Chapter 12: Management and Restoration of Coastal Ecosystems

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SUMMARY

The South Florida Water Management District (SFWMD or District) has selected the Florida Bay area to highlight in this chapter for Water Year 2007 (WY2007) (May 1, 2006 through April 30, 2007). The District has been particularly active in this area sustaining a program of monitoring, research, and modeling to better understand the importance of water management in ecological change. It will also help to improve the District's ability to forecast the effects of water deliveries and develop different methods for the protection and restoration of the Florida Bay ecosystem. In addition, the District has completed a draft Coastal Ecosystems Division Science Plan (Appendix 12-1) and a Strategic Research Plan for the Everglades Division (Appendix 6-1, which includes Florida Bay plans) for review by this year's South Florida Environmental Report (SFER) peer-review panel. Research needs for each ecosystem are provided in these plans and in each coastal ecosystem section of this chapter.

Reports of scientific and modeling activities in the coastal ecosystems address a variety of ongoing studies, the initiation of baseline studies, and in some instances the conclusions of data acquisition or analysis during WY2007. In the St. Lucie Estuary, flow and salinity monitoring continued with no exceedances of the Minimum Flows and Levels rule. A hydrodynamic/salinity/water quality model was calibrated to evaluate the effectiveness of pollutant reduction strategies and the effects of the Ten Mile Creek facility. Scientific activities in support of the Northwest Fork of the Loxahatchee River Restoration Plan included the initiation of a baseline vegetation study in the freshwater floodplain and a baseline freshwater fish study. Groundwater monitoring continued to be conducted. The District's water quality monitoring partnership with the Loxahatchee River District is continuing. In response to last year's SFER peer-review panel's comments, water quality is now being collected at select sites on a monthly basis. Salinity, oyster, and seagrass monitoring in the Northwest Fork is continuing. In Lake Worth Lagoon, a new long-term salinity monitoring program was established to help determine appropriate salinity levels in the lagoon. Biscayne Bay salinity-level information is being developed to produce freshwater inflow criteria. The Florida Bay report presents: (1) results from monitoring projects (regarding hydrologic and salinity conditions, water quality, and seagrass habitat); (2) an update on conditions relevant to the Minimum Flow and Level (MFL); (3) an analysis of the status of the eastern algal bloom and current understanding of the causes and effects; and (4) progress on water quality and seagrass research and modeling. In the Naples Bay area, a long-term salinity monitoring plan is currently under development. Freshwater flow ranges

for the tributaries to Estero Bay have been developed and preferred inflow ranges based on performances measures have been identified. The relationships of inflows to salinity in the Caloosahatchee Estuary are of significant interest. Research and modeling conducted by the District has resulted in the identification of an average monthly flow distribution to protect and promote desirable estuarine biota and resources. This distribution has been adopted as a performance measure target by the Comprehensive Everglades Restoration Plan for the Caloosahatchee River and Estuary. Each section in this chapter provides more in-depth information on each of the estuaries within the District boundaries.

INTRODUCTION

This chapter provides an overview of key science and technical activities associated with coastal ecosystems within the South Florida Water Management District (SFWMD or District) as it relates to freshwater inflows and science strategies. The responsibility for implementation of restoration and management programs is primarily in programs such as the Comprehensive Everglades Restoration Plan (CERP), Operations and Maintenance, or Water Supply. The management of Total Maximum Daily Loads (TMDLs) and determining impaired waters is the primary responsibility of the Florida Department of Environmental Protection (FDEP); however, the SFWMD cooperates with the FDEP and shares information, knowledge, and tools to assist the department with that program. A primary role of the Coastal Ecosystem Program is to provide the required information necessary to design effective restoration and protection measures for the estuaries, and inform decision makers. The District concentrates this effort within several major coastal ecosystems in South Florida (**Figure 12-1**). These coastal systems share common problems; however, the magnitude of any one issue may be quite different among areas. The District conducts or participates in scientific research and monitoring for the majority of these ecosystems, and works closely with other local, state, and federal partnering agencies for those areas where the District is not the lead agency.

In keeping with the goal of maintaining brevity, this year's chapter provides brief summaries of the status of freshwater inflows and salinity in each of several priority estuaries, while giving a more detailed description of additional issues and results in Florida Bay. Each year, the District will select one of the estuaries to highlight. It should also be noted that the St. Lucie Estuary and the Caloosahatchee Estuary are included in the newly implemented Northern Everglades Initiative (see Chapter 7A of this volume). It is anticipated that progress related to this initiative will be reported in future *South Florida Environmental Reports*.

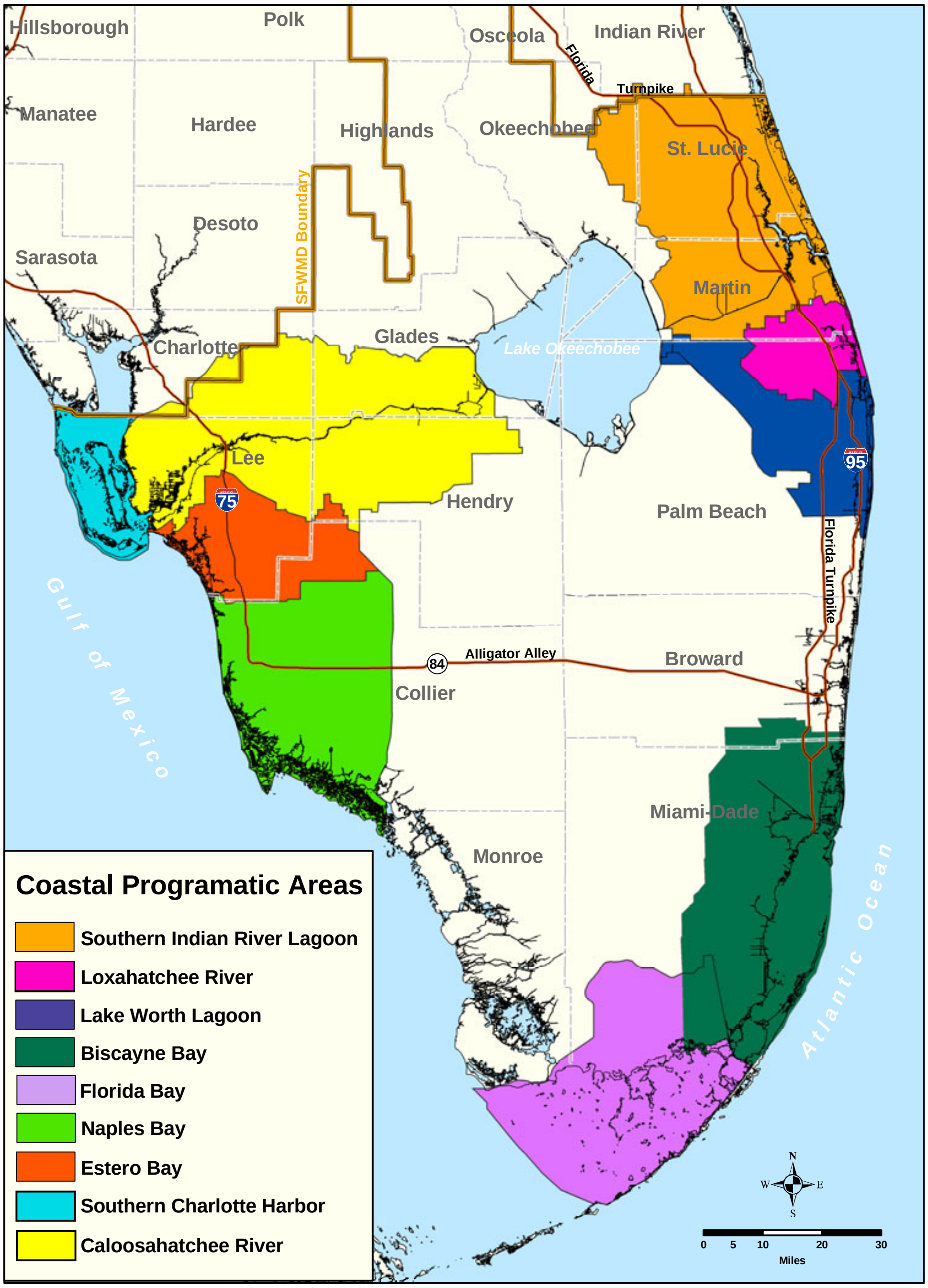

Figure 12-1. Priority coastal watersheds within the South Florida Water Management District.

A primary objective of the District is to ensure that an appropriate pattern of fresh water is supplied to the estuaries. This requires knowledge about the current conditions and ecology of each one of the water bodies and watersheds, appropriate ecological end points, and a means to predict potential changes to the freshwater inflow patterns. To address these needs, the Coastal Ecosystems Division, which oversees science programs for all of the coastal areas except Florida Bay, has developed the Coastal Ecosystems Science Plan (Appendix 12-1) to ensure the most important science needs are addressed and to guide budgetary decisions. See Appendix 6-1 for the science plan for Florida Bay, including development of integrative models. **Table 12-1** lists the priority estuaries and a summary of facts about them. **Table 12-2** summarizes the status of the development of tools such as required models for each of the estuaries presented in this chapter. The Science Plan is designed to develop information to produce the tools and products required for characterizing and predicting responses in these systems resulting from water management.

Table 12-1. Estuaries of the South Florida Water Management District.

Estuary	Approximate Area*		Description
	km^2	mi^2	
Southern Indian River Lagoon	860	332	Designated for special study, protection, and restoration as part of the regional National Estuary Program; characterized by the greatest species diversity of any estuary in North America; supports fishing, clamming, ecotourism, agriculture, and recreation.
St. Lucie River and Estuary	24	9	**Part of the Indian River Lagoon** estuary system with drainage from several creeks and canals that flow into the North or South Fork of the St. Lucie River before entering the lagoon near the St. Lucie Inlet; provides habitat for thousands of plant and animal species and supports commercial, recreational, and educational activities.
Loxahatchee River and Estuary	1.5	4	First federally designated National Wild and Scenic River; watershed contains large tracts of undisturbed land, protected parcels, and agricultural land; diverse habitat includes coastal sand pine scrub, pinelands, xeric oak scrub, hardwood hammock, freshwater marsh, wet prairie, cypress swamps, mangrove swamps, seagrass beds, tidal flats, oyster beds and coastal dunes.
Lake Worth Lagoon	11	30	Watershed is mostly urbanized; lagoon was historically a freshwater lake with occasional brackish conditions and converted to a marine environment since the early 1900s with the opening of inlets; most runoff is conveyed into the lagoon through canals.

Table 12-1. Continued.

Estuary	Approximate Area*		Description
	km²	**mi²**	
Biscayne Bay	1100	428	Subtropical estuary with diverse habitats including hardground designated as an aquatic preserve and Outstanding Florida or Outstanding National Resource Water; the southern portion is contained within Biscayne National Park or the Florida Keys National Marine Sanctuary; the northern watershed is urbanized, but the northern bay was historically brackish until the opening of inlets; most runoff is conveyed into the bay through canals; wetlands border the southwestern shoreline.
Florida Bay and Florida Keys	2200	849	About 80 percent of the bay is within Everglades National Park; a broad, shallow expanse of brackish-to-salty water that contains numerous small islands, extensive mud banks and grass flats; mangroves and seagrasses provide valuable habitat for many species; keys watershed consists of a limestone island archipelago of about 800 islands extending southwest for over 320 kilometers (200 miles) contained with the Florida Keys National Marine Sanctuary.
Naples Bay	4	2	Urbanized watershed and physically altered shore line and bottom; seagrass and oyster habitat greatly reduced from c. 1920s; most runoff enters from Golden Gate Canal.
Estero Bay	39	15	A shallow water body; several barrier islands separate the bay from the Gulf of Mexico; the bay has five rookery and roosting islands utilized by thousands of native birds; most runoff enters the bay from three primary rivers.
Caloosahatchee River and Estuary	82	32	Estuary where the Caloosahatchee River flow mixes with the Gulf of Mexico; lower reaches of the estuary are characterized by a shallow bay, extensive seagrass beds, and sand flat; extensive mangrove forests dominate undeveloped shoreline area; most runoff enters via the Caloosahatchee River which can include excess water from Lake Okeechobee.
Charlotte Harbor	336	130	Florida's second-largest open water estuary and one of the state's major environmental features; designated for special study, protection and restoration as part of the regional National Estuary Program; area contains three national wildlife refuges and four aquatic preserves.

* Water body area only

Table 12-2. Status of Coastal Ecosystems Science Plan products for each estuary.

Numeric Models Watershed	Present Conditions	Natural System
St. Lucie and South Indian River Lagoon	Calibrated WaSh Model for hydrology and water quality. Field data for inflows and water quality being collected for verification (SLT Program)	HSPF model hydrology simulations completed.
Loxahatchee River Estuary	Calibrated WaSh model for hydrology	RSM under development.
Lake Worth Lagoon	CERP North Palm Beach Plan flow modeling ongoing using LECsR Modflow model	
Biscayne Bay	Currently using the SFWMM regional model. A groundwater/surface water model is being developed by USGS	
Florida Bay	South Florida Water Management Model (2X2), RSM, USGS TIME Model calibrated and reviewed by IMC for CERP (FBFKFS)	NSM output used to estimate salinity via statistical model with paleoecologically-based correction (RECOVER).
Naples Bay		
Estero Bay		
Caloosahatchee River Estuary	(1) Calibrated MIKE SHE Regional for stage and flow (hydrology) – existing conditions set-p completed and will under go quality assurance/quality control (2) Sub-regional MIKE SHE model developed and undergoing modifications (3) Water quality model completed that provides time varying loading rates. (4) Spreadsheet model for estimating watershed water quantity delivery through S-79	Natural system information for input to MIKE SHE is compiled and NSM runs are scheduled for the end of August 2007

Table 12-2. Continued.

Numeric Models Estuary	Hydrodynamics	Salinity	Water Quality	Sediment
St. Lucie and South Indian River Lagoon	CH3D calibrated; additional data being collected for verification	CH3D calibrated; additional data being collected for verification	CH3D calibrated; additional data being collected for verification	CH3D calibrated; additional data being collected for verification
Loxahatchee River Estuary	RMA calibrated; integrated surface/groundwater model under development	RMA calibrated; integrated surface/groundwater model under development	CH3D model is done that can be calibrated for water quality simulations	Both RMA and CH3D models can be calibrated for sediment transport simulations
Lake Worth Lagoon	CERP North Palm Beach Plan EFDC model will be used to establish flow targets to meet desired salinity ranges	CERP North Palm Beach Plan EFDC model will be used to establish flow targets to meet desired salinity ranges		CERP North Palm Beach Plan flow modeling ongoing using LECsR Modflow model
Biscayne Bay	Calibrated TABS-MDS Model	Calibrated TABS-MDS Model		
Florida Bay	EFDC calibrated and reviewed by IMC for CERP (FBFKFS; EFDC domain from Cape Romano to South Biscayne Bay); HYCOM ocean-gulf boundary model for FBFKFS	EFDC calibrated and reviewed by IMC for CERP; HYCOM ocean-gulf boundary model for FBFKFS; FATHOM mass balance model completed and reviewed for MFL	EFDC in development for CERP (FBFKFS)	EFDC in development for CERP (FBFKFS)
Naples Bay	A preliminary CH3D model is under development	A preliminary CH3D model is under development		
Estero Bay	A calibrated CH3D model is available	A calibrated CH3D model is available		
Caloosahatchee River Estuary	CH3D calibrated	CH3D calibrated with a regression routine added to estimate salinity at key locations to reduce time run		

Table 12-2. Continued.

Ecological Models	Oysters	SAV	Fish	Floodplain	Other
St. Lucie and South Indian River Lagoon	Spreadsheet model, daily time step of oyster stress/ salinity		Under development: Spawning and survival success of estuarine dependent fishes	Under development: Digital Elevation Model and plant species composition	
Loxahatchee River Estuary					
Lake Worth Lagoon					
Biscayne Bay			HSI shoreline fishes underdevelopment		
Florida Bay		Dynamic seagrass community model (multispecies; complete for *Thalassia* and *Halodule* with IMC review)	General additive statistical models (populations and forage base) completed, applied to MFL, peer reviewed		Pink shrimp population model: lobster population model; spoonbill statistical model; documentation under way for IMC review
Naples Bay					
Estero Bay					
Caloosahatchee River Estuary	HSI model (depends on predicted salinity and flow from models)	(1) HSI model (depends on predicted salinity and flow from models (2) Tape grass numerical model with daily time step of density/salinity, light and temperature	(1) HSI model (depends on predicted salinity and flow from other models) – blue crabs, fish and zooplankton		Target Flow Index – (spreadsheet model) that compares project flows to S-79 target flow distribution

Table 12-2. Continued.

Ecological Models	Oysters	SAV	Fish	Floodplain	Other
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Loxahatchee River Estuary					
Lake Worth Lagoon					
Biscayne Bay			HSI shoreline fishes underdevelopment		
Florida Bay		Dynamic seagrass community model (multispecies; complete for *Thalassia* and *Halodule* with IMC review)	General additive statistical models (populations and forage base) completed, applied to MFL, peer reviewed		Pink shrimp population model: lobster population model; spoonbill statistical model; documentation under way for IMC review
Naples Bay					
Estero Bay					
Caloosahatchee River Estuary	HSI model (depends on predicted salinity and flow from models)	(1) HSI model (depends on predicted salinity and flow from models (2) Tape grass numerical model with daily time step of density/salinity, light and temperature	(1) HSI model (depends on predicted salinity and flow from other models) – blue crabs, fish and zooplankton		Target Flow Index – (spreadsheet model) that compares project flows to S-79 target flow distribution

Table 12-2. Continued.

Model Integration and Application	
St. Lucie and South Indian River Lagoon	Indian River Lagoon - South Feasibility Study
Loxahatchee River Estuary	Restoration Plan for the Northwest Fork of the Loxahatchee River Scenarios for the CERP North Palm Beach Plan – Part 1
Lake Worth Lagoon	Scenarios for the CERP North Palm Beach Plan – Part 1
Biscayne Bay	Scenarios for CERP Biscayne Bay Coastal Wetlands Project
Florida Bay	FBFKFS, MFL, RECOVER
Naples Bay	Will support the implementation of SWIM Plan and Southwest Florida Feasibility Study
Estero Bay	
Caloosahatchee River Estuary	C-43 Basin ASR (CERP) and Southwest Florida Feasibility Study

Note: Blank cell indicates that no model is available.

ASR – Aquifer Storage and Recovery
CERP – Comprehensive Everglades Restoration Plan
EFDC – Environmental Fluid Dynamics Code
FATHOM – Flux Accounting and Tidal Hydrology at the Ocean Margin
FBFKFS – Florida Bay and Florida Keys Feasibility Study
FDEP – Florida Department of Environmental Protection
FWRI – Fish and Wildlife Research Institute
HIS – Habitat Suitability Index
HSPF – Hydrological Simulation Program
HYCOM – Hybrid Coordinate Ocean Model
IMC – Interagency Modeling Center
MFL – Minimum Flow and Level
NSM – Natural System Model
RECOVER – Restoration Coordination and Verification
RSM – Regional Simulation Model
SAV – Submerged Aquatic Vegetation
SFWMM – South Florida Water Management Model
SLT Program – St. Lucie Tributary Water Quality Monitoring Program
SWIM – Surface Water Management and Improvement
TIME – Tides and Inflows in the Mangrove Ecotone
USGS – U.S. Geological Survey
VEC – Valued Ecosystem Component

The Eastern oyster (*Crassostrea virginica*) is a key indicator in many of the estuaries that the District and other organizations actively monitor. A concern is that a non-native species of green mussel (*Perna viridi*) may impact populations of the native oyster, however, Asian green mussels have not yet been detected in the estuaries within the District.

SOUTHERN INDIAN RIVER LAGOON AND ST. LUCIE RIVER AND ESTUARY

Daniel Haunert

INTRODUCTION

The St. Lucie Estuary (SLE) is a relatively large brackish water body on the east-central coast of Florida in Martin and St. Lucie counties and is a primary tributary to the Southern Indian River Lagoon (SIRL). Most of the watershed drains into the North and South Forks [6.4 square miles, (sq mi) or 16.6 square kilometers (km^2)] that converge and flow to the middle estuary (4.7 sq mi; 12.2 square kilometers) that extends east for approximately five miles (8 km) to the Indian River Lagoon and the Atlantic Ocean at the St. Lucie Inlet.

The SLE and its watershed (**Figure 12-2**) have been highly altered to accommodate human development. During recent history, the freshwater St. Lucie River was exposed to ocean waters only when large storms caused ephemeral passes in the protective barrier islands. In 1892, however, the St. Lucie Inlet was dug and maintained, allowing for the current brackish water system. As part of a South Florida flood control project, the South Fork of the estuary was connected to Lake Okeechobee to control water levels in 1924. Periodic high-volume flood control discharges from the lake have turned the entire estuary to fresh water, from days to months at a time, causing considerable negative impacts to the system. Between 1935 and 1960 an extensive drainage system was constructed in the watershed which included dredging and channelizing the North Fork Narrrows, C-23, and C-24. Major effects of this drainage system include reductions in groundwater levels and evaporation as well as rapid watershed drainage manifested by changes in the quantity, quality, timing, and distribution of inflows to the estuary. Discharges from the lake, altered watershed hydrology, and water quality have degraded estuarine resources such as submerged aquatic vegetation (SAV), oyster communities, and fisheries.

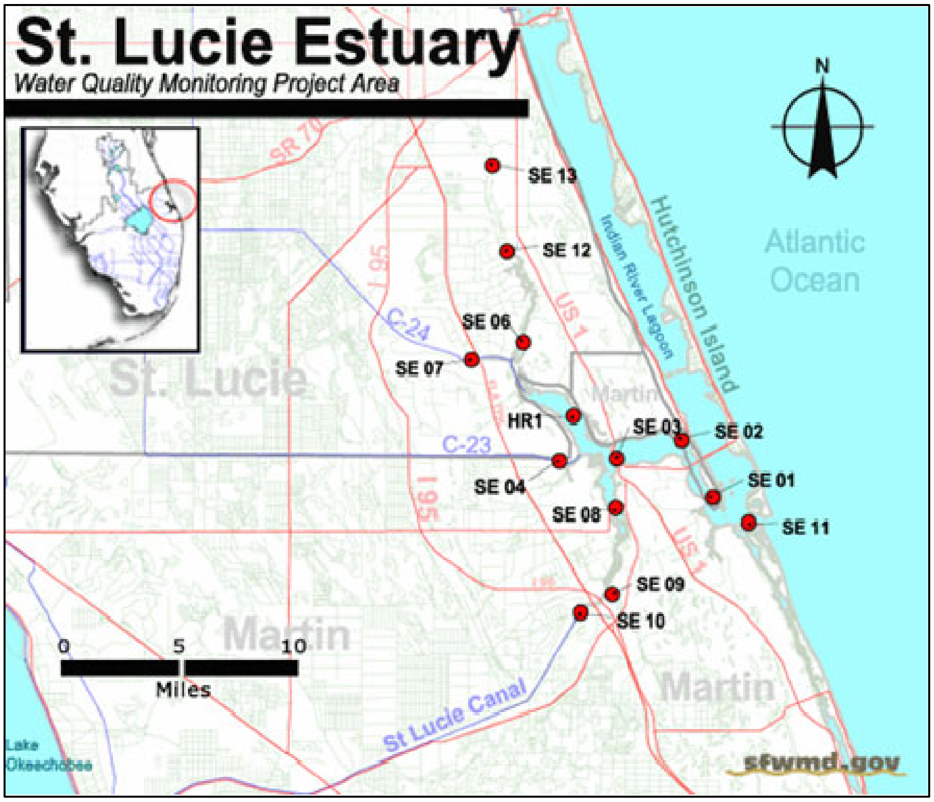


Figure 12-2. St. Lucie Estuary (SLE) water quality monitoring network.

STATUS OF FRESHWATER INFLOWS AND SALINITY IN THE ST. LUCIE ESTUARY

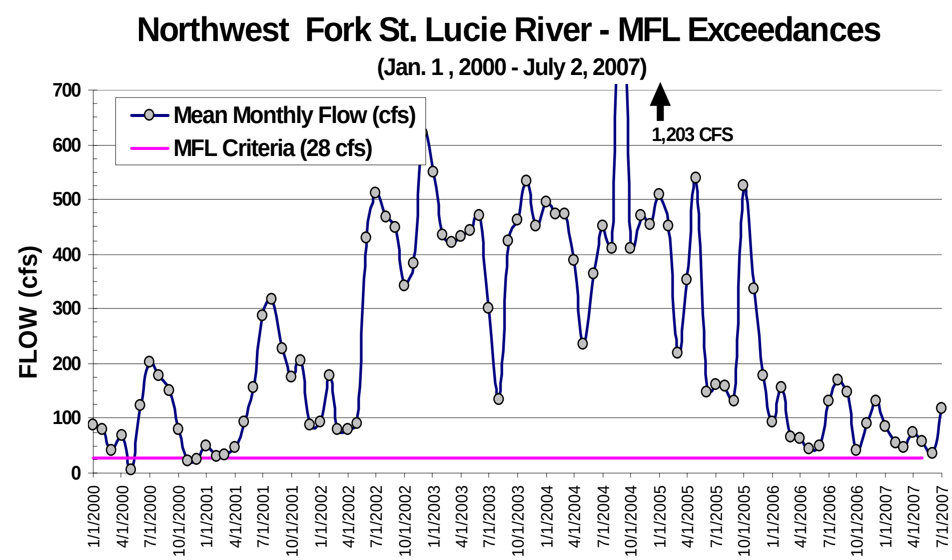
To protect key components of the estuary, the Minimum Flows and Levels (MFL) rule for the North Fork of the St. Lucie Estuary was established on November 6, 2002 (see SFWMD 2002). Inflows less than 28 cubic feet per second (cfs) (0.8 cubic meters/s), monthly average, at the inland Gordy Road structure for two consecutive months for two consecutive years is considered an exceedance. **Figure 12-3** shows flows at this structure from the year 2000 to present with no exceedances.

To avoid unfavorable low salinity that could impact mesohaline benthic communities in the middle estuary, the District established that inflows from the watershed and/or flood control releases from Lake Okeechobee should not exceed about 2,000 cfs (56.6 cubic meters/s) (monthly average) which results in a salinity at the U.S. Highway 1 bridge of about 7 practical salinity units (psu). The bridge is at the confluence of the North and South Forks and, therefore, salinity at this location indicates the integrated salinity effects of the majority of inflows into the system. **Figure 12-4** reveals that maximum inflows were not been exceeded during the last year. A salinity and water stage monitoring site was established in May 2007, in cooperation with the Florida Department of Environmental Protection, on the north side of the St. Lucie Inlet. Data from this site will provide boundary conditions for the District's hydrodynamic/water quality model and high resolution salinity values for seagrass studies.

RESEARCH NEEDS IN THE ST. LUCIE RIVER ESTUARY AND INDIAN RIVER LAGOON

Although modeling of the St. Lucie Estuary and Southern Indian River Lagoon is relatively advanced, a major objective for the SLE is to develop Valued Ecosystem Component (VEC) evaluation tools. Once the cause-and-effect relationships of inflows on VECs such as Eastern oysters and early life history of fishes are reasonably well established and used as performance measures of estuarine health, mathematical optimization techniques can be utilized to enhance water management operations in the watershed. A greater understanding of the eco-physiological requirements of VECs is required for Minimum Flows and Levels (MFLs), water reservations, Lake Okeechobee regulation, and Comprehensive Everglades Restoration Plan/Restoration Coordination and Verification (CERP/RECOVER).

In 2007, the Florida legislature expanded the Lake Okeechobee Protection Area to include protection and restoration of the Lake Okeechobee watershed and the Caloosahatchee and St. Lucie estuaries. The legislation, being implemented as the Northern Everglades and Estuaries Protection Program, will focus resources on restoration efforts for Lake Okeechobee and the Caloosahatchee and St. Lucie estuaries.



MFL Criteria: Mean monthly flows to the North Fork St. Lucie Estuary should not fall below 28 cfs as measured at the Gordy Road structure for more than two consecutive months during a 365-day period, for two consecutive years.

MFL Status: There have been no exceedances of the MFL since adoption of the rule on November 6, 2002.

Figure 12-3. Average monthly flow to the Northwest Fork compared to the minimum flow criterion.

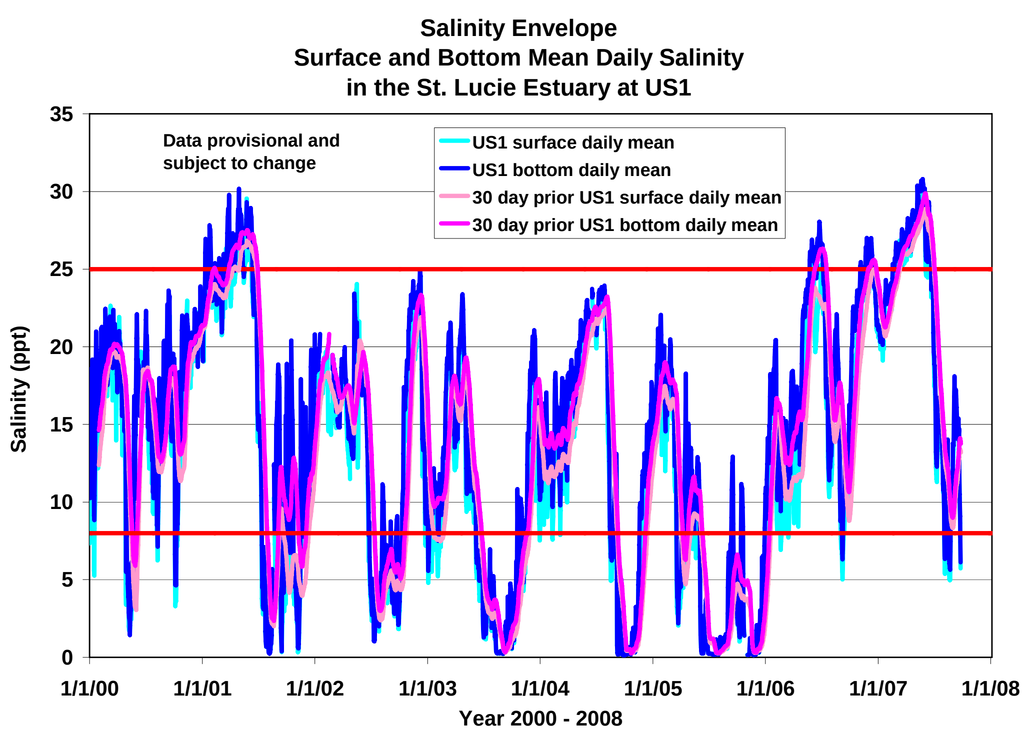


Figure 12-4. Salinity results in the St. Lucie River at the U.S. 1 Bridge compared to the preferred range.

A long-term water quality-monitoring program was started in October 1989 in the SLE (SFWMD and SJRWMD, 2002). Ten water quality monitoring stations were established to detect long-term spatial and temporal trends in the SLE (**Figure 12-5**). Data were collected biweekly from October 1990 through December 1996. A monthly frequency was determined to be adequate, started in January 1997 to present. In situ physical parameters included temperature, pH, conductivity, and dissolved oxygen (DO). Samples were analyzed for turbidity, total suspended solids, color, total phosphorus, total Kjeldahl nitrogen, orthophosphate, total nitrogen, organic and inorganic nitrogen and chlorophyll *a*. The data collection effort supports several critical restoration efforts in SLE including SWIM projects and the restoration plan and implementation.

The District calibrated a CH3D and EFDC hydrodynamic/salinity/water quality model to evaluate the effectiveness of pollutant reduction strategies and the effects of the Ten Mile Creek facility. The ten Mile Creek Reservoir is a component of CERP The purpose of the reservoir and associated Stormwater Treatment Area (STA) is to restore historic flows and water quality to Ten Mile Creek, which flows into the St. Lucie Estuary. The District is also modifying the EFDC water quality model into a stand-alone model so that it can be coupled with other hydrodynamic models such as CH3D.

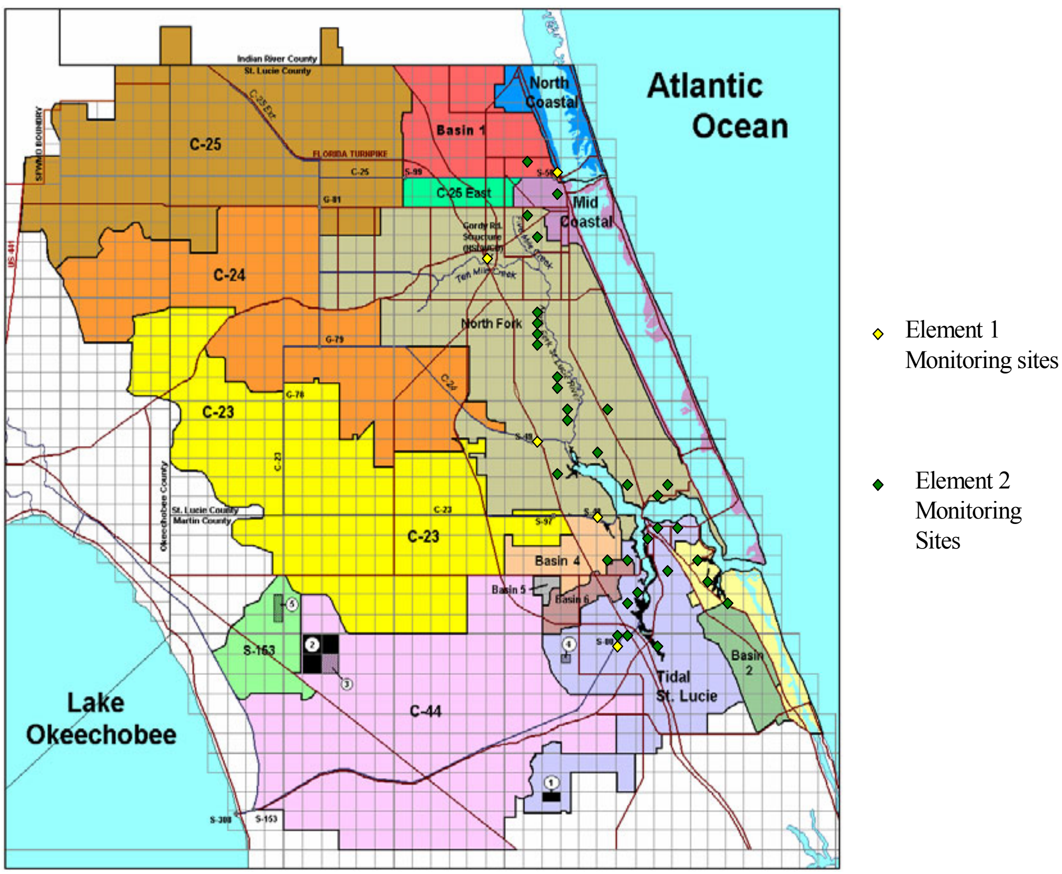


Figure 12-5. St. Lucie Estuary/Indian River Lagoon basin boundaries and water quality monitoring locations.

LOXAHATCHEE RIVER ESTUARY

Patricia Walker and Marion Hedgepeth

INTRODUCTION

The Loxahatchee River and Estuary are located along the lower east coast of Florida (**Figure 12-6**). This watershed drains an area of approximately 210 sq mi (544 square kilometers) within northern Palm Beach and southern Martin counties and connects to the Atlantic Ocean through the Jupiter Inlet, in Jupiter, Florida. Just west of the inlet the river opens into a central embayment area, at the confluence of three major tributaries, the Northwest Fork, North Fork, and the Southwest Fork. The Loxahatchee River is generally referred to as the "last free-flowing river in southeast Florida." In May 1985, 9.5 miles of the Northwest Fork of the Loxahatchee River, between River Mile 6 (RM 6) and River Mile 15.5 (RM 15.5) was federally designated as Florida's first National Wild and Scenic River. Other unique resources of the river and estuary include designations of Aquatic Preserve, Outstanding Florida Waters, and Jonathan Dickinson State Park.

Originally the Loxahatchee River was a freshwater system, the headwaters of which originated in what is known as the Grassy Waters Preserve, the Loxahatchee Slough, and Hungryland Slough. Most of the watershed was drained by the Northwest Fork of the Loxahatchee River. During the past 100 years, the natural hydrologic regime of the Loxahatchee Watershed has been altered by the permanent opening of the Jupiter Inlet in 1947, the construction of the C-18 canal, and drainage activities associated with urban and agricultural development. Hydrologic changes, which have occurred in the Loxahatchee River and Estuary due to navigation, drainage, and flood control activities, have significantly altered the volume, timing, and distribution of freshwater flow. This network of canals and barriers has reduced water storage in natural areas, reduced dry season flows to natural systems, and increased wet season discharges to the Loxahatchee River Central Embayment and Estuary areas.

On April 12, 2006, the SFWMD Governing Board adopted the Restoration Plan for the Northwest Fork of the Loxahatchee River. Immediate implementation occurred when the Preferred Restoration Flow Scenario was incorporated into SFWMD water supply and CERP modeling efforts. Chapter 10 of the plan document outlines data collection and analysis necessary for the development of more accurate predictive models and operational protocols for new and existing structures in place to provide restorative flows. To further implement the plan, a draft Northwest Fork Science Plan has been developed. The objective of this section is to provide a status report on the hydrologic and ecologic data collection conducted by the District and its partners during Water Year 2007 (WY2007).

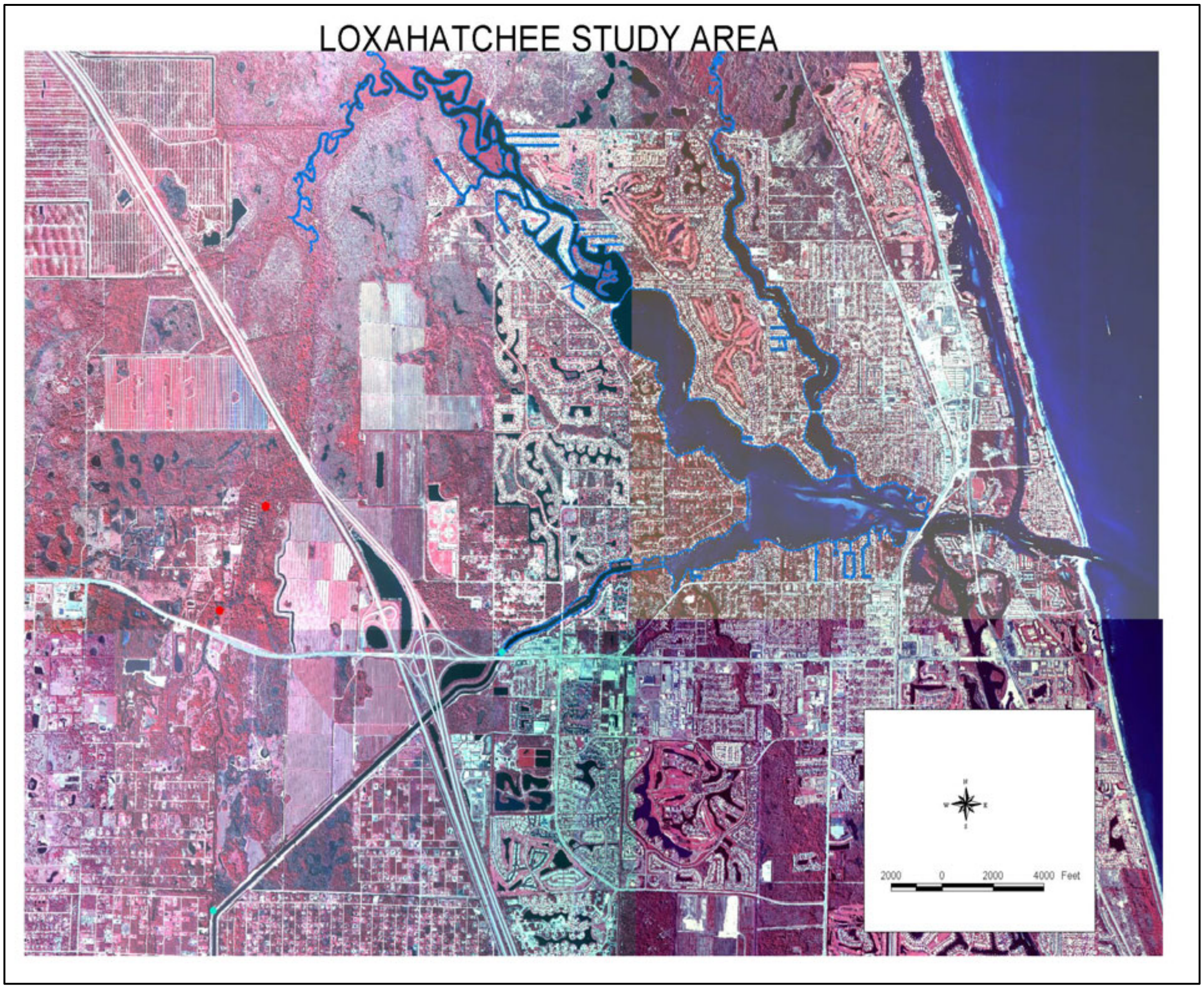


Figure 12-6. Geographic location of the Loxahatchee River and Estuary.

DATA COLLECTION AND ANALYSIS ACTIVITIES

2007 Vegetation and Groundwater in the Floodplains of the Loxahatchee River Watershed Study

Significant changes in the distribution of fresh water and salt water along the floodplains of the Northwest Fork of the Loxahatchee River have altered vegetative communities in the freshwater and tidal floodplains. While cypress and other freshwater communities can still be found in the upper reaches of the Northwest Fork of the Loxahatchee River, the lower reaches of the floodplain are now subject to daily tidal fluctuations and dominated by mangrove forest. Anthropogenic alterations within the Loxahatchee River Watershed have been well documented and described in previous South Florida Environmental Reports.

As recommended in the Restoration Plan for the Northwest Fork (SFWMD, 2006) and established in the related Coastal Ecosystems Science Plan, ongoing vegetation and groundwater studies are being conducted jointly by staff from the SFWMD and the FDEP's Florida Park Service The objectives of this joint monitoring program are to (1) determine the current composition and structure of floodplain plant communities and their associated surface and groundwater hydrological and chemical characteristics, (2) identify short-term indicator plant species for salinity, (3) identify key chemical parameters in the soils that are indicative of the various forest types, (4) examine the influence of exotic plants on this system, (5) determine if additional dry season freshwater flows to the river system are improving or changing the structure of the vegetative communities and/or ground water, and (6) providing guidance for an adaptive management approach to operational deliveries of supplemental flows in the dry season.

A total of 10 belt transects are examined at locations that are representative of riverine (predominantly non-impacted fresh water) and upper and lower tidal (salt water intruded with fresh and brackish water) communities (**Figure 12-7**). Seven transects were established at designated locations along the middle and upper segments of the Northwest Fork of the Loxahatchee River. Additional transects are established in the lower segments of Kitching and Cypress creeks (tributaries of the Northwest Fork), and in the upper North Fork of the Loxahatchee River. Just one 190-meter transect is monitored in the lower tidal area since vegetation is dominated by white and red mangroves and not expected to change over time even if flows are restored.

In support of the 2003 vegetation study, 12 groundwater wells were installed along Vegetation Transects 1, 3, 7, 8, and 9. The objectives of this monitoring project are to measure long-term water levels, salinity, and DO of ground water in the floodplains. It also provides data critical for estimation of hydroperiods, model calibration, and interpretation of vegetation health in the floodplains.

In addition, vegetation monitoring was established in the Restoration Plan for the Northwest Fork and in the related Science Plan, at a frequency of every six years for canopy vegetation and every three years for groundcover and shrubs. Therefore, between February and July 2007, Florida Park Service and SFWMD staff conducted the 2007 Shrub and Groundcover Field Monitoring at the 10 established vegetative transects. Shrub cover was measured by examining all woody plant species with a height greater than 1 m (3.28 feet) and dbh less than 10 cm with a 10 m line-intercept nested within each 10 m^2 plot. Cover and stem counts of all herbaceous plants and woody plant species (groundcover) less than 1 m in size were measured within three, 1 m^2 subplots nested within each 10 m^2 plot. Additional information, collected within each vegetation plot, included presence of hummocks, presence of cypress stumps, as well as estimates of percent open ground, percent exposed roots, percent leaf litter, and percent fallen logs. The 2007 shrub and groundcover field data are currently being converted into a Microsoft Excel data file. A report will be prepared this fall with comparisons of the 2003 and 2007 data. Continued monitoring of the 10 transects on a routine basis as established in the Northwest Fork Science Plan is necessary and expected to continue.

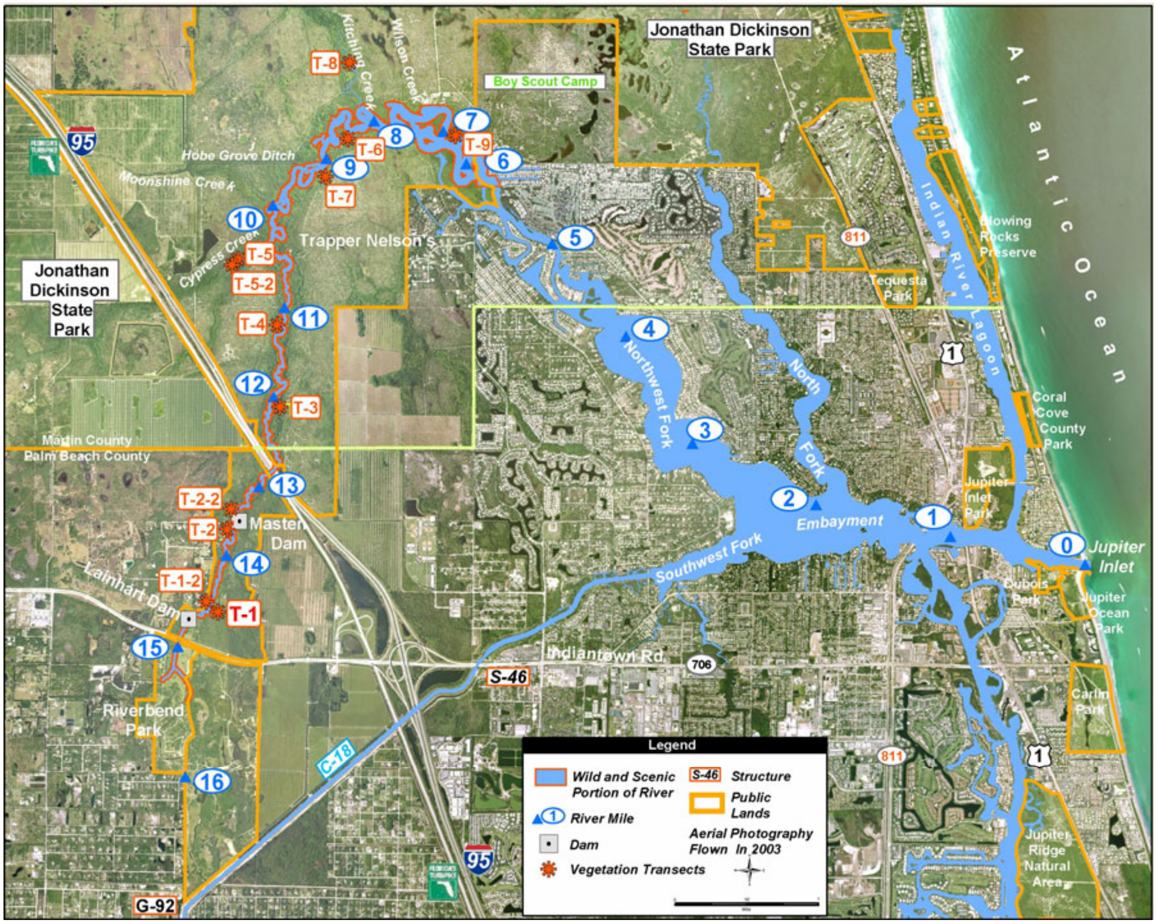


Figure 12-7. Vegetation transects on the Northwest Fork of the Loxahatchee River.

Loxahatchee River Water Quality Monitoring

The Loxahatchee River District (LRD) has established a comprehensive water quality monitoring network at approximately 40 sites in the freshwater and tidal segments of the Loxahatchee River (**Figure 12-8**) for about 30 parameters including salinity, nutrients, chlorophyll, and bacteria (Arrington, 2006). In response to SFER Peer Review Panel comments, water quality is now gathered at select sites on a monthly basis, which should result in improved trends analysis and predictive analysis. The District is currently in the process of working together with LRD to determine the long-term trend in water quality in the Loxahatchee River and Estuary.

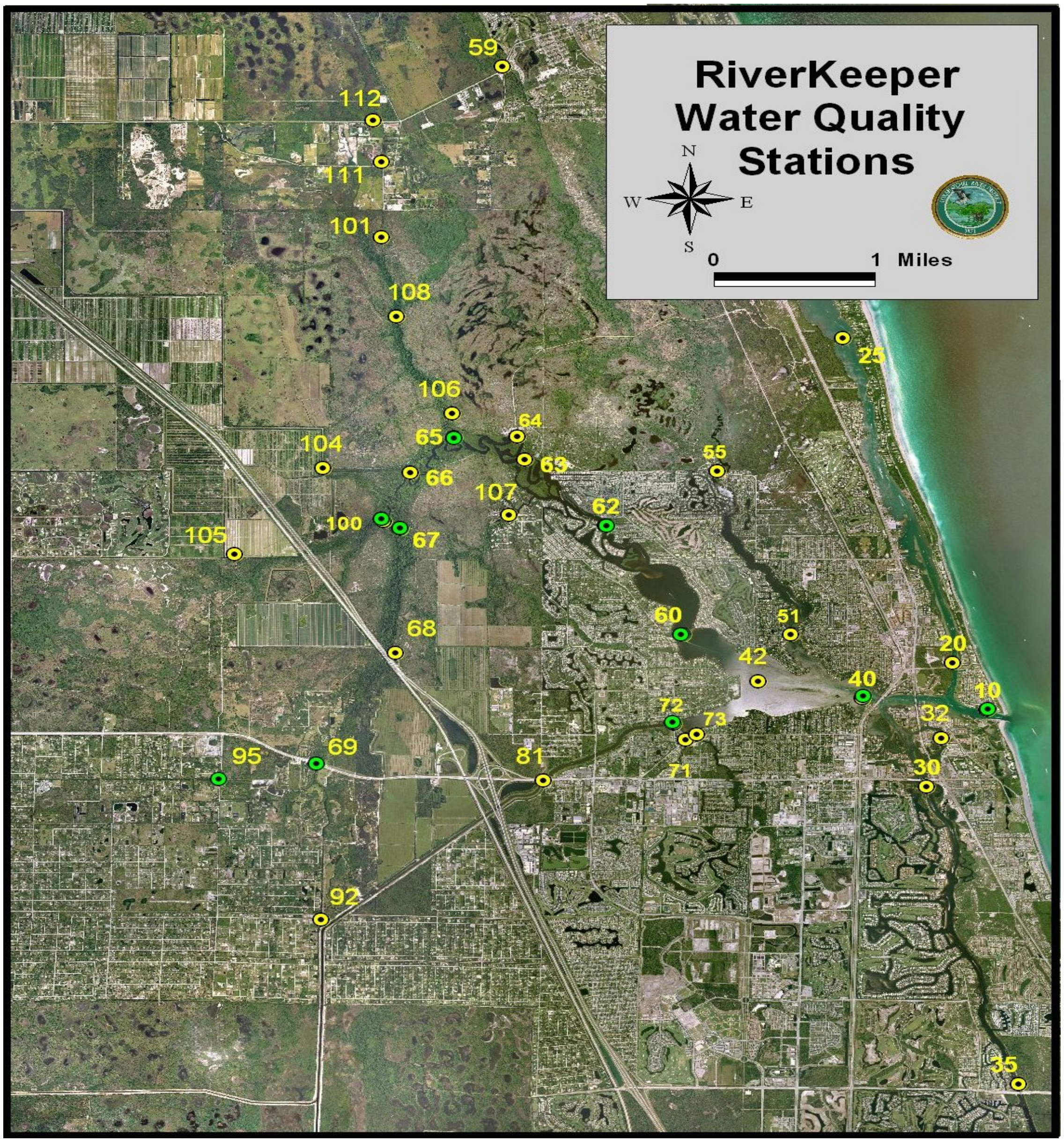


Figure 12-8. Water quality monitoring stations in the Loxahatchee River system. Sites indicated in green are monitored monthly. Sites indicated in yellow are monitored bimonthly.

Comparison of average water quality conditions from September 2005–July 2006 to the interim water quality targets given in the Restoration Plan for the Northwest Fork of the Loxahatchee River reveals that water quality conditions in the Loxahatchee River met or exceeded interim target water quality conditions for the majority of parameters sampled throughout most zones of the river (Arrington, 2006). Water quality data have been compiled and analyzed by the FDEP to determine current status and trends in this system. Results of this analysis indicate that water quality is generally adequate to meet designated uses (SFWMD, 2006).

Loxahatchee River Baseline Freshwater Fish Study

In accordance with the Northwest Fork Science Plan, a plan was drawn up in February 2007 to initiate a freshwater fish survey for the Loxahatchee River. The survey is expected to provide a baseline list of fish species that occur in the floodplains and channel of the Northwest Fork of the Loxahatchee River and its major tributaries. This information will be used to compare with future species composition and abundances once more natural hydroperiods are established with supplement deliveries provided from sources established in the greater watershed. It will also contribute to the statewide survey of exotic and nuisance fish species that is conducted by the Florida Fish and Wildlife Conservation Commission. A literature review is being conducted as an initial step in the study, which will provide information on habitat, food, reproduction, and hydrological needs of listed species, which will help to predict the potential impact of restorative flows on the abundance and distribution of these species. In addition, it is information that will provide guidance for an adaptive management approach to the development of operational protocols for restorative flow deliveries in the dry season. Plans are to begin sampling in the summer 2007.

Loxahatchee River Estuary Oyster Monitoring

The Loxahatchee River District (LRD) and the South Florida Water Management District continue to work cooperatively to assess the oyster resources in the Loxahatchee Estuary. These data will provide baseline information on current oyster health and geographic location. Analysis of the data will provide information on the impacts of proposed upstream restoration efforts on estuarine communities. Increased flow as recommended by the Preferred Flow Scenario may eliminate some of the existing oyster beds between RM 5 and RM 6. The majority of oyster beds downstream RM 5 should remain. As a first step in this effort, the LRD mapped live oysters during 2003. Approximately 9.5 acres (3.8 hectares) of live oyster bars were found in the area of RM 4.5 in the Northwest Fork and 0.74 acres (0.3 hectares) in the Southwest Fork. Monitoring did not detect the presence of the exotic Asian green mussel. Maps resulting from the 2003 oyster mapping project are provided in **Figures 12-9** and **12-10**.

Beginning in WY2006, the Florida Fish and Wildlife Conservation Commission conducted monthly surveys of oyster health in the Northwest and Southwest Forks of the Loxahatchee River, which was funded by the CERP/RECOVER program. These surveys identify the occurrence of disease, density and size of living oysters, growth rates, and the rate of recruitment during most of the year. Monitoring sites are limited to the upper river areas, because the main embayment of the Loxahatchee River lacks the appropriate substrate and salinity regime to support dense, healthy populations of oysters. This situation occurred after the Jupiter Inlet was constructed and maintained (1947), causing the embayment to experience a higher salinity regime unfavorable for oyster bed development. A contemporary mapping of oyster resources with side scan sonar is also planned as part of the RECOVER monitoring. Additionally, in WY2008, the

LRD and SFWMD are planning to introduce oyster substrate (cultch) to an area immediately downstream of the existing oyster beds at approximately RM 4.5. This cultch will be monitored for colonization and health once they are established. Information from this study in concert with salinity, rainfall, and flow data will allow a more detailed evaluation of oyster responses to proposed upstream restorative flows to the Northwest Fork.

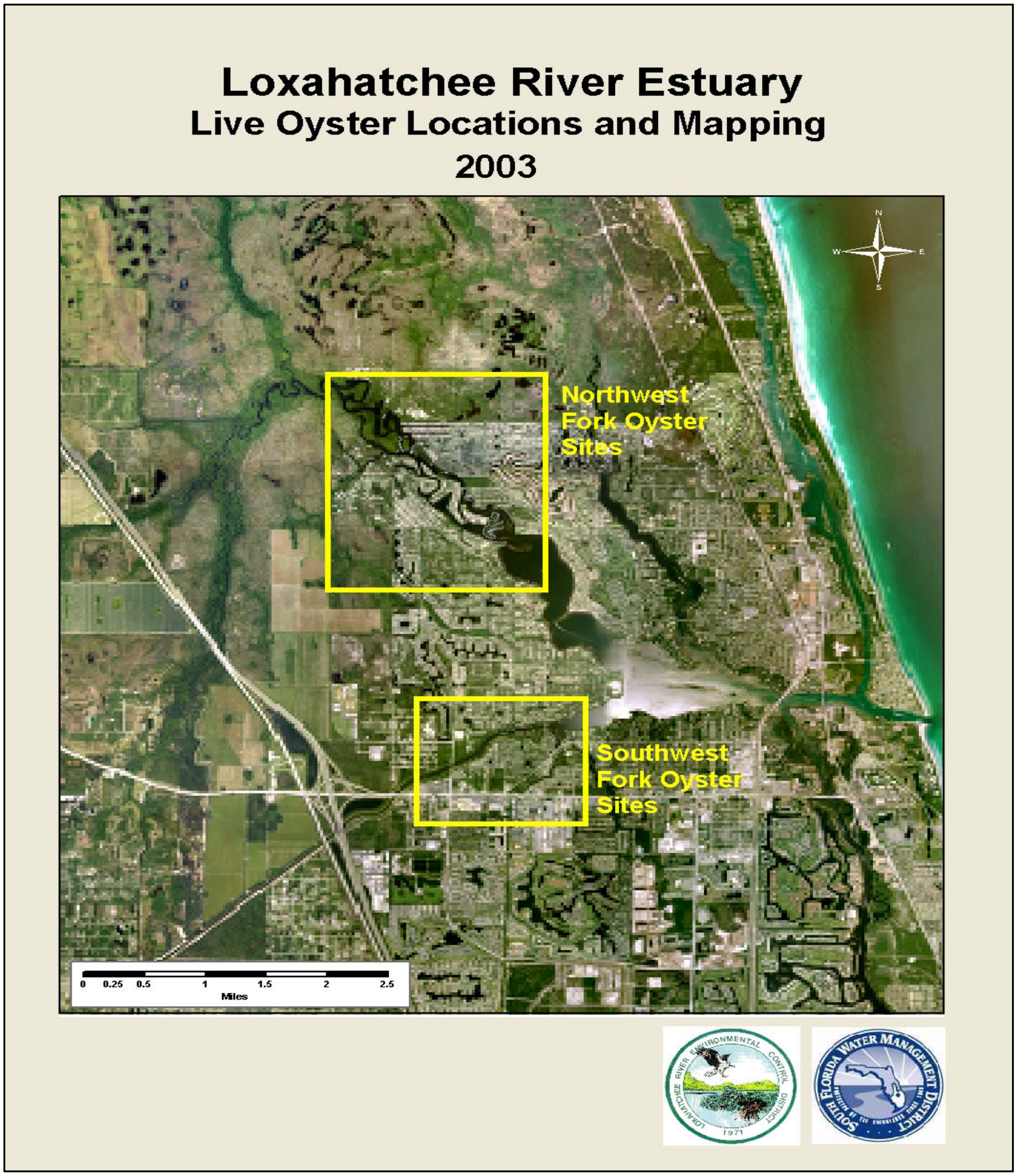


Figure 12-9. Loxahatchee Estuary live oyster locations.

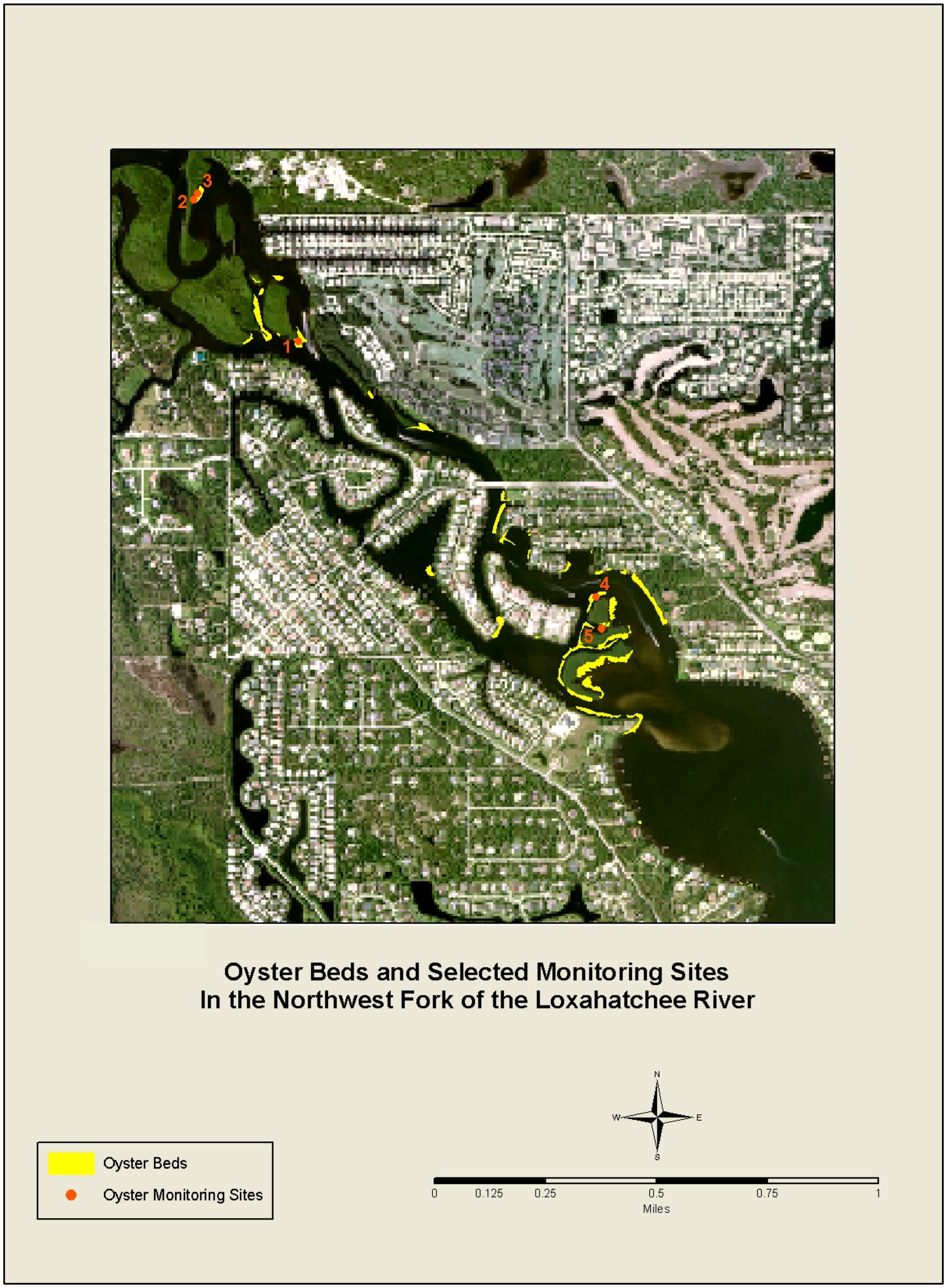


Figure 12-10. Live oyster beds in the Northwest Fork of the Loxahatchee Estuary.

Loxahatchee Estuary Seagrass Monitoring

In June 2003, the LRD in partnership with the SFWMD began a project to monitor seasonal trends in seagrass at three sites along a salinity gradient in the Central Embayment of the Loxahatchee Estuary (**Figure 12-11**) to better understand (1) the natural seasonal variability of seagrass in the study area, and (2) the response of the seagrass community to freshwater discharge. A fourth site (Hobe Sound) is removed from the direct influence of the Loxahatchee River and is considered a reference site. Monitoring is conducted monthly and includes shoot counts, canopy height, percent cover, species diversity, species shifts, and species depth distribution. Over the past year, this monitoring program documented seagrass recovery from impacts that occurred during the 2004/2005 hurricane seasons. The LRD will summarize these data in a report to be submitted to the SFWMD in September 2007.

In July 2003, the SFWMD began mapping seagrasses in the Central Embayment using benthic mapping methods consistent with those used for the adjacent Indian River and Lake Worth Lagoons (mapping from aerial photographs by simultaneously interpreting/rectifying the habitat polygons using an analytical stereoplotter). The study includes a reference site at Hobe Sound that is not influenced as greatly by large discharges of fresh water. Mapping was also conducted in 2004 and 2006, and is planned for 2007. The 2006 seagrass coverage is shown in **Figure 12-12**. Additionally, the LRD is conducting detailed ground-truthing using submeter accuracy GPS technology to produce a species-specific seagrass map of the Loxahatchee Estuary for the summer of 2007.

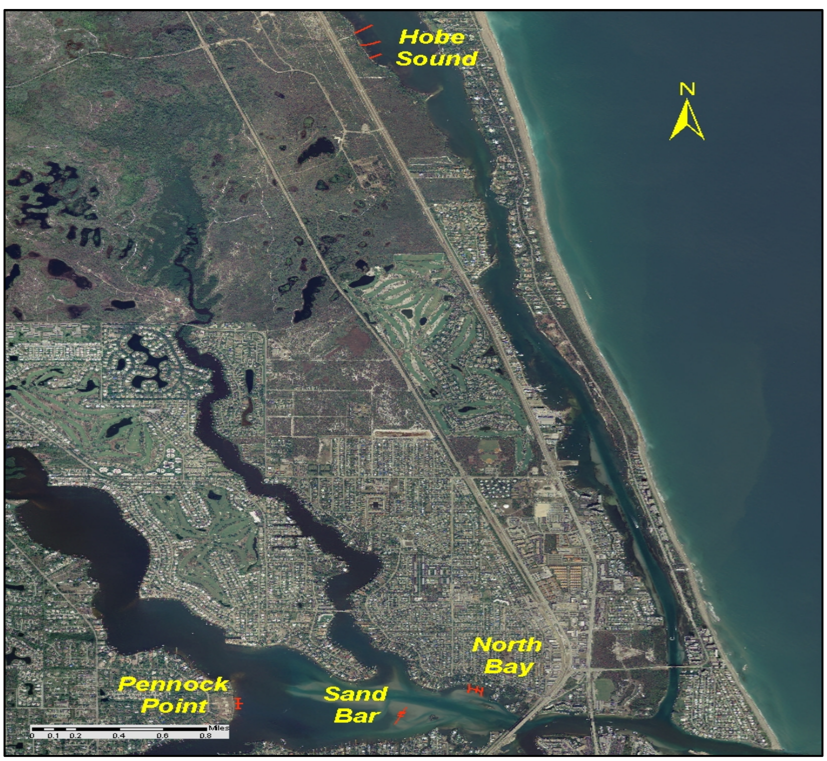


Figure 12-11. Map showing locations of seagrass monitoring stations in the Loxahatchee River Embayment area.

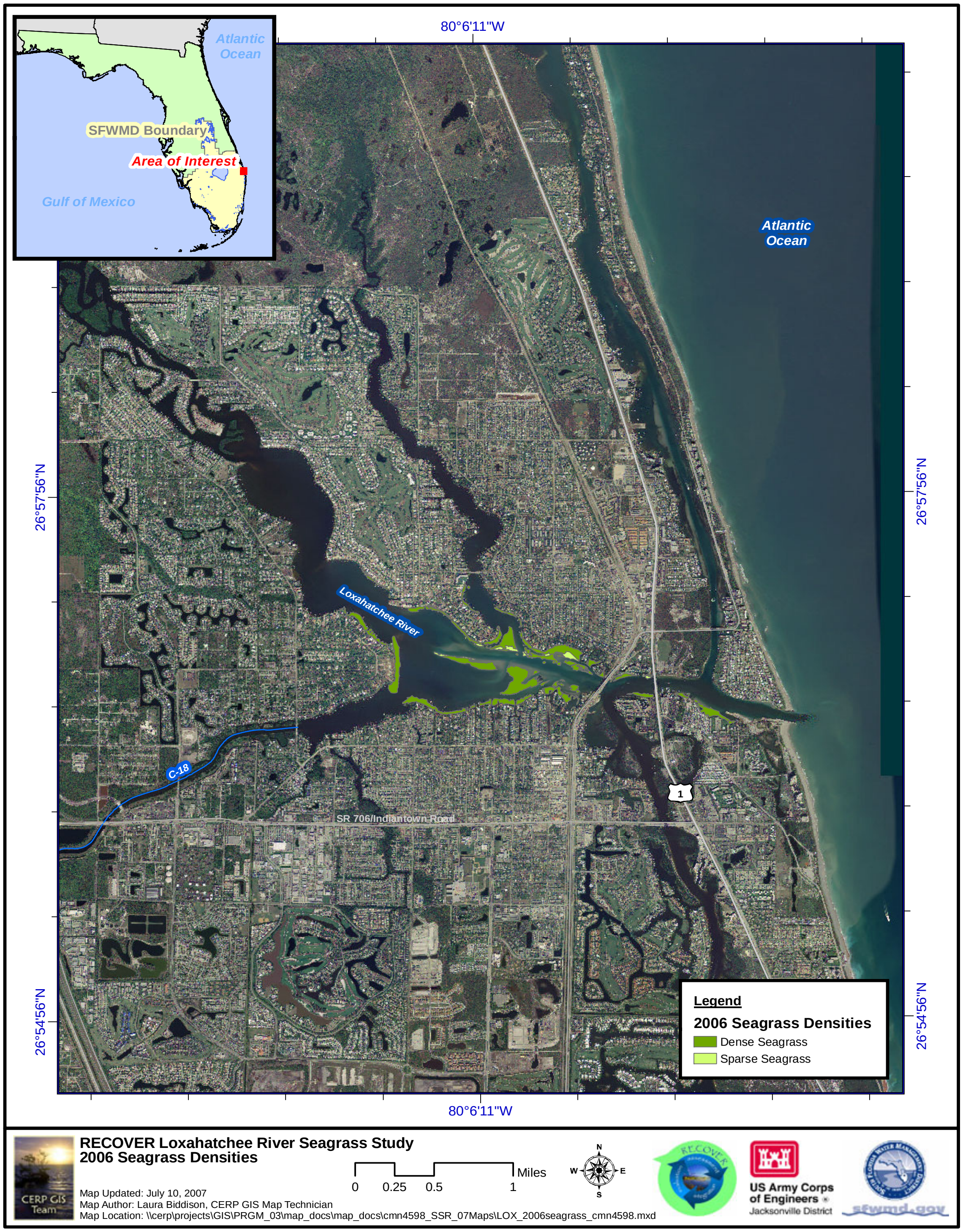


Figure 12-12. Map of 2006 seagrass densities in the Loxahatchee River Central Embayment area.

Salinity Monitoring

Through an agreement with the United States Geological Survey (USGS), the South Florida Water Management District is able to monitor salinity at River Miles 8.2 and 9.1 to measure compliance with the MFL rule, and to assess the benefits of supplemental dry season flows in terms of salinities in the Northwest Fork. The rule establishes a minimum flow of 35 cfs (1 cubic meter/s) over the Lainhart Dam to the Northwest Fork of the Loxahatchee River during the dry season. It is anticipated that salinity will be lower than 2 psu at River Mile 9.1 if all the projects (G-160 and G-161) that will allow the District to deliver the minimum flow are constructed and operational. G-160 is constructed and the G-161 was completed during WY2007. Operational protocols for these structures are under development. Actual flows to the Northwest Fork at the Lainhart Dam (RM 14.78) for the past four years are depicted in **Figure 12-13.**

Overall, water flows are measured for about 70 percent of the inflows from the watershed. The rest of the watershed is tidally influenced, so inputs cannot be discerned readily from tidal currents. In the tidal areas, inflows are estimated based on a hydrologic model. A Digital Elevation Model was produced to improve the prediction of inundation estimates in the flood plain.

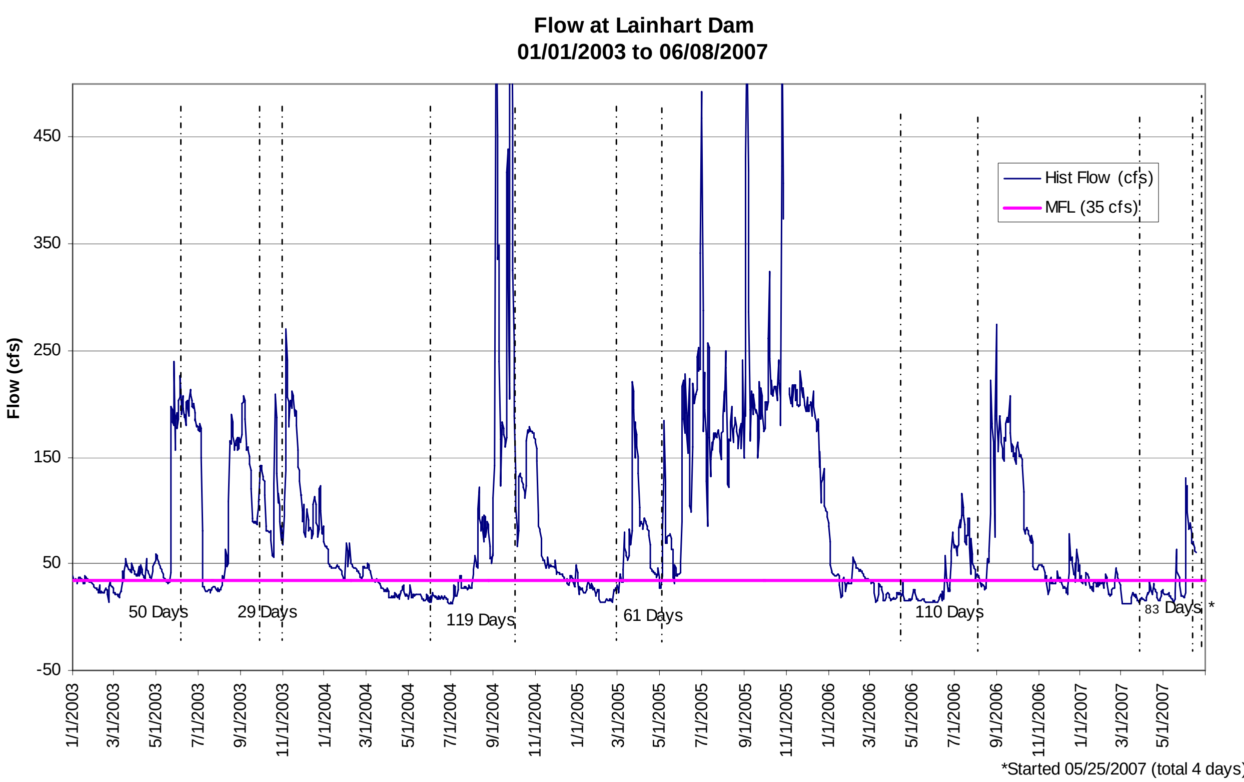


Figure 12-13. Flow at Lainhart Dam in the Northwest Fork of the Loxahatchee River between October 2003 and May 2007.

LAKE WORTH LAGOON

Michael Gostel and Richard Alleman

INTRODUCTION

Lake Worth Lagoon (LWL) is an estuary located in eastern Palm Beach County, Florida (**Figure 12-14**) bounded by barrier islands. Lake Worth Lagoon is about 22 miles (35.4 km) long, and typically 6 to 10 feet (1.8–3 meters) in depth. The Atlantic Intracoastal Waterway channel runs through the entire length from north to south. Tidal exchange with the Atlantic Ocean occurs at North Lake Worth (Palm Beach) and South Lake Worth (Boynton) Inlets. The Lake Worth Lagoon watershed is about 450 sq mi (1,165 square kilometers) with most of the land urbanized. Communities include North Palm Beach, Lake Park, Riviera Beach, Magnolia Park, Palm Beach Shores, West Palm Beach, Palm Beach, South Palm Beach, Lake Worth, Lantana, Hypoluxo, Manalapan, Boynton Beach, and Ocean Ridge.

The Lake Worth Lagoon has been divided into three segments (north, central, and south) based on hydrological factors including water quality, circulation, and physical characteristics (**Figure 12-15**). Sources of freshwater runoff include primary and secondary canal systems. The major sources of freshwater are the C-17 canal (Earman River), C-51 canal (West Palm Beach Canal), and the C-16 canal (Boynton Canal). The C-51 canal contributes about 50 percent of the freshwater runoff to the lagoon. Studies indicate that about 75 percent of the canal discharge turns northward in the Lagoon and about 25 percent southward (Chui et al., 1970).

Similar to many of South Florida's heavily urbanized coastal areas, Lake Worth Lagoon has been negatively impacted by anthropogenic changes. Sedimentation and turbidity is a primary concern in Lake Worth Lagoon. Differences observed in the macroinvertebrate community structure have been attributed to physical effects caused by the velocity of fresh water from the C-51 canal. The average daily flow is 514 cfs (14.6 cubic meters/s), but ranges up to more than 7,000 cfs (198 cubic meters/s). Salinity can be depressed below thresholds considered optimum for key species such as the Eastern oyster and the seagrass *H. johnsonii*. Therefore, current performance measures are targeted at limiting the discharges from the C-51 canal so that salinity does not stay below 15 psu more than 26 days or less than 5 psu more than 7 days from April through July.

Figure 12-14. Geographic location of Lake Worth Lagoon.

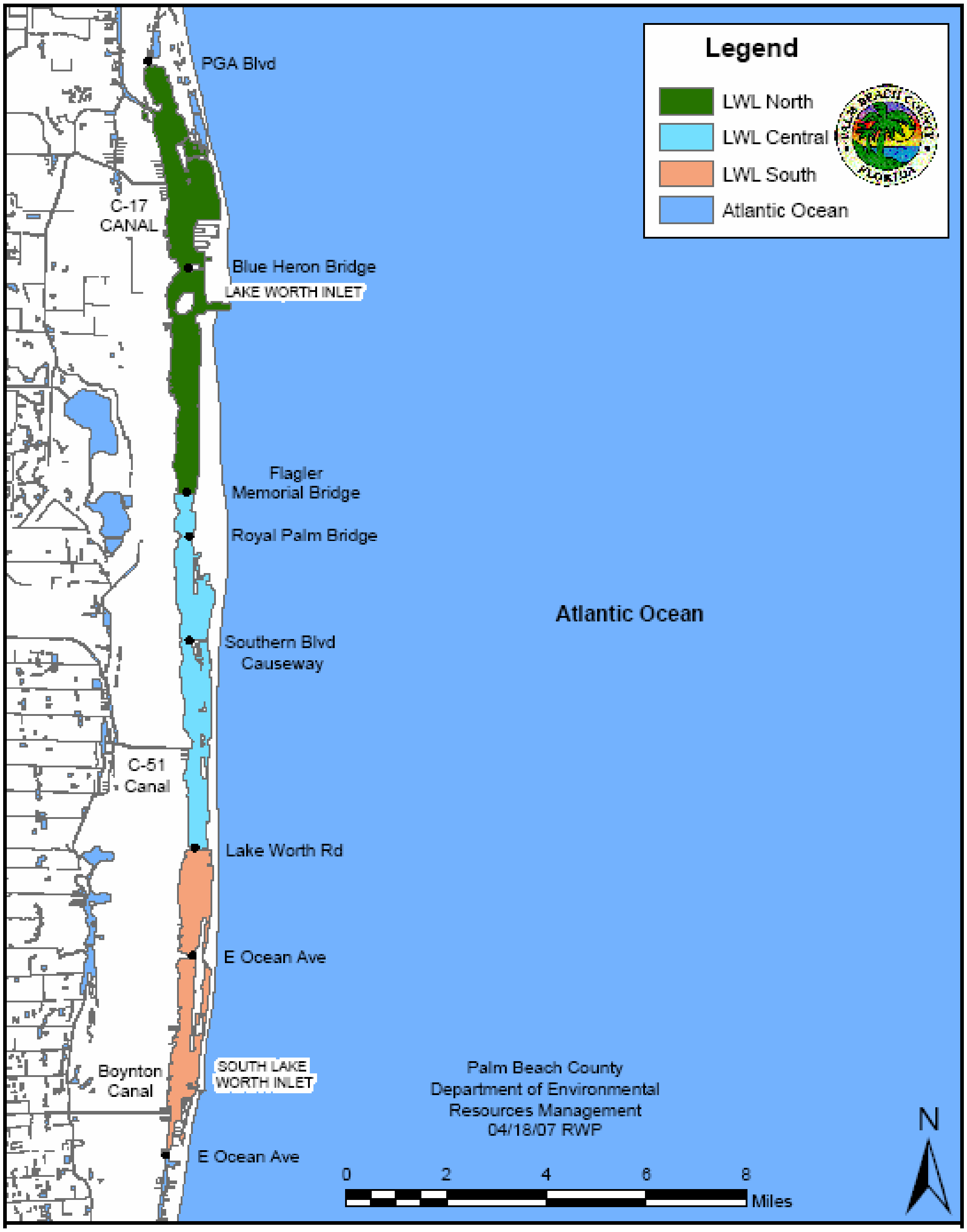


Figure 12-15. Lake Worth Lagoon segments.

STATUS OF FRESHWATER INFLOWS AND SALINITY IN LAKE WORTH LAGOON

No freshwater Minimum Flow and Level criteria or reservation of water has been developed for Lake Worth Lagoon to date. The primary concern in Lake Worth Lagoon is that too much fresh water is discharged at times. For example, a CERP evaluation target was established by an interagency team in 2007 to limit salinity to a minimum of 15 psu to protect seagrasses and oysters near the outfall of C-51. (Northern Estuaries Performance Measure Salinity Envelopes, April 2007). A new salinity monitoring program designed to evaluate the new target was established in 2007, so long-term salinity results at the new sites are not available. Results are available from two salinity monitoring sites that have since been discontinued with a period of record from 1990 to 2006 (**Figures 12-16** and **12-17**). These results suggest that salinity has been decreasing over time. The decrease may be a result of a long-term increase in flows from C-51 as indicated in **Figure 12-18**.

RESEARCH NEEDS IN LAKE WORTH LAGOON

It is anticipated that many existing information gaps relative to resource assessment and future enhancements of the LWL will be addressed through investigations by Palm Beach County Department of Environmental Resources Management (PBC-ERM), CERP Restoration Coordination and Verification (RECOVER), and the CERP North Palm Beach County Project – Part 1 study.

The CERP North Palm Beach County – Part 1 Project is evaluating redirection of flows and additional retention of storm water from the C-51 basin, and sediment removal and control technologies within the C-51 canal. Additional evaluations are focused on removal or trapping of existing sediment deposits in the lagoon downstream of the S-155 structure. It is anticipated that the draft Project Implementation Report will be available in early 2008.

PBC-ERM has increased collaboration with the RECOVER Team of CERP. Future collaborative efforts will address additional opportunities for enhanced monitoring and assessment of valued ecosystem components, such as seagrasses.

PBC-ERM is updating the Lake Worth Management Plan and has developed a more integrated monitoring and assessment plan for the LWL. The updated management plan will include specific action plans for future projects. The updated plan is expected to be finalized by the end of 2007. PBC-ERM will also continue to implement projects through the Lake Worth Lagoon Partnership Grant Program.

Highlighting the current status of LWL collaborative efforts was the Lake Worth Lagoon Symposium. Held on May 16, 2007, more than 275 environmental professionals, managers, local government officials, educators, residents, and industry and community leaders convened at Palm Beach Atlantic University. The daylong symposium provided shared updates on the state of the lagoon, conservation and habitat enhancement efforts, and economic aspects of the lagoon. Many of the research components described at the symposium have been incorporated into the update of the Lake Worth Management Plan.

As noted in the previous sections, the District is committed to ongoing collaboration efforts, short-term implementation projects, and longer-term infrastructure and operational projects consistent with the Coastal Watersheds Program Strategies that are included in the current SFWMD Strategic Plan.

The Coastal Ecosystems Science Plan for the Lake Worth Lagoon currently anticipates a continuation of the existing level of effort. PBC-ERM and FDEP are acknowledged lead agencies for LWL. Coastal Ecosystems Division (CED) staff will continue to provide technical review and support for ongoing CERP project and RECOVER activities. CED will also continue to support the SFWMD Palm Beach Service Center, as requested. In addition, coordination and collaboration with PBC-ERM on routine planning, monitoring, and analysis activities will continue.

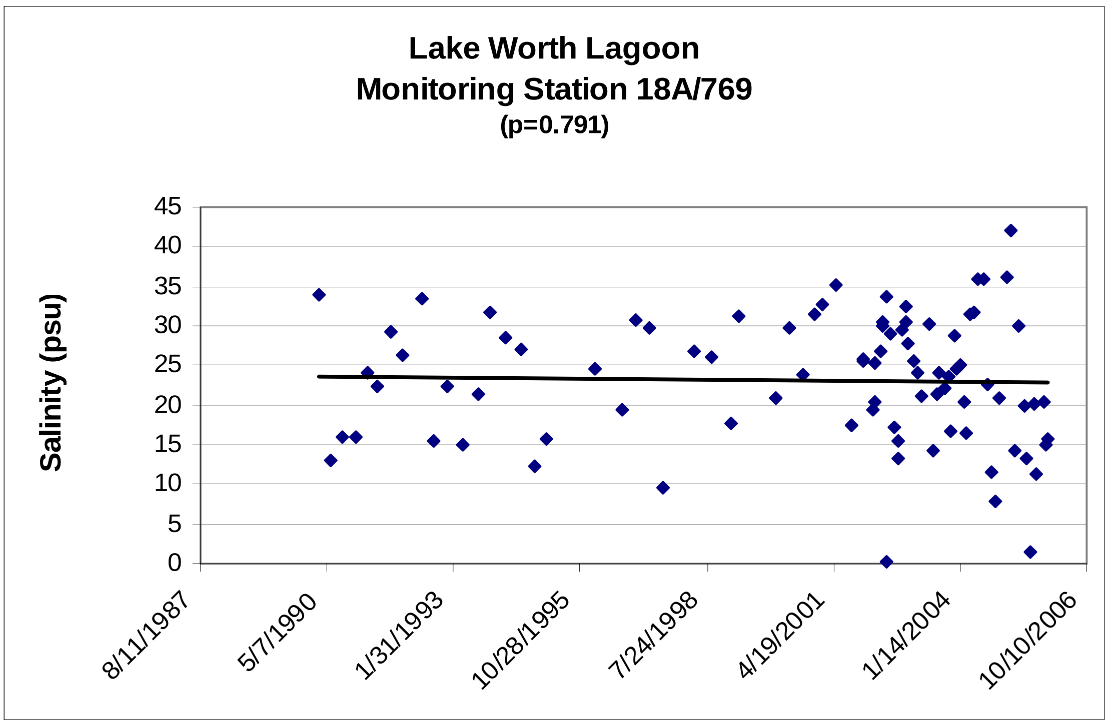


Figure 12-16. Long-term salinity results at a Lake Worth Lagoon monitoring site near the mouth of C-51. Data collection intensity has been variable over time.

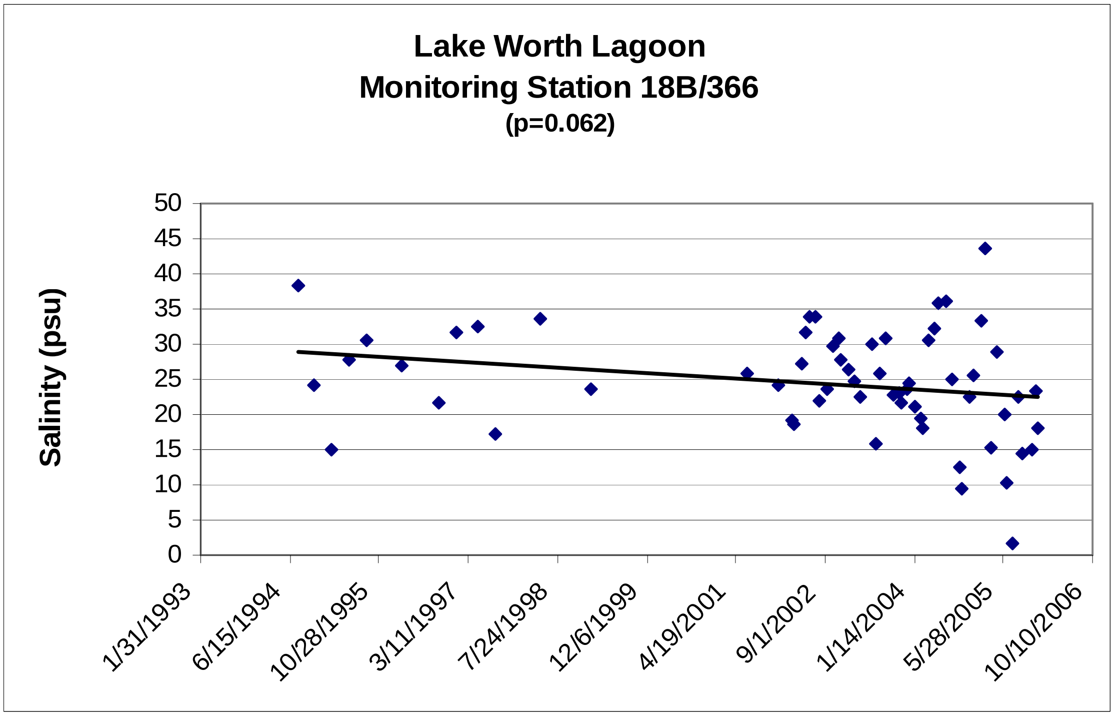


Figure 12-17. Long-term salinity results at a Lake Worth Lagoon monitoring site near the mouth of C-51 with a fitted linear regression line. Data collection activities have been variable over time.

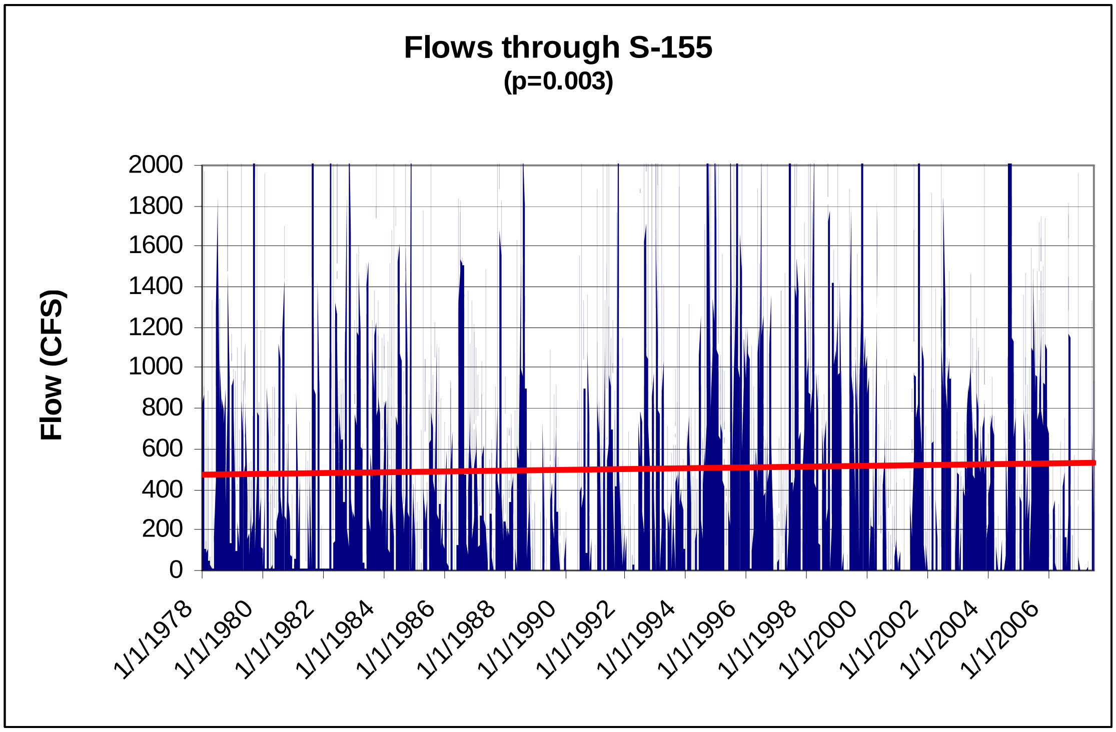


Figure 12-18. Long-term flow rate from C-51 into Lake Worth Lagoon with a fitted linear regression line (Y scale is truncated to show detail).

BISCAYNE BAY

Richard Alleman

INTRODUCTION

Biscayne Bay is a shallow subtropical estuary located along the southeastern coast of Florida (**Figure 12-19)**. The city of Miami is the largest city within the watershed, but most of the northern and central areas of the watershed are urban. Everglades National Park borders the southwestern part of the watershed and shares some of it. The bay is about 428 square miles (1,109 square kilometers), and the watershed is about 938 square miles (2,429 square kilometers).

Figure 12-19. Geographic location of Biscayne Bay watershed.

Development of the watershed has altered the delivery of freshwater inflows into the bay. Northern and central Biscayne Bay has been strongly affected by the urban development associated with the growth of metropolitan area. Southern Biscayne Bay is influenced by drainage from the Everglades, and runoff from the southern watershed that includes some urban and agricultural land uses. The concentration of chlorophyll *a*, an indicator of water quality, was low in 2006 compared to the other southern estuaries (see Chapter 7B of this volume) except in Barnes Sound. The opening of artificial inlets and construction of artificial islands and channels particularly in the northern area has contributed to the bay's transition from a freshwater estuary to more of a marine lagoon. Even in the southern area of the Bay, salinity has increased since about 1900 in many areas (Wingard et al., 2004). Today, about half of the freshwater inputs consist of discharges from 16 canals that regulate water levels within the watershed for flood control and water supply, and discharge about 1.4 million acre-feet (ac-ft) (1.73 billion cubic meters) per year on average. Additional significant sources of fresh water include rainfall that averages about 60 inches per year (1.37 million ac-ft/year; 1.68 billion cubic meters)) and groundwater flux which is estimated to be roughly 5 percent of surface water inputs (Langevin, 2001).

Salinity in Biscayne Bay is strongly affected by discharges from canals, and exhibits a marked seasonality. Salinity ranges from about 15 to 45 psu, but tends to be lowest in the tidally restricted northern area and along the western shore of the central area. While many of the species typically seen in the bay are marine, salinity gradients are sufficient to support an array of estuarine species in abundance including pink shrimp, blue crab and mullet. In addition, the lower salinity habitats maintain species diversity as evidenced by the presence of seagrasses such as *R. maritima*, *H. wrightii*, and *S. filiforme*, although *T. testudinum* dominates.

STATUS OF FRESHWATER INFLOWS AND SALINITY IN BISCAYNE BAY

No minimum flow and level criteria have been formally adopted for Biscayne Bay to date, nor have there been any specific quantities of water reserved. The SFWMD is proceeding, however, to develop information and tools to facilitate the process of producing freshwater inflow criteria. Many of the activities listed below in the Coastal Ecosystems Science Plan relate to this effort. In addition, projects managed within other areas of the SFWMD are contributing to the knowledge base. For example, the Water Supply Department currently has an ongoing study to relate freshwater inflow to salinity in different parts of the bay, and the CERP Planning Department manages several projects to collect data in Biscayne Bay that are essential for populating models and analytical approaches.

Systematic and spatially comprehensive salinity monitoring in Biscayne Bay began in 1979 by the Miami-Dade Department of Environmental Resources Management, and has continued to date. Examining these data reveals that no significant increase of salinity has occurred in Biscayne Bay over the past 27 years (**Figure 12-20)**. The data record also shows how climatic cycles affect salinity on a decadal scale, increasing during dry periods and decreasing during wet periods. It is important to factor these oscillations into trend analyses so that conclusions are not based on just a part of the record that may indicate a shorter-term trend. This can lead to serious misinterpretation, and resulted in at least one case of an inappropriate water rule in Florida (SWFWMD, 2004). That is not to say that existing salinity patterns are always healthy in Biscayne Bay. For example, salinity frequently exceeds more than 35 psu along the mainland within Biscayne National Park in dry seasons. This is one phenomenon that SFWMD is investigating to determine the causes and potential impacts.

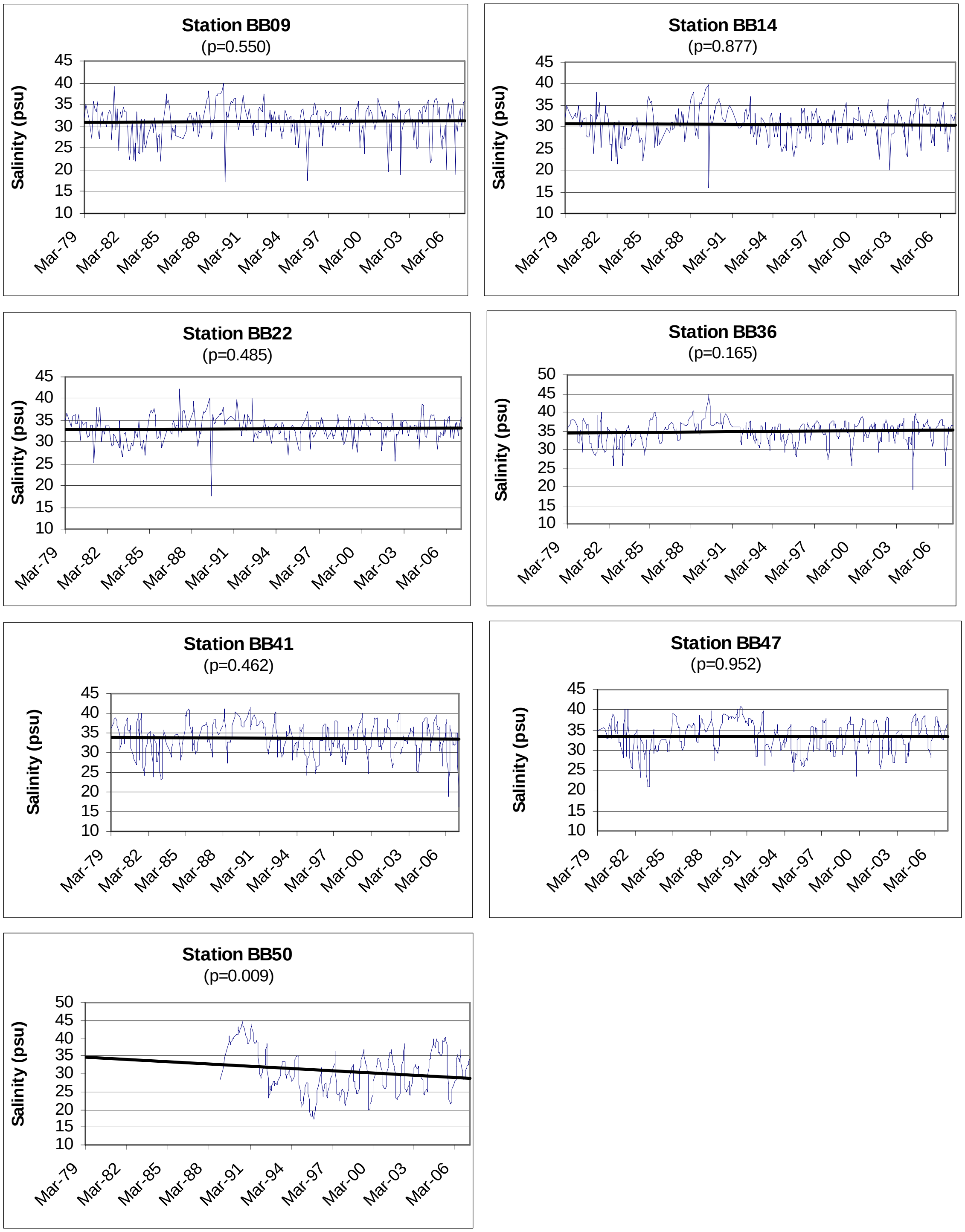


Figure 12-20. Long-term salinity recorded at key stations in Biscayne Bay with fitted linear regression lines.

RESEARCH NEEDS IN BISCAYNE BAY

Detailed quantitative information on specific urban impacts is essential to effectively guide management decisions related to future growth, development, and consumptive uses in and around Biscayne Bay. For example, better hydrologic models are needed to describe with some certainty how withdrawals from wellfields affect flows into the bay, or how changing water stages may affect existing land uses and the flood control level of service. Major water resource issues are posed in the near term, not only by CERP, but also by many preexisting activities and obligations. A series of CERP projects could directly, or indirectly, affect Biscayne Bay water supply and water quality. In addition, planned projects such as the Lower East Coast Regional Water Supply Plan, MFL criteria, and the Flooding Task Force's charge to enhance flood protection for Miami-Dade County could affect Biscayne Bay.

Each of these activities has significant scientific information needs. For example, the development of MFL criteria for Biscayne Bay requires quality information and tools that relates freshwater inflow to salinity and biological resources. Currently, the Water Supply Department is preparing a technical document summarizing the relevant, available scientific information and modeling tools that can be used to relate basin-level freshwater flows to living resources in Biscayne Bay. Following a peer review the District will either proceed with rule development or implement a program to fill data and modeling gaps.

Several information gaps and research and monitoring needs have already been identified (cf the 2002 Strategic Science Plan for Biscayne Bay; Alleman et al., 2002). Some examples include: A paucity of seagrass data in critical areas such as the western nearshore area within the southern region. These data are needed to determine whether and how species abundance and distribution patterns (many currently unknown) change in relation to salinity dynamics. Critical spatial gaps still exist in salinity data, especially in the southern nearshore zone and adjacent wetlands. Also important for MFL criteria analysis is an understanding of freshwater fluxes. Current understanding is that the majority of fresh water enters Biscayne Bay through a series of gated canals, where flows are estimated based on water stage; although the precision of these estimates is uncertain. Groundwater contributions are a relatively small percentage of freshwater inputs compared to canal flow and rainfall, but may be a significant source of fresh water in some areas where groundwater flux is large, and also during the end of the dry season. However, very little information has been collected about the spatial distribution, rates of groundwater flux, and the quantity or quality of the groundwater in the bay. Additionally, since a large part of Biscayne Bay lies within Biscayne National Park, many stakeholders are interested in characterizing the bay's habitats prior to 1900, after which most changes in land cover, and its influences on the bay, took place. While some data indicate an overall salinity increase since 1900, the causes, which may include increasing sea level and decreasing rainfall, are not well understood. In addition, the effects caused by a change in the distribution of runoff from a series of creeks to a handful of canals, and the timing and velocity of runoff, are difficult to determine based on empirical information. An effective way to simulate conditions in the past, or "hindcast" historical Biscayne Bay conditions, would help in understanding how the system functioned in the past, and set expectations about possible restoration opportunities.

The strategy for Biscayne Bay science includes the application of the integrated modeling and assessment framework similar to that described for the other coastal areas. This approach will help structure and organize priority needs to formulate a detailed science plan and design and implement projects to fulfill the identified data and modeling gaps in Biscayne Bay. Current projects include the development of a linked hydrologic and hydrodynamic model for Biscayne

Bay, development of habitat suitability indices relating salinity to fish abundance along the shoreline, and a literature search for salinity dose responses for species in Biscayne Bay.

FLORIDA BAY

David Rudnick, Christopher Madden, Robin Bennett,
Amanda McDonald, Stephen Kelly and Kevin Cunniff

SUMMARY

The Florida Bay area is highlighted in this year's chapter for Water Year 2007 (WY2007). This Florida Bay report presents: (1) results from monitoring projects (regarding hydrologic and salinity conditions, water quality, and seagrass habitat); (2) an update on conditions relevant to the Minimum Flow and Level (MFL); (3) an analysis of the status of the eastern algal bloom and current understanding of the causes and effects; and (4) progress on water quality and seagrass research and modeling. These scientific activities serve operational planning and implementation (especially Combined Structural and Operational Plan), Minimum Flows and Levels, the Everglades Forever Act, and the Comprehensive Everglades Restoration Plan (CERP).

Unlike the central and northern SFWMD regions, which experienced severe drought in the latter part of WY2007, Florida Bay and Everglades National Park wetlands received near average or above-average precipitation in the WY2007 dry season and near-average annual precipitation. Total annual discharge of fresh water from creeks flowing from the southeast Everglades was 21 percent less in WY2007 than the annual average discharge. While wet season discharge was near average, dry season discharge (especially early dry season) was below average. Ongoing operational attempts to restore more natural water distribution patterns in the southeast Everglades by increasing water flow through Taylor Slough, as opposed to transport via the more easterly C-111 canal, appeared to be successful – WY2007 creek discharge to Florida Bay downstream of Taylor Slough was above average, while it was below average downstream of C-111. Florida Bay salinity followed this spatial pattern, such that WY2007 annual mean salinity in eastern Florida Bay was 21 percent (5.3 practical salinity units, or psu) above average, while salinity in central Florida Bay (an area especially prone to hypersalinity) was only 6 percent (2.0 psu) above average.

The Florida Bay MFL rule was approved in WY2007 and established a 30 psu salinity criterion (30-day running average) at an indicator site, Argyle Hendry Pond, between Taylor Slough and Florida Bay. This criterion was largely based on the goal of protecting submerged aquatic vegetation (SAV) habitat. Following two consecutive years (WY2005–WY2006) with salinity well above the rule's criterion, salinity at this site began WY2007 (prior to the MFL rule approval) at 29.8 psu, but remained below the criterion for the remainder of the year. SAV surveys from the indicator site showed that there was little recovery through WY2007 after SAV loss in WY2005.

After years of improving water quality conditions, with generally decreasing concentrations of phosphorus, nitrogen, and turbidity (from about WY1995–WY2004), water quality degraded in WY2006 and WY2007. Chlorophyll *a* concentrations, which are an indicator of phytoplankton (microalgae) blooms, increased in central Florida Bay and in the basins along the eastern boundary of the bay to southern Biscayne Bay (especially Blackwater Sound, Barnes Sound, and Manatee Bay). Such blooms have been common in the central bay (notably in the mid-1990s and

following Hurricane Irene in 1999), but do not appear to be closely related to the annual quantity of fresh water flowing from canals or into Florida Bay. However, they may be related to pulses of fresh water and other factors associated with tropical storms. Before fall 2005, algal blooms had never been documented in the eastern boundary waters of the bay. The likely cause of this eastern bloom was a combination of disturbances from three hurricanes in fall 2005 (including discharge of fresh water and associated nutrients from the C-111 canal) and road widening construction activities along the 18 mile stretch of U.S. Highway 1 (see the 2007 SFER – Volume I, Appendix 12-3).

The algal bloom was generally dominated by cyanobacteria, or blue-green algae. It persisted in WY2007 in the eastern boundary waters of Florida Bay and in southern Biscayne Bay and remained centered around U.S. 1. Based on measured nitrogen to phosphorus ratios and bioassays, nitrogen availability in WY2007 became much more important for algae than in previous years. The bloom persisted without direct input of nutrients (nitrogen and phosphorus) from the C-111 canal in WY2007; with dry conditions, canal water was not released through S-197. However, the bloom may have been sustained by nutrients from a destructive feedback loop: the bloom appears to have caused a die-off of SAV in Blackwater Sound and Barnes Sound, which in turn supplied nutrients to the bloom and likely also destabilized sediments. Both the bloom and suspended sediment decrease light penetration to SAV and can cause more SAV mortality and continuing blooms. Seagrass loss, compared to the WY2000–WY2005 average, is estimated to have been 74 percent in Blackwater Sound and 36 percent in Barnes Sound and was accompanied by extensive loss of calcareous green algae. Nutrients sustaining the bloom may also have been supplied by U.S. Highway 1 construction activities through WY2007.

A large increase (1,400 metric tons) of total organic carbon (TOC) in the region's water during WY2006 and WY2007 provides clues as to nutrient sources sustaining the algal bloom. This increase was highest in basins near U.S. Highway 1, coincident with the bloom distribution. Up to about one-third of the TOC increase could have come from the SAV die-off. Road disturbance (of mangrove trees and soils) may account for much of the remaining TOC increase.

Monitoring of SAV in other regions of Florida Bay found that turtle grass (*Thalassia testudinum*) has expanded in both coverage and density in central and western Florida Bay since the mid-1990s. However, other seagrass species in these regions remain sparse. Increasing the diversity of SAV habitat is a CERP restoration goal. Research on salinity effects on three major SAV species found that all species were very tolerant of high salinity, but had broadly different responses to low salinity; *Thalassia* dominance likely reflects the absence or rarity of low salinity conditions throughout most of Florida Bay.

Evaluation of the adequacy of the CERP design for the benefit of Florida Bay is the mandate of CERP's Florida Bay and Florida Keys Feasibility Study (FBFKFS). Model development for this evaluation proceeded in WY2007, with completion of a hydrodynamic model (not described in this chapter). Experiments on dissolved organic matter decomposition rates were completed and provide key parameters for the bay water quality model. In WY2007, the Florida Bay seagrass community model, which was previously applied to MFL development, was fully documented and successfully reviewed by the Interagency Modeling Center. Expansion of the model to include widgeon grass (*Ruppia maritima*), one of three major SAV species of the bay, began this year. With these models, the FBFKFS is evaluating whether restoration targets are likely to be achieved by CERP implementation and, if not, the FBFKFS will identify modifications by which salinity and ecological targets can be achieved.

INTRODUCTION

Florida Bay covers a triangular area of 2,200 square kilometers at the southern tip of the state, between the Everglades and the Florida Keys (**Figure 12-21**). About 80 percent of this estuary is within the Everglades National Park (ENP or Park) and part of the Everglades Protection Area (EPA). The bay is shallow, with an average depth of about 1 meter. Most of the bay's bottom is covered by seagrass, which is habitat for many invertebrate and fish species. Starting the late 1980s, a series of ecological changes were apparent, including widespread seagrass die-off, the occurrence of algal booms and high turbidity in what had been clear waters, widespread mortality of sponges, and decreases in some other invertebrates and fish species (Fourqurean and Robblee, 1999). A major hypothesis of Everglades Restoration is that historical decreases in freshwater inflow from the Everglades and resultant increases in salinity have contributed to these ecological changes (Rudnick et al., 2005). Since fall 2005, an algal bloom has been sustained at the eastern boundary of Florida Bay and in southern Biscayne Bay. The role of water management and construction along the Florida Keys' Overseas Highway (U.S. 1) as causes of the bloom has a major concern to the District and other agencies.

The District has sustained a program of Florida Bay monitoring, research, and modeling to better understand the importance of water management as a driver of these and other ecological changes, to improve our ability to forecast the impacts of changing water management, and to improve management structures and operations for the protection and restoration of the Florida Bay ecosystem. In this report, we present results that are related to water management operations near Everglades National Park, Florida Bay Minimum Flows and Levels (MFLs), and CERP Florida Bay and Florida Keys Feasibility Study (FBFKFS), C-111 Spreader Project, and (Restoration Coordination and Verification (RECOVER). The FBFKFS is of particular importance because this study is charged with evaluation of the current state of the Florida Bay ecosystem and the adequacy of CERP, as currently conceived, to benefit the bay. This is being done through model development (hydrologic, hydrodynamic, water quality, and ecological models), with synthesis of information through these models. Results reported here contribute to FBFKFS evaluations (especially regarding seagrass modeling) and RECOVER assessment of baseline (pre-restoration) conditions.

This report includes results from major monitoring projects (regarding hydrologic and salinity conditions, water quality, and seagrass habitat), an update on conditions relevant to the MFL, an analysis of the status of the eastern algal bloom and current understanding of the causes and effects of this bloom, and progress on water quality and seagrass research and modeling.

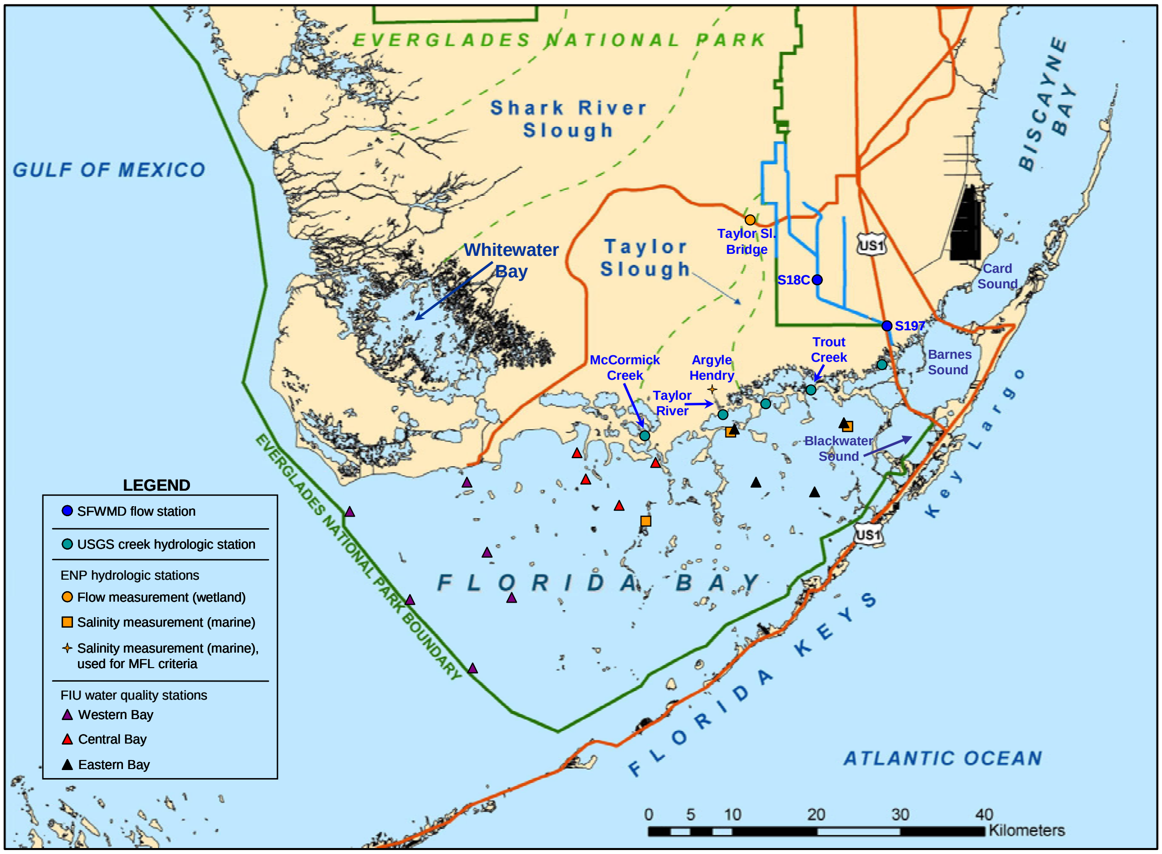


Figure 12-21. Geographic location of Florida Bay.

Precipitation and Freshwater Flow to Florida Bay

Unlike the central and northern SFWMD regions, which experienced severe drought in the latter part of WY2007, Florida Bay and ENP wetlands received near-average or above-average precipitation in the WY2007 dry season and near average annual precipitation. Estimates for Florida Bay were calculated on a daily basis as mean precipitation measured at ENP platforms in eastern bay (mean of Little Madeira, Duck Key, Long Sound, and Highway Creek) and central bay (mean of Whipray Basin and Terrapin Bay) (**Figure 12-22**). Annual precipitation in WY2007 totaled 48.4 inches in the eastern bay and 44.0 inches in the central bay, compared to an average of 44 inches for both regions (WY1997–WY2005). Southern ENP wetlands, which typically receive more precipitation than the bay, also had near-average rainfall with a total of 53 inches in WY2007 (see Chapter 2 of this volume). The timing of WY2007 precipitation deviated from typical patterns, with higher than average quantities during the early wet season (June–July) and lower than average quantities during the late wet season.

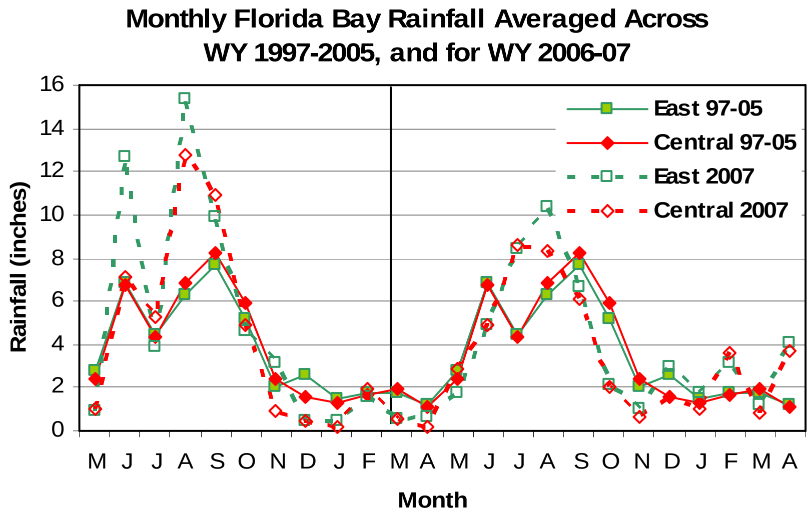


Figure 12-22. Monthly precipitation in eastern and central Florida Bay in WY2006 and WY2007, compared with monthly averages from WY1997, when measurements of freshwater flow into Florida Bay via creeks began.

Water discharge from three major creeks that flow into the bay, Trout Creek, and Taylor River (flowing into the eastern bay) and McCormick Creek (flowing into the central bay), are shown in **Figure 12-23**. Total annual discharge of fresh water from these creeks was 21 percent less in WY2007 than the annual average discharge (WY1997–WY2005; note that USGS measurements began in 1996). Based on measurements of nine mangrove creeks flowing into northern Florida Bay (most only measured occasionally), the three creeks presented here account for about 60 percent of all creek flow (Hittle et al., 2001). The largest single point source of water flow to the bay is Trout Creek. In WY2007, annual discharge from Trout Creek was 115 million m^3, approximately 40 percent less than its long-term average (WY1997–2005) of 183 million m^3. At the southern outlet of Taylor Slough, Taylor River discharge in WY2007 was near average with 35 million m^3 (WY1997–2005 average = 35 million m^3). Further west, McCormick Creek flows into central bay and WY2007 discharge was much greater than the long-term annual average (34 million m^3 in WY2007, 16 million m^3 annual average). The overall seasonal pattern of discharge in WY2007 was similar to that of precipitation (**Figure 12-22**): most discharge occurred during the first half of the year (May–September) for all three creeks. Consistent with low late wet season rainfall, October discharge was well below average in all creeks. However, while local dry season rainfall was near average, there was very little (and below-average) creek discharge for the entire dry season.

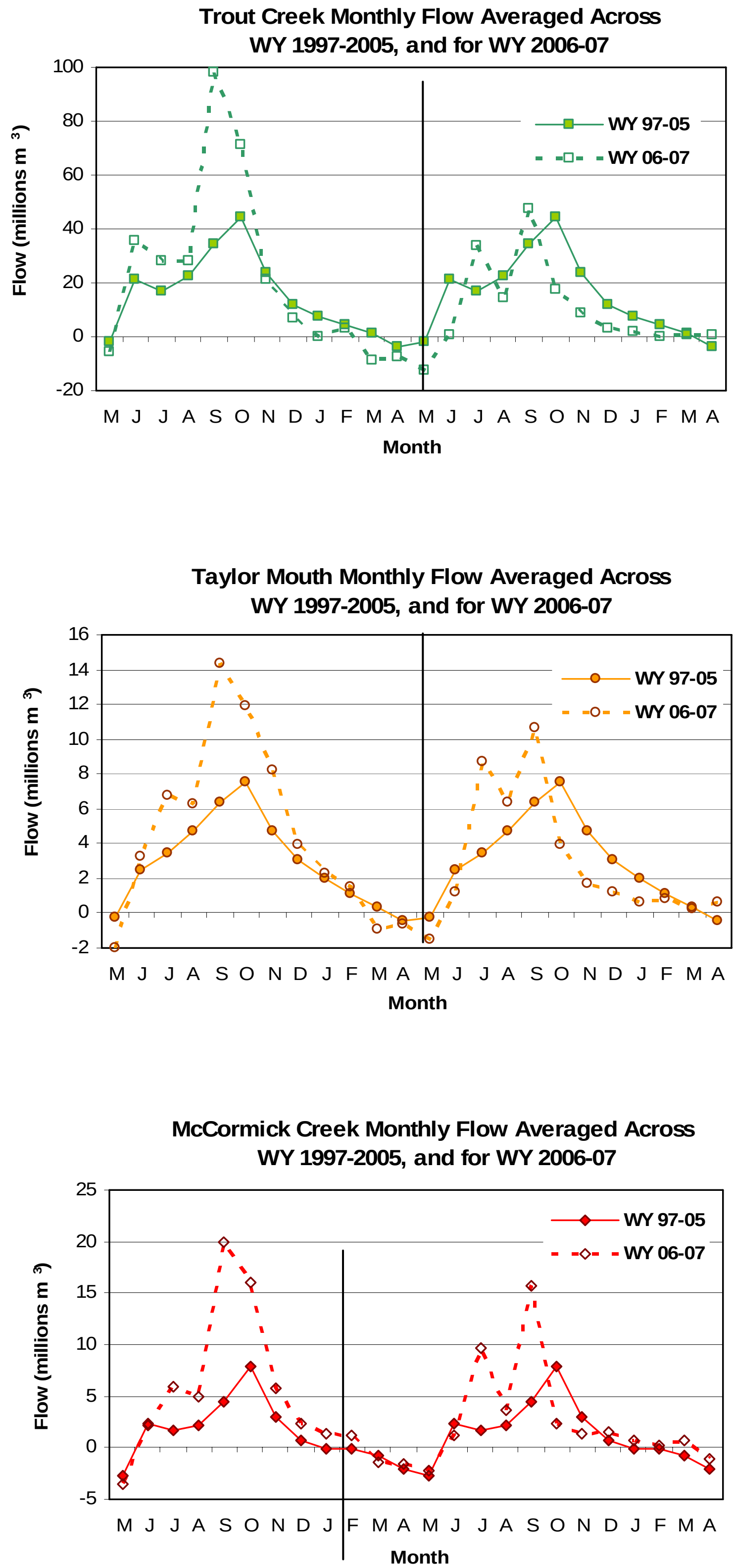


Figure 12-23. Monthly discharge of water from the southern Everglades into Florida Bay through three major creeks in WY2006 and WY2007 compared to mean monthly values of the previous nine years.

The spatial pattern of creek discharge indicates a westward shift in water distribution in WY2007 relative to the nine-year average. This may reflect local rainfall patterns, wind patterns that can alter water levels and hydrologic gradients, and water management. An operational objective of the C-111 Project is to shift water flow from the C-111 canal more toward Taylor Slough, and such a shift appears to have occurred in WY2007. The rapid decline in flow in October is not in keeping with the long-term goal to provide a slow release of water from C-111 into the southern Everglades through much of the dry season.

Salinity in Florida Bay

Salinity conditions in Florida Bay are a key factor influencing the ecology of the bay and the primary variable that can be altered via water management (Rudnick et al., 2005). Salinity performance measures are part of major projects that affect fresh water flow to the bay, including CSOP and CERP (RECOVER, FBFKFS, and C-111 Spreader). Salinity targets reflect magnitude, timing, and distribution and generally are focused on minimizing hypersalinity events, especially by minimizing salinity in the early dry season.

The magnitude, distribution, and timing of salinity fluctuations in Florida Bay are determined by the freshwater inputs from the Everglades, rainfall (generally event-driven with dominance of cold fronts in the dry season and tropical waves and storms in the wet season), evaporation, exchange with marine waters of the Gulf of Mexico and Atlantic Ocean, groundwater exchange, and internal circulation. Because Florida Bay is shallow and its circulation is restricted, it is highly susceptible to rapid and abrupt changes in salinity, and to hypersalinity events that affect the biology and chemistry of the bay. Data are collected at frequent (< 1 h) intervals at stations in the ENP's Marine Monitoring Network (MMN) and creek mouth stations monitored by the USGS, and monthly as part of SFWMD's water quality monitoring (contract with the Florida International University, or FIU), providing information on spatial and temporal trends in salinity throughout the bay. Monthly average salinity for representative MMN and USGS sites (Trout Creek, Duck Key, and Little Madeira Bay for the eastern bay and Whipray Basin for the central bay) were averaged with FIU data collected in the corresponding months and regions (FIU eastern sites 9, 11, 23, and 24, and central sites 12–15; locations are available on FIU's web site at http://serc.fiu.edu/wqmnetwork/SFWMD-CD/Pages/FB.htm).

Salinity in WY2007 (**Figure 12-24**) reflected the spatial and temporal trends described above for rainfall and creek discharge to the bay. Salinity in eastern bay remained well above long-term monthly averages (shown starting in WY1997 to be consistent with creek discharge period of record). Mean annual salinity was 30.0 psu, compared to the WY1997–WY2005 mean of 24.7 psu. Salinity in central bay, an area especially prone to hypersalinity, was only slightly above average for most months of WY2007. Mean annual salinity was 35.3 psu, compared to the WY1997–WY2005 mean of 33.3 psu. Corresponding with peak freshwater flow through McCormick Creek in September 2006, central bay salinity dropped to its WY2007 minimum in September. This was the only month when salinity was below average in the central bay. Salinity in the eastern bay had a similar temporal pattern to that of the central bay, with a WY2007 minimum in September corresponding to peak creek discharge. Notably, salinity in the eastern bay typically remains near its annual minimum in the late wet season and early dry season, but in WY2007 began an early rise in October.

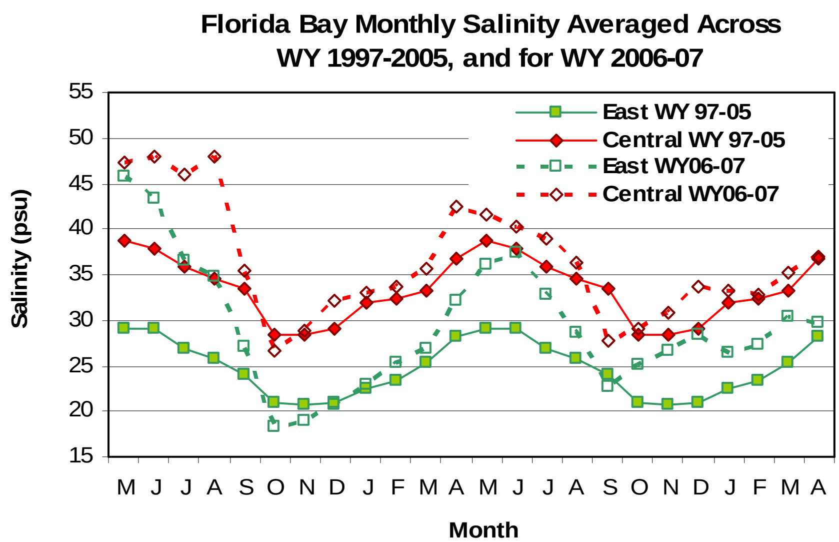


Figure 12-24. Monthly mean salinity in eastern and central Florida Bay in WY2006 and WY2007, compared to mean monthly values of the previous nine years.

Florida Bay Minimum Flows and Levels Status

During WY2007, the first Minimum Flows and Levels (MFL) rule for Florida Bay was approved by the Governing Board and accepted by the Florida Department of Environmental Protection. This rule was based on past technical work including hydrological and ecological studies and modeling of the Florida Bay regions (see the 2006 SFER for details). The rule identifies a salinity indicator site in a pond (Argyle Hendry Pond) along a mangrove creek that flows from Taylor Slough to Florida Bay (upper Taylor River). It states that a MFL exceedance occurs when the 30-day running average of salinity at the Taylor River site is over 30 psu at any time during a 365-day period and that a MFL violation occurs when there are exceedances in two consecutive years more often than once in a 10-year period. This salinity criterion was primarily based on the inference that SAV habitat in this salinity transition zone is lost with salinity above this threshold. The rule also specifies the guideline that flows from five major mangrove creeks into Florida Bay should exceed 105,000 ac-ft per year (= 130 million m^3/y) in order to avoid a salinity exceedance.

The Florida Bay MFL rule requires the District to "continue field monitoring and research to assess salinity, water level and flow conditions, and biological resources response in the region…" and that a Prevention Strategy would be incorporated into the Lower East Coast (LEC) Water Supply Plan. A portion of the 2005–2006 LEC Water Supply Plan Update (Appendix H) includes this prevention strategy for the Florida Bay MFL. This strategy is the implementation of ongoing efforts to protect Florida Bay (especially the Combined Structural and Operational Plan for the C-111 Project and Modified Water Deliveries to the ENP (CSOP), the C-111 Spreader Project, and the Florida Bay and Florida Keys Feasibility Study) and for continued hydrologic and ecological monitoring, research, and modeling to assess the state of the Florida Bay ecosystem, assess the validity of the adopted MFL criteria to prevent significant harm and improve the scientific basis for any future revision of the criteria. Much of the research specified in this strategy was based on the 2005 peer review (Stevenson et al., 2005) of the Florida Bay MFL Technical Documentation Report (Hunt et al., 2006) and is further described in the Everglades Division Strategic Plan (see Appendix 6-1 of this volume).

Salinity was monitored at the Taylor River (TR) indicator site and **Figure 12-25** shows TR salinity (30 day (d) running average) for the past two water years in order to examine if there was an exceedance of MFL criteria during WY2007. Salinity reached well over the 30 psu threshold in the early part of WY2006 (up to 48 psu), thus leading to concern that dry conditions in WY2007 could yield an exceedance in the first dry season since adoption of the rule. Moreover, as WY2005 saw 30 d average salinity at TR nearly reach 40 psu, the District wanted to avoid a third consecutive year of such high salinity – a condition that the MFL rule defines as constituting "significant harm" to Florida Bay (although conditions prior to rule adoption do not contribute to a declaration of subsequent rule violations). Regardless, the 30 d salinity average reached a maximum of 29.8 psu in the early part of June 2006, very nearly reaching, but not exceeding, the 30 psu MFL threshold. This peak salinity coincided with a low period of creek discharge into Florida Bay, approaching the minimum freshwater flow quantity specified in the Florida Bay MFL rule: 365 d cumulative flow through five major creeks of 105,000 ac-ft.

Following this period of relatively high salinity, heavy rains and flow through Taylor River in July 2006 (**Figures 12-22** and **12-23**) decreased TR salinity more rapidly than it does in an average water year (**Figure 12-25**). Salinity remained low at TR throughout much of the remainder of the water year, rising only slightly above average in the early dry season months. Rain events in the latter part of the dry season (February–April 2007) allowed salinity to remain low for the remainder of the water year. Moreover, following the event in the early part of the water year, the 365 d cumulative five creek discharge quickly rebounded, staying well over 105,000 ac-ft and further relieving any concerns about crossing the 30 psu threshold at TR in WY2007.

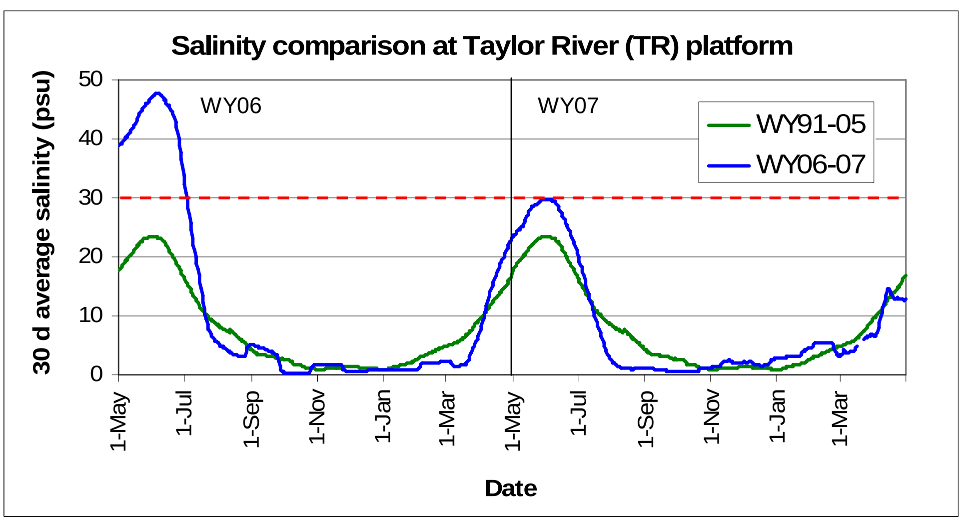
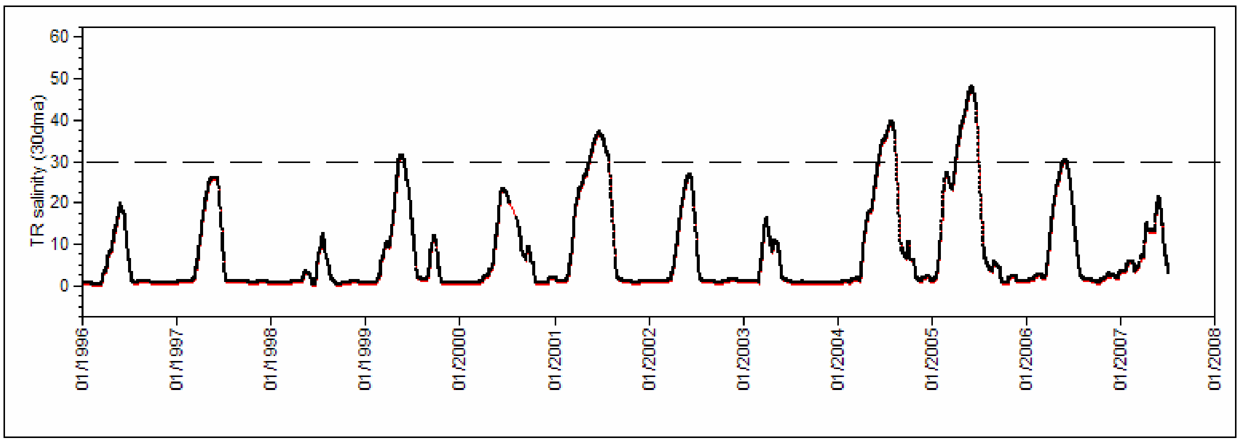


Figure 12-25. Tracking salinity (30-day running average) at the upper Taylor River (in Argyle Hendry Pond) site to determine whether Florida Bay MFL criteria (red line is the salinity criterion) were exceeded.

The sustenance of SAV habitat was the primary basis of the Florida Bay MFL criteria. Continued SAV monitoring by the Audubon Society and their generous provision of data enable us to further assess salinity-SAV relationships and status in this report. SAV data from upstream Taylor River show that after the denuding of *Ruppia* in WY2005 (coincident with very high salinity in 2004 and 2005), there was little recovery of *Ruppia* has occurred over WY2006 and WY2007 (**Figure 12-26**) when 30-day average salinities approached, but did not exceed 30 psu. This finding is in accordance with expectations derived from the Florida Bay MFL criterion. Low *Ruppia* cover is considered to be associated with average salinities greater than 30 psu, and recovery is expected to take at least two years (Hunt et al., 2006). The exact mechanism causing this effect on *Ruppia* survival is unknown, since laboratory experiments suggest that *Ruppia* can physiologically withstand salinities greater than 50 psu (Koch et al., 2007). This is an area of study that will be examined more closely in a future update of the MFL studies for Florida Bay.



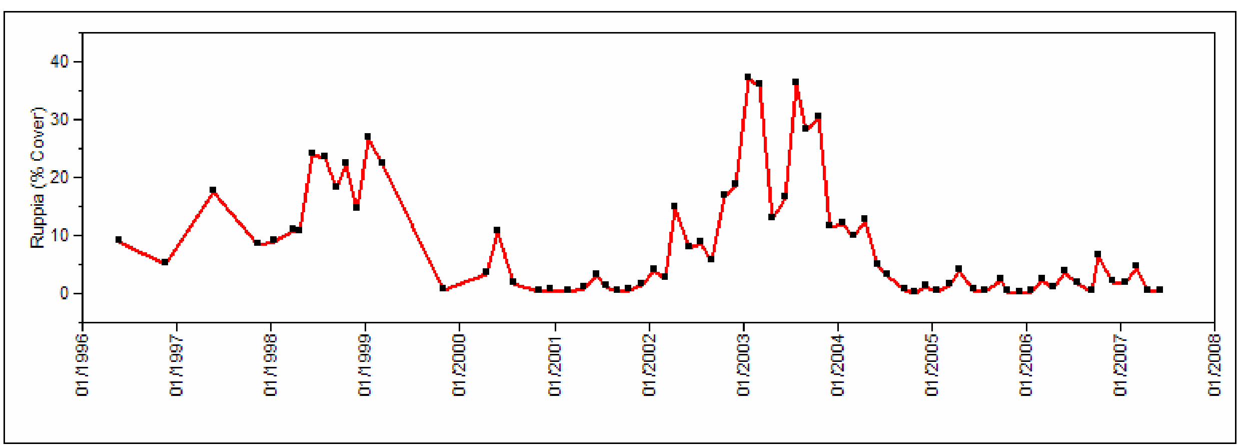


Figure 12-26. *Ruppia maritima* cover from an upstream Taylor River SAV monitoring site (from four 0.25 m^2 quadrats per sampling event in Argyle Hendry pond; data courtesy of P. Frezza and J. Lorenz, National Audubon Society) and salinity (calculated as a 30-day moving average of 15 min interval samples) from the Argyle Hendry salinity monitoring platform. Low *Ruppia* cover is correlated with 30-day average salinities greater than 30 psu (the Florida Bay MFL criterion).

Water Quality in Florida Bay

Assessment of water quality in Florida Bay, which is part of the Everglades Protection Area, is necessary in order to ensure that District operations and projects protect and, to the extent possible, restore the ecosystem. CERP performance measures (in RECOVER and the FBFKFS) focus on chlorophyll *a* concentrations (as an indicator of algal blooms) and call for no increase in the magnitude, duration, or spatial extent of blooms compared to conditions since monitoring began (1991). Water quality is thus considered a constraint on restoration efforts, with the objective of doing no harm. Water quality monitoring provides a basis for assessing the status and trends of this part of the Everglades Protection Area and also builds a foundation for understanding and forecasting the effects of changing water management on the ecosystem.

A striking trend from the early 1990s through early 2000s was a decrease in the concentration of several water quality constituents through most of Florida Bay and especially in the central bay. The strongest trend was for decreasing total nitrogen (TN) through WY2002, but decreases in total phosphorus (TP), total organic carbon (TOC), and turbidity also occurred (**Figure 12-27**). [Note: See the 2005 SFER – Volume, Chapter 12, for a more detailed description of these trends through WY2003.] This year's chapter focuses on major changes that have occurred since WY2003, particularly during WY2006 and WY2007. It should be noted that nutrient analyses for WY2007 are incomplete, as of the time this report is being written, so WY2007 annual means are not included in this report. Results presented herein represent the means of four to six stations per region, with samples collected and analyzed monthly under contract with Florida International University (FIU). Nutrient concentrations are presented here with molar units and can be converted to weight-based units (per liter) as follows: 12 µg/µM C, 14 µg/µM N, 31 µg/µM P.

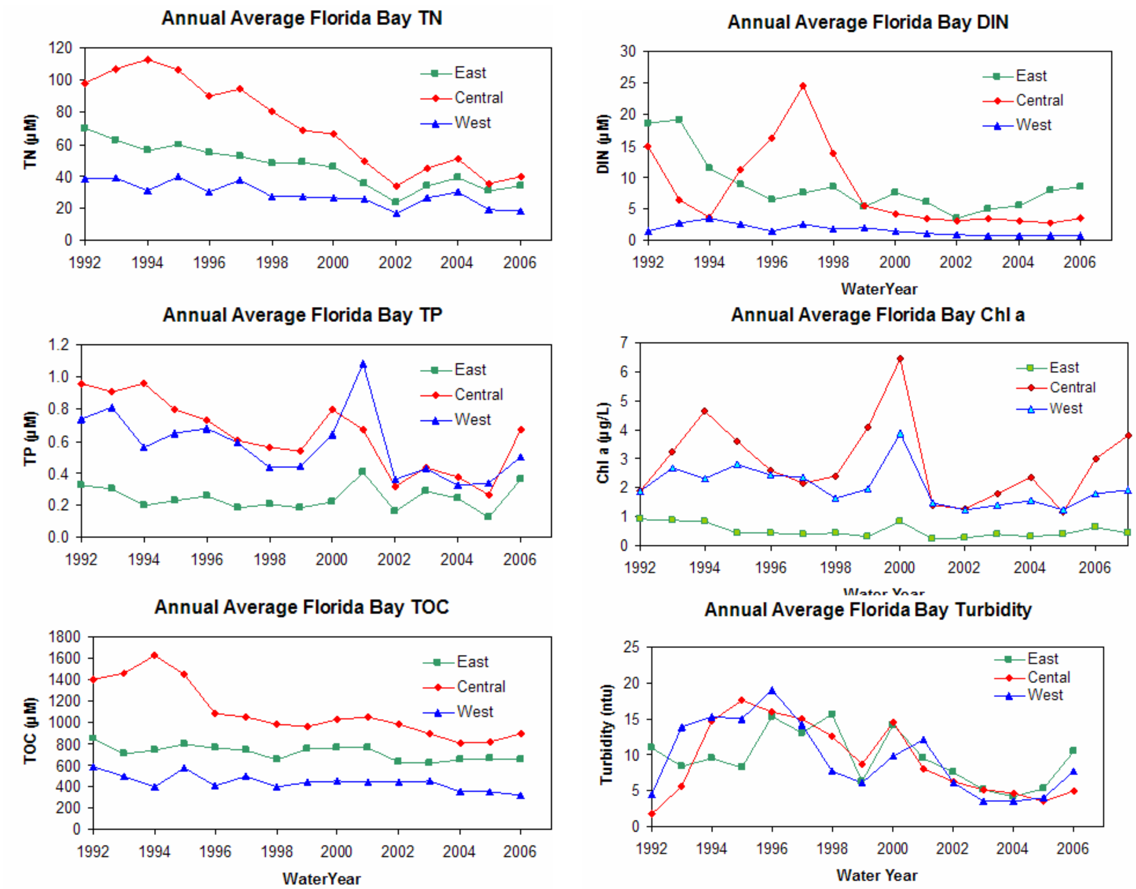


Figure 12-27. Long-term water quality annual means (of monthly duplicate samples at 4 to 6 stations per region) in Florida Bay from the District/Florida International University water quality monitoring network.

Spatial and temporal patterns of Florida Bay water quality have been described in a recent technical report (Hunt and Nuttle, 2007) and publications (Boyer et al., 1997; Boyer and Jones, 1999; Boyer et al., 1999; Rudnick et al., 1999). Evident from **Figure 12-27**, there is a regional spatial relationship among nutrients. TP concentrations are very low in eastern bay and higher in the central and western bays. Primary production is strongly P limited in eastern bay (Tomas et al., 1999). The Gulf of Mexico is more N limited and thought to be the primary source of P to the bay (Fourqurean et al., 1993; Rudnick et al., 1999), accounting for the higher western TP concentrations. Chlorophyll *a* concentrations tend to be positively correlated with TP concentrations (Boyer and Jones, 1999) and algal blooms have almost exclusively occurred in the central and western bays over the monitoring period of record. A notable exception is the WY2006–WY2007 algal blooms centered in Blackwater Sound and Barnes Sound (see 2007 SFER – Volume I, Chapter 12, and the *Algal Bloom* section in this chapter).

Coincident with relatively high TP concentrations, the western bay has relatively low total nitrogen and dissolved inorganic nitrogen (DIN) concentrations and the more common occurrence of nitrogen limitation than other parts of the bay (Tomas et al., 1999). With sparse seagrass, very low phytoplankton, and Everglades surface water inputs containing relatively high TN (about 50 µM with DIN contributing about 10 percent of this nitrogen (Childers et al., 2006), the eastern bay is relatively nitrogen rich (with molar TN:TP averaging 200 in from WY1992–WY2006). The central bay is a region where eastern and western bay's waters mix and where physical isolation of basins results in long water residence time (Lee et al., 2006) and the associated strong influence of internal nutrient cycling. The Central Bay is the region with the highest salinity and the highest concentrations of nutrients (TN, TP), TOC, and chlorophyll *a*.

By WY2003, the long-term decrease in the concentrations of TN and other water quality components appears to have greatly slowed or ceased; inter-annual differences from WY2003 through WY2005 were relatively small (**Figure 12-27**). However, TP concentrations greatly increased in WY2006 in all bay regions (relative to WY2005: 47 percent in west, 152 percent in central, 183 percent in east). Turbidity in WY2006 (relative to WY2005) also increased by > 90 percent in the eastern and western bays and chlorophyll *a* increased by 157 percent in the central bay. Elevated mean WY2006 TP concentrations were driven by very high values measured throughout the bay in October 2005 (**Figure 12-28**). Concurrent turbidity measurements showed that that these high TP values were not associated with high suspended sediment concentrations (**Figure 12-30**). The high TP concentration followed the disturbance of Hurricane Katrina in August 2005 and Hurricane Rita in September 2005 (but preceded Hurricane Wilma later in October). It is notable that the highest mean annual chlorophyll *a* concentrations measured in the bay occurred in WY2000 following Hurricane Irene (**Figure 12-27**), which, similar to Katrina, produced high precipitation and a runoff pulse.

Also evident (from long-term monthly means) in **Figures 12-28** through **12-30** is the seasonality of Florida Bay water quality. Chlorophyll *a* and TP concentrations tend to be highest in the fall and lowest in the spring, especially in the central bay. As noted above, TP was particularly high in October 2005 throughout the bay (following Hurricane Rita) and, despite the absence of tropical disturbances in 2006, also high in October 2006. In the central bay, chlorophyll *a* concentrations were higher than long-term mean values for most months following the October 2005 TP peak. TN and TOC tend to be highest in the summer and lowest in the winter and spring, while DIN has an opposite pattern with a summer minimum and winter-spring maximum, probably reflecting the seasonality of DIN uptake and coupled nitrification-denitrification. DIN concentrations were unusually high in the eastern bay in fall 2005, concurrent with the onslaught of three hurricanes (starting with Katrina in August) and a high DIN concentration peak was measured in September 2005 in the central bay. These water quality patterns point to the importance of storm disturbance and associated pulse runoff events as important drivers of phytoplankton bloom dynamics. However, long-term decreases in nutrient concentrations, as well as seasonal characteristics, likely reflect both changes in loading and internal processing, including changing patterns of SAV growth and decomposition.

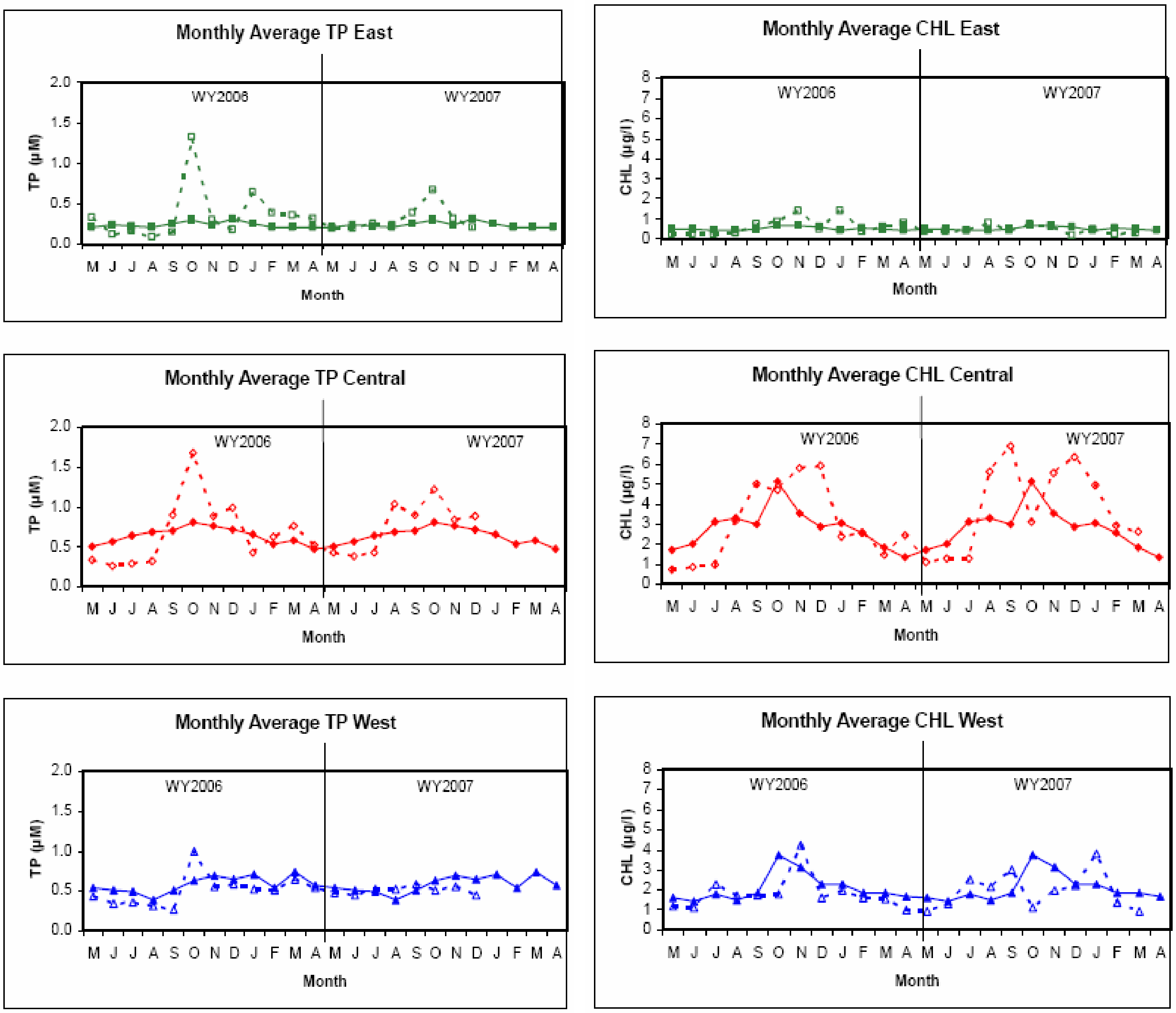


Figure 12-28. Monthly total phosphorus and chlorophyll *a* concentrations in regions of Florida Bay during WY2006 and 2007 (dashed line with open symbols) compared to monthly means from WY1992–WY2005 (solid line with closed symbols).

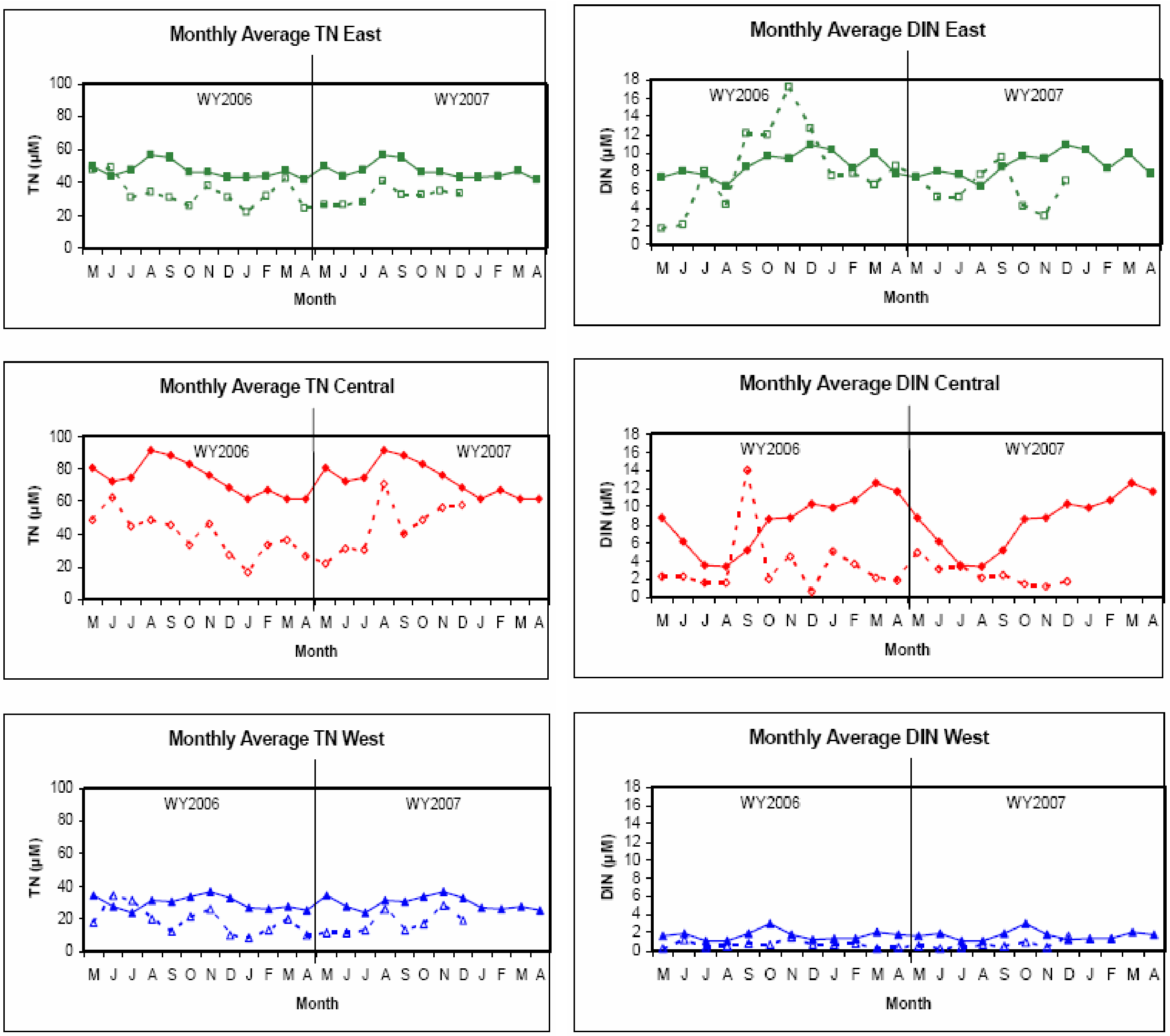


Figure 12-29. Monthly total nitrogen and dissolved inorganic nitrogen concentrations in regions of Florida Bay during WY2006 and WY2007 (dashed line with open symbols) compared to monthly means from WY1992–WY2005 (solid line with closed symbols).

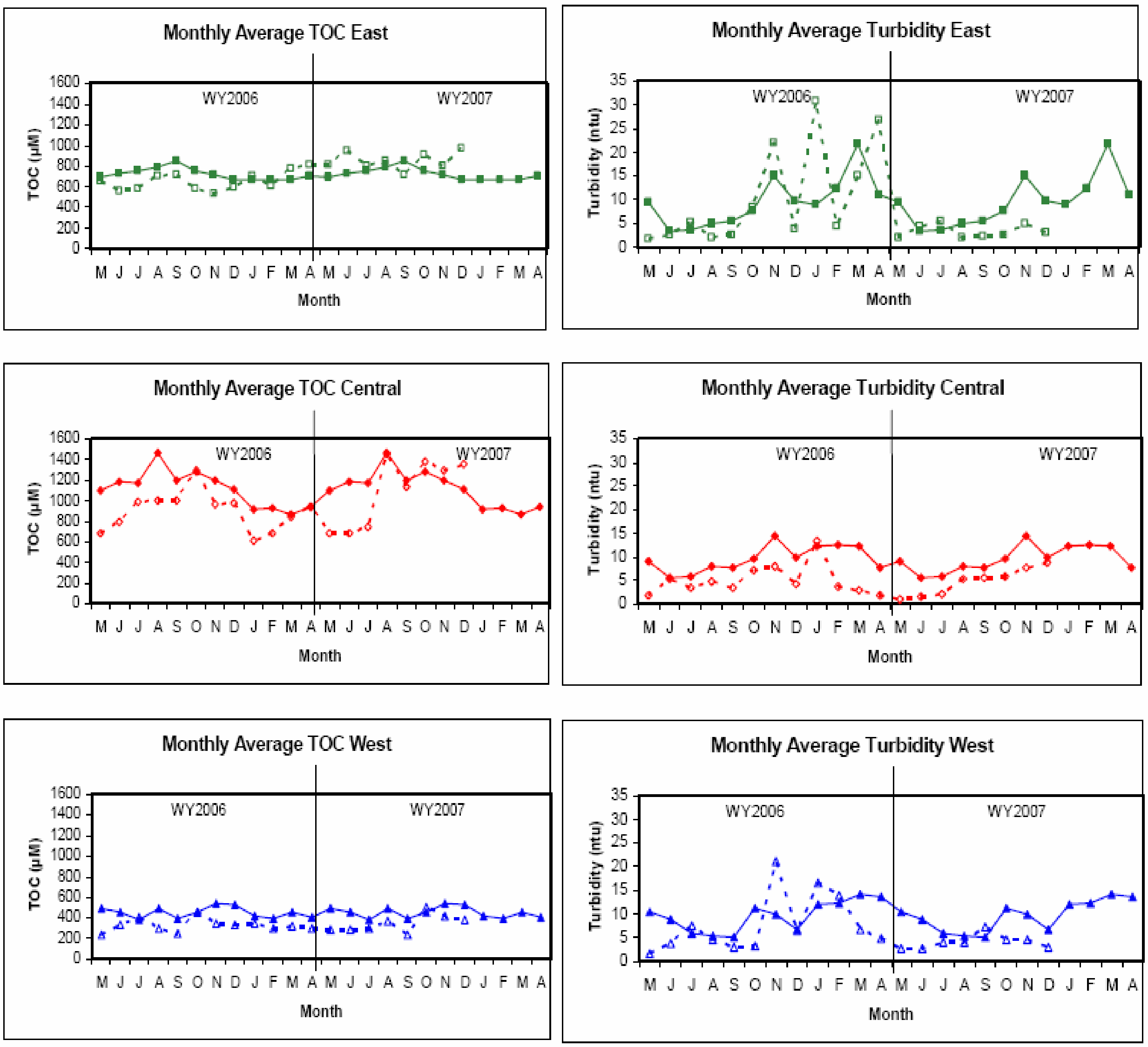


Figure 12-30. Monthly total organic carbon concentrations and turbidity in regions of Florida Bay during WY2006 and WY2007 (dashed line with open symbols) compared to monthly means from WY1992–WY2005 (solid line with closed symbols).

While phytoplankton growth appears to be stimulated by such storm events (for a detailed assessment of WY2006 hurricane effects in the eastern Florida Bay and southern Biscayne Bay, see the 2007 SFER), inter-annual variability of chlorophyll *a* concentrations is not clearly related with inter-annual variability in total freshwater discharge from the southern Everglades toward and into Florida Bay (**Figure 12-31**). Based on a sixteen-year record, regressions of annual mean chlorophyll *a* concentrations in the central bay (where blooms have been most common) and either estimates of canal discharge or mangrove creek outflow to the bay yield poor fits ($R^2 = 0.07$) and slopes that do not significantly differ from zero ($P > 0.3$). This finding is not consistent with the hypothesis that an increment of increased freshwater discharge with Everglades Restoration will stimulate algal blooms in Florida Bay (Brand, 2002). Given the long renewal time of water in Florida Bay [6 to 12 months in the central bay estimated by Lee et al. (2006)], an annual time-step would be expected to detect a positive relationship between discharge and chlorophyll *a* if the relationship were strong. The statistical insignificance of the relationship does not prove that this relationship does not exist and points toward the need for more powerful analyses (e.g., via dynamic modeling). It should be noted that estimates from CERP modeling indicate that no increase in total freshwater input from the southeast Everglades is expected with CERP implementation as currently planned.

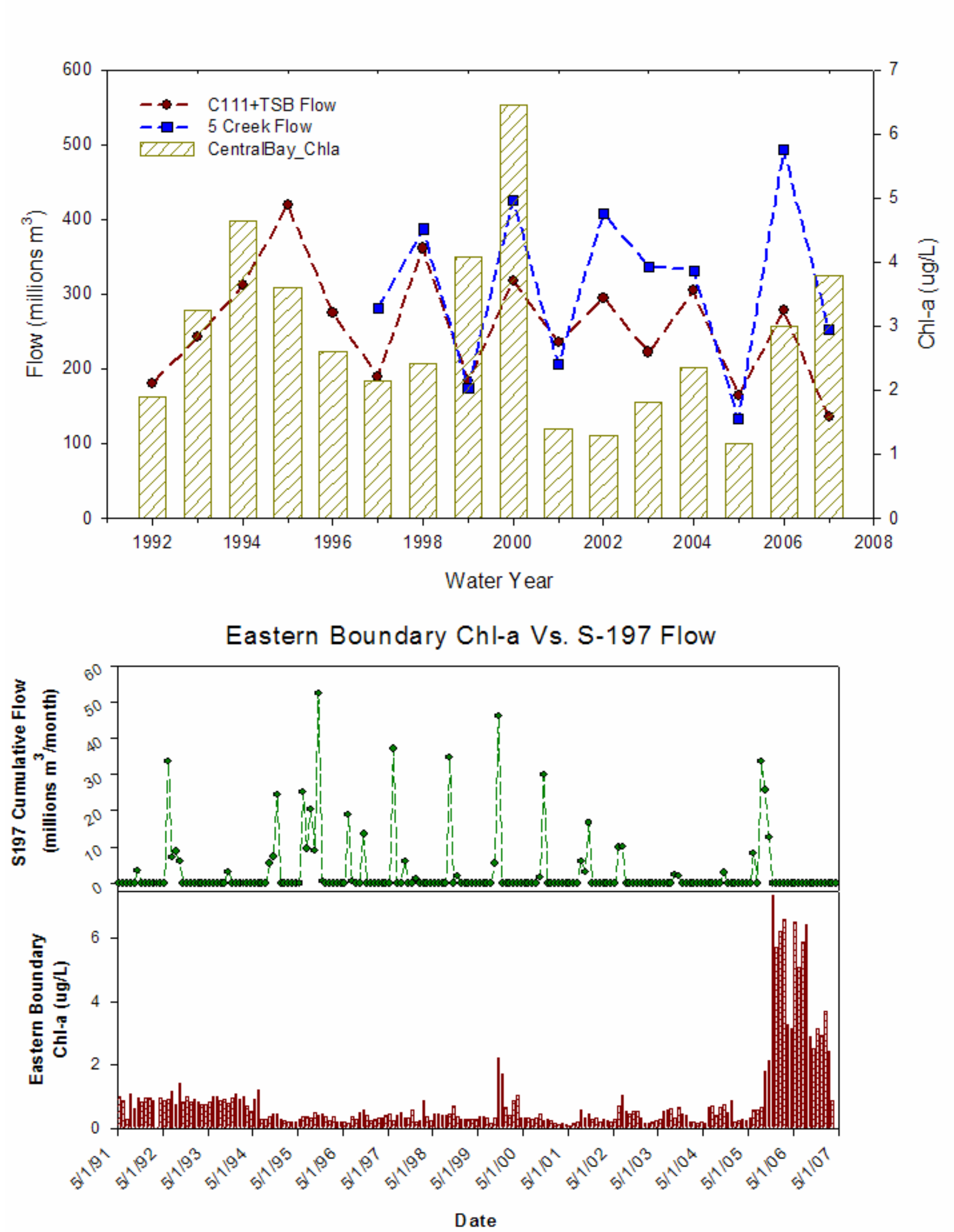


Figure 12-31. Upper panel shows long-term variations in annual total water discharge in the southern Everglades (at S-18C structure and through Taylor Slough Bridge), the sum of flow through five major creeks flowing into Florida Bay, and mean chlorophyll *a* in the Central Bay. Lower panel shows discharges from the C-111 canal through S-197 into Manatee Bay and mean chlorophyll *a* concentrations in this bay and adjacent basins (Barnes Sound, Blackwater Sound, and Little Blackwater Sound).

Eastern Florida Bay and Southern Biscayne Bay Algal Bloom Update

An algal bloom, dominated by cyanobacteria (blue-green algae), began in southern Biscayne Bay and the eastern boundary waters of Florida Bay in fall 2005 and has continued since that time (lower panel of **Figure 12-31**). No bloom of similar magnitude has previously been documented in this eastern region, although cyanobacteria blooms have commonly occurred in the central bay (Hunt and Nuttle, 2007). A detailed report on the initiation and possible causes of the eastern bloom, including construction along U.S. Highway 1 and three successive hurricanes in fall 2005 (with a large water discharge from the C-111 canal following Hurricane Katrina) was presented in the 2007 SFER – Volume I (Rudnick et al., 2007). Here we present and update of the status of this bloom and document the occurrence of SAV mortality during the time of the bloom.

The algal bloom persisted in WY2007 and remained centered in the Blackwater Sound–Barnes Sound region (**Figure 12-32**). Chlorophyll *a* concentrations decreased considerably during the spring of 2006, rebounded during the summer, and decreased again during spring 2007 (**Figure 12-33**). A similar seasonal pattern has been observed in central and western bay (**Figure 12-28**). Six high-resolution chlorophyll *a* surveys in WY2007, using the Dataflow multi-probe mapping system (Madden and Day, 1992), showed detailed spatial patterns (**Figure 12-34**). Chlorophyll *a* concentrations consistently were higher in basins adjacent to U.S. 1 than basins further east or west and tended to be highest near Key Largo, with Lake Surprise concentrations in excess of 20 µg/L. The bloom expanded eastward during summer 2006 such that by August 2006, it had expanded past Card Sound and into southern Biscayne Bay proper (**Figure 12-34**). By June 2007 the bloom had largely contracted to basins adjacent to U.S. 1.

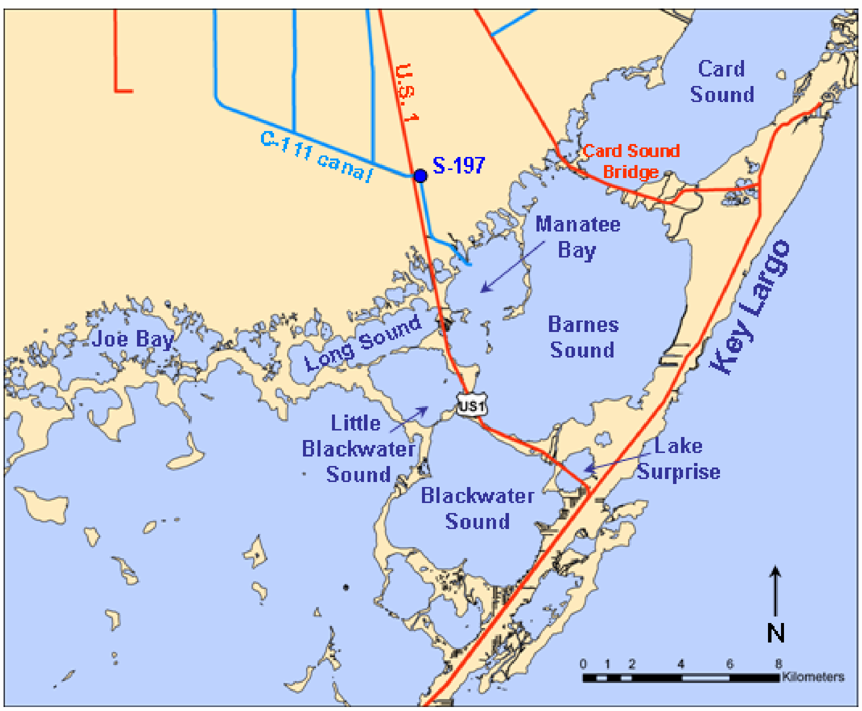


Figure 12-32. Eastern Florida Bay – southern Biscayne Bay algal bloom area.

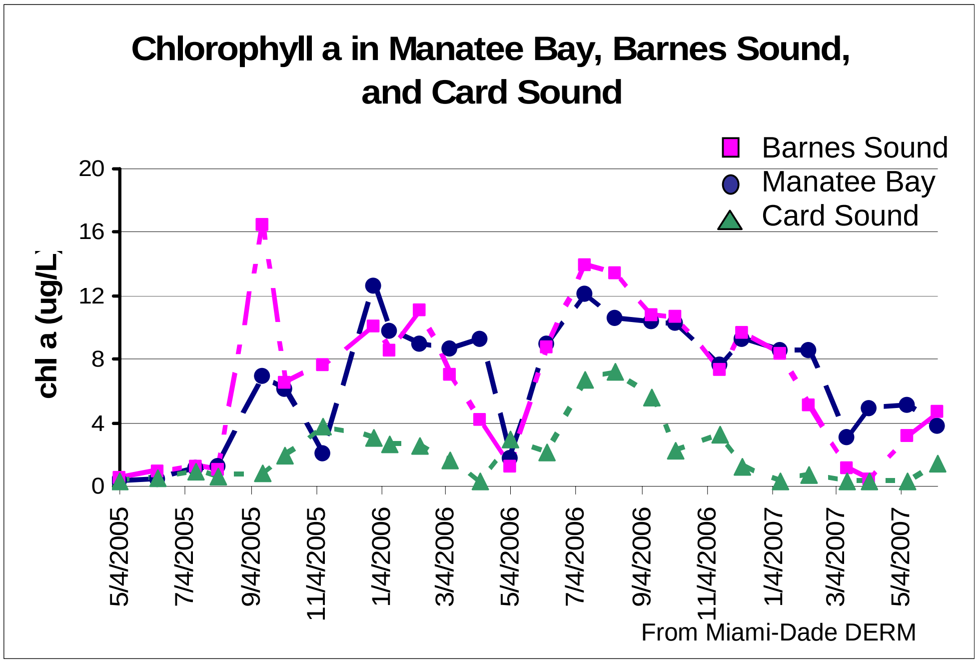


Figure 12-33. Time series of chlorophyll *a* concentrations in three southern Biscayne Bay basins since algal bloom initiation.

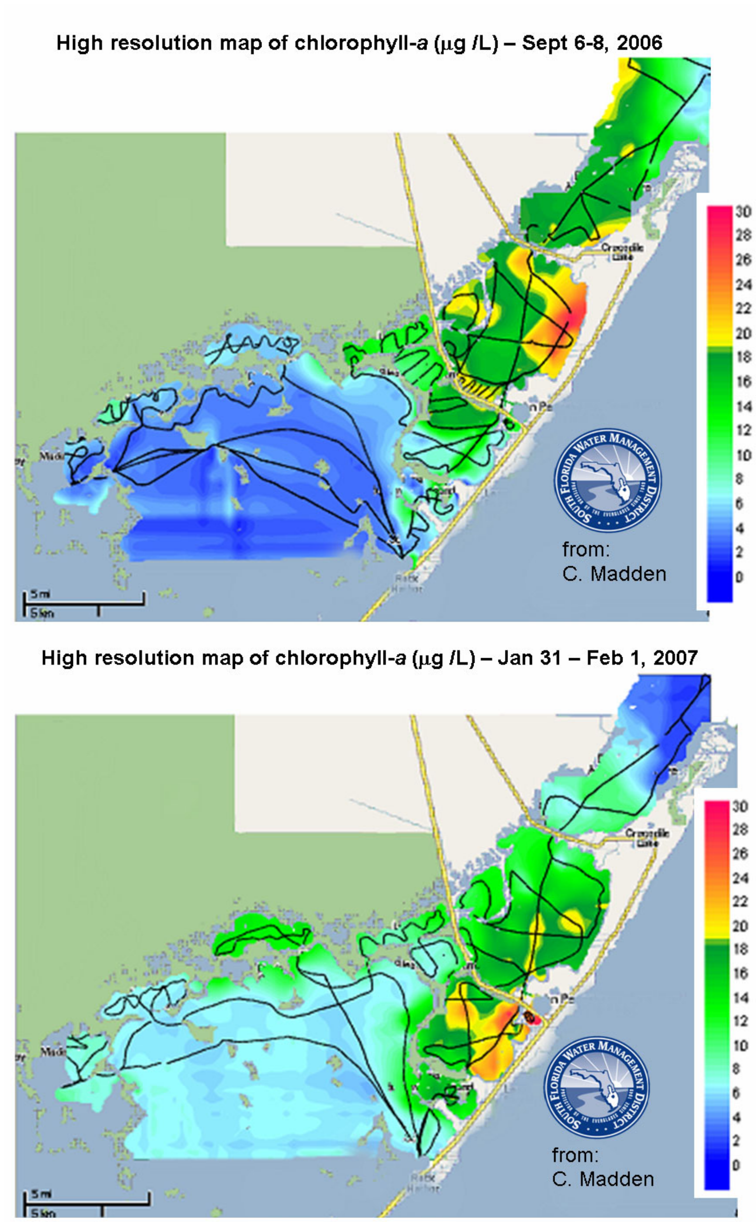


Figure 12-34. Chlorophyll *a* concentration, as estimated from continuous flow in vivo fluorometry (Dataflow, with boat tracks shown as black line) in WY2007.

Detailed studies of the composition and nutrient response of the bloom were done by NOAA-funded investigators (P. Glibert and C. Heil) in October 2006 and April 2007, in collaboration with District scientists; we are jointly conducting field studies and incorporating findings in our Florida Bay SAV-Ecosystem model (see the *SAV Research and Modeling* subsection). In October 2006, Glibert and Heil found that the bloom had markedly different compositions in Barnes Sound and Manatee Bay versus Blackwater Sound, Little Blackwater Sound, and eastern Florida Bay. East of U.S. 1, the bloom was dominated by cells < 1 μm in size, which were mostly *Synechoccocus elongata* (personal communication, P. Glibert and C. Heil). West of U.S. 1, the bloom had a higher proportion of larger microflagellates and dinoflagellates, with *Prymnesium* sp. as the dominant taxon, indicating that the influence of grazing on *Synechoccocus* may be more important in this region than in Barnes Sound.

The long duration of this regional algal bloom likely reflects the long residence time of water in this region, efficient P retention and cycling, typically high ambient inorganic N concentrations with N inputs from the watershed and other sources, and possibly a continuing supply of P. Regional bloom initiation occurred after high peaks in inorganic N, and TP occurred in fall 2005. Sources of this nutrient pulse are not certain, but likely included nutrients from the C-111 canal (associated with discharges after Hurricane Katrina), nutrients from mulched mangroves and disturbed soils associated with U.S. Highway 1 widening, and wind and wave disturbance associated with three successive hurricanes in three months in fall 2005 (possibly including nutrient enrichment from the transport of roadway materials, bay sediments and groundwater nutrients, and detritus from SAV beds and other vegetation) (Rudnick et al., 2007). TP concentrations have remained near 20 ppb (0.65 μM) (**Figure 12-35**; Rudnick et al., 2007). Based on chlorophyll *a* concentrations and stoichiometric assumptions, most of this elevated TP was within phytoplankton cells. By February 2006, dissolved inorganic N (DIN) had decreased to the lowest concentrations measured over the 16-year period of record (averaging 0.7 μM, SD = 0.4), resulting in a DIN/TP ratio that decreased below 1.7 (mean = 0.9, SD = 0.4) for the rest of 2006 (compared to the previous period of record's mean of 20). Not surprisingly, a set of bioassays with Barnes Sound water in October 2006 showed strong positive responses to inorganic and organic nitrogen additions and N + P additions, but not P additions alone (Glibert et al., 2007). The coherence of increased total organic carbon with TP and (with much greater variability) total organic N (**Figure 12-35**) is also notable and provides insight regarding nutrient sources that have contributed to bloom sustenance.

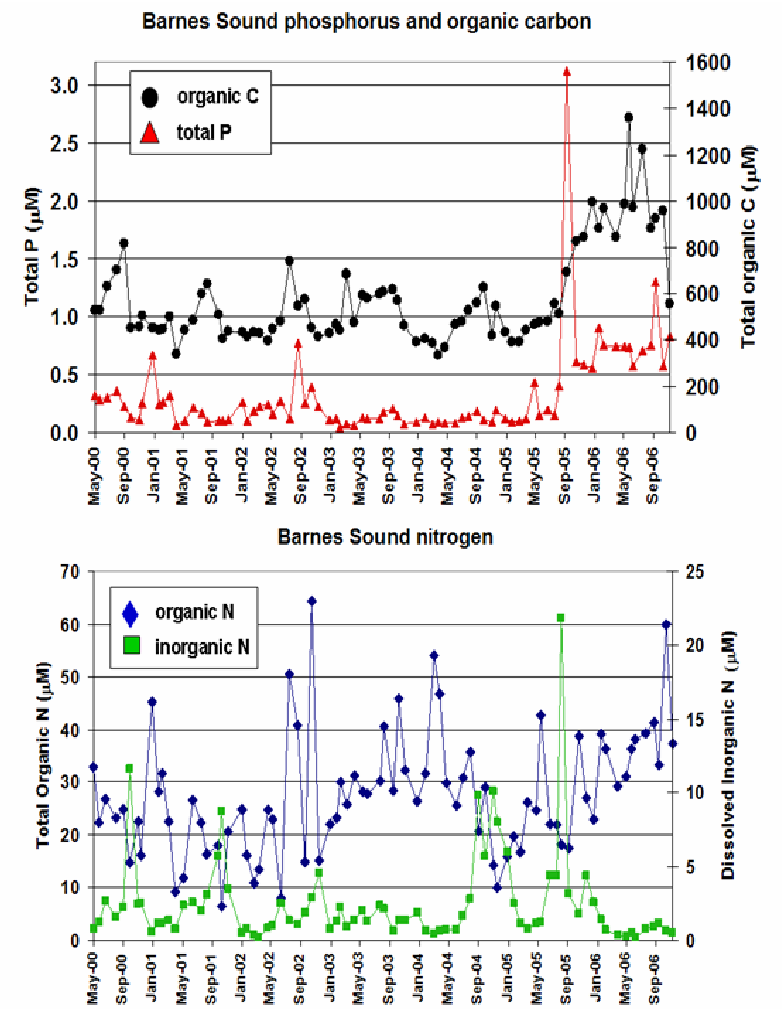


Figure 12-35. Monthly concentrations of total phosphorus, total organic carbon, total organic nitrogen, and dissolved inorganic nitrogen in Barnes Sound since WY2001. WY2001–WY2005 are given to show variations prior to bloom initiation in fall 2005. Note that 5µM TP is equal to 15.5 ppb TP.

Nutrient inputs to Manatee Bay and Barnes Sound from the watershed via the C-111 canal were minimal in WY2007, because there were no openings of the S-197 gated culverts (**Figure 12-31**) during the year. Nutrients could have been supplied by continuing construction and soil and sediment disturbance along U.S. 1 (e.g., via the construction of bridge pilings), but the magnitude of this source is unknown. A major supply of nutrients was likely derived from SAV mortality (seagrass and benthic macro-algae) in areas where the bloom persisted (Blackwater Sound and Barnes Sound; **Figure 12-36**). Based on short-shoot counts in WY2007, seagrass loss was about 74 percent in Blackwater and 36 percent in Barnes relative to a WY2000–WY2005 baseline (see the *Submerged Aquatic Vegetation Monitoring in the Southern Estuaries* section below for more details).

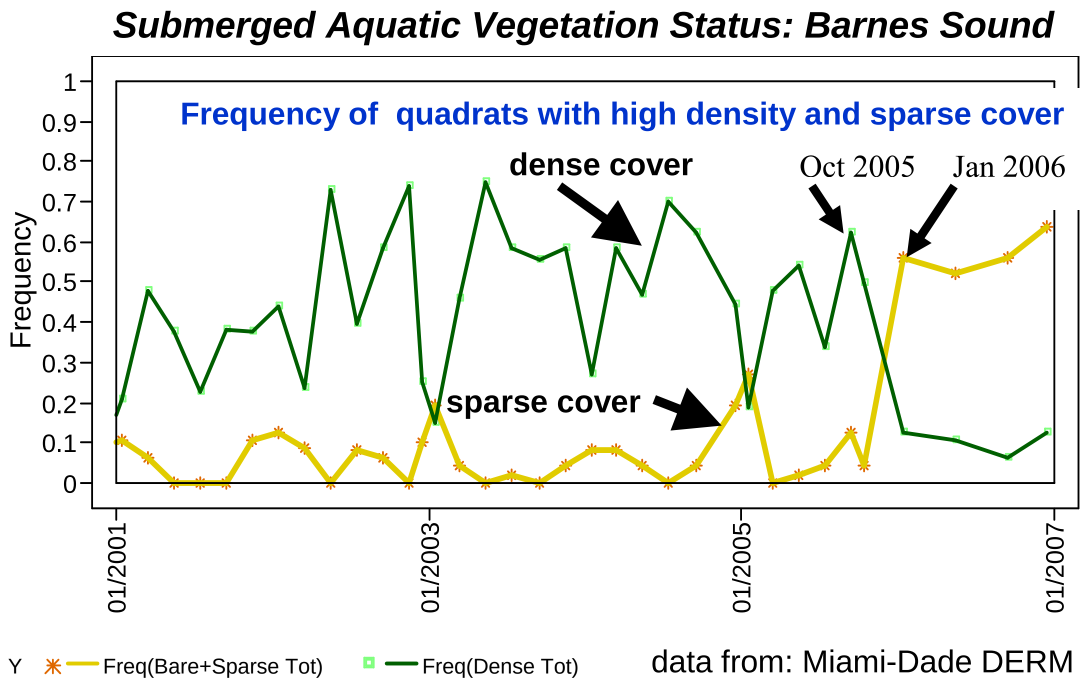


Figure 12-36. Change in the frequency of high density (75% or more cover) and low density (25% or less cover) submerged aquatic vegetation (SAV) in Barnes Sound, with apparent SAV loss in the late fall–early winter 2005.

Extensive SAV mortality could have been caused by the bloom via decreasing light availability. Furthermore, a positive feedback loop between the algal bloom and SAV mortality (as in Rudnick et al., 2005), could have been initiated by the bloom, such that decreased light caused SAV mortality, which increased nutrient availability (via SAV decomposition and decreased nutrient uptake by SAV), enabling continued algal productivity and associated light extinction, yielding more SAV mortality. SAV mortality can also decrease sediment stabilization, increasing sediment suspension and further increasing light extinction.

A remarkable regional increase in the concentration of total organic carbon (TOC) in the water column occurred following the initiation of the algal blooms and may in part be derived from SAV decay (**Figure 12-37**) and in part from U.S. 1 construction disturbance. In Barnes Sound and other basins adjacent to U.S. 1, TOC increased in fall 2005 and subsequently remained well above the range of almost all values measured over the previous 15 years, peaking with concentrations more than double the recent (WY2001–WY2005) baseline. Basins further to the east or west also had elevated TOC, but within the range of past variations (**Figure 12-38**). The spatial pattern of elevated TOC is very similar to bloom distribution patterns centered around U.S. 1. Total N concurrently increased but with much greater variability (**Figure 12-35**). Molar ratios of TOC/TON increased from a pre-WY2006 mean of 19 (median = 17) in Barnes Sound and Blackwater Sound, which is approximately the ratio of local seagrass biomass (Fourqurean and Zieman, 2002) to a 2006 (calendar year) mean of 28 in Barnes Sound and 27 in Blackwater Sound (medians = 28). These increases are directionally consistent with increased inputs from terrestrial or mangrove sources, which can be expected to have C/N ratios of at least 100 (Davis et al., 2003), but are inconsistent with inputs from phytoplankton or SAV sources.

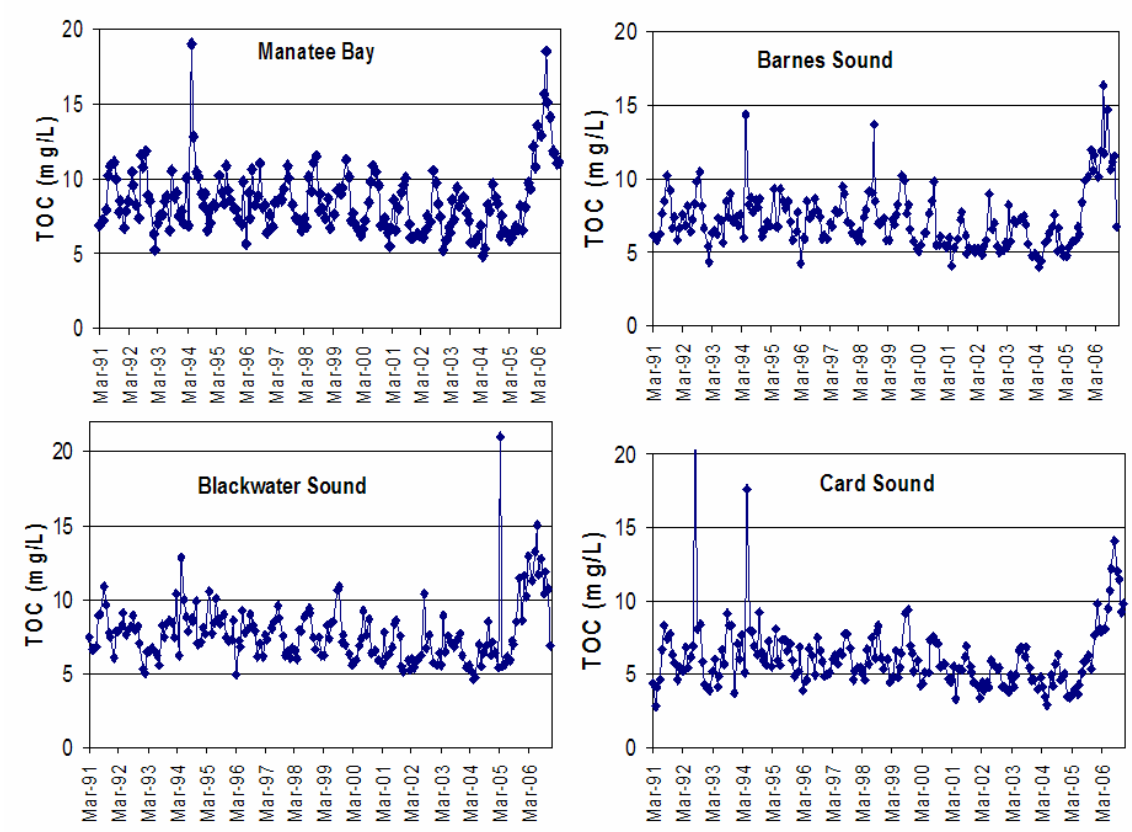


Figure 12-37. Long-term changes in total organic carbon concentration (monthly samples) in basins where the eastern algal bloom, which began in fall 2005, has been most pronounced.

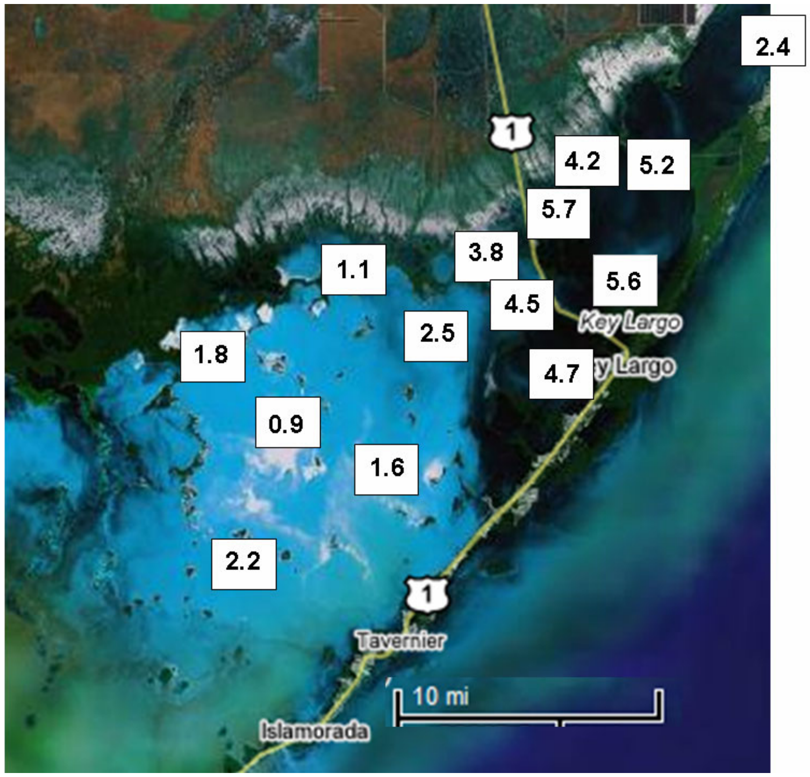


Figure 12-38. Map of the magnitude of elevated TOC concentrations mg C/L), calculated as the difference between mean WY2001–WY2005 monthly values and calendar year 2006 values.

Understanding the cause of the increase in TOC is important because this increase indicates an input of organic matter with associated nutrients (N and P) that could have contributed to the algal bloom. The District has not identified the source of elevated TOC, but estimate that SAV mortality could account for about one-third of the estimated 1,400 metric ton (mt) increase in TOC in the region (**Table 12-3**). It is notable that little SAV mortality occurred in Manatee Bay (*Thalassia* short shoots in WY2007 were only 11 percent lower than the WY2000–WY2005 mean), yet this basin had the greatest increase in TOC concentration (**Figure 12-38**). Mulching of the mangrove trees and soil excavation and mixing along U.S. 1 may also have contributed TOC to adjacent waters. The Florida Department of Transportation's (FDOT) consultants estimate (personal communication) that about 225 mt of mangrove canopy was mulched and decay and leaching of this material likely contributed only about 2 percent of the increased TOC. However, decay and leaching of mangrove wood, roots, and disturbed organic soils along U.S. 1 may have contributed much of the unaccounted TOC. About 50 acres (20 hectares) of soils were mixed to bedrock (2 m to 3 m; unpublished, FDOT) and we estimate these soils contained more than 8,000 mt of organic carbon (to 2 m, bulk density 0.5 g/cm^3, 4 percent OC; FDOT unpublished results). The rate and magnitude of organic carbon leaching from these soils, which were stabilized with cement and slag, is unknown. Inputs from the southeast Everglades do not appear to account for the observed TOC increase in the region's waters, evidenced by the finding of lower increases in basins that receive most of the region's fresh water (Joe Bay and Long Sound) and that the increase occurred during the dry season (**Figures 12-37** and **12-38**). It should be noted that the observed TOC increase in these estuarine waters is not explained by algal biomass within the bloom; this source accounts for less than 10 percent of the TOC increase from pre-bloom conditions.

Table 12-3. Estimated magnitude of elevated phosphorus and organic carbon in eastern Florida Bay and southern Biscayne Bay, and estimates of potential sources of these materials.

	Total Phosphorus (metric tons)	Organic Carbon (metric tons)
Estimated increased P and C		
October 2005 peak elevated TP	19[a]	
Persistent 2005-2006 elevated TP and TOC (mean)	4.7[b]	1400[b]
Elevated TP and TOC in phytoplankton biomass	3[c]	120[c]
Potential P and C sources		
C-111 discharge during 2005 hurricane season	2.6[d]	?
Mulched mangrove canopy (U.S. 1 construction)	< 0.9[e]	30[e]
Mulched mangrove wood (U.S. 1 construction)	< 0.1[e]	?
Dead mangrove roots (decay, leaching; U.S. 1 construction)	?	?
Disturbed U.S. 1 soils (organic matter decay, leaching)	?	?
Seagrass mortality (above-ground)	0.8[f]	480[f]
Seagrass mortality (below-ground)	?	?
Import and decay of detritus via hurricane wind, wave, surge	?	?
Import of groundwater nutrients via hurricane surge	?	?

a. From difference between October 2005 TP and long-term mean TP per basin times basin volume, with sum of basin values.

b. From difference between bloom period (October 2005–December 2006) and long-term mean TP per basin times basin volume, with sum of basin values. For TOC, differences between the 2006 mean and WY2001–WY2005 mean were used.

c. From chlorophyll *a*, assuming a 10 µg/L elevation, a 50:1 C:chl *a* ratio, and 106:1 molar C:P ratio.

d. From District S-197 and S-18C discharge estimates and TP measurements.

e. From FDOT (unpublished)

f. Assumes uniform mortality in Blackwater and Barnes Sounds, 50 g/m^2 biomass with 50% mortality and 50% input of detritus to water column TOC; 40% C content; molar C:N:P of 1600:80:1 (from regional measurements).

A budget of TP sources is likewise presented in **Table 12-3**. Regional algal bloom initiation began after the October 2005 TP peak (Rudnick et. al., 2007), which required the input of roughly 19 mt of phosphorus above the pre-bloom baseline quantity. Mean elevated TP concentrations since bloom initiation (through December 2006, the last date data were available for this report) total 4.7 mt of P above this baseline. Major sources that could have contributed to peak and sustained water column TP quantities include the C-111 discharge following Hurricane Katrina (2.6 mt P, likely as sediment load entering Manatee Bay; Rudnick et al., 2007), U.S. 1 disturbances (mangrove mulching, soil mixing, excavation), and seagrass mortality. Aboveground SAV decomposition could have contributed less than 20 percent (0.8 mt) of the observed sustained TP increase (4.7 mt). The sum of the estimated TP sources is far less than the October peak TP quantity, indicating major contribution from some of the unknown sources (U.S. 1 soils, ground water, imported detritus). We estimate that soil mixed over 50 acres (see above) contained at least 50 mt P and P fractionation studies contracted by FDOT (unpublished) estimated that about 25 percent of this P was in an extractable (potentially mobile) form. The rate and magnitude of P leaching from these soils is unknown. Given the magnitude of the October 2006 peak and likelihood of efficient P retention and cycling in the region, the finding of sustained blooms is not surprising.

Submerged Aquatic Vegetation Monitoring in the Southern Estuaries

Submerged aquatic vegetation (SAV) habitat is the central performance measure for Florida Bay assessment and restoration (Rudnick et al., 2005). A restoration target for the bay (performance measures documented for RECOVER and the Florida Bay and Florida Keys Feasibility Study) is the sustainability of mixed species seagrass beds with moderate to dense cover through most subregions. Assessment of ecological changes and prediction of potential restoration effects on SAV requires the use of long-term datasets from spatially comprehensive benthic habitat surveys. In this report, data from the benthic habitat surveys conducted by three organizations are used to assess patterns and trends in the southern estuaries (an area including southern Biscayne Bay, Florida Bay, Whitewater Bay, and Lostman's River). Miami-Dade Department of Environmental Resource Management (DERM) and the Florida Fish and Wildlife Conservation Commission (FWC) currently receive funding from the District to conduct these surveys.

DERM conducts benthic habitat surveys in eastern Florida Bay and southern Biscayne Bay. These surveys are conducted quarterly within each of the 12 monitoring basins (**Figure 12-39**) using a modified Braun-Blanquet Cover Abundance Index (BBCA) (Fourqurean et al., 2002) where benthic cover is estimated by bottom occlusion (0 = not present; 0.1 = single shoot; 0.5 = few shoots, < 5% cover; 1 = numerous shoots, < 5% cover; 2 = 5-25% cover; 3 = 25-50% cover; 4 = 50-75% cover; 5 = > 75% cover). Four or twelve randomly selected sites (depending on basin size) are sampled in each basin area using four haphazardly thrown 0.25 m^2 quadrats. These data are aggregated to the basin level for analysis and can be used to determine intra- and inter-annual trends in benthic habitat cover.

The Fisheries Habitat Assessment Program (FHAP) of the FWC has been sampling in 10 basins of Florida Bay since 1995. In 2004, RECOVER began funding the program and expanded the region covered by FHAP to include Whitewater Bay, Coot Bay, Lostmans's River, and nearshore Biscayne Bay for a total of 22 sampling basins (**Figure 12-39**). Sampling is currently conducted once a year using the same methodology and BBCA scale as DERM at 30 sites within each sampling basin (with eight haphazardly thrown 0.25 m^2 quadrats per site). The increased resolution within the basins allows for the analysis of spatial distributions within the individual basins, but the coarse temporal resolution precludes the assessment of intra-annual trends.

The National Audubon Society (hereafter, Audubon) monitors SAV in the coastal ponds of northeastern Florida Bay's mangrove transition zone, upstream of DERM sites, approximately every six weeks. Audubon uses a point-intercept method for estimating percent cover at six sites along two transects (one along Taylor River and one through Joe Bay; **Figure 12-39**). These data are currently provided to the District as a professional courtesy in the interest of informing management decisions, but a formal agreement for data provision in the future is under discussion.

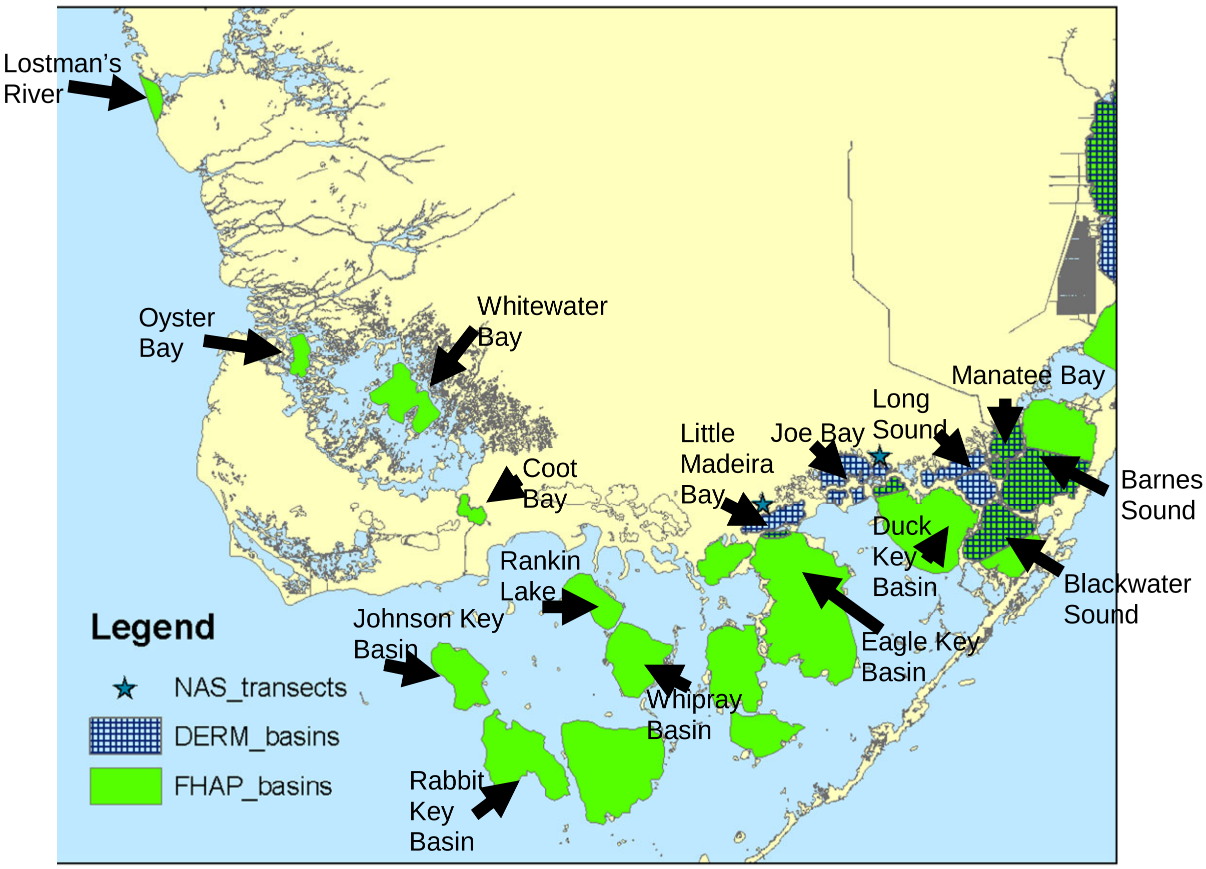


Figure 12-39. Map of regional SAV monitoring sites.

SAV in Eastern Boundary Florida Bay and Southern Biscayne Bay

Basins at the eastern boundary of Florida Bay and in southern Biscayne Bay have been the focus of much attention in recent times due to the persistent algal bloom that developed in this region during autumn 2005 (see the algal bloom section above and Rudnick et al., 2007). The basins grouped into this region are Long Sound, Blackwater Sound, Manatee Bay, Barnes Sound, and Card Sound. Both FHAP and DERM survey portions of this region with slightly different sampling areas and sampling resolution within the areas.

Long Sound and Manatee Bay are the basins closest to freshwater discharge and flank US Highway 1. Both basins show a significant increase in the average BBCA score for calcareous green algae from WY1999 to WY2002 ($p < 0.05$ when regressed against water year). The genera of green algae in this region include *Halimeda*, *Acetabularia*, *Batophora*, and *Penicillus*. The increase in green algae cover continued until WY2005 in Long Sound and then decreased in WY2006 and WY2007, while Manatee Bay experienced a decrease beginning in WY2003, continuing until WY2007. No significant change is discernible in the seagrass data for either basin during the period from WY1999 to WY2004, but Long Sound experienced *Thalassia* loss from WY2004 through WY2007 ($p < 0.05$ for both short-shoot density and average BBCA score when regressed against water year). This loss was first observed in WY2005 (May 1, 2004 to April 30, 2005), prior to initiation of the algal bloom.

Blackwater Sound and Barnes Sound also flank U.S. Highway 1, but are further away from freshwater discharges. As in Long Sound and Manatee Bay, these basins showed a significant increase in green algae from WY1999 to WY2004 (data are aggregated by water year). The frequency of observations with no or sparse green algae (< 25 percent cover) decreased ($p < 0.01$ when regressed against water year) while the frequency of observations with 25 percent or greater cover increased. In WY2005, Barnes Sound experienced a significant decline in cover (mostly green algae loss) and most of this decline occurred between October 2005 and January 2006, coincident with the regional algal bloom initiation (**Figure 12-35**). The frequency of green algae cover in the range of 25 percent or greater was 59 percent in WY2004, 44 percent in WY2005, 22 percent in WY2006, and finally, in WY2007, 5 percent. Blackwater Sound also experienced this decline of green algae, but it did not begin until WY2006.

Seagrass data for Blackwater Sound show a declining trend in *Thalassia* from WY1999 to WY2007, while Barnes Sound showed no significant trend over this period, maintaining a sparse to moderate coverage of *Thalassia* (> 60 percent of *Thalassia* observations have less than 50 percent cover). The negative trend for Blackwater Sound was significant ($p < 0.05$) in both the short-shoot density data and the frequency of occurrence for *Thalassia* when regressed against water year. Both Blackwater Sound and Barnes Sound experienced a loss of *Thalassia* between WY2006 and WY2007. Over the period of WY1999 to WY2006, Blackwater Sound had an average frequency of occurrence for *Thalassia* of 78 percent (SD = 6 percent) and Barnes Sound had an average frequency of occurrence for Thalassia of 84 percent (SD = 4 percent). In WY2007, the frequency of occurrence dropped to 42 percent in Blackwater Sound and 73 percent in Barnes Sound. This may have been caused by light limitation due to the algal bloom. **Figure 12-40** shows the spatial distribution of *Thalassia* in Blackwater Sound during WY2006 and WY2007. The central area of the basin that lost *Thalassia* cover is the deeper area of Blackwater Sound.

The finding of an increase in green macro-algae in this region during the late 1990s and early part of this decade is notable, because it could indicate chronic nutrient enrichment (Ferdie and Fourqurean, 2004; Collodo-Vides et al., 2007), which could have played some role in the current phytoplankton bloom. Water quality monitoring data from this region shows no increased concentrations of total or inorganic nutrients in this region's basins during the time of increased macro-algae (data not shown), but rather suggest either decreasing concentrations or no change since the early 1990s. However, benthic algae could intercept nutrients from ground water and water column concentrations may not be conclusive because they reflect the balance of nutrient input and uptake. It is unclear whether nutrient inputs to this region have increased, and whether calcareous algae indicate this change; other factors, such as grazing may be important. Regardless of the nutrient source for increased macro-algae, with recent mortality of this SAV, nutrients that had been sequestered in benthic biomass became available for phytoplankton.

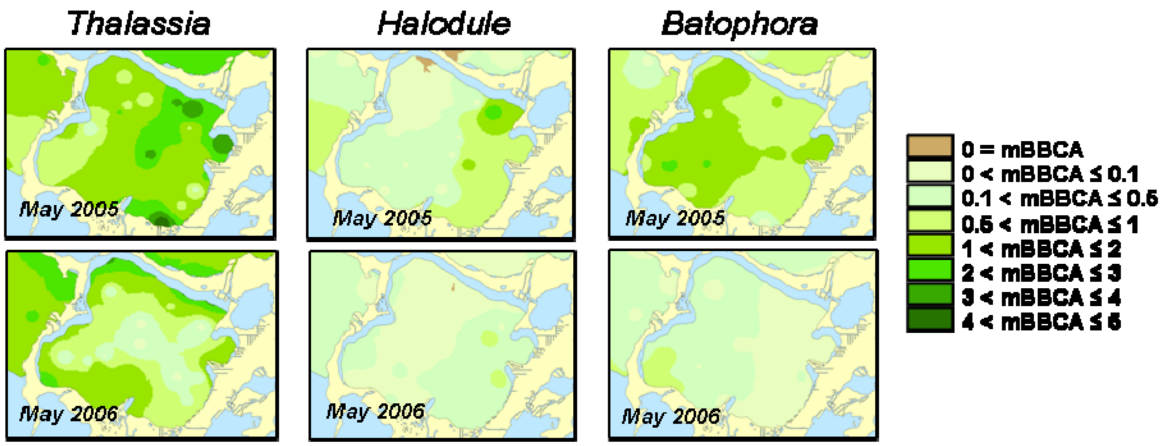


Figure 12-40. FHAP data mapped to show the spatial distribution of *Thalassia testudinum*, *Halodule wrightii*, and generic *Batophora* in Blackwater Sound during May 2005 and 2006. Values mapped are the average of the Braun-Blanquet Cover Abundance scores (mBBCA) for each site. Decline shown between 2006 and 2005 is likely caused by decreased light penetration.

SAV in Northeastern Transition Zone

DERM results (aggregated by water year for the period of May 1999 to April 2007) from sites along the northeast coastal areas of Florida Bay showed an increase in the average BBCA score of green macro-algae from roughly 0.25 in WY1999 to approximately 1 in WY2007 ($p < 0.05$ when regressed against water year). No regional pattern for seagrass was found except for areas with sparse *Halodule* (< 70 short shoots/m^2), where there was a significant decline in both short-shoot density and average BBCA score for *Halodule* during this period ($p < 0.05$ when regressed against water year). Little Madeira Bay experienced an increase in the average BBCA score for green algae ($p = 0.0534$) and a decrease in *Thalassia* detectable in both the short-shoot density ($p < 0.0001$) and the average BBCA score ($p = 0.0018$). Highway Creek (north of Long Sound), the location furthest upstream from Florida Bay, showed no pattern in the seagrass data, but a decrease in green algae from 1999 to 2007 ($p = 0.0003$ for average BBCA regressed against water year).

SAV in Northeastern Florida Bay

In the 2004 FHAP expansion, Duck Key Basin was included to represent the northeastern Florida Bay area along with preexisting surveys of Eagle Key Basin. This area of Florida Bay is characterized by sparse, uniform *Thalassia* interspersed occasionally with shoots of *Halodule*. Only 7 percent of observations in this region had no *Thalassia* in May 2006, compared to 10 percent in May 2005 (**Table 12-4**). Only 11 percent of observations had 25 percent or greater *Thalassia* cover in 2006 (up from 5 percent in 2005). The most frequent BBCA score for *Thalassia* was a 2 (5–25 percent cover) in both years (36 percent in 2005 and 33 percent in 2006). *Halodule* was present in 31 percent of observations in 2006 (up from 24 percent in 2005) but never at cover levels higher than 25 percent. Also present were *Acetabularia*, *Batophora*, *Halimeda*, and *Penicillus* but generally in less than 40 percent of the observations (the exception is *Batophora* in 49 percent of observations in 2005) and at less than 25 percent of the cover (with the exception again of *Batophora* in 2005, which had observations of 75 percent or greater cover at one station in Duck Key Basin).

Table 12-4. Seagrass coverage data from FHAP for WY2006 and WY2007. Data presented are the frequency of occurrence of seagrass (percent of observations that include at least one species of seagrass), the frequency of occurrence for each species of seagrass (percent of observations that include the species), and mean number of species in a single observation where seagrass is present. While northeast Florida Bay is represented by Duck Key Basin and Eagle Key Basin in WY2006 and WY2007, only Eagle Key Basin is included for WY1996 (no FHAP monitoring in Duck Key Basin at that time). Seagrass species: Tt = *Thalassia testudinum*, Hw = *Halodule wrightii*, Sf = *Syringodium filiforme*, Rm = *Ruppia maritima*, Hd = *Halophila decipiens*, and He = *Halophila engelminii*.

Basin/Region		Seagrass	*Tt*	*Hw*	*Sf*	*Rm*	*Hd*	*He*	*Species#*
Lostman's River	WY1996	-	-	-	-	-	-	-	-
	WY2006	27.5	21.9	10.6	0	0	0	0	1.2
	WY2007	13.3	5.4	9.2	0	0	0	0	1.1
Whitewater Bay	WY1996	-	-	-	-	-	-	-	-
	WY2006	22.7	0	18.6	0	0.2	3.8	0	1
	WY2007	33.3	0.2	9.5	0	0	23.7	0	1
Coot Bay	WY1996	-	-	-	-	-	-	-	-
	WY2006	1.8	0	1.8	0	0	0	0	1
	WY2007	0	0	0	0	0	0	0	-
Western Florida Bay	WY1996	85.2	73.8	30.7	4.5	0	0	0	1.3
	WY2006	99.9	96	58	62.5	0	0	0.8	2.2
	WY2007	100	98.4	62.1	68.4	0	0	2	2.3
Central Florida Bay	WY1996	68.3	51.4	34.4	0.9	0	0	0	1.3
	WY2006	96.8	83.7	62.5	11.7	0.1	0	4	1.7
	WY2007	95.8	88.5	55.8	10.2	0	0	1.9	1.6
Northeast Florida Bay	WY1996*	93.6	91.3	13.3	1.1	0.4	0	0	1.1
	WY2006	93.8	89.4	23.5	0	0	0	0	1.2
	WY2007	94.8	93.3	30.6	0	0	0	0	1.3

SAV in Central and Western Florida Bay

Rabbit Key Basin and Johnson Key Basin, in Western Florida Bay, were sites of seagrass die-off in the late 1980s and early 1990s (Robblee et al., 1991; Zieman et al., 1999). FHAP results from 1995 to present show that a successional trend, with *Halodule wrightii* establishment between WY1996 and WY2000 and the reestablishment of *Thalassia testudinum* dominance occurred from WY2000 to WY2007 (**Figure 12-41**). In May 2006 (WY2007), *Thalassia* was not present in only 1.6 percent of the observations in these western basins, and all observations showed the presence of at least one species of seagrass (**Table 12-4**). The average number of species present per observation for the western basins rose during the period from 1.2 in May 1995 to 2.3 in May 2006 (**Table 12-4**) and is indicative of a mixed species bed. However, species other than *Thalassia* were sparse: 57 percent of the *Halodule* observations in May 2006 had less than 5 percent cover, and 44 percent of the *Syringodium filiforme* observations had less than 5 percent cover (and 76 percent with less than 25 percent *Syringodium* cover).

Rankin Lake and Whipray Basin (central Florida Bay and also a late 1980s seagrass die-off region) can be characterized as having *Thalassia*-dominated seagrass beds, although coverage was moderate compared to the western bay. Both the spatial extent (indicated in **Table 12-4**) and density of *Thalassia* increased from WY1996 to WY2007 in the central bay without a similar increase for other species. The most frequent cover category for *Thalassia* was 5–25 percent over this period, but the frequency of this category increased from 10 percent in WY1996 to 32 percent in WY2005 and 35 percent in WY2007. The mean BBCA score for *Thalassia* increased from 0.72 in WY1996 to 1.75 in WY2006 to 2.24 in WY2007 suggesting that the average percent cover for *Thalassia* increased over this period. Other seagrass species (*Halodule* and *Syringodium*) had sparse coverage; the frequency of observations with less than 5 percent cover was 90 percent for *Halodule* and 99 percent for *Syringodium* in May 2006 (compared to 92 and 96 percent, respectively, in May 2005 and 92 and 100 percent, respectively, in May 1995). A concern regarding this region is that *Thalassia* beds could be redeveloping toward a monospecific status, a condition that may have contributed to past die-off events (Zieman et al., 1999).

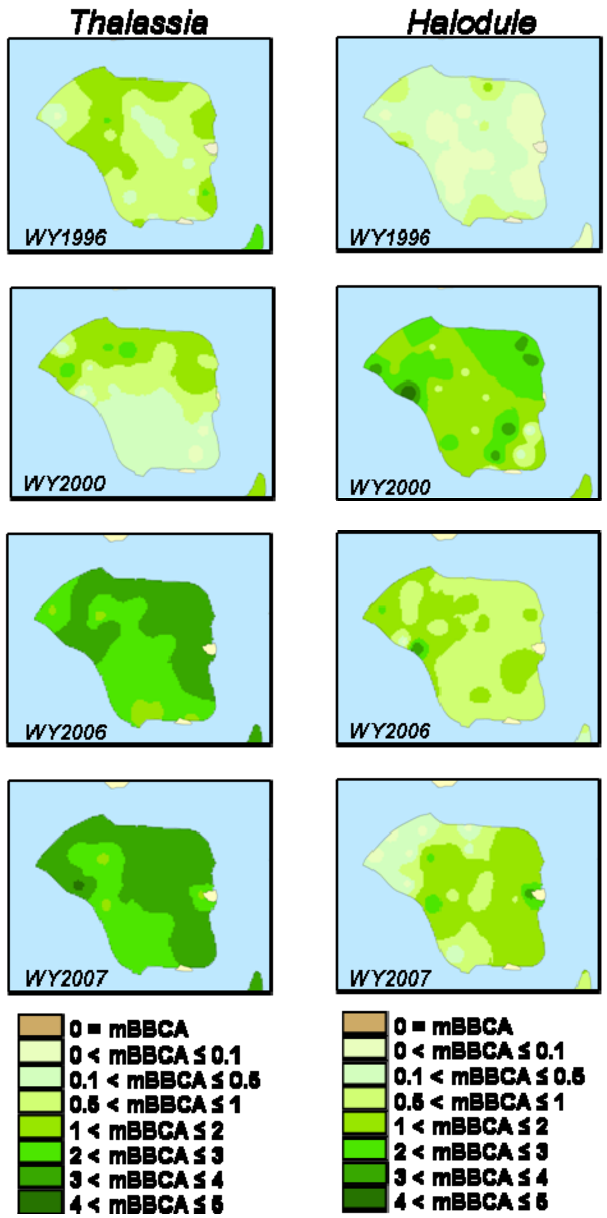


Figure 12-41. FHAP data showing *Thalassia* and *Halodule* distributions in Johnson Key Basin from WY1996 to WY2007 indicating the successional shift from *Halodule* to *Thalassia* during the basin's recovery after the die-off event in 1987. Values mapped are the average BBCA value (mBBCA), which can range from 0 to 5 at each of 30 sites. Generally, larger values equate to more bottom cover, but the nonlinear scale used in BBCA prevents a direct conversion of the average BBCA value back to a percent cover.

SAV in Whitewater Bay and Lostman's River

Establishing an information baseline on SAV habitat along the ENP southwestern coast is necessary because Whitewater Bay is the primary receiving water body of Shark River Slough and an estuary that will be directly affected by implementation of CSOP (with modified water deliveries to the ENP) and the Decompartmentalization Project of CERP. CERP implementation is also likely to increase freshwater flow through Lostman's Slough and Lostman's River. Salinity in Whitewater Bay, Oyster Bay, Coot Bay, and Lostman's River is highly variable on a seasonal and inter-annual basis, ranging from 0.2 psu to 40 psu (mean salinity from 12 psu to 15 psu). Chlorophyll *a* concentrations were commonly higher than found in Florida Bay, with maxima of 30 µg/L in Whitewater Bay, 38 µg /L in Coot Bay, and 13 µg /L in Lostman's River (means of 14 µg /L, 10 µg /L, and 3 µg /L, respectively).

Initial surveys documented sparse coverage by seagrass and macro-algae at these southwest ENP coastal locations. Lostman's River had sparse *Thalassia testudinum* and *Halodule wrightii*. Between May 2005 and May 2006, the frequency of observations with seagrass declined (**Table 12-4**) suggesting a reduction in the spatial extent of seagrasses in this area. The largest BBCA score recorded for either species in 3 (25–50 percent cover) in May 2005 was 2 (5–25 percent cover) in May 2006. The frequency of observation for *Halodule* was similar from WY2006 to WY2007, while the frequency of observation for *Thalassia* declined. Among macro-algae, only *Caulerpa* and unspecified drift reds were noted.

Whitewater Bay had greater species richness than Lostman's River, but cover was sparse for all seagrass species. *Halophila decipiens* was the most common seagrass species, occurring in 24 percent of observations. Many taxa of macro-algae were observed, with red drift algae most common (in 51 percent of observations in 2006).

Coot Bay was also sampled in FHAP during May 2005 and May 2006. This bay was characterized by moderate to dense *Chara* during both years. *Chara* was present at 75 percent or greater coverage in 64 percent of the observations in May 2005 and 59 percent of the observations in May 2006. In May 2005, small amounts of *Halodule* and drift red algae were also noted.

Rapid Assessment of Lake Surprise SAV and Sediments

An assessment of the SAV community and sediment characteristics of Lake Surprise were done in WY2007 to document baseline conditions prior to removal of a causeway through the lake, which is a component of FDOT's U.S. 1 construction project, and to provide information that could assist any modification of the project's restoration plan for the lake. Lake Surprise is a saline lake, located directly east of Blackwater Sound and south of Barnes Sound, in northeast Florida Bay (**Figures 12-32** and **12-42**). Construction of a causeway across Lake Surprise for the Flagler Railroad to Key West began in 1905, and was completed 15 months later in February 1907. This causeway subsequently became part of the Overseas Highway U.S. 1 that currently connects the entire Florida Keys to the Florida mainland.

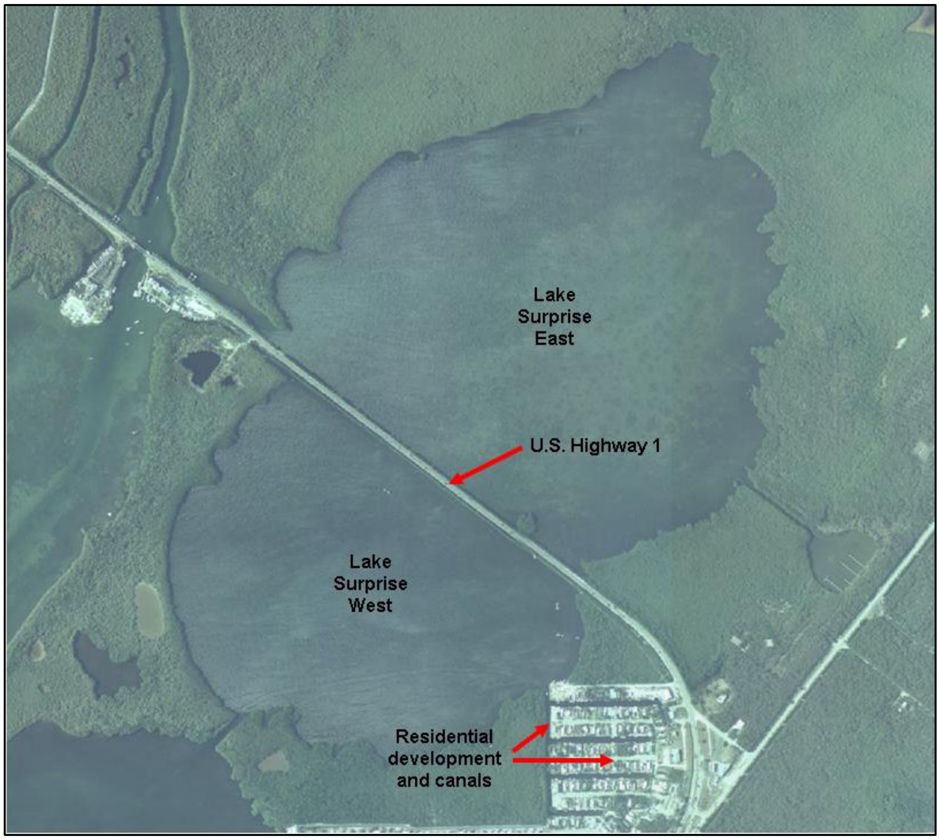


Figure 12-42. Lake Surprise showing the causeway bisecting the Lake into Lake Surprise East (LSE) and Lake Surprise West (LSW).

Removal of the causeway is currently planned as part of FDOT's widening and improvement of the 18-Mile Stretch in order to reconnect the east and west basins, improve habitat for the endangered American crocodile and other fauna, and increase access for public recreation. However, concerns exist regarding the water quality consequences of this mitigation because Lake Surprise has been the geographic center of a persistent algal bloom in northeast Florida Bay and southern Biscayne Bay. Chlorophyll *a* concentrations within the shallow, poorly flushed lake have been the highest in the region, averaging 19 µg/L (eight sampling times from January 2006 to January 2007). With causeway removal, the potential exists for increased sediment resuspension and increased flushing and associated sediment and nutrient transport into adjacent waters. Such nutrient export could exacerbate the bloom in Blackwater Sound and Barnes Sound. A key factor that may prevent or minimize such a negative effect is the presence of SAV, which can bind and stabilize sediments.

Lake Surprise was surveyed in March and April 2007 at 11 sites for SAV cover and species composition, estimated using a modified Braun-Blanquet technique, and sediment characteristics, estimated from duplicate cores per site with measurement of bulk density, percent water content, loss on ignition to estimate percent organic matter, and nutrient (CNP) concentrations. Lake Surprise SAV generally included *T. testudinum*, mixed with calcareous green algae and may be characterized as dense seagrass in the Lakes western portion (LSW) or moderately dense seagrass in its eastern portion (LSE). Compared to the LSE, the LSW had more dense *T. testudinum* and total SAV cover (with dense cover (> 50 percent) at LSW sites and moderate cover (5–50 percent) at LSE sites. In contrast, the LSE had more *Halimeda* spp. (moderate cover in LSE, sparse (< 5 percent) cover in WSE) and total calcareous green algae (moderate in LSE, sparse in LSW) than the western part of the lake. These results are similar to those of a previous investigation of Lake Surprise SAV community composition conducted by Rutten (2002), who documented the presence of moderate-to-dense seagrass mixed with calcareous green algae in LSW and LSE (see www.fiu.edu/~seagrass). Additionally, a preconstruction survey of Lake Surprise seagrass conducted in areas near (< 25 m) U.S. Highway 1 revealed "generally uniform, dense seagrass beds" in the survey areas (FDOT, 2004).

Surface sediments (to 5 cm) were highly organic and carbonate mud mixed with shell hash (*Halimeda* hash and gastropods) at most sites, and had a 1–3 cm surface flocculent material layer at all sites. Sediment bulk density (dry weight g cm^{-3}) was very low (i.e., sediments were "soft" with low compaction), but higher (more compacted) in sediments of 2–5 cm depth relative to 0–2 cm depth. This corresponded with a high water content (generally near 80 percent of sediment weight), particularly in the top 0–2 cm layer. Sediments were rich in organic matter (~10 percent to 30 percent of dry weight), with a greater percent organic matter content in the 0–2 cm depth than the 2–5 cm depth. These data demonstrate that LSW and LSE surface sediments are soft, organic-rich mud with high water content. Near-surface sediments had low bulk density with higher water content and higher organic content. Subsurface sediments had higher bulk density with lower water content and lower organic content.

Sediment nitrogen (N) content was moderate, ranging from ~0.25 percent to 1.4 percent N as a proportion of dry weight. Sediment phosphorus (P) content was low, ranging from ~0.005 percent to 0.03 percent P as a proportion of dry weight (note that 0.005 percent is equivalent to 50 mg/kg or 50 ppm). Sediment N and P content was generally higher in the 0–2 cm sediment depth relative to the 2–5 cm depth; however, there was no significance difference in mean sediment N or P between LSW and LSE sites. Sediment total carbon content (TC) was higher and relatively consistent among sites, ranging from ~11 percent to 17 percent as a proportion of dry weight. TC was generally lower in the 0–2 cm sediment depth relative to the 2–5 cm depth; however, there was no significant difference in mean sediment TC between LSW and LSE sites.

Given the high water and organic content of the surface sediments, there is an expectation of a high potential for sediment suspension and transport within this basin and to the surrounding areas. Seagrasses can strongly influence the potential effects of causeway removal as they bind sediments with their roots and rhizomes and decrease current velocity, turbulence, and sediment resuspension within their canopy. Dense seagrass beds, such as those present in western Lake Surprise, thus stabilize sediments and minimize sediment erosion and nutrient transport. Any loss of seagrass coverage in the Lake Surprise basin may increase the potential for sediment suspension and transport. Despite the duration and intensity of the algal bloom that has affected this region, and apparent SAV loss in adjacent waters (see the algal bloom section above), the Lake Surprise benthic community did not appear to be in a state of decline at the end of WY2007. This was likely the consequence of the shallow depth of Lake Surprise (mean of 1.7 m). Despite higher chlorophyll *a* concentrations in the lake than Barnes Sound or Blackwater Sound, more light likely penetrated to the SAV canopy of the lake than the SAV canopy of these deeper basins (which have a mean depth of about 2.5 m).

Experiments on Dissolved Organic Matter Bioavailability

Information on the fate and effects of dissolved organic matter (DOM) from the Everglades after it enters Florida Bay is needed, because most of the nitrogen and phosphorus exported from the Everglades are contained within dissolved organic compounds (Rudnick et al., 1999; Hunt and Nuttle, 2007) and the magnitude and quality of this nutrient export may change with water management operations and restoration. The effect of this export on the bay ecosystem, particularly the potential to stimulate phytoplankton blooms, depends on the rate at which this DOM is decomposed by microorganisms — its bioavailability. Research on DOM bioavailability is called for as part of the RECOVER MAP, and is also needed as a parameter of the Environmental Fluid Dynamics Computer Code (EFDC) water quality model for the CERP FBFKFS.

Experiments have been conducted to determine decomposition rates and bioavailability of Everglades DOM, specifically dissolved organic nitrogen (DON) and carbon (DOC) in Florida Bay. A total of five experiments have been completed since 2004, including two additional experiments during WY2007. These experiments tested three factors that may influence decomposition: DOM source (oligotrophic southeast Everglades in Taylor Slough versus the more nutrient-rich southwestern Everglades in Shark River Slough), phosphorus limitation, and sediment interactions (the presence or absence of sedimentary particles with associated microbes). Experiments were conducted for two- to three-month periods in 2.5-liter bottles in a dark incubator to estimate DOM mineralization rates and the magnitude of labile (bioavailable) and refractory DOM pools. These estimates were derived from oxygen fluxes (measured by incubation of sub-samples in triplicate 60 ml BOD bottles at 12h, 24h, 48h and 4d, 15d, 30d, 60d, and 90d), DON and DOC measurements, and stoichiometric assumptions (Moran et al., 1999; Twilley et al., 1986). Filtered (0.2 micron) surface water from Taylor Slough (TS) and Shark River Slough (SRS) served as DOM sources. Four replicate bottles per treatment were inoculated with (primarily) bacterioplankton (5 ml l^{-1} of GF/F filtrate) contained in Florida Bay water, or this water plus an aliquot of a sediment slurry (1 g l^{-1} wet weight) collected from northeastern Florida Bay. For the sediment treatment, a control was run with artificial sea water plus the sediment slurry to account for sedimentary oxygen consumption and material regeneration, with consumption in control bottles subtracted from consumption in experimental bottles with sediment. An additional experimental treatment amended with inorganic phosphorus (to a final concentration of 5 µM PO_4 in bottles with and without sediment, as well as artificial seawater plus sediment control) was included to assess the effect of phosphorus limitation.

The minimum bioavailable carbon pool and the decay constants (k d^{-1}) for this pool were calculated from natural logarithm transformed oxygen uptake rates, using a single-pool and multiple-pool first-order decay model (Westrich and Berner, 1984). The single-pool decay model can be expressed as:

$$G = G_0 exp\{-kt\}$$

where G is the concentration, k is the first-order decay constant and t is time in days. The model representing the oxygen uptake rates (in place of concentration data), assuming a carbon:O_2 of 1:1, then becomes:

$$-((dG)/(dt))=kG_0 exp\{-kt\}$$

and the natural logarithm transformed version:

$$LN(-(dG)/(dt))=-kt+ln(kG_0).$$

The intercept equals $ln(kG_0)$ and if C = intercept, then G_0 can be expressed as:

$$G_0=exp\{C\}/k.$$

The multiple-pool decay model can be represented by the equation:

$$G = G_{1ø}exp\{-k_1t\}+G_{2ø}exp\{-k_2t\}+G_R$$

where G is the concentration, $G_{1ø}$ the concentration of the highly reactive fraction, $G_{2ø}$ the concentration of the less reactive fraction, GR the concentration of the nonreactive fraction, k_1 the first-order decay constant of the highly reactive fraction, k_2 the first-order decay constant of the less reactive fraction, and t the time of decomposition in days. The model representing the oxygen uptake rates (in place of concentration data), assuming a carbon:O_2 of 1:1, then becomes:

$$-((dG)/(dt)) = k_1G_{1ø}exp\{-k_1t\}+k_2G_{2ø}exp\{-k_2t\}.$$

An example of the models fit to the data is provided in **Figure 12-43**.

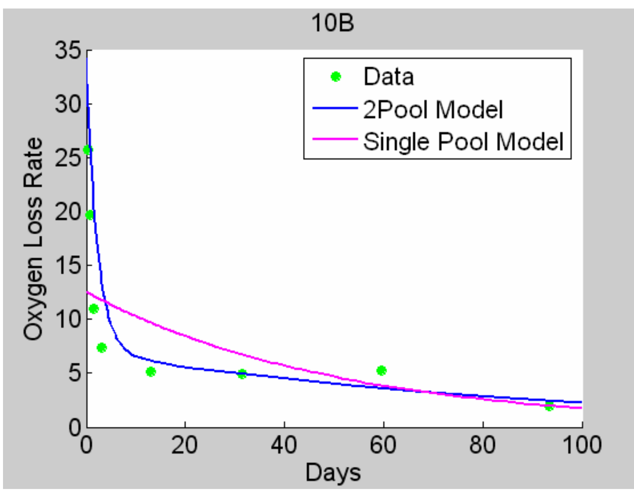


Figure 12-43. Results from Taylor Slough (July 2005) for the sediment and phosphorus addition treatment.

Results from all experiments (**Table 12-5**) show that about 11 to 40 percent of DOM (with a mean and median of 25 percent) from both Taylor Slough and Shark River Slough appears to be bioavailable. This is consistent with other studies in Florida Bay and the southern Everglades where median rates of bioavailability are reported as 23 percent with a range of 1.1 to 36 percent (Boyer et al., 2005; 2006). A small proportion (1 to 14 percent with a mean and median of 5 percent) of the DOM is quickly decomposed with a decay constant of 3 to 64 percent per day (with a mean of 27 percent and a median of 23 percent). The large remainder of the bioavailable DOM decomposed more slowly with a decay constant of 0.01-3 percent per day (with a mean and median of 0.9 percent per day). Both phosphorus enrichment and the presence of sediment particles significantly affected DOM decomposition, increasing the magnitude of cumulative oxygen uptake rates and DOM loss (**Table 12-5**). These results point toward the importance of phosphorus for the decay of less labile DOM by sedimentary microbes. Results also indicate that Everglades DOM decomposition may be more rapid at the sediment-water interface and during resuspension events than in clear Florida Bay waters, especially in central and western parts of the bay, where phosphorus levels are relatively high.

Table 12-5. Medians and ranges (in parentheses, representing individual bottles) of the estimated pool size of bioavailable dissolved organic carbon (BDOC, as percent of initial total DOC) and associated exponential decay constants (k) from all experiments. First-order decay models with either a single BDOC pool or two BDOC pools (G1 and G2) were used (see text). Treatments represent with and without additions of a sediment slurry (+ Sed or No Sed) and inorganic phosphorus amendment (+ P or No P) using either water with DOM from Taylor Slough (TS) or Shark River Slough (SRS).

Site	Treatment	Single Pool BDOC (%)	Single Pool k (% d^{-1})	G1 Pool BDOC (%)	G1 Pool k (% d^{-1})	G2 Pool BDOC (%)	G2 Pool k (% d^{-1})	G1+G2 Pool BDOC (%)
TS	No Sed/No P	18 (13-20)	2.0 (1.5-2.4)	3.3 (1.2-10.0)	20 (4-64)	20 (13-28)	1.0 (0.3-1.4)	24 (14-30)
TS	No Sed/+ P	28 (24-34)	1.7 (1.0-2.2)	4.3 (2.2-9.2)	20 (7-59)	35 38-81)	0.4 (0.1-1.3)	45 (31-83)
TS	+ Sed/No P	25 (18-37)	2.2 (1.5-2.7)	4.9 (3.0-9.4)	23 (4-46)	22 15-28)	1.4 (0.1-1.8)	26 (21-34)
TS	+ Sed/+ P	37 (27-42)	2.0 (1.5-2.1)	3.9 (3.7-5.1)	37 (25-47)	37 (28-41)	1.2 (0.9-1.6)	41 (32-45)
SRS	No Sed/No P	21 (17-24)	1.9 (1.5-2.5)	4.4 (2.6-10.7)	22 (4-56)	27 (20-39)	0.5 (0.4-1.4)	34 (26-41)
SRS	No Sed/+ P	28 (25-41)	1.6 (1.0-2.0)	2.9 (2.5-13.5)	37 (3-50)	56 (41-68)	0.3 (0.2-1.3)	62 (57-70)
SRS	+ Sed/No P	14 (11-27)	3.3 (2.8-3.7)	5.1 (3.8-5.4)	14 (11-46)	9 (7-23)	1.6 (0.9-2.8)	14 (11-27)
SRS	+ Sed/+ P	23 (19-42)	2.2 (1.8-2.8)	4.3 (3.3-6.8)	23 (15-47)	36 (15-74)	0.3 (0.0-1.3)	42 (22-77)

Given the long residence times of central and eastern bays (roughly 3 to 6 months; Lee et al., 2006) it is likely that almost all of the bioavailable DOM entering the bay through Taylor Slough and Shark River Slough will be mineralized within the bay. Effects of changing DOM inputs will be calculated during FBFKFS evaluations using the EFDC water quality model, which is in development.

SAV Research and Modeling

Field and Mesocosm Research in Support of Ecosystem Modeling and MFL Evaluation

During WY2007, the Everglades Division scientists collaborated with researchers at Florida Atlantic University on a series of field and mesocosm experiments to investigate the physiology and ecology of Florida Bay seagrasses in and near the mangrove transition zone (Koch, 2007). This information is adding to our knowledge base of seagrass function and is being directly input to the Florida Bay seagrass community ecological model (described below), which is being developed by the Everglades Division's Florida Bay Group. This model has been used for development and acceptance of Florida Bay MFLs (see 2006 SFER). With further development, the model will be used to perform a mandated reassessment of the MFL by 2011, as well as to evaluate CERP restoration strategies under the Florida Bay and Florida Keys Feasibility Study.

The concept behind the mesocosm experiments is to isolate seagrasses and quantify responses to changes in specific environmental conditions so as to understand seagrass function under existing conditions in the field and predict responses to changing water management operations and restoration projects. This information is important for understanding how changes in environmental conditions might impact the natural system, as well as for designing those management strategies necessary to achieve a certain degree of recovery and restoration. Performance thresholds for seagrasses are being developed based on these experiments and on model predictions of seagrass response to improved conditions.

The three dominant species of seagrasses in eastern and central Florida Bay, *Thalassia testudinum*, *Halodule wrightii*, and *Ruppia maritime*, were examined in mesocosm studies to measure response to: (1) gradual hypersalinity development, (2) different rates of salinity reduction following hypersalinity, and (3) hyposalinity. Samples of these three species were collected from Florida Bay during the 2006 growing season. Intact cores (15 cm diameter, 20 cm deep) were collected in May, 2006 from sites in north-central Florida Bay and transported to the FAU Marine Lab in Boca Raton, Florida. Plants were immediately placed into mesocosm tanks with ambient coastal seawater (36 psu) and put on a 12:12 hr light-dark cycle where they were allowed to equilibrate for two weeks. The mesocosm experimental facility included sixteen 500 L (3 m diameter x 3 m height) fiberglass tanks. Experiments were run as a closed system with coastal seawater added weekly to each tank to maintain nutrient levels in the tanks and daily salinity adjustments. For each tank, salinity and temperature were monitored daily, while dissolved oxygen and light were monitored weekly.

Experiments lasted about two months and tested the effects of hypersalinty (at 55 psu), hyposalinity (to 15 psu), and the rate of salinity decrease (1 or 5 psu d^{-1}). Experiments were run in phases, with the first phase being either a salinity increase at 1 psu d^{-1} (similar to evaporative rates in the field) to 55 psu or maintenance at 35 psu. The second phase was a recovery of hypersaline mesocosms to 35 psu at variable rates (1 or 5 psu d^{-1}). The third phase was a decrease of the former hypesaline and ambient mesocosms from 35 psu to 15 psu at either 1 or 5 psu d^{-1}.

Live shoots were counted for all species to determine percent survival. Leaf tissue samples were taken at each salinity treatment interval to determine total osmolality. Leaf productivity and respiration rates were measured on leaf segments (~5 cm) of *T. testudinum* and whole leaves of *H. wrightii* and *R. maritima* in individual 60 mL BOD bottles.

Results of the experiments showed that all three species were well adapted to hypersalinity as high as 55 psu when salinity was gradually increased from ambient (35 psu) at a rate of 1 psu d^{-1}, which is common in Florida Bay during dry periods. A gradual increase allows for osmotic adjustment in the plants. Seagrasses in general are relatively tolerant of hypersaline conditions with a slow rate of salinity increase. Shoot counts, leaf elongation rates, and productivity levels remained stable during the hypersalinity treatment up to 55 psu. *R. maritima* demonstrated an increase in respiration with the 55 psu treatment. Overall, all three seagrass species were capable of adapting to a 20 d exposure to 55 psu, a level of hypersalinity occasionally observed in Florida Bay at the end of the dry season (**Figure 12-44**).

As salinity was gradually reduced to ambient salinity (35 psu) no negative affects of the previous hypersaline exposure were detected in the plants (**Figure 12-45**). The rate of salinity decline (1 versus 5 psu per day) did not influence physiological parameters or shoot density in any of the three species. Shoot numbers for all three species were maintained well above initial densities and leaf elongation rates in *T. testudinum* were not significantly different in 55 psu pretreatments compared to 35 psu controls. Hypersalinity stress did not affect O_2 production in any of the three species, and while osmolality values remained higher in plants previously exposed to hypersaline condition, osmolality declined at 35 psu, showing the plasticity of leaf osmoregulation in these seagrass species.

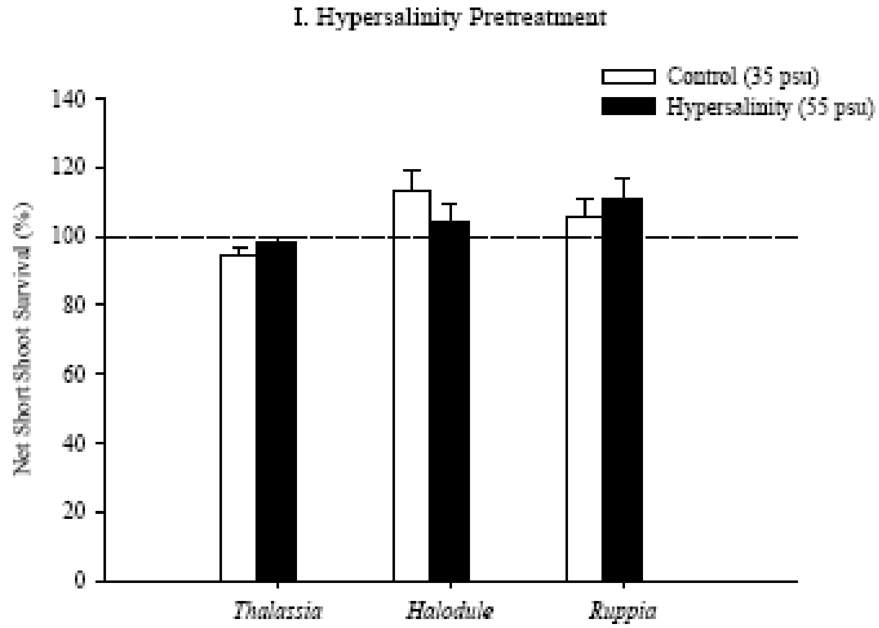


Figure 12-44. Percent change (mean + SE, n = 8) in live short-shoot numbers in intact cores of *Thalassia testudinum*, *Halodule wrightii*, and *Ruppia maritima* after 20 d at hypersaline conditions (55 psu) and ambient seawater controls (35 psu).

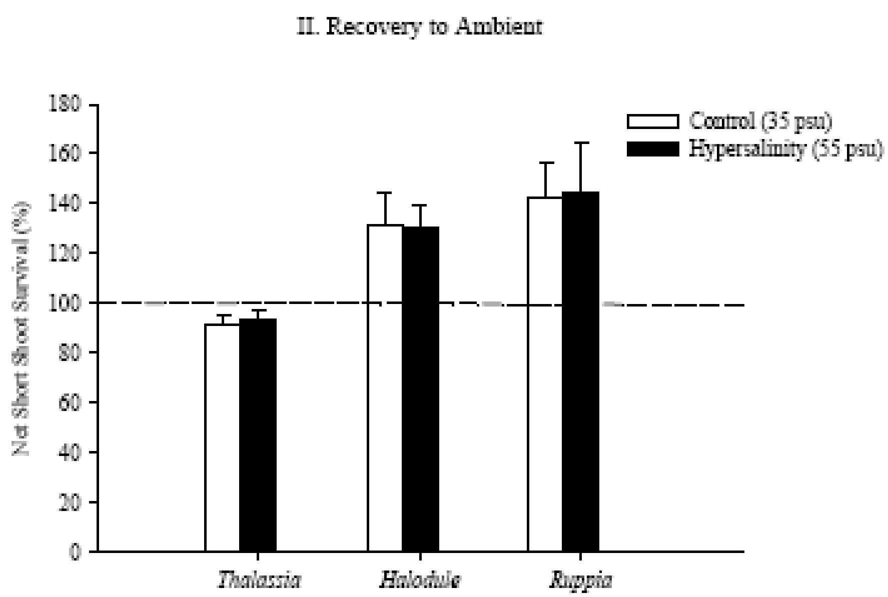


Figure 12-45. Percent change (mean + SE; n = 8) in live short-shoot numbers in intact cores of *Thalassia testudinum*, *Halodule wrightii*, and *Ruppia maritima* once hypersaline treatment tanks were back at ambient salinity (35 psu) using variable rates (1 and 5 psu d-1). Rates were not significantly different, so these data were pooled.

All three seagrass species examined were clearly adapted to tolerate short-term hypersaline (~55 psu) conditions common in Florida Bay through osmotic adjustment with a low rate of salinity increase in the field. *T. testudinum*, *H. wrightii*, and *R. maritima* also tolerate freshwater inputs at variable rates that reduce salinities from hypersaline to ambient seawater conditions of 35 psu. However, during the hyposalinity phase of the experiment, differences among species and across treatments were observed. Below 30 psu, species tolerance to hyposalinity conditions proved to be species-specific. Shoot numbers in *T. testudinum* and *H. wrightii* significantly declined when salinity reached 15 psu, while the euryhaline species *R. maritima* maintained consistent shoot numbers under hyposaline conditions (**Figure 12-46**).

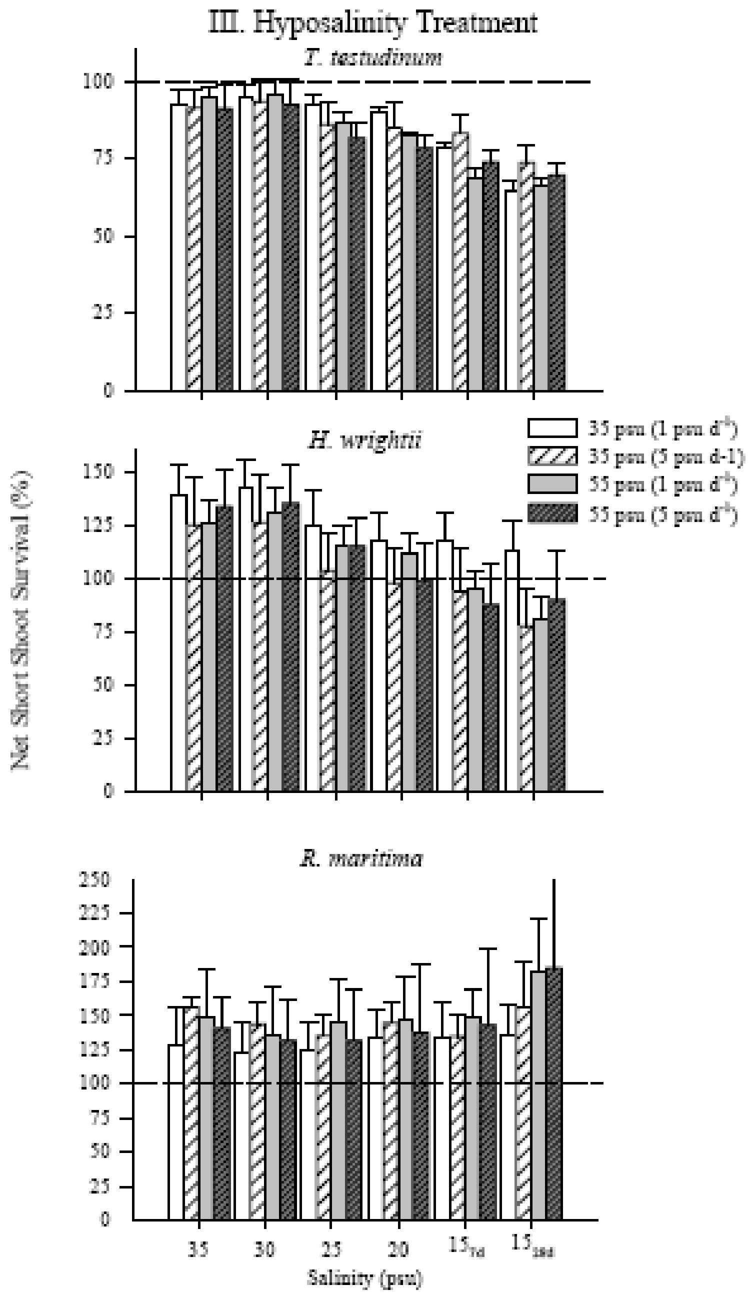


Figure 12-46. Percent change (mean + SE, n = 4) in live short-shoot numbers in intact cores of *Thalassia testudinum*, *Halodule wrightii*, and *Ruppia maritima* under hyposalinity exposure to 30, 25, 20, and 15 psu for 7d and 15 psu for 28d. Pretreatment of plants to 55 psu hypersalinity is represented by shaded bars and 5 psu d^{-1} rate of salinity reduction is shown with diagonal bars; no horizontal bars represent 1 psu d^{-1}.

Based on the results of this study, *R. maritima* dominance at the dynamic salinity transition zone in northern Florida Bay is probably accounted for by the fact that this species is more tolerant of hyposalinity exposure than *T. testudinum* and *H. wrightii* following exposure to high salinity. *T. testudinum* and *H. wrightii* appear to initiate shoot loss at hyposalinity levels of approximately 25 and 20 psu, respectively, while *R. maritima* maintained shoots at 15 psu indefinitely during the course of these experiments (minimum of 28 d). Further, in contrast to hypersalinity tolerance, a slow rate of hyposalinity exposure did not appear to ameliorate the hypo-osmotic stress in these two species. It therefore appears that hypo-osmotic stress is a major factor structuring seagrass communities at the marine-freshwater interface in Florida Bay and that the sorting of species along the ecotone will respond to the parameters of the changing salinity regime. Seagrass response is a slow process, as the surviving shoots have the capacity to sustain some metabolic activity for several weeks, as shown in this study at 15 psu for 28 d.

This study also describes for the first time that, while seagrass species in the bay are quite tolerant of hypersalinity exposure, their capacity to subsequently sustain shoots under suboptimal hyposalinity stress may be compromised by previous exposure to hypersalinity. Both *T. testudinum* and *H. wrightii* had a consistent decline in shoots under hyposalinity treatments after hypersalinity pretreatments.

Additional experiments show that net internal O_2 production via photosynthesis is reduced as a function of hypersalinity in both *T. testudinum* and *H. wrightii*, particularly at 65 psu (**Figure 12-47**). Because photosynthesis and root rhizosphere (sediment area surrounding the roots) oxidation are explicitly linked in seagrass, a reduction in O_2 production, particularly under highly reducing conditions in the sediment and/or water column, may limit the plants' ability to resist sulfide poisoning at the upper salinity levels observed in Florida Bay.

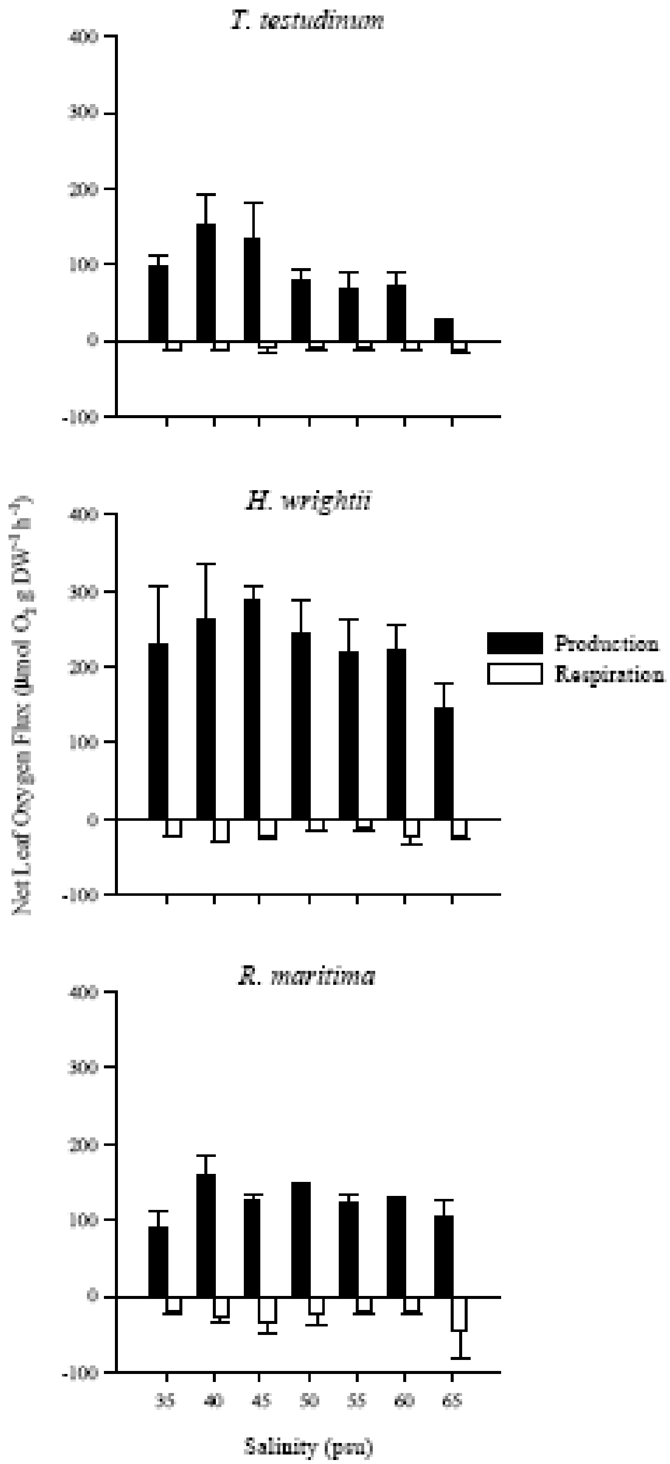


Figure 12-47. *Thalassia*, *Halodule*, and *Ruppia* net productivity and respiration rates following exposure for seven days to different levels of salinity in mesocosms.

Investigations on the role of hypersalinity and other stressors on O_2 balance will be continued in the field, in addition to ongoing mesocosm experiments. Current ongoing mesocosm studies are measuring the response of *Ruppia* seeds and seedlings to salinity stress under a variety of temperature, light, and antecedent conditions. Results of these studies will be incorporated into the seagrass community model as described in the next section.

Florida Bay Seagrass and Ecosystem Model Development

Since 2000, a simulation model of the seagrass community ecosystem in Florida Bay has provided an integrative approach to establishing performance targets and predicting ecosystem responses to water management strategies. The model (**Figure 12-48**) was developed and is maintained in-house at the Everglades Division of SFWMD. The specific goals and applications of the model are to develop an understanding of, test hypotheses about, and predict how the seagrass community responds to environmental forcing. Model runs are targeted to optimize water management strategies that enhance the health and desirable biomass levels and species mix of the seagrass community for different regions of Florida Bay. With restoration, the northern bay transition zone is expected to revert to a more freshwater environment under most restoration alternatives, which will promote the vigor and spatial expansion of the *Ruppia* and brackish macro-algal community. A fresher, more variable salinity regime is also expected to promote a more diverse seagrass community by supporting *Halodule* growth and allowing that species to compete with *Thalassia*. Development of mixed seagrass beds have been inferred to provide a more favorable habitat for fish and other nekton important to the Florida Bay ecosystem (Hunt et al., 2006). The model will continue to be used to identify target salinity ranges to meet this objective.

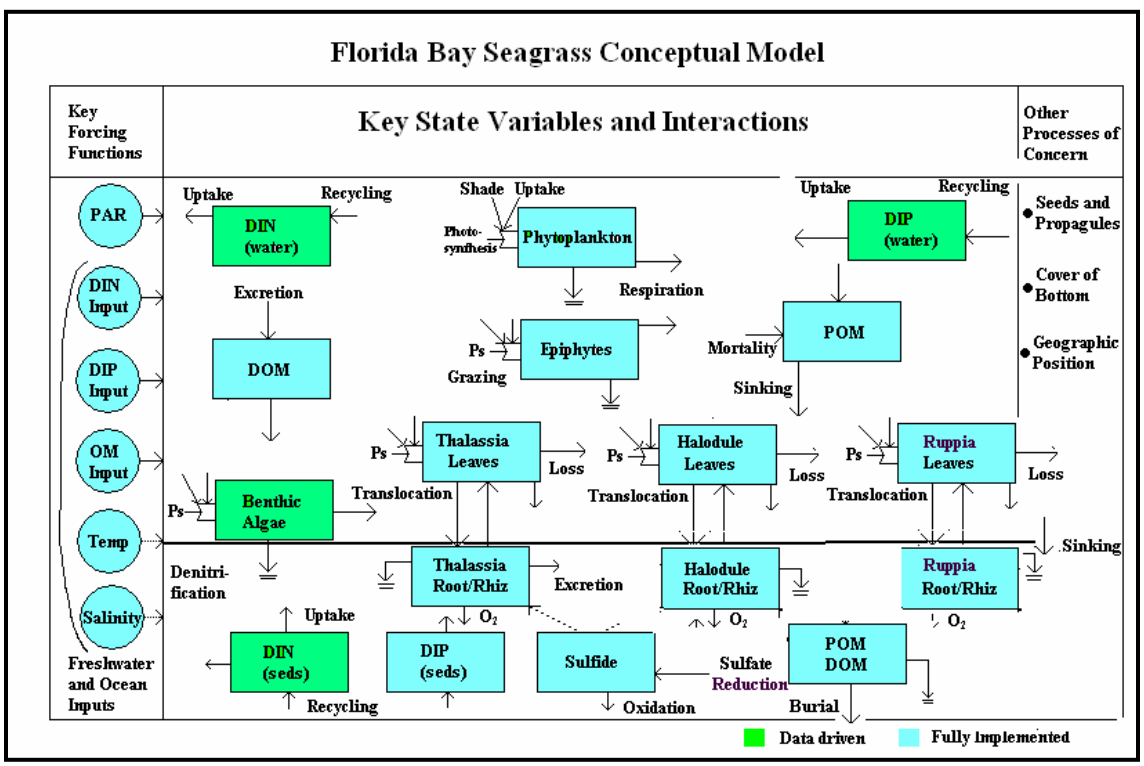


Figure 12-48. Conceptual model showing major components and interactions of the Florida Bay seagrass community and ecosystem model.

The Florida Bay seagrass model is a spatially averaged, mechanistic ecological simulation of seagrass calibrated for different sectors of Florida Bay. It consists of a stand-alone system of linked ordinary differential equations running on both MATLAB and FORTRAN platforms. Model forcing functions are salinity, net nutrient and organic imports, water temperature, and ambient light with initial conditions for sediment sulfide and organic matter concentration, seagrass species composition, and seagrass and phytoplankton biomass levels established from field data. Each seagrass species in the model has salinity requirements established from the mesocosm studies mentioned above (Koch and Durako, 2004). Other dynamic variables are derived from internal model process calculations including sediment organic matter pools and interstitial hydrogen sulfide concentrations based on organic decay rates, oxygen, and water temperature. Model outputs are updated on a sub-daily timescale, allowing calculations of rapidly changing variables such as oxygen regime, photosynthesis rate, and sediment nutrient dynamics in addition to slower, more integrative variables, such as changes in seagrass above and below ground biomass.

The stand-alone seagrass model is currently run using inputs of salinity from the FATHOM transport model (Cosby et al., 1999; Nuttle et al., 2000). However, the process of converting the input source for salinity profiles from FATHOM to the EFDC hydrodynamic model (Hamrick, 2006) has been initiated. Three expert workshops were convened in October, December, and January during 2006–2007 with the goal of integrating the EFDC output into the seagrass community model and the additional goal of incorporating key features of the seagrass model into the emerging water quality component of the EFDC. This process will continue through 2007 resulting in two complementary tools: the fully spatialized three-dimensional water quality model capable of simulating salinity, nutrient, turbidity, and seagrass for Florida Bay and the autonomous seagrass point-model that is well suited to producing detailed scenario analysis involving seagrass growth and physiology. Both models will be used to develop and evaluate restoration alternatives for the FBFKFS.

Seagrass cover and biomass estimates are from the Miami-Dade DERM and FHAP programs and nutrients are from several long-term monitoring programs, most notably selected Florida Bay stations of the SFWMD-FIU Water Quality Monitoring Network. The model is calibrated for a 1996–2001 baseline period and stable. It has been configured to examine *T. testundinum* and *H. wrightii* response to multiple stresses and provide estimates of predicted biomass under different flow conditions (Madden et al., 2003; Madden and McDonald, 2004). Model code and documentation (Madden and McDonald, 2006) have been reviewed by the Interagency Modeling Center and approved for use in CERP evaluations; the model is currently ready for FBFKFS production runs and other management applications. The model was most recently used to support Minimum Flows and Levels implementation for Florida Bay and in developing statutory minimum water delivery requirements for ecological health of Florida Bay (see Chapter 12 of the 2006 SFER – Volume I) (Hunt et al., 2006). There is a five-year reassessment built into the MFL program, which we will initiate in 2008, and new model runs will be produced after integration of components, including a phytoplankton module and additional seagrass dynamics.

Activities are currently directed toward gathering data and developing model structures that will extend the existing seagrass community model's capabilities, to include depiction of *Ruppia* in the transitional bays and mangrove transition zone. Additional information is being developed for *Ruppia* in mesocosm experiments that test growth rates under a variety of salinity and temperature conditions (see the SAV research section above). All three principal seagrass species' responses to salinity level and rate of change are being analyzed in other mesocosm measurements (Koch, 2007). Seeds and seedlings of *Ruppia* are also being incubated under a variety of environmental conditions to determine recruitment characteristics and seed-bank reserves. During 2007, the District initiated coding of this species into model and set up the model to run in Little Madeira Bay, near Taylor River. SAV cover data for the Taylor River ponds and the input datasets have been obtained for completion of a version of the model for the mangrove transition zone. District staff plan to produce an upgraded version of the model that fully incorporates *Ruppia* demographics online for CERP planning and MFL reevaluation in fall 2007.

Also begun is an additional upgrade that incorporates diatom, dinoflagellate, and cyanophyte phytoplankton functional groups. This phytoplankton module is currently in test-bed status and will be inserted into the seagrass model when fully calibrated and validated in early 2008. The importance of this expansion of the model has been emphasized by the development of an expansive phytoplankton bloom in the eastern bay in 2005.

As nutrient kinetic data are developed experimentally (Glibert et al., 2007) refinements to phytoplankton Michealis Menten parameters are being made, along with incorporation of growth parameters measured from cultures of several species dominant in Florida Bay. Nutrient mass balance and seagrass and phytoplankton resource competition is currently being enabled based on field and microcosm bioassay incubations. Algorithms for water column light attenuation based on phytoplankton species and concentration are being established using field surveys and literature values. Continued and expanded monitoring of SAV cover and biomass for the transition zone areas and sampling of associated fish assemblages will provide key information to be used directly in the model expansion and for MFL evaluation updates. Plans for the 2007–2009 time frame are to continue refinement of the autonomous seagrass community model as well as coordinate its integration into the EFDC hydrodynamic/water quality model. The new model code is being developed in MATLAB and will be ported to FORTRAN for maximum compatibility with the EFDC three-dimensional hydrodynamic water quality model currently under development (Hamrick, 2006).

The near-term efforts on the model will include:

- Incorporation of refined estimates of salinity distributions from the FATHOM model, better nutrient limitation and plant growth kinetics equations for seagrasses (Koch, 2007) and for phytoplankton (Glibert et al., 2007).
- Use of recently acquired field monitoring data on seagrass distribution to refine calibration of three-species mix.
- Additional information from laboratory measurements of phytoplankton growth and species composition based on different nutrient substrates.
- Mesocosm and field work on seagrass nutrient competition, hyposalinity, and seedling viability.
- Incorporation of P allocation and partitioning information for SAV.
- Incorporation of DOM information for phytoplankton, SAV and geochemistry modules.
- Prediction of SAV and phytoplankton spatial pattern within representative sectors of Florida Bay.

Output from the seagrass modeling project will link directly to other simulation models being developed for use by CERP, and other management programs, in predicting seagrass and ecosystem responses to water management. Restoration alternatives are now being designed and will be tested using the model to project short (2010), intermediate (2025), and long-term (2050) outcomes of restoration activities under the FBFKFS, the C-111 Spreader Canal (Acceler8 and CERP), and Biscayne Bay Coastal Wetlands CERP projects. In addition to application to the Florida Bay MFL update, the model will be used for Biscayne Bay MFL rule development and Everglades MFL evaluation, operational planning (CSOP evaluations). Adaptive management strategies and the Monitoring and Assessment Plans (MAPs) for the C-111 Spreader Canal Project will be informed by model projections as restoration moves forward.

Ecosystem Restoration Indicator Development

SFWMD staff in the Everglades Division is participating in an effort to develop a standard way of summarizing data about several key resources in Florida Bay for rapid reporting to a wide audience in a simple, consistent format. This effort involves the creation of summary metrics that quantify essential current information about critical resources, their status and trends relative to past condition. Currently, metrics are being developed for the following parameters in Florida Bay:

Seagrass (SAV) Algal Blooms

Pink Shrimp Roseatte Spoonbills

Crocodilians

The summary will be regularly reported to the U.S. Congress as part of updates from CERP (RECOVER) and the Science Coordination Group of the South Florida Ecosystem Restoration Task Force. Status is reported relative to target thresholds that correspond to “good,” “fair,” and “poor” condition that will be illustrated using green, yellow, and red diagrams in a “report card.” Trends relative to previous time points describe “improving,” “stable,” and “declining” conditions, also using the tricolored diagrams. This interpretation system is intended to foster both understanding and outreach to community and government agencies to increase awareness of problems and solutions being developed for the ecosystem.

Everglades Division scientists have the lead for determining the indicators, targets, and thresholds for SAV, and are assisting in developing the algal bloom metrics. For SAV, division staff has established indices of bottom cover and species diversity as important status parameters. For bottom cover, the chosen metric is the mode of all Braun-Blanquet measurements (see the *SAV Research and Modeling* section above) within a zone, with the target being species-specific per zone (**Table 12-6**) or total SAV coverage per zone. Ultimately, zones may be collapsed into larger regions (eastern bay, central bay, western bay, and southern bay).

Table 12-6. Florida Bay seagrass status and trends indicator targets for the Florida Bay and Florida Keys Feasibility Study performance targets being adapted for the Ecosystem Indicator Project. Zones are FBFKFS zones (approximately sequenced from east to west); SAV coverage is the modal Braun-Blanquet Cover Assessment (BBCA) score for each species in a zone in order of *Thalassia* (Tt), *Syringodium* (Sf), *Halodule* (Hw), and *Ruppia* (Rm). Dominance indicates species that is expected to optimally dominate a zone in terms of BB coverage.

Florida Bay ZONE	SAV Coverage Tt Sf Hw Rm	SAV Dominance Tt Sf Hw Rm
1	0,0,3,5	Rm
2	North: 3,0,3,5 South: 4,0,4,1	North: Rm South: Hw or Tt
3	North: 3,0,4,4 South: 4,0,4,1	North: Rm or Hw South: Hw or Tt
4	4,2,3,1	Tt
5	2,0,3,4	Rm or Hw
6	4,2,3,0	Tt
7	4,5,3,0	Tt or Sf
8	4,5,3,0	Tt or Sf
9	4,5,3,0	Tt or Sf
10	4, 3,2,0	Tt
11	4,3,2,0	Tt
12	4,3,2,0	Tt
13	North: 2,0,3,4 South: 3,0,4,1	North: Rm or Hw South: Hw or Tt
14	North: 2,0,3,4 South: 4,0,3,1	North: Rm South: Tt or Hw
15	0,0,1,5	Rm
16	4,3,4,1	Tt or Hw

For the SAV species diversity indicator, the Coastal Ecosystems Division has developed an index of optimal species diversity where the mean number of species present in all vegetated plots is greater than 2 as follows:

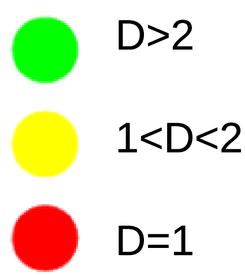
$$D = \frac{\sum S_i}{n}$$

where:

S_i = number of species with BBCA value >0 within observation i

n = number of observations with seagrass present

An example of a summary indicator using SAV species diversity is that conditions are good if the number of seagrass species in an area average two or more; conditions are fair if the average is between 1 and 2, and conditions are poor if there is a monoculture. This is displayed as:



This activity is important because it makes regular assessment of progress or deficiency in restoration efforts for key ecosystem components and threatened wildlife in a form that is readily reportable to managers, policy makers, and stakeholders.

NAPLES BAY

Chenxia Qiu and Peter Doering

INTRODUCTION

Naples Bay and its watershed are located in western Collier County, Florida. It is a relatively narrow and shallow estuarine system. Its width ranges from 100 to 1,500 feet (30–457 meters), and its depth varies from 1 to 13 feet (0.3–4 meters). It is formed by the confluence of the Gordon River and other small tributaries that empty into the Gulf of Mexico through Gordon Pass. Dollar Bay, the portion of the Naples Bay system south of Gordon Pass, is connected to Rookery Bay through a shallow waterway with a dredged channel (**Figure 12-49**). Naples Bay is typical of estuarine systems along the coast of Florida that have been heavily altered by drainage, agriculture, and urban development. The construction of waterfront homes converted 70 percent of the fringing mangrove shoreline to residential developments. The perimeter of the shoreline was doubled from 1927 to 1965, and was further expanded from 1965 to 1978 (**Figure 12-50**).

Freshwater flows into Naples Bay from Golden Gate Canal, Gordon River, and Rock Creek to the north, Haldeman Creek to the east, and urban runoff surrounding the bay. In the 1960s, the construction of the Golden Gate Canal system increased the Naples Bay watershed from 10 sq mi to 130 sq mi (26–337 square kilometers), resulting in a 20 to 40 times increase in freshwater inflow. The alternation of the watershed changed volume, quality, timing, and mixing characteristics of freshwater flows reaching Naples Bay.

Very limited salinity monitoring has been conducted in Naples Bay, so at this point to quantify the relationships between freshwater inflow, salinity, and ecology is not possible. Some description of the salinity impact on the ecology in the bay can be found in previous reports. The increased volume of inflow from the canal and stormwater systems has drastically changed mixing and circulation patterns in Naples Bay and negatively impacted the survival and health of estuarine-dependent species. As a consequence of the combined effects of dredging and inflow alterations, seagrass and oyster habitats within Naples Bay have been reduced 80 to 90 percent.

A 2006 chronological study documented changes to the shoreline and bottom of Naples Bay since before the 1950s using aerial photos and interviews (Schmid et al., 2006). Prior to development around Naples Bay in the 1950s, habitats included about 24 hectares of seagrasses and 20.6 hectares of Eastern oysters. In 2005, an inventory revealed that about 1.7 hectares of sparse seagrass remained and 5 hectares of Eastern oyster habitat. Yokel (1979) determined that the excessive discharge from the Golden Gate Canal had resulted in severe reductions in benthic invertebrate communities, and may also displace planktonic organisms from the bay. More studies are needed to document the change of inflow on biological activities in Naples Bay.

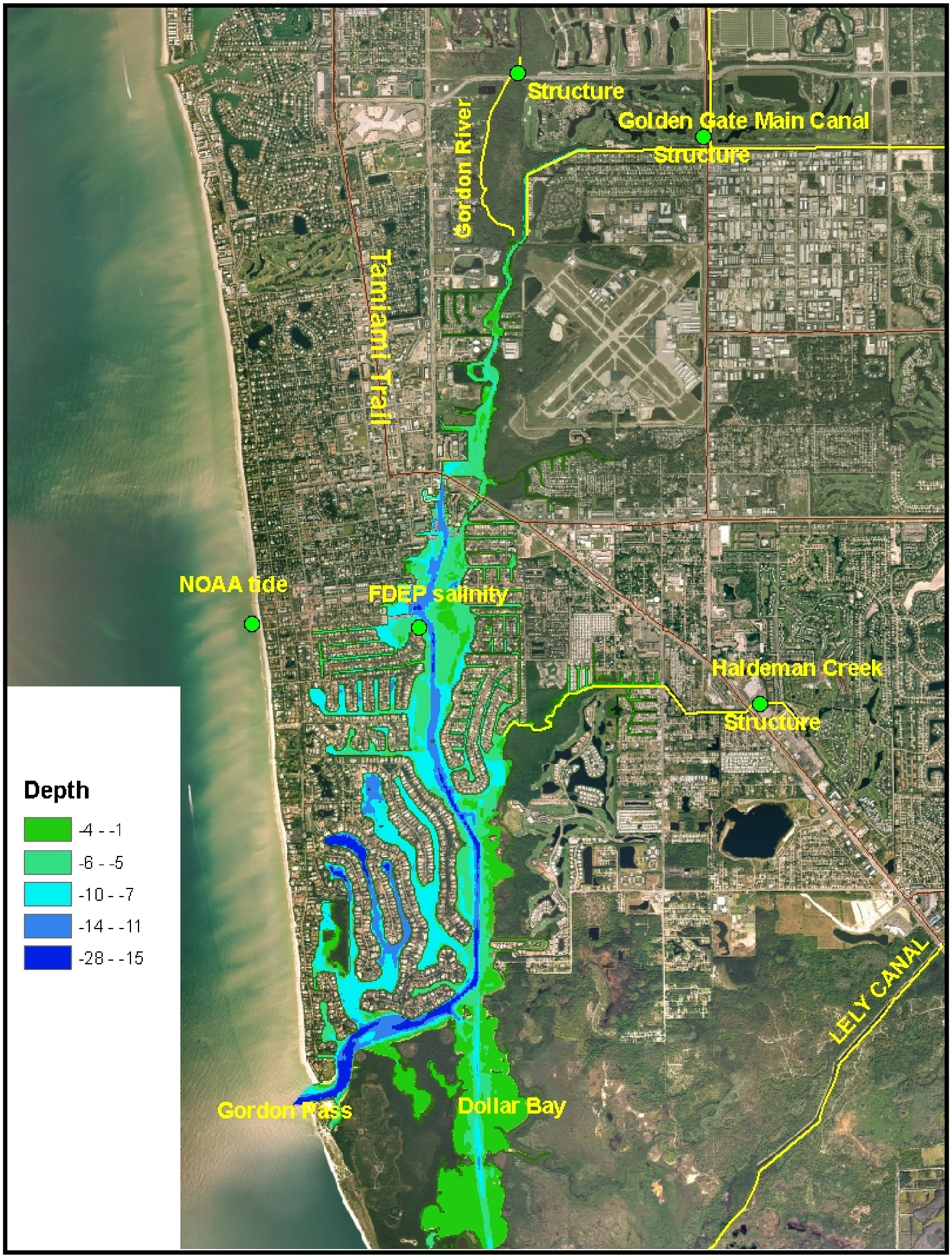


Figure 12-49. Area of Naples Bay showing bathymetry and other features.

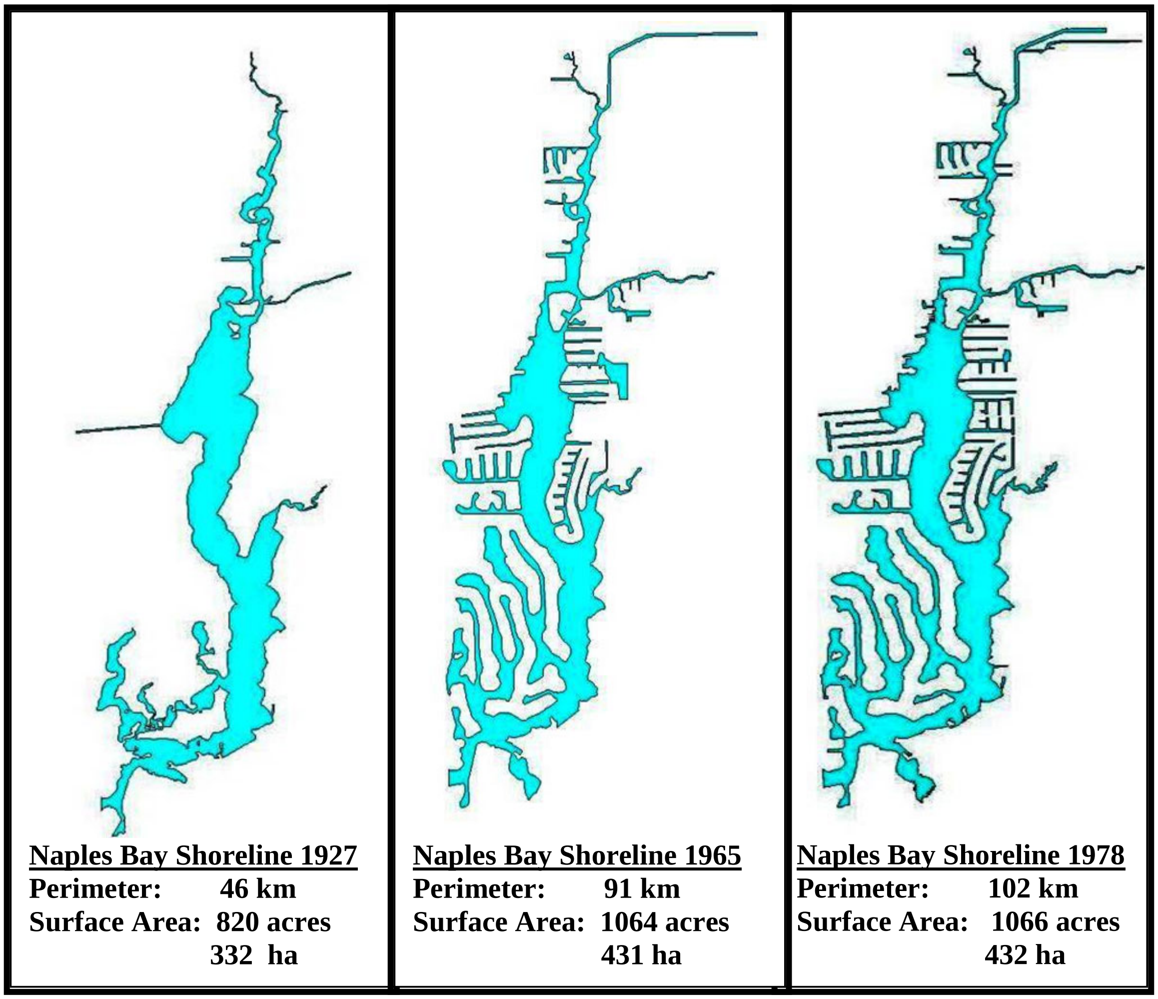


Figure 12-50. Historical (1927, 1965, and 1978) changes in the shoreline of Naples Bay.

STATUS OF FRESHWATER INFLOWS AND SALINITY IN NAPLES BAY

No minimum flow criteria or reservation of water have been established for Naples Bay to date. The inflow from Golden Gate Canal, a key inflow point, during 1994–2002 was recorded. The District is working on resuming flow monitoring on Golden Gate Canal. It became necessary to develop a new rating curve for estimating flow through the water control structure after it was reconstructed in 2003. The District should have new water level sensors operational in 2008 that can be used with the newly calibrated flow estimating algorithm. A long-term salinity monitoring plan is under development.

RESEARCH NEEDS IN NAPLES BAY

In 2007, a Surface Water Improvement and Management Plan for Naples Bay was approved by the Governing Board of the South Florida Water Management District. Among the issues identified by the plan are water quantity, water quality, and habitat loss. The present key research strategy is to provide the scientific basis for addressing water quality and water quantity issues in Naples Bay, in support of the implementation of the Naples Bay SWIM plan. A list of ongoing projects is shown in Coastal Ecosystems Science Plan.

The key short-term plans are (1) developing a preliminary CH3D hydrodynamic model, (2) conducting monitoring programs to collect the data required for the final calibration and verification of the hydrodynamic model, and (3) assessment of valuable ecosystem components (VECs).

Future needs that have been identified include (1) survey of the benthic communities including submerged aquatic vegetation; (2) development of a watershed model quantifying the flow and nutrient loading entering Naples Bay, and a water quality analysis tool in the bay; and (3) development of ecological models related to flow alteration on the biological activities in Naples Bay.

ESTERO BAY

Melody Hunt and Beth Orlando

INTRODUCTION

Estero Bay is a relatively small, long and narrow, shallow bar-built estuary located on the southwest coast of Florida (**Figure 12-22)**. The watershed of the bay includes central and southern Lee County and parts of northern Collier and western Hendry counties. The bay is oriented along a north-south axis with barrier islands separating it from the Gulf of Mexico. Estero Bay is Florida's first Aquatic Preserve, designated by the state in 1966.

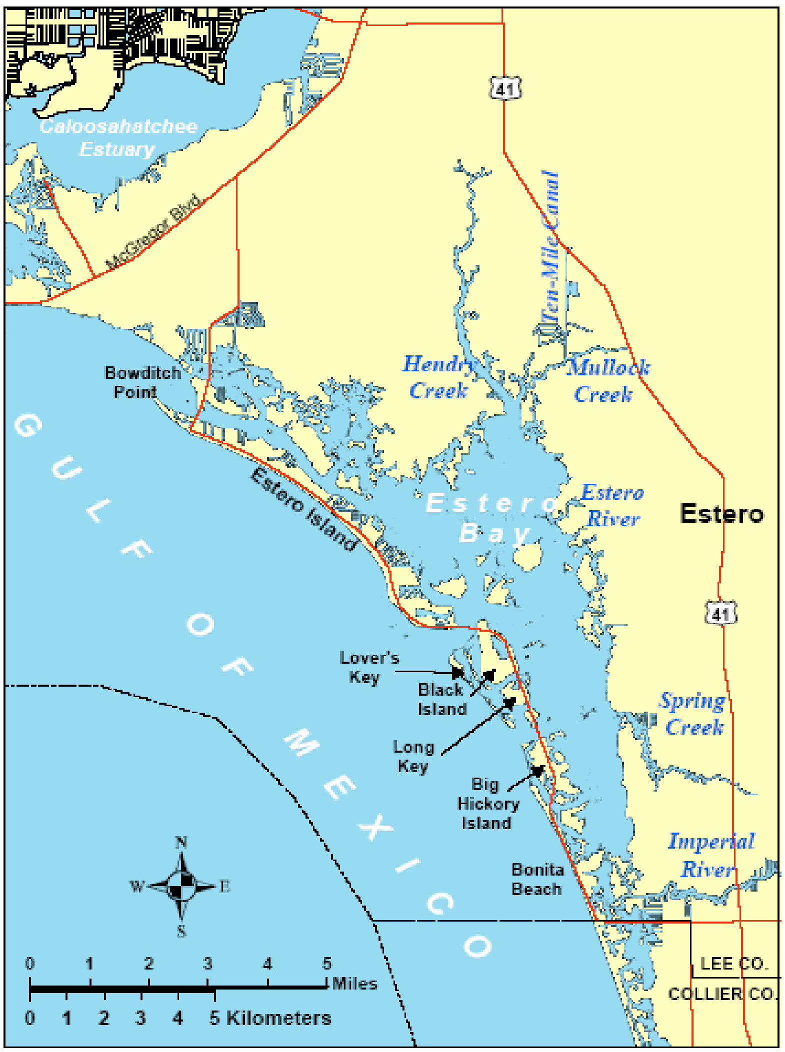


Figure 12-51. Geographic location of Estero Bay.

Surficial freshwater inflow comes from five major creeks that are distributed along the eastern shore of the bay. From north to south these are Hendry Creek, Mullock Creek, the Estero River, Spring Creek, and the Imperial River. While four of the five creeks empty into the main body of the estuary, the influence of the Imperial River may be limited to the most southern reaches of the bay. Much of the flow from this river may enter the Gulf of Mexico quickly through Big Hickory Pass.

Some historical records for freshwater inflow exist, but there is little information that relates freshwater inflow to salinity in Estero Bay. Further, no studies quantifying the responses of Estero Bay biota to changes in salinity or freshwater inflow are available. Because the tributaries are estuarine, salinity gradients in the bay, and within the tributaries, can form a complex temporal and spatial mosaic. Estero Bay is dynamic and opening, closing, and migration of inlets due to storms and long-shore erosion and deposition have been documented. Both oysters and seagrasses are considered valuable ecosystem components and are being monitored. Information on the aerial extent of oyster reefs in Estero Bay is summarized in the 2004 SFER – Volume I, Chapter 12. Updated seagrass maps were created in WY2007 using aerial surveys from January 2006. Based on the mapping process, there were approximately 1355.5 hectares of seagrass (including attached algae) in Estero Bay at the time of the survey or about 7 percent of the total bottom area.

STATUS OF FRESHWATER INFLOWS AND SALINITY IN ESTERO BAY

No MFL criteria have been established for Estero Bay to date. As part of the CERP Southwest Florida Feasibility Study (available at http://www.evergladesplan.org) flow ranges have been developed to evaluate flows for three of the major tributaries to Estero Bay: Ten Mile Canal, the Estero River (South Branch), and the Imperial River. These flow ranges are based on the salinity tolerances of the Eastern oyster (*Crassostrea virginica*), and are used to define flow envelopes that maintain appropriate salinity at creek mouths where oysters are located. The preferred inflow ranges result in salinity levels (15 to 25 psu) that are optimal for adults, and performance measures recommend that the number of days within this range be maximized. Flows that result in salinity below 5 psu are considered lethal to juvenile oysters (**Table 12-7**).

Table 12-7. Recommended flows for the eastern oyster in Estero Bay.

Tributary Control Station	Monitoring Station	Flow Ranges for Salinity 15-25 psu	Flows Resulting in Salinity < 5 psu
Imperial River	Imperial River mouth	8-26 cubic feet/sec	> 94 cubic feet/sec
South Branch Estero River	Estero River mouth	3-9 cubic feet/sec	> 31 cubic feet/sec
Ten Mile Canal	Mullock Creek downstream	4-50 cubic feet/sec	> 215 cubic feet/sec

Freshwater inflows to the three major tributaries were examined regarding their current and historical deviation from the recommended flows to maintain appropriate salinity as described in the previous section at the creek mouths for the eastern oyster adults (**Table 12-8**).

Table 12-8. Comparison of historical and WY2007 tributary inflow in Estero Bay.

Tributary Control Station	Historical Mean (Days) 1988-2006	Days in WY2007
Imperial River		
8-26 cubic feet/sec	130.6 ± 23.5	223
> 94 cubic feet/sec	109.6 ± 28.4	82
South Estero		
3-9 cubic feet/sec	70.3 ± 17.9	37
> 31 cubic feet/sec	45.3 ± 13.9	39
Ten Mile Canal		
4-50 cubic feet/sec	143.8 ± 18.7	246
> 215 cubic feet/sec	32.6 ± 14.6	55

The number of days in WY2007 when flow was within the minimum flow range is compared to the historical mean ± 95 percent confidence interval (95% C.I.). The number of days in WY2007 when flow exceeded the recommended maximum is compared to the historical mean ± 95% C.I.

RESEARCH NEEDS IN ESTERO BAY

To date, projects have focused on developing a CH3D hydrodynamic/salinity model within the bay and evaluating various organisms or groups of organisms as potential VECs. Issues of concern are degraded estuarine water quality, altered freshwater inflow, altered sedimentation, and loss of biotic resources within the bay such as seagrass beds and oyster bars. With continued development in the watershed, scrutiny and scientific investigation of Estero Bay is increasing. However, perceptions of environmental degradation, such as loss of seagrass beds, and events of low DO remain either anecdotal or have not been tied to anthropogenic disturbance. Thus key strategies for current research are: (a) synthesizing data to include quantification of the responses of Estero Bay biota to changes in salinity and freshwater inflow, and (b) extending modeling capabilities. This includes both upgrading existing models and integrating or linking modeling efforts (i.e., hydrodynamic, watershed, water quality, and ecological). Projects to date, not only function as providing baseline environmental assessment data as part the District's Fiscal Year 2008 Strategic Plan for Estero Bay, but will also be used for development of MFLs or water reservations and provide information for TMDL development. The potential VECs being evaluated include seagrasses, oysters, fish, and benthic macroinvertebrates. Seagrasses are being assessed by aerial photography and using hydroacoustic methods to quantify distribution and response to freshwater inflow. Ongoing oyster projects seek to characterize the utilization of creek mouth oyster beds by fish. Additionally juvenile and larval fish are being monitored to establish relationships with freshwater inflow and nursery function of Estero Bay. Characterization of benthic invertebrates is being performed both within the bay and near freshwater tributaries. The benthic organisms are being evaluated as potential indicators of inflow response and as indicators of sediment and water quality. A list of ongoing projects is presented in the Coastal Ecosystems Science Plan, Appendix 12-1 of this volume.

Key plans are (1) extending the CH3D hydrodynamic/salinity model into the tributaries, (2) characterization of tributary biota, and (3) synthesizing available fish data to determine effects of freshwater inflow and salinity on juvenile fish in Estero Bay. Future needs that have been identified include (1) water quality programs to support modeling and environmental projects, (2) development of a detailed watershed model (such as WaSh) that can route flows to the bay and support a water quality module, and (3) development of ecological models.

CALOOSAHATCHEE RIVER ESTUARY AND SOUTHERN CHARLOTTE HARBOR

Robert Chamberlain

INTRODUCTION

The Caloosahatchee Estuary and Southern Charlotte Harbor are located on the southwest coast of Florida. The major source of fresh water to the Caloosahatchee Estuary is the Caloosahatchee River, which runs 65 km from Lake Okeechobee, to the head of the estuary at the Franklin Lock and Dam (S-79). Geographically, the estuary extends about 42 km downstream to Shell Point, where it empties into San Carlos Bay at the lower end of Southern Charlotte Harbor (**Figure 12-52**).

Charlotte Harbor is Florida's second largest open-water estuary, and one of the state's major environmental features with three National Wildlife Refuges and four aquatic preserves. It has a broad barrier island chain, extensive meadows of submerged vegetation, and a largely intact mangrove shoreline. Only the southern portion of the Charlotte Harbor system lies within the District's boundaries, which includes the Caloosahatchee Estuary, San Carlos Bay, and almost all of Pine Island Sound and Matlacha Pass. Large fluctuations in flows from the Caloosahatchee between the wet and dry seasons affect its salinity, other water characteristics, and natural resources.

Major environmental concerns for the Caloosahatchee Estuary that can extend into Southern Charlotte Harbor are altered freshwater inflows, nutrient enrichment, and habitat loss. For a more complete summary of background information regarding problems and related historical research, please see the *Caloosahatchee River and Estuary and the Southern Charlotte Harbor* sections in Chapter 12 of the 2004 and 2005 South Florida Environmental Reports – Volume I.

DESCRIPTION OF INFLOWS

Freshwater inflow to the Caloosahatchee Estuary from the water control structure S-79 totaled about 693,391 ac-ft (855,285,204 cubic meters) during this 2007 Water Year (WY2007) (May 1, 2006 through April 30, 2007). Lake Okeechobee contributed about 93,153 ac-ft (114,902,533 cubic meters) (13.4 percent) of the total flow to the estuary. This year's total was approximately 20.6 percent of the 3.36 million ac-ft (4.1 billion cubic meters) that were discharged in WY2006, of which 2.2 million ac-ft (2.7 billion cubic meters) were contributed by the lake. The long-term average discharge at S-79 is approximately 1.2 million ac-ft (1.5 billion cubic meters).

Sub-level 1 pulses from the lake were made during May 2006 through half of June until the discharge from the watershed increased and was the only source to the estuary by the end of the month (**Figure 12-53**). Moderate wet season discharges to the estuary occurred until the end of August. The 30-day average flow was within the preferred range (450–2,800 cfs) (12.7–79.3 cubic meters/s) during this nearly four-month period. At the end of August, daily flows through S-79 from the watershed began to increase sharply due to heavy local rainfall. Daily S-79 inflows peaked at 21,000 cfs (595 cubic meters/s) on the last day of August, and then began to steadily decline, with discharges returning to below 300 cfs (8.5 cubic meters/s) by mid-September, and the 30-day average flow returning to the preferred range by mid-October. Occurrences of daily inflows after the beginning of October were rare, causing the 30-day average flow to fall below the preferred range and the MFL rule during the third week in October. Almost no flow reached the estuary throughout November as the area began its entry into the current draught. Small environmental pulses were begun in mid-December to protect the most upstream beds of Vallisneria americana from terminal salinity levels. These pulses were repeated until mid-February, when field monitoring found no remaining plants and the declining lake level became an increasing concern. From mid-February through the remainder of WY2007 (April 30), no fresh water was discharged through the S-79 Dam.

Relationship of Inflows to Salinity and Ecology

Six continuous salinity sensors are located in the Caloosahatchee Estuary (**Figure 12-52**). The salinity from the Ft. Myers and Shell Point recorders are depicted in **Figure 12-53.** Salinity at both locations was much different during WY2007 compared to WY2006. Salinity at Shell Point remained between 20 and 30 psu from January to July 2006, which is an ideal range for the oysters in this area. Wet season rains began to force salinity down, and it oscillated between 10 and 20 psu during July, but then salinity returned to nearly 25 psu in August. Unlike WY2006, salinity at Shell Point was forced to near 0 psu only once for a period of several days during the peak discharges at the end of the August-September period, after which it steadily climbed to above 25 psu by end of September, and then continued to trend up to above 35 psu by the end of the WY2007.

The generally higher salinity conditions associated with the reduction in flushing events during WY2007 compared to WY2006 should be beneficial to oyster spat settlement and survival, especially near Shell Point. Volety (personal communication, 2007.) reported that, unlike previous years, oyster spat recruitment was observed in upstream locations such as Iona Cove and Pepper Tree Point (upstream of Shell Point) as a result of the low rainfall (less releases) during WY2007.

In San Carlos Bay, the seagrass *Halodule wrightii* growth peaked early in the growing season, in May 2005, before the large discharges negatively impacted it for the remainder of the WY2006 (**Figure 12-54a**). However, *Halodule* rebounded at the beginning of WY2007. Plant densities remained higher than normal during the dry season and are starting to increase again at the beginning of the new growing season (end of WY2007). However, this same level of plant recovery did not occur for the seagrass *Thalassia* (**Figure 12-54b**). After its densities sharply declined during the WY2006 wet season, it remained very low (about 25 percent of normal) for the entire WY2007.

Upstream of the Ft. Myers sensors is the highest concentration of the fresh-brackish water plant, tape grass (*Vallisneria americana*). It requires a minimum flow of fresh water to maintain salinity below its upper tolerance limits (30-day average 10 psu). During the last major drought (WY2001─WY2002), the plant was lost from the estuary (**Figure 12-55a**) and it took until the beginning of WY2004 for it to reappear. Recovery has been slow, and the new drought has caused salinity in the upper estuary to exceed 25 psu at the end of WY2007 (**Figure 12-55b**), resulting again in the total loss of the plant from the estuary. The regrowth of *Vallisneria* was beginning to recover; however, full recovery may require years to achieve to a comparable abundance prior to the WY2001–WY2002 drought, assuming conditions are favorable.

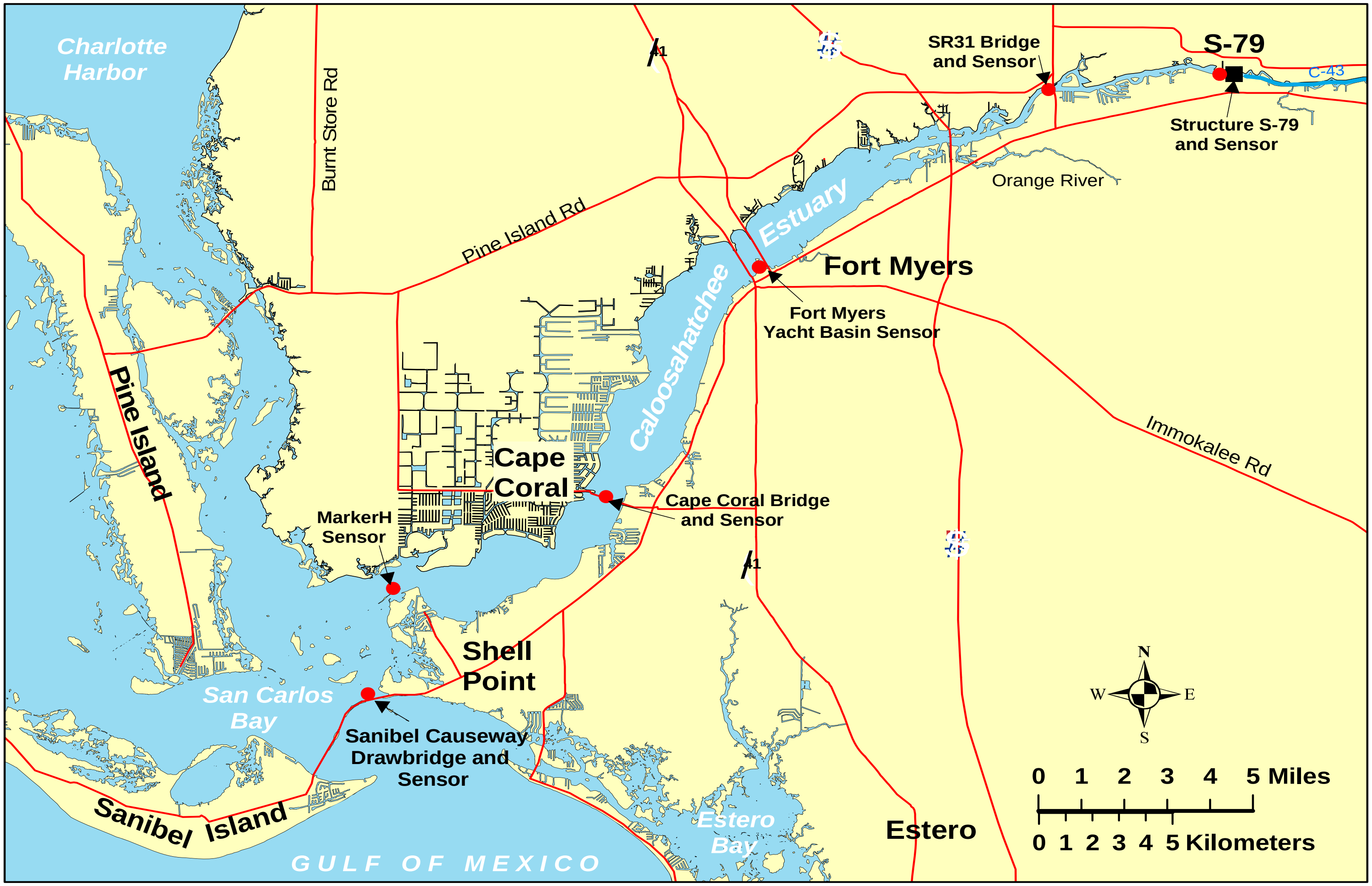


Figure 12-52. Caloosahatchee Estuary salinity sensors and important landmarks.

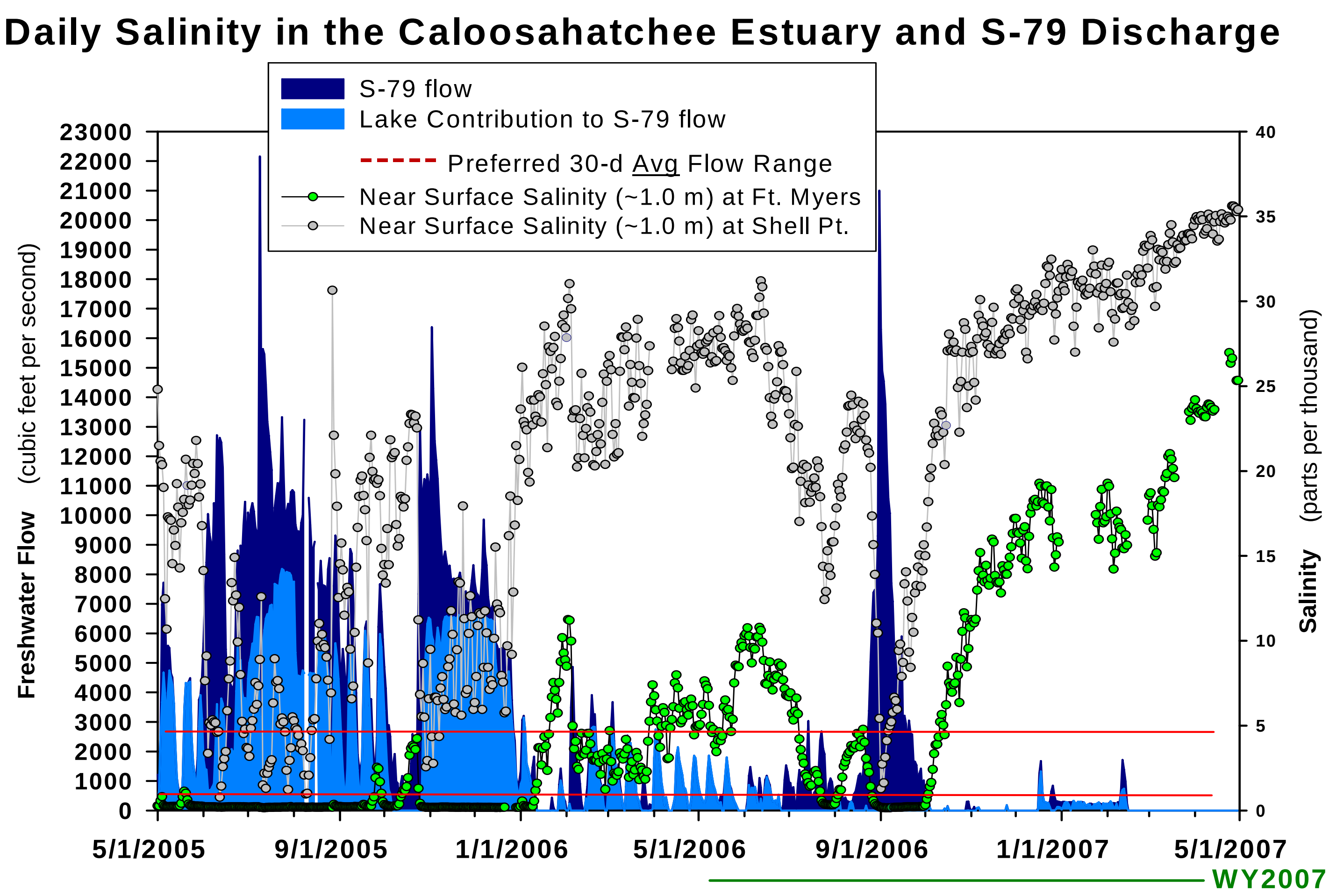


Figure 12-53. Total discharge into the Caloosahatchee Estuary (watershed releases) at S-79 during WY2006 and WY2007. The portion of the discharge accounted for by Lake Okeechobee releases is shown in light blue. Daily average salinity at Ft. Myers Yacht Basin (between U.S. 41 bridges) and Shell Point are also shown (location of sensors depicted in **Figure 12-52**).

STATUS OF FRESHWATER INFLOWS AND SALINITY IN THE CALOOSAHATCHEE RIVER ESTUARY

Description of Flow Criteria, Status and Trends Relationship

Research and modeling conducted by the District has resulted in the identification of an average monthly flow distribution between 450 and 2,800 cfs (12.7–79.3 cubic meters/s) to protect and promote desirable estuarine biota and resources. This distribution has been adopted as a performance measure target for discharge at S-79 by CERP and the SWFFS. In an ordinary year, flows less than 450 cfs occur during 4.2 months and are greater than 2,800 cfs for 2.6 months. During WY2007, only one month had average monthly flows greater than 2,800 cfs [September 2006: > 6,000 cfs (170 cubic meters/s)]. The following seven months had average flows less than the 450 cfs. By comparison, almost just the opposite flow concerns occurred the previous WY2006, when mean monthly flows exceeded only the upper limit of the envelop during the first eight months of the year (May through December 2005). Flows exceeded 4,500 cfs (127 cubic meters/s) during six of those eight months, which may have significantly impacted San Carlos Bay seagrass. Half (4) of the 8 exceedances were attributed to average monthly flows greater than 8,000 cfs (227 cubic meters/s), which can extend freshwater influence well into lower Pine Island Sound and into the Gulf of Mexico.

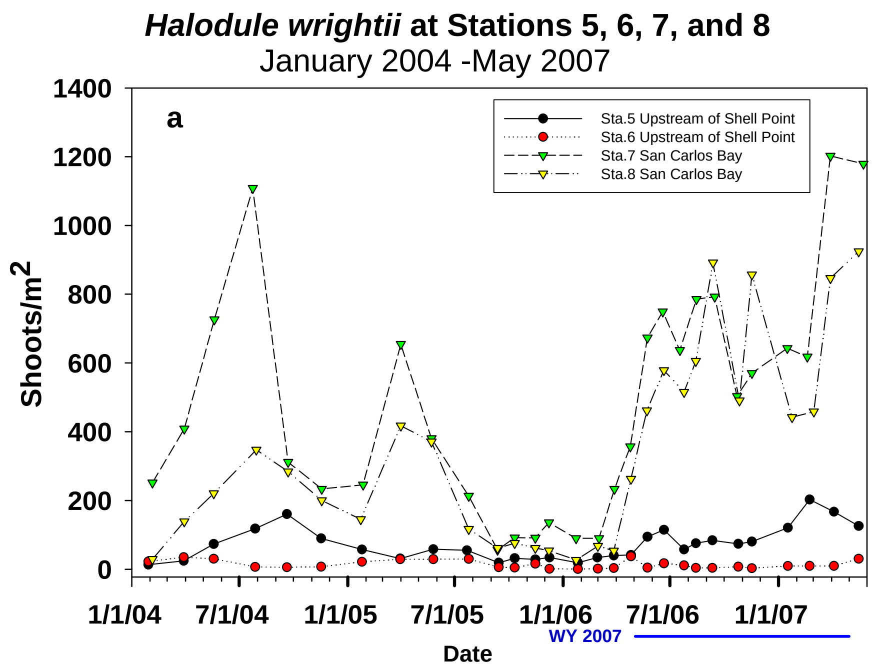
RESEARCH NEEDS IN THE CALOOSAHATCHEE RIVER ESTUARY

Key Short-Term Research Needs

Several prominent species have been identified for long-term monitoring and environmental assessment because they constitute important habitat in the Caloosahatchee, San Carlos Bay, Matlacha Pass, and Pine Island Sound. In addition to tape grass, which serves as an indicator of estuarine health in the upper estuary, monitoring of oysters, marine seagrasses, and fishery resources needs to continue. The three years of fish monitoring by the Florida Fish and Wildlife Research Institute needs to be analyzed to determine population changes related to variability in freshwater inflow, salinity and their habitat.

The District should continue to maintain a series of electronic monitoring stations that collects salinity and temperature data every 15 minutes (**Figure 12-53**). A sensor at Sanibel Causeway was destroyed during Hurricane Charley in August 2004. It is funded for replacement during Fiscal Year 2008. In addition to the parameters at these existing six locations, DO sensors also need to be installed and monitored at selected stations where hypoxia may occur. Currently, there is no diurnal monitoring of DO and no understanding of how it varies with flow and salinity in the estuary, nor if and when DO levels violate Florida state water quality standards.

The District continued to make improvements to the Caloosahatchee Hydrodynamic/Salinity Model during WY2007. The District employed this model to predict salinity distribution in Caloosahatchee River and Estuary for the Acceler8, C-43 (Caloosahatchee River) West Reservoir Project. The Caloosahatchee section of the District's Coastal Ecosystems Division plans to support these continuing programs during WY2008 and improvement of the model will be required, especially if it is to support a water quality component for addressing concerns related to the new TMDL program and the new Northern Everglades initiatives. To support these new efforts, additional nutrient limitation studies are being considered for WY2008 as the CED takes the lead in developing the research and monitoring plan for the Northern Everglades Legislative Act. Therefore, Caloosahatchee Estuary will be a major focus of attention in 2008.



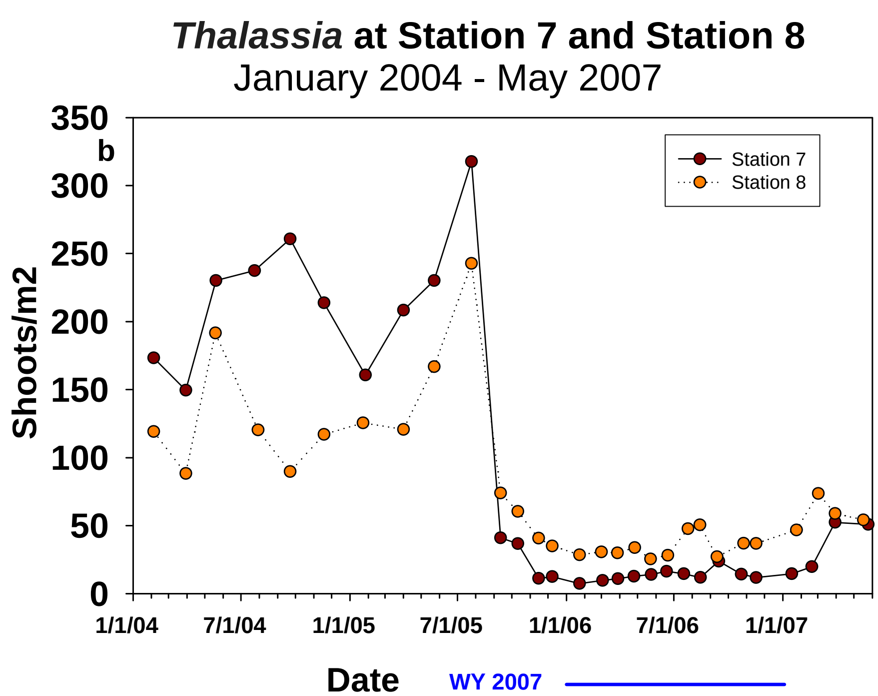


Figure 12-54. Density of seagrass: (A) *Halodule wrightii* (shoal grass) and (B) *Thalassia testudinum* (turtle grass) in the Caloosahatchee Estuary and San Carlos Bay. Data collected by the Sanibel-Captiva Conservation Foundation.

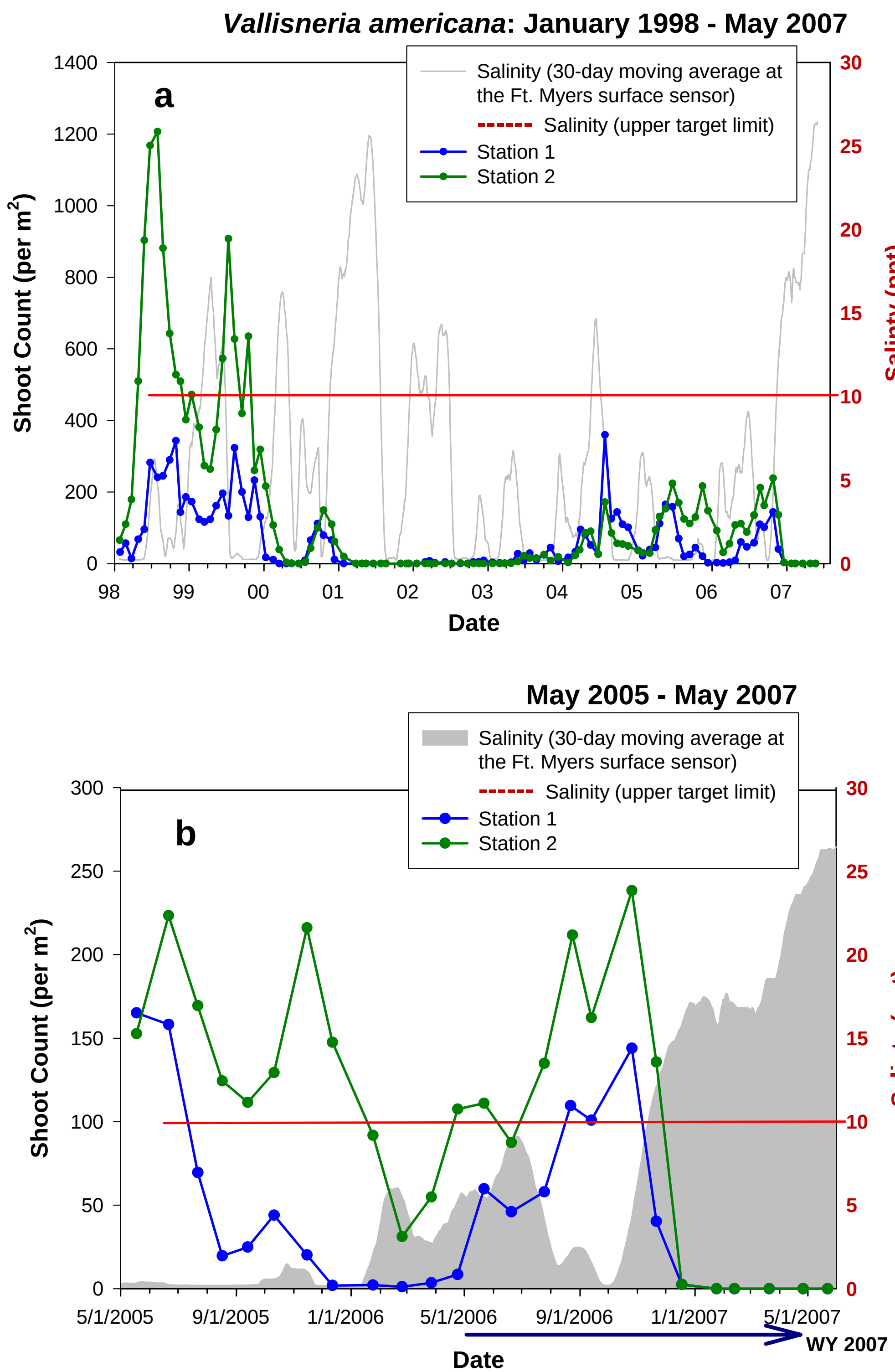


Figure 12-55. Tape grass (*Vallisneria americana*) shoot density in the upper Caloosahatchee Estuary. Recent data are from stations monitored by the Sanibel-Captiva Conservation Foundation and Mote Marine Laboratory.

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