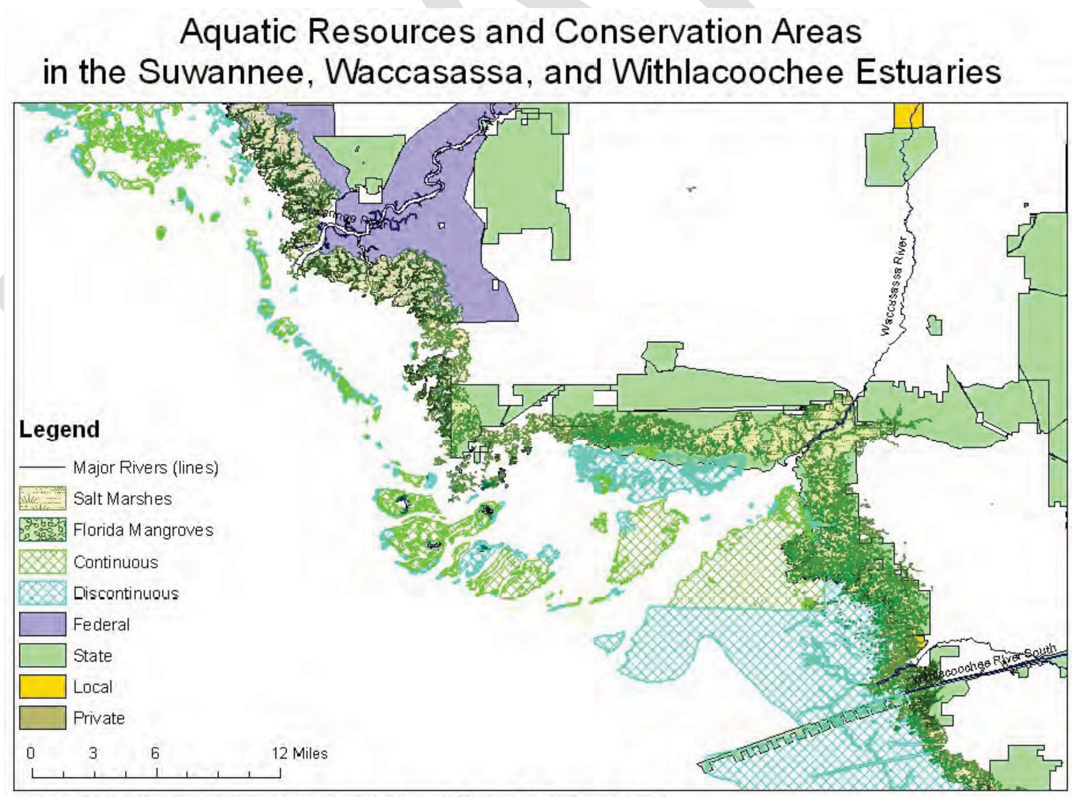

Figure 3. Coast of Dixie and Levy Counties, estuaries of the Suwannee, Waccasassa, and Withlacoochee Rivers. Shown are conservation areas (federal, state, local, and private), seagrass coverage (continuous, discontinuous), and coverage of saltwater marshes along the shores.

The plume of fresh water from the Suwannee River can be far-reaching, especially during major storm events. During the heavy rainfall El Niño event from October 1997 to June 1998, the freshwater discharge from the Suwannee River was nearly three times the long term average (Carlson *et al.* 2010). Modeling of the Suwannee River plume or colored dissolved organic matter (CDOM) for portions of 1998 showed that the CDOM of the river stretched from the Big Bend to the Charlotte Harbor area (Figure 4; Jolliff *et al.* 2003). Jolliff *et al.* (2003) estimated the maximum amount of nitrogen potentially made available to phytoplankton by the photochemical degradation of CDOM, and concluded that the nitrogen made available would, at most, support 5% of the nitrogen demand on primary production. This plume of CDOM from the Suwannee River plume does not normally reach this far south. The occurrence in 1998 was the result of several hydrologic conditions in the Gulf (Jolliff *et al.* 2003). However, the Suwannee River commonly influences areas to its north and south (Figure 5).

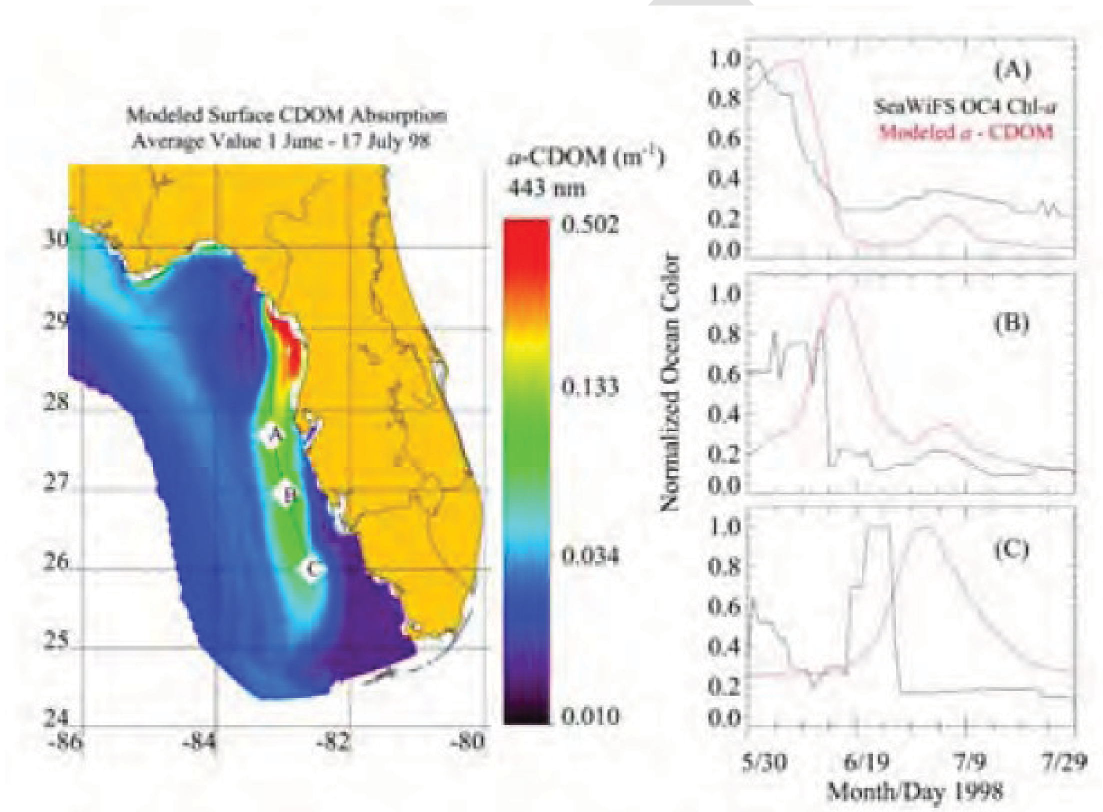

Figure 4. The average surface CDOM absorption over the West Florida Shelf for the period 1 June 98-17 July 98 shows the southward dispersal of the Suwannee River plume. At right, a time series (5 May 98 – 29 July 98) for locations along a transect through the river plume shows the variability in the modeled surface CDOM normalized by the highest value modeled for that location during the time period (red). Similarly, 7-day composite SeaWiFS chlorophyll-a values for the corresponding pixel locations are presented (black) as values normalized by the highest value observed during that time period. Values were interpolated when cloud cover obscured retrieval (from Jolliff et al. 2003).

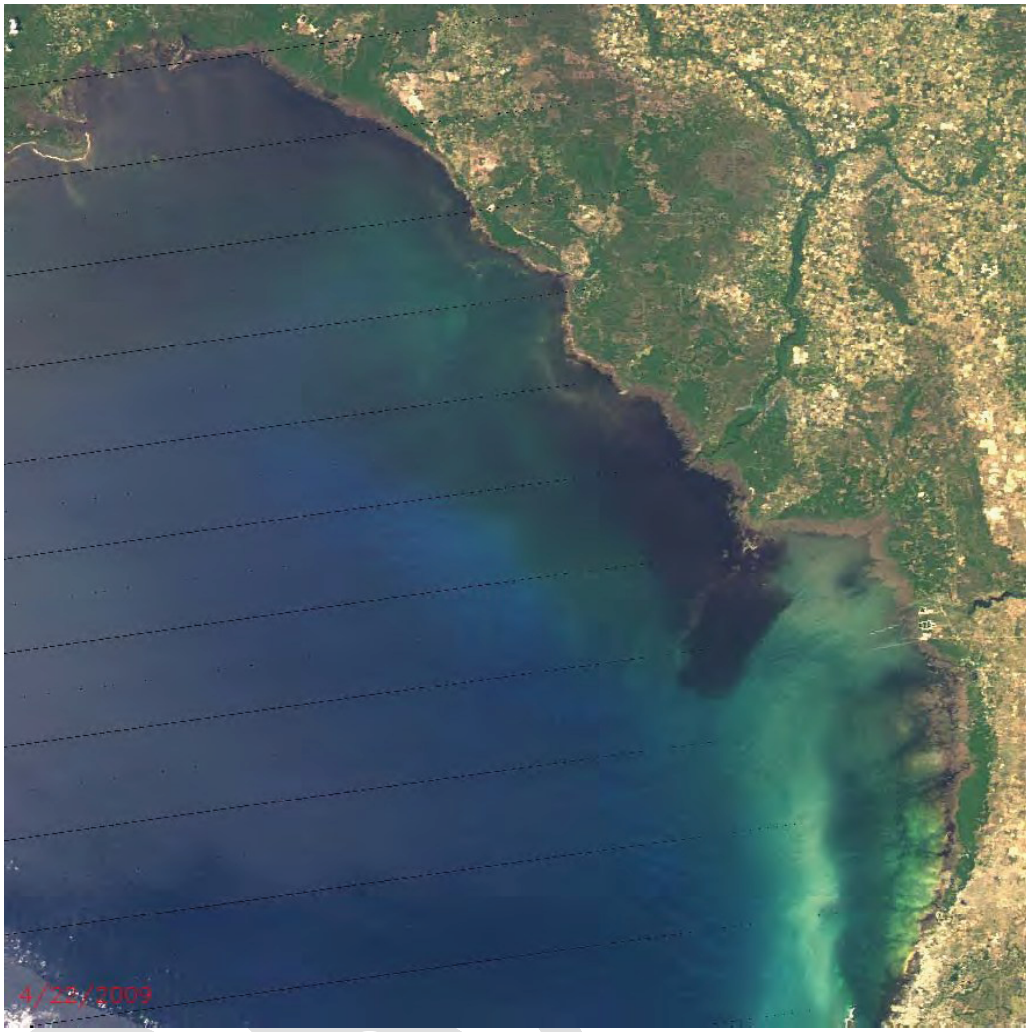

Figure 5. MODIS satellite imagery from 4/22/2009 of the Big Bend and Springs Coast, showing abundance of colored dissolved organic matter (CDOM) from the Suwannee River surrounding Cedar Keys to the south and extending north to Horseshoe Beach.

Waccasassa Bay

The Waccasassa Bay Estuary is a small, shallow estuary at the mouth of the Waccasassa River. The Waccasassa River drains forest and wetlands of Waccasassa Flats and is characterized as a blackwater river that begins as a small stream in Devils Hammock. The river's headwaters arise at Blue Spring (Levy County) and then run through Gulf Hammock for 29 miles to Waccasassa Bay (Charbonneau 2010). The Waccasassa River is the largest tributary to the Waccasassa Bay. Otter Creek, Cow Creek, Ten Mile Creek, and the Wekiva River are three of the larger tributaries to the Waccasassa River. There are a total of seven known springs within the coastal drainage area (CDA). There is no major commercial or residential development along the river (Charbonneau 2010). Several small towns are located along the tributaries in the northern extreme of the basin and include: Gulf Hammock, Otter Creek, and Lebanon Station. Wetlands and silviculture are the dominant land use, followed by agriculture (Table 1). The land uses that surround the river and line the coastal areas are very benign in terms of energy intensity (Figure 6). The estuary is very shallow and broad, and is separated from land by vast salt marshes.

Wind-driven resuspension of organic materials in the estuary contributes to its productivity (Putnam 1967).

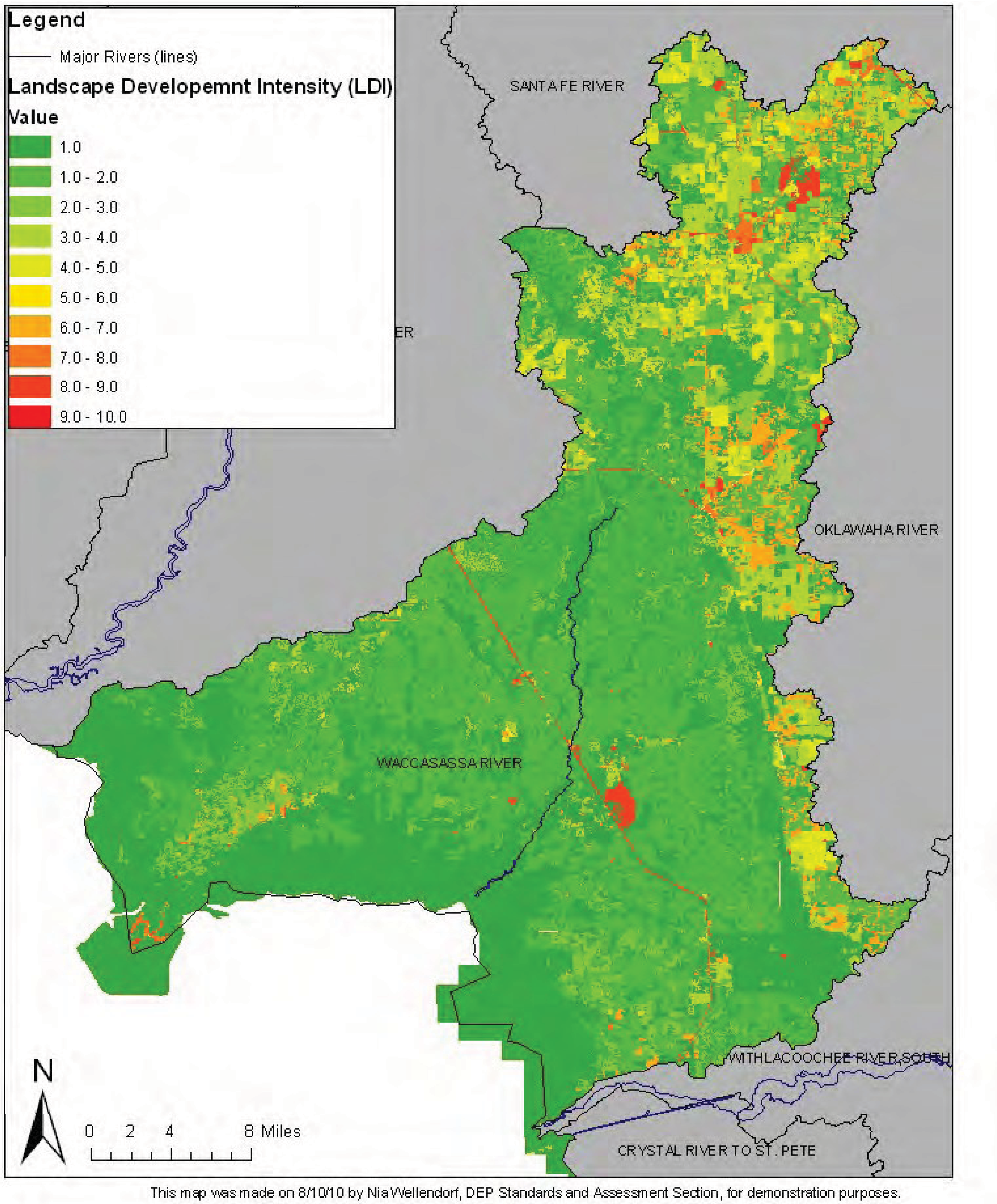

Figure 6. Landscape Development Intensity coefficients of land uses within the Waccasassa watershed, based on 2005-2008 aerial photos. LDI coefficients as in Table 3.

Withlacoochee Watershed

The 157-mile-long Withlacoochee River originates in the 2,250 km^2 Green Swamp in northern Polk County, draining 80% of this protected swamp (Wolfe 1990). From there, it meanders northwest and then west, discharging into the Withlacoochee Bay Estuary in the Gulf of Mexico near Yankeetown. The river's waters are tea colored from tannins and other humic acid substances produced by decaying organic material (predominantly leaf litter in Florida swamps).

The 5.7-mile-long Rainbow River in western Marion County is a spring-fed tributary to the Withlacoochee River. The Rainbow River's waters are exceptionally clear, originating from the Floridan Aquifer-fed Rainbow Springs. This system of 18 springs is the largest in the watershed, containing Florida's fourth largest spring, and the tenth largest freshwater spring in the world. It contributes up to 462 million gallons of fresh water daily to the Withlacoochee River. The river feeds Lake Rousseau, a 3,657-acre reservoir that was created in 1909 when the Florida Power Corporation completed the construction of the Inglis Dam (now the Inglis Lock) across the Withlacoochee River,

The channel of the lower Withlacoochee River from Inglis to the river mouth was dramatically altered by the construction of the now-deactivated Cross-Florida Barge Canal in the 1960s. The canal bisected the lower river two miles below the dam. Numerous control structures regulate flows in both the river and its surrounding tributaries and wetlands, affecting flows to the Withlacoochee Bay Estuary. The estuary is part of a large complex of estuaries and bays that extend from Tarpon Springs in the south to the Big Bend/Apalachee Bay region in the north. These areas contain diverse fish and wildlife habitat and are extremely important for commercial and recreational fisheries and other wildlife.

The watershed's natural communities form an extensive and diverse ecosystem, ranging from river floodplain forests, cypress domes, pine flatwoods, and sandhills in the Green Swamp, to extensive lake systems and marshes in the middle of the watershed, to salt marshes and the estuary at the river mouth. This ecosystem supports nearly 500 vertebrate species, including freshwater and saltwater fish, amphibians, reptiles, birds, and mammals. In addition to a wide range of common vertebrate species, a number of state and federally protected species inhabit the Withlacoochee watershed.

Public land ownership is significant in the watershed. The Withlacoochee State Forest is currently the second largest state forest in Florida. It covers more than 140,000 acres in eastern Citrus and Hernando Counties. The Withlacoochee River and Little Withlacoochee River flow through it.

The land use within the Withlacoochee watershed is nearly evenly divided between natural land uses (forests, wetlands) and human impact land uses (urban and agriculture) (Table 1; Figure 7). The natural land use within the watershed, especially the wide buffer around the river, and the reservoir at Lake Rousseau mitigate effects of the human land uses on the water quality in the Estuary. The majority of the agricultural land use is low intensity rangeland, which contributes relatively little in terms of nutrient load to the river. Urban centers are concentrated on the fringes of the watershed, while the headwaters are largely natural and protected (the Green Swamp).

Withlacoochee Estuary

The Withlacoochee Bay system is a large, shallow, wind-driven estuary at the mouth of the Withlacoochee River, opening to the Gulf of Mexico to the southwest. The bay system covers approximately 52,000 acres between South Mangrove Point and the Cross-Florida Barge Canal. The bay averages less than 3 feet at mean low tide, and the maximum depth is 20 feet at mean low tide within the Cross-Florida Barge Canal (DeHaven 2004a).

The hydrology of Withlacoochee Bay has been altered by the dam at the Lake Rousseau reservoir and the canal that was built as part of the halted Cross Florida Barge Canal. These alterations limit the maximum flow rate of the lower river channel to a level that was the average flow rate before the alterations (Wolfe 1990). The flow from north to south in the coastal area is also somewhat restricted by the canals and berms created for inflow and outflow of cooling water for the Crystal River Nuclear Power Plant (Charles Kovach, personal communication).

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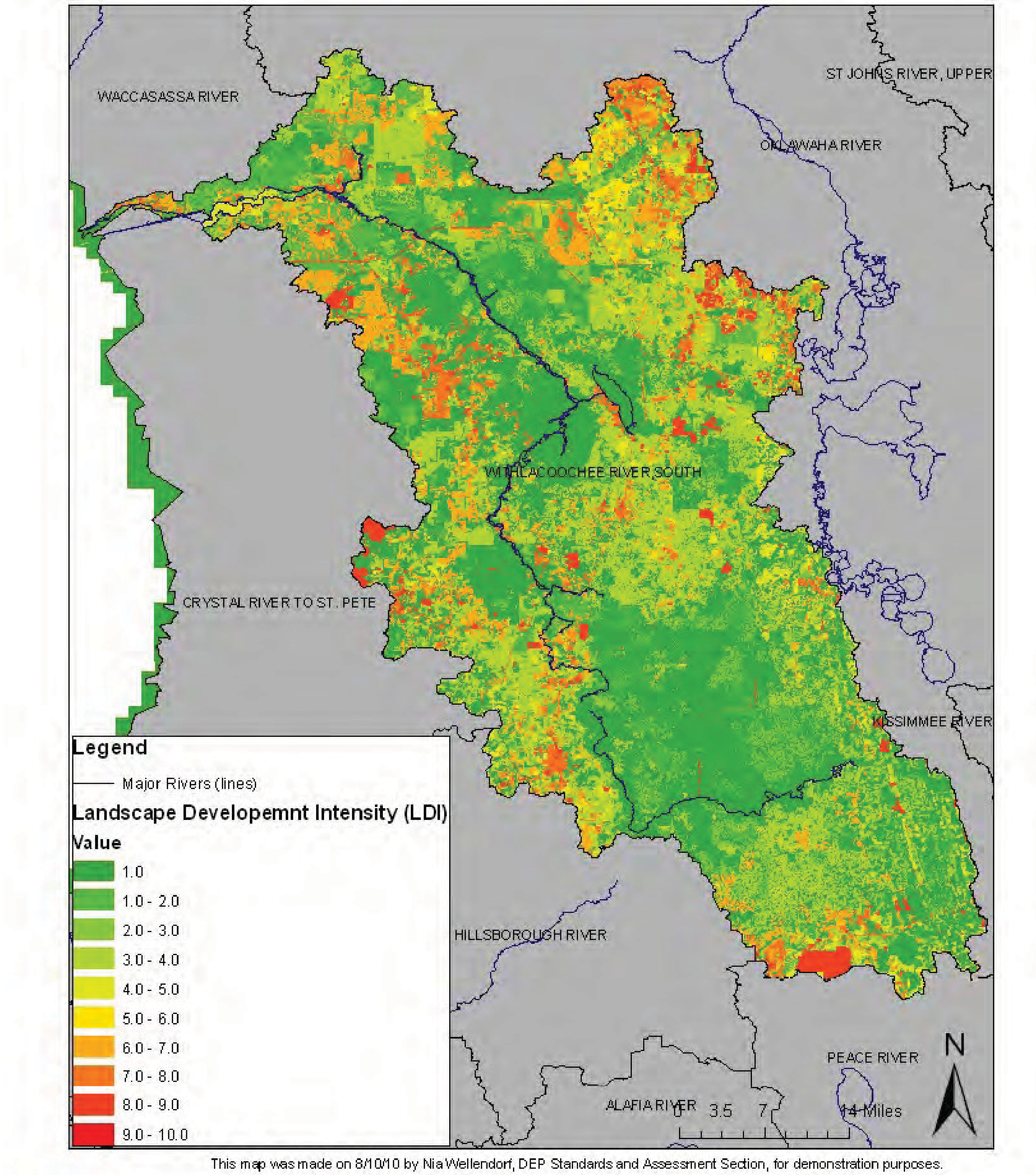

Figure 7. Landscape Development Intensity coefficients of land uses within the Withlacoochee watershed, based on 2005-2008 aerial photos. LDI coefficients as in Table 3.

Sources of Nutrients

Suwannee

FDEP's TMDL report by on the Middle and Lower Suwannee River (Hallas and Magley 2008) describes various nutrient sources on the river, as follows:

- *Beef, poultry, and dairy production and processing;*
- *Pastures and row crops;*
- *Estimated 9,000 – 10,000 septic tanks in the Middle and Lower Suwannee basins;*
- *Atmospheric deposition; and*
- *Permitted facilities.*

Estimated nonpoint source inputs of total nitrogen for 2007 were 66,005,375 lbs for the Middle Suwannee and 24,381,502 lbs for the Lower Suwannee, with the largest contributions from fertilizer, followed by dairy, beef, and poultry, and atmospheric sources. Excess nitrate, leached primarily from agricultural activities (row and forage crops and dairy and poultry production) contaminates ground water in the watershed. In 2000, the Suwannee River Water Management District (SRWMD) staff calculated that 78% of the nitrate load carried by the Suwannee River to the Gulf of Mexico was introduced into the river from the middle Suwannee watershed and the bottom section of the Santa Fe watershed. Virtually all the nitrate load comes from ground water discharge via springs.

Other sources of nutrients to the basin include permitted facilities that discharge treated effluent to surface waters (Table 4).

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Table 4. Permitted facilities in the Suwannee Basin (from Hallas and Magley 2008).

- = Empty cell/no data
IW - Industrial Wastewater; DW – Domestic; CFO - Concentrated Animal Feeding Operation; CBP - Concrete Batch; PET - Petroleum Cleanup GP (long term); WWTP ISW - Individual Stormwater

FACILITY ID	FACILITY NAME	Facility Type	DESIGN Capacity (MGD)	COUNTY
FL0000051	EI Dupont De Nemours Trailridge Mine	IW	30.0	Bradford
FL0000183	Progress Energy FL - Suwannee River Power Plant	IW	342.0	Suwannee
FL0001465	Pilgrim's Pride Processing Plant	IW	1.5	Suwannee
FL0028126	Starke, City of WWTF	DW	1.65	Bradford
FL0038300	Mead Westvaco Corp	IW	0.0482	Columbia
FL0043567	Cochran Forest Products	IW	0.05	Columbia
FL0189120	High Springs Commercial Park WWTF	DW	0.03	Alachua
FLA011323	IFAS - Dairy Research Unit	CFO	0.151	Alachua
FLA116173	Dairy Production Systems - Branford Farm	CFO	0.175	Gilchrist
FLA116190	Piedmont Dairy	CFO	0.045	Gilchrist
FLA116521	Alliance Dairies	CFO	0.37	Levy
FLA161977	Oak Grove Dairy, Inc	CFO	0.11	Dixie
FLA184047	Lafayette Dairy	CFO	-	Lafayette
FLA184993	Hill Top Dairy	CFO	-	Gilchrist
FLA282821	North Florida Holsteins	CFO	-	Gilchrist
FLA285331	Bell Farm (FKA Aurora 1)	CFO	-	Gilchrist
FLA362778	Shenandoah Dairy	CFO	-	Suwannee
FLA371912	Full Circle Dairy, LLC	CFO	-	Madison
FLA470031	Suwannee Farms Inc	CFO	-	Suwannee
FLG110015	A Materials Group Inc - Plant #11	CBP	-	Columbia
FLG110073	Florida Rock Industries Inc - High Springs CBP	CBP	-	Alachua
FLG110190	Florida Rock Industries - Starke CBP	CBP	-	Bradford
FLG110278	Bell Concrete Products	CBP	-	Gilchrist
FLG110304	Columbia Ready Mix Concrete Inc	CBP	-	Columbia
FLG110369	A Materials Group Inc - Plant #12	CBP	-	Levy
FLG110370	Bell Concrete	CBP	-	Levy
FLG110374	Columbia Ready Mix Concrete Inc	CBP	-	Suwannee
FLG110450	Mayo Ready Mix Concrete	CBP	-	Lafayette
FLG110558	Mayo Ready Mix Concrete	CBP	-	Lafayette
FLG911679	Badcock Live Oak Warehouse	PET	-	Suwannee
FLS000062	Lake City, City of - WWTF	WWTP ISW	-	Columbia
FLS000062	Lake City, City of - WWTF	WWTP ISW	-	Columbia

According to the Springs Initiative 2010 Monitoring Report, springs in the Suwannee Basin have some of the highest nitrate concentrations in the state (Harrington *et al.* 2010). Groundwater nitrate concentrations are very high due to a significant percentage of agricultural land use over very vulnerable groundwater resource due to the karst geology. Springs in the Suwannee Basin also have elevated orthophosphate concentrations, when compared with springs statewide, although this observation could be related to the phosphorus leaching from the surrounding Hawthorne Formation (a high phosphate marine clay complex). Harrington *et al.* (2010) also reported that the Suwannee Basin springs have elevated potassium concentrations that are potentially due to human sources, likely agriculture. They reported that most of the nitrate in Troy springs was from inorganic fertilizers and poultry manure. For Fanning and Manatee Springs, the likely sources of nitrate are fertilizer use and dairy operations. The springsheds of Troy, Fanning, and Manatee Springs contain numerous groundwater wells with nitrate concentrations greater than 10 mg/L, and some with greater than 50 mg/L (Harrington *et al.* 2010). Inorganic fertilizer is also thought to be the primary contributor of nitrate in Rainbow Springs in the Withlacoochee basin (Harrington *et al.* 2010).

Reports of the Shellfish Harvesting Areas of the Suwannee Sound (Kuhman 2007) and Horseshoe Cove (Kuhman 2004) identify wildlife as a major source of fecal coliforms along the coastline, due to the abundance of conservation areas and wildlife preserves. Wildlife also likely contributes some nutrients to the coastal area.

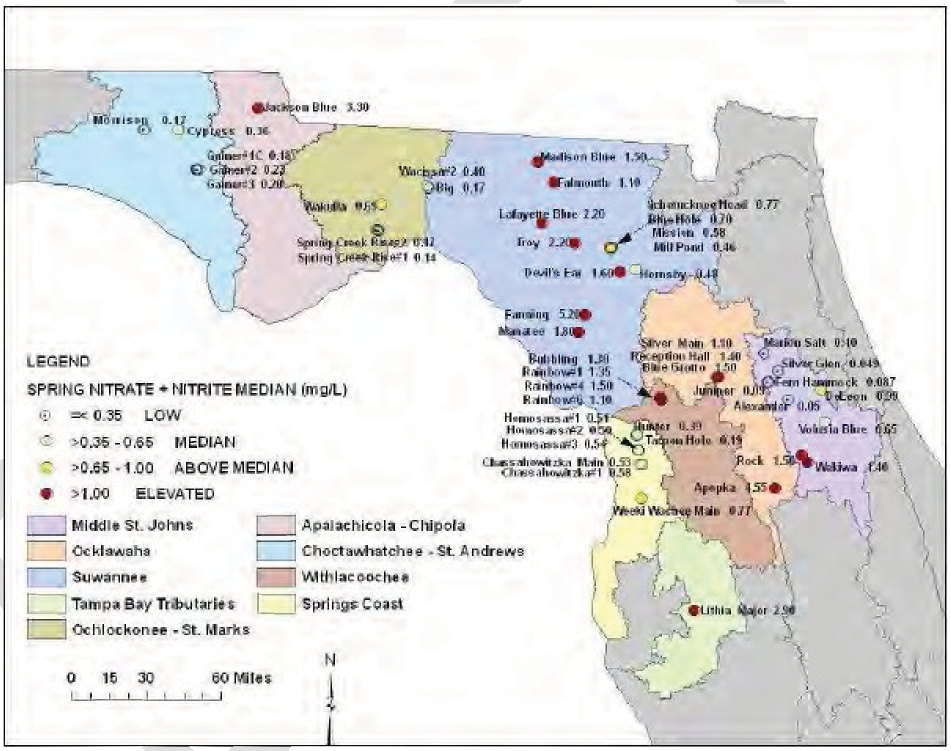

Figure 8. Median concentrations of nitrate+nitrite in the Spring Network, 2001–06 (from Harrington et al. 2010).

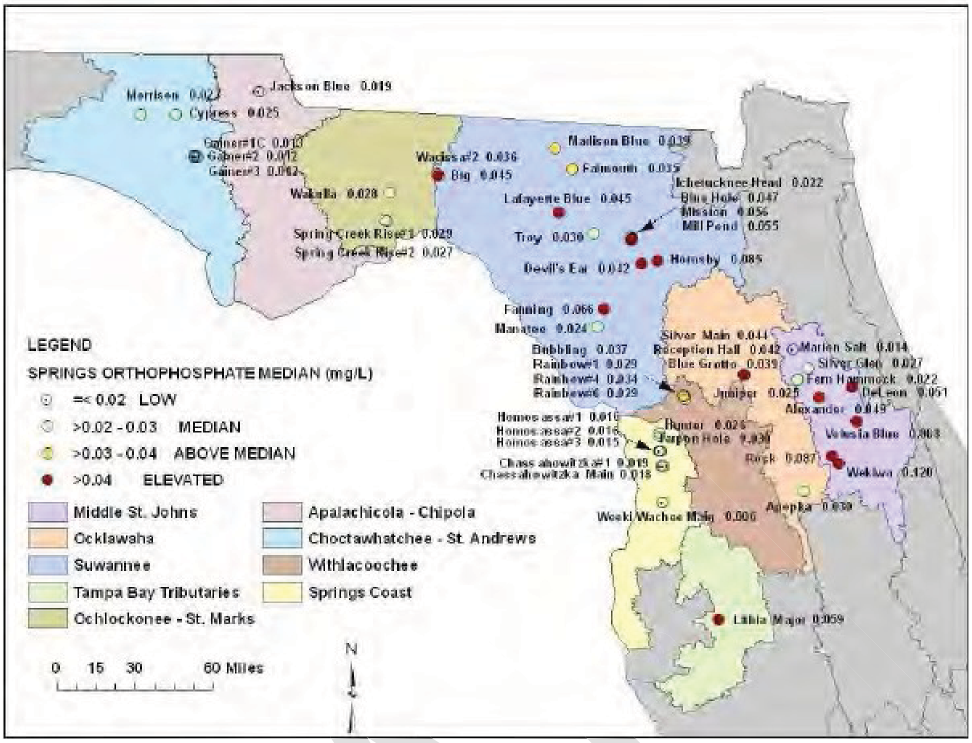

Figure 9. Median orthophosphate concentrations in the Spring Network (2001-2006) from Harrington et al. (2010).

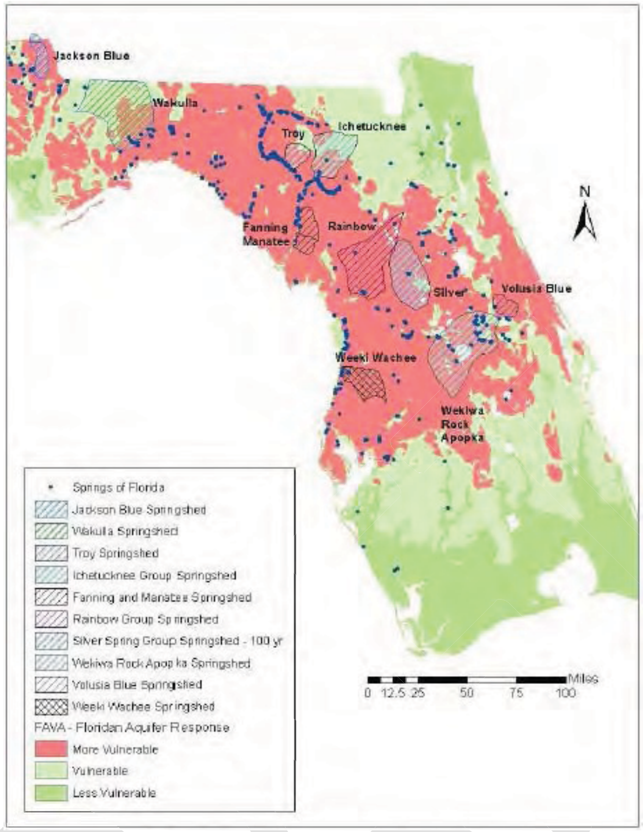

Figure 10. Aquifer vulnerability in spring areas, Figure 16 from Harrington et al. (2010).

Waccasassa

There are several domestic wastewater facilities that discharge in the watershed, with three facilities that discharge to percolation ponds, two facilities that discharge to surface water outfalls, and three facilities that discharge to land application (Charbonneau 2010; Table 5**).** Percolation ponds and land application sites likely contribute nutrients to the groundwater, which may seep to the estuary in this karst landscape (Harrington *et al.* 2010). There are also dairy farms and mines that discharge to surface waters (Table 5).

Table 5. Permitted facilities in the Waccasassa River watershed (from FDEP WAFR database).

FACILITY ID	FACILITY NAME	FACILITY TYPE	DESIGN CAPACITY (MGD)	COUNTY NAME
FLA017396	Watson Farms Dairy	AFO	0	Gilchrist
FLA011647	Levy County Jail WWTF	DW	0.024	Levy
FLA317659	Bronson, Town of WWTF	DW	0.083	Levy
FLA011656	Levy Forestry Work Camp WWTF	DW	0.035	Levy
FLA011292	Newberry, City of WWTF	DW	0.415	Alachua
FLG110540	A Materials Group Inc - Plant #13	CBP	0	Alachua
FLA178322	Florida Rock - Newberry Mine	IW	0	Alachua
FL0633275	PEF Levy County Nuclear Plant Units 1 & 2	IW	0	Levy
FLA663492	Tarmac America - King Road Mine	IW	0	Levy
FLA016620	Forestry Youth Training Center WWTF	DW	0.01	Levy
FLA285757	Southeast Dairy Company	AFO	0	Levy
FL0031216	Cedar Key WRF	DW	0.18	Levy

Individual residences and businesses not served by WWTF's dispose of domestic waste in septic systems. The soils within close proximity to Waccasassa River and tributaries are limited in terms of their condition for disposal of domestic wastewater. Stormwater runoff from urban, agricultural, and silviculture operations is a source of nutrients within the Waccasassa coastal drainage area. Many rural areas have a lack of stormwater infiltration/catch basins. Wildlife in coastal conservation areas are likely contributing some nutrients to the coastal area.

Withlacoochee

The dominant land uses and land coverage in the Withlacoochee Watershed are wetlands, upland forest, rangeland, agriculture, mining, and urban (Table 1). Agricultural activities in the watershed include cattle ranching, row crops, sod, pasture, pine plantation, and cypress harvesting. The primary industrial land use is limerock mining. Other types of mining include the extraction of sand and horticultural peat. Although residential and commercial development in the region is increasing, the watershed as a whole remains largely undeveloped (FDEP 2006).

The Withlacoochee River's headwaters in the Green Swamp are mostly surrounded by rural areas and wetlands. Farther downstream, land use is more urbanized near Dade City in Pasco County, but low intensity agriculture (e.g., pasture) and wetlands still predominate. From the area around Lake Tsala Apopka downstream to Dunnellon, more land is developed, but low intensity agriculture and wetlands remain a dominant part of the landscape. Currently, there are no large urban centers on the Withlacoochee River.

Human activities over the last 150 years have significantly altered the character of the Rainbow River, especially in its lower reaches. Historically, the major land uses along the river and surrounding areas were agriculture and mining. The construction of Lake Rousseau in 1909 raised water levels in the lower reaches of the Rainbow River, altering the river's flow and floodplain habitat. Land use immediately surrounding the Rainbow River has slowly shifted from mining and agriculture to mostly residential. Although most of the 73-square-mile watershed is still largely rural, portions are rapidly losing their rural

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character. Within a ten-mile radius of Dunnellon, the population increased 37.5 percent between 1994 and 2004, however, population in Florida has leveled out during the past 2 years.

Nitrate concentrations in the ground water discharging from Rainbow Springs have steadily increased over the last 30 years. The spring recharge area covers 650 square miles in Marion, Levy, and Alachua Counties. In western Marion County, residential and commercial growth has occurred at a rapid rate, and with it, potential sources and increased loads of nitrates and other contaminants.

Of the wastewater treatment plants in the watershed, disposal methods are: 90 Percolation Ponds, 11 Outfalls, and 63 Land Application Sites (Charbonneau 2010). There is very little discharge to surface waters, according to the FDEP WAFR database (Table 6). Percolation ponds and land application sites likely contribute nutrients to the groundwater, which may seep to the estuary in karst areas of the watershed (Harrington *et al.* 2010). Individual residences and businesses not served by WWTF's in the towns of Yankee Town and Inglis (near the mouth of the river) dispose of domestic waste in septic systems. Stormwater runoff from urban, agricultural, and silviculture operations is a source of nutrients within the Withlacoochee Watershed. Yankee Town and Inglis lack stormwater infiltration/catch basins.

The 30,784 acre Waccasassa Bay State Preserve and the 24,625 acre Gulf Hammock Wildlife Management Area, which border the estuary (Figure 3), contribute fecal coliforms from wildlife sources (DeHaven 2004a), and wildlife may also contribute nutrients.

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Table 6. Permitted facilities that discharge to surface waters in the Withlacoochee River watershed (from FDEP WAFR database).

Facility ID	Facility Name	Facility Type	Design Capacity	County
FLA128538	Cal-Maine Foods, Inc.- Dade City, 88	CFO	0.00	Pasco
FLA135381	CAL MAINE FOODS INC - BUSHNELL FACILITY	CFO	0.00	Sumter
FL0025569	Dixie Lime & Stone Company	IW	0.00	Sumter
FLG110559	Dublin Investments LLC	CBP	0.00	Sumter
FLG110686	Prestige AB Management Co LLC-Coleman CBP	CBP	0.00	Sumter
FLG110790	Paleen Ready Mix LLC CBP	CBP	0.00	Citrus
FLG110379	CEMEX LLC- Oxford Ready-Mix Plant	CBP	0.00	Sumter
FLG110317	Florida Rock Industries Inc - Holder Plant	CBP	0.00	Citrus
FLG110676	Prestige AB Management Co LLC-Hernando CBP	CBP	0.00	Citrus
FLG110507	CEMEX LLC - Cobb Rd CBP	CBP	0.00	Hernando
FLG110121	CEMEX LLC- Wildwood Ready - Mix Plant	CBP	0.00	Sumter
FLG110237	Florida Rock Industries - Leesburg CBP	CBP	0.00	Lake
FLG110222	CEMEX LLC - Brooksville Plant	CBP	0.00	Hernando
FLG110711	CEMEX LLC - Bushnell RM Plant	CBP	0.00	Sumter
FLG110321	Bower Enterprises Inc	CBP	0.00	Polk
FL0322890	Mazak Limerock Mine	IW	0.00	Sumter
FLG110397	Prestige AB Ready Mix, LLC	CBP	0.00	Marion
FL0135372	CEMEX Construction Materials Florida LLC - St Catherine Mine	IW	0.00	Sumter
FL0707686	Dumont Chemical	IW	0.00	Sumter
FL0031895	CEMEX Construction Materials Florida LLC - Center Hill Mine	IW	0.00	Sumter
FLG110761	Florida Rock Industries Inc - Brooksville CBP	CBP	0.00	Hernando
FLG110316	CEMEX LLC - Dunnellon Plant	CBP	0.00	Marion
FLG110232	Evans Septic Tank & Ready Mix - Belleview CBP	CBP	0.00	Marion
FLG110651	CEMEX Construct Materials FL LLC - Belleview Ready Mix Plant	CBP	0.00	Marion

Biological Summary

SAV and Species Composition

SAV beds along this portion of the coastline are substantial and relatively stable, due to the low energy coastline and the extensive marsh systems along the coastline that act as natural filters for sediment carried from upstream sources (Wolfe 1990). Seagrass species found along this part of the coast are *Thalassia testudinum, Syringodium filiforme, Halodule wrightii, Ruppia maritime*, and *Halophila engelmannii* (Iverson and Bittaker 1986). *T. testudinum, S. filiforme,* and *H. wrightii* were only found to 9 m depth, whereas *H. engelmannii* was found at greater depths in association with marine macroalgae.

SAV mapping in this region from 1984, 2001, and 2006 imagery showed a decline in SAV in the area north of the Suwannee River (Carlson *et al.* 2010). Carlson *et al.* (2010) attributed that loss to reduced clarity during high discharge periods of the Suwannee River; however, it is not clear if the reduced clarity was due to excessive color, turbidity, or chlorophyll *a*. Preliminary results from a 2004-2009 optical water quality study by the Florida Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Conservation Commission (FWCC) show that there is a gradient of chlorophyll *a* and turbidity along the coast, with higher values near the Suwannee River, and declining concentrations along the Big Bend to St. Marks. Their preliminary analyses for the entire study area suggest that chlorophyll *a* and turbidity are more highly correlated with light attenuation than color (Paul Carlson and Laura Yarbro, FWRI, personal communication 7/31/10). SAV has not been mapped south of the Suwannee River.

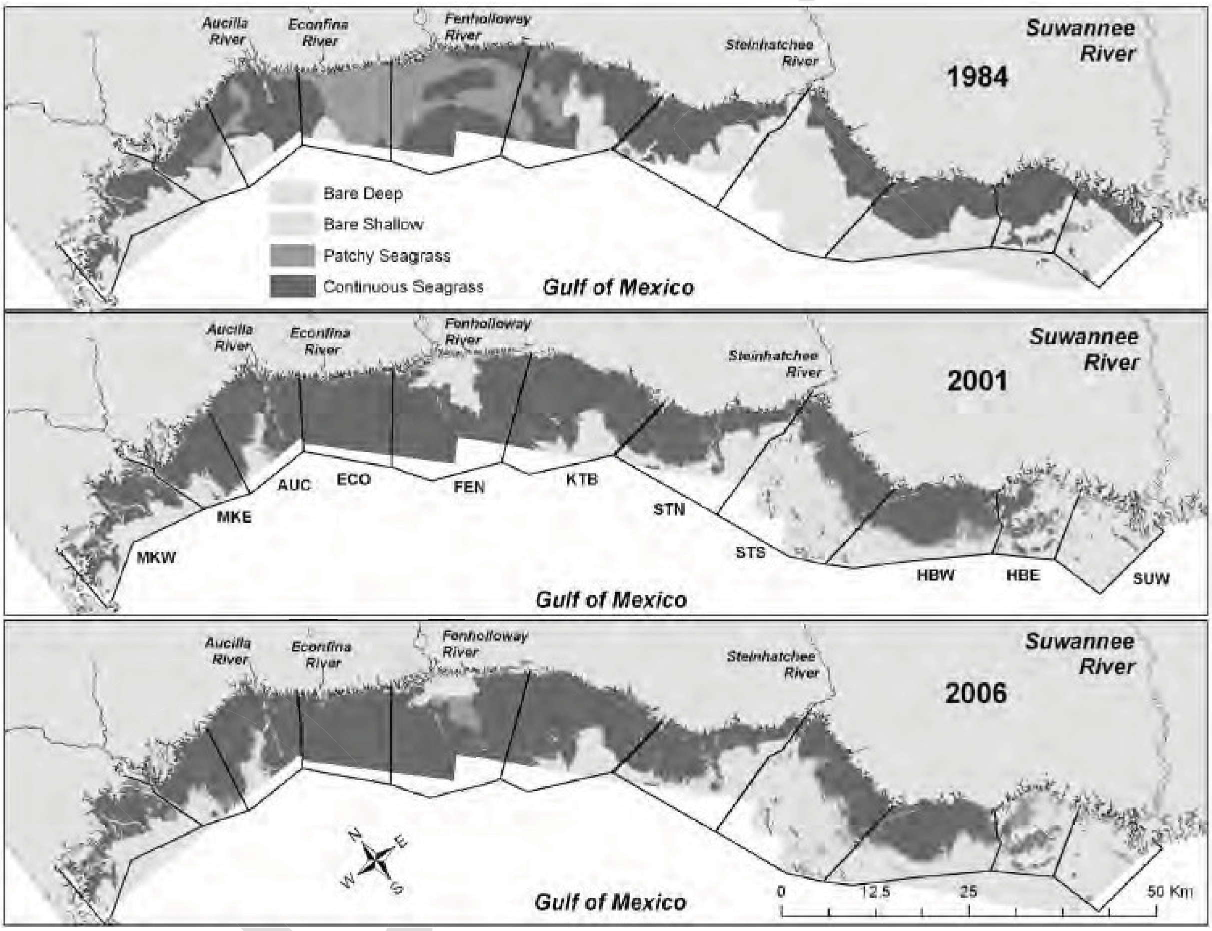

Figure 11. Big Bend seagrass cover in 1984, 2001, and 2006. Of note for this report is the apparent decline in seagrass coverage north of Suwannee Sound potentially due to effects from the Suwannee River (from Carlson et al. 2010).

Field SAV surveys were conducted in 1974-1980 (Iverson and Bittaker 1986) and repeated in 2000 (Hale *et al.* 2004) in the Springs Coast and along the Big Bend Coast. Results showed some local species shifts but no overall trend of shift or SAV loss in the region from the Suwannee to the Withlacoochee Rivers (hypothesized species shift off Springs Coast discussed further in FDEP Springs Coast Summary). There was some replacement of *Thalassia* with *Halodule* at sites just north of the Suwannee River between those time periods (Hale *et al.* 2004). Figures 12-14 show the location of the three dominant species of seagrass, and increase or decrease from the 1974-80 study to the 2000 study.

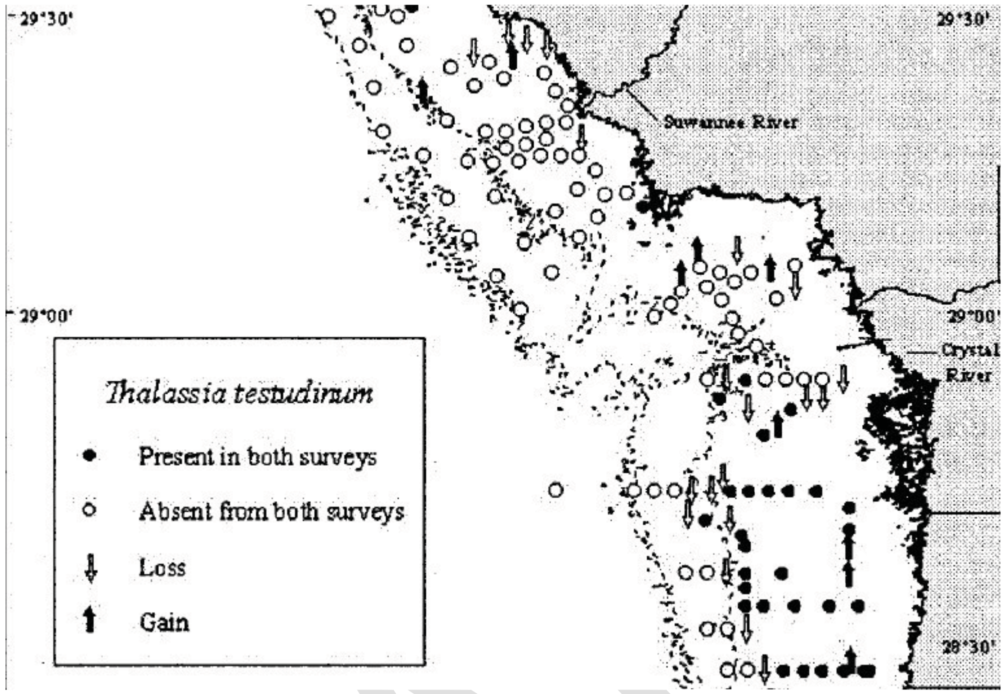

Figure 12. Distribution map for Thalassia testudinum, showing comparison of 1984 and 2000 surveys (from Hale et al. 2004).

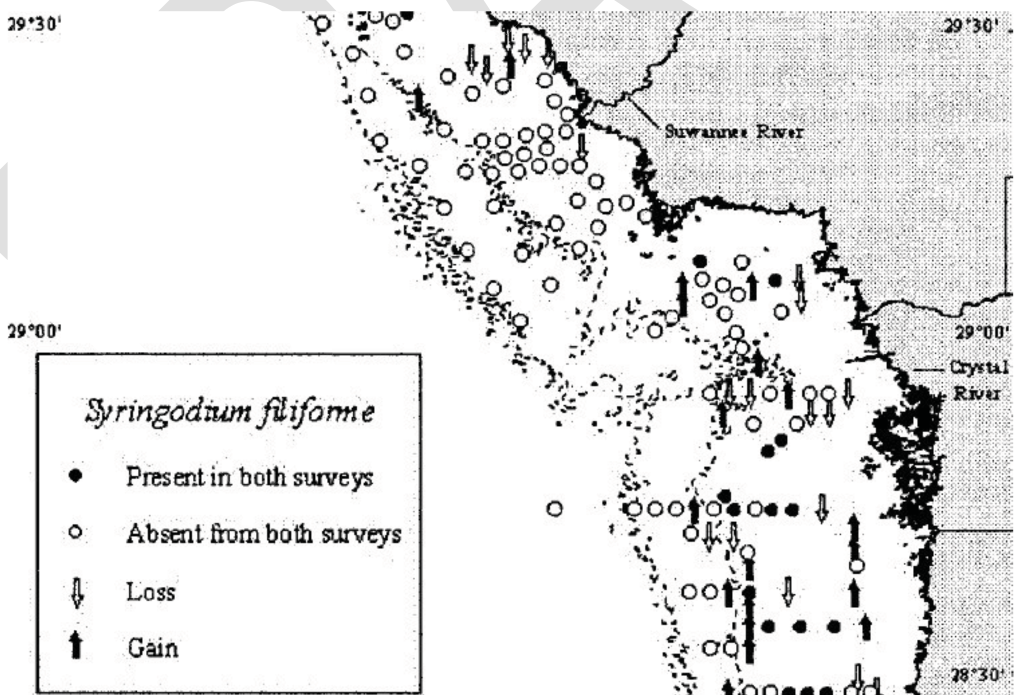

Figure 13. Distribution map for Syringodium filiforme, showing comparison of 1984 and 2000 surveys (from Hale et al. 2004).

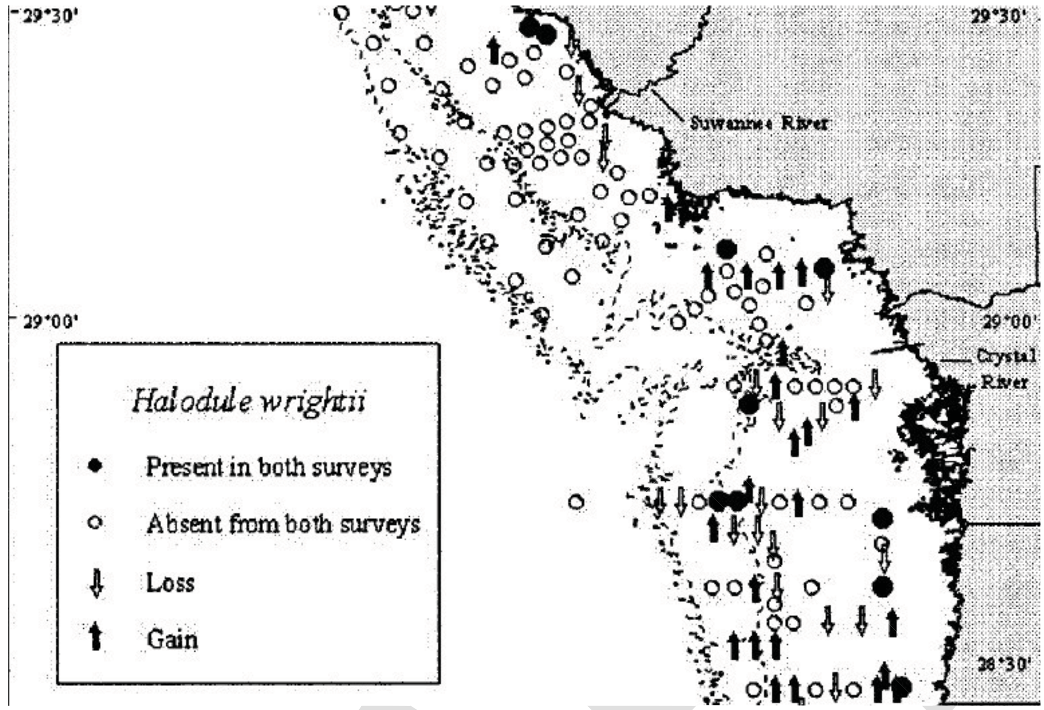

Figure 14. Distribution map for Halodule wrightii, showing comparison of 1984 and 2000 surveys (from Hale et al. 2004).

Staff from the Big Bend and St. Martin's Marsh Aquatic Preserves have been conducting seagrass surveys at 25 fixed sites around Cedar Keys since 2006 (Figure 15). At each site, 4 replicate quadrats are randomly selected, totaling 100 quadrats. Coverage estimates of seagrass, rooted macroalgae, and drift algae are made using Braun-Blanquet (B&B) sampling methods. This involves identifying percent coverage of all seagrass and algae species represented and within a 1 m^2 "quadrat." The coverage abundance codes that the preserve uses are the following: 1 = <5% cover; 2 = 5-25% cover; 3 = 25-50% cover; 4 = 50-75% cover; 5 = 75-100% cover. The type of data collected has been adjusted throughout the study period, but the site locations have remained the same. The Preserve continues to collect data on indicators that prove to be the most accessible and comparable and include: seagrass and macroalgae abundance, seagrass species composition, canopy height, epiphyte density (1 = clean, 2 = light, 3 = moderate, 4 =heavy), water quality measurements (DO, pH, temp, salinity, turbidity, color, PAR), sediment type/grain size, and presence of other organisms present in the bed such as bay scallops and sea urchins. The monitoring program goals are to provide information to resource managers to assess the status of this resource within the aquatic preserve, and are not representative of the entire Springs Coast. The study area is located in Levy County around the waters of Seahorse Key, North Key, Atsena Otie, and Snake Key. Overall, preserve staff monitor 100 seagrass stations from Crystal River to St. Marks. The database is relevant for comparing parameters like species composition, blade lengths, total coverage and sediment types along the entire Big Bend coastline.

The dominant seagrass species within the project area are *Thalassia testudinum* and *Halodule wrightii* (Figure 16). Total seagrass coverage has ranged between 3.66 and 4.38 (Braun-Blanquet scale; Figure 17). The decline in total seagrass coverage could be attributed to the patchiness of seagrass in the study sites. Total epiphyte coverage density has been stable throughout the study period (Figure 18). The study area may lack optimal growing conditions for green macroalgae. Since 2006*, Caulerpa prolifera* is the only green marcoalgae found within the study area. However, calcareous red algae are abundant in some of deeper *Thalassia* beds. This area of Florida coast is extremely shallow and is located approximately 20 km from the mouth of the Suwannee River. Therefore, the waters around Cedar Key are characterized by a mixture of sand, silt and mud bottom types. The particulate matter in the water column attenuates light at shallow depths, partially limiting the overall growth of seagrass. Seagrass blade lengths tend to be shorter and percent coverage tends to be less dense when compared to other areas with better water clarity (Big Bend Seagrasses and St. Martins Marsh Aquatic Preserve staff).

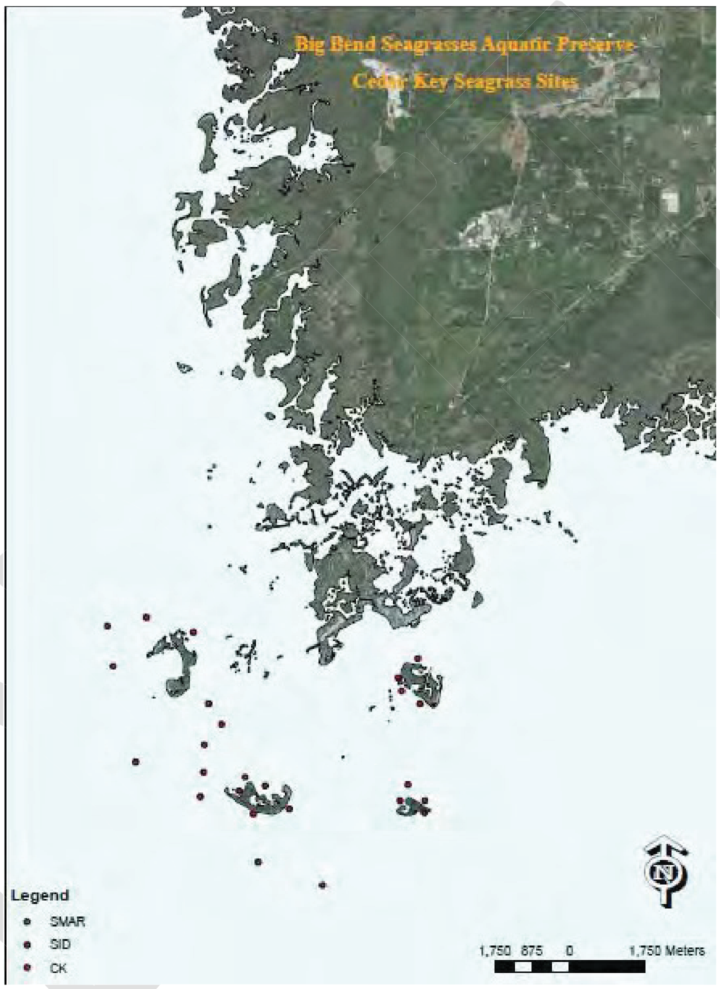

Figure 15. FDEP Aquatic Preserves SAV sampling sites at Cedar Keys, Levy County, Florida.

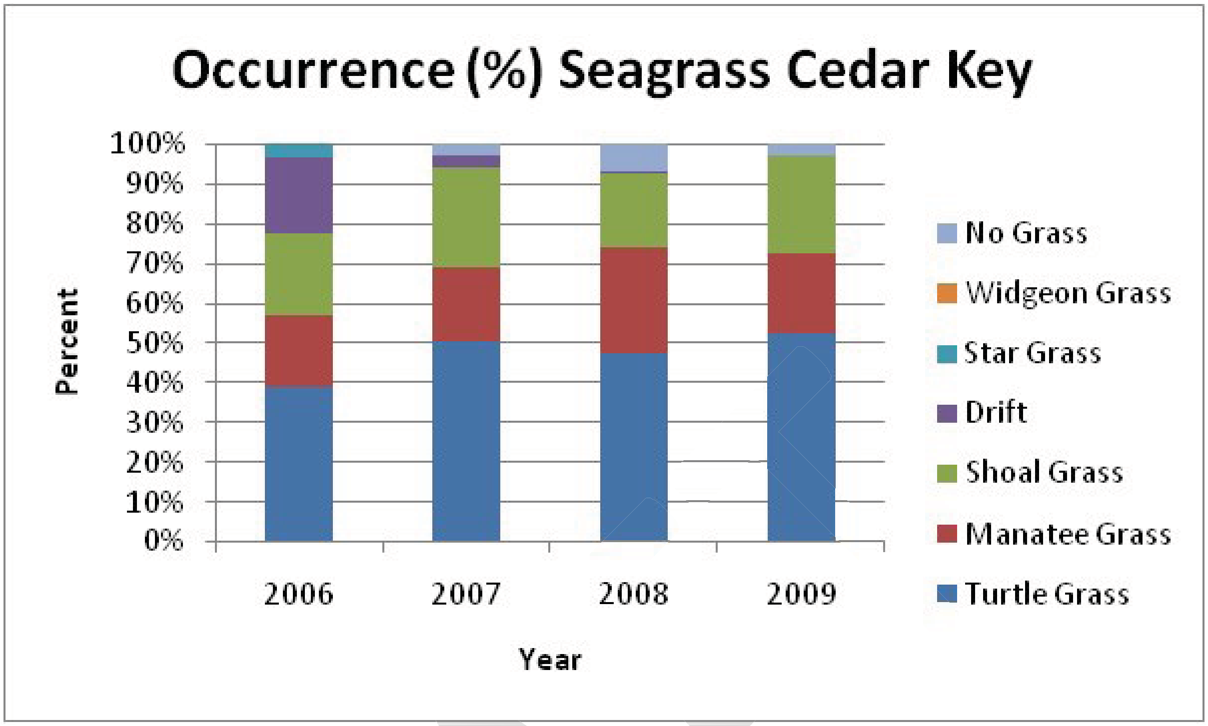

Figure 16. Frequency of occurrence of seagrass species at Cedar Keys, 2006-2009.

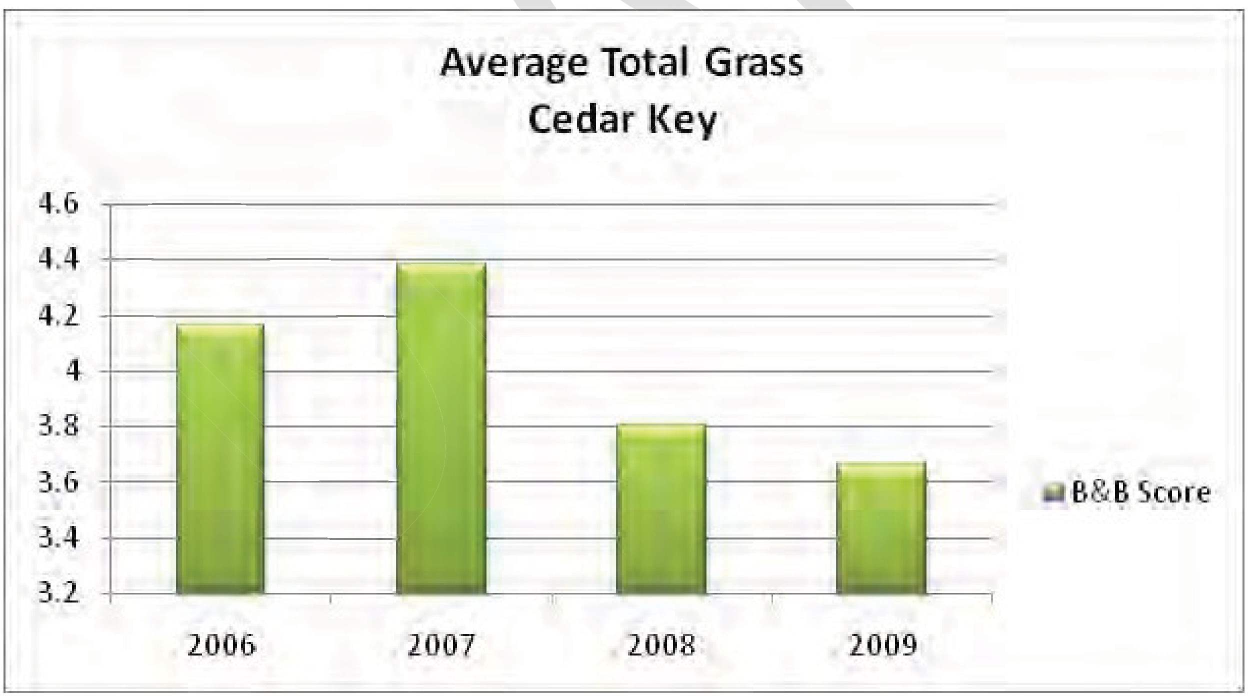

Figure 17. Average total grass coverage, Cedar Keys, 2006-2009. AVG B&B represents the average Braun-Blanquet ranking assigned at each of 100 sampling quadrats per year. Ranks are abundance codes ranging from 1-5.

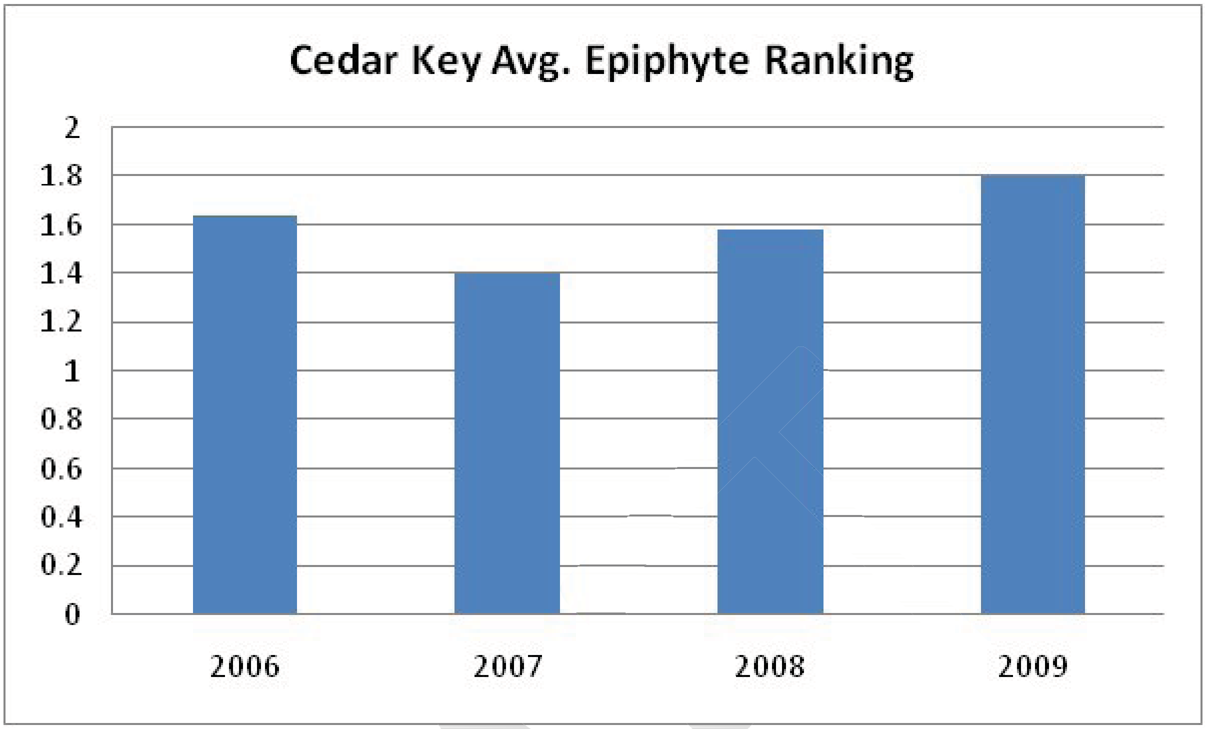

Figure 18. Average epiphyte ranking, St. Martins Marsh Aquatic Preserve ,2004-2009. Shown are average epiphyte rankings of 100 sampled quadrats. Possible epiphyte ranks range from 1-4.

Phytoplankton Species Composition

Putnam (1967) studied algal production and photosynthesis in the Waccasassa Estuary and found that, 93% of the time, production in the Waccasassa Bay is likely to be higher than in either the river or the Gulf (Figures 19 and 20). He also conducted limiting nutrient bioassays, and concluded that nitrogen was the limiting nutrient. Interestingly, streamflow of the Waccasassa River was not correlated with productivity for any of the sampling stations in this study, and the author concluded that "the land apparently is infertile and following heavy rains nutrients leach out of the soil in insufficient amounts to alter productivity in any immediate way in the estuary" (Putnam 1967). This study was conducted when Florida's population was 6 million people. Putnam (1967) notes that "nutrients accumulate and are recycled metabolically within the system" such that added nutrients would not be exported readily out to the Gulf. Diatoms were the dominant phytoplankton group all year.

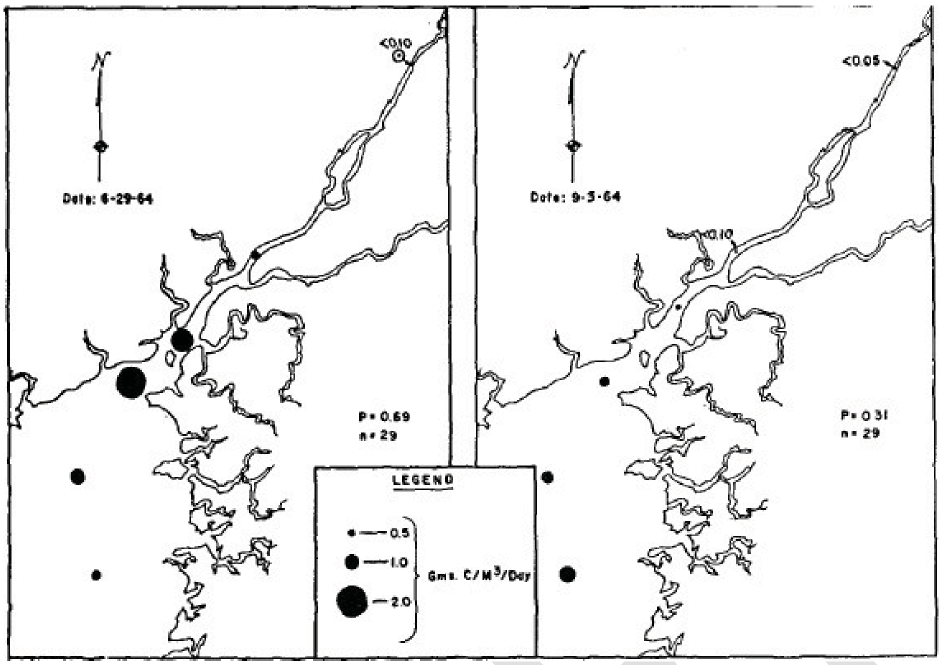

Figure 19. Variation in productivity pattern in Waccasassa Bay (from Putnam 1967). Larger circles indicate higher primary productivity.

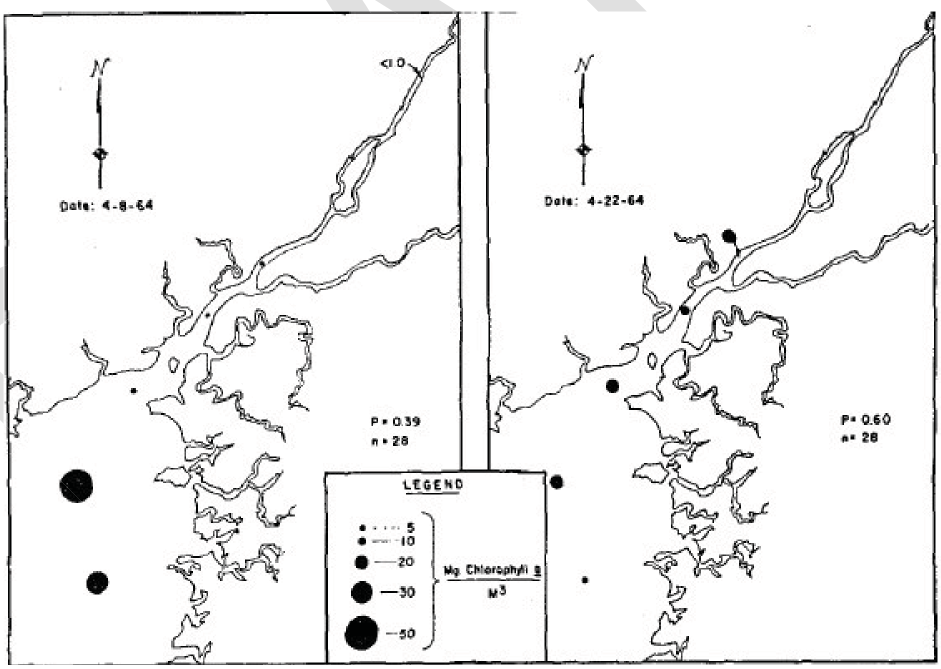

Figure 20. Variation of chlorophyll a in estuarine surface water in Waccasassa Bay (Figure 7 from Putnam 1967).

Phytoplankton production in Suwannee Sound is relatively high, however, zooplankton production and food web assimilation is sufficient that excess chlorophyll is not observed. Quinlan *et al.* (2009) estimated that the resident microzooplankton could remove up to 83% of total daily primary production. The microzooplankton community was primarily composed of ciliates, dinoflagellates, and copepod nauplii, and ciliate densities were comparable to those reported for productive estuaries (Quinlan *et al.* 2009). The phytoplankton communities in the estuarine regions (reef and nearshore) of Suwannee Sound were dominated by diatoms. Studies of phytoplankton along the gradient from the river to the nearshore area revealed that salinity, light, and temperature play important roles in the distribution of phytoplankton species, with salinity as the most important factor (Quinlan and Phlips 2007). Riverine communities were light-limited, especially during periods of typical or high flow, and nearshore communities are nutrient-limited (Bledsoe and Phlips 2000, Quinlan and Phlips 2007). During periods of record low flow, phytoplankton biomass increased in the river due to increased residence time and water clarity (Quinlan and Phlips 2007). During the whole period of her study, Dr. Quinlan did not observe any traditional bloom species, including typical cyanobacteria in fresh portions or *Karenia brevis* in marine portions (E. Quinlan, personal communication). She suggests that the Suwannee River's low salinity outflow precludes the maintenance of *K. brevis* blooms (Quinlan and Phlips 2007).

Macroalgal Species Composition and Biomass (Including Calcareous Forms)

Seasonal periods of high macroalgae biomass were observed during the winter and spring from 1999 to 2001 (low flow years) at the mouth of the Suwannee River (Figure 21). Seasonal changes in water clarity and tidal cycles may affect the abundance and distribution of macroalgae in the Suwannee River Estuary. Benthic algal biomass was measured during 2000 and 2001 by Dr. Erin Quinlan, and spatial patterns indicated that benthic algal biomass is higher in the plume of the Suwannee River (Figure 22). The levels of algae measured in these studies were not linked with any biological impairment.

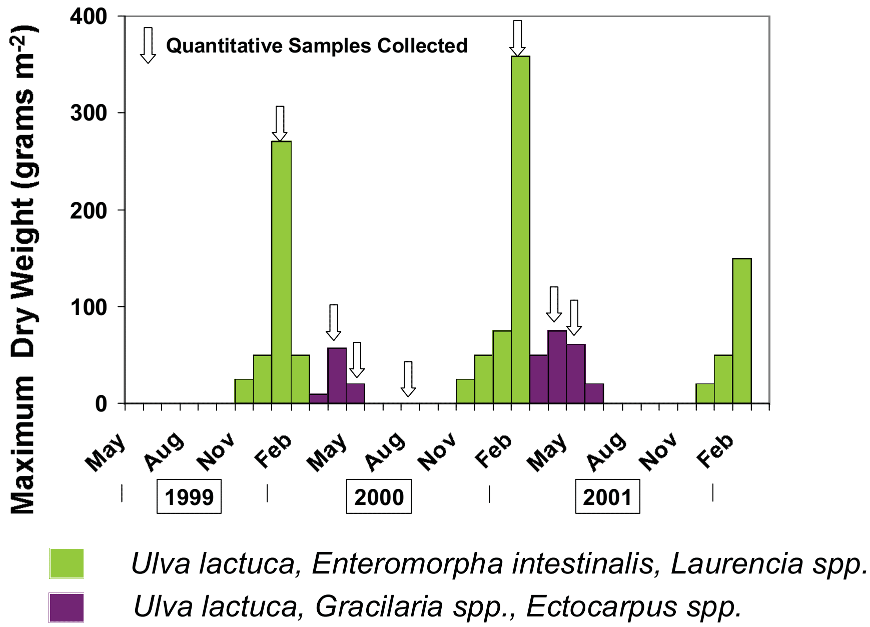

Figure 21. Observed macroalgal succession on a subset of oyster reef at the mouth of the Suwannee River, 1999-2001 (from Quinlan 2010).

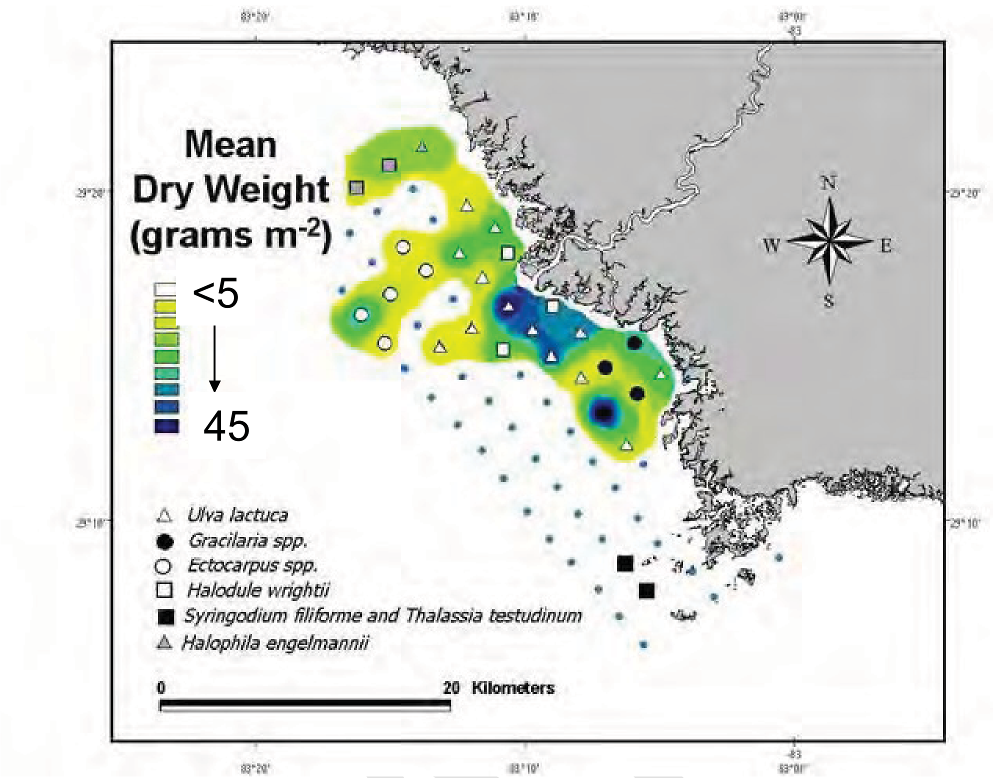

Figure 22. Macroalgal biomass and SAV species distribution in Suwannee Sound, measured in Spring 2000 and Spring 2001 (from Quinlan 2010).

Shellfish Production and Frequency/Duration of Bed Closures

There are five monitored shellfishing areas within the region covered in this summary: Horseshoe Beach, Suwannee Sound, Cedar Key, Waccasassa Bay, and Withlacoochee Bay. Information can be accessed through the Florida Department of Agriculture and Consumer Services (DACS) Shellfish Environmental Assessment Section (SEAS) website http://www.floridaaquaculture.com/seas/seas_shamap.htm and in Shellfish Harvesting Area reports (DeHaven 2004a, 2004b, 2004c, Kuhnman 2004, 2007). There are open, closed, and conditionally approved shellfish harvesting areas within those regions, and those assignments are dependent upon season, freshwater flow from the rivers, and other ongoing monitoring parameters. Shellfish areas may be closed due to high levels of fecal coliforms in water samples, high density of *Karenia brevis* (see later section on HABs), or simply certain levels of freshwater discharge from rivers feeding the estuaries. Later sections in this report include discussions of the relevance of red tide and fecal coliforms to nutrient criteria development.

Fish Community Studies

Studies by Tukey and Dehaven (2006) of fish community composition in seagrass and tidal creek habitats in the Suwannee estuary (monthly sampling 1997-1999; Figure 23) showed clear support of all age groups of fishes and high diversity in seagrass and tidal creek habitats. Thirty-five species were unique to seagrass habitat, and 35 species were unique to tidal creeks, with a total of 111 species found in the study altogether. Expected seasonal changes in community composition were observed, due to recruitment of young of year fish (YOY).

Tukey and Dehaven (2006) found more species of fishes in the tidal creeks (80) than were found in studies of tidal creeks in other states and regions. The most common fish species found in seagrass habitats were *Harengula jaguana, Anchoa hepsetus, Anchoa mitchilli, Membras martinica, Syngnathus floridae, Syngnathus scovelli, Eucinostomus* spp.*, Orthopristis chrysoptera, Lagodon rhomboides, Bairdiella chrysoura, Cynoscion nebulosus,* and *Menticirrhus americanus*. The most common fish species found in tidal creek habitats were *Brevoortia* spp., *Anchoa hepsetus, Anchoa mitchilli, Adinia xenica, Fundulus grandis, Fundulus majalis, Membras martinica, Menidia* spp.*, Oligoplites saurus, Eucinostomus harengulus, Eucinostomus* spp.*, Lagodon rhomboides, Bairdiella chrysoura, Cynoscion arenarius, Cynoscion nebulosus, Leiostomus xanthurus, Menticirrhus americanus, Sciaenops ocellatus, Mugil cephalus,* and *Gobiosoma bosc.* Fish species spatial distribution was driven primarily by salinity (Tukey and Dehaven 2006). The authors commented that maintenance of healthy seagrasses is critical to fisheries support in this area. The results of Tukey and Dehaven's (2006) study were similar to a study conducted at Cedar Key 50 years prior (Reid 1954).

Cedar Keys (including Suwannee Sound) is one of the intensive annual study areas for the Fisheries Independent Monitoring (FIM) Program operated by the FWCC (Figure 24). FWCC produces an annual report of sampling results, summaries of the 2008 results suggest that this system is diverse and fully functioning (Tables 7 and 8; from FIM 2009). The FIM program has been sampling in the Cedar Keys/Suwannee Sound area for 10 years, but no long term data analyses are available.

Suwannee Sound is a designated critical habitat area for the federally threatened Gulf sturgeon (Federal Register Vol. 68, No. 53, 3/19/03). This designation was supported by Edwards *et al.* (2003), who studied the movements of adult Gulf Sturgeon in 1996 and 1998. Their study showed that adult fish that spawn up the Suwannee River spend 4-5 months of the year feeding in shallow marine waters off the mouth of the Suwannee River.

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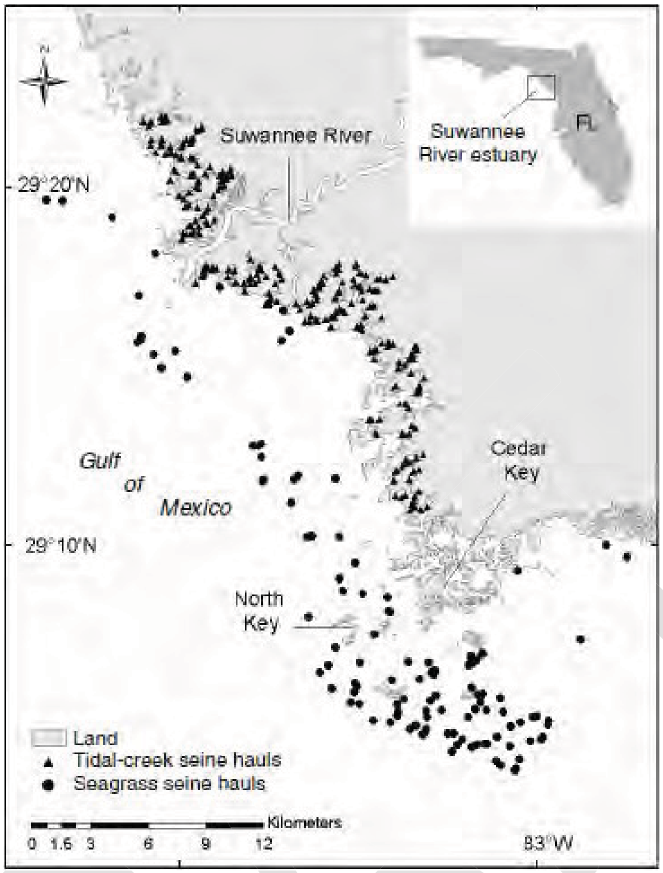


Figure 23. Sampling sites for the 1997-1999 fish community study by Tukey and Dehaven (2006) (figure from Tukey and Dehaven 2006).

Table 7. The top 10 numerically dominant fish taxa collected in the Fisheries Independent Monitoring program stratified random sample areas, 2008. Totals in bold represent total of top 10 dominant, total recreationally important species, and grand total.

Cedar Key	
Scientific Name	**Number**
Anchoa mitchilli	95,951
Leiostomus xanthurus	15,901
Lagodon rhomboides	10,144
Membras martinica	9,503
Bairdiella chrysoura	6,411
Anchoa hepsetus	4,038
Menidia spp.	3,301
Mugil cephalus	2,908
Orthopristis chrysoptera	2,214
Eucinostomus spp.	1,885
	152,256
	27,118
	174,950

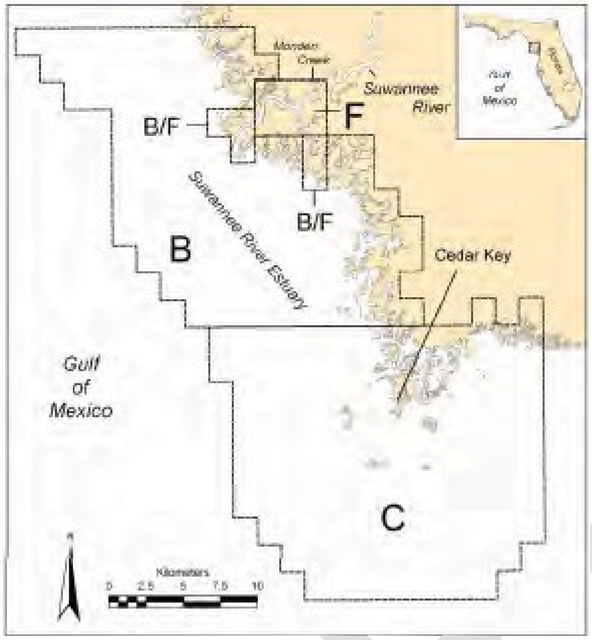


Figure 24. Map of Cedar Key sampling area of the Fisheries Independent Monitoring Program. Zones are labeled B, C, and F. Grids containing portions of Zones B and F are labeled B/F.

Table 8. Number of recreationally important species (Selected Taxa) collected in the Fisheries Independent Monitoring program stratified random sample areas, 2008.

Cedar Key	
Scientific Name	**Number**
Leiostomus xanthurus	15,901
Mugil cephalus	2,908
Cynoscion arenarius	1,502
Menticirrhus americanus	870
Menippe spp.	791
Callinectes sapidus	733
Mugil gyrans	694
Mugil curema	687
Micropogonias undulatus	617
Farfantepenaeus duorarum	605
Elops saurus	417
Sciaenops ocellatus	372
Paralichthys albigutta	259
Cynoscion nebulosus	213
Pogonias cromis	189
Archosargus probatocephalus	146
Lutjanus griseus	55
Scomberomorus maculatus	48
Lutjanus synagris	36
Trachinotus falcatus	24
Menticirrhus saxatilis	15
Pomatomus saltatrix	11
Centropomus undecimalis	10
Mycteroperca microlepis	5
Paralichthys lethostigma	4
Trachinotus carolinus	4
Megalops atlanticus	1
Mycteroperca sp.	1
Total	**27,118**

__Quantification of Landings from Commercial/Recreational Fisheries__

Fish landings data are available by county from the Florida Fish and Wildlife Conservation Commission. Shellfish, shrimp, and finfish landings have remained relatively constant over time for Dixie and Levy Counties (Figures 25-27). Missing bars indicate no landings for that year.

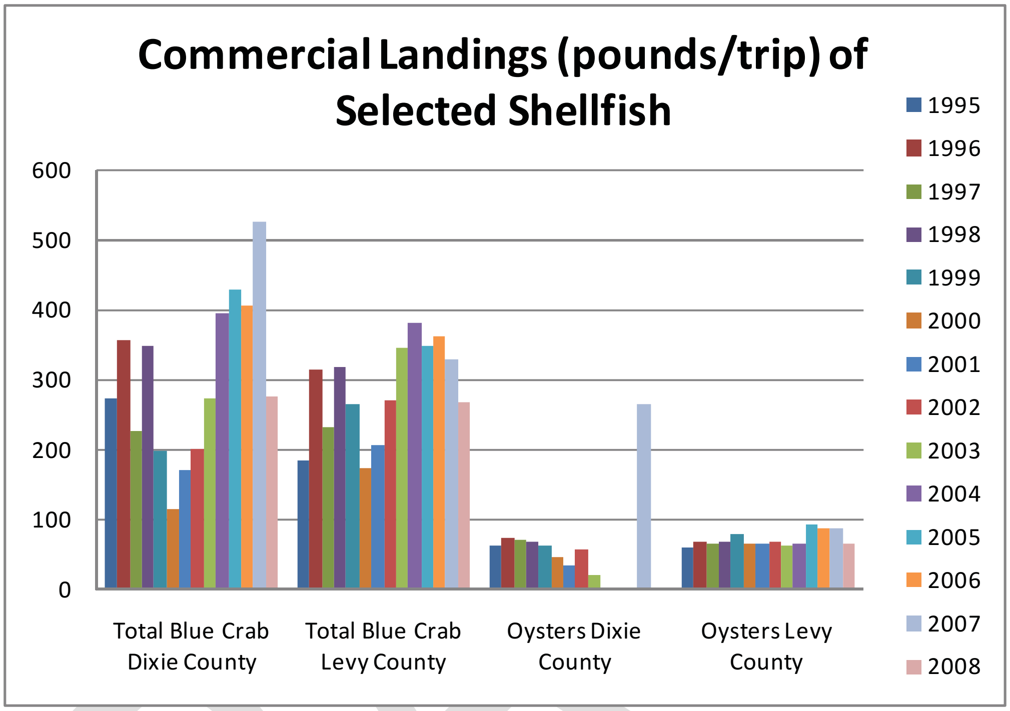


Figure 25. Total commercial blue crab and oyster catch (pounds/trip) for Dixie and Levy Counties from 1995-2008. Data from the Florida Fish and Wildlife Conservation Commission.

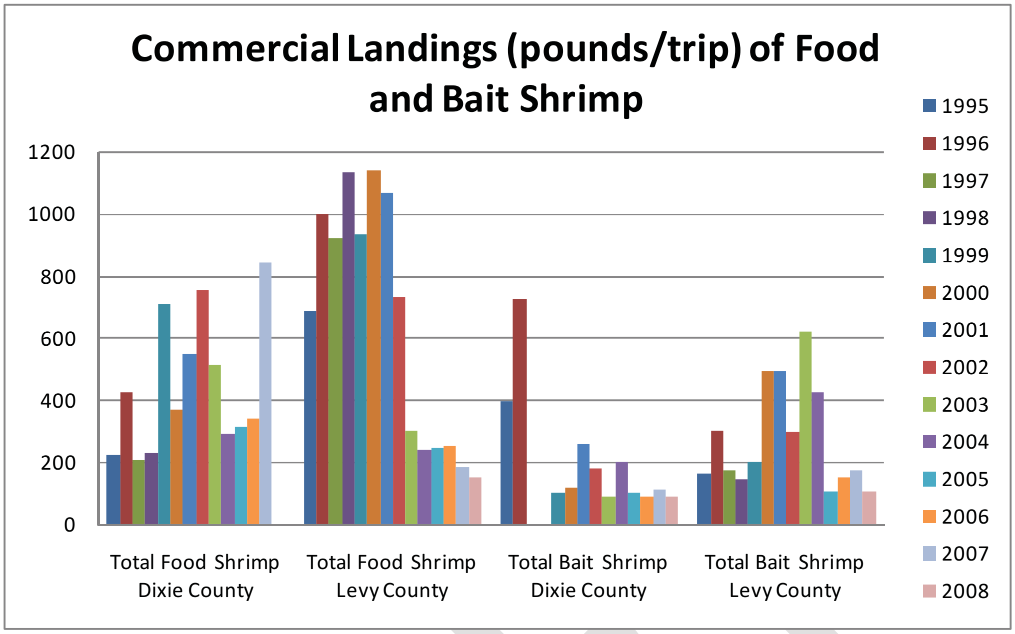


Figure 26. Total commercial shrimp catch (pounds/trip) for Dixie and Levy Counties from 1995-2008. Data from the Florida Fish and Wildlife Conservation Commission.

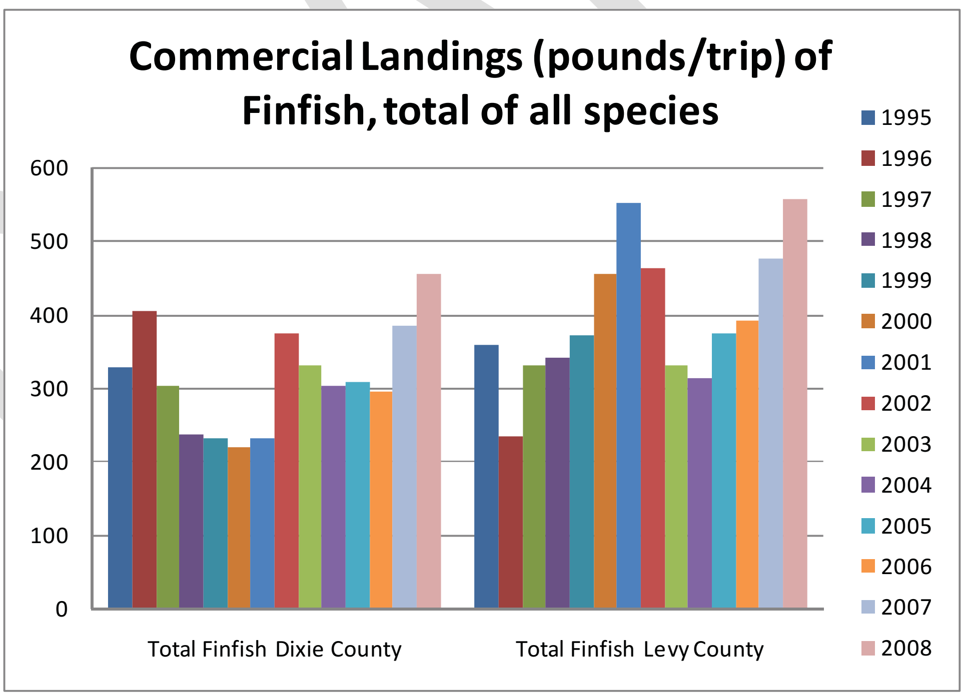


Figure 27. Total commercial finfish catch (pounds/trip) for Dixie and Levy Counties from 1995-2008. Data from the Florida Fish and Wildlife Conservation Commission.

Harmful Algal Blooms

Karenia brevis is a toxic dinoflagellate associated with Florida saltwater fish kills, neurotoxic shellfish poisoning, and an airborne irritant in seaspray that can cause respiratory discomfort in humans and other animals. This phenomenon, known as "red tide," occurs when *K. brevis* concentrations increase above normal background levels of 1,000 cells/L (Kuhnman 2007). Red tide concentrations above 250,000 cells/L can cause fish kills; however, concentrations as low as 5,000 cells/L may cause shellfish to become toxic if the animals are exposed for a sufficent period. Shellfish become toxic by feeding on the dinoflagellates and absorbing toxin into their digestive tissues (Kuhnman 2007).

Shellfish areas are closed to harvesting when concentrations in the vicinity exceed 5,000 cells/liter. Field studies indicated that shellfish may retain toxicity for two to four weeks; therefore, after concentrations return to normal in water, shellfish meats must be tested for toxicity before the area may be reopened to shellfish harvesting (Kuhnman 2007). The Contingency Plan for Control of Shellfish Potentially Contaminated by Marine Biotoxins explains the procedure in more detail.

The latest red tide event in the general Suwannee Estuary area occurred from September 2005 until January 2006, in Dixie and Levy counties, resulting in temporary closures of the Cedar Key, Suwannee Sound, Horseshoe Beach and Waccasassa Bay shellfish harvesting areas. This event affected essentially all of the Florida Gulf Coast with no previous event of this magnitude recorded in this region (Kuhnman 2007). From December 18, 2003 to January 1, 2004, Dixie, Levy and Citrus counties also had temporary closures of the Cedar Key, Suwannee Sound and Citrus County Shellfish Harvesting Areas, as well as a precautionary closure of the Withlacoochee Bay Shellfish Harvesting Area due to red tide. In all cases, Contingency Plan protocols were enacted. Following implementation of contingency plan protocols, all areas were re-opened. Prior to the aforementioned blooms, there had not been a Big Bend shellfish harvesting area closure due to red tide since 1979. Prevailing currents of the Big Bend coastal region typically hold blooms offshore (Kuhnman 2007).

Two red tide occurrences have been recorded in the Withlacoochee Bay area (DeHaven 2004a). Levy County was closed for red tide in December 1979, and the area had high red tide counts in June of 1980 but was not closed. The Citrus County Shellfish Harvesting Area, adjacent to and south of Withlacoochee Bay, was closed to red tide in January 2004. Several rounds of water samples were analyzed from Withlacoochee Bay, but none of the samples contained the red tide organism (all samples 0 cells/liter). The shallow coastal shelf and the offshore current patterns, for the most part, prevent red tides from reaching the Withlacoochee Bay.

The causes of red tide bloom and proliferation are still somewhat unknown, but the prevailing through is that the blooms begin offshore and can be supported closer to shore under certain conditions. Controls of bloom dynamics include physical parameters such as temperature and salinity, and nutrient form and availability. Evaluating the significance of a single factor is difficult (Vargo et al. 2008). Vargo (2009) reviewed the historic and current theories for *K. brevis* initiation and maintenance, and identifies 24 hypotheses, falling into several main categories: 1) rainfall and/or riverine flux, 2) benthos or benthic flux, 3) water column hydrodynamics, and 4) chemical/allelopathy related.

Vargo et al. (2004, 2008) evaluated many nutrient sources for their contributions to bloom initiation and maintenance: atmospheric deposition, estuarine flux, N-fixation by the cyanobacteria *Trichodesmium*, zooplankton excretion, benthic flux, and the decay of dead fish. Atmospheric deposition and benthic flux were found to be minor sources to N and P fluxes, while zooplankton and dead fish were possibly significant contributors. The combined estuarine flux from Tampa Bay, Charlotte Harbor, and the

Caloosahatchee River was found to supply varying, but sometimes adequate levels of N and P to support K. brevis populations at moderate, but not high biomass levels. Hu et al. (2006) studied riverine nutrient inputs for major estuaries on the central west Florida Coast (Peace, Caloosahatchee, Alafia, and Suwannee Rivers) and determined that estuarine nutrient flux, even in a high discharge period following hurricanes (when nutrient concentrations also were elevated), could not support significant blooms. They suggested that submarine groundwater discharge accounts for the necessary missing nutrients and can initiate and sustain major bloom events off the coast of central west Florida. In the recent studies examining the role of various nutrient sources in supporting *K. brevis* blooms, a combination of sources is required to maintain a high biomass blooms (>10^6 cells/L).

Hypoxia

No reports of hypoxia in this region were found, nor are any estuary WBIDs impaired for low dissolved oxygen.

Water Quality Studies

Several reports or data were available for the Suwannee, Waccasassa, and Withlacoochee area. If reports were available, they are summarized in this section. If data were available and additional analyses conducted by FDEP, they are also reported in this section. The studies included:

- *1964 study of Waccasassa Bay (Putnam 1967);*
- *Mote Marine Lab study of the Waccasassa and Withlacoochee Rivers 1984-1985;*
- *Project COAST, Dr. Tom Frazer, UF IFAS. Monthly monitoring at ten sites at each of these three estuary systems monthly since roughly 1997. Some data were in Florida STORET, and some were made available to FDEP from Aquatic Preserve staff;*
- *Erin Quinlan (neé Bledsoe) dissertation work in the Suwannee Estuary. Conducted a series of research projects and monitoring, focused on phytoplankton and water quality, from 1996-2002. Results available in various publications. FDEP did not acquire these raw data;*
- *Suwannee River Water Management District (SRWMD). Monthly or quarterly monitoring at several Suwannee Estuary sites 1997-2009, data available in Florida STORET; and*
- *FWRI IMAP program sampled the Suwannee Sound in 2000 and 2003, and Waccasassa Bay in 2001. These were one-time probabilistic sampling programs that provide a snapshot of the water quality and biological communities.*

Putnam 1967 Study of Waccasassa Bay

Hugh Putnam from the University of Florida conducted a 2-year study of Waccasassa Bay in the 1960s. He described the system as a small shallow estuary with extensive salt marshes on the landward fringe. He describes the Waccasassa watershed as very minimally disturbed, with no industrial or domestic waste input. Mean chlorophyll *a* values (not phaeophytin-corrected) for March, April, June, and July were between 15 and 20 µg/L (mg/m^3), with lower concentrations during other months. The mean chlorophyll *a* value he reported for all stations and all dates was 11.95 µg/L (Putnam 1967). He observed a productivity pattern of low phytoplankton production in the river and the open Gulf, and higher production where the river widens into an embayment. Table 9 contains summary information from the study.

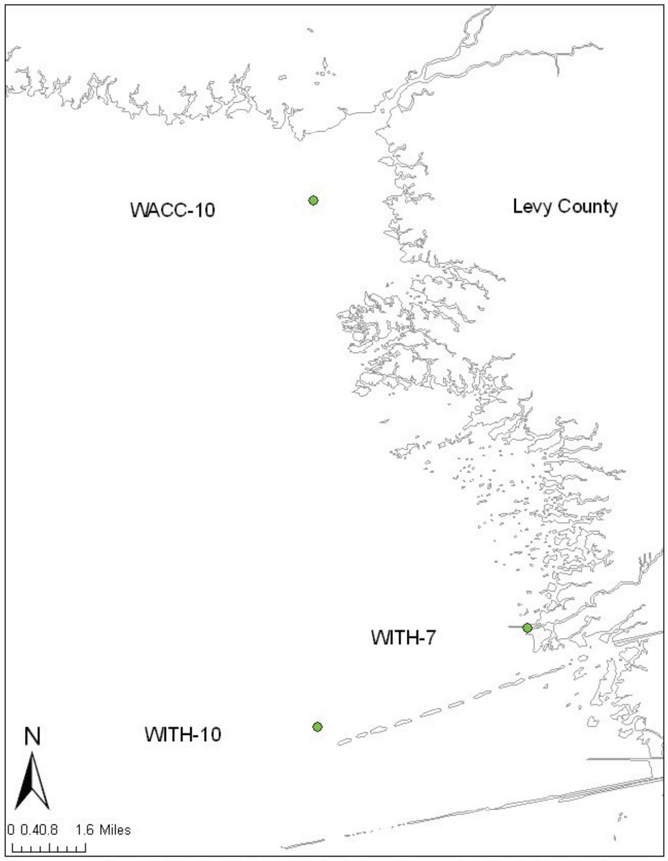
__Table 9. Physical and chemical characteristics of Waccasassa Estuary, as reported in Table 1 of Putnam (1967).__

Tidal range	2.6 ft (0.8 m)	Salinity (ppt)	11.76
Tidal prism $\times 10^6$	166.5 cu ft (4.7 cu m)	DO (mg/l.)	6.6
Mean depth	1.1 m	BOD (mg/l.)	1.4
Secchi disc	0.7 m	Total organic nitrogen (mg/l.)	0.46
Temp. range	25°C	NO_3-N (mg/l.)	0.03 ca.
pH (7.0–8.3)	7.79	Total PO_4-P (mg/l.)	0.06 ca.
Drainage area	570 sq miles (1,476 sq km)		

1984–85 Mote Marine Lab Study of Selected Rivers

Mote Marine Lab conducted a 2-year study of water quality at river and estuary stations of the Waccasassa, Withlacoochee, Crystal, Weeki Wachee, and Aripeka rivers, under contract with the SWFWMD for minimum flows and levels determination. With the exception of the Aripeka sites, those data are in LEGACY STORET and in the IWR database. Data are reported and analyzed in Dixon (1986). Systems discussed here are Waccasassa and Withlacoochee. Metered parameters (salinity, pH, DO, and temperature) were recorded at 10 sites in both systems, with water chemistry (nutrients, turbidity, color, TSS, chlorophyll *a,* phaeophytin *a*, and transparency) collected at 5 stations. Withlacoochee River stations were sampled in 1984 and 1985, but Waccasassa was only sampled in 1985.

The authors' interpretation of this study included the observation that dissolved oxygen levels were lowest in the Waccasassa River and Bay, of all the sampling sites from Waccasassa to Aripeka (Springs Coast) (Dixon 1986). They attribute these levels to the high organic matter and low photosynthetic activity. In their studies, they did not observe submersed vegetation in the Waccasassa River or Bay. The dissolved oxygen in Waccasassa Bay is dependent upon seasonal fluctuations of flow and organic matter. Waccasassa River and Bay was the most colored system of the study, followed by Withlacoochee and then the Springs Coast systems. Suspended solids and turbidity were also highest for the Waccasassa. The authors explain that this observation is likely due to turbulence within the Bay and release of organic particulate matter from the coastal marshes. In the Waccasassa system, there was a direct relationship between TSS and turbidity, and chlorophyll *a* was not a driver of turbidity, though this system had the highest chlorophyll a values of the study, with means of 13.6 and 7.6 µg/L uncorrected chlorophyll *a* for sites seven and ten, respectively (Table 10). Suspended solids and turbidity were lower in the Withlacoochee, and authors hypothesize that wind-driven resuspension was the main driver there. Water clarity data are summarized in Table 10. Water quality data for Waccasassa station 10 and Withlacoochee stations 7 and 10 (Figure 28) were available in LEGACY STORET and are described later in this report.



This map was made on 5/17/10 by Nia Wellendorf, DEP Standards and Assessment Section, for informational purposes.

Figure 28. Locations of sampling sites for which data were analyzed from the 1984-1985 Mote Marine Lab study in the Waccasassa and Withlacoochee estuaries.

DRAFT

Table 10. Summary of water clarity data for estuarine sites off the Waccasassa and Withlacoochee Rivers, from the 1984-85 study by Mote Marine Lab. Values are means and standard deviations, from Tables 48, 49, and 50 of Dixon (1986). Negative river miles indicate distance from the mouth of the river to the estuary sampling point.

Data Type	Waccasassa	Waccasassa	Withlacoochee	Withlacoochee
Station	7	10	7	10
River Mile	-0.16	-2.37	0.00	-4.73
Color (PCU)	45/18	27/9	34/22	11/6
TSS-Surface (mg/L)	22/9	20/9	6/4	9/4
TSS-Mid (mg/L)	36/29	21/10	8/3	10/5
TSS-Bottom (mg/L)	34/23	25/10	8/3	14/12
Turbidity (NTU)	15.4/5.7	12.0/6.2	4.4/1.8	4.2/2.5
Chlorophyll *a*, uncorrected (mg/m^3)	13.6/5.5	7.6/2.9	4.9/2.3	5.2/3.1
Extinction Coefficient (m^{-1})	1.82/0.43	1.81/0.08	0.85/0.43	0.74/0.33
Depth receiving 20% light (m)	0.9	0.9	4.4	2.4

FDEP Data Analysis of the Mote Marine Lab Study

FDEP analyzed the data available in LEGACY STORET from the Mote Marine study. FDEP calculated total nitrogen as the sum of nitrate+nitrite and TKN, if both data points were available. Total nitrogen ranged from 0.4 – 1.2 mg/L, with values for Waccasassa higher than for Withlacoochee (Figure 29; Table 11). Uncorrected chlorophyll *a* values ranged from 1-12 µg/L (Figure 29; Table 11). Total phosphorus data from this study were not analyzed and are not presented here because the accuracy of those data is unknown at this time.

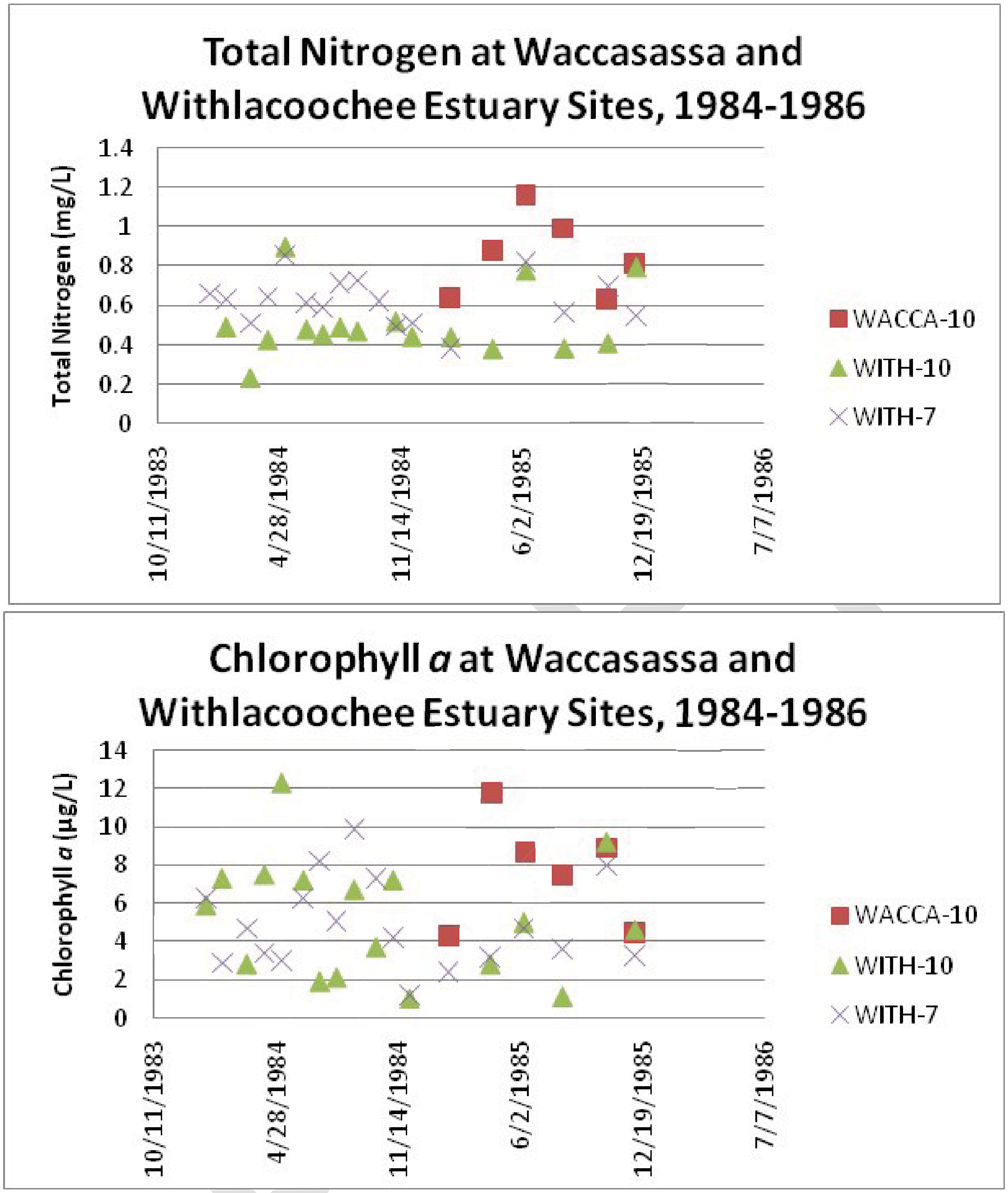


Figure 29. Total nitrogen and chlorophyll a data collected 1984-1985 by Mote Marine Lab for SWFWMD minimum flows and levels studies. Sites as in Figure 72. Chlorophyll a values are not phaeophytin-corrected and were analyzed with the trichromatic method.

Table 11. Annual geometric means of chlorophyll a (uncorrected) and total nitrogen for 1984-1985 study of Waccasassa and Withlacoochee River sites by Mote Marine Lab. Number of samples per year in parentheses.

Site	Total Nitrogen (mg/L)1984	Total Nitrogen (mg/L)1985	Chlorophyll a (µg/L)1984	Chlorophyll a (µg/L)1985
WACCA-10	n/a	0.834 (n=6)	n/a	7.14 (n=6)
WITH-7	0.629 (n=12)	0.588 (n=5)	4.58 (n=12)	3.88 (n=6)
WITH-10	0.471 (n=10)	0.506 (n=6)	4.43 (n=12)	3.65 (n=5)

Project COAST, 1997–Present

Ten sites in each of the Suwannee, Waccasassa, and Withlacoochee estuaries have been sampled monthly since 1997 as part of project COAST led by Dr. Tom Frazer of the University of Florida (Figure 36). This project measures total nitrogen, total phosphorus, chlorophyll *a*, light extinction coefficient, Secchi depth, color, salinity, dissolved oxygen, and temperature. Water quality analyses are conducted at the University of Florida by the LAKEWATCH program. This is the most extensive and comprehensive dataset available for this region.

Project COAST data are summarized as mean concentrations for all estuary stations in Figures 30-32. Results of FDEP analyses will be presented later in this report. The Withlacoochee estuary is included in reports of Project COAST results for Citrus County (see Jacoby *et al.* 2009 for most recent), but no published analyses of the Suwannee or Waccasassa data are available. Dr. Tom Frazer presented some information from his dataset at the FDEP public meeting on 2/23/10, and that information is summarized here.

Overall, the Suwannee, Waccasassa, and Withlacoochee have higher TP and chlorophyll *a* values than the Springs Coast to the south or the Steinhatchee to the north (Figures 31 and 32).

Nutrient limitation studies conducted by Dr. Frazer on monthly samples collected from the Withlacoochee coastal system in 2000-2001 showed that 50% of samples were limited by nitrogen, 27% were limited by phosphorus, 15% were co-limited, and 8% were undetermined (Frazer and Jacoby 2010).

High concentrations of total nitrogen, total phosphorus, and chlorophyll *a* were detected in 1998, 2004, and 2005 (Figures 33-35). 1998 was an El Niño year, with unusually high rainfall and heavy discharge from rivers along the Big Bend, while in 2004 and 2005 numerous hurricanes hit the Florida Big Bend.

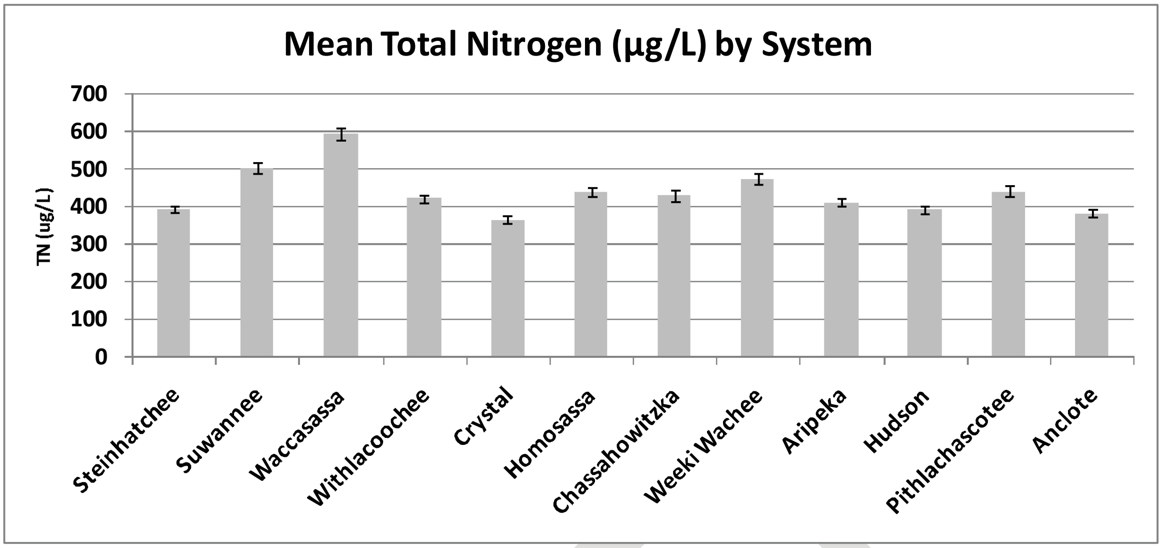


Figure 30. Mean total nitrogen (µg/L) across all sample years (approx. 1997-2009) and all estuary sites (excludes freshwater sites). From Frazer and Jacoby (2010).

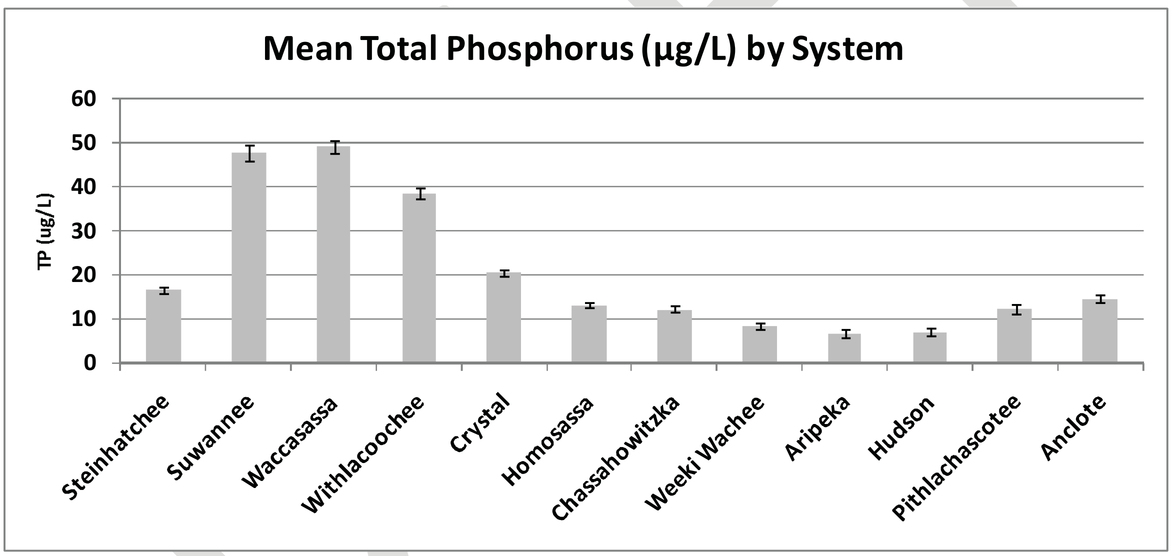


Figure 31. Mean total phosphorus (µg/L) across all sample years (approx. 1997-2009) and all estuary sites (excludes freshwater sites). From Frazer and Jacoby (2010).

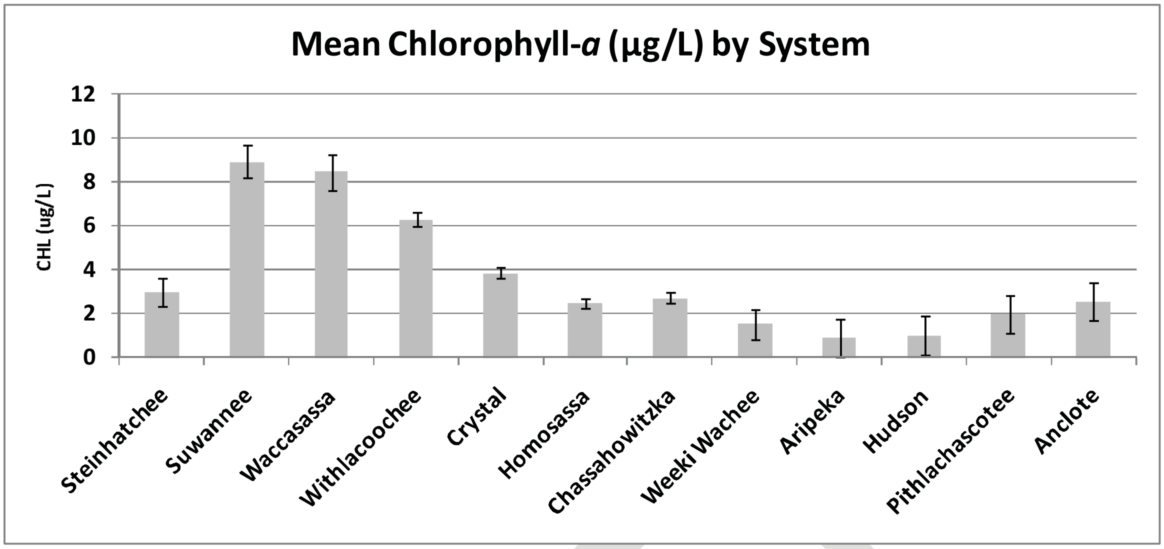


Figure 32. Mean chlorophyll a (µg/L) across all sample years (approx. 1997-2009) and all estuary sites (excludes freshwater sites). From Frazer and Jacoby (2010).

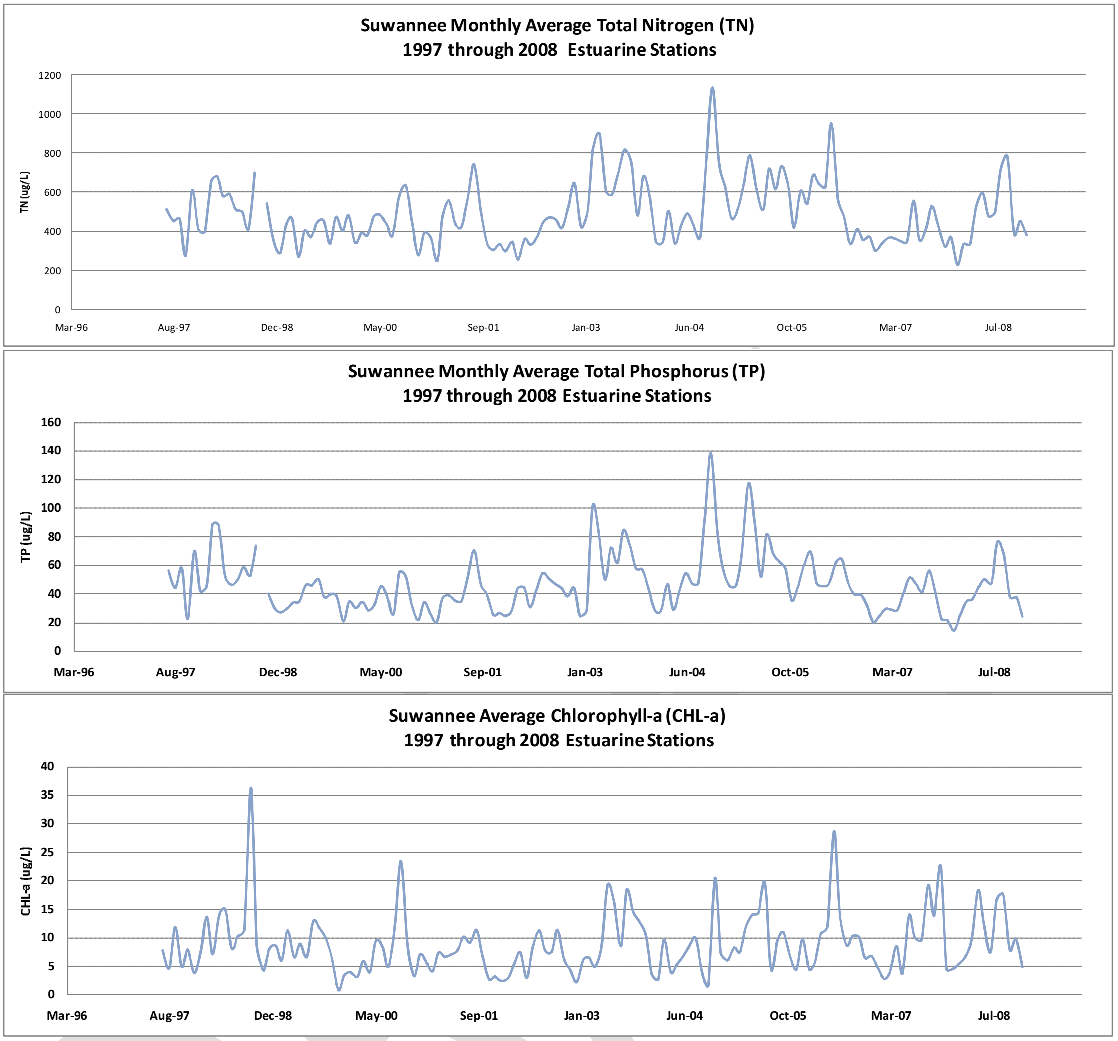


Figure 33. Long term average data for the Suwannee Estuary, including all estuary sites (excludes freshwater sites) (from Frazer and Jacoby 2010).

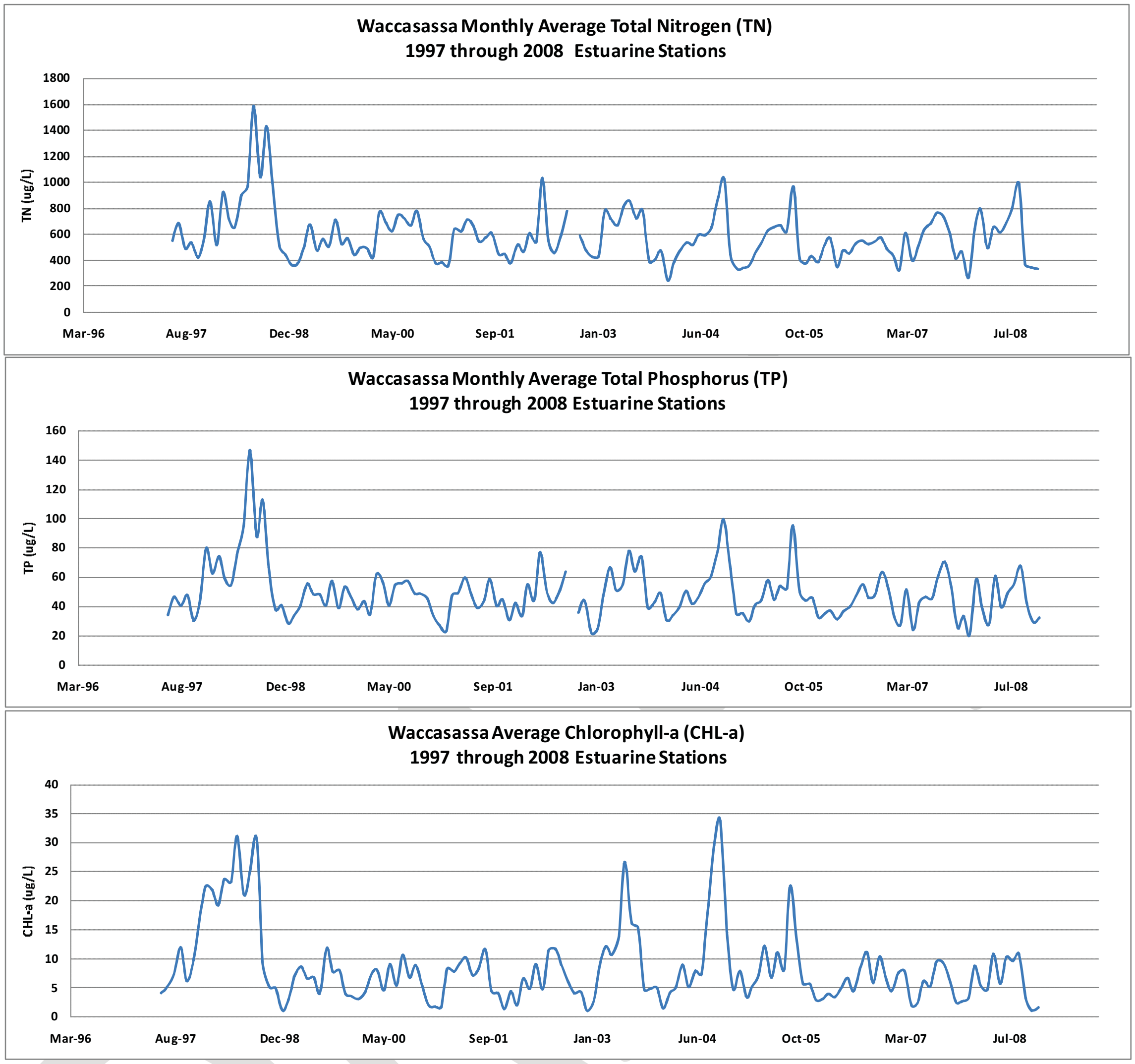


Figure 34. Long term average data for the Waccasassa Estuary, including all estuary sites (excludes freshwater sites). From Frazer and Jacoby (2010).

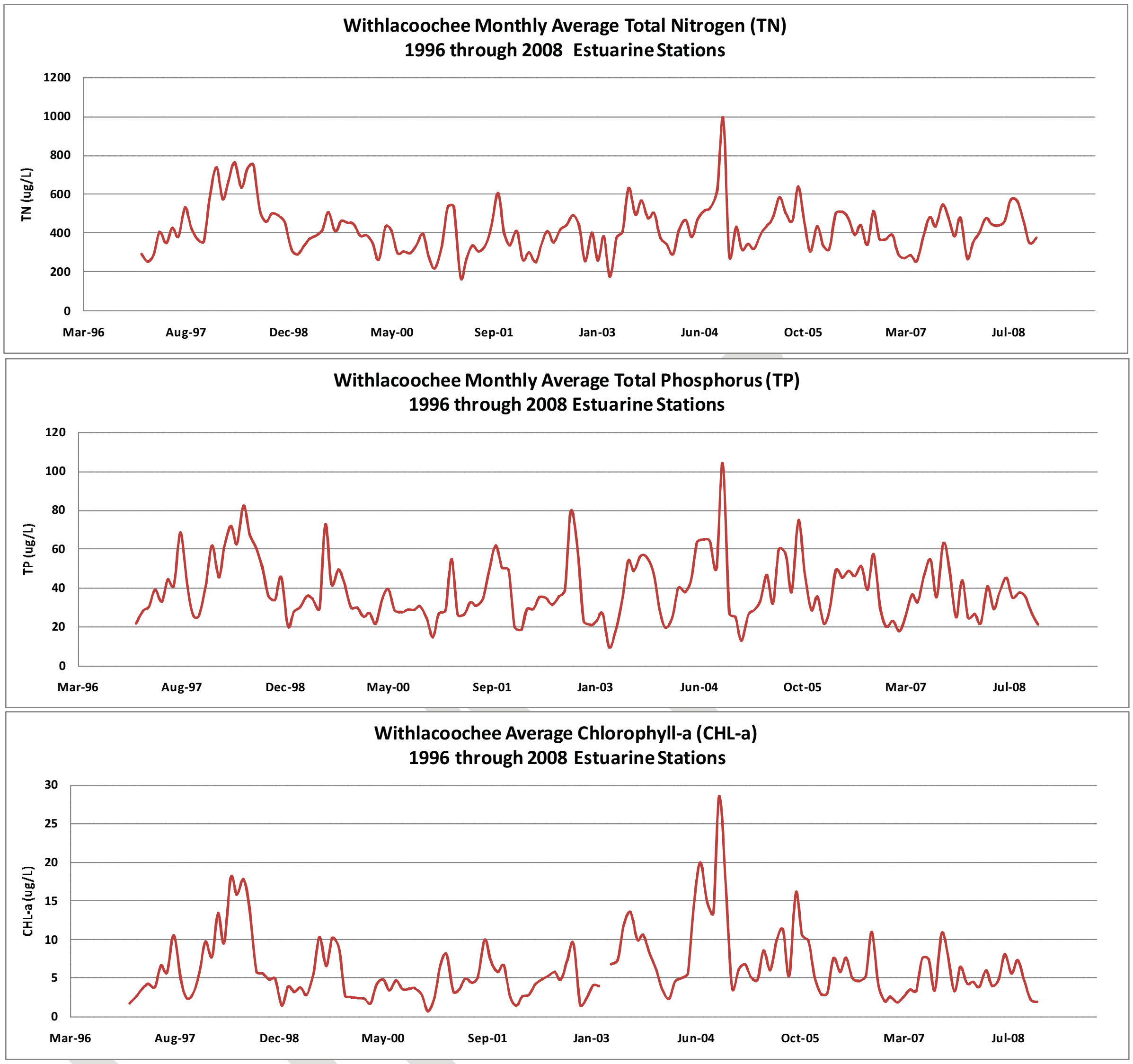


Figure 35. Long term average data for the Withlacoochee Estuary, including all estuary sites (excludes freshwater sites). From Frazer and Jacoby (2010).

Data Analyses by FDEP

Project COAST data were available in STORET through 2006 for the Withlacoochee sites (with 2005 data absent), and datasets through 2007 for the Suwannee and Waccasassa sites were obtained from FDEP Aquatic Preserve staff (Table 12). Annual geometric means of total nitrogen, total phosphorus, and chlorophyll *a* (uncorrected) were calculated and plotted for each station each year (Figures 37-45). The following sites were excluded from calculation of geometric means due to predominantly fresh nature (mean salinity < 3 ppt): Suwannee sites 1 and 2, Waccasassa site 1, and Withlacoochee sites 2 and 3. From these plots of annual geometric means through time, it is clear that the sites closest to the river mouths have highest nutrient concentrations. On the Suwannee, sites 3, 4, 5, and 6 have higher TN and TP concentrations than sites 7, 8, 9, and 10, which are further offshore (Figures 37 and 40). Geometric mean TN ranged from 400-800 µg/L in nearshore sites and 250-400 µg/L in offshore sites, and geometric mean TP ranged from 40-80 µg/L in nearshore sites and 20-40 µg/L in offshore sites for the Suwannee.

The zonation was more gradual in the Waccasassa, with geometric means ranging from 400-700 µg/L for TN and 20-60 µg/L for TP (Figures 38 and 41). Zonation in the Withlacoochee was also gradual, with geometric means ranging from 250-500 µg/L for TN and 20-40 µg/L for TP (Figures 39 and 42). The geographic zonation is different for chlorophyll *a* due to the interaction with color, described below.

There is a clear negative relationship between salinity and TN and between salinity and TP for all three systems, though the relationship is weakest for the Waccasassa (Figure 46 and 47). The strength of these relationships can likely be explained by the level to which the estuaries are dominated by the rivers that feed them or the locations of the sites (Figure 36). If the river is the dominant force in the estuary and there is a relatively short holding time, as for these systems, then the nutrient concentration is largely a function of dilution, as is salinity. The positive relationships between TN and color for these systems (shown for the Suwannee in Figure 49) also demonstrate that dilution.

Waccasassa Bay is somewhat more enclosed than the other two, and may be restricted by currents such that the residence time is longer. Waccasassa Bay is very shallow and wind driven circulation may also be a factor (Putnam 1967, Dixon 1986). TN concentrations are fairly consistent throughout the study area of Waccasassa Bay despite salinity levels, except for the high flow year of 1998, which brought unusually high nutrient concentrations into the bay (Figure 50).

For chlorophyll *a*, there is a peak in concentration (~10-12 µg/L) at mid-salinity (see Suwannee example in Figure 48 bottom panel) because that is the region in which phytoplankton are no longer limited by flow and tannins, but there are sufficient nutrients to sustain higher chlorophyll *a* levels than in the open nearshore area. This pattern is consistent with results of Quinlan (2003).

These relationships suggest that nutrient criteria could and should be linked to salinity in these river-driven systems. Salinity values at individual sites vary greatly within and between years (Table 13), such that it would not be appropriate to place geographic restrictions on salinity divisions for the purpose of assigned numeric criteria. However, relationships between nutrients and salinity are consistent from year to year, as shown for the Suwannee in Figure 48. These data suggest that a continuous salinity function may be appropriate for the Suwannee and Withlacoochee estuaries.

Table 12. Number of times each of 10 stations were sampled in each estuary system each year for Project COAST, directed by Dr. Tom Frazer at UF.

Year	Suwannee	Waccasassa	Withlacoochee
1996	Not sampled	Not sampled	1
1997	6	7	12
1998	12	12	12
1999	12	12	12
2000	12	12	11
2001	12	12	12
2002	12	12	12
2003	12	12	12
2004	12	12	12
2005	12	12	Not available
2006	12	12	12
2007	9	9	Not available

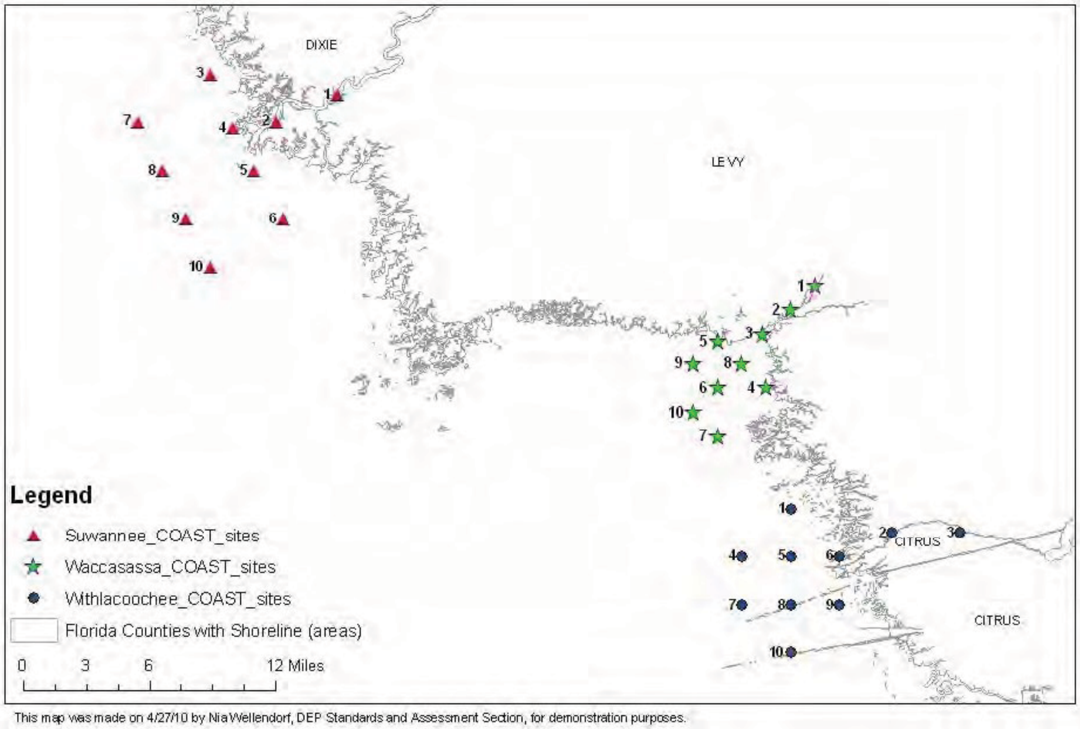


Figure 36. Project COAST sampling sites in the Suwannee, Waccasassa, and Withlacoochee estuaries.

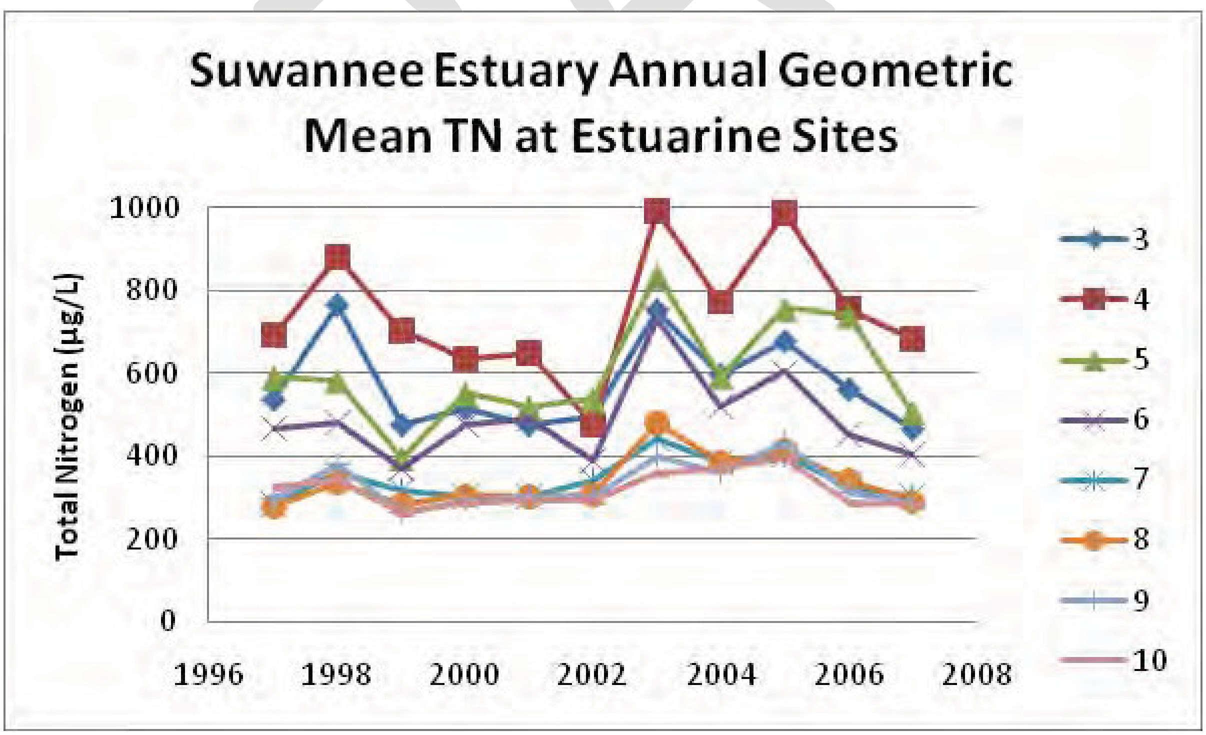


Figure 37. Mean TN at Project COAST Suwannee estuarine sites.

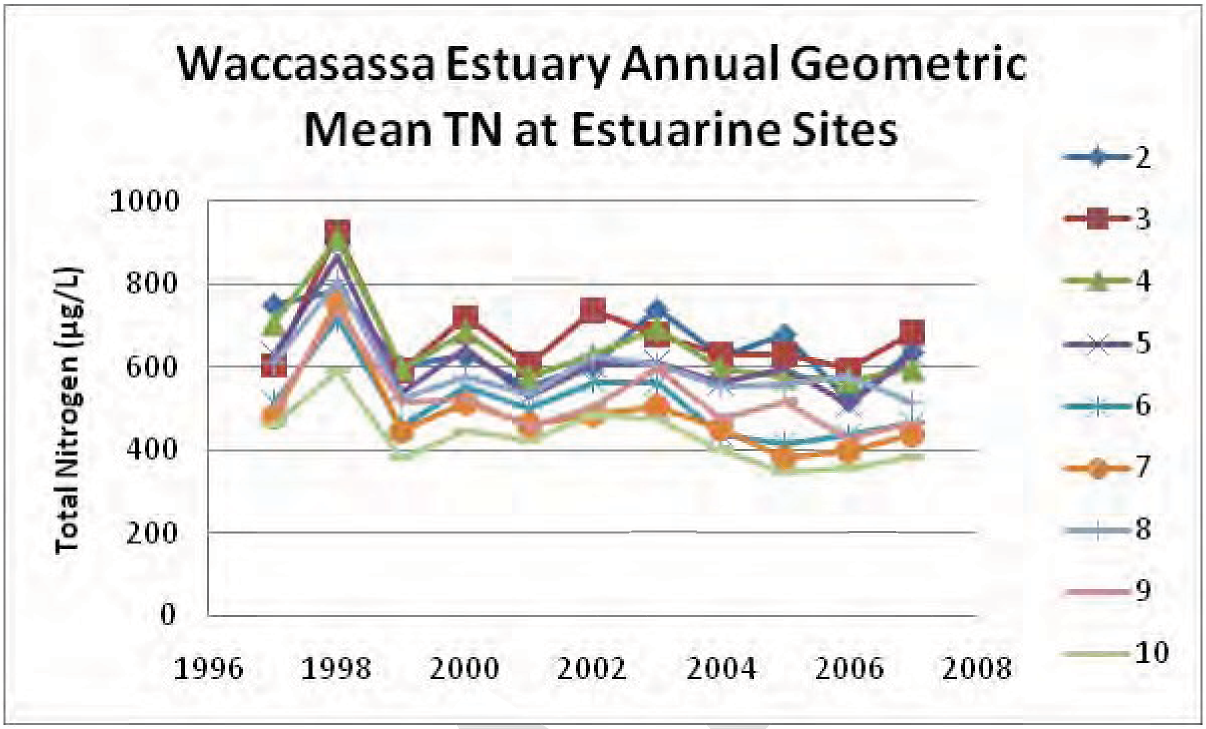


Figure 38. Mean TN at Project COAST Wacasassa estuarine sites.

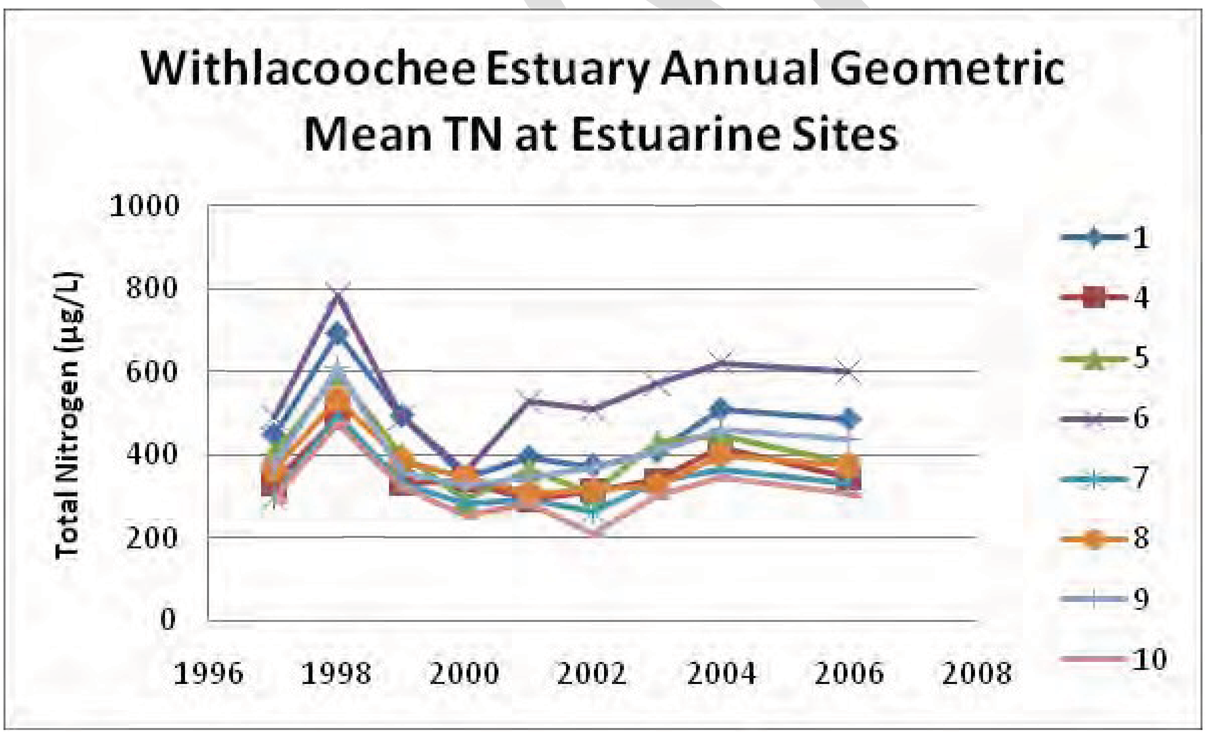


Figure 39. Mean TN at Project COAST Withlacoochee estuarine sites.

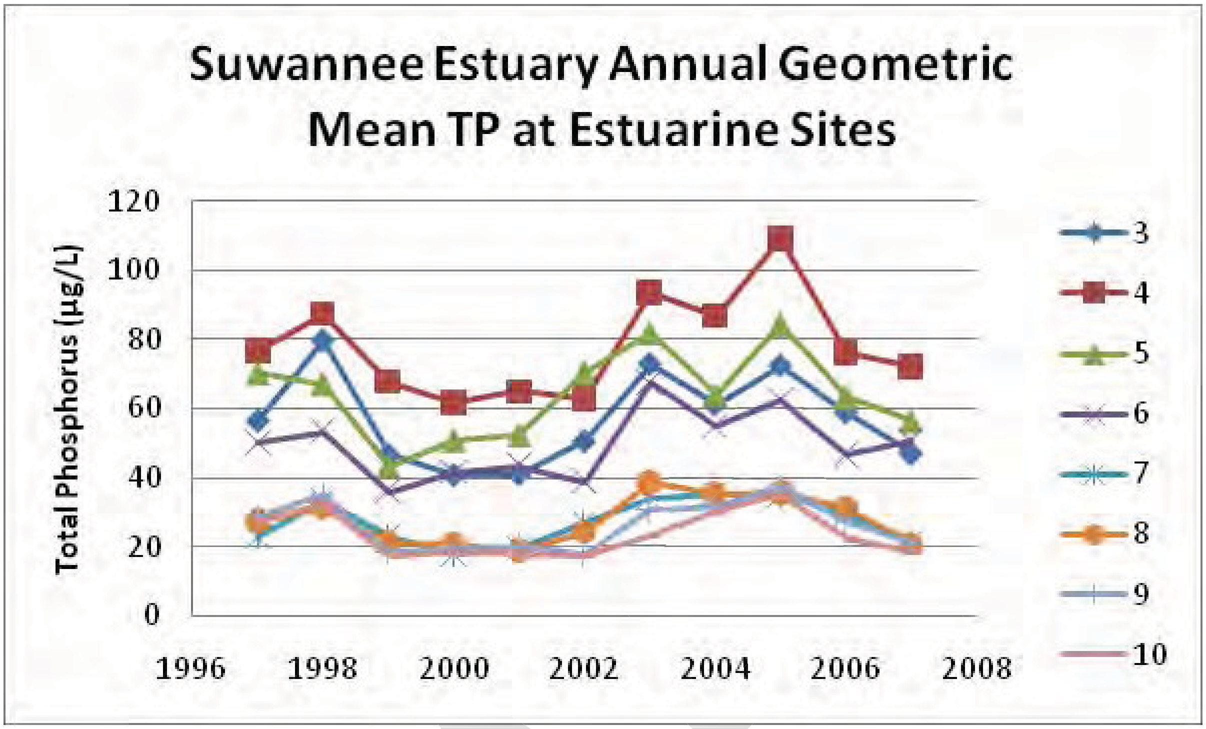


Figure 40. Mean TP at Project COAST Suwannee estuarine sites.

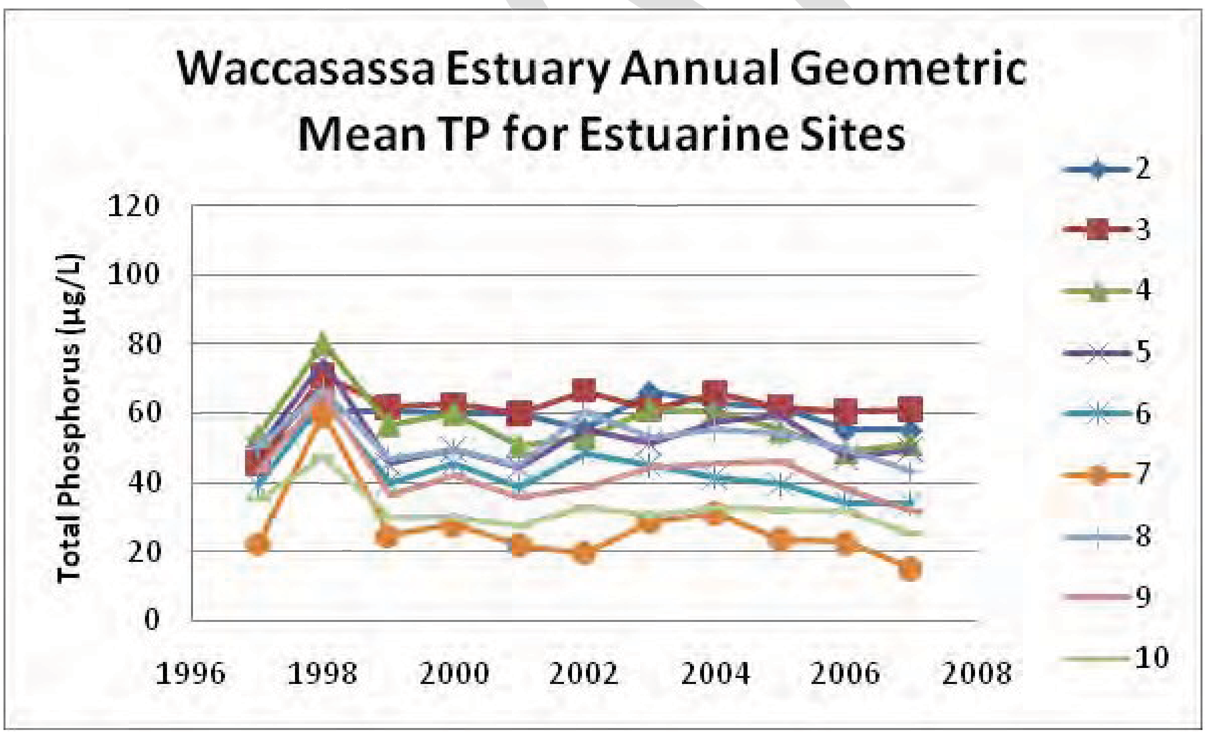


Figure 41. Mean TP at Project COAST Waccasassa estuarine sites.

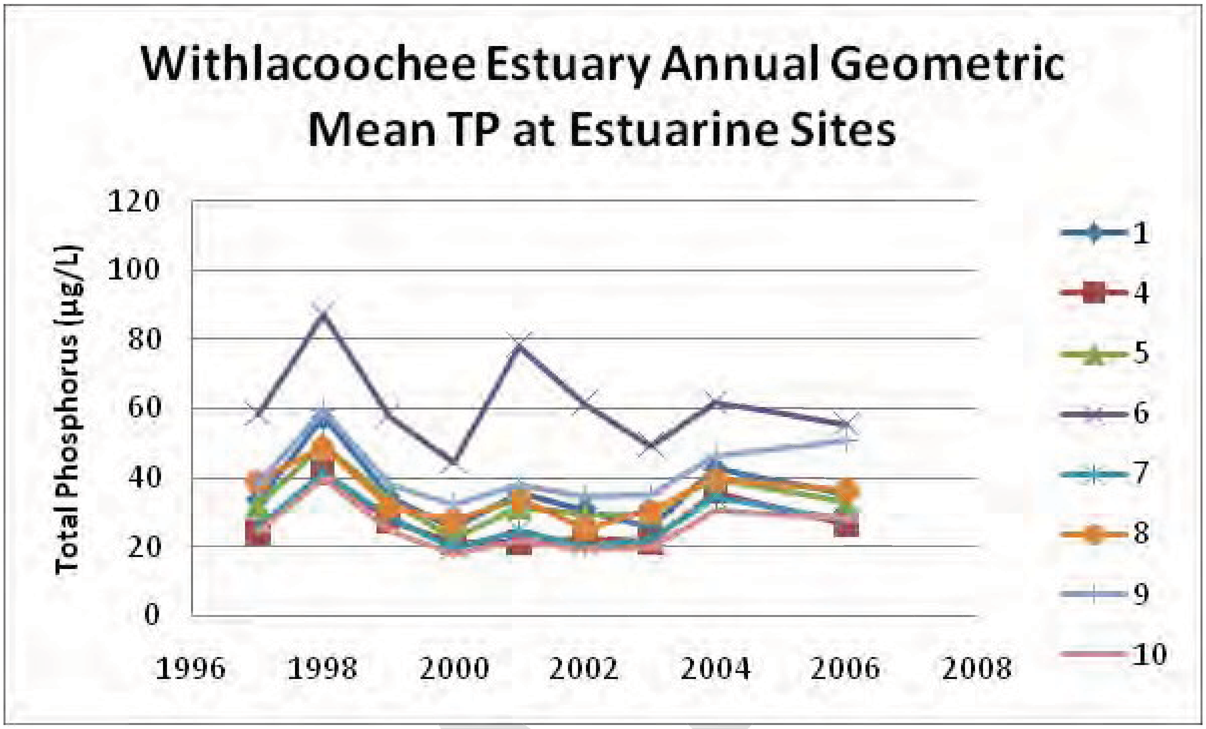


Figure 42. Mean TP at Project COAST Withlacoochee estuarine sites.

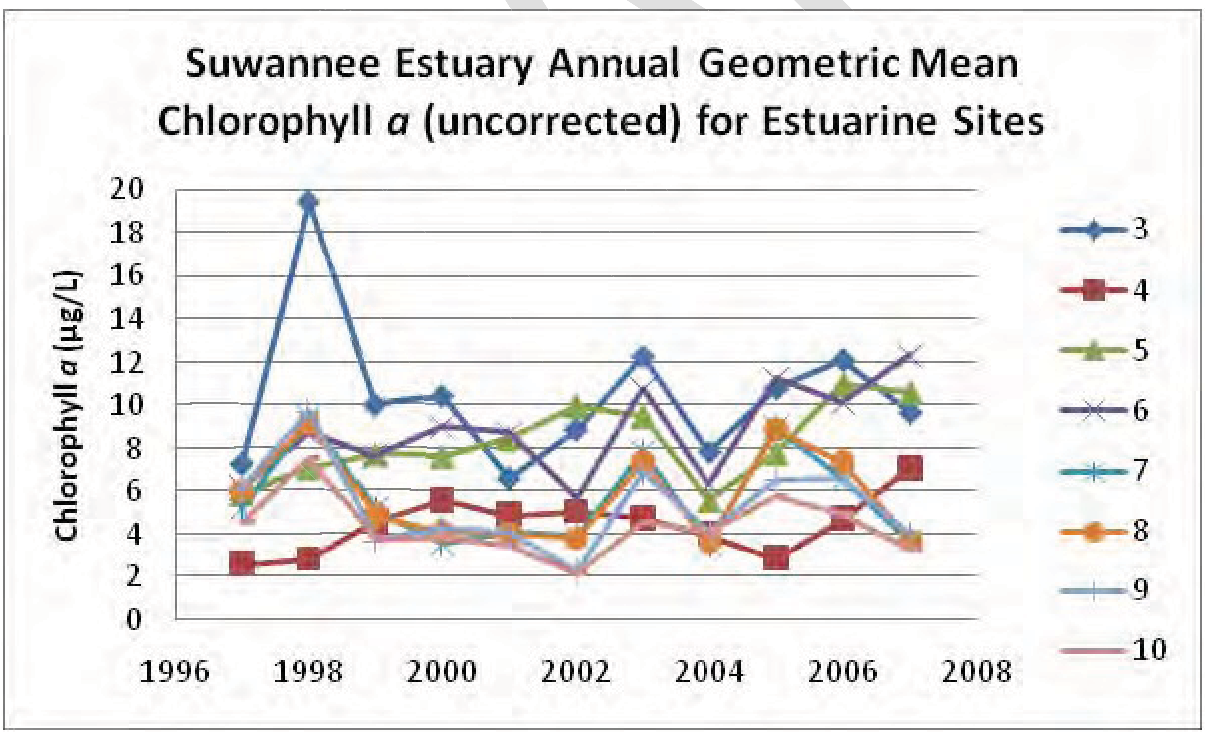


Figure 43. Mean chlorophyll a at Project COAST Suwannee estuarine sites.

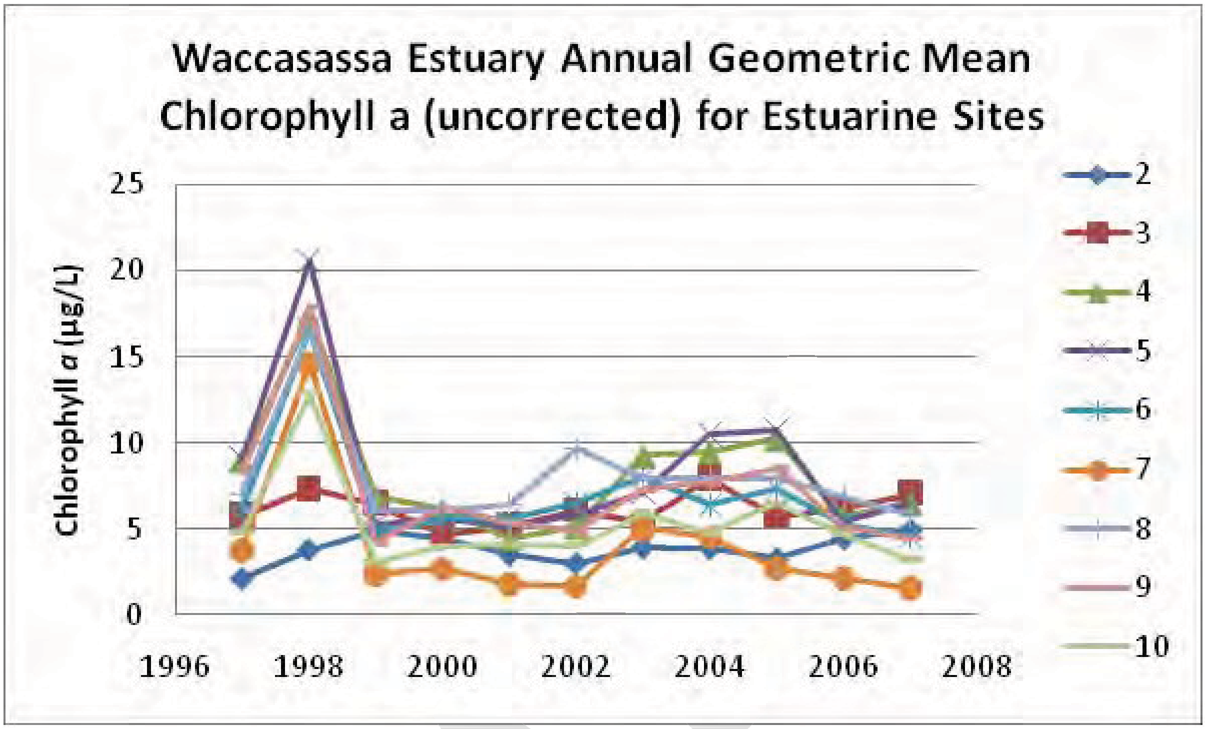


Figure 44. Mean chlorophyll a at Project COAST Waccasassa estuarine sites.

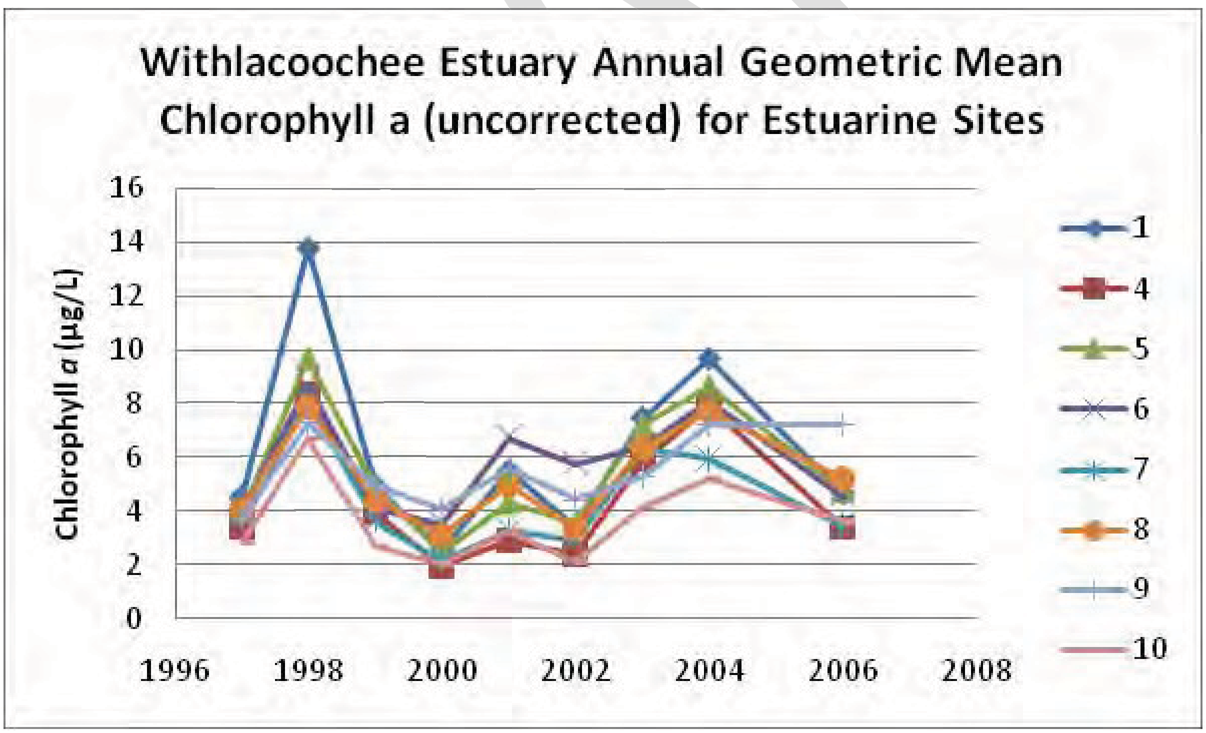


Figure 45. Mean chlorophyll a at Project COAST Withlacoochee estuarine sites.

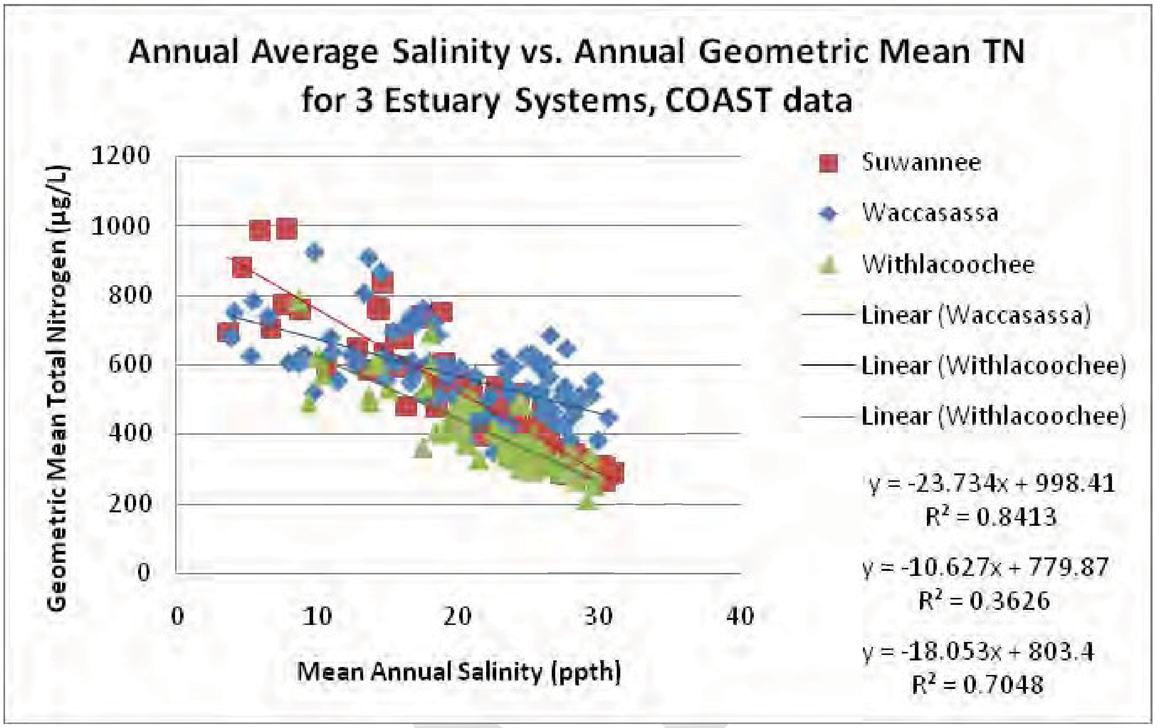


Figure 46. Stations 1 and 2 excluded for Suwannee, Station 1 excluded for Waccasassa, and Stations 2 and 3 excluded for Withlacoochee. R^2= 0.84 for Suwannee, R^2= 0.36 for Waccasassa, R^2= 0.70 for Withlacoochee.

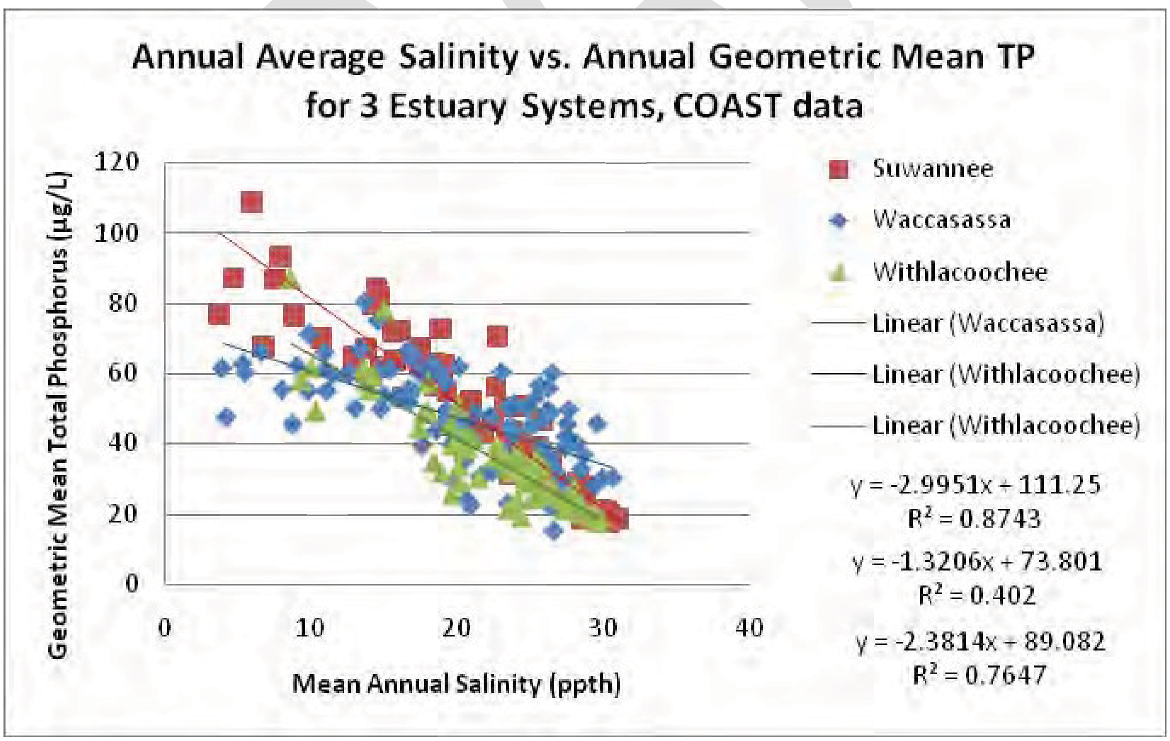


Figure 47. Stations 1 and 2 excluded for Suwannee, Station 1 excluded for Waccasassa, and Stations 2 and 3 excluded for Withlacoochee. R^2= 0.87 for Suwannee, R^2= 0.40 for Waccasassa, R^2= 0.76 for Withlacoochee.

Table 13. Average, minimum, and maximum salinity values (parts per thousand) for Suwannee Estuary sites sampled by Project COAST for each year and all data for each site. Sample sizes as in Table 10.

Station 3				Station 4				Station 5				Station 6			
Year	Average	Minimum	Maximum	Year	Average	Minimum	Maximum	Year	Average	Minimum	Maximum	Year	Average	Minimum	Maximum
1997	18.50	8.00	26.00	1997	3.67	0.00	9.00	1997	10.67	7.00	15.00	1997	21.00	14.00	31.00
1998	14.22	2.00	26.30	1998	4.68	0.00	22.90	1998	13.70	0.00	25.70	1998	16.28	2.00	26.00
1999	22.47	14.40	34.30	1999	6.73	0.60	26.90	1999	21.77	10.30	30.60	1999	23.89	11.70	29.70
2000	24.28	16.20	28.60	2000	14.72	3.40	22.76	2000	20.54	13.80	26.80	2000	23.41	20.77	28.40
2001	23.46	9.46	29.79	2001	12.85	0.15	23.29	2001	20.96	14.02	28.17	2001	23.79	14.56	30.55
2002	23.30	13.33	25.50	2002	18.50	2.26	25.24	2002	22.75	13.52	26.46	2002	25.57	16.77	32.24
2003	18.86	10.41	28.70	2003	7.88	0.04	20.93	2003	14.69	0.30	29.61	2003	17.52	3.64	27.73
2004	18.51	5.50	24.31	2004	7.55	0.05	19.25	2004	15.72	0.52	25.27	2004	19.26	1.21	26.16
2005	16.08	0.09	30.14	2005	5.92	0.09	15.70	2005	14.48	0.04	26.85	2005	19.06	4.83	28.45
2006	18.98	3.06	29.26	2006	8.79	0.06	21.18	2006	17.42	9.02	27.80	2006	20.85	10.76	29.15
2007	25.91	21.66	29.77	2007	15.61	6.58	27.91	2007	22.63	15.49	29.24	2007	24.52	17.91	28.62
all data	20.42	0.09	34.30	all data	9.86	0.00	27.91	all data	18.02	0.00	30.60	all data	21.34	1.21	32.24

Station 7				Station 8				Station 9				Station 10			
Year	Average	Minimum	Maximum	Year	Average	Minimum	Maximum	Year	Average	Minimum	Maximum	Year	Average	Minimum	Maximum
1997	28.33	22.00	31.00	1997	27.67	23.00	33.00	1997	28.33	24.00	33.00	1997	28.50	22.00	35.00
1998	23.56	15.00	32.20	1998	23.67	8.00	31.40	1998	24.03	12.00	30.80	1998	25.07	10.00	32.00
1999	28.05	15.50	34.60	1999	28.18	15.40	34.00	1999	29.84	20.70	34.10	1999	30.38	20.00	34.50
2000	30.43	27.40	33.00	2000	30.14	26.80	32.40	2000	30.39	25.60	33.58	2000	31.00	27.03	34.30
2001	29.43	23.01	33.60	2001	28.46	22.26	32.72	2001	28.81	22.06	32.18	2001	29.61	26.02	32.36
2002	28.26	23.26	31.23	2002	28.84	21.10	31.65	2002	29.95	22.96	32.84	2002	30.18	24.54	33.13
2003	24.12	17.30	30.82	2003	23.20	14.72	31.41	2003	25.10	19.68	31.45	2003	26.91	21.99	31.51
2004	24.70	17.53	29.64	2004	24.96	10.00	30.48	2004	25.62	14.40	29.03	2004	25.49	8.49	30.26
2005	24.35	17.11	32.70	2005	25.50	16.74	30.90	2005	25.76	13.03	30.77	2005	26.50	9.29	31.41
2006	26.74	16.43	31.79	2006	26.20	19.32	31.05	2006	26.34	18.87	31.81	2006	27.31	20.27	33.03
2007	29.57	24.86	33.24	2007	29.67	25.89	32.73	2007	29.78	26.50	32.76	2007	30.66	27.12	32.90
all data	26.95	15.00	34.60	all data	26.85	8.00	34.00	all data	27.56	12.00	34.10	all data	28.28	8.49	35.00

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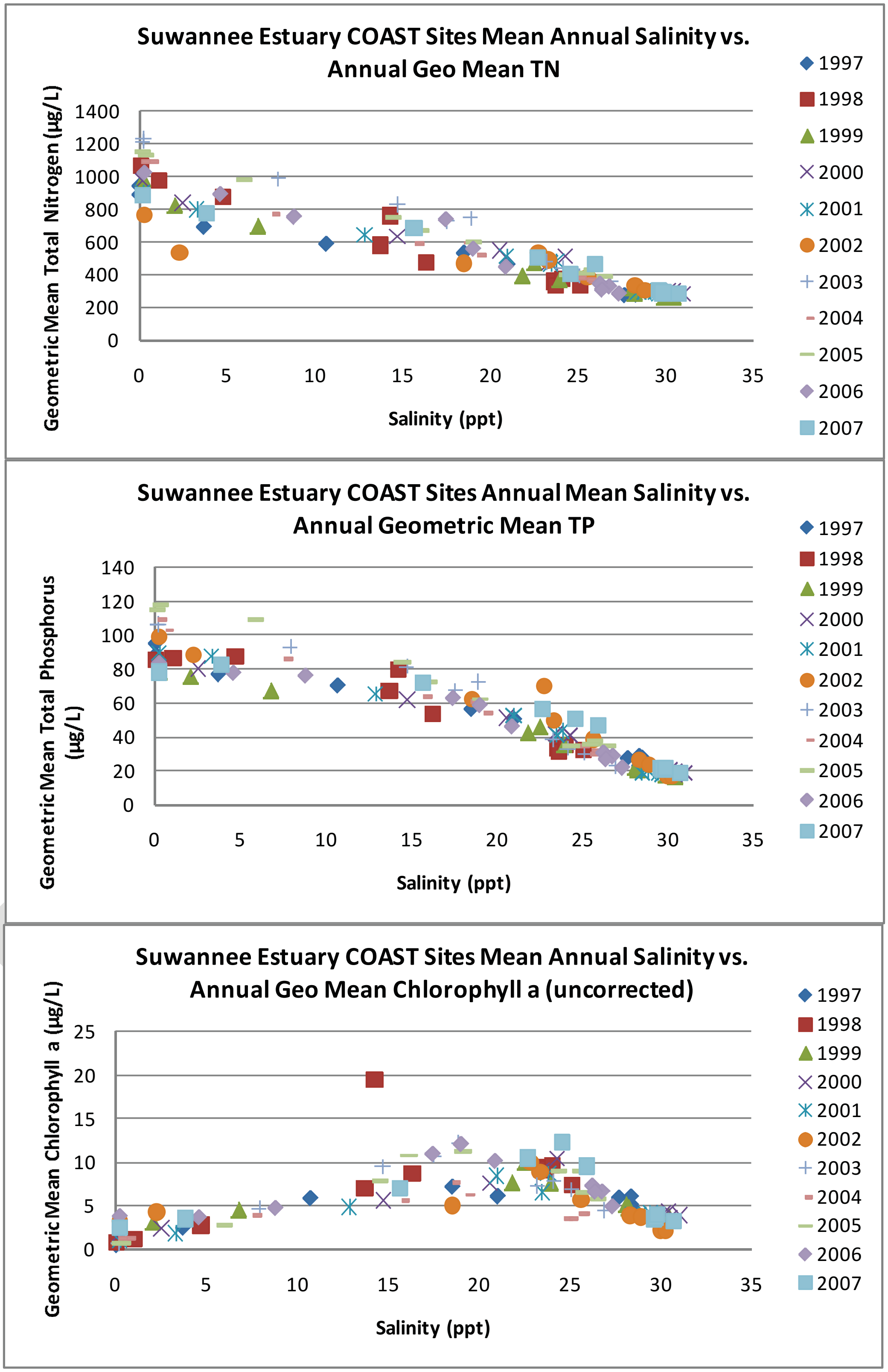


Figure 48. Average annual salinity for each site plotted against the annual geometric means for total nitrogen, total phosphorus, and chlorophyll a for each site sampled for Project Coast 1997-2007.

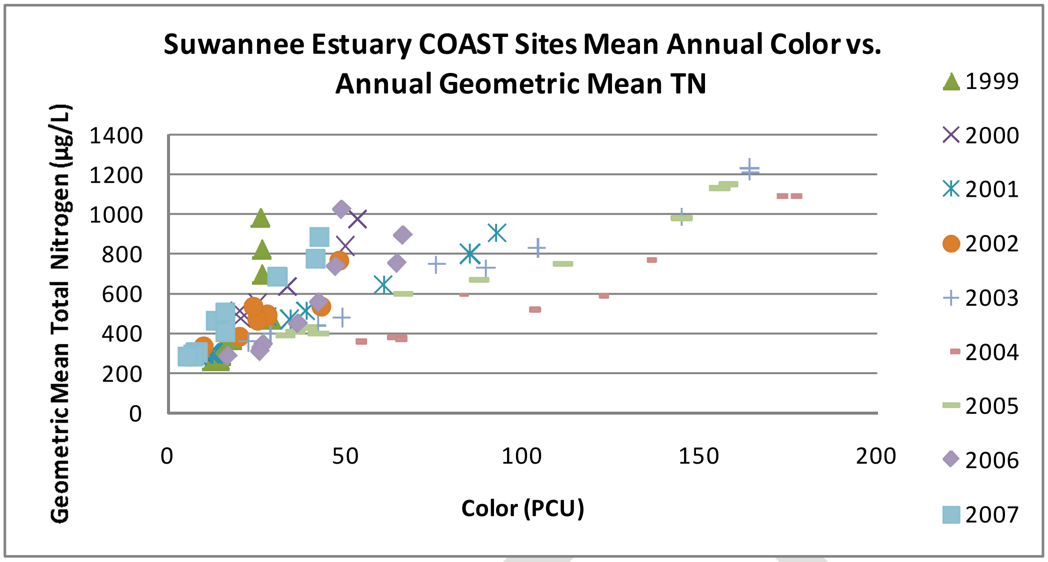


Figure 49. Color vs. TN in the Suwannee estuary.

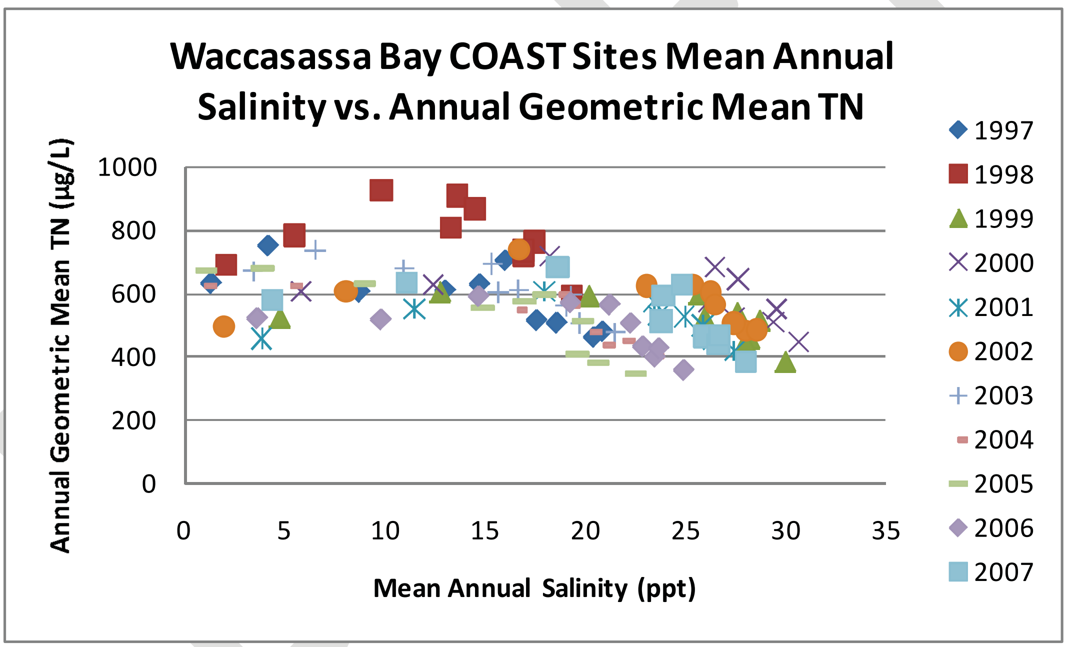


Figure 50. Salinity vs. TN in Waccasassa Bay.

For most of the study period, only uncorrected chlorophyll *a* was analyzed. However, both uncorrected and phaeophytin-corrected chlorophyll *a* were reported for 9 months of 2007 for the Suwannee and Waccasassa estuaries only. For both estuary systems, the two measurements are very highly correlated (Figures 51 and 52), and the geometric means were typically within 1 µg/L of each other (Table 14). This comparison is important because FDEP prefers to use phaeophytin-corrected values for assessment purposes.

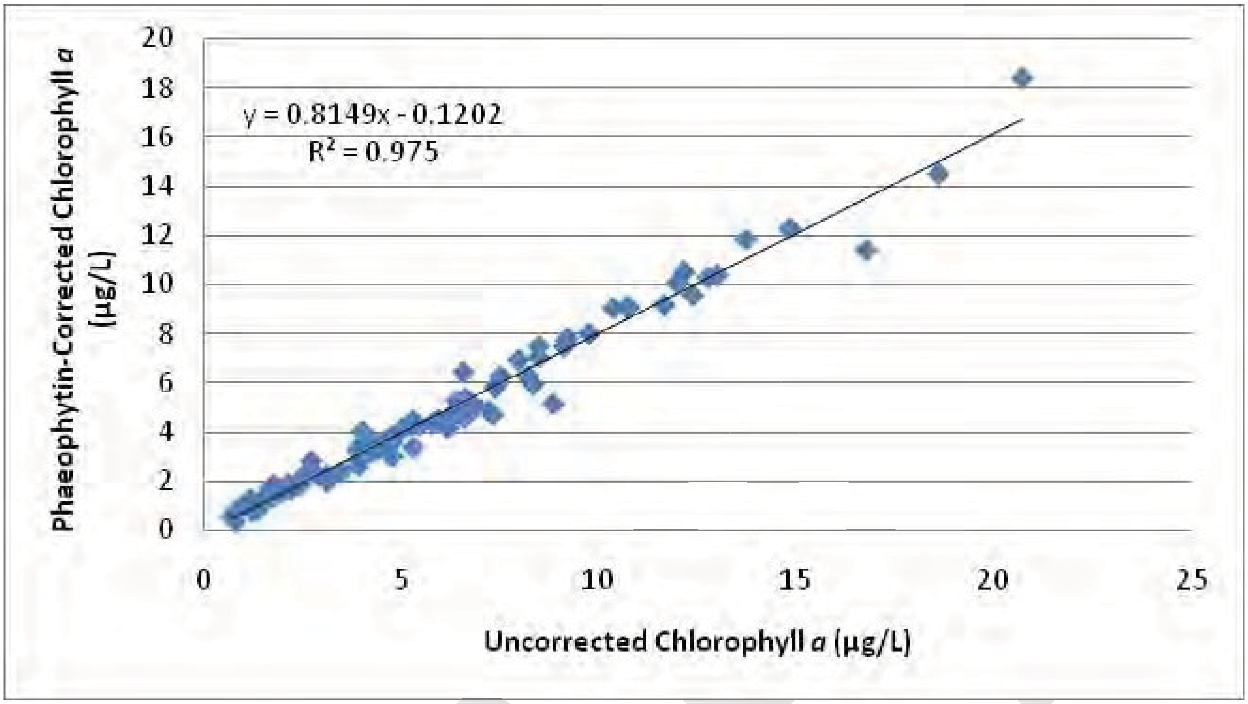


Figure 51. Comparison of uncorrected and phaeophytin-corrected chlorophyll a (µg/L) for 10 sites in the Waccasassa Estuary for the first nine months of 2007.

Table 14. Comparison between station geometric means for the first 9 months of 2007 (n = 9 monthly samples) uncorrected and phaeophytin-corrected chlorophyll a (µg/L) measurements for the Waccasassa and Suwannee Estuaries.

Site	Waccasassa Estuary Uncorrected	Waccasassa Estuary Corrected	Waccasassa Estuary % Difference	Suwannee Estuary Uncorrected	Suwannee Estuary Corrected	Suwannee Estuary % Difference
1	4.71	3.73	21%	2.62	1.65	37%
2	4.95	3.81	23%	3.61	2.54	29%
3	7.07	5.41	23%	9.65	7.76	20%
4	6.50	4.86	25%	7.12	4.80	33%
5	6.61	5.18	22%	10.58	8.73	17%
6	4.54	3.73	18%	12.35	10.67	14%
7	1.50	1.05	30%	3.64	2.88	21%
8	5.86	4.92	16%	3.66	3.05	17%
9	4.46	3.77	16%	4.04	3.36	17%
10	3.27	2.69	18%	3.33	2.82	15%

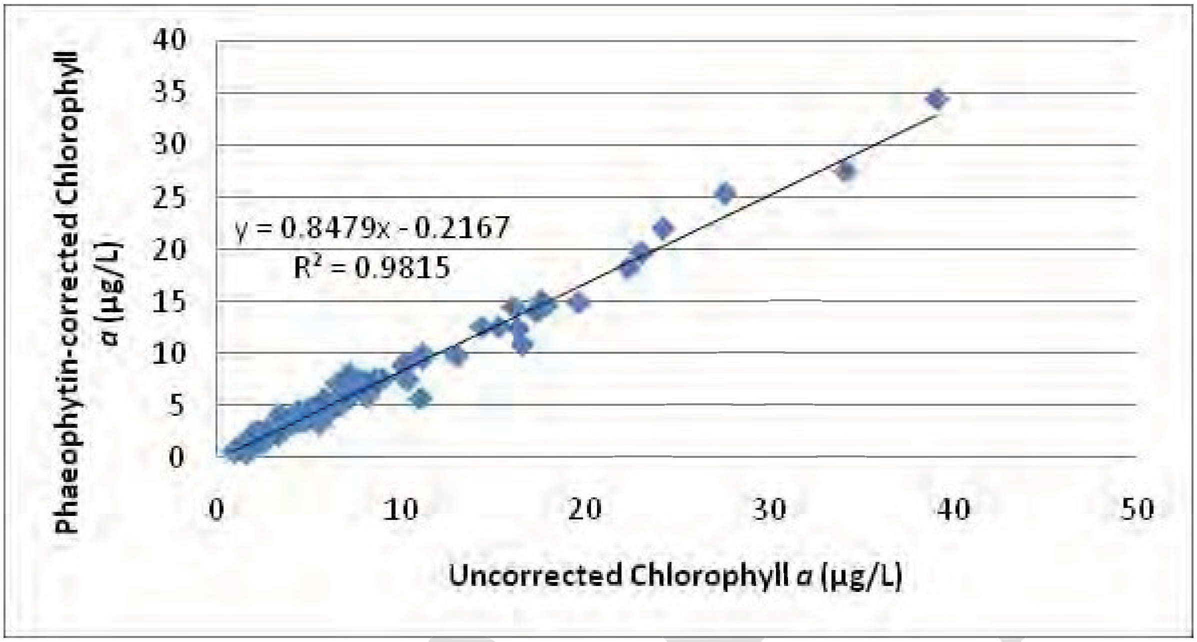


Figure 52. Comparison of uncorrected and phaeophytin-corrected chlorophyll a (µg/L) for 10 sites in the Suwannee Estuary for the first nine months of 2007.

Quinlan Dissertation on Water Quality and Phytoplankton in the Suwannee Estuary

For her dissertation work, Erin (Bledsoe) Quinlan conducted studies of water quality, phytoplankton, and zooplankton in the Suwannee Estuary, and her results are available in various publications (Bledsoe and Phlips 2000, Bledsoe *et al.* 2004, Quinlan 2003, Quinlan and Phlips 2007, Quinlan *et al.* 2009). She collected water quality samples via an integrated tube (3 m max) for the following analyses: chlorophyll, bacteria, TP, SRP, TN, NO3, NO2, NH4, Silica, and nutrient limitation experiments. She measured salinity, temperature, DO, dissolved color, suspended solids, and flushing rates. She also sampled phytoplankton, zooplankton, macroalgae, and periphyton. These collections were made in various combinations at various time intervals and frequency throughout the study period 1996-2003. Water quality analyses were conducted in the NELAC-certified lab of Dr. Phlips with FDEP and EPA-approved analyses. For a short period in the beginning of her studies, Dr. Quinlan collected grab samples along with the integrated tube samples, and she said that most of the study area is so well-mixed that results were comparable between the two collection methods.

Her studies showed a clear gradient of phytoplankton community from the dark water river to the open estuary. She separated the study area into three regions: the river, reef, and nearshore regions (Figure 53).

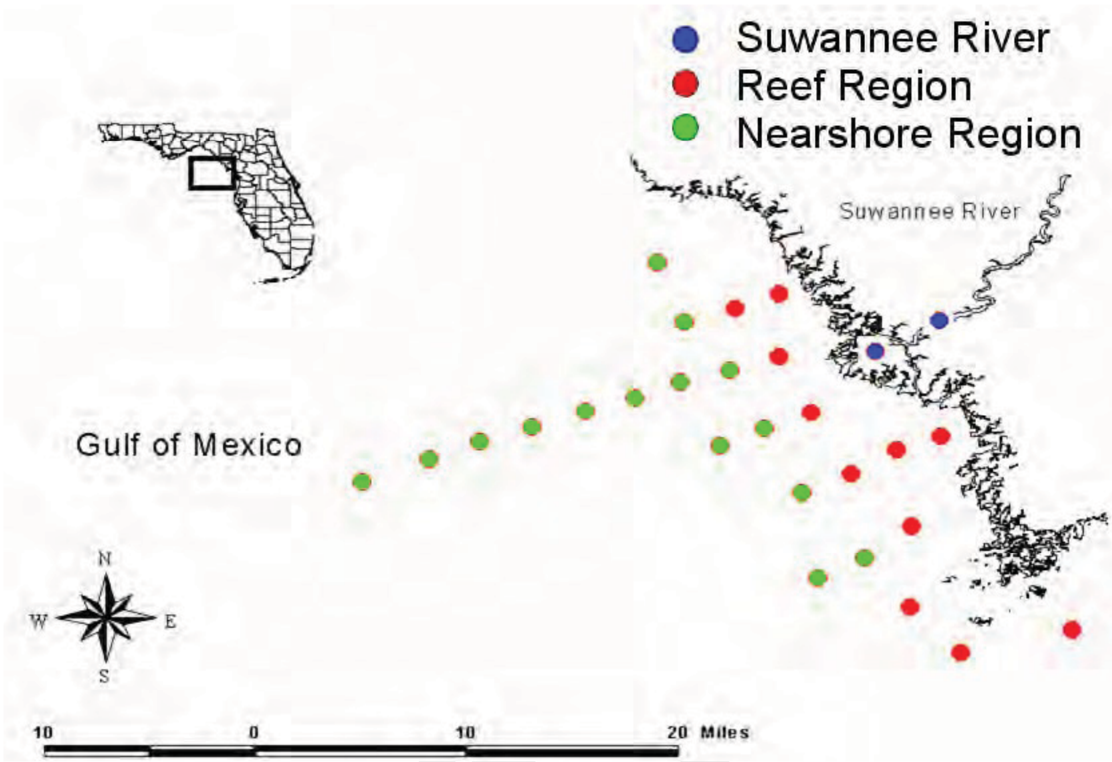


Figure 53. Sampling sites used by Quinlan and Phlips, 1996-2003.

The limiting nutrient varied by both the location and river flow. Nitrogen was the primary limiting nutrient in the reef region at all times. During periods of average riverine discharge, nitrogen was also limiting outside the oyster reefs in the nearshore region. During periods of low riverine discharge, phosphorus and nitrogen were co-limiting in the nearshore region. An example of this limitation can be seen in the chlorophyll *a* estimates of phytoplankton biomass. The reef region typically had higher chlorophyll a values (>10 µg/L) than the nearshore region (<5 µg/L). The nearshore region experienced a significant increase in chlorophyll *a* to nearly 10 µg/L during the average-high discharge season, in comparison to the low flow years in which levels are around 3 µg/L (Table 15). This contrast suggests that the nutrient rich riverine plume moving farther offshore during high discharge supplied additional nutrients for phytoplankton growth.

Table 15. Mean annual values for phytoplankton abundance (chlorophyll a) in the "reef" and "nearshore" regions of the Suwannee River estuary, and discharge-weighted nutrient loading rates (g s^{-1} of TN and TP) from the Suwannee River. Standard errors are in parentheses (Table 2-1 of Quinlan 2003).

	Reef chl a µg L^{-1}	Nearshore chl a µg L^{-1}	TN Load g N s^{-1}	TP Load g P s^{-1}	Discharge
4/98-3/99	18 (2.1)	9.8 (0.84)	320 (150)	35 (28)	Medium-high
4/99-3/00	13 (1.5)	3.3 (0.27)	110 (24)	11 (4.0)	Low
4/00-4/01	11 (1.1)	3.1 (0.27)	130 (58)	14 (10)	Low

Seasonal periods of high macroalgae biomass were observed during the winter and spring at the mouth of the Suwannee River, probably due to natural seasonal changes in water clarity and tidal cycles. Algal and sediment samples were collected for biomass and species composition from 1999 to 2001. Nutrients from the Suwannee River plume may play a significant role in defining the abundance and distribution of microalgae in the sediment of the Suwannee River estuary. Results during 1999 and 2000 were from record low flow periods for the Suwannee River (Figure 54). Groundwater from the many springs along the Suwannee River dominated the flow during periods of low rainfall, and it is well-known that the nitrate levels in some springs are high enough to cause algal imbalances (FDEP freshwater nutrient criteria documents).

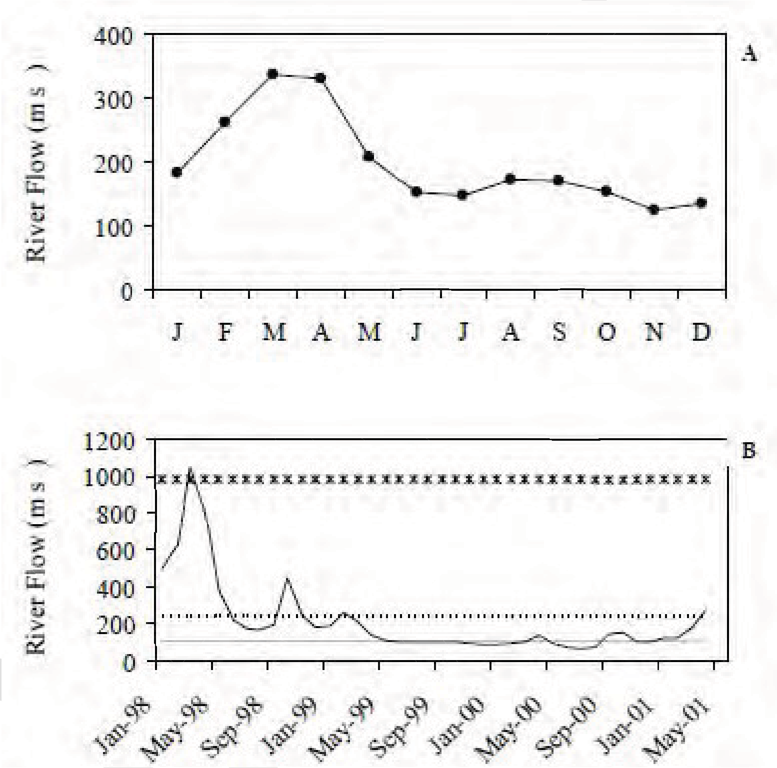


Figure 54. Flow rates in the Suwannee River at the Wilcox gauging station. (A) Long-term mean monthly flow rates from 1932 to 1999. (B) Mean monthly flow rates from 1998-2001. The dashed line (---) indicated median flow rate for the Suwannee River. The gray line represents the flow rate exceeded 99% of the time from 1960-2001, and the asterisk (***) line represents the flow rate exceeded only 1% of all dates from 1960-2001. Figure from Quinlan (2003).

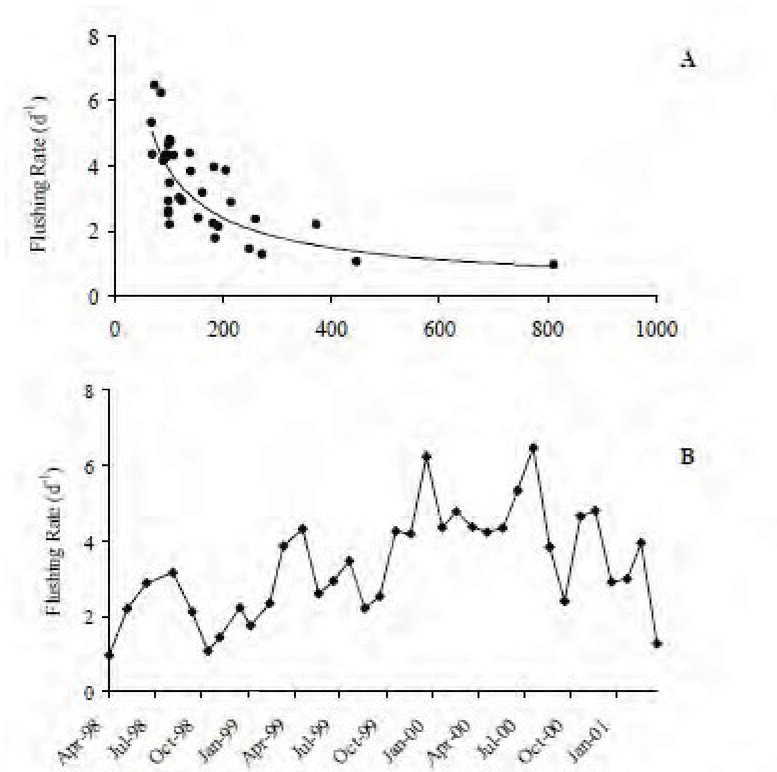


Figure 55. Flushing rates in the reef region of the Suwannee River estuary. (A) Calculated flushing rate (d^{-1}) of the reef region compared to riverine flow from April 1998 to April 2001. The points are the flushing rates, and the line is the least squares fit of the estimated flushing rates based on riverine flow. (B) Flushing rate (d^{-1}) in the reef region from 1998-2001 (mean 3.4 ± 1.4 days, n=35). Figure from Quinlan (2003).

The light extinction coefficient in the estuarine areas (oyster reef and nearshore) was most strongly correlated with tripton (particulate organic matter), followed by CDOM and chlorophyll *a* (Table 16). Only during very low flow periods was light extinction highly correlated with chlorophyll *a*. These results indicate that phytoplankton biomass is not the major contributor to water clarity reductions, but rather the organic materials from swamp source waters (the Okeefenokee Swamp National Wildlife Refuge) in the Suwannee River.

Dr. Quinlan found that the Suwannee Estuary is a very productive estuary, which commercial and sports fishers in the region have known for a long time. Phytoplankton production is high, and zooplankton production is high enough for food web assimilation to produce desirable fisheries biomass (fish, shrimp, and crabs). Quinlan *et al.* (2009) estimated that the resident microzooplankton could remove up to 83% of total daily primary production. The microzooplankton community was primarily composed of ciliates, dinoflagellates, and copepod nauplii, and ciliate densities were comparable to those reported for highly productive estuaries (Quinlan *et al.* 2009).

The phytoplankton communities in the estuarine regions (oyster reef and nearshore) were dominated by diatoms. Studies of phytoplankton along the gradient from the river to the nearshore area revealed that salinity, light, and temperature play important roles in the distribution of phytoplankton species, with salinity as the most important factor (Quinlan and Phlips 2007).

Riverine communities are light-limited, especially during periods of typical or high flow, and nearshore communities are nutrient-limited (Bledsoe and Phlips 2000, Quinlan and Phlips 2007). During periods of record low flow, phytoplankton biomass increased in the river due to increased residence time and water clarity (Figure 55; Quinlan and Phlips 2007). During the period of study, Dr. Quinlan did not observe any traditional bloom species, including typical cyanobacteria in fresh portions and *K. brevis* in marine portions (E. Quinlan, personal communication). She suggested that the Suwannee River's low salinity outflow precludes the maintenance of *K. brevis* blooms (Quinlan and Phlips 2007).

Table 16. Light extinction coefficient (Kd) and Pearson correlation coefficients for three major components of light absorption: Tripton, CDOM, and phytoplankton chlorophyll a in the Suwannee River and its estuary. Table from Quinlan (2003).

Year	Region	K_d	Tripton	CDOM	Chl a
1998-99	Suwannee River	1.8	0.72 **	0.92 ***	-0.51
	Reef	1.5	0.66 ***	0.58 ***	0.52 ***
	Nearshore	1.4	0.72 ***	0.71 ***	0.39 *
1999-00	Suwannee River	1.3	0.29	0.66 *	0.11
	Reef	1.5	0.78 ***	0.25 *	0.70 ***
	Nearshore	0.5	0.92 ***	0.29 **	0.49 ***
2000-01	Suwannee River	2.0	-0.29	0.90 ***	-0.41
	Reef	1.7	0.68 ***	0.28 *	0.54 ***
	Nearshore	0.9	0.88 ***	0.23 *	0.11
Overall	Suwannee River	1.8	0.34	0.87 ***	-0.30
	Reef	1.5	0.69 ***	0.57 ***	0.40 ***
	Nearshore	0.9	0.81 ***	0.52 ***	0.45 ***

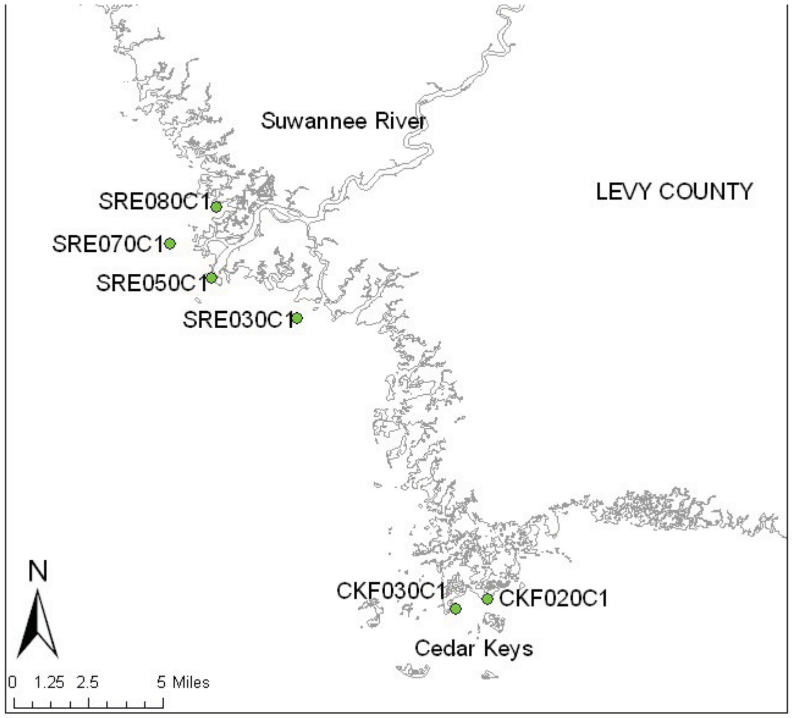
Note: Asterisks denote the level of significance; those marked with a single asterisk indicate significance at the 5% level, a double asterisk denotes significance at the 1% level, and a triple asterisk denotes significance at the 0.1% level. Empty cells indicate that the significance of the difference was above the 5% level.

Suwannee River Water Management District Monitoring

The Suwannee River Water Management District (SRWMD) has sampled four estuary sites bimonthly in the Suwannee Estuary from 1995-present (Figure 56). Robbie McKinney of the SRWMD analyzed these long term data using Lowess regression, and found no significant trends for TKN, NO_{2+3}, or TP (McKinney 2010). He found an increase in ammonia at the four estuary sites, but FDEP workshop participants (2/23/10 in Crystal River) were surprised at the relationships and hypothesized that the relationships were likely a function of salinity. Analysis of these data by FDEP revealed that the SRWMD detection limit for ammonia ranged from 0.02 to 0.099 mg/L, with the higher detection limit in more recent years. The change in detection limit and plotting of non-detect values as the detection limit is likely the reason for the perceived increase in ammonia in this time series.

Figure 56. SRWMD long term sampling sites within the Suwannee Estuary (from McKinney 2010).

SRE030C1 – East Pass Channel, SRE050C1 – Alligator Pass, SRE070C1 – Wadley Pass, and SRE080C1 – Salt Creek.



This map was made on 5/18/10 by Nia Wellendorf, DEP Standards and Assessment Section, for informational purposes.

Figure 57. Location of SRWMD sampling sites in the Suwannee River Estuary (SRE) and Cedar Keys (CKF).

FDEP Analysis of SRWMD Data

FDEP analyzed the SRWMD data from the four Suwannee Estuary sites and two Cedar Keys sites (Figure 57). These data are available and were retrieved from STORET. Table 17 contains number sample dates per year for these sites. The SRWMD had additional sampling sites (SRE010C1, SRE020C1, SRE040C1, SRE060C1) that were sampled in a more limited number of years (1995-1999). Data were only analyzed from sites with the longest term record.

Data were screened prior to analysis, and data qualified with "J" and "Q" remark codes were excluded. If there was more than one result for an analyte at a site on a given day, values were averaged for each site for each sampling date. Total nitrogen was only calculated if data were available for both nitrate/nitrite and TKN. Results below detection were assigned a value at half the method detection limit (MDL). If the MDL was reported as zero (this occurred for chlorophyll *a* for SRE sites and for nitrate+nitrite for CKF sites), the value was assigned as half the average MDL of the dataset for that analyte. For chlorophyll *a*, the average MDL was 1 µg/L. The detection limit for NO3/NO2 was 0.2 or 0.1 mg/L in 1997-2000, and decreased to 0.0032 in 2005-2006, with many data points for which the MDL was not reported (including all years in between those). A value of 0.005 was assigned for NO3/NO2 data labeled as non-detect but without a reported MDL, because that is half the value of the MDL for which a U was assigned (i.e., no samples were reported below detect with 0.2 as the detection limit.) The value of 0.003 mg/L was assigned to total phosphorus results labeled as non-detect for which no MDL was reported because 0.006 mg/L was the only reported MDL for that analyte.

Apparent outliers of 0.04 mg/L (below detect) for TKN at both Cedar Keys sites on 1/14/99 and 3/10/99 were checked with SRWMD and it was determined that they were values in their database. Early 1999 was a period of very low water. On June 11, 1998 at station CKF020C1 a corrected chlorophyll a of 54.2 µg/L and an uncorrected value of 22.3 µg/L were reported. A corrected value reported at that scale and more than double the uncorrected value suggests an analytical error, and although an error could not be verified with SRWMD, those points were excluded from these analyses as probable erroneous data.

The geometric means for TN, TP, and chlorophyll *a* (uncorrected and phaeophytin-corrected) were calculated for each site and each year for which there were at least four data points. There is a negative relationship between TN concentrations and salinity (Figure 58). It was not as strong as in the COAST dataset, and that is likely because the salinity range for these sites is narrower, there are fewer sites in this dataset, and they are all close to shore. Geometric mean TN ranged from 0.6-1.5 mg/L (Figure 59), geometric mean TP ranged from 0.04-0.13 mg/L (Figure 60), and geometric mean chlorophyll *a* (corrected and uncorrected, as available) ranged from non-detect to 6 µg/L (Figures 61). Annual geometric mean nutrient concentrations are somewhat higher at these sites than at the COAST sites overall, and that is likely due to the proximity of all of the SRWMD sites to freshwater sources (see Figure 73 for comparison of locations of COAST and SRWMD sites). The COAST dataset also contains more observations per year for nearly all years.

Table 17. Range of sample sizes used in this analysis for TN, TP, and chlorophyll a data for each site and year. Annual geometric mean not calculated if n<4. Data points could be missing due to availability or exclusion of J or Q qualified data.

Note: Phaeophytin-corrected chlorophyll a data only available 1995-2002.

Year	SRE030C1	SRE050C1	SRE070C1	SRE080C1	CKF020C1	CKF030C1
1995	0-3	0-3	0-3	0-3	3	3
1996	0-12	0-12	0-12	8-12	9	9
1997	8-12	8-12	6-12	9-12	11	11
1998	12	12	12	12	5	5
1999	7	7	7	7	7	7
2000	0	0	0	0	6	6
2001	2	2	2	2	6	6
2002	4-6	4-6	4-6	3-6	6	6
2003	5-6	5-6	5-6	5-6	6	6
2004	4-6	5-6	4-6	4-6	6	6
2005	4-6	3-6	5-6	4-6	6	6
2006	5-6	5-6	5-6	5-6	4	4
2007	3-4	4	2-4	4	0	0
2008	2	3	3-5	2	0	0
2009	2-5	2-5	2-5	2-5	0	0

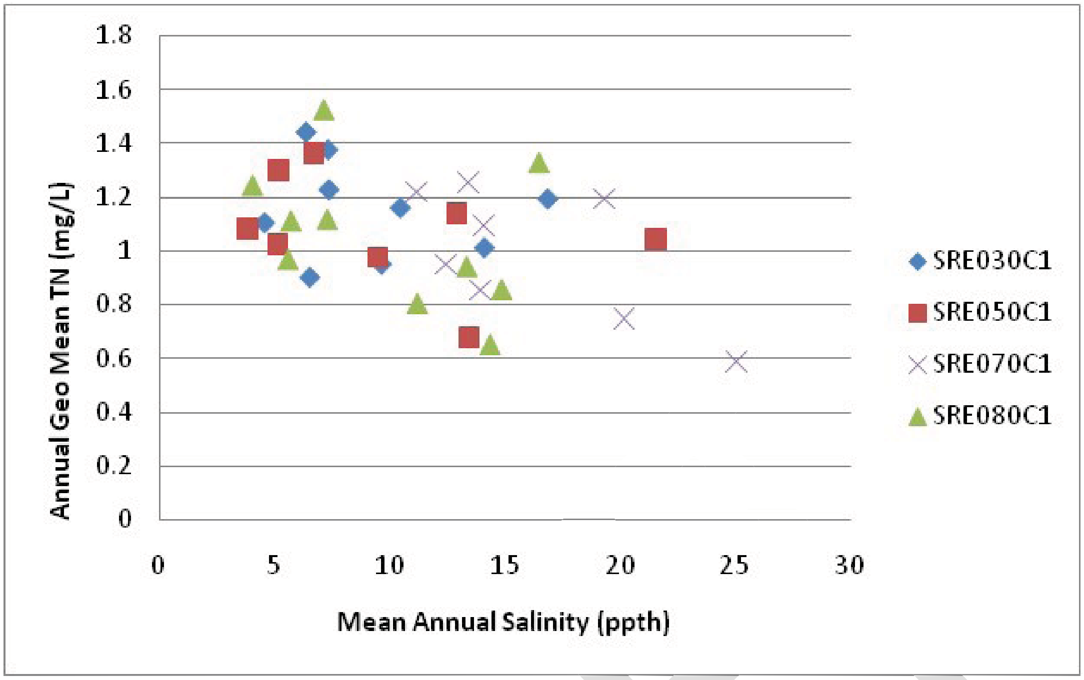


Figure 58. Annual mean salinity vs. annual geometric mean TN for 4 sites in the Suwannee Estuary, sampled by SRWMD or their contractors. Only site-years with four or more data points were used. Salinity data include "0" data points from Robbie McKinney, who indicated confidence in those data points (especially for earlier years). Data are from sites as in Figure 38.

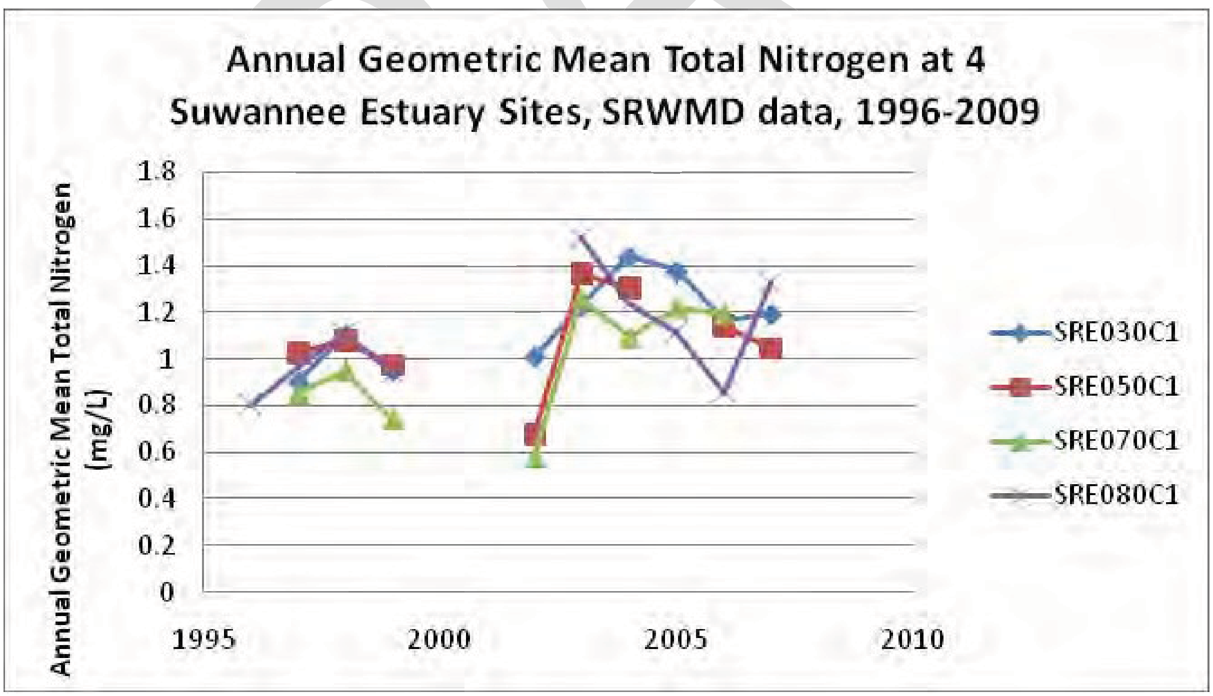


Figure 59. Annual geometric means for TN at four Suwannee Estuary sites.

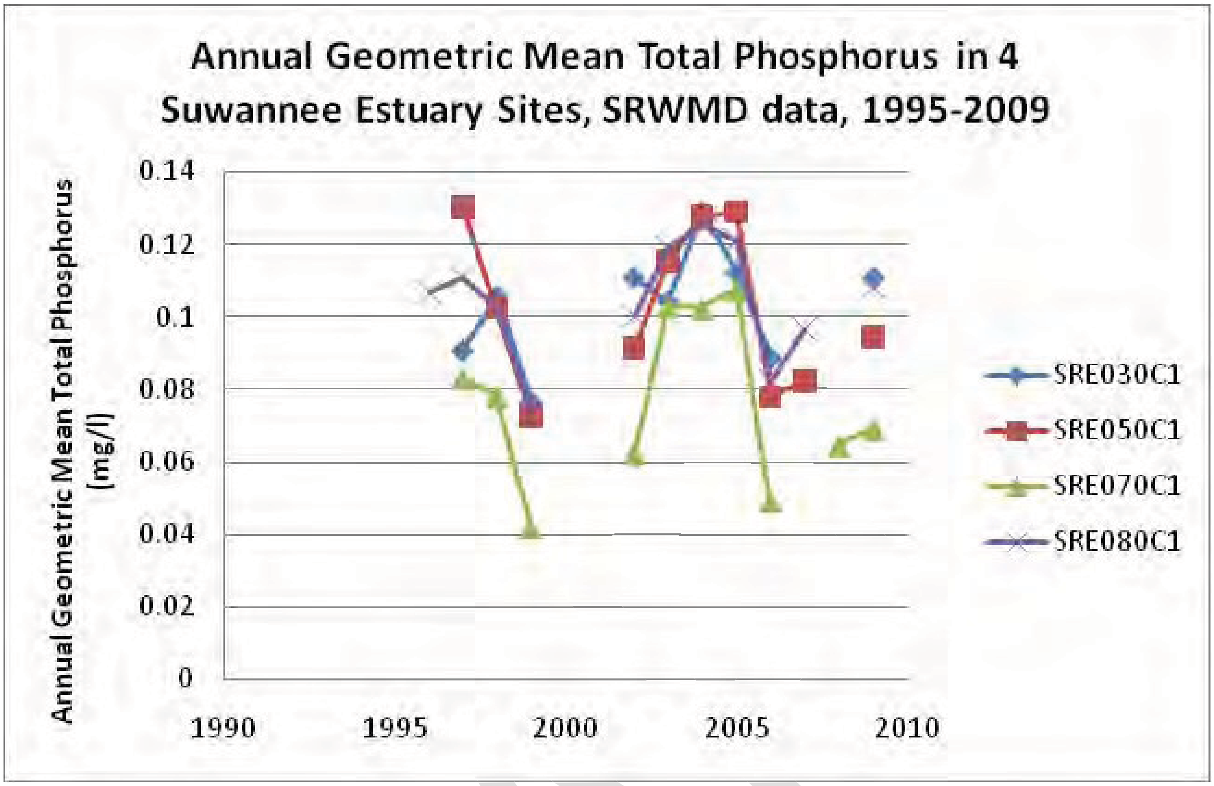


Figure 60. Annual geometric means for TP at four Suwannee Estuary sites.

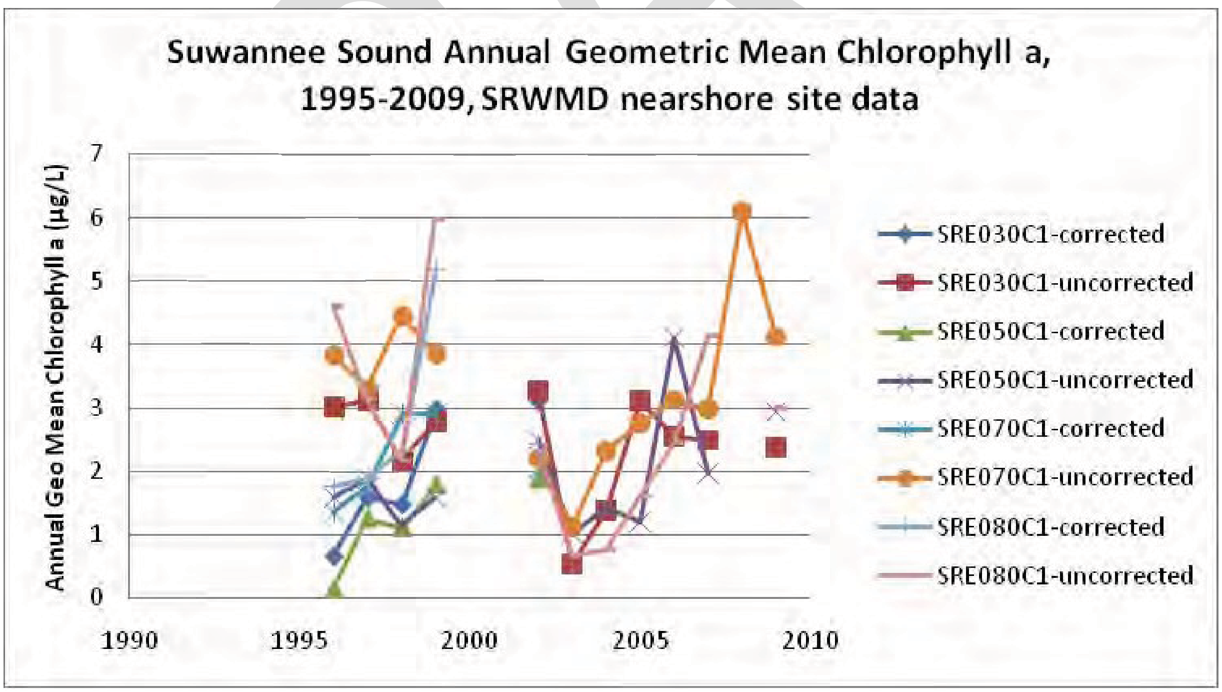


Figure 61. Annual geometric means for chlorophyll a at four Suwannee Estuary sites.

Cedar Keys Water Quality

The SRWMD data for Cedar Keys were analyzed in the same manner as the Suwannee estuary data. There was not a strong relationship between salinity and total nitrogen as was observed at Cedar Keys sites (Figure 62), likely due to the lack of major freshwater inputs in the immediate vicinity of these sites. Annual geometric means of TN, TP, and chlorophyll *a* are similar to those of the Suwannee Estuary. Geometric means range from 0.4-1.2 mg/L for TN, 0.04-0.09 mg/L for TP, and 2-14 µg/L for chlorophyll *a* (Figures 63-65). The apparent decreasing trend in chlorophyll *a* is more likely a function of an abnormally high year in 1998 than of a true downward trend.

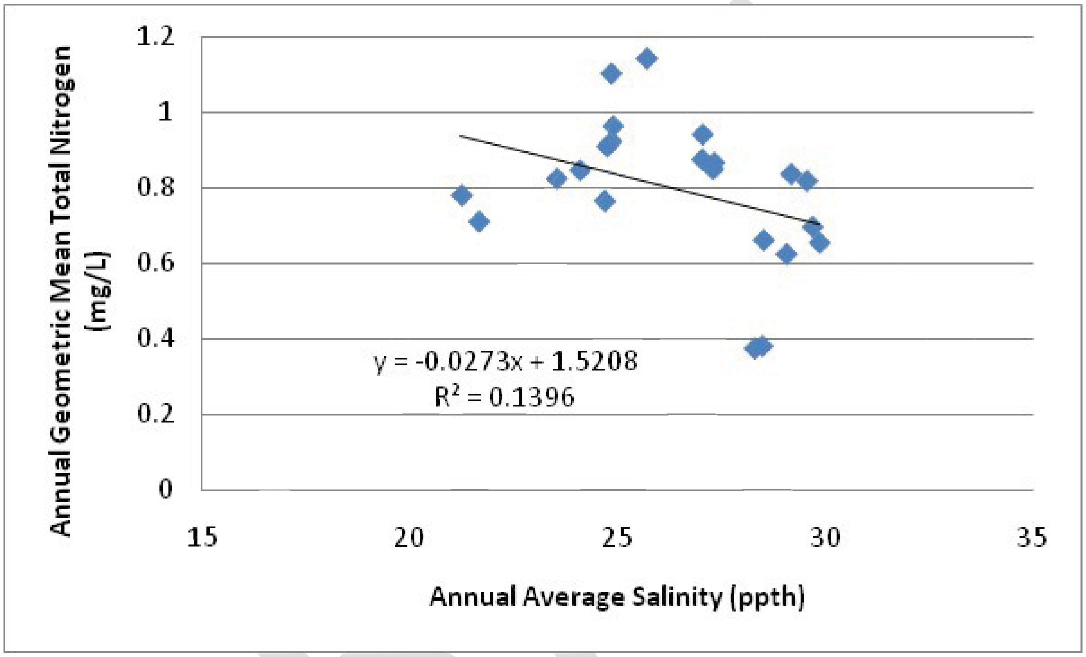


Figure 62. Annual average salinity versus annual geometric mean total nitrogen for sites CKF020C1 and CKF030C1 at Cedar Keys collected by the SRWMD from 1996-2006 (n = 22 site-years).

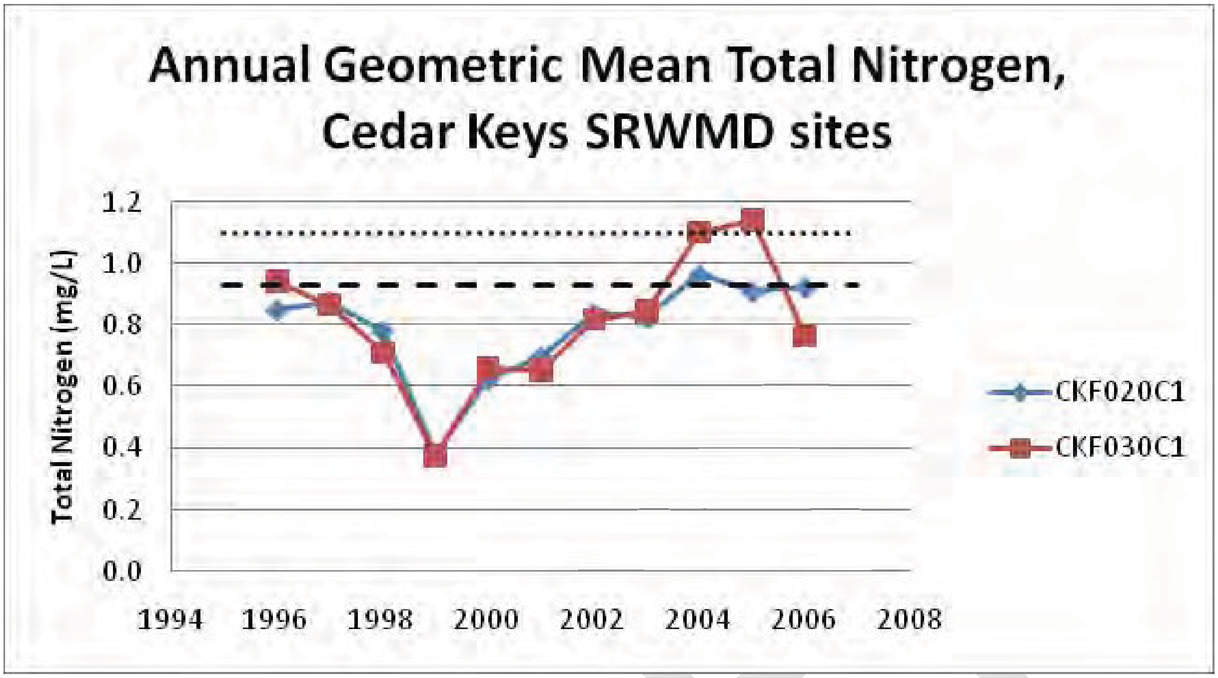


Figure 63. Annual geometric mean Total Nitrogen for Cedar Keys SRWMD sites, 1996-2006. The dashed and dotted lines indicates the 75th and 90th percentile of all annual geometric means, respectively (from both sites, n=22 annual geometric means, calculated with lognormal distribution function).

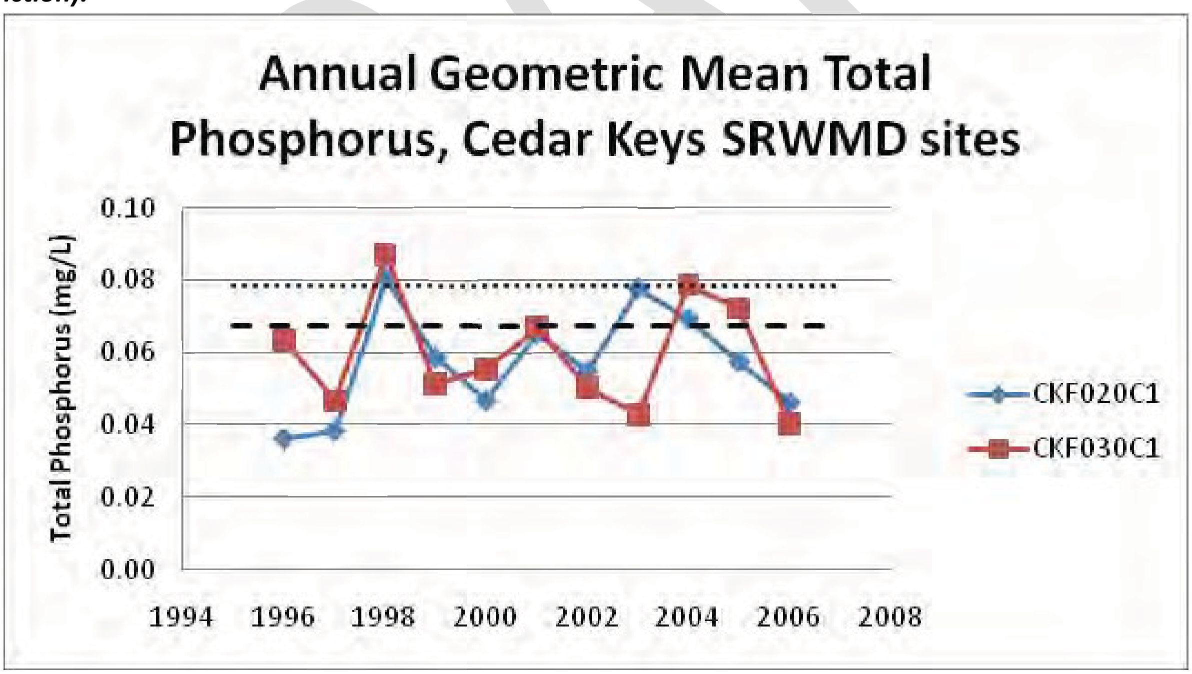


Figure 64. Annual geometric mean Total Phosphorus for Cedar Keys SRWMD sites, 1996-2006. The dashed and dotted lines indicates the 75th and 90th percentile of all annual geometric means, respectively (from both sites, n=22 annual geometric means, calculated with lognormal distribution function).

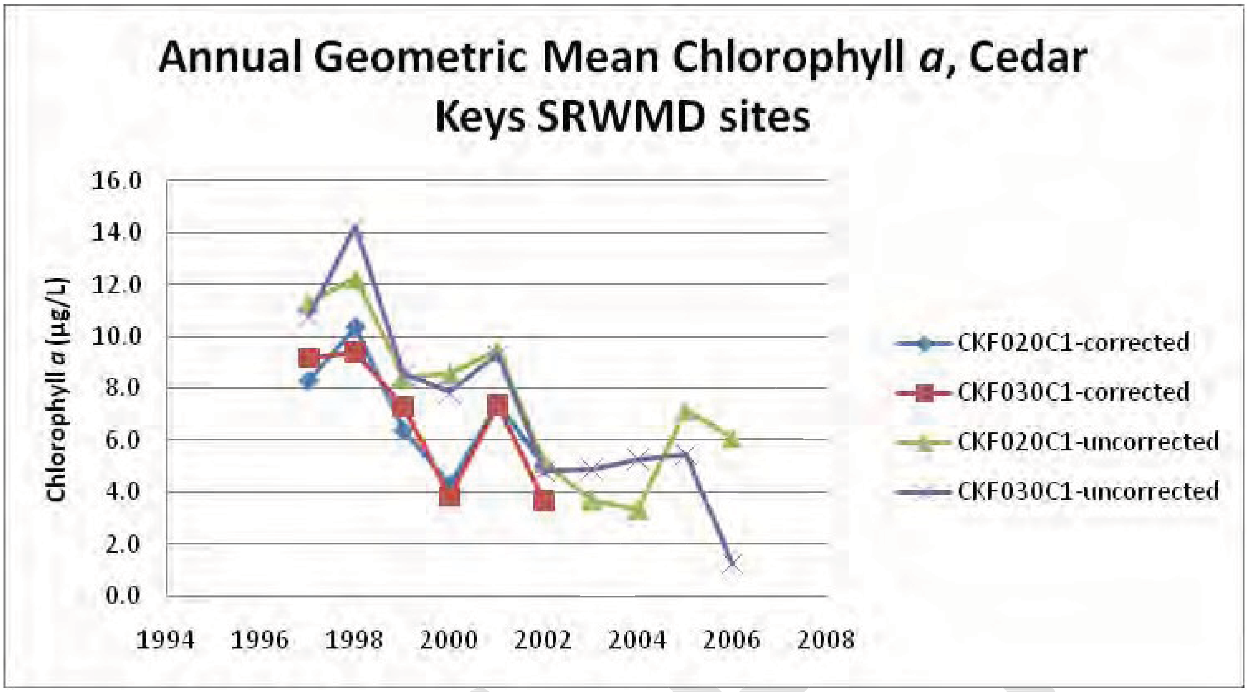


Figure 65. Annual geometric mean corrected and uncorrected chlorophyll a for Cedar Keys SRWMD sites, 1996-2006.

Random Sampling by IMAP Program through FWRI

Florida's Inshore Marine Monitoring and Assessment Program (IMAP) was a probabilistic sampling program for Florida's marine waters that sampled the whole state from 2000-2004. This program was conducted by the Florida Wildlife Research Institute (FWRI) in cooperation with EPA Gulf Breeze office. The areas considered in this report were sampled during the following years: Suwannee Sound in 2000 and 2003, Waccasassa and Withlacoochee Bays in 2001, and Big Bend in 2002 (including Horseshoe Cove, north of Suwannee). Table 18 contains summary water quality data from the IMAP program as reported in FDEP's IWR database Run 40 (2010). Although the IMAP reports indicate that TN was analyzed, only nitrate/nitrite data were in the IWR. Mean chlorophyll *a* ranged from 6.29-22.52 µg/L, mean color ranged from 20-167 PCU, and mean TP ranged from 0.053-0.093 mg/L. The lowest color and chlorophyll *a* means co-occurred with the lowest salinity value (Table 18).

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Table 18. Mean values by area and year for IMAP sampling in the regions of the Suwannee, Waccasassa, and Withlacoochee Estuaries (data from FDEP IWR Run 40). Cedar Keys and Horseshoe Cove were part of the Suwannee Sound sampling unit. Samples for chlorophyll a were depth integrated, others were surface grabs.

Geographic Area	Year	N	Chlorophyll a (corrected, µg/L)	Color (PCU)	Nitrate + Nitrite (mg/L)	Total Phosphorus (mg/L)	Salinity (ppt)
Cedar Keys	2000	8	16.55	20	0.002	0.062	30.2
Cedar Keys	2003	1	9.75	35	0.009	0.093	20.0
Horseshoe Cove	2000	3	12.42	49	0.006	0.053	20.5
Horseshoe Cove	2002	1	19.94	53	0.002	0.068	21.2
Horseshoe Cove	2003	2	22.52	71	0.002	0.088	19.8
Suwannee Sound	2000	11	12.46	26	0.032	0.067	23.4
Suwannee Sound	2003	7	6.29	167	0.334	0.072	8.1
Waccasassa	2001	12	10.07	30	0.017	0.061	23.5
Withlacoochee	2001	9	12.33	47	0.015	0.057	22.0

IMAP reports from 2000 and 2003 include results for Suwannee Sound, including Cedar Keys and Horseshoe Cove. These reports do not include a qualitative assessment of the study findings, but rather just a report of the quantitative results.

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YSI data from FDEP Aquatic Preserves Dataloggers

FDEP staff from the Big Bend Seagrass and St. Martins Marsh Aquatic Preserves maintain YSI dataloggers at three sites within this region, including the mouth of the Suwannee River, Seahorse Key of Cedar Keys, and in the Withlacoochee Estuary. They measure salinity, dissolved oxygen, and temperature. Results are only available for a limited number of years to date, but Figures 66 – 72 provide a picture of the regime at these sites. Plots of dissolved oxygen were only available for Seahorse Key, and mean values were always greater than 5 mg/L.

Figure 66. Monthly mean, standard deviation, and ranges of salinity from an on-site YSI probe datalogger at Seahorse Key, near Cedar Key (from Charbonneau 2010). Zeros indicate missing data due to lag in monitoring effort.

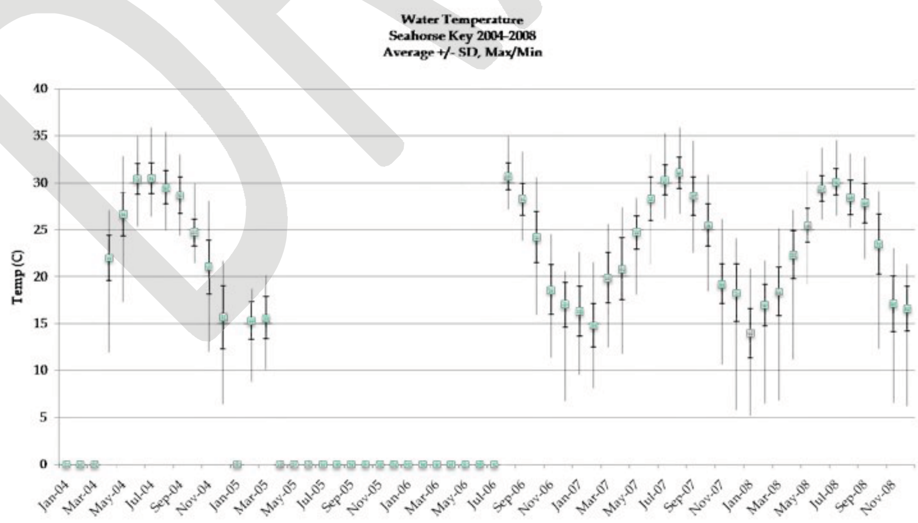

Figure 67. Monthly mean, standard deviation, and ranges of water temperature from an on-site YSI probe datalogger at Seahorse Key, near Cedar Key (from Charbonneau 2010). Zeros indicate missing data due to lag in monitoring effort.

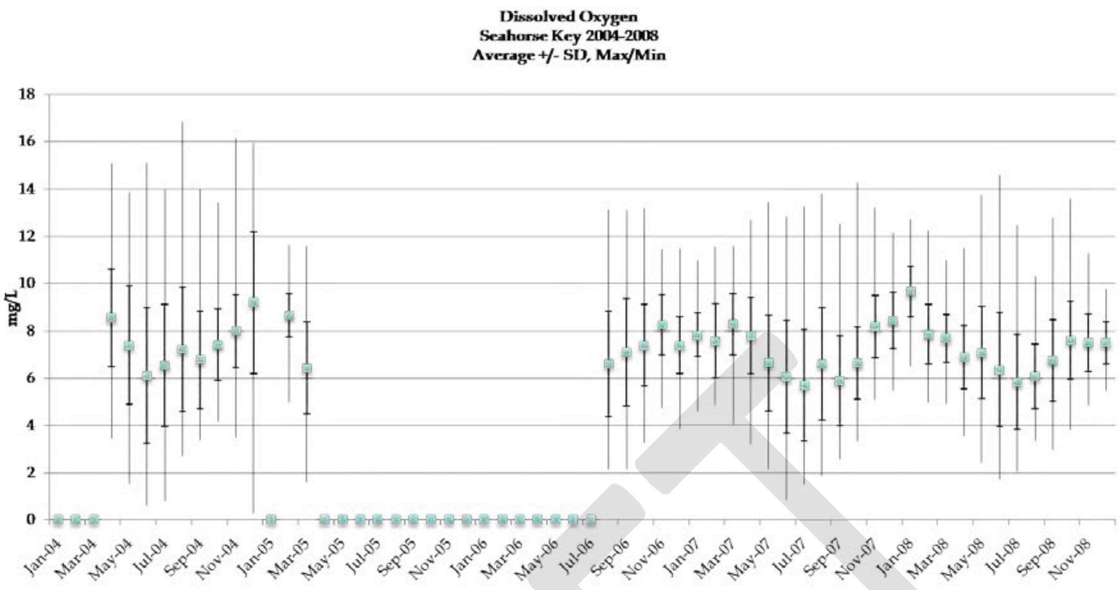

Figure 68. Monthly mean, standard deviation, and ranges of dissolved oxygen from an on-site YSI probe datalogger at Seahorse Key, near Cedar Key (from Charbonneau 2010). Zeros indicate missing data due to lag in monitoring effort.

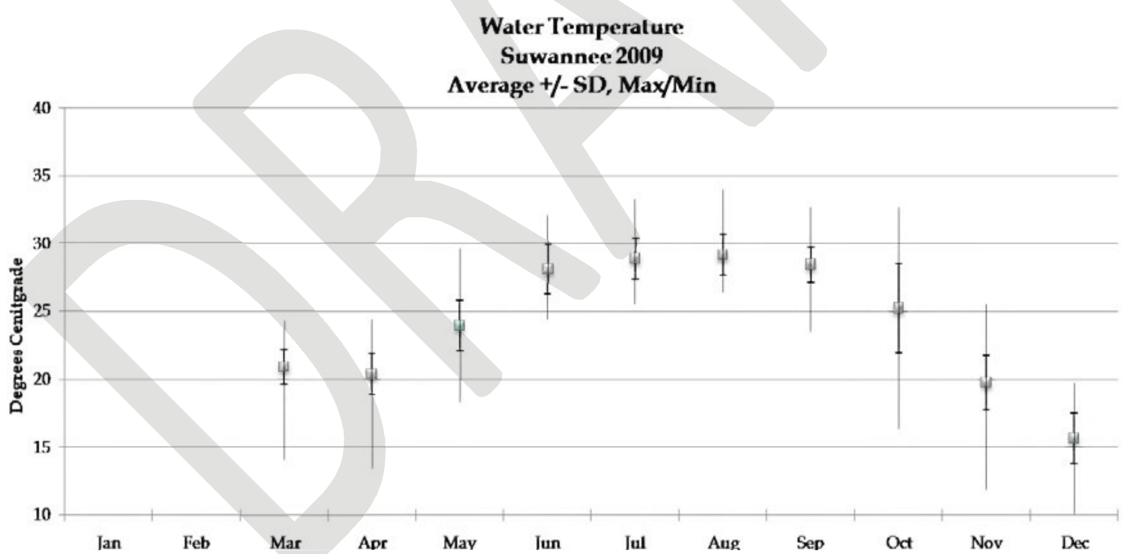

Figure 69. Monthly mean, standard deviation, and ranges of water temperature from an on-site YSI probe datalogger at the mouth of the Suwannee River (from Charbonneau 2010).

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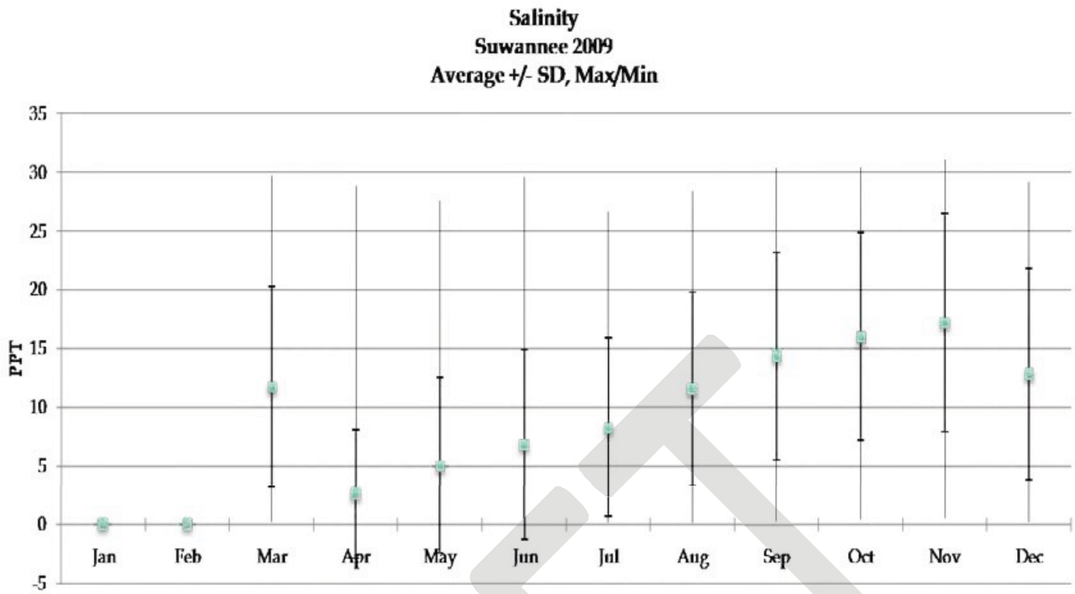

Figure 70. Monthly mean, standard deviation, and ranges of salinity from an on-site YSI probe datalogger at the mouth of the Suwannee River (from Charbonneau 2010).

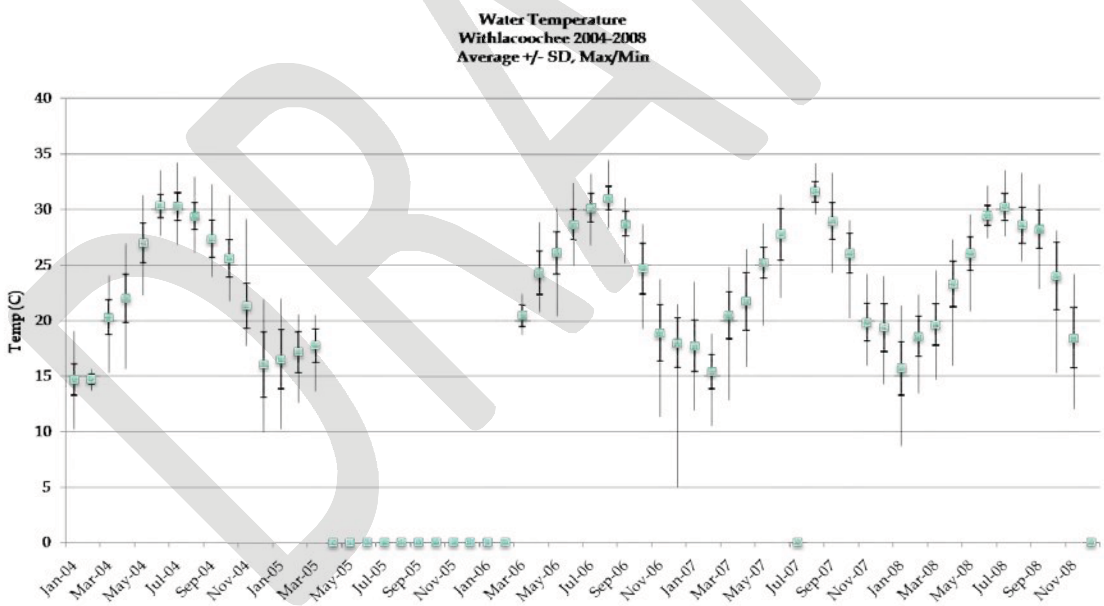

Figure 71. Monthly mean, standard deviation, and ranges of water temperature from an on-site YSI probe datalogger at the mouth of the Withlacoochee River (from Charbonneau 2010).

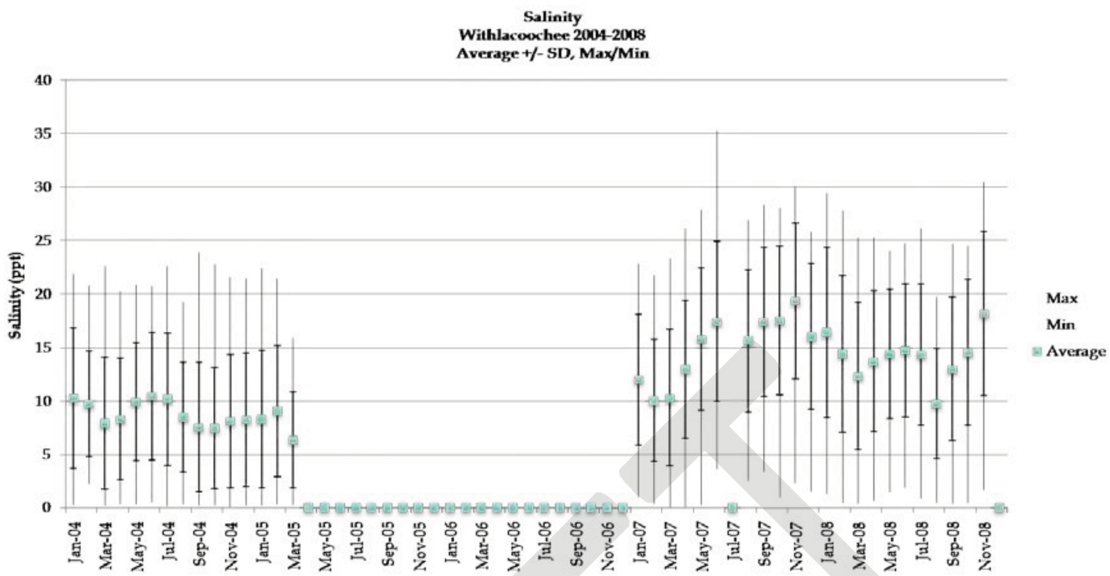

Figure 72. Monthly mean, standard deviation, and ranges of salinity from an on-site YSI probe datalogger at the mouth of the Withlacoochee River (from Charbonneau 2010).

Comparison of Nutrient Levels through Time between Sampling Entities

This section summarizes the annual geometric means calculated by FDEP for TN, TP, and chlorophyll *a* for areas that were sampled by more than one organization over various time periods. The purpose of this summary is to compare results by different organizations, and to look for trends through time at geographically comparable sites. Table 19 compares such pairs of sites (circled in Figure 73) through time. Data are also shown in Figures 74-76 for sites sampled during the same time periods. At these sites, sampling was conducted on different frequencies by different organizations, but all were sampled throughout the year, with > 4 samples used to calculate the geometric mean.

Total phosphorus data compare fairly well, but total nitrogen and chlorophyll *a* geometric means show some discrepancies. For SRE070C1 and Suwannee-4, for which there were eight sampling years in common, the TP values differed by an average of 15% (s.d. = 14%), TN values differed by an average of 27% (s.d. = 17%), and chlorophyll a values differed by an average of 39% (s.d. = 24%). TN values from the SRWMD sampling were always higher than from the COAST sampling (Figure 74), and chlorophyll a values from COAST tended to be higher than from SRWMD (Figure 76).

Annual geometric mean TN was plotted against annual mean salinity for SRWMD site SRE070C1 and COAST site Suwannee-4 to determine if the apparent bias is simply due to differences in salinity and influence from the river. Indeed, the salinities are different, but the bias remains. For a given salinity, the COAST TN values are lower than the SRWMD values (Figure 77). It is unknown which values are closest to the true TN concentrations. Duplicate samples have been collected at a subset of COAST sites and are being analyzed by the FDEP lab in Tallahassee and the LakeWatch Lab to determine comparability of results.

Table 19a. Annual geometric means for TN (mg/L) for estuarine sites in the Suwannee, Waccasassa, and Withlacoochee estuaries. Site pairs and sampling entities as in Figure 73.

- = Empty cell/no data

Pair	Site	1984	1985	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	SRE070C1	-	-	-	0.85	0.95	0.75	-	-	0.58	1.26	1.10	1.22	1.20	-
1	Suwannee-4	-	-	-	0.69	0.88	0.70	0.63	0.65	0.47	0.99	0.77	0.98	0.76	0.68
2	SRE040C1	-	-	-	0.87	0.92	0.81	-	-	-	-	-	-	-	-
2	Suwannee-5	-	-	-	0.59	0.58	0.39	0.55	0.52	0.54	0.83	0.59	0.76	0.74	0.51
3	MML WACC-10	-	0.83	-	-	-	-	-	-	-	-	-	-	-	-
3	Waccasassa-8	-	-	-	0.61	0.81	0.52	0.58	0.53	0.62	0.60	0.55	0.56	0.57	0.51
4	MML WITH-10	0.47	0.51	-	-	-	-	-	-	-	-	-	-	-	-
4	Withlacoochee-7	-	-	-	0.30	0.49	0.33	0.28	0.29	0.26	0.34	0.36	-	0.33	-
5	MML WITH-7	0.63	0.59	-	-	-	-	-	-	-	-	-	-	-	-
5	Withlacoochee-6	-	-	-	0.49	0.79	0.49	0.36	0.53	0.51	0.57	0.62	-	0.60	-

Table 19b. Annual geometric means for TP (mg/L) for estuarine sites in the Suwannee, Waccasassa, and Withlacoochee estuaries. Site pairs and sampling entities as in Figure 73.

- = Empty cell/no data

Pair	Site	1984	1985	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	SRE070C1	-	-	-	83	78	42	-	-	62	103	102	108	49	-
1	Suwannee-4	-	-	-	77	87	68	62	65	63	93	87	109	76	72
2	SRE040C1	-	-	-	67	79	54	-	-	-	-	-	-	-	-
2	Suwannee-5	-	-	-	70	67	43	51	52	70	82	64	84	63	56

Table 19c. Annual geometric means for chlorophyll a for estuarine sites in the Suwannee, Waccasassa, and Withlacoochee estuaries. Site pairs and sampling entities as in Figure 73. All chlorophyll a means shown are not phaeophytin-corrected.

- = Empty cell/no data

Pair	Site	1984	1985	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	SRE070C1	-	-	3.83	3.31	4.44	3.86	-	-	2.21	1.12	2.33	2.76	3.13	2.98
1	Suwannee-4	-	-	-	2.57	2.85	4.57	5.60	4.92	5.07	4.77	4.00	2.88	4.75	7.12
2	SRE040C1	-	-	5.78	4.62	4.17	6.67	-	-	-	-	-	-	-	-
2	Suwannee-5	-	-	-	5.93	7.06	7.71	7.63	8.46	9.98	9.50	5.63	7.81	10.99	10.58
3	MML WACC-10	-	7.14	-	-	-	-	-	-	-	-	-	-	-	-
3	Waccasassa-8	-	-	-	7.01	16.55	6.08	6.03	6.42	9.68	7.94	7.99	7.93	6.88	5.86
4	MML WITH-10	4.43	3.65	-	-	-	-	-	-	-	-	-	-	-	-
4	Withlacoochee-7	-	-	-	3.78	8.18	3.61	2.21	3.29	2.97	6.34	5.96		3.50	
5	MML WITH-7	4.58	3.88	-	-	-	-	-	-	-	-	-	-	-	-
5	Withlacoochee-6	-	-	-	4.01	8.70	4.15	3.55	6.74	5.78	6.40	8.11	-	4.60	-

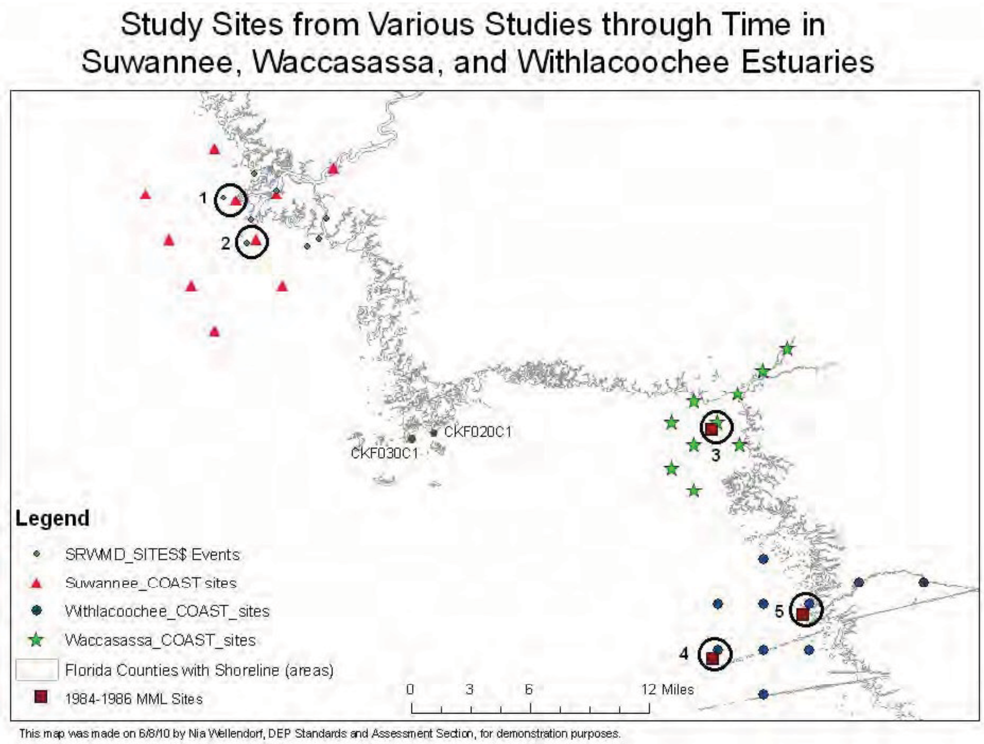

Figure 73. All study sites for which FDEP analyzed data within this report. Circled areas indicate pairs of sites sufficiently close enough in space for data comparison. 1 – COAST Suwannee-4 = SRWMD SRE070C1; 2 – COAST Suwannee-5 = SRWMD SRE040C1; 3 – MML WACC-10 = COAST Waccasassa-8; 4 – MML WITH-10 = COAST Withlacoochee-7; 5 - MML WITH-7 = COAST Withlacoochee-6.

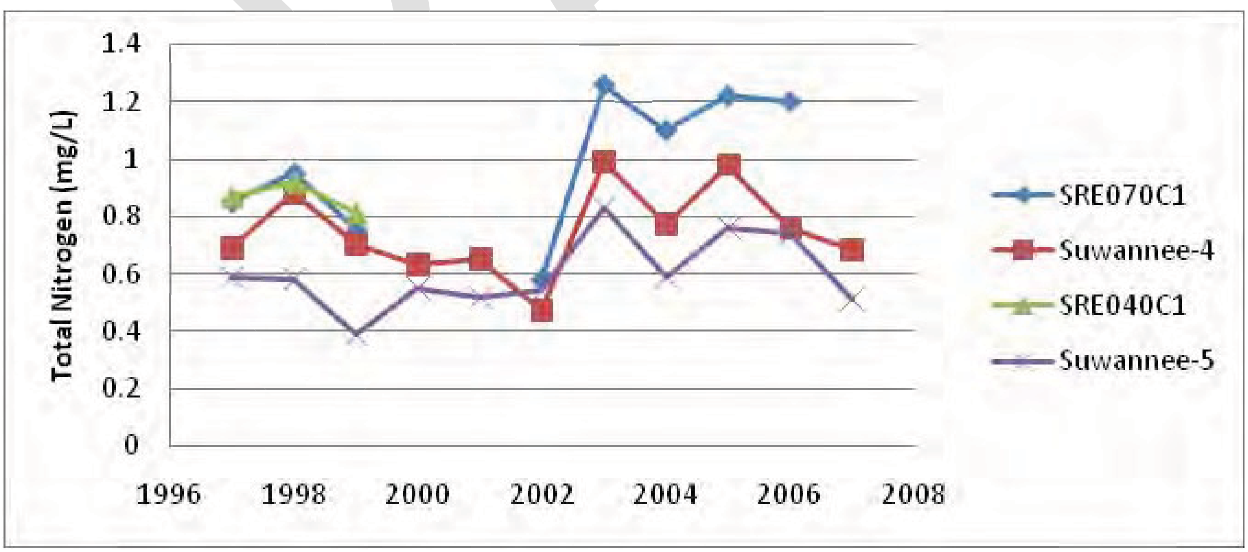

Figure 74. Comparison of annual geometric mean total nitrogen at 2 pairs of sites in the Suwannee Estuary in which the members of each pair are located fairly close to one another. Site pairs as in Figure 73.

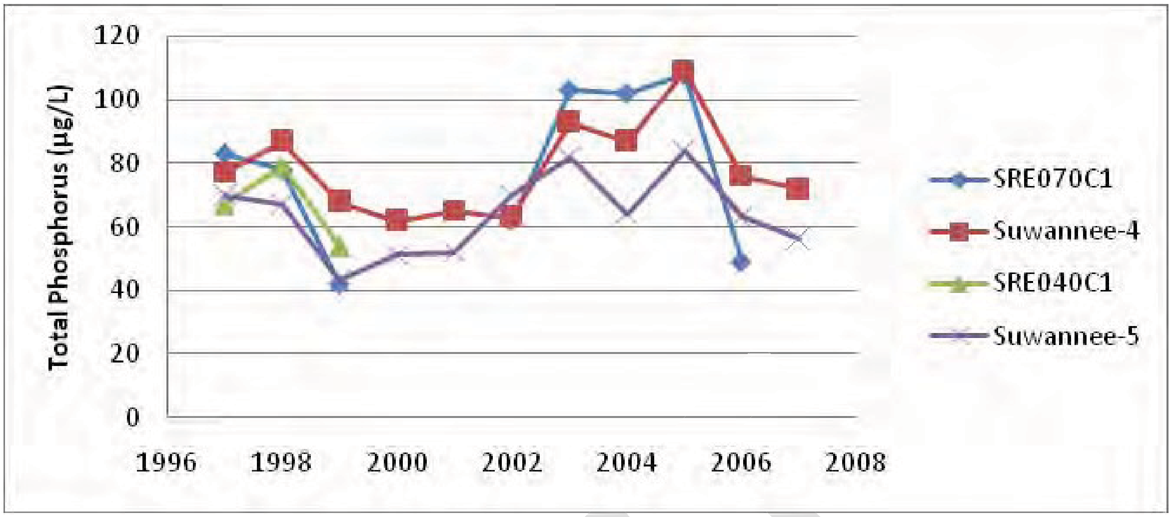

Figure 75. Comparison of annual geometric mean total phosphorus at 2 pairs of sites in the Suwannee Estuary in which the members of each pair are located fairly close to one another. Site pairs as in Figure 73.

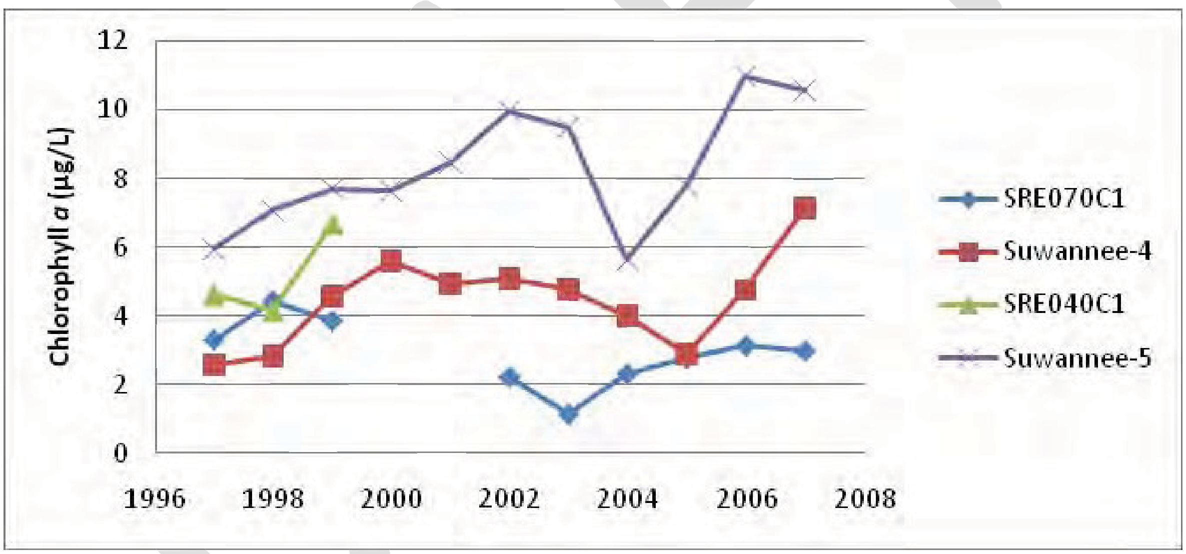

Figure 76. Comparison of annual geometric mean chlorophyll a (uncorrected) at 2 pairs of sites in the Suwannee Estuary in which the members of each pair are located fairly close to one another. Site pairs as in Figure 73.

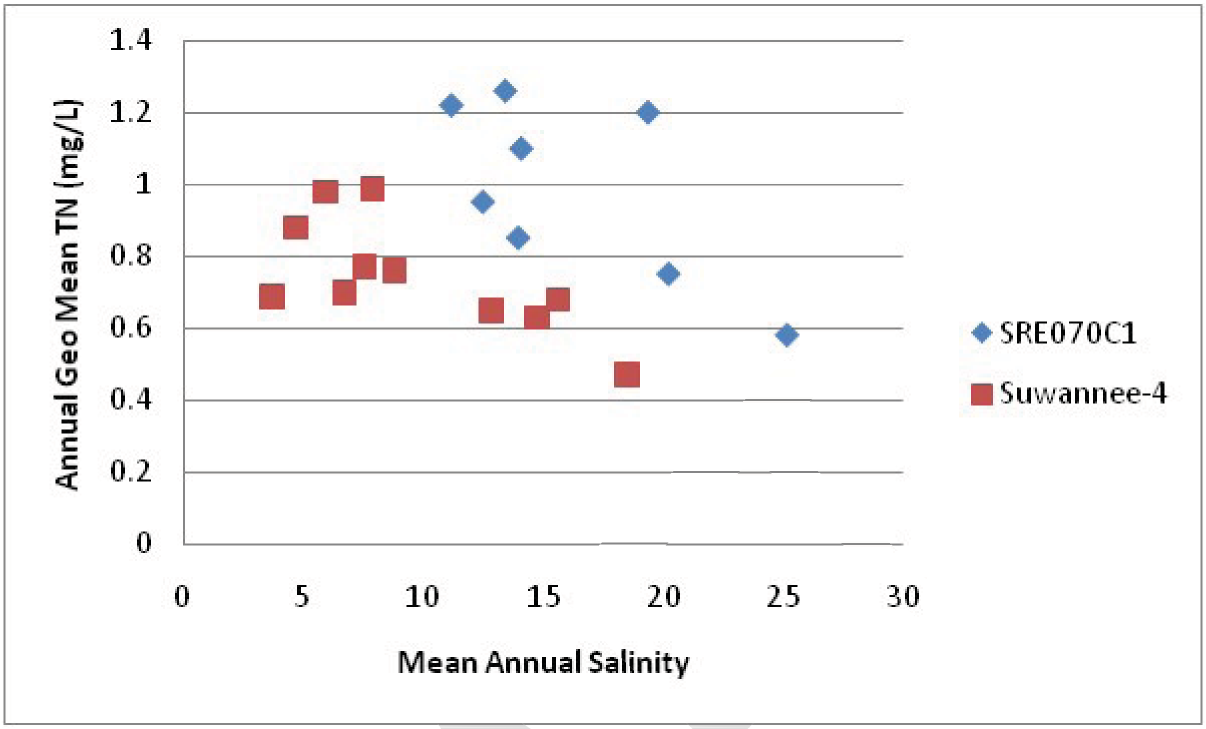

Figure 77. The relationship between mean annual salinity and annual geometric mean total nitrogen for two sites located fairly close together in the Suwannee Estuary (sites shown in Figure 73).

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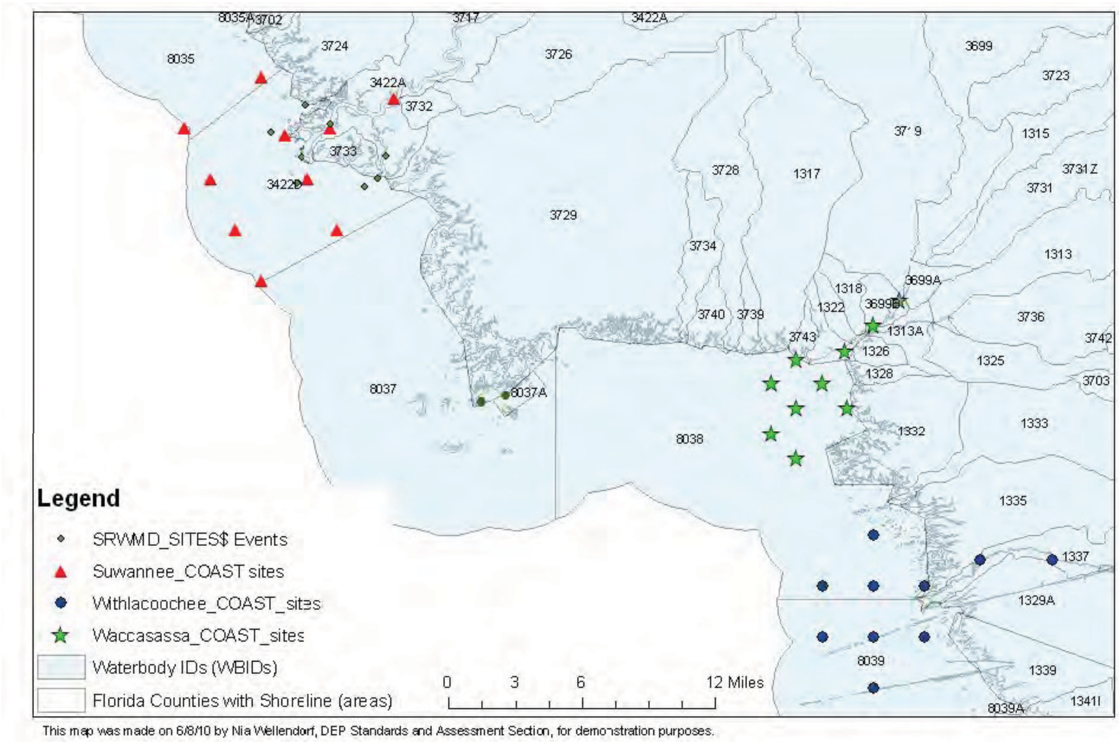

Figure 78. WBIDs in the Suwannee, Waccasassa, and Withlacoochee Estuary regions, and sampling stations from Project COAST and the SRWMD.

Waters on the 303(d) List

The Gulf of Mexico is listed as impaired for mercury, but FDEP does not believe that the impairment is related to nutrients.

The Suwannee Estuary is listed as impaired for nutrients because the chlorophyll *a* concentration in 2004 and 2005 was more than 50% higher than the historic minimum concentration (Table 20). The only data available for this IWR assessment were from the SRWMD. The TMDL established for nitrate in the Suwannee River (Hallas and Magley 2008) is expected to address this increase. It should be noted that there is no evidence to suggest that 6 mg/L chlorophyll *a* is detrimental to aquatic life use.

Table 20. Cycle 2 Verified List of impaired waters– Lower Suwannee Planning Unit.

IIIM = Class III Marine

WBID	Waterbody Segment Name	Waterbody Type	Waterbody Class	Parameters Assessed under 2007 IWR	Concentration Causing Impairment	Priority for TMDL Development	Comments
3422D	LOWER SUWANNEE ESTUARY	ESTUARY	IIIM	Nutrients (Chlorophyll-a)	Median TN= 1.165 mg/L; Median TP= 0.0944 mg/L	High	Listed based on two consecutive years of annual average chlorophyll a values that exceeded the historical minimum of 4.0 ug/L by more than 50%. Annual averages: 1997 - 2.79 µg/L; 1998 - 4.63 µg/L; 2002 - 3.43 ug/L; 2004 - 6.14 ug/L; 2005 - 6.44 µg/L; 2006 - 5.06 µg/L.

The COAST dataset analyzed in this report was not considered in the determination of impairment, and that the chlorophyll *a* values reported in the COAST study are not corrected for phaeophytin and cannot be directly compared with the early values in Table 16.

Portions of the Waccasassa Estuary were listed on the 303(d) Verified List as impaired for chlorophyll *a* due to exceedances of the IWR's 11 µg/L chlorophyll *a* threshold for impairment in estuaries (Table 21). These exceedances occurred primarily in years of abnormally high rainfall, as documented by Carlson *et al.* (2010). The data that led to impairment for WBID 8037 are the SRWMD data for Cedar Key, presented above (Figure 65). Although the mean chlorophyll *a* values exceed the 11 µg/L threshold established in the Impaired Waters Rule, those values are similar to levels detected in studies of this estuary that took place prior to human disturbance (Putnam 1967, Dixon 1986).

Table 21. Cycle 2 Verified List of Impaired Waters–Waccasassa Planning Unit.

- = Empty cell/no data

WBID	Waterbody Segment Name	Waterbody Type	Waterbody Class	Parameters Assessed under 2007 IWR	Concentration Causing Impairment	Priority for TMDL Development	Comments
3729	BLACK POINT SWAMP	ESTUARY	IIIM	Nutrients (Chlorophyll-a)	Median TN= 1.225 mg/L; Median TP= 0.108 mg/L	Medium	Annual averages for 1997, 1998, 2000, and 2005 exceeded the threshold of 11 µg/L for estuaries. Annual averages: 1997 - 12.78 µg/L; 1998 - 37.18 µg/L; 2000 - 12.72 µg/L; 2001 - 8.59 µg/L; 2002 - 6.99 µg/L; 2004 - 3.06 µg/L; 2005 - 19.78 µg/L. Based on TN/TP ratios of 3.45 to 28.82 with a median of 11.09 (n=52) over the verified period. Nitrogen and phosphorus are the limiting nutrients.
8037	WACCASASS ARIVER GULF 1	COASTAL	IIIM	Nutrients (Chlorophyll-a)	Median TN= 0.83 mg/L; Median TP= 0.0643 mg/L	Medium	Annual averages for 1998 and 2005 exceeded the threshold of 11 µg/L for estuaries. Annual averages: 1997 - 9.94 µg/L; 1998 - 12.95 µg/L; 2000 - 7.93 µg/L; 2001 - 8.24 µg/L; 2002 - 4.90 µg/L; 2004 - 8.93 µg/L; 2005 - 15.45 µg/L. Based on TN/TP ratios of 4.56 to 106.7 with a median of 13.64 (n=98) over the verified period. Nitrogen and phosphorus are the limiting nutrients.

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Impairment for Bacteria

There are also waters in this region that are on the 303(d) list for bacteria (fecal coliforms). They are not listed above because FDEP has evidence that the presence of fecal coliforms does not necessarily indicate an anthropogenic nutrient source. The use of fecal coliforms as indicators of the presence of human pathogens has been under scrutiny in Florida for the past decade. One of the priorities of the Gulf of Mexico Alliance (GOMA) is the need to improve microbial source tracking and pathogen-detection methods for use under Gulf of Mexico conditions (GOMA 2009). The GOMA Pathogens Workgroup recently submitted comments regarding the status of EPA recreational water quality criteria (GOMA 2009). They expressed concern that the EPA recreational criteria were derived in places that do not represent Gulf of Mexico conditions, and that the use of fecal indicators was not appropriate for waters primarily influenced by animal sources. Areas in the Gulf of Mexico for which they thought the EPA criteria may not be appropriate included low population density coastal areas, areas of heavy rainfall, subtropical latitudes, and areas where waters contain a large amount of organic detritus material and/or colored dissolved organic matter (CDOM; GOMA 2009). Boehm *et al.* (2009) express similar concern about the current and proposed recreational criteria, and specifically call attention to the need for further research and revision in tropical waters and waters adversely impacted by urban runoff and animal feces. This is not to say that fecal coliform and *Enterococci* bacteria cannot indicate human sources or cannot co-occur with nutrient inputs; this suggests that there is ample evidence to caution against making the assumption that the presence of these bacteria automatically indicates the presence of anthropogenic nutrients.

The following text is from a review conducted by Dr. V. Jody Harwood of the University of South Florida as part of a microbial source tracking project she is conducting for FDEP:

> *The main groups of indicator bacteria for recreational water quality assessment in use today include fecal coliforms, or a specific member of that group, Escherichia coli, in fresh water and the genus Enterococcus in both fresh and estuarine/marine waters. However, in order for the indicator concept to work optimally there are many assumptions that must hold true. One of the most important assumptions is that indicator bacteria must co-occur with human pathogens when pathogens are present and pose a human health risk. Unfortunately, recent research has indicated that this assumption is often false by showing that the presence of indicator bacteria do not always correlate well with the presence of pathogens such as Salmonella, Campylobacter, Cryptosporidium, Giardia, or enteric viruses (Anderson et al. 2005, Bonadonna et al. 2002, Harwood et al. 2005, Lemarchand and Lebaron 2003, Lund 1996, Rees et al. 1998).*
>
> *One important reason for the lack of correlation between traditional fecal indicator bacteria and pathogens is that the indicator bacteria are not specific to humans, nor to other hosts known to shed human pathogens in their feces, but are present in the intestines of all warm-blooded animals and some cold-blooded animals (Souza et al. 1999). Because not all animals are equally likely to carry human pathogens, contamination from all sources does not represent an equal health risk. Thus, some sources of fecal contamination in water are of greater concern than others. Furthermore, there is increasing evidence of naturalized or environmentally adapted strains indicator bacteria (both coliforms and enterococci) that are capable of persisting in a culturable form for extended periods, or even growing, in a wide variety of environmental matrices, including terrestrial soils, aquatic sediments, and attached to*

aquatic vegetation (Byappanahalli and Fujioka 1998, Byappanahalli et al. 2003, Ishii et al. 2006, Jeng et al. 2005, Ksoll et al. 2007, Solo-Gabriele et al. 2000, Topp et al. 2003, Whitman et al. 2003). If indicator bacteria are persisting in environmental matrices their reintroduction into the water column, such as might occur during storms or high recreational activity, may lead to false positive indications regarding contamination and public health risk. As a result of these two confounding factors, it is now clear that simply measuring concentrations of waterborne indicator bacteria do not offer detailed enough information to properly determine health risks associated with recreational water use. Furthermore, this practice does not allow specific sources of contamination to be identified or targeted for remediation of water quality.

Proposed Numeric Nutrient Criteria

The evidence gathered by FDEP and presented in this document demonstrates that the aquatic life use in the Waccasassa and Withlacoochee estuaries is fully supported, and that the aquatic life use in the Suwannee estuary will be fully supported after implementation of the nitrate TMDL. FDEP therefore proposes that the numeric nutrient criteria be crafted to maintain the nutrient regime of the past 15 years for which data are available, to protect the healthy aquatic life use over that time period, coupled with reductions of nitrate in the Suwannee that would correspond with implementation of the TMDL. Due to the strong relationship between salinity and nutrients, assessment areas should be delineated by salinity, and expected nutrient concentrations should reflect variation based on salinity.

Suwannee Estuary

Anthropogenic nitrate loading is known to be excessive in the Suwannee River. Subsequently, there is a TMDL for nitrate and proposed nitrate limits for springs within the basin to address the imbalances of flora that have occurred due to the nitrate loading (Hallas and Magley 2008). Despite the riverine loading, the estuary has a healthy fishery, no impairments of dissolved oxygen, and no harmful algal blooms. Evidence shows that high flow events from the Suwannee River have contributed to losses and changes in the SAV community in Horseshoe Cove (Carlson *et al.* 2010) and possibly the deep edges of Springs Coast seagrasses (Hale *et al.* 2004, Jolliff *et al.* 2003). Studies by Quinlan (2003) showed color to be the chief factor in light limitation in the Suwannee Estuary, but preliminary results of FWRI studies suggest that chlorophyll *a* and turbidity play a greater role in light limitation in the Big Bend region as a whole (Paul Carlson, personal communication). During a period of low flow, when the river was more dominated by anthropogenic loading of nitrate-nitrite, increased macroalgal growth was observed in the near shore oyster beds (Quinlan 2010). Current nutrient loading to the estuary is higher than in years before human settlement, but it is unclear if there have been any long term negative impacts thus far on the estuary. FDEP is confident that once the TMDL for the Suwannee River is met, the nutrient levels within the estuary will be fully protective of the designated aquatic life use.

Waccasassa Bay

Anthropogenic loading to Waccasassa Bay is extremely small, yet the bay has the highest nutrient and chlorophyll a concentrations of the region. These levels are due to the high percentage of wetlands in the watershed and the shallow and turbid nature of the estuary. Waccasassa Bay naturally has lower water clarity than the coastal areas to the north and to the south, so the SAV communities are not as well developed or studied. However, evidence gathered in this report demonstrates that conditions have not changed in this estuary since the 1960s (including chlorophyll *a* concentrations), so it is logical that the existing condition protects the aquatic life use in the estuary.

Withlacoochee Estuary

The Withlacoochee River is subject to some human development, but is also characterized by an abundance of protected land, and the river serves as a freshwater reference site. The estuary has been hydrologically modified by the Inglis Dam and the Cross Florida Barge Canal. It is possible that this modification actually prevents some of the nutrient loading from reaching the estuary. TN and chlorophyll *a* concentrations have not changed since the mid-1980s in this estuary, which suggests that anthropogenic activities are not having any measureable effect on the estuary.

[FDEP is seeking input on appropriate regionalization or separation by salinity in these estuaries]

Methodology for Criteria Development

For consistent application and for providing an appropriate level of protection, water quality criteria need to include magnitude, frequency, and duration components. The magnitude is a measure of how much of a pollutant may be present in the water without an unacceptable adverse effect. Duration is a measure of how long the pollutant may be above the magnitude, and frequency relates to how often the magnitude may be exceeded without adverse effects. It is preferred to derive the magnitude component of a criterion through a cause-effect relationship (such as those measured through toxicity testing). The magnitude would then be set at a level that would protect a majority of the sensitive aquatic organisms inhabiting the system. Absent a demonstrated cause-effect relationship, the magnitude may be set at a level designed to maintain the current data distribution, accounting for natural temporal variability, when the current conditions are protective of the designated uses of the waterbody. Since a criterion derived based on the existing data distribution has no direct link to any observed cause and effect relationship, it is assumed that maintaining the current data distribution will preserve the uses associated with that distribution.

The frequency and duration components of the criteria are best established as additional descriptors of the reference condition data distribution. Specifically, these components should be part of a statistical test designed to determine whether the long-term distribution of data has shifted upward (or in some cases, downward) from the reference distribution. This test would then be used to determine whether future monitoring data are consistent with the magnitude (long-term average) defined by the reference dataset. It is critical to account for the natural variability surrounding the magnitude expression and to control for statistical errors.

The derivation of the magnitude, frequency and duration components of the numeric nutrient criteria for Suwannee, Waccasassa, and Withlacoochee Estuaries is described briefly below. More details concerning the statistical approaches used can be found in the document "Overview of FDEP Approaches for Nutrient Criteria Development in Marine Waters" (FDEP 2010).

Magnitude

The magnitude component can be set at a variety of values based on the frequency and duration that will be used to determine compliance. For the "healthy existing conditions" approach, FDEP established the magnitude at: a) an adjusted long-term central tendency (geometric mean) of the distribution, expressed as a long-term geometric mean never to be exceeded; and b) an annual geometric mean, not to be exceeded more than two times over a five- year period. The long-term average condition was adjusted to a level that represents an insignificant increase from the baseline. Allowing for an insignificant increase accounts for uncertainty in the estimate of the mean and partially addresses the fact that the reference based approach fails to identify a threshold of imbalance, and thus is highly prone to excessive Type I error. For the purpose of antidegradation evaluations, EPA has established that a ten percent change in a water quality parameter represents an insignificant departure from the historical condition, known as a *de minimus* change (US Sixth Circuit Court 2008). Therefore, the long-term geometric mean limit was derived to allow for up to a ten percent increase in the long-term geometric mean, which was calculated as the geometric mean of the annual geometric means of the long-term dataset for each segment of the waterbody.

Because it is not always practical to assess compliance with the criteria on the same long-term basis, FDEP also developed criteria expressed as an annual geometric mean so that estuaries could be assessed on an annual basis. It should be noted that the duration and frequency components of the criteria must be linked to the response timeframe of the sensitive endpoint. Short-term averaging periods (e.g., 1 to 30 days) might be appropriate for nutrient criteria where a sufficiently robust cause-effect relationship has demonstrated that a eutrophic response occurs over such timeframes. If however, such a short-term response cannot be demonstrated, or there is no indication of use impairment, longer averaging periods should be used.

Duration and Frequency

Since the duration and frequency components of the criteria must be consistent with the derivation of the magnitude component, the long-term geometric mean target cannot simply be applied as an annual mean. Doing so would result in an unacceptability high Type I failure rate (identifying a healthy system as being impaired) since approximately 50 percent of the individual yearly means are expected to be above the long-term mean. Therefore, the long-term target must be adjusted to allow for the application to a shorter duration with an acceptable Type I error rate of no more than a 10 percent.

An annual criterion with an approximate 10 percent Type I error rate for a given frequency was derived by appropriately accounting for the annual variability above the mean. This annual target concentration was derived as an upper percentile of the distribution of the annual geometric mean concentrations. Previous proposals by EPA have utilized three-year assessment periods to express the duration nutrient criteria components. Although it is possible to construct a test that achieves the 10 percent Type I error rate target over a 3-year period, a slightly longer period (5 years) will provide better control for Type II error and will more fully capture climatic cycles (*e.g*., el nino, la nina), which tend to be longer than three years in Florida (and may actually be on a multi-decadal scale). Furthermore, a five year period is more consistent with both the State's five year 303(d) assessment and NPDES permit renewal cycles.

Given a five year assessment period, FDEP derived criteria expressed as an annual geometric mean by using the 75th percentile of the annual geometric means from the long-term dataset. FDEP demonstrated that setting the criteria at this percentile results in a magnitude that, when expressed as an annual geometric mean not to be exceeded more than twice during a five-year period, will achieve the targeted 10 percent error rate**.** The magnitude component of the criteria (not to be exceeded more than twice in a 5 year period) was established to allow for two separate assessments:

- *As an annual geometric mean for a network of stations in a specified segment of the waterbody; and*
- *As an annual geometric mean for a single station in a given segment.*

The two expressions of magnitude differ in the handling of within-segment spatial variability. The network average magnitude was calculated based on the distribution of spatially averaged annual geometric means, while the single site magnitude was calculated using the distribution of station annual geometric means. Use of the network average magnitude is appropriate for assessing overall segment status. However, a network average is only representative of overall segment status if it is relatively homogeneous. If the segment is not well mixed, is very large, or contains localized nutrient sources, then there is a potential that isolated areas of enrichment may be masked in the network spatial average. Therefore, the single station annual geometric mean has the benefit of assessing localized enrichment patterns. DEP has not decided whether both expressions of magnitude are needed in all cases, and we are seeking additional feedback from local experts and stakeholders.

Summary of the Proposed Criteria

FDEP proposes three sets of potential criteria: a) a long-term geometric mean concentration; b) an annual geometric mean of values from a network of stations over a given area, not to be exceeded more than twice in a five-year period; and c) an annual geometric mean of values from a single location, not to be exceeded more than twice in a five-year period.

The proposed long-term concentrations for the protection of a healthy, well-balanced aquatic community in Suwannee, Waccasassa, and Withlacoochee Estuaries, as well the annual limits for each segment, are provided in Table 22. Offshore values represent stations with annual average salinity greater than 25 ppt. Nearshore values represent stations with annual average salinity less than 25 ppt and greater than 3 ppt. The following COAST sites were excluded due to their predominantly fresh nature (mean salinity < 3 ppt): Suwannee sites 1 and 2, Waccasassa site 1, and Withlacoochee sites 2 and 3. Suwannee offshore sites were COAST sites 7, 8, 9, and 10, and two SRWMD stations at Cedar Keys. Suwannee COAST sites 3, 4, 5, and 6, and six SRWMD Suwannee River Estuary (SRE) sites were used for the nearshore calculation. Waccasassa COAST sites 6, 7, 9, and 10 represent the offshore region, and sites 2, 3, 4, 5, and 8 comprised the nearshore. For the Withlacoochee, the offshore region includes COAST sites 4, 7, and 10, and the nearshore region includes COAST sites 1, 5, 6, 8, and 9. NOTE: Values proposed for nearshore Suwannee TN and chlorophyll *a* will be revised to take into account reductions in nitrate required for the Suwannee River TMDL. All COAST chlorophyll *a* data used are not corrected for phaeophytin.

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Table 22a. Proposed numeric nutrient criteria for all segments of the Suwannee Estuary for TP, TN, and chlorophyll a. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period.

- = Empty cell/no data

Segment	LT_GM	LT_Limit	Network Average 2:5 Annual Limit	Assessed as a Single Site GM 2:5 Annual Limit	Comments
TP	-	-	-	-	-
Nearshore	69.7	76.7	92.8	101.6	-
Offshore	32.3	35.5	43.9	46.8	-
TN	-	-	-	-	-
Nearshore	722	794	969	1075	To be determined
Offshore	422	464	560	600	-
Chla	-	-	-	-	-
Nearshore	4.60	5.06	7.25	9.84	To be determined
Offshore	5.27	5.79	7.40	7.83	

Table 22b. Proposed numeric nutrient criteria for all segments of the Withlacoochee Estuary for TP, TN, and chlorophyll a. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period.

- = Empty cell/no data

Segment	LT_GM	LT_Limit	Network Average 2:5 Annual Limit	Assessed as a Single Site GM 2:5 Annual Limit
TP	-	-	-	-
Nearshore	**39.4**	**43.3**	**50.0**	**51.8**
Offshore	**25.6**	**28.2**	**33.5**	**34.0**
TN	-	-	-	-
Nearshore	**427**	**470**	**536**	**546**
Offshore	**326**	**358**	**408**	**413**
Chla	-	-	-	-
Nearshore	**5.31**	**5.84**	**7.46**	**7.68**
Offshore	**3.80**	**4.18**	**5.66**	**5.78**

Table 22c. Proposed numeric nutrient criteria for all segments of the Waccasassa Estuary for TP, TN, and chlorophyll a. For compliance purposes, the long term geometric mean shall not exceed the long term limit nor shall the average of all stations in a segment exceed the network average more than twice in a 5 year period. The last column shows the value which single station shall not exceed, by segment, more than twice in a 5 year period.

- = Empty cell/no data

Segment	LT_GM	LT_Limit	Network Average 2:5 Annual Limit	Assessed as a Single Site GM 2:5 Annual Limit
TP	**-**	**-**	**-**	**-**
Nearshore	56	62	69	76
Offshore	35	38	47	55
TN	**-**	**-**	**-**	**-**
Nearshore	627	690	772	835
Offshore	480	528	610	664
Chla	**-**	**-**	**-**	**-**
Nearshore	6.3	7.0	8.8	10.8
Offshore	5.0	5.5	8.0	9.4

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