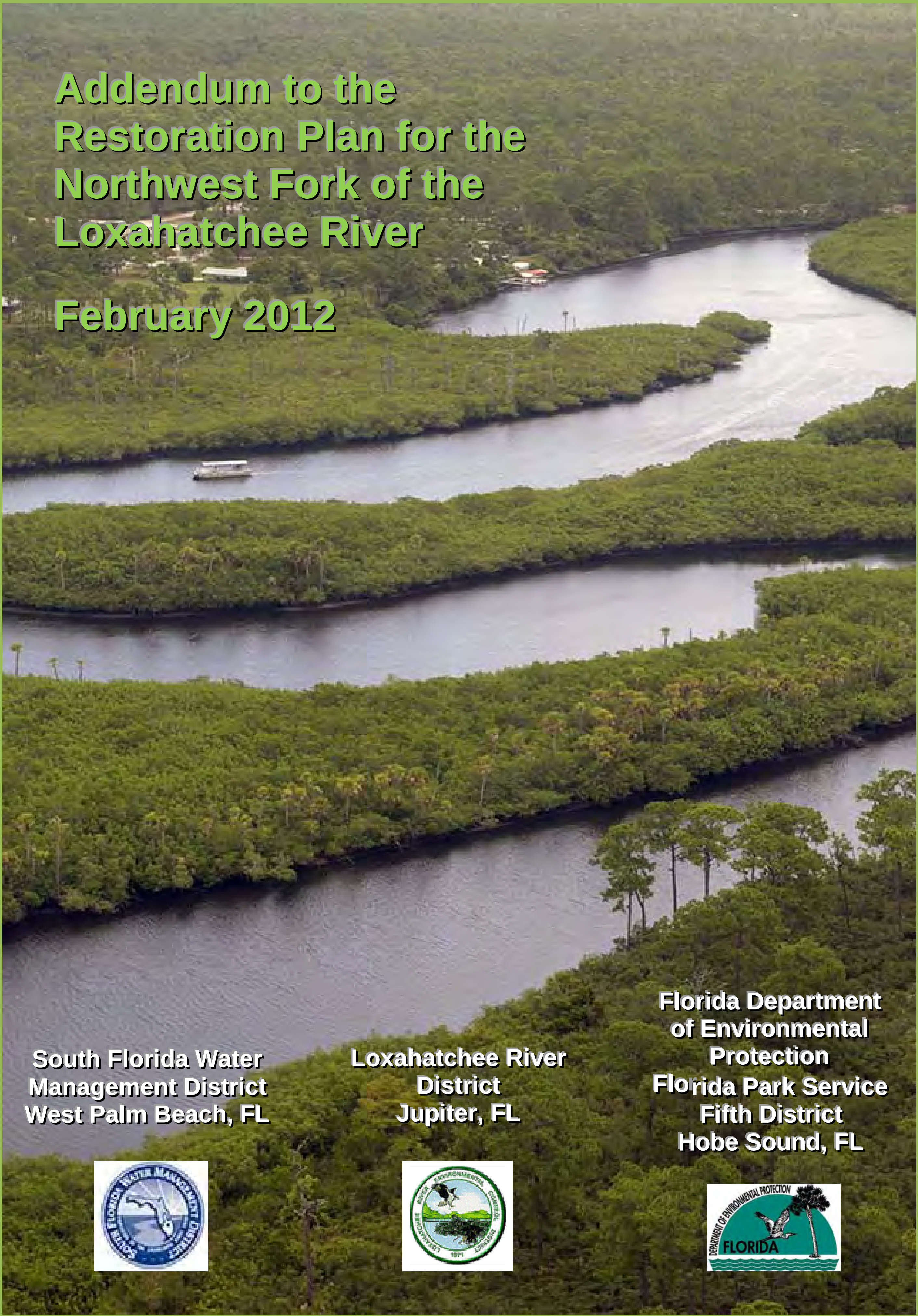

# Addendum to the Restoration Plan for the Northwest Fork of the Loxahatchee River

## February 2012

South Florida Water Management District
West Palm Beach, FL

Loxahatchee River District
Jupiter, FL

Florida Department of Environmental Protection
Florida Park Service
Fifth District
Hobe Sound, FL

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## ACKNOWLEDGEMENTS

This document is the result of a collaborative effort between the South Florida Water Management District (SFWMD), Florida Department of Environmental Protection (FDEP) Florida Park Service (FPS) District 5, and Loxahatchee River District (LRD).

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| Linda Lindstrom | Chief, Bureau of Applied Sciences |
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| Paul Rice | Bureau Chief, FPS District 5 |
| Mark Nelson | Park Manager, Jonathan Dickinson State Park |
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Many thanks to the following staff who through their professional contributions accomplished so much:

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Recognition is extended to the LRD for the monitoring of water quality, oysters and seagrass in the Loxahatchee River and overall support and partnership in the addendum development. Appreciation goes to University of Florida for technical support in soil moisture monitoring and groundwater analysis. Special thanks to Rob Rossmanith (FPS) for his continuous help in groundwater data collection.

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# EXECUTIVE SUMMARY

Often referred to as the last free flowing river in South Florida, the Northwest Fork of the Loxahatchee River is one of only two federally-designated Wild and Scenic Rivers in Florida. The Wild and Scenic portion of this river consists of 9.5 miles of freshwater riverine and tidal floodplain that provides essential habitat. A combination of the opening of Jupiter Inlet, sea level rise, diversion of flows from the Northwest Fork to the Southwest Fork, and development has resulted in significant encroachment of saltwater and saltwater tolerant mangroves into what was once a large expanse of bald cypress freshwater floodplain.

To begin to address these issues, the South Florida Water Management District (SFWMD) developed and adopted a Minimum Flows and Levels (MFL) Rule in 2003 (Chapter 40E, Florida Administrative Code). The MFL criteria were written to protect the remaining floodplain swamp community from "significant harm":

> A MFL violation occurs within the Northwest Fork of the Loxahatchee River when an exceedance of the minimum flow criteria occurs more than once every six years. An "exceedance" is defined as when Lainhart Dam flows to the Northwest Fork of the river decline below 35 cubic feet per second (cfs) for more than 20 consecutive days within any given calendar year or when the 20-day moving average salinity measured at River Mile 9.2 exceeds 2 psu [practical salinity units].

As required by the MFL legislation, a recovery strategy was developed. This strategy committed the SFWMD and the Florida Department of Environmental Protection (FDEP) to develop "a practical restoration plan and goal" (SFWMD 2002a).

Staff from the SFWMD, FDEP Florida Park Service (FPS) District 5, and Loxahatchee River District (LRD) collected and analyzed data and developed tools and models to investigate effects of several restoration flow scenarios on Northwest Fork flora and fauna. Although emphasis was placed on improving conditions in the floodplain and along riverine portions of the Northwest Fork, downstream ecological indicators were evaluated under increased flow scenarios to assure these flows would not detrimentally affect the Loxahatchee Estuary. A "preferred restoration flow scenario**"** that incorporated both dry and wet season hydrologic flow patterns was determined. This scenario is expected to provide the greatest ecological benefit to the freshwater riverine and tidal floodplain with minimal impact on the estuary. The preferred restoration flow scenario includes a variable dry season flow between 50 and 110 cfs, with a 69 cfs mean monthly flow over Lainhart Dam, while providing an additional 30 cfs of flow from downstream tributaries. These efforts are documented in the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006) available at www.sfwmd.gov.

In addition to the preferred restoration flow scenario, the restoration plan recommended (1) development of a science plan for the Loxahatchee River and (2) a five-year update of the restoration plan. The purpose of the science plan was to 1) monitor effects of restoration efforts to support adaptive management of the system and 2) fill knowledge gaps critical to ecosystem restoration success. The *Loxahatchee River Science Plan* (SFWMD et al. 2010) was completed in 2010 and is also available at www.sfwmd.gov.

Since 2006, monitoring efforts recommended by the restoration plan have been conducted. These efforts culminated in this *Addendum to the Restoration Plan for the Northwest Fork of the Loxahatchee River*. This addendum is a compilation of new knowledge gained during the last five years and focuses on analysis of factors identified in the 2006 restoration plan as needing more attention. The new research and monitoring results were organized into six major categories: (1) salinity and stage, (2) floodplain vegetation, (3) floodplain fish and wildlife, (4) estuarine flora and fauna, (5) water quality, and (6) restoration progress. In addition, this addendum evaluates the 2006 flow scenario in light of the results of these monitoring efforts. Generally, the new information further validates the recommendations made in the 2006 restoration plan.

Salinity and stage are discussed in **Section 2.0**. The freshwater flow–salinity relationships at River Mile (RM) 9.1 and Kitching Creek were revisited confirming the relationships established in the restoration plan and showing a 99.9 percent probability that salinity at RM 9.1 will remain below 2 psu provided freshwater flow over Lainhart Dam remains above 35 cfs. The flow–stage relationships established in the restoration plan for at RM 11 and RM 12 were also re-evaluated and confirmed.

The estimated average groundwater seepage upstream of RM 6 was found to be around 9 cfs with a minimum of 2 cfs and a maximum of 14 cfs. Compared with the minimum flow target of 35 cfs, the groundwater contribution to the river can be a significant source of fresh water, particularly in the dry season. The implication is that wetland restoration in the watershed will help achieve a healthy groundwater contribution to the river.

In order to evaluate the potential impact of sea level rise on the stage of the Northwest Fork tidal floodplain stage, an analytical solution was derived based on a tidal-averaged one-dimensional model. The derived analytical solution suggests the influence of downstream tidal stage could be greater on floodplain stage than watershed inflow.

Floodplain soil moisture, ground water stage and Lainhart Dam flow relationships were developed to help manage flows and stages for a healthier floodplain community. It was found that infiltration of salt water inundated on the floodplain during high tides, not the diffusion of salt water in the river to the aquifer, contributed to high porewater salinity in the floodplain. This finding suggests tidal inundation of the floodplain should be the emphasis for salinity control in the floodplain.

**Section 3.0** presents results from vegetation surveys. Five additional tree species (black mangrove, cocoplum, mulberry, climbing cassia and poison ivy) have been introduced. Increases in abundance and relative abundance of tree species were attributed mainly to white mangrove and pond apple, while there were losses in bald cypress, cabbage palm, wax myrtle, Brazilian pepper and red maple. Most of the losses were attributed to damage from the 2004–2005 hurricanes, saltwater intrusion, and exotic removal programs within Jonathan Dickinson State Park. The highest percentage of shrub coverage was provided by leather fern, pond apple, swamp fern, red mangrove and tri-veined fern. Cabbage palm shrubs were more abundant on riverine transects and responded negatively to the 2007 drought and positively to increased freshwater dry season flows in 2010. Few bald cypress shrubs were present. Groundcover was dominated by tri-vein fern, white mangrove, water hyssop and penny wort. White mangrove seedlings showed a positive reaction to the 2007 drought and a negative reaction to the increased freshwater dry season flows in 2010. Bald cypress showed an increase in seedling production; however, most of these seedlings were present on transects of the upper tidal reach, which characteristically has lower salinity and is tidally inundated twice daily. During the vegetative surveys, 30 nonnative species were encountered within the floodplain. The Loxahatchee River Vegetational Demonstration Research project showed that if exotic vegetation is removed, native vegetation can naturally recruit back into areas of the upper tidal reach.

Results of various wildlife monitoring were analyzed in **Section 4.0**. The purpose of this monitoring was to obtain pre-restoration baseline data. Few frogs with longer life cycles were observed, indicating that perhaps water levels were not sufficient in the observed years to adequately sustain them. This should change with restorative flows and the system could be managed in the future to have an excess of 90 days of inundation in the floodplain. Alligators are using the freshwater (i.e. ≤ 1 psu) portions of the river much more than the lower tidal reaches of the river perhaps due to higher salinity. The riverine reach of the river supports a wider variety of species due to the older and more complex vegetation community structure. Drying out of the riverine reach of the river allows for small mammals to utilize this part of the floodplain for longer periods of time; however it is more important for aquatic species to have an inundated floodplain for their life cycle events. No one species or set of species was found to be clear cut candidates for potential indicators of river health, but alligators and small mammals seem to have the clearest relationship with fresh water in the river and floodplain. The Florida Park Service, who conducted these studies, recommends further study of these species. It is important that once restorative flows reach the river floodplain, this work be revisited for the sake of comparison.

**Section 5.0** contains new research and monitoring results for seagrass and oysters. Detailed species mapping results confirmed that shoal grass and Johnson's seagrass are the dominant seagrass species throughout the estuary. Maps from aerial photographs revealed the dynamic nature of the core seagrass beds. An apparent increasing trend in seagrass acreage was observed, but only shoal grass and Johnson's seagrass successfully recruited to the darker water areas with the greatest salinity variations. Seagrass species diversity and coverage increased downstream of RM 2 because of more stable and higher salinity. The dynamic nature of the sediments in the Loxahatchee River Estuary may play an important role in seagrass distribution including species distribution.

The patterns of oyster abundance, health, and population ecology within the Loxahatchee generally fell within the bounds expected for South Florida oyster populations. Through an American Recovery and Reinvestment Act of 2009 stimulus grant, an oyster reef habitat restoration project was initiated on June 21, 2010 by the LRD and their partners. The project significantly increased suitable oyster recruitment substrate from approximately 8.5 to 13.5 acres. It is expected that overall acreage of live oyster reefs in the Loxahatchee River Estuary will ultimately increase with the addition of this suitable substrate.

A significant supplement of this addendum to the restoration plan is the water quality status and nutrient loads estimation presented in **Section 6.0**. Water quality in the Loxahatchee River in 2010 was generally good. Total nitrogen and total phosphorus concentrations were generally below target values established by the United States Environmental Protection Agency and LRD. Elevated chlorophyll a concentrations, particularly in the meso/oligohaline and brackish water tributaries, and low dissolved oxygen levels were observed at a variety of sampling sites throughout the watershed. Further investigation into the causes and potential consequences of the elevated chlorophyll a concentration is needed.

Water quality and flow data were used to estimate nutrient loads to the estuary from 2003 to 2008. The estimated nutrient loads that flow over Lainhart Dam contributed 65 percent of the dissolved inorganic nitrogen to the river while Cypress Creek is the major contributor in total nitrogen (45%), dissolved inorganic phosphorus (47%), and total phosphorus (52%). Also, increased flows and associated nutrient loads will generally increase nutrient concentrations and reduce oxygen content and water clarity in the downstream areas, but no discernable increase in chlorophyll a was observed.

Lastly, **Section 7.0** describes restoration progress. The Comprehensive Everglades Restoration Plan's Loxahatchee River Watershed Restoration Project (formerly the North Palm Beach County – Part 1 Project) has already completed acquisition of the L-8 Reservoir, construction of the Control 2 pump station and G-160 and G-161 structures, and widening of the M-Canal. In the dry season from March 1 to April 19, 2011, the L-8 Reservoir Pilot Test Project was successfully implemented. The project was a collaborative effort between the SFWMD, City of West Palm Beach, Palm Beach County and LRD. The primary purpose of the project was to provide operational testing of the existing facilities' ability to deliver flows to the Northwest Fork of the Loxahatchee River. One conclusion from the test was that delivering 'dedicated water' from the L-8 Reservoir to Grassy Waters Preserve and the Northwest Fork of the Loxahatchee River had a multitude of complexities and constraints related to operations, water quality, wildlife concerns, public water supply and water losses. Data collected from the pilot project will be used to provide the technical basis for validation of modeling tools needed to design the L-8 pump station.

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# ACRONYMS AND UNITS OF MEASUREMENT

| | |
|---|---|
| μg/L | micrograms per liter |
| ANOSIM | analysis of similarities |
| ANOVA | analysis of variance |
| CAP | canonical analysis of principal coordinates |
| CERP | Comprehensive Everglades Restoration Plan |
| cfs | cubic feet per second |
| CH3D | Curvilinear-grid Hydrodynamics Three-Dimensional Model |
| cm | centimeters |
| cm/yr | centimeter per year |
| dbh | diameter breast height |
| DBHYDRO | SFWMD database containing hydrologic and water quality data |
| DFA | dynamic factor analysis |
| DIN | dissolved inorganic nitrogen |
| DIP | dissolved inorganic phosphorus |
| DO | dissolved oxygen |
| EC | electrical conductivity |
| ET | evapotranspiration |
| FDEP | Florida Department of Environmental Protection |
| ft | feet |
| FLEPPC | Florida Exotic Pest Plant Council |
| FMRI | Florida Marine Research Institute (a division of the FWC) |
| FPS | Florida Park Service |
| FWC | Florida Fish and Wildlife Conservation Commission |
| FWRI | Fish and Wildlife Research Institute (a program of the FWC) |

| | |
|---|---|
| GIS | geographic information system |
| GPS | geographic positioning system |
| HH | hydric hammock forest type |
| IFAS | Institute for Food and Agricultural Sciences |
| LIDAR | light detection and ranging |
| LRD | Loxahatchee River District |
| LTmix | lower tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| LTsw1 | lower tidal reach swamp forest type 1 |
| LTsw2 | lower tidal reach swamp forest type 2 |
| LTsw3 | lower tidal reach swamp forest type 3 |
| M | marsh forest type |
| m | meters |
| $m^2$ | square meters |
| $/m^2$ | per square meter |
| $m^3m^{-3}$ | cubic meter per cubic meter |
| $m^3$/sec | cubic millimeters per second |
| mg/L | milligrams per liter |
| mm | millimeters |
| mm/yr | millimeters per year |
| MFL | Minimum Flows and Levels Rule criteria |
| MH | mesic hammock forest type |
| NGVD | National Geodetic Vertical Datum |
| NOAA | National Oceanic and Atmospheric Administration |
| PBCERM | Palm Beach County Environmental Resources Management |

| | |
|---|---|
| PCA | principal coordinates analysis |
| psu | practical salinity units (practical salinity scale) |
| Rblh1 | bottomland hardwood forest type 1 |
| Rblh2 | bottomland hardwood forest type 2 |
| Rblh3 | bottomland hardwood forest type 3 |
| RECOVER | Restoration Coordination and Verification Team |
| RM | river mile; indicates the number of miles upstream of the river mouth |
| Rmix | riverine forest type with canopy dominance 50 percent bald cypress and 50 percent cabbage palm |
| RMSE | root mean square error |
| Rsw1 | riverine reach swamp forest type 1 |
| Rsw2 | riverine reach swamp forest type 2 |
| Rsw3 | riverine reach swamp forest type 3 |
| SFWMD | South Florida Water Management District |
| S/m | Siemens per meter |
| SWE | surface water elevation |
| T# | denotes a vegetation transect |
| T#W# | denotes a groundwater monitoring well along a vegetation transect |
| TINS | triangular irregular networks (of LIDAR data) |
| TKN | total kjeldahl nitrogen |
| TL | total length of fish |
| TN | total nitrogen |
| TP | total phosphorus |
| TSS | total suspended solids |
| U | uplands forest type |

| | |
|---|---|
| USACE | United States Army Corps of Engineers |
| USCG | United States Coast Guard |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| UTmix | upper tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| UTsw1 | upper tidal reach swamp forest type 1 |
| UTsw2 | upper tidal reach swamp forest type 2 |
| UTsw3 | upper tidal reach swamp forest type 3 |
| VEC | valued ecosystem component |

# 1.0 INTRODUCTION

This document is an addendum to the *Restoration Plan for the Northwest Fork of the Loxahatchee River* published in 2006 (SFWMD 2006). The Loxahatchee River and Estuary area is shown in **Figure 1-1**. A brief description of the purpose of the restoration plan is provided below. A detailed introduction and description of the Loxahatchee River and its watershed can be found in the 2006 plan (SFWMD 2006). Also provided below is a brief description of the contents of this addendum.

Over the past several decades adverse impacts to the ecosystem of the Loxahatchee River and Estuary and the associated watershed have occurred due to alterations in hydrology. The most widely recognized alteration is the reduction of dry season flows to the Northwest Fork and associated saltwater intrusion into downstream freshwater wetland vegetation communities. The historical flows through Loxahatchee and Hungryland Sloughs to the Northwest Fork were shunted for agricultural and urban use. Construction of numerous small drainage canals in the early 1900s, inlet dredging in 1947, and construction of the C-18 Canal in 1958 diverted freshwater flows from the Southwest Fork at the S-46 structure to tide. Today, the C-18 Canal diverts much of the runoff from the Northwest Fork to the Southwest Fork of the river (SFWMD et al. 2010).

In 2006, the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006) was developed to provide the basis for the management of flows to protect and restore the freshwater floodplain, tidal floodplain, and estuarine reaches of the Northwest Fork of the Loxahatchee River. Using the best available information, the plan identified a preferred restoration flow scenario that specifies deliveries of water at the Lainhart Dam and other tributaries of the Northwest Fork of the Loxahatchee River. The plan recommended updates and progress reports every five years. Since the plan was developed, much hydrologic and ecologic data have been obtained. These data have been used to conduct various data analyses and research by local agencies. This document presents new scientific information gained since the publication of the 2006 plan on restoration indicators including salinity and stage, riverine and tidal floodplain vegetation, floodplain fish and wildlife utilization, estuarine vegetation and wildlife, and water quality. A summary of restoration progress is also provided in this addendum. Generally, data analysis and research results presented in this addendum support the findings presented in the 2006 restoration plan.

The salinity and stage indicators and their relationship are discussed in **Section 2.0** of this addendum. The specific items discussed are (1) relationship validation of upstream freshwater inflow and salinity at river mile (RM) 9.1 using the latest available five-year data record, (2) an analytical solution based on a tidal-averaged one-dimensional model used to identify major influencing factors on river stage, (3) floodplain soil moisture and groundwater analysis, (4) porewater salinity dynamics, and (5) flow-stage analysis using the latest hydrologic and topographic data collected along riverine floodplain transects.

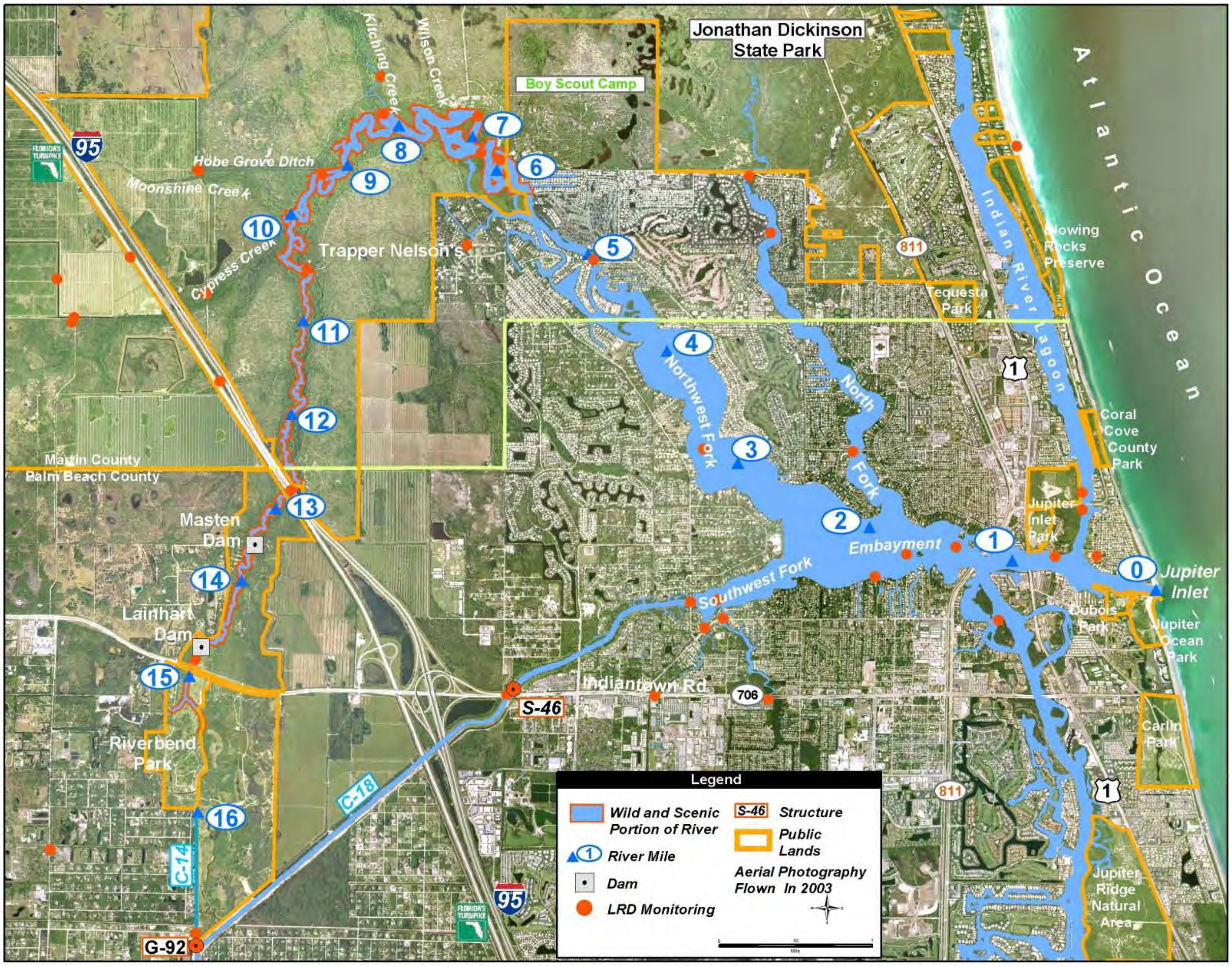


**Figure 1-1. Map for the Loxahatchee River and Estuary showing mile designations, the central embayment, lateral forks, Wild and Scenic River boundaries, and water quality stations.**

Biological indicators are discussed in **Sections 3.0**, **4.0** and **5.0**. A comprehensive data analysis of riverine and tidal floodplain vegetation surveys conducted in 2003, 2007, 2009 and 2010 are provided in **Section 3.0** and its appendices. **Section 3.0** also discusses several floodplain vegetation research projects. Floodplain fish and wildlife monitoring and utilization are discussed in **Section 4.0**. Latest seagrass and oyster results and analysis are addressed in **Section 5.0**.

Water quality data and analysis, which was barely addressed in the 2006 plan, are included in **Section 6.0**. This new component presents water quality monitoring and status in detail and provides nutrient load estimates from the watershed.

**Section 7.0** provides information on restoration projects. Projects that have been completed in the past five years, as well as ongoing restoration projects are described. These projects include a Comprehensive Everglades Restoration Plan (CERP) project, the L-8 Pilot Project, and projects conducted under the Loxahatchee River Preservation Initiative.

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# 2.0 SALINITY AND STAGE AS SYSTEM HEALTH INDICATORS

Salinity regimes are crucial to all valued ecosystem components (VECs) in the estuary. Freshwater inflow to the Northwest Fork of the Loxahatchee River is critical to maintaining salinity in the preferred range (SFWMD 2006, Hu 2002). Salinity in the Northwest Fork is controlled by both surface water and groundwater freshwater inflows and tidal exchange with the ocean (SFWMD 2006). In addition to flow and salinity within surface water and groundwater, soil moisture, groundwater salinity and pore water salinity are also important factors affecting overall salinity within the Northwest Fork. The flow-stage relationship is also discussed in this section.

## 2.1 Flow-Salinity Relationship

To simulate salinity and freshwater inflow from the watershed into the estuary, the South Florida Water Management District (SFWMD) calibrated and verified a two-dimensional finite element hydrodynamic model (Hu 2002). In the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006), a quantitative relationship was established between freshwater input and salinity at 20 locations in the estuary by conducting 11 model simulations with various levels of freshwater inflow along with statistical analysis of measured flow and salinity data (Hu 2006). The correlation between freshwater inflow and salinity is strongest in the upper Northwest Fork. Both the field data and model results indicate that a change of freshwater input as small as 10 cubic feet per second (cfs) at Lainhart Dam can cause detectable salinity changes in the upper Northwest Fork of the Loxahatchee River (SFWMD 2002a).

An analysis of the relationship between freshwater inflow and salinity in the riverine portion of the Northwest Fork of the Loxahatchee River was performed as an update to the original work presented in the 2006 restoration plan. The flow-salinity relationship of the updated simulation is based on the period of record from 2002 through 2009. Fresh water only appears to be the dominant factor for salinity in the upper portion of the river. The tidal influence is stronger downstream, which is addressed in **Section 2.3**.

Of the four tributaries contributing fresh water to the Northwest Fork, the largest portion of flow is from the Lainhart Dam. Since 1971, the United States Geological Survey (USGS) has been monitoring water stage immediately upstream of the Lainhart Dam. The magnitude of flow is calculated from a stage-flow rating curve. The SFWMD also started monitoring stage at the same location in 1977 to calculate real-time flows for management purposes. In 2004, the rating curve established in 1977 was revisited, and periodic updates were recommended to maintain appropriate levels of accuracy (Gonzalez 2004). The freshwater flow from the three additional tributaries downstream of Lainhart Dam has also been monitored since 2002. Stage recorders were installed outside of the region of tidal influence at Kitching Creek, Cypress Creek and Hobe Grove Ditch for flow calculation (**Figure 1-1** in **Section 1.0**).

**Figure 2-1** presents combined freshwater flow from the four monitoring stations at the Lainhart Dam, Cypress Creek, Kitching Creek and Hobe Grove Ditch in the period from 2002 to 2009. This flow data set was used for the freshwater inflow and salinity relationship analysis. The flow monitoring stations capture flow from about 80 percent of the entire watershed discharging into the Loxahatchee Estuary (Wan and Hu 2006). Highest flows recorded in the period were during the 2004 and 2005 hurricanes.

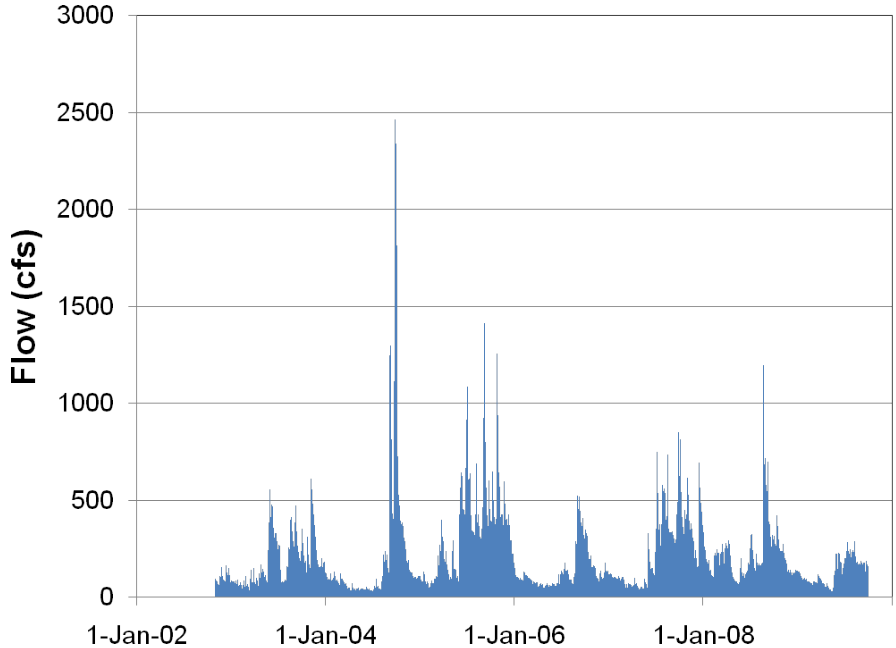



**Figure 2-1. Surface water inflow to the Northwest Fork of the Loxahatchee River**

The *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006) established a relationship between freshwater inflow and salinity based on regression of both model data and field records. Regression analysis of the results yielded regression curve equations with excellent fit.

Although the regression equations express salinity as a single dependent variable function of freshwater inflow, other driving forces affect salinity including tide, wind, flux between river and groundwater, etc. On the other hand, the regression between freshwater flow and salinity indicates a strong correlation between salinity and freshwater flow in the riverine portion of the estuary in the upper Northwest Fork. This confirms that the freshwater inflow is the most important driving force of salinity in the upper Northwest Fork under normal tidal condition. When tidal action is stronger, such as during the 2004 hurricanes, the influence of tide is more significant.

**Figure 2-2** and **Figure 2-3** overlay the 2006 regression curve for river mile (RM) 9.1 , which is 9.1 miles upstream of the river mouth (Jupiter Inlet), and Kitching Creek, respectively, with all available data points that have been accumulated since the inception of the tide/salinity gauge at RM 9.1 since 2003. The flow in the figures includes recorded flows at Lainhart Dam, Cypress Creek, Hobe Ditch and Kitching Creek.

Since the updated data set has a wider range of data values in both flow magnitude and salinity, the original regression curve does not extend as far as the updated data set. On the other hand, the most critical data points around 2 practical salinity units (psu) salinity still conform well to the original regression line. The comparison of the 2006 regression curve with updated data set at the Kitching Creek site has a similar pattern. The original regression curve goes through the middle of the data points around the 2 psu salinity line.

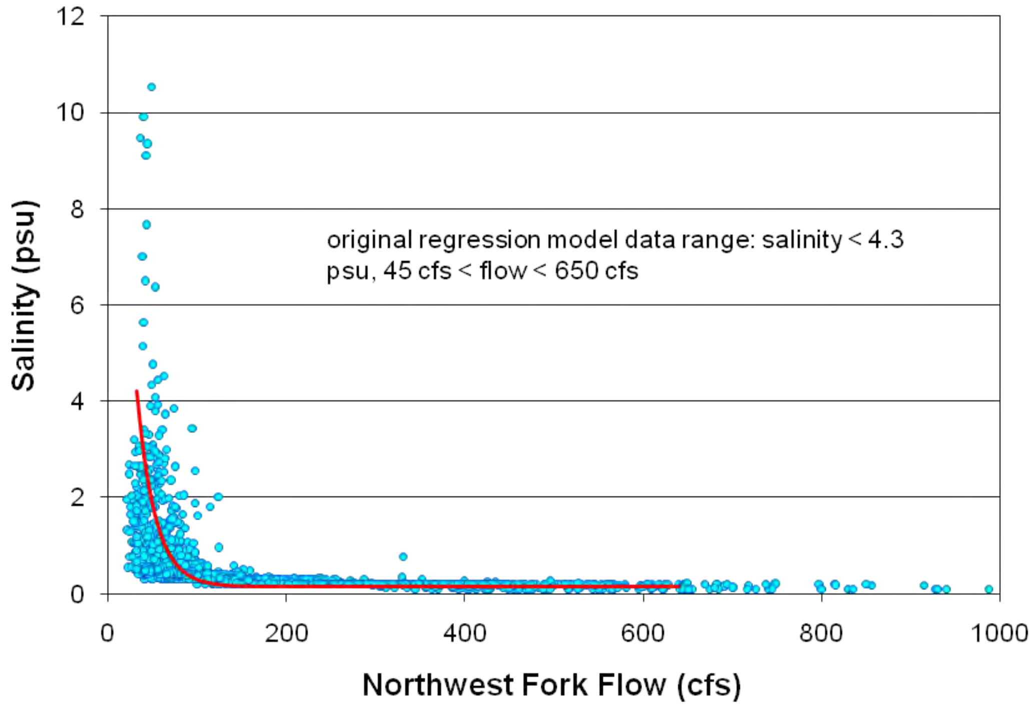



**Figure 2-2. Flow versus salinity relationship at RM 9.1**

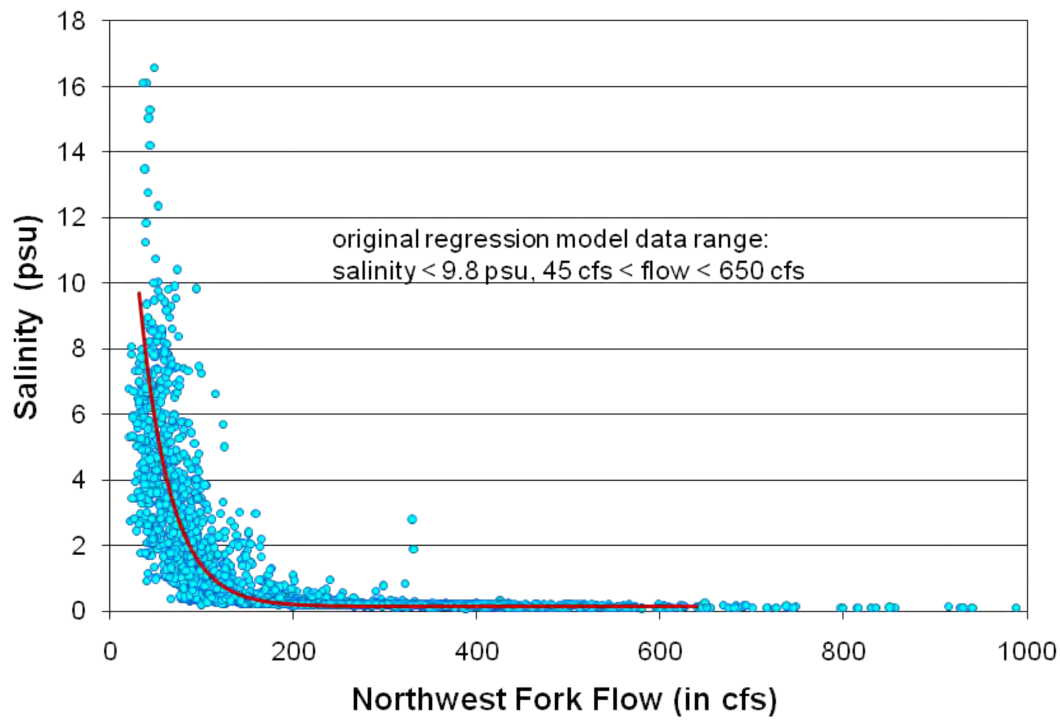



**Figure 2-3. Flow versus salinity relationship at Kitching Creek**

The Loxahatchee salinity model and regression equation for RM 9.1 was used for the minimum flows and levels (MFL) rulemaking (SFWMD 2002). The threshold flow that would keep the salinity at RM 9.1 below 2 psu was determined to be 35 cfs. The L-shaped grey area in **Figure** 2-4 is where the data points should fall to satisfy the minimum flow requirements for salinity control. Since the data points are so dense in the chart, it is hard to tell that over two thousand data points have been plotted into the grey box. Of the over two thousand data points, two fell outside the prediction. This leads to a 99.9 percent probability that salinity at RM 9.1 would be kept below 2 psu provided that the freshwater flow from the Lainhart Dam remains above 35 cfs. Flow from tributaries such as Cypress Creek, Hobe Grove and Kitching Creek also affect the salinity in the Northwest Fork. Historic flow records indicate that the ratio between Lainhart Dam flow and tributary flows are relatively steady. This explains the strong correlation in the empirical relationship between the Lainhart Dam flow and salinity at RM 9.1. In the model simulation, the tributary flows were included in the calculation either using historic flow record or the flow ratio.

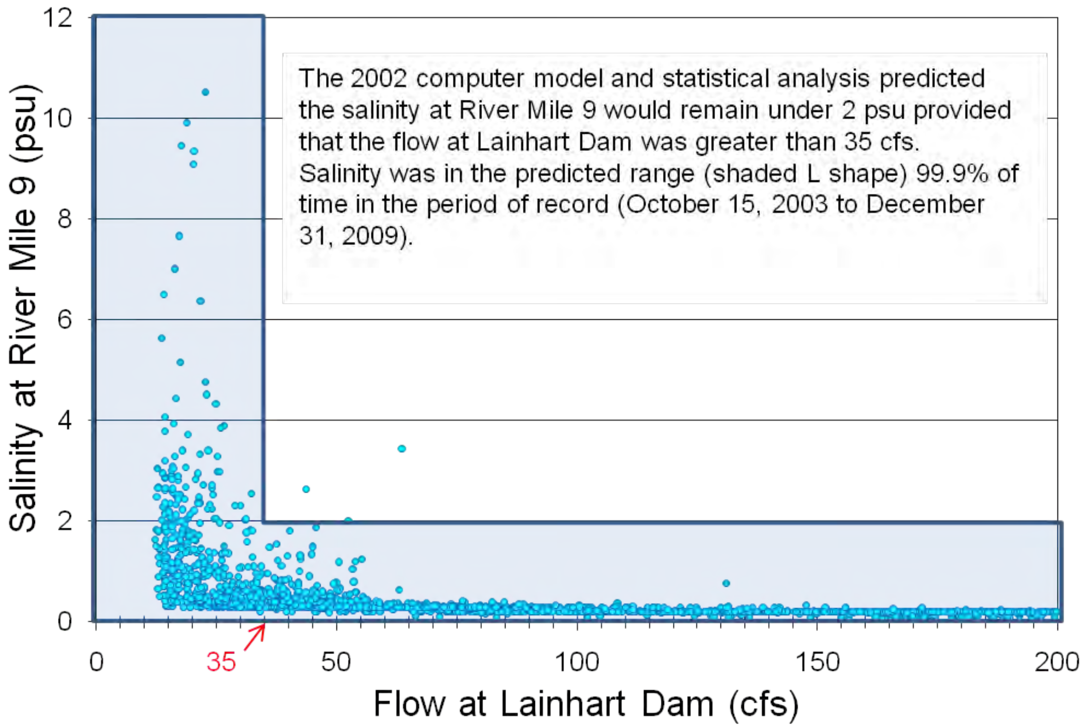



**Figure 2-4. Flow at Lainhart Dam versus salinity at RM 9.1**

The relationship between freshwater flow at the Lainhart Dam and salinity at RM 9.1 was also examined by a field study conducted by the University of Florida (Kaplan et al. 2010). The study concluded that maintaining surface water elevation (SWE) at Lainhart Dam at 10.86 feet (ft) National Geodetic Vertical Datum (NGVD) would prevent 95 percent of salinity events exceeding 2 psu in salinity. Based on the stage-flow relationship at the Lainhart Dam, the discharge over the structure is approximately 35.31 cfs at a stage of 10.86 ft NGVD. The conclusion of the paper was based on a shorter data set, which may explain the difference in the probability of salinity exceedance. Nonetheless, 95 percent is still a very high probability that salinity would be maintained below the 2 psu threshold.

## 2.2 Groundwater Contribution to Flow

The previous USGS study indicated that groundwater seepage is a significant source of fresh water to the Loxahatchee River (Swarzenski et al. 2006). The objective of this section is to use a simpler approach to provide an initial estimate of groundwater contribution to the Northwest Fork of the Loxahatchee River. Data from two studies were used in this estimation.

The first study, conducted by the USGS in 2003 and 2004, characterized the radium isotopic signature of surface water and groundwater within the Loxahatchee River and its floodplain (Swarzenski et al. 2006). Samples were taken in September 2003 and March 2004. The radium isotope technique and other methods were used to quantify wet and dry season fresh groundwater input into the Loxahatchee River system.

In 2003, the SFWMD installed 12 shallow groundwater monitoring wells along Transect 1 (T1), T3, T7, T8 and T9 (see **Figure 3-1** in **Section 3.0**). Electronic monitoring at 15- to 20-minute intervals measured stage, temperature, electrical conductivity (EC), dissolved oxygen (DO), barometric pressure and water pressure. Upriver transects T1 and T3 each have only one well, while transitional and tidal transects have multiple wells to document differences in groundwater EC from the river channel towards the upland. T7 has four wells and T8 and T9 each have three wells (**Figure 2-5**). **Table 2-1** summarizes important attributes of the twelve wells in the study.

**Table 2-1. Well locations and characteristics**

| Well | River Mile | Transect Type | Elevation (ft NGVD) | Elevation (meters NGVD) | Upland/ Floodplain |
|---|---|---|---|---|---|
| T1W1 | 14.5 | Riverine | 13.75 | 4.19 | Upland |
| T3W1 | 12.1 | Riverine | 8.24 | 2.51 | Upland |
| T7W1 | 9.1 | Transitional | 4.17 | 1.27 | Floodplain |
| T7W2 | 9.1 | Transitional | 4.40 | 1.34 | Floodplain |
| T7W3 | 9.1 | Transitional | 4.82 | 1.47 | Floodplain |
| T7W4 | 9.1 | Transitional | 12.63 | 3.85 | Upland |
| T8W1 | 8.1 | Transitional | 3.38 | 1.03 | Floodplain |
| T8W2 | 8.1 | Transitional | 4.17 | 1.27 | Floodplain |
| T8W3 | 8.1 | Transitional | 10.47 | 3.19 | Upland |
| T9W1 | 6.5 | Tidal | 4.33 | 1.32 | Floodplain |
| T9W2 | 6.5 | Tidal | 5.02 | 1.53 | Floodplain |
| T9W3 | 6.5 | Tidal | 12.63 | 3.85 | Upland |

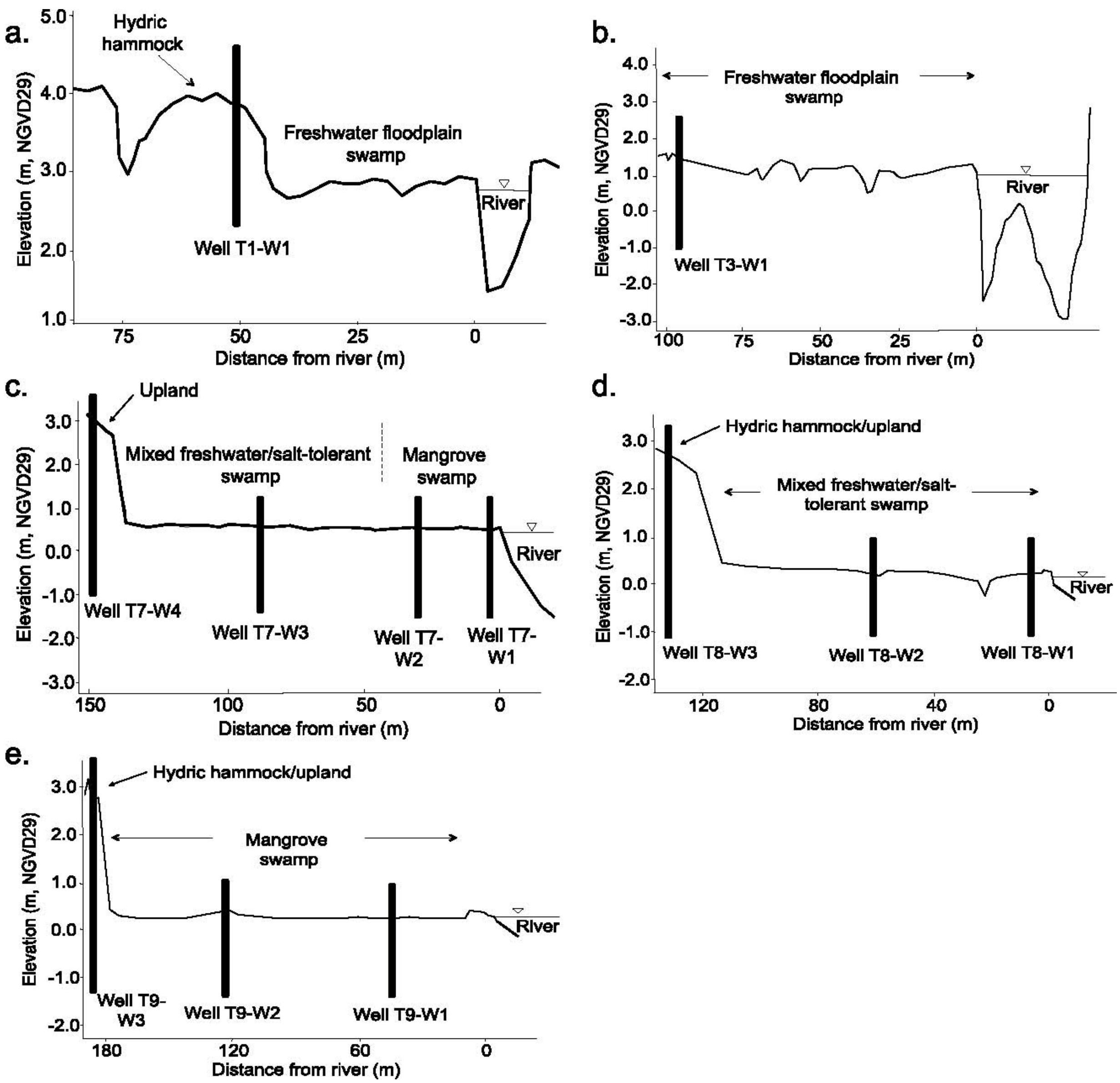



**Figure 2-5. Layout of wells along transects**

The Florida Department of Environment Protection (FDEP) Florida Park Service (FPS) conducted maintenance and data retrieval from the groundwater monitoring wells (**Figure 2-6**). These data are essential to document hydroperiods and saltwater movement within the groundwater of the upper and lower tidal floodplains so they can be related to changes in vegetation. Additionally, these data are being used by the SFWMD to monitor groundwater movement under various hydrological conditions.

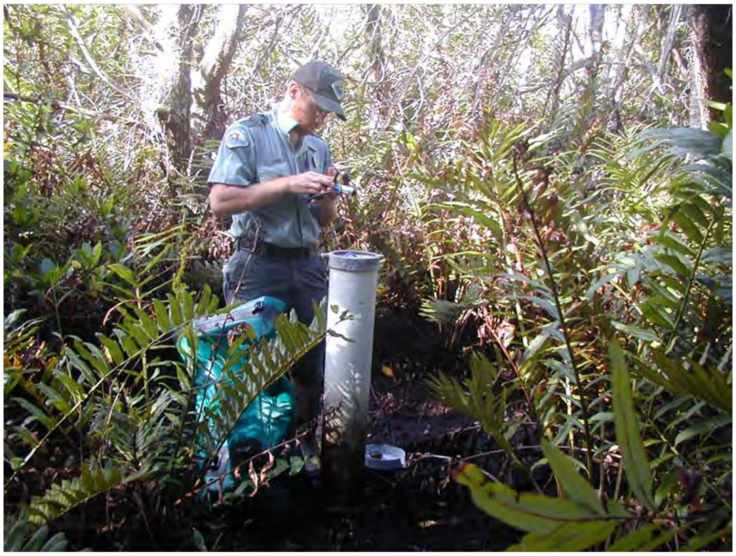


**Figure 2-6. Groundwater monitoring well on the floodplain**

Data from these 12 wells were analyzed together with river surface water salinity data at the Indiantown Road, RM 9.1, Kitching Creek outlet, Boy Scout dock and United States Coast Guard (USCG) dock sampling stations. The results indicated that the major factors impacting groundwater salinity are rainfall, flow over Lainhart Dam, and salinity at the Kitching Creek outlet.

The chart in **Figure 2-7** plots the groundwater head at two wells along T7. Well 1 along T7 (T7W1) is located near the shoreline of the upper Northwest Fork of the Loxahatchee River. T7W4 is located on the upland approximately 490 ft (150 meters [m]) from the river. The groundwater heads at T7 show a positive slope that tilts toward the river. This is a good indication that groundwater discharged to the river throughout the period of record. The magnitude of groundwater flow rate is proportional to the head difference between two points. The groundwater head at T7 became very small during dry periods. Therefore, the amount of groundwater movement toward the river would have been greatly reduced accordingly during these dry periods. In order to maintain the necessary freshwater input to the river, it is important to maintain the water table around the river at an appropriate level. An understanding of how the groundwater head is related to groundwater seepage to the river will help better manage the hydrology of the system.

The USGS study concluded the average Loxahatchee River estuary submarine groundwater discharge rate was 0.49 to 1.84 gallons per square feet per day (20 to 75 liters per square meter per day). Assuming a relatively uniform groundwater seepage rate over the footprint of the river channel, the seepage rate of groundwater into the upper Northwest Fork would be in the range of 3.9 to 14.6 cfs. This calculation included the river channel upstream from RM 6. Since the USGS sampling was conducted in both wet and dry seasons, we may assume the average groundwater contribution to the upper Northwest Fork of the Loxahatchee River above RM 6 is approximately 9 cfs. Based on the uniform seepage rate assumption, the estimated average groundwater discharge rates into the Northwest Fork above river mile markers and for the entire Northwest Fork are listed in **Table 2-2**.

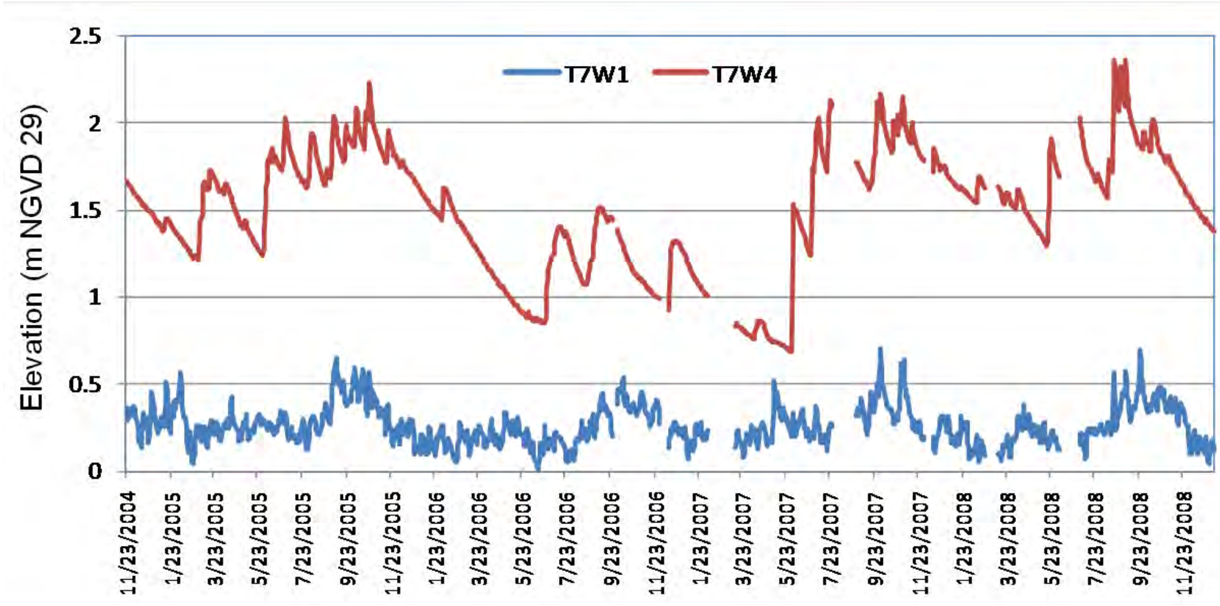



**Figure 2-7. Groundwater gradient at T7**

**Table 2-2. Estimated average groundwater discharge rate into the Northwest Fork**

| River Reach | Groundwater Seepage Rate |
|---|---|
| Northwest Fork | 65 cfs |
| Northwest Fork above RM 3 | 42 cfs |
| Northwest Fork above RM 4 | 26 cfs |
| Northwest Fork above RM 5 | 16 cfs |
| Northwest Fork above RM 6 | 9 cfs |

According to Darcy's Law, the flow rate through porous media should be proportional to the groundwater head loss and inversely proportional to the length of the flow path. Considering the hydraulic conductivity of the system would not change significantly in a time span of a few years, the seepage rate of groundwater flow into the Northwest Fork should fluctuate following the same pattern of head loss variation over the same time period. Assuming the measured seepage rate represents the average seepage rate at T7, the hydraulic conductivity at T7 could be estimated as approximately 2 m per day. This hydraulic conductivity value is consistent with fine sand with some silt content.

Based on this reasoning, a time series of groundwater seepage into the upper Northwest Fork was reconstructed based on the floodplain well data. The daily average head difference between wells T7W1 and T7W4 was used as an indicator of the overall groundwater condition in the area.

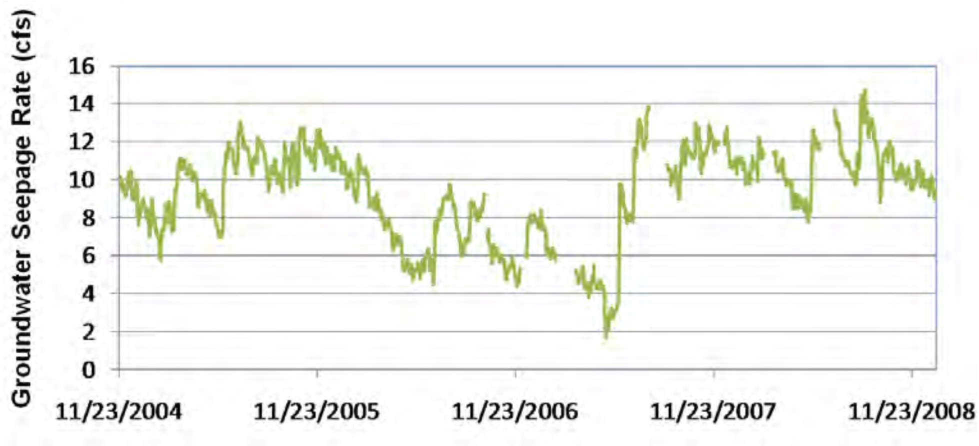



**Figure 2-8. Groundwater contribution to the Northwest Fork**

**Figure 2-8** presents an estimated flow rate time series for the upper Northwest Fork above RM 6. The chart covers the period where well data are available from November 2004 to the end of 2008. The estimated peak seepage rate for the 2008 wet season is almost eight times higher than the low seepage rate in the 2007 dry season. While the absolute values of these estimates were based on assumptions made in the calculations, the variation of groundwater heads is a good indication that the amount of groundwater contribution to the Northwest Fork is highly seasonal and highly dependent on the overall groundwater condition in the watershed. The well record is not long enough to establish dry and wet season seepage flow patterns. The minimum seepage rate over the four-year period was approximately 2 cfs. And the estimated maximum seepage rate for the same period was 14 cfs.

The 2002 study on the minimum flow requirement for the Northwest Fork found that it is necessary to maintain flow at Lainhart Dam above 35 cfs to avoid harm to the ecosystem (SFWMD 2002). Comparing the minimum flow target with the amount of groundwater inflow in **Figure 2-8**, it is apparent that the groundwater contribution to the river is a significant source of fresh water to the Northwest Fork. It is necessary to maintain the groundwater level in the watershed so the groundwater contribution to the river is at a healthy level.

## 2.3 Tidal Influence

Tidal regime is another important factor that affects salinity. Freshwater inflows appear to be the dominant factor for salinity in the upper portion of the river, but the tidal influence is stronger in the downstream portion. The relationship between freshwater inflow and salinity is not as close in the lower portion of the estuary as in the river at RM 6. This pattern was also observed in the previous analysis conducted in 2005 during the development of the *Restoration Plan for the Northwest Fork of the Loxahatchee* (SFWMD 2006).

Since 2002, tidal stage and salinity have been monitored in the Northwest Fork. This salinity monitoring effort includes the River Keeper project with monthly or bimonthly sampling, and the data sonde monitoring program with high frequency sampling (every 60 minutes) conducted by the Loxahatchee River District (LRD) in partnership with the SFWMD. The SFWMD also sponsored a USGS long-term tide and salinity monitoring program since 2002 at stations located at the USCG dock, Pompano Drive, Boy Scout dock, Kitching Creek and, since 2003, RM 9.1.

### 2.3.1 Tidal and Salinity Surge during 2004 Hurricane Season

In 2004, two major hurricanes, Frances and Jeanne, made landfall near the Loxahatchee River and caused substantial damage. Hurricane Frances made landfall on September 5 with maximum sustained winds of 105 miles per hour (Category 2 strength). Hurricane Jeanne came ashore on September 26 as a Category 3 hurricane with maximum sustained winds of 120 miles per hour. During Hurricanes Frances and Jeanne, most monitoring stations in the Loxahatchee River survived the storms and recorded a relatively complete data set. The flow and salinity data collected during the hurricanes provided an opportunity to observe the impact of both freshwater inflow and tide on the salinity regime in the upper Northwest Fork (Hu and Wan 2006).

The Northwest Fork inflow reached 1,188 cfs (including Lainhart Dam and other tributary flows) during Hurricane Frances and 2,211 cfs during Hurricane Jeanne. The corresponding peak discharge from S-46 was 1,551 cfs and 2,574 cfs, respectively. After the storm, salinity recovered from 35 psu to the 30 psu level approximately a week later at the USCG dock sampling station located near Jupiter Inlet.

The overall tidal pattern and the magnitude of tidal surge in the upper Northwest Fork recorded by monitoring stations at RM 6, RM 8 and RM 9.1 are approximately the same as those at the USCG dock. The water level rise was nearly 2.95 ft at all three sites during the landfall of Hurricane Frances and about 2.62 ft during Hurricane Jeanne.

In spite of the similarity in the tidal amplitude, the salinity regime in the Northwest Fork differed significantly from the salinity condition near Jupiter Inlet. Because the tidal surge pushed a large mass of water with high salt content into the upper Northwest Fork, a sharp salinity increase was observed at RM 6 during both hurricanes. Salinity at this site reached 24 psu during the first storm and reached 15 psu during the second storm. The sustained tidal impact prior to the landfall of Hurricane Jeanne created salinity oscillation ranging from about 1 psu to as high as 18 psu for three days in spite of high rainfall and increased freshwater inflow. However, for stations at RM 8 and RM 9.1, such salinity spikes were observed only during Hurricane Frances but not during Hurricane Jeanne. This is possibly due to the fact that freshwater inflow into the Northwest Fork prior to and during Hurricane Jeanne was much greater than that during Hurricane Frances. As a result, the salt wedge was impeded by the large amount of freshwater flow.

### 2.3.2 Tidal Stage and Floodplain Inundation

Freshwater inflow is apparently one of the main factors affecting tidal stage. In general, as freshwater inflow increases, stage increases and so does the likelihood or frequency of inundation. Other important factors include tide, wind and bottom friction, and length of the tidal channel. Another potentially important, but often neglected factor, is the stage downstream, for example, at the inlet. These factors will be considered in the following analysis.

The following governing equations for continuity and momentum are appropriate for a one-dimensional tidal channel (van de Kreeke 1971):

$$\frac{\partial \eta}{\partial t} + \frac{\partial q}{\partial x} = 0 \qquad (2\text{-}1)$$

$$\frac{\partial q}{\partial t} + \frac{2}{h} q \frac{\partial q}{\partial x} + g(h+\eta)\frac{\partial \eta}{\partial x} = -\frac{Fq|q|}{(h+\eta)^2} + \frac{\tau_W}{\rho} \qquad (2\text{-}2)$$

Where,

$\eta$ = SWE with respect to still water
$q$ = discharge per unit width
$g$ = gravity
$h$ = depth with respect to still water
$F$ = friction factor when using a quadratic relation between friction and velocity
$x$ = horizontal Cartesian coordinate
$t$ = time
$\tau_w$ = wind stress
$\rho$ = water density

The left-hand side of **Equation 2-2** contains both linear and nonlinear terms. When assuming the linear terms to be of $O(a/h)$ ($a$ = tidal amplitude, $h$ = depth), the nonlinear terms are of $O(a^2/h^2)$ and thus the importance of the nonlinear terms increases for increasing a/h.

The Loxahatchee River is not a one-dimensional channel because it has branches. However, **Equations 2-1** and **2-2** should apply piecewise with appropriate boundary conditions for each branch.

**Equations 2-1** and **2-2** can be solved numerically. In fact there is a more sophisticated three-dimensional hydrodynamic model available for the Loxahatchee River (Sun 2004). Here analytical expression is sought because analytical solution wherever possible is more intuitive and more revealing of the importance of various contributing factors. To derive the analytical expression, a simplified form of the momentum equation is used:

$$\frac{\partial q}{\partial t} + \frac{2}{h} q \frac{\partial q}{\partial x} + g(h+\eta)\frac{\partial \eta}{\partial x} = -\frac{F_1 q}{(h+\eta)} + \frac{\tau_W}{\rho} \qquad (2\text{-}3)$$

In which $F_1$ = linear friction factor.

Solutions to **Equations 2-1** and 2-3 for $q$ and $\eta$ can be sought in series of the form:

$$\eta = \eta^* + \eta_1(x,t) + \eta_2(x,t) + \ldots \qquad (2\text{-}4)$$

$$q = q^* + q_1(x,t) + q_2(x,t) + \ldots \qquad (2\text{-}5)$$

The functions $\eta_1$, $q_1$, $\eta_2$, $q_2$, etc. are periodic in time and it is assumed that if $\eta_1$ and $q_1$ are of $O(a/h)$, the others are of $O(a^2/h^2)$ or higher.

Substituting the series expansion of $\eta$ and $q$ into **Equations 2-1** and **2-3**, averaging over the tidal period and retaining only the terms of $O(a^2/h^2)$ or lower yields:

$$\frac{\partial q^*}{\partial x} = 0 \tag{2-6}$$

$$\frac{\partial}{\partial x}\left(\frac{\overline{q_1^2}}{h} + g\frac{\overline{\eta_1^2}}{2} + gh\eta^*\right) = -\frac{F_1 q^*}{h} + \frac{\tau_w}{\rho} \tag{2-7}$$

Where the over bar indicates tidal averaging.

Integrating **Equation 2-7** along two points $x1$ and $x2$:

$$(gh\eta^*)_{x1}^{x2} + \left(\frac{\overline{q_1^2}}{h} + g\frac{\overline{\eta_1^2}}{2}\right)_{x1}^{x2} = -q^*\int_{x1}^{x2}\frac{F_1}{h}dx + \int_{x1}^{x2}\frac{\tau_w}{\rho}dx \tag{2-8}$$

$$(gh\eta^*)_{x1}^{x2} + \left(\frac{q_A^2}{2h} + g\frac{a^2}{4}\right)_{x1}^{x2} = -q^*\int_{x1}^{x2}\frac{F_1}{h}dx + \int_{x1}^{x2}\frac{\tau_w}{\rho}dx \tag{2-9}$$

Where $q_A$ is the amplitude of $q$, and $a$ is the amplitude of $\eta_1$.

**Equation 2-9** can be used to estimate tidal averaged elevation at $x2$:

$$\eta_2^* = \eta_1^* - \frac{1}{gh_1}\left(\frac{q_A^2}{2h} + g\frac{a^2}{4}\right)_{x1}^{x2} - q^*\frac{1}{gh_1}\int_{x1}^{x2}\frac{F_1}{h}dx + \frac{1}{gh_1}\int_{x1}^{x2}\frac{\tau_w}{\rho}dx \tag{2-10}$$

Where $h$ is the water depth (assuming uniform water depth for simplicity), and $\eta_1^*$ and $\eta_2^*$ are tidal averaged SWE at $x1$ and $x2$, respectively.

The first term on the right-hand side of the equation is the downstream stage, the second term is the contribution from tide and it is a nonlinear term, the third term is the friction term which is dependent on the friction coefficient and tidal averaged flow $q^*$.

From **Equation 2-6** $q^*$ is spatially constant and should equal freshwater inflow Q or

$$q^* = -Q \tag{2-11}$$

The negative sign is due to the fact that Q is opposite to the x axis. The last term in **Equation 2-10** is the contribution from wind. An onshore wind would cause higher elevation. Although it would be difficult to numerically evaluate each term in **Equation 2-10** without a numerical model, it clearly suggests the potentially important relationship between stages upstream and downstream and freshwater inflow.

The theoretical analysis was encouraging. It is possible to use data collected to demonstrate or confirm the relationship as shown by **Equation 2-10**. For this purpose, SWE data collected at RM 9.1 (upstream) and USCG dock stations were daily averaged. The relationship between daily averaged SWE at RM 9.1 and daily flow from Lainhart Dam and other sources into the Northwest Fork was sought using regression analysis.

**Figure 2-9** shows the stage-flow relationship at RM 9.1 on a daily basis. **Figure 2-10** shows the relationship between daily averaged stage difference between RM 9.1 and the USCG dock stations and total daily flow into the Northwest Fork. The results show, as one would expect, a positive stage-flow relationship ($R^2$=0.32) at RM 9.1, but the correlation is significantly enhanced ($R^2$=0.55) if the stage difference is used instead of the stage at RM 9.1 itself, and this confirms what is predicted by **Equation 2-10**. The enhanced correlation between stage difference and freshwater inflow indicates the upstream tidal floodplain stage could be influenced by downstream stage and, therefore, low frequency (subtidal) variation, including sea level rise at open sea, could have a significant impact on the stage and inundation at the upstream locations. **Figure 2-9** and **Figure 2-10** also suggest higher inflow into the Northwest Fork will result in higher stage upstream including both tidal and riverine floodplains and the influence is monotonic, meaning as long as the inflow increases, the stage will increase. And when inflow is small, for example at around 35 cfs (minimum flow level), its influence could be insignificant and the influence of downstream stage could be a more important factor (**Figure 2-11**). However, a more accurate quantitative analysis and a more sophisticated model are needed to determine the relative importance of each contributing factor.

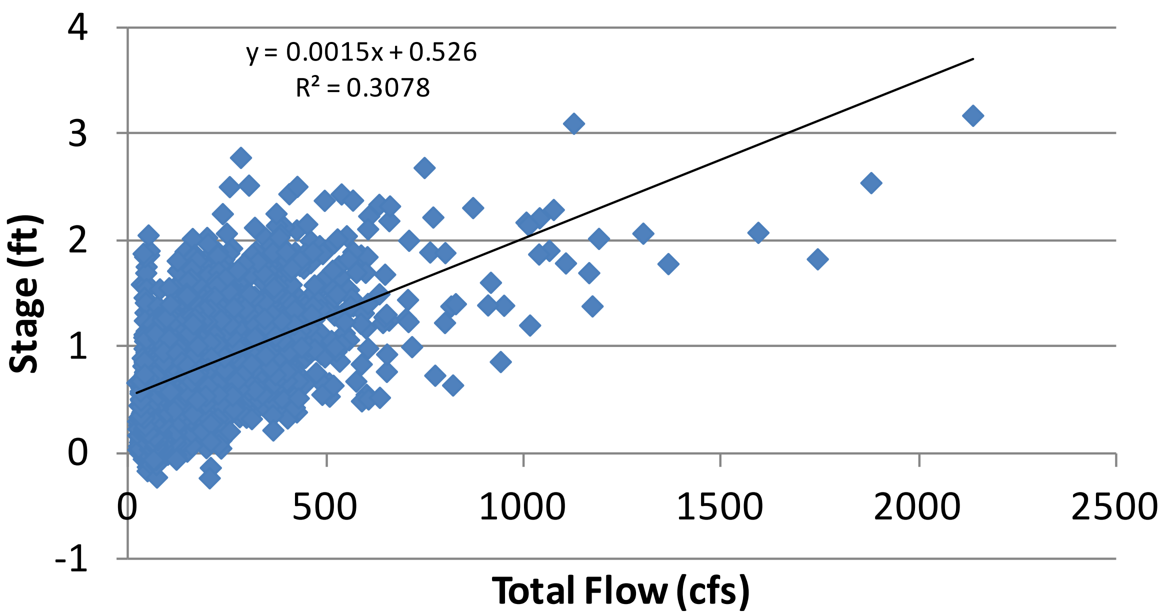



**Figure 2-9. Relationship between daily averaged stage and total daily flow into the Northwest Fork**

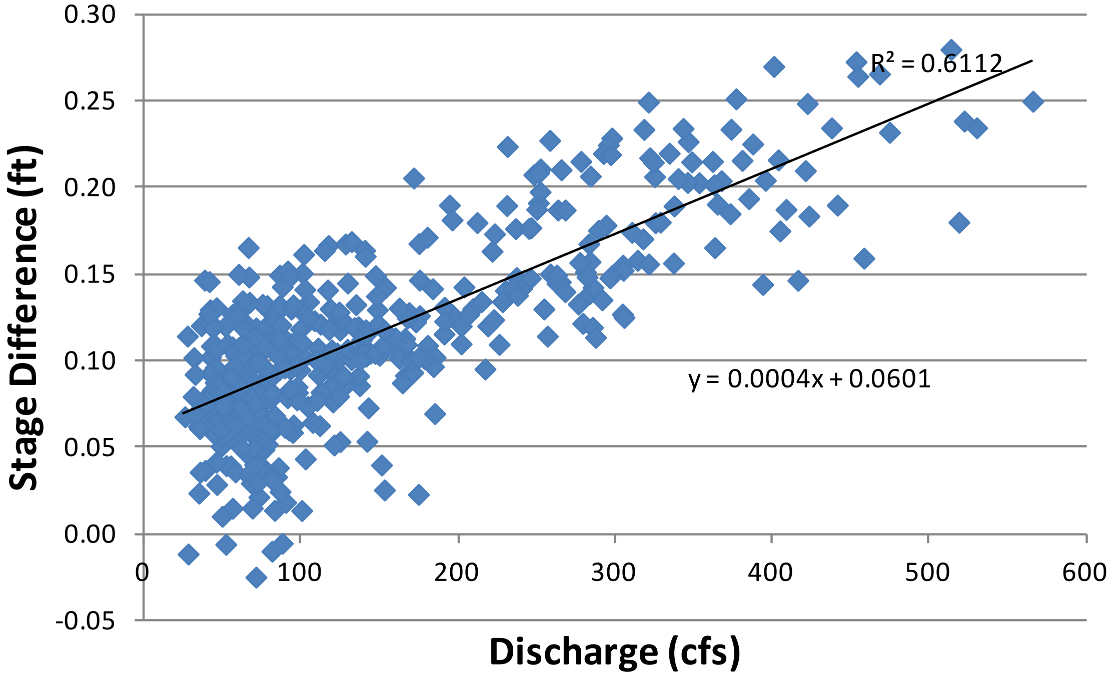



**Figure 2-10. Relationship between daily averaged stage difference between RM 9.1 and the USCG dock stations and total daily flow into the Northwest Fork**

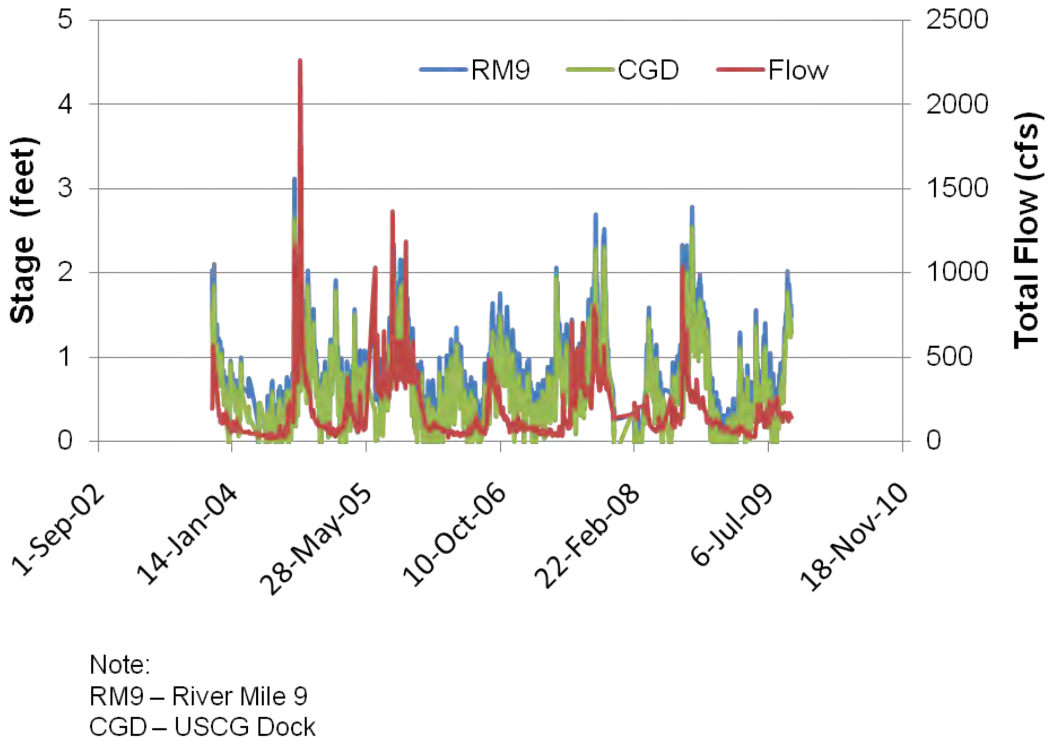
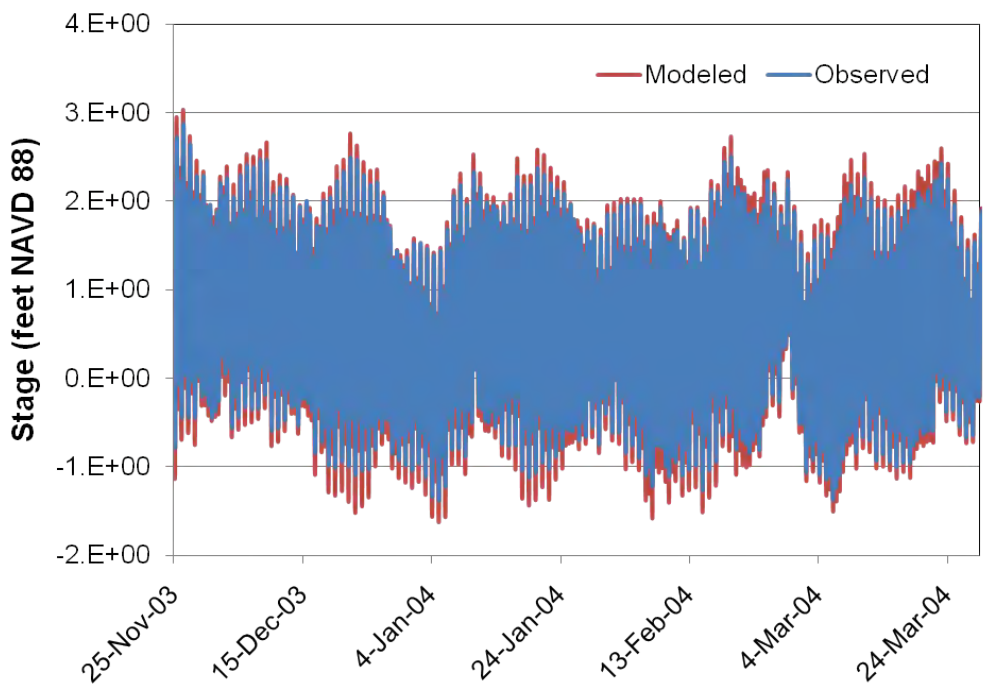



**Figure 2-11. Daily averaged stages at RM 9.1 (blue) and USCG dock (green) stations and daily total inflow (red) into the Northwest Fork**

To further evaluate the contributing factors affecting stage, a Curvilinear Hydrodynamic Three-Dimensional (CH3D) model (Sheng 1986), was applied to the Loxahatchee River Estuary. This model was already calibrated, verified and applied to the Loxahatchee River to study the feasibility and effectiveness of saltwater barriers for the prevention of saltwater intrusion (Sun 2004). For the present analysis, results from the model simulation for the period from January 2003 to April 2004 (**Figure 2-12** and **Figure 2-13**) for SWE and salinity at RM 9.1 were analyzed according to **Equation 2-10**. Daily average values of SWE at the USCG dock and RM 9.1 stations were obtained along with amplitudes of tide and total discharges. Daily average wind stresses were also computed. Each of the terms in the right-hand side of **Equation 2-10** was evaluated. **Figure 2-14** shows the three contributing factors to the daily averaged stage difference between the RM 9.1 and USCG dock stations. Stage fluctuates day to day depending on wind direction (onshore or offshore). On average, wind effect is small. Nonlinearity due to interaction between tide and the mean motion can cause tidal setup similar to wave setup on beaches. The contribution from this nonlinear mechanism is noticeable but minor relative to the bottom friction, which is clearly the dominant term. **Figure 2-15** shows the linear regression between model-computed daily averaged stage difference and the freshwater inflow into the Northwest Fork. The $R^2$, 0.61, is close to the $R^2$ from the data analysis (**Figure 2-10**). This shows the dynamics are well represented in the CH3D model and it confirms the relationship between daily averaged stage difference and bottom friction from both the analytical solution and empirical analysis.




Note:
NAVD 88 – North American Vertical Datum of 1988

**Figure 2-12. CH3D modeled SWE compared with observation at RM 9.1 December 2003–March 2004**

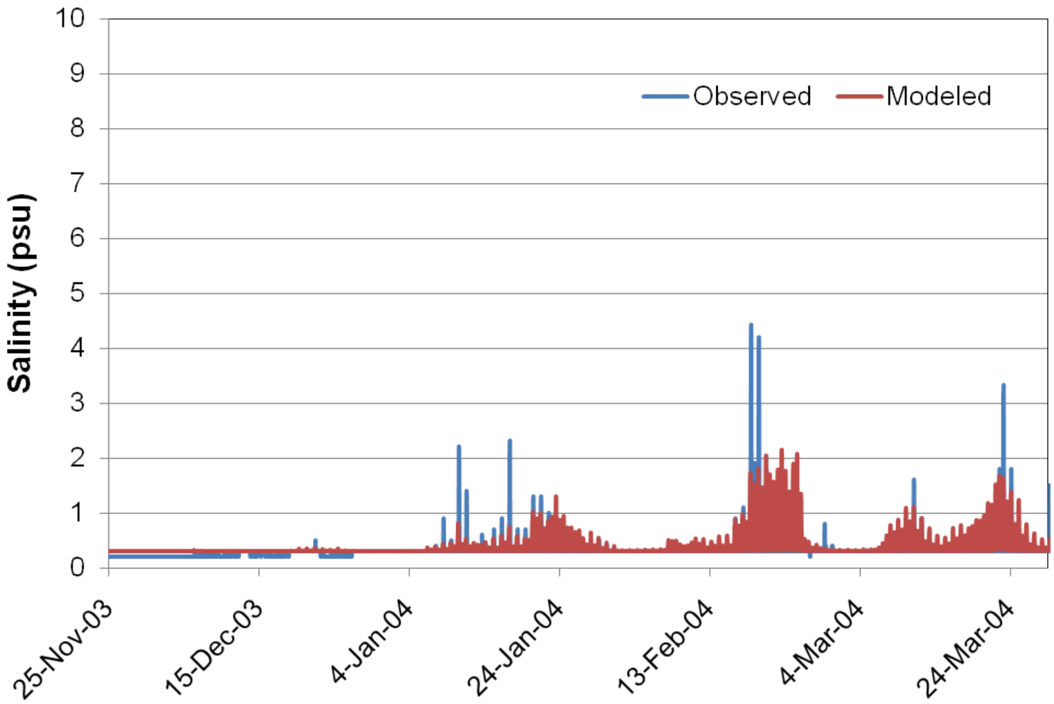



**Figure 2-13. CH3D modeled salinity compared with observation at RM 9.1 December 2003–March 2004**

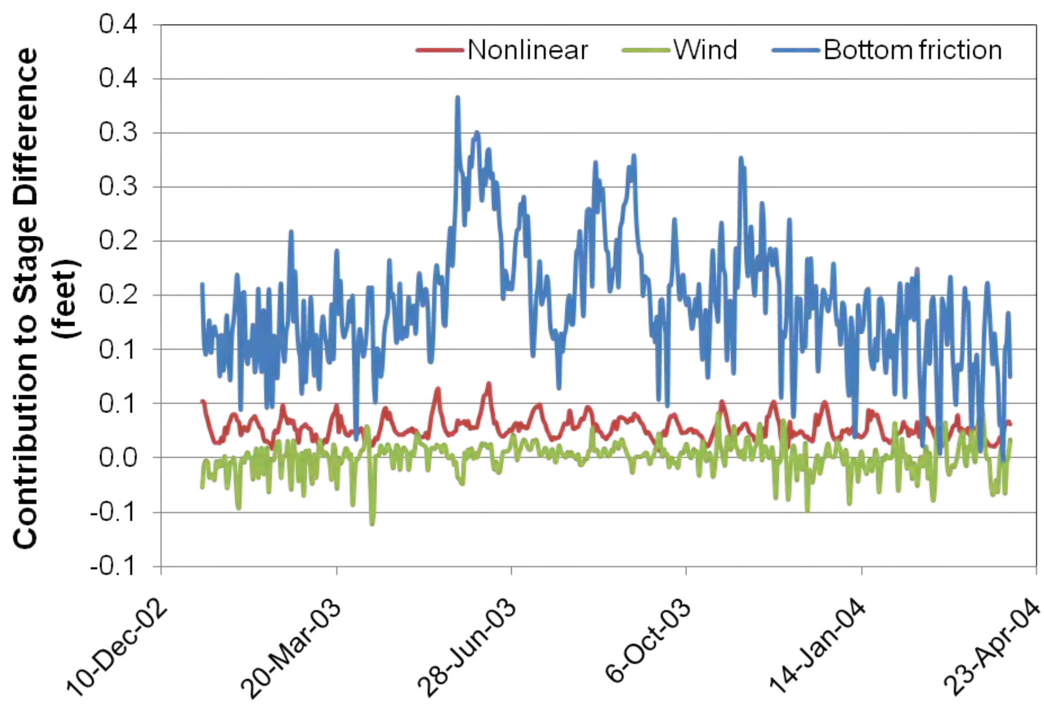



**Figure 2-14. Bottom friction, nonlinear interaction between tide and residual flow and wind effect on mean (daily averaged) stage differences between RM 9.1 and USCG dock stations as numerically evaluated by the CH3D model**

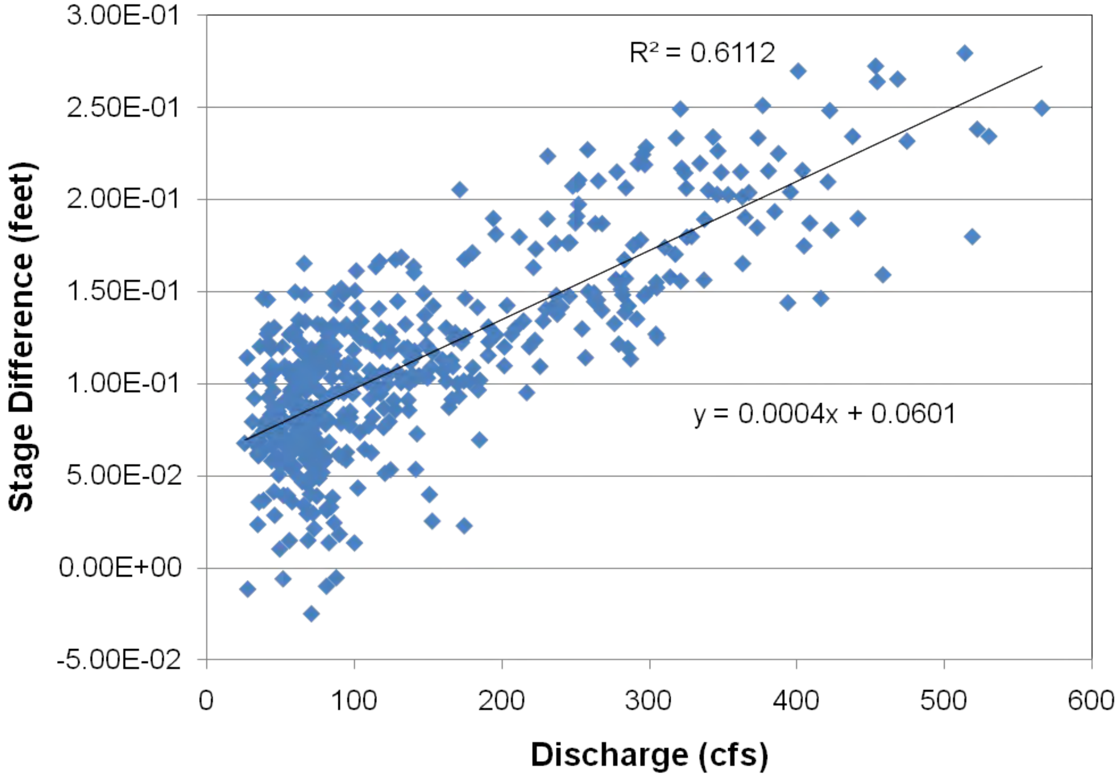



**Figure 2-15. Relationship between daily averaged stage difference between RM 9.1 and USCG dock stations and total daily flow into the Northwest Fork, same as Figure 2-10, but stages were computed by the CH3D model**

## 2.4 Soil Moisture, Groundwater Salinity and Pore Water Salinity

Soil moisture, groundwater salinity and pore water salinity monitoring within the Northwest Fork floodplain are part of the monitoring program established by the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006). Up to 2009, measured soil and groundwater data were available and SFWMD funded University of Florida scientists to conduct a series of analysis on floodplain soil and groundwater data. The overall objective of the analyses was to develop relationships between surface water, groundwater and soil moisture to better predict the effects of proposed restoration and management scenarios on ecological communities in the floodplain. This is achieved by long-term experimental characterization of soil moisture and pore water salinity dynamics in the floodplain at several depths and distances from the river — complemented by surface water and groundwater stage and salinity, and meteorological monitoring — to identify differences between areas with varying soils, hydrology and vegetation. This section provides a summary of the analyses presented in reports and products submitted by the University of Florida scientists (Muñoz-Carpena et al. 2007, 2008, 2009; Kaplan et al. 2010), as well as recently conducted exploration of pore water salinity dynamics in the floodplain.

### 2.4.1 Soil Moisture

Probes were deployed and installed along vegetation transects T1 and T7 (**Figure 3-1**) to measure soil moisture, EC and temperature. Each transect had four monitoring locations and at each location probes were placed at three different depths (**Figure 2-16**). Data collection began in September 2004 at transect T1 and in January 2005 at transect T7 and continued through September 2008. Descriptions of transects T1 and T7 can be found in **Section 3.0**.

In order to compare and conduct soil moisture analysis of different soil types, the actual (measured) soil moisture data were normalized using effective soil moisture, which scales values from 0 to 1 and is calculated by the following equation:

$$\Theta_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \qquad (2\text{-}12)$$

Where,
$\Theta_e$ = effective soil moisture content (-)
$\theta$ = actual (measured) soil moisture content (cubic meters per cubic meters [$m^3m^{-3}$])
$\theta_r$ = residual soil moisture content ($m^3m^{-3}$)
$\theta_s$ = saturated soil moisture content ($m^3m^{-3}$)

Relationships between effective soil moisture content ($\Theta_e$) and SWE at the river were explored at each transect.

For the 12 measurement locations at upstream transect T1, average daily effective soil moisture content ($\Theta_e$) in the floodplain versus average daily SWE of Lainhart Dam headwater was fit to a common model (sigmoid, two parameters) of the following form:

$$\Theta_e = \frac{1}{1 + e^{-(\frac{h-a}{b})}} \qquad (2\text{-}13)$$

Where,
$h$ = river stage elevation measured at Lainhart Dam (m NGVD)
$a$ = curve parameter
$b$ = curve parameter

**Figure 2-17** shows the fit with good results (overall Nash-Sutcliffe Coefficient $C_{eff}$ = 0.92 for the 12 soil moisture measurement locations). The fit curve parameters for each measurement location are shown in **Table 2-3**.

Values of saturated soil moisture content ($\theta_s$) for the three soil groups given in Mortl (2006) were based on composite soil samples and did not represent the variability in saturated soil moisture content ($\theta_s$) observed on transect T1, especially in the layered soil of the fluvent.

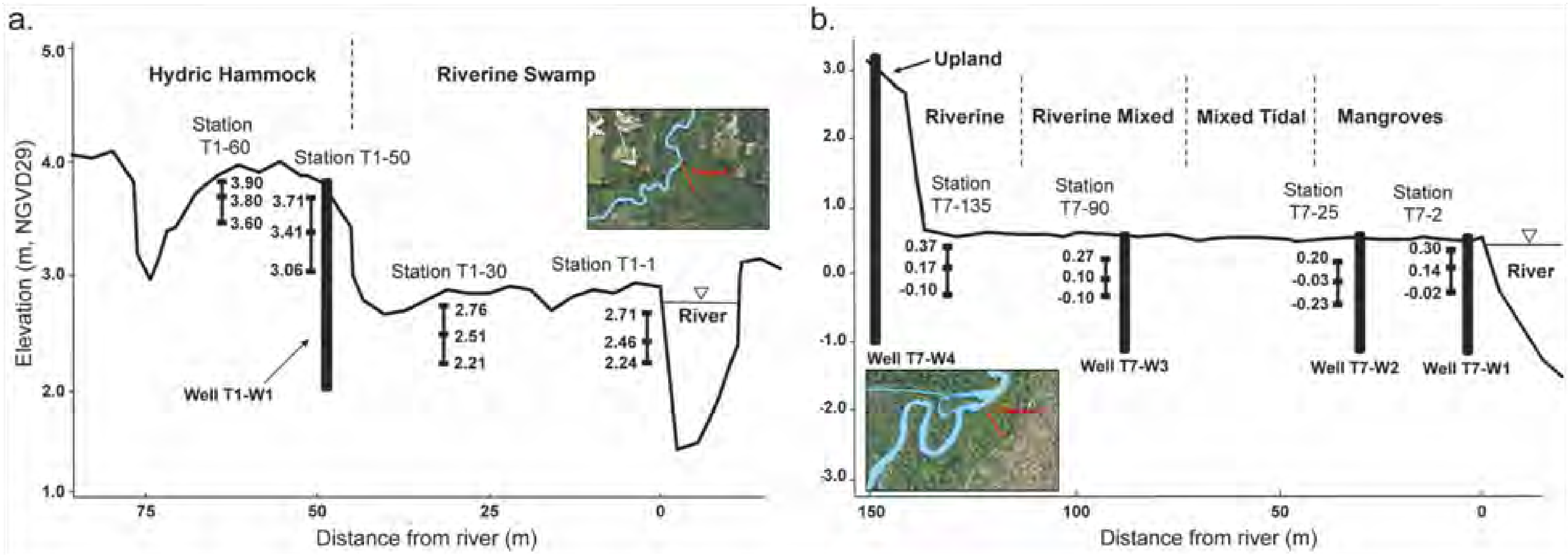



**Figure 2-16. Topography, layout of vadose zone monitoring stations and groundwater wells, and dominant vegetation communities on (a) T1 and (b) T7 with probe installation elevations listed below each station**

(after Kaplan et al. 2010)

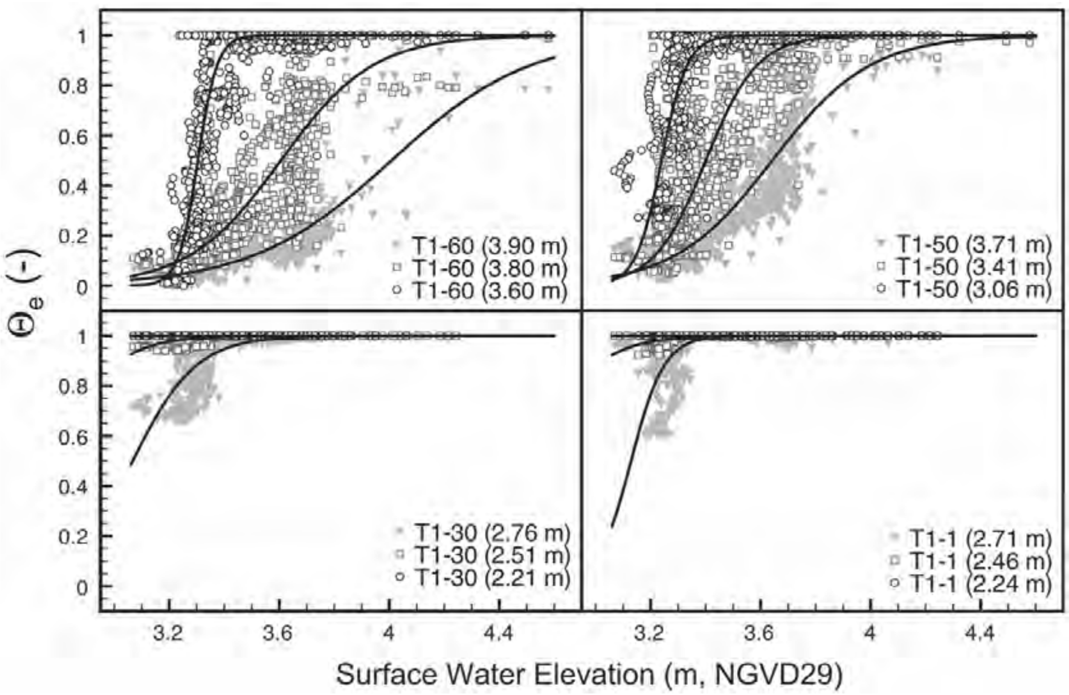



**Figure 2-17. Observed (symbols) and modeled (lines) effective soil moisture ($\Theta_e$) versus surface water elevation at Lainhart Dam for the 12 monitoring locations on T1**

m, NGVD29 – meters National Geodetic Vertical Datum of 1929

**Table 2-3. Saturated soil moisture content ($\theta_S$) used to calculate effective soil moisture ($\Theta_e$) and curve parameters a and b fit to Equation 2-13 to model effective soil moisture ($\Theta_e$) as a function of SWE on T1**

| Probe Number | Elevation (ft) | Elevation (m) | Saturated Soil Moisture Content ($\theta_S$) | Curve Parameters | | Nash-Sutcliffe Coefficient ($C_{eff}$) |
|---|---|---|---|---|---|---|
| | | | | a | b | |
| T1-60 | 12.80 | 3.90 | 0.40 | 3.91 | 0.24 | 0.64 |
| T1-60 | 12.47 | 3.80 | 0.35 | 3.63 | 0.15 | 0.72 |
| T1-60 | 11.81 | 3.60 | 0.28 | 3.33 | 0.06 | 0.78 |
| T1-50 | 12.17 | 3.71 | 0.34 | 3.63 | 0.16 | 0.77 |
| T1-50 | 11.19 | 3.41 | 0.35 | 3.41 | 0.07 | 0.82 |
| T1-50 | 10.04 | 3.06 | 0.33 | 3.26 | 0.06 | 0.65 |
| T1-30 | 9.06 | 2.76 | 0.74 | 3.01 | 0.12 | 0.54 |
| T1-30 | 8.24 | 2.51 | 0.74 | 2.75 | 0.12 | 0.33 |
| T1-30 | 7.25 | 2.21 | 0.71 | —§ | —§ | 1.00 |
| T1-1 | 8.89 | 2.71 | 0.80 | 3.13 | 0.09 | 0.51 |
| T1-1 | 8.07 | 2.46 | 0.75 | 2.76 | 0.12 | 0.34 |
| T1-1 | 7.35 | 2.24 | 0.63 | —§ | —§ | 1.00 |

Although consideration of rain, evapotranspiration (ET), antecedent moisture conditions and surface topography would improve the model's predictive ability, this simplified relationship is useful for evaluating the effects of river management on actual (measured) soil moisture content ($\theta$) profiles because MFL and restoration scenarios are based on flow at the Lainhart Dam.

A nomograph describing effective soil moisture content ($\Theta_e$) at transect T1 was developed based on the simpler model (**Figure 2-18**), which can be used to estimate moisture profiles across the floodplain under different management scenarios. For example, the MFL of 35.31 cfs (1 cubic meter per second) corresponds to 10.86 ft (3.31 m) head water stage at Lainhart Dam (vertical dashed line in **Figure 2-18**). This yields a $\Theta_e$ profile ranging from 0.06 on top of the hydric hammock (on the 3.9 m curve) to 1.00 in the consistently flooded soils of the floodplain (on the < 2.5 m curve), with $\Theta_e = 0.86$ at the lower floodplain soil surface (average elevation 2.81 m; filled black circle in **Figure 2-18**).

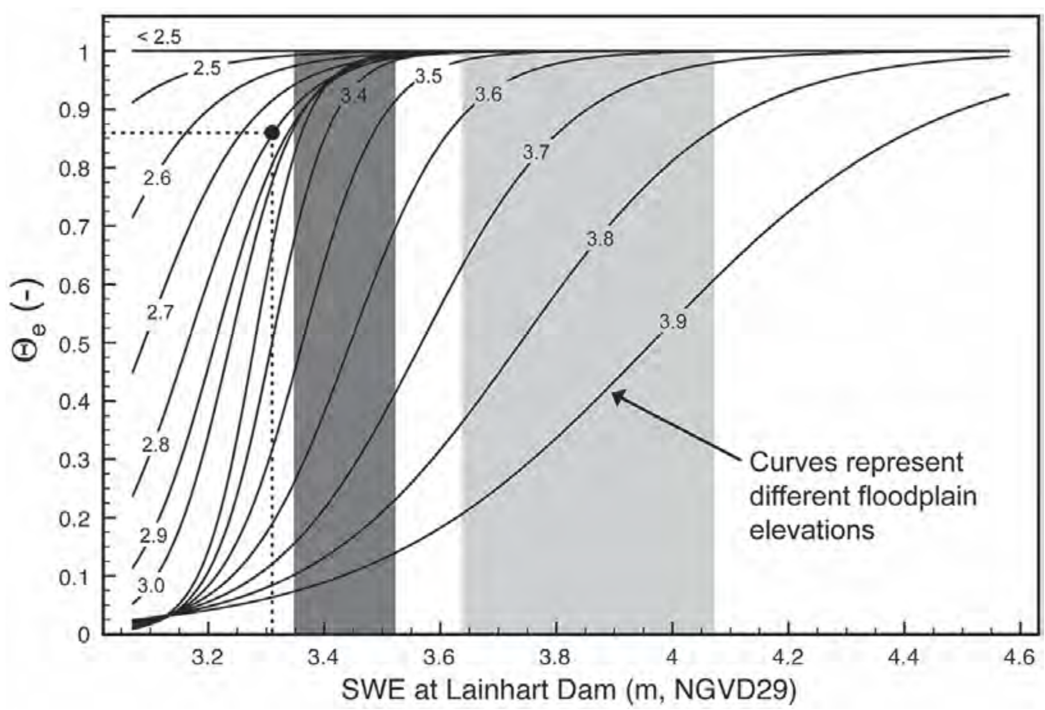



**Figure 2-18. Nomograph for estimating effective soil moisture ($\Theta_e$) profiles along T1 based on SWE at Lainhart Dam and soil elevation (m NGVD29; labeled on curves).**

Filled circle represents at the average soil surface elevation, which is 9.22 ft (2.81 m) in the lower floodplain under the minimum flow level (SWE = 10.86 ft [3.31 m]).

Dark-shaded area corresponds to dry season flow levels, which is 10.99 ft ≤ SWE ≤ 11.55 ft (3.35 m ≤ SWE ≤ 3.52 m) (identified in the restoration plan [SFWMD 2006]).

Light-shaded area corresponds to wet season floods with one- to two-year return interval, which is 11.94 ft ≤ SWE ≤ 13.35 ft (3.64 m ≤ SWE ≤ 4.07 m) (identified in the restoration plan [SFWMD 2006]).

m, NGVD29 is meters National Geodetic Vertical Datum of 1929.

At transect T7, due to daily tidal inundation, actual soil moisture content ($\theta$) was relatively consistent over the study period, with very little variation regardless of elevation or distance from the river. However, inspection of actual soil moisture content ($\theta$) data from the highest elevation (i.e., shallowest) probe revealed a correlation between actual soil moisture content ($\theta$) and river stage. **Figure 2-19** shows a six-day time series of soil moisture for the highest elevation probe on transect T7 (T7-135; 1.21 ft [0.37 m]). Fourier smoothing of 30-minute actual soil moisture content ($\theta$) data and 15-minute river stage data to six-hour time series reveals that when mean river stage is above the probe elevation, actual soil moisture content ($\theta$) and river stage are tightly coupled, with coinciding peaks and valleys corresponding to low and high tides. When mean tide drops below probe elevation, this relationship breaks down, and the surface soil continues to dry (though slightly). The total range of variation in soil moisture observed at transect T7 is small (a change of 1.24 percent between saturation and "drawdown" moisture contents in **Figure 2-19**), and is unlikely to affect seed germination or seedling survival at this transect. Instead, germination and seedling survival are likely more limited by tidal inundation range and periods of high river stage and pore water salinity.

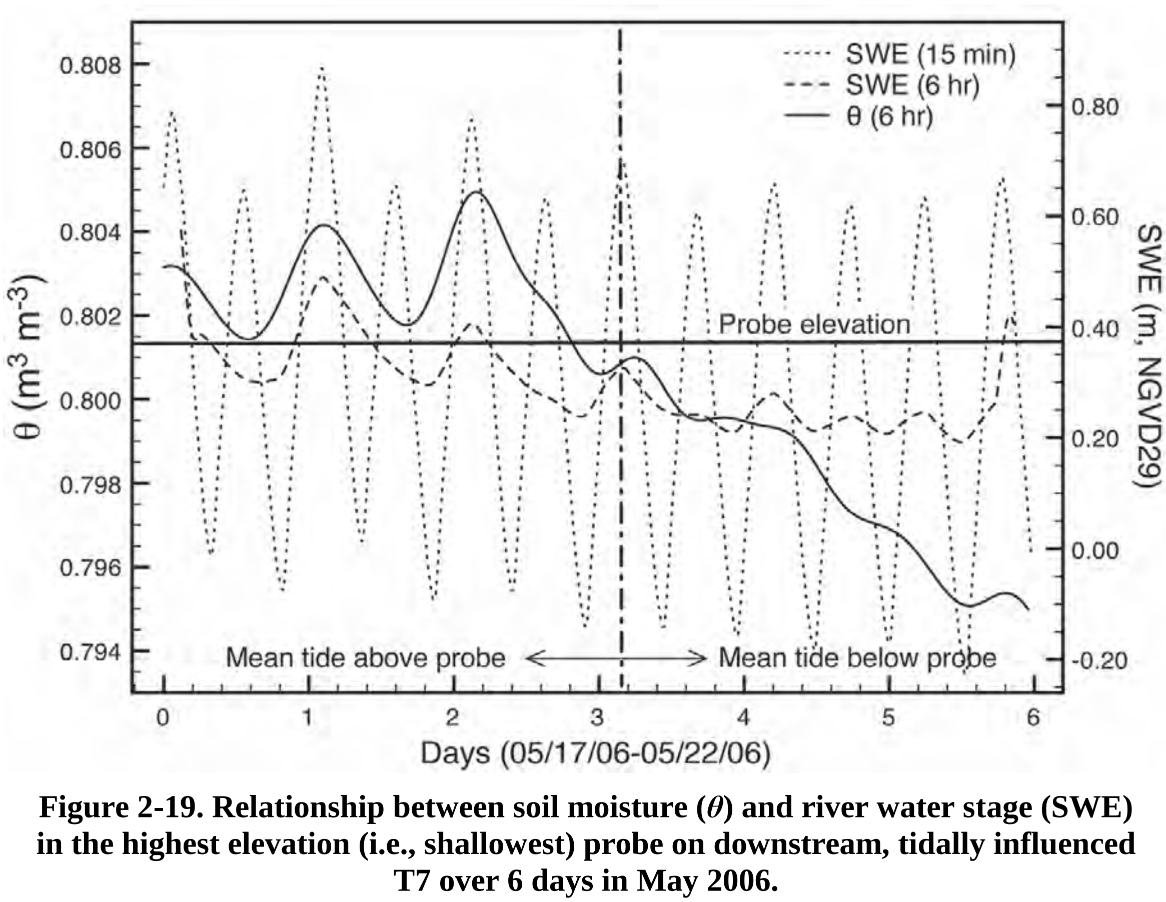



**Figure 2-19. Relationship between soil moisture ($\theta$) and river water stage (SWE) in the highest elevation (i.e., shallowest) probe on downstream, tidally influenced T7 over 6 days in May 2006.**

Changes in soil moisture were small (~1 percent) and tightly coupled with SWE but only when mean tide was above probe elevation.

m, NGVD29 – meters National Geodetic Vertical Datum of 1929

### 2.4.2 Groundwater Stage

Groundwater stage data from 2005 to 2008 at 12 wells along four transects (**Figure 2-5**) were collected and processed. Preliminary data analysis shows river stages in the Northwest Fork, where available, correlate well with groundwater elevations in upriver and tidal locations further confirming the reliability of the final groundwater data sets. Also, on the transitional transects T7 and T8, a general progression of increasing water table with distance from the river is apparent, with the upland wells exhibiting higher water elevations than bottomland floodplain wells. During the 2006–2007 dry season, this freshwater head falls sharply, nearly equalizing with water table elevations in the floodplain, but always remaining higher. This indicates a variable flow of fresh water from the uplands towards the river, even in extremely dry seasons.

Description and modeling of hydroperiod, groundwater elevation and salinity, soil moisture and soil pore water salinity are essential to understanding the hydrological and ecological functioning of the floodplain forest (e.g., Mitsch and Gosselink 2000) where Valued Ecosystem Components (VECs) live and die. However, finding direct relationship between basic hydrological inputs (rainfall, river stage, river salinity, etc.) is not always straightforward (Ritter et al. 2009) because of the complex interactions between surface water, groundwater, and pore water in a variably saturated matrix with heterogeneous soils, vegetation and topography.

In order to investigate the relationship between groundwater stages and other associated impact factors, dynamic factor analysis (DFA) was applied to study the interactions between hydrological conditions in the floodplain and other hydrological variables obtained throughout the Loxahatchee River watershed. DFA is a dimension reduction technique originally developed for the interpretation of economic time series (Geweke 1977). It is a multivariate application of classic time series analysis and can be a powerful tool for the modeling of short, incomplete, nonstationary time series in terms of common trends and explanatory variables (Zurr et al. 2003b). With DFA, underlying temporal variation in observed data (input time series) is modeled as linear combinations of common trends (unexplained variability), a constant level (or intercept) parameter, zero or more explanatory variables (additional observed time series), and noise (Zuur et al. 2003a). Like other time series models, DFA aims to maintain a good fit while minimizing the number of common trends, and thus, model selection is made using Akaike's information criterion, which includes a penalty for each additional estimated parameter (Akaike 1974, Zuur et al. 2003a).

DFA is based on the structural time series models (Harvey 1989), and provides for the description of a time series with N response variable using a dynamic factor model consisting of a combination of M common trends, K explanatory variables, a level or intercept parameter and noise (Lütkepohl 1991, Zuur et al. 2003a):

$$H_{gwt,n}(t) = \sum_{m=1}^{M} \gamma_{m,n}\alpha_m(t) + \mu_n + \sum_{k=1}^{K} \beta_{k,n}\nu_k(t) + \varepsilon_n(t) \qquad \text{(2-14)}$$

Where,

$H_{gwt,n}(t)$ I = size *N* (*1* $\le n \le N$) vector containing the groundwater stages at time *t*

$\alpha_m(t)$ = length *M* (*1* $\le m \le N$) vector containing the common unknown patterns at time *t*

$\gamma_{m,n}$ = factor loadings or weighting coefficients for each $\alpha_m(t)$ pattern

$\beta_{k,n}$ = fitted regression parameter for the *k-th* (for $1 \leq k \leq K$) explanatory variable $v_k(t)$

The constant level parameter $\mu_n$ shifts up or down each linear combination of common patterns.

K corresponds here to the number of explanatory variables considered in the DFA.

In this study, the following hydrological variables were included: (1) river stages at Lainhart Dam head water, RM 9.1, Kitching Creek up/downstream, Boy Scout dock, and USCG dock; (2) groundwater table elevation from wells near the Loxahatchee River including M1001, M1024, M1048, M1234, M1255, M1261, PB565, PB689 and PB1642; (3) cumulative net rainfall (rainfall minus ET) from weather stations at the S-46 structure (NR S46) and in Jonathan Dickinson State Park (JDWX) in the Loxahatchee River watershed. Locations of USGS wells and rainfall gauge stations are shown in **Figure 2-20**.

The hydrological data collected during this study represent a wide range of climatic conditions. These include four wet-dry seasonal cycles, two wet years with hurricane-induced flooding (2004 and 2005), and the driest two-year period (2006 to 2007) recorded in south Florida since 1932 (Neidrauer 2009).

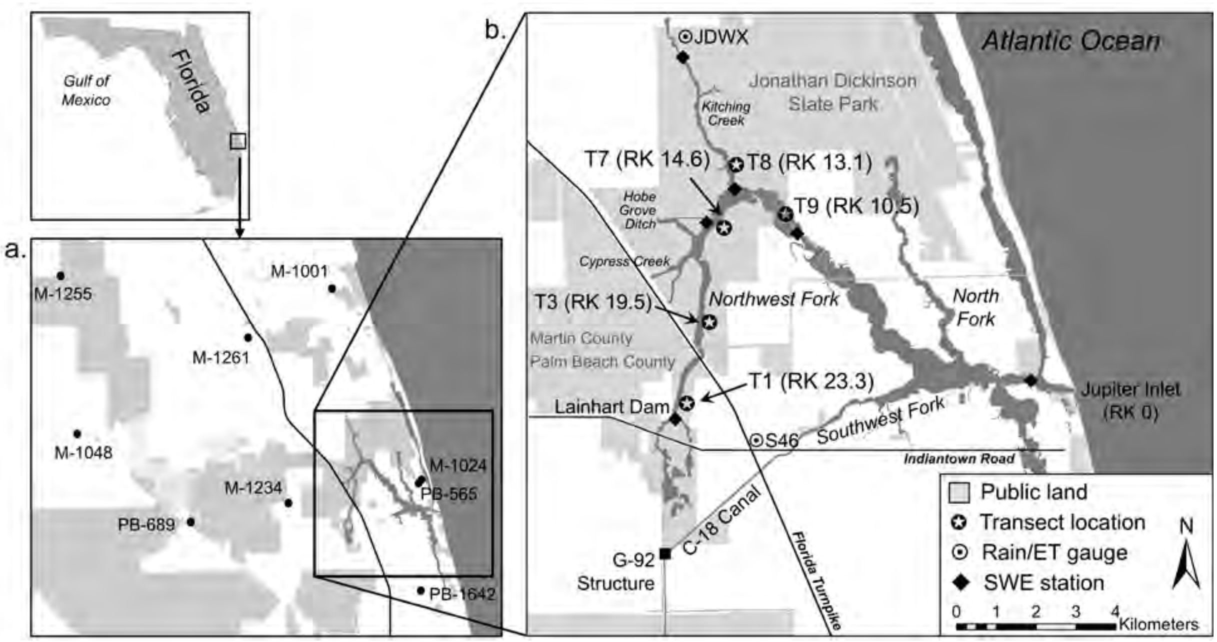



**Figure 2-20. The Loxahatchee River and surrounding area, showing (a) the location of USGS wells (WTE_R) used in this study and (b) transect locations (T1, T3, T7, T8 and T9), surface water elevation (SWE) and meteorological measurement locations, and major hydraulic infrastructure.**

Transect notation is followed by distance from river mouth (river kilometer [RK]).
NR_S46 is the S-46 structure.
After Kaplan et al. (2010).

Through DFA, a final multilinear regression model was developed with only five explanatory variables identified as significantly contributing to floodplain groundwater variation. This model has an overall Nash Sutcliffe coefficient of efficiency $C_{eff}$ ($-\infty \leq C_{eff} \leq 1$) (Nash and Sutcliffe 1970) value of 0.81 ($0.59 \leq C_{eff} \leq 0.94$). The model does a good job predicting groundwater stages in higher elevation wells farthest from the river and in lower elevation wells close to the river, and a fair job for middle distance and elevation wells. The model parameter and coefficients of efficiency $C_{eff}$ are presented in **Table 2-4**.

**Table 2-4. Constant level parameters ($\mu_n$), model parameters and coefficients of efficiency ($C_{eff}$) from a multilinear regression model[1]**

| Well | $\mu_n$ | Model Parameters ($\beta_{k,n}$) | | | | | $C_{eff}$ |
|---|---|---|---|---|---|---|---|
| | | River Stage at Lainhart Dam | River Stage at RM 9.1 | Net Rainfall at S-46 | Net Rainfall at JDWX[2] | Regional Groundwater Stage at M1001 | |
| T1W1 | 0.0 | 0.69 | -0.09 | 0.41 | 0.07 | -0.02 | 0.91 |
| T3W1 | 0.0 | 0.70 | -0.06 | 0.35 | 0.08 | 0.00 | 0.94 |
| T7W1 | 0.0 | -0.07 | 0.95 | 0.09 | 0.08 | -0.05 | 0.93 |
| T7W2 | 0.0 | 0.07 | 0.86 | 0.09 | -0.05 | -0.31 | 0.76 |
| T7W3 | 0.0 | 0.13 | 0.65 | -0.32 | 0.42 | 0.30 | 0.59 |
| T7W4 | 0.0 | 0.18 | 0.03 | 0.68 | 0.07 | 0.23 | 0.91 |
| T8W1 | 0.0 | 0.18 | 0.78 | 0.07 | -0.38 | -0.09 | 0.80 |
| T8W2 | 0.0 | 0.06 | 0.55 | 0.35 | -0.12 | 0.01 | 0.68 |
| T8-W3 | 0.0 | -0.34 | -0.04 | 0.69 | -0.05 | -0.04 | 0.81 |
| T9-W1 | 0.0 | -0.12 | 0.87 | 0.10 | -0.06 | -0.11 | 0.81 |
| T9-W2 | 0.0 | 0.12 | 0.87 | -0.04 | -0.17 | 0.15 | 0.86 |
| T9-W3 | 0.0 | 0.14 | 0.38 | 0.5 | -0.01 | 0.05 | 0.77 |
| | | | | | | Overall | 0.81 |

[1]After Muñoz-Carpena et al. (2009).

[2]The weather station within Jonathan Dickinson State Park.

Closer to the edges of the system, explanatory variables act as boundary conditions (regional groundwater stage at the farthest landward end of transects and river stage at the river) and their effects can be seen directly in the floodplain groundwater stage series. In middle distance and middle elevation wells, the interaction of surface water and groundwater is most complex and nonlinear, which is not as well captured by a linear combination model. Despite these limitations, overall performance of the model is adequate to describe variation in groundwater stage in the Loxahatchee River floodplain and may be useful in assessing Loxahatchee River restoration scenarios, especially considering the wide range of climatic conditions captured in the study. This empirical model may be deemed useful for assessment of the effect of Loxahatchee River restoration and management scenarios on water table elevation dynamics, including increased groundwater withdrawals, sea level rise, and changes in rainfall and ET patterns associated with climate change.

### 2.4.3 Groundwater Salinity

Groundwater EC data used to determine groundwater salinity was collected from the 12 wells along the five transects discussed in previous sections and shown in **Figure 2-20.** Trends in EC can be observed over individual tidal cycles as well as over longer seasonal and yearly time periods. In general, the EC values recorded were low upstream and increased with proximity to the Jupiter Inlet and Atlantic Ocean. On transects with multiple wells, observed EC was generally greatest closest to the river and decreased with distance towards uplands. Seasonal variation in groundwater temperature was observed in all 12 groundwater wells. Seasonal amplitude of these variations appears to be greatest at the river and decreases with distance to the river. This trend could be used to explore mixing ratios between groundwater and surface water in the floodplain.

### 2.4.4 Porewater Salinity

At transect T1, pore water and groundwater salinity were low and had similar magnitudes, with averages of 0.054 and 0.068 Siemens per meter (S/m), respectively. Salinity remained well below the 0.3125 S/m threshold over the entire study period. In the floodplain, porewater salinity was consistently two to three times higher than river water and groundwater salinity, although no consistent relationships between porewater salinity and other hydrological or meteorological variables were found. Values of porewater salinity were highest in the surface soils closest to the river and exceeded the 0.3125 S/m threshold slightly for 59 days in 2007. Based on the data recorded in this study, it is unlikely that pore water salinity reaches a high enough level to cause acute salt stress to bald cypress (*Taxodium distichum*) along transect T1 even during extended dry periods. The salinity may cause chronic stress for shallow-rooted, salt-sensitive species, however, which could be ameliorated by more frequent, longer duration inundation of the floodplain by the adjacent, low salinity surface water (Abrol et al. 1988, Richardson and Hussain 2006).

In order to explore the porewater-salinity relationship with other hydrologic factors, the porewater salinity variation of two monitoring sites along transect T7 (**Figure 2-21e** for T7-135 and **Figure** 2-21**f** for T7-25) are plotted together with rainfall data (**Figure 2-21a**), river stage at RM 9.1 (**Figure 2-21a**), groundwater stage (**Figure 2-21b**), groundwater EC (**Figure 2-21c**) and surface water EC (**Figure 2-21d**). River stage at RM 9.1 is influenced primarily by daily and monthly tidal cycles, although high water events may also be associated with storm surges and large rainfall events. For example, the high river stage in September 2004 was caused by tidal surges and increased freshwater flows during Hurricanes Frances and Jeanne (**Figure 2-21a**). Groundwater stage in the upland well (T7-W4) showed responses to wet and dry season rainfall patterns similar to those observed in upstream river and groundwater stages at T1 (**Figure 2-21b**, upper line). During the 2006 and 2007 dry seasons, groundwater stage in this well fell considerably, but remained higher than groundwater stages in floodplain wells (**Figure 2-21b**, lower lines), which were lower (close to mean sea level) and more influenced by daily tidal oscillations. This indicates a variable, but consistently positive, flow of fresh water from the uplands to the river through the floodplain, even under extreme drought conditions.

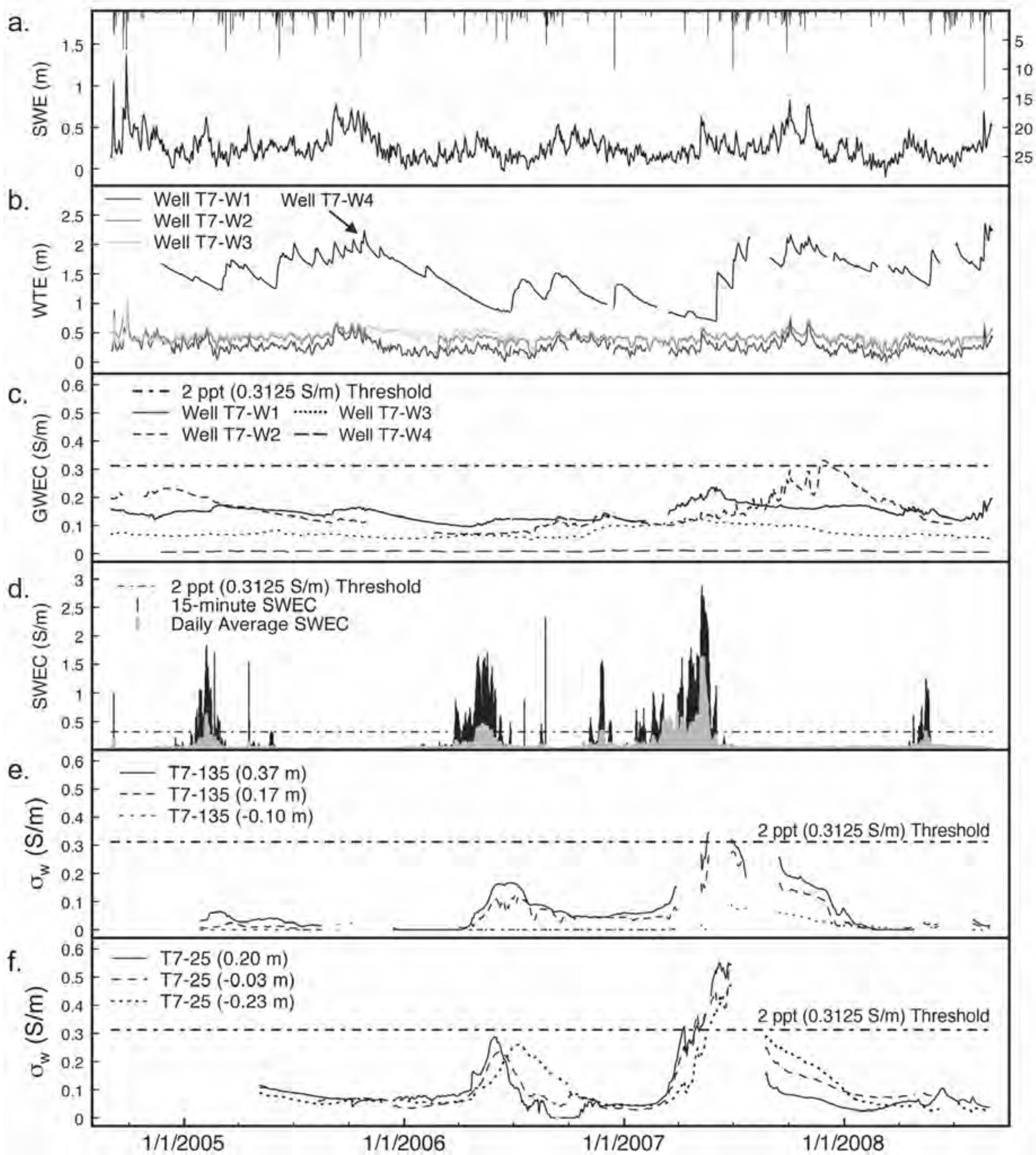



**Figure 2-21. (a) River stage (SWE) and rainfall, (b) groundwater stage (water table elevation), (c) groundwater EC, and (d) surface water EC measured at selected stations on or near downstream T7 and (e) soil pore water EC at T7-135 and (f) soil pore water EC at T7-25**

WTE – water table elevation
GWEC – groundwater EC
SWEC – surface water EC
$\sigma_w$ – soil pore water EC

cm – centimeters
ppt – parts per thousand; equivalent to practical salinity units (psu)

Upland well T7-W4 had the lowest groundwater salinity along T7 (**Figure 2-21c**, lower hashed line).[1] This low groundwater salinity, combined with the high groundwater stage in the uplands, likely plays a role in regulating pore water and groundwater salinity in the floodplain, mitigating the severity of saltwater intrusion at this transect. **Figure 2-21c** shows that groundwater salinity was generally highest closest to the river and decreased toward the uplands, although this trend reversed in 2007, when groundwater salinity in well T7-W2 surpassed that of well T7-W1 for the duration of the year before falling in 2008. Groundwater salinity approached the 0.3125 S/m threshold only briefly at the end of 2007 in well T7-W2, several months after peaks in river and pore water salinity (**Figure 2-21d**, **e** and **f**). Based on these results, it is unlikely that groundwater directly contributes to increases in the pore water observed on this transect; instead, groundwater salinity shows a damped and delayed response to high salinity in river water.

Salinity peaks at RM 9.1, near transect T7, occurred in four distinct periods corresponding to dry seasons with low rainfall and low upstream river stage at Lainhart Dam (**Figure 2-21d**). The maxima measured EC at 15-minute intervals reached 1.250 to 2.890 S/m during dry seasons of 2005 to 2008 (4 to 9 times the 0.3125 S/m threshold). The daily average EC maxima were lower (1 to 5 times the threshold) but still exceeded the threshold for 6 days in 2005, 18 days in 2006, and 64 days in 2007.

Peaks in porewater salinity corresponding to river water salinity were observed across transect T7 during each dry season (**Figure 2-21e** and **f**). At station T7-135, which is farthest from the river, pore water shows peaks during the dry season, but the highest elevation soils salinity reached the critical limit for only a brief period in 2007. The lowest elevation soils had low salinity, similar in magnitude to that of groundwater, throughout the measurement period (**Figure 2-21c**). Despite repeated river salinity peaks at RM 9.1, the porewater salinity remained relatively low at T7-135. The porewater salinity at T7-90 showed a very similar pattern, with salinity approaching the critical value only in the 2007 dry season.

Station T7-25 is closer to the river and had higher pore water salinity (**Figure 2-21f**), exceeding the critical value for a considerable time in 2007 (53, 55 and 34 days in the surface, middle and lower soil monitoring points, respectively, not including days during a gap in data). Applying linear interpolation to the data gap during this time period, the estimated days exceeding critical salinity value are 83, 85 and 64, respectively, for the three soil elevations. Porewater salinity at T7-2 closely mirrored the timing and magnitude of river water salinity variation with slightly lower salinity levels and longer lag times (up to 90 days) on peaks.

**Table 2-5** summarizes the duration of river water, groundwater and porewater salinity exceedances along transect T7 from 2005 to 2008. River water salinity exceeds the 0.3125 S/m limit for extended periods of time in three of the four study years but does not explain the distribution of variable salt-tolerant vegetation across the transect. Transect T7 has very little variation in elevation and received tidal inundation over most or all of its length nearly every day and soil moisture on this transect was relatively constant at or near saturation. Although groundwater generally decreased with increasing distance from the river, it was lower than the

[1] Note that **Figure 2-21c, d, e** and **f** present electrical conductivity (EC), not salinity. Conductivity is the ability of water to conduct an electrical current, and dissolved ions are the conductors. Salt consists of charged ions. Salinity is a measure of the amount of salts in the water. Because dissolved ions, such as those in salt, increase salinity as well as conductivity, the two measures are related.

critical salinity threshold at all locations on all but three days of the four-year study period and thus, also failed to explain the observed vegetation patterns. On the other hand, the 12 porewater salinity data series described EC dynamics at the interface between river water and groundwater and showed that porewater salinity in the soil profile was above the critical limit 6.6 and 82 ft (2 and 25 m) from the river, where vegetation is dominated by salt-tolerant mangroves, but below the limit (90 and 135 m) from the river, where vegetation consist of riverine and mixed swamps, dominated by bald cypress and pop ash (*Fraxinus caroliniana*) (**Figure 2-21b**). This suggests that porewater salinity dynamics help to explain the distribution of variable salt-tolerant species across the floodplain, which neither river water nor groundwater were able to do (Kaplan et al. 2010).

**Table 2-5. Number of days that the 2 psu bald cypress salinity tolerance threshold was exceeded in pore water, surface water and groundwater at T7[1]**

| Site[2] | Elevation (m) | Elevation (ft) | Days Threshold Exceeded | | | |
|---|---|---|---|---|---|---|
| | | | 2005 | 2006 | 2007 | 2008 |
| **Porewater** | | | | | | |
| T7-135 | 0.37 | 1.21 | 0 | 0 | 26 | 0 |
| T7-90 | -0.10 | -0.33 | 0 | 0 | 6 | 0 |
| T7-25 | 0.20 | 0.66 | 0 | 0 | 83 | 0 |
| T7-25 | -0.03 | -0.10 | 0 | 0 | 85 | 0 |
| T7-25 | -0.23 | -0.75 | 0 | 0 | 64 | 0 |
| T7-2 | 0.30 | 0.98 | 0 | 0 | 113 | 0 |
| T7-2 | 0.14 | 0.46 | 0 | 0 | 51 | 0 |
| T7-2 | -0.20 | -0.66 | 0 | 0 | 9 | 0 |
| **River Water** | | | | | | |
| RM 9.1 | | | 6 | 18 | 64 | 0 |
| **Groundwater** | | | | | | |
| T7-W2 | | | 0 | 0 | 3 | 0 |

[1] After Kaplan et al. 2010
[2] Monitoring stations and groundwater wells in which EC did not exceed 0.3125 S/m in any year are excluded.

### 2.4.5 Porewater Salinity Variation in the Upper Tidal Floodplain

While Kaplan et al. (2010) shows that vegetation change in saltwater-affected wetland communities is a result of root zone porewater salinity dynamics, salinity dynamics along the tidal floodplain were not explored in the study. For example, the porewater salinity increases and decreases with lag time in low soil compared with top soil. The study did not investigate the reason for the lag time phenomenon. This section explores the salinity variation and its causation relationships with other environmental factors, such as river stage, river water salinity, and groundwater in the upper tidal floodplain using observed hydrological and soil data. The porewater salinity dynamics at transect T7 are further characterized. **Figure 2-22** shows the transect T7 profile and porewater salinity sensors at three different depths at four locations along the floodplain.

The dry season between 2006 and 2007 started in October 2006 and ended in June 2007. Salinity along transect T7 increased significantly during this very dry wet season (**Figure 2-21e** and **f**) to as high as 0.6 S/m, which is beyond the salinity tolerance threshold (0.3125 S/m) for bald cypress. Then, in the 2007 wet season, the porewater salinity decreased back to 0 S/m. It is apparent that the porewater salinity increase is due to saltwater intrusion. However, the mechanism of how river salt water impacts floodplain pore water salinity remains unknown.

River salt water could affect floodplain porewater salinity in two ways. In the first scenario, salt water in the river could recharge the groundwater in the aquifer underneath the river bed causing groundwater salinity to increase. When groundwater stage increases, it could transport salt into the soil causing porewater salinity to increase. In the second scenario, salt water in the river could flow into the floodplain and remain there infiltrating into the soil causing porewater salinity to increase. By comparing porewater salinity and groundwater salinity along transect T7 (Kaplan et al. 2010), it was found that groundwater salinity (**Figure 2-21b**) was never as high as porewater EC (**Figure 2-21e** and **f**). Thus, groundwater is not the source of porewater salinity along transect T7, which leads to a conclusion that the first scenario does not occur along transect T7. Therefore, the focus is on the second scenario to explore the salinity dynamics along the tidal floodplain.

Comparisons between water level stage and EC at RM 9.1, rainfall at station JDWX, and porewater EC at four locations were conducted (**Figure 2-23**). Comparing the river stage at RM 9.1 (**Figure 2-23b**) and the topographic data, it is apparent that the floodplain is inundated almost every day. A series of contour maps of porewater salinity were generated to show spatial and temporal porewater salinity variation, and to assist in exploration of porewater salinity dynamics along the transect T7 floodplain. It was found that salinity of surface water that inundated the transect T7 floodplain was completely different during the dry season than during the wet season. This difference caused the porewater salinity variation along the floodplain. The variation in river water salinity was compared with the porewater salinity variation in different layers and at different distances from the river. This comparison clearly shows the river surface salinity variation caused porewater salinity increases and decreases in the floodplain with a lag time from the shallow layer to the deep soil layer.

<u>Dry Season Floodplain Inundation Process</u>

**Figure 2-24** through **Figure 2-33** show the inundation process over a complete tidal cycle (from February 17, 2007 3:00 pm to February 18, 2007 4:00 pm) in the dry season along transect T7. The figures include the river stage and EC changes at RM 9.1 (near T7), ground surface (topographic elevation) profile, soil EC contour (color underneath ground surface), soil EC probe locations, and groundwater stage. Since the fresh water from upstream (mainly from the Lainhart Dam) significantly decreases in the dry season, the tidal salt water intrudes into the river and floodplain during high tide. From **Figure 2-24** to **Figure 2-26** and from **Figure 2-29** to **Figure 2-31**, we can see the river stage rising while water with high EC inundating the floodplain. From **Figure 2-26** to **Figure 2-29** and from **Figure 2-31** to **Figure 2-33**, we can see that the river stage

recesses from high to low. Through the inundation process, the river EC is low at low stage and high at high stage. In other words, the water inundating the floodplain is salt water.

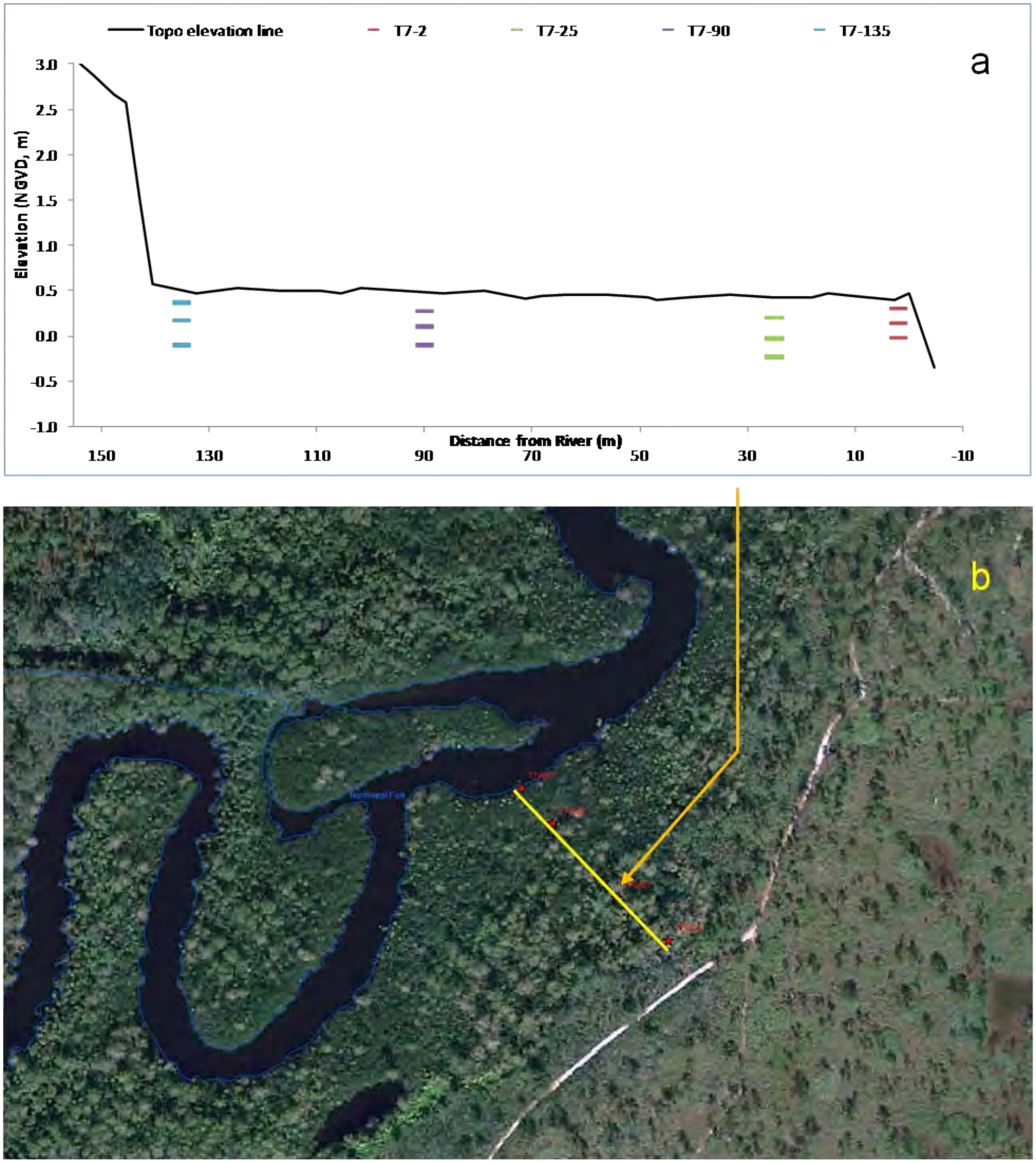



**Figure 2-22. (a) T7 profile and (b) soil probe locations along T7**

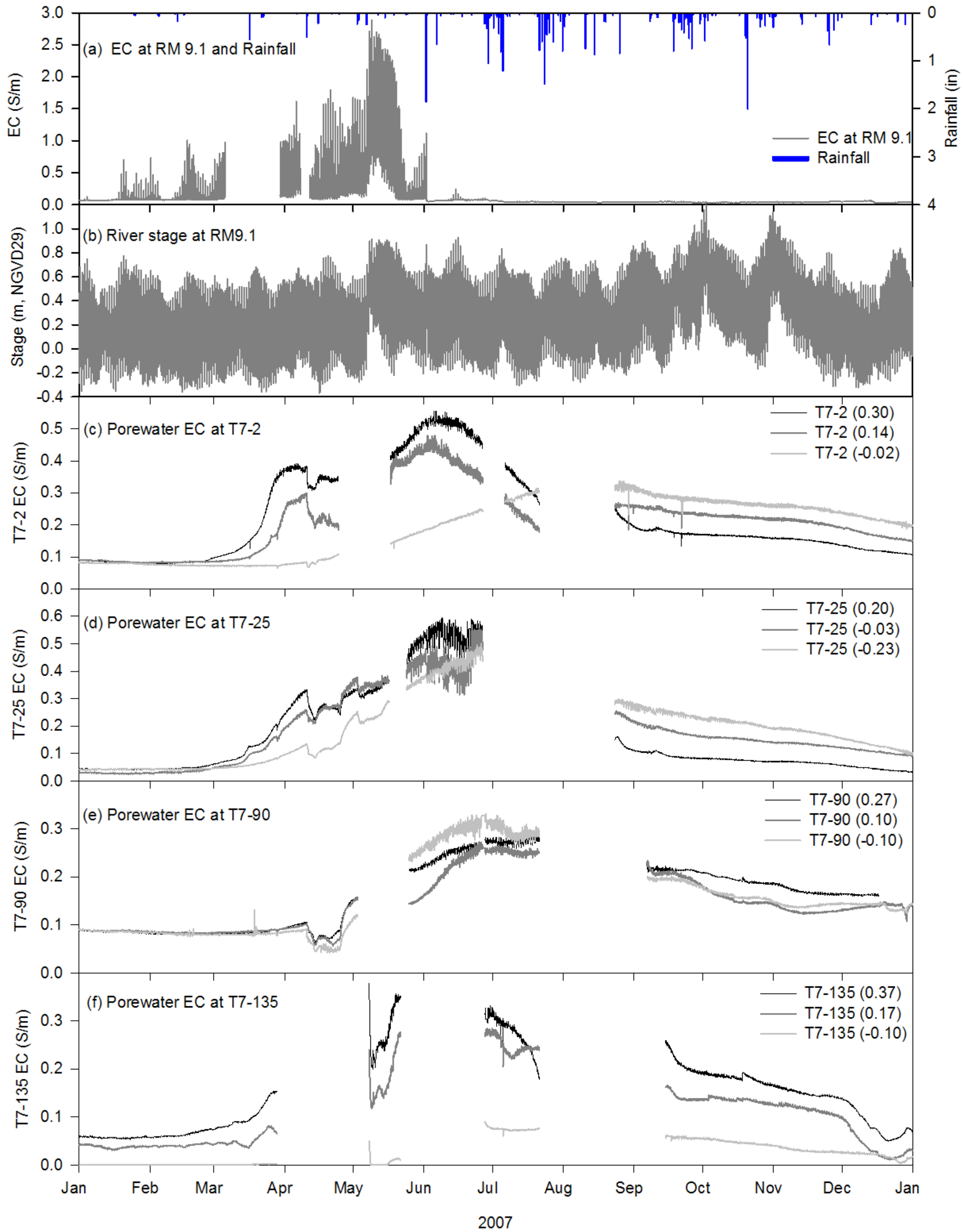



**Figure 2-23. (a) River EC at RM 9.1 and rainfall at JDWX, (b) river stage at RM 9.1, and pore water EC for three different layers at wells (c) T7-2, (d) T7-25, (e) T7-90 and (f) T7-135 during 2007**

Notes: m, NGVD29 – meters National Geodetic Vertical Datum of 1929; in - inches

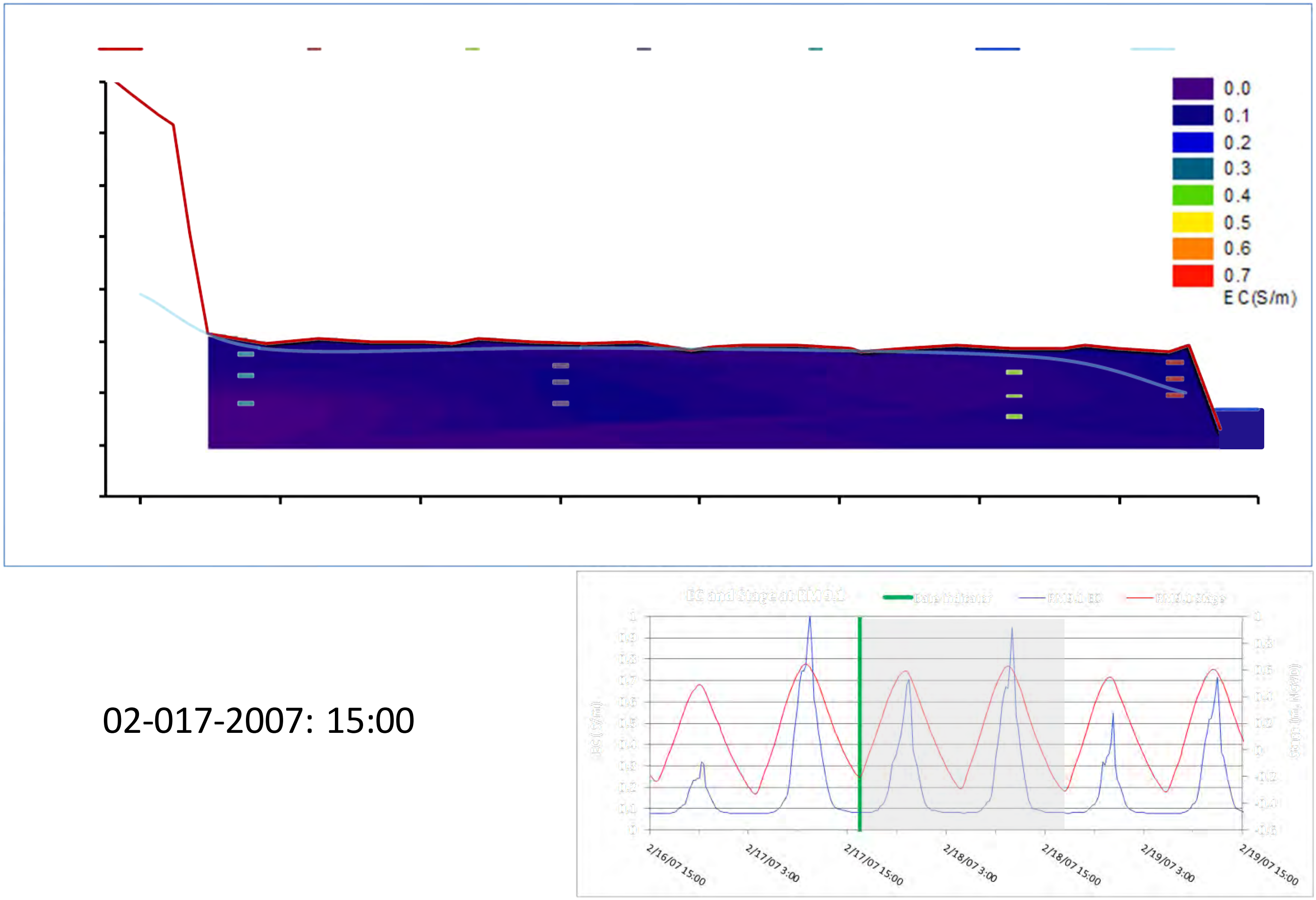



**Figure 2-24. Observed river stage and EC at RM 9.1 at the beginning of a complete dry season tidal cycle**

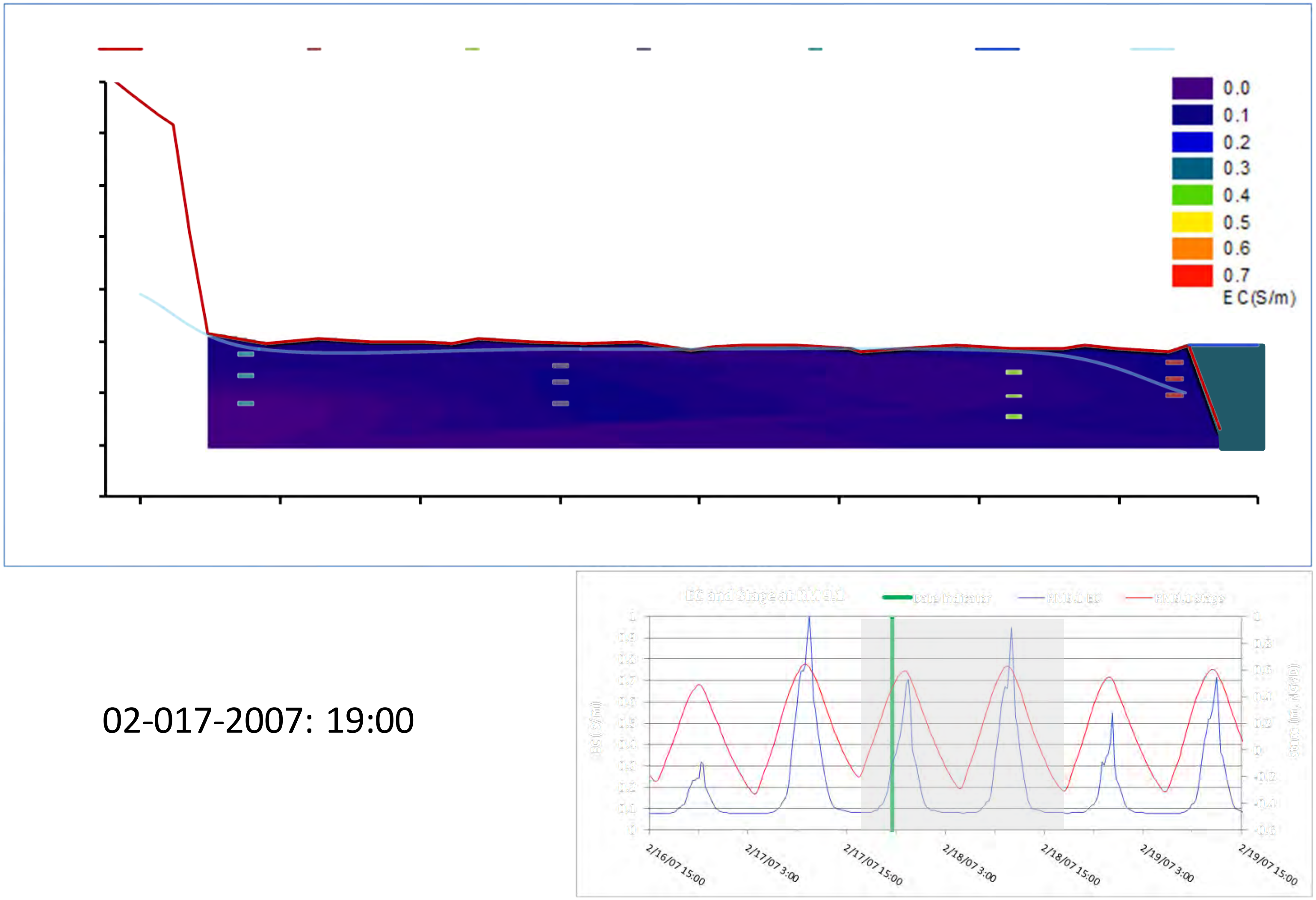



**Figure 2-25. Observed river stage and EC at RM 9.1 during the second time frame of a dry season tidal cycle**

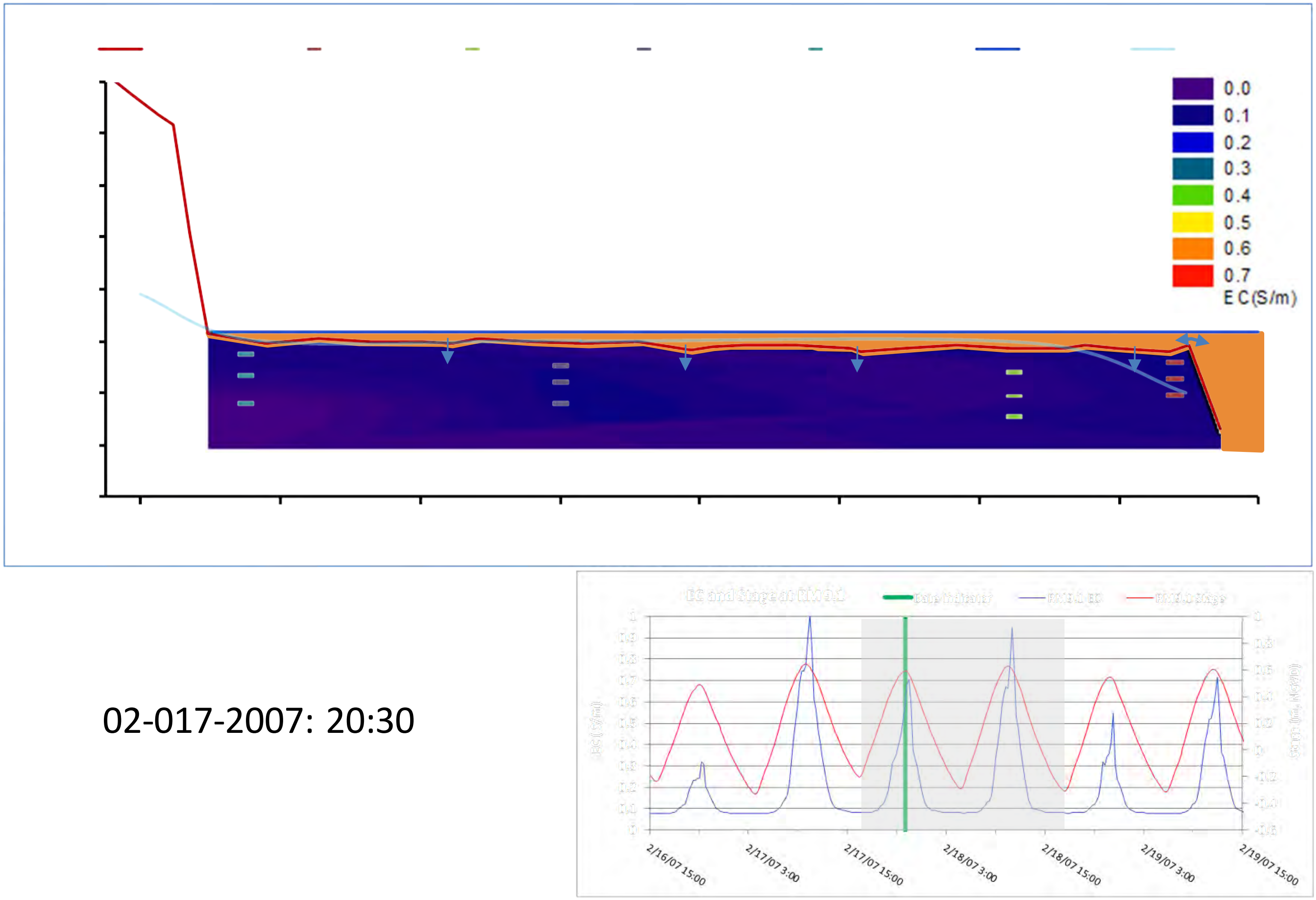



**Figure 2-26. Observed river stage and EC at RM 9.1 during the third time frame of a dry season tidal cycle**

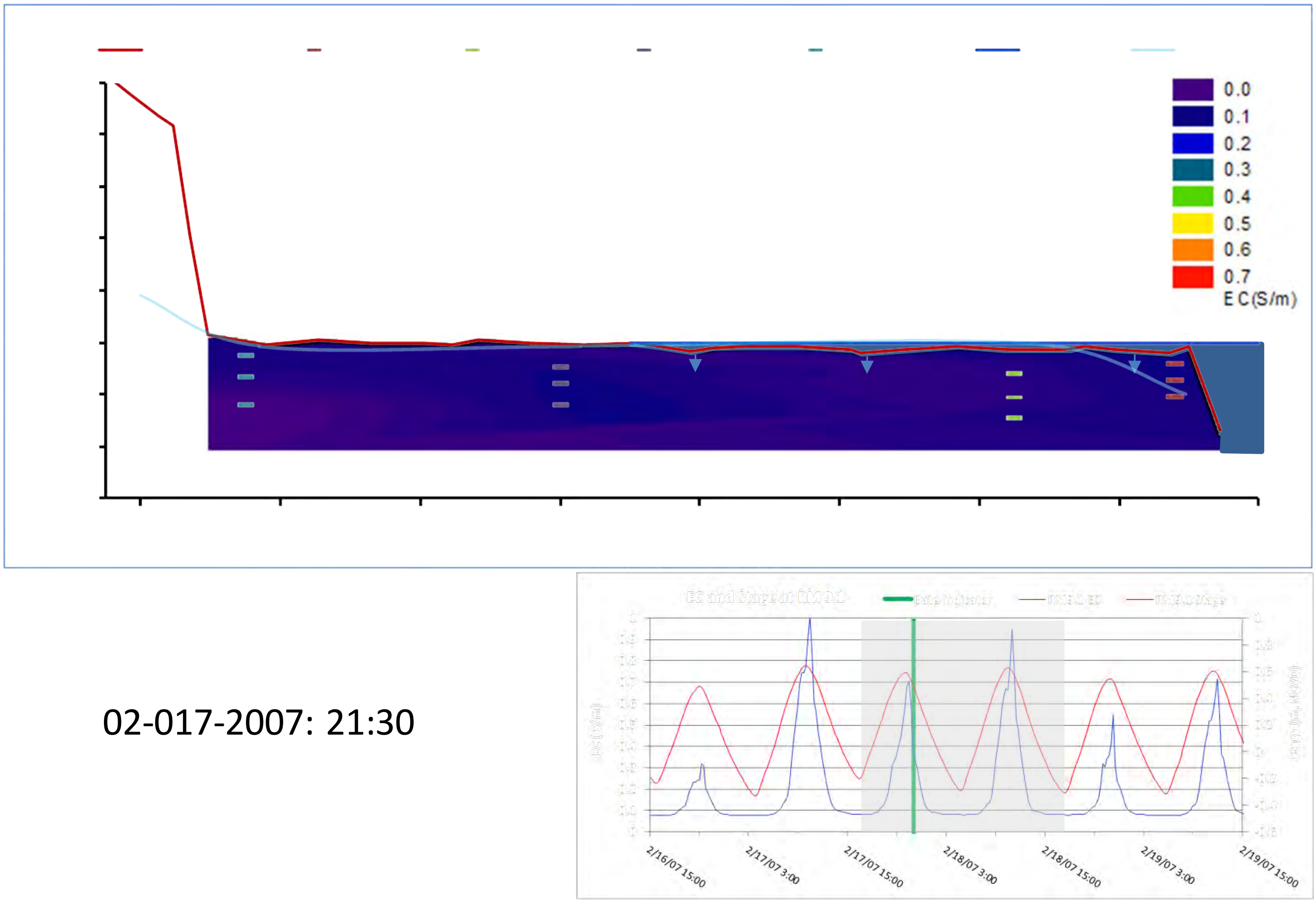



**Figure 2-27. Observed river stage and EC at RM 9.1 during the fourth time frame of a dry season tidal cycle**

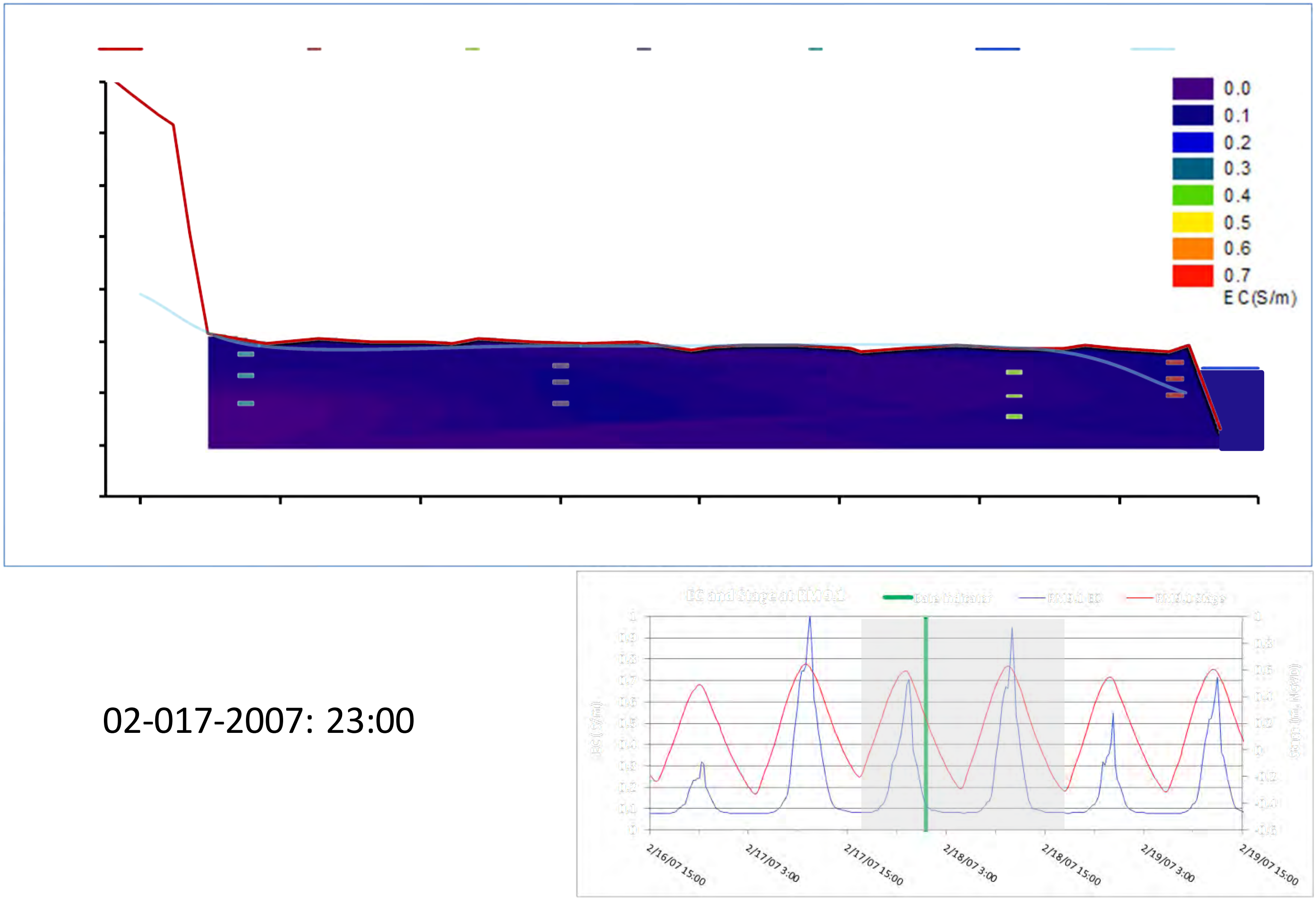



**Figure 2-28. Observed river stage and EC at RM 9.1 during the fifth time frame of a dry season tidal cycle**

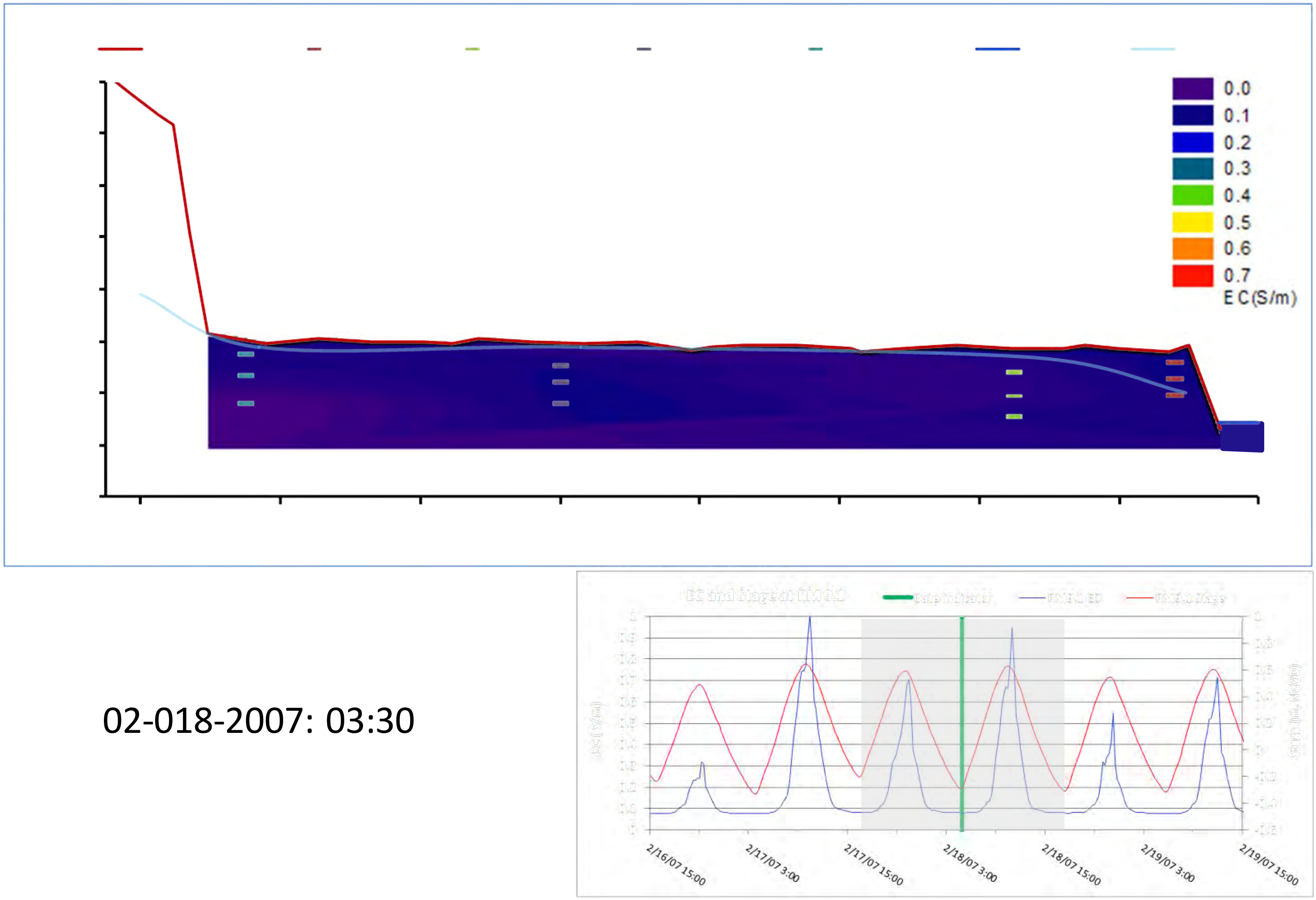



**Figure 2-29. Observed river stage and EC at RM 9.1 during the sixth time frame of a dry season tidal cycle**

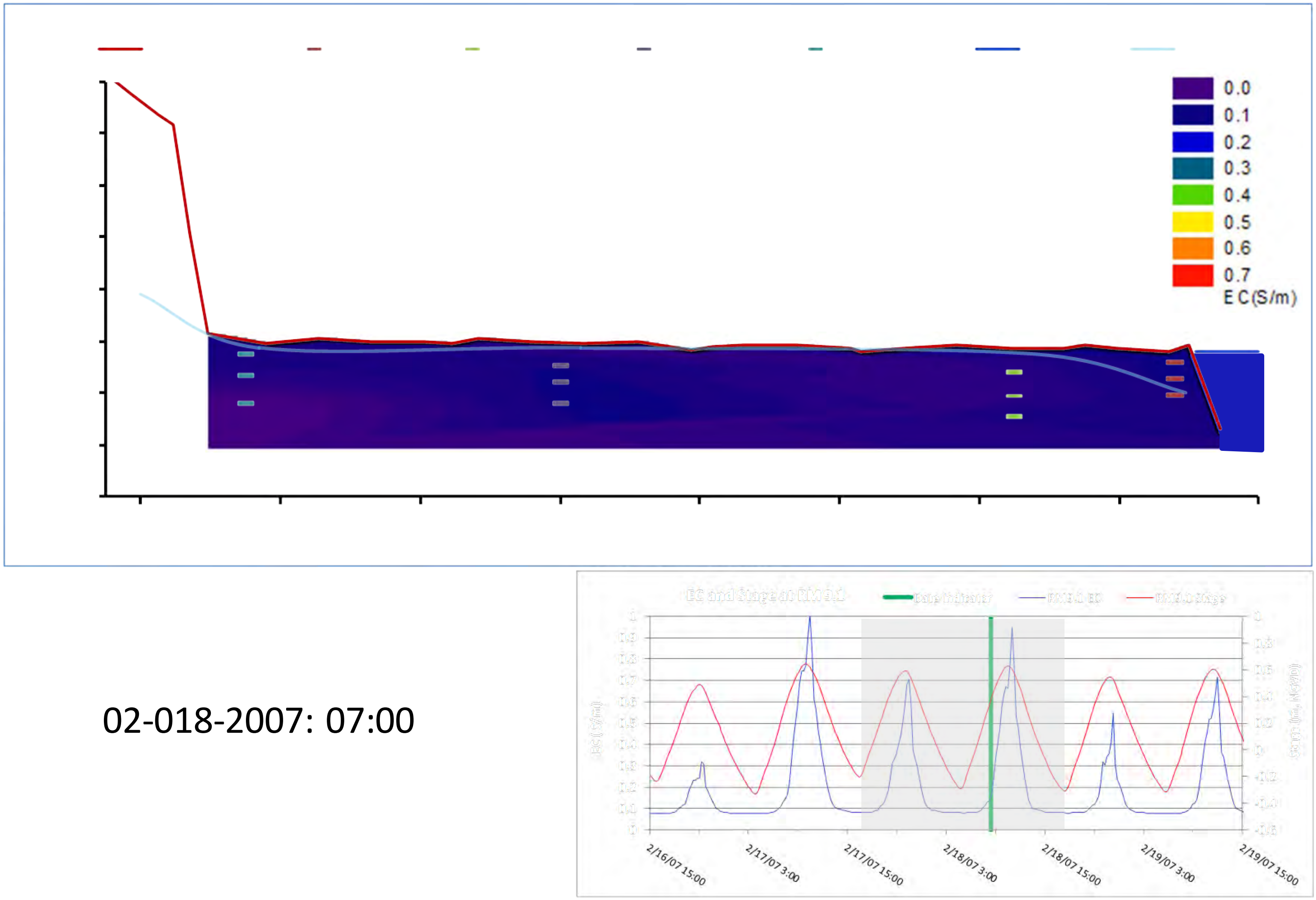
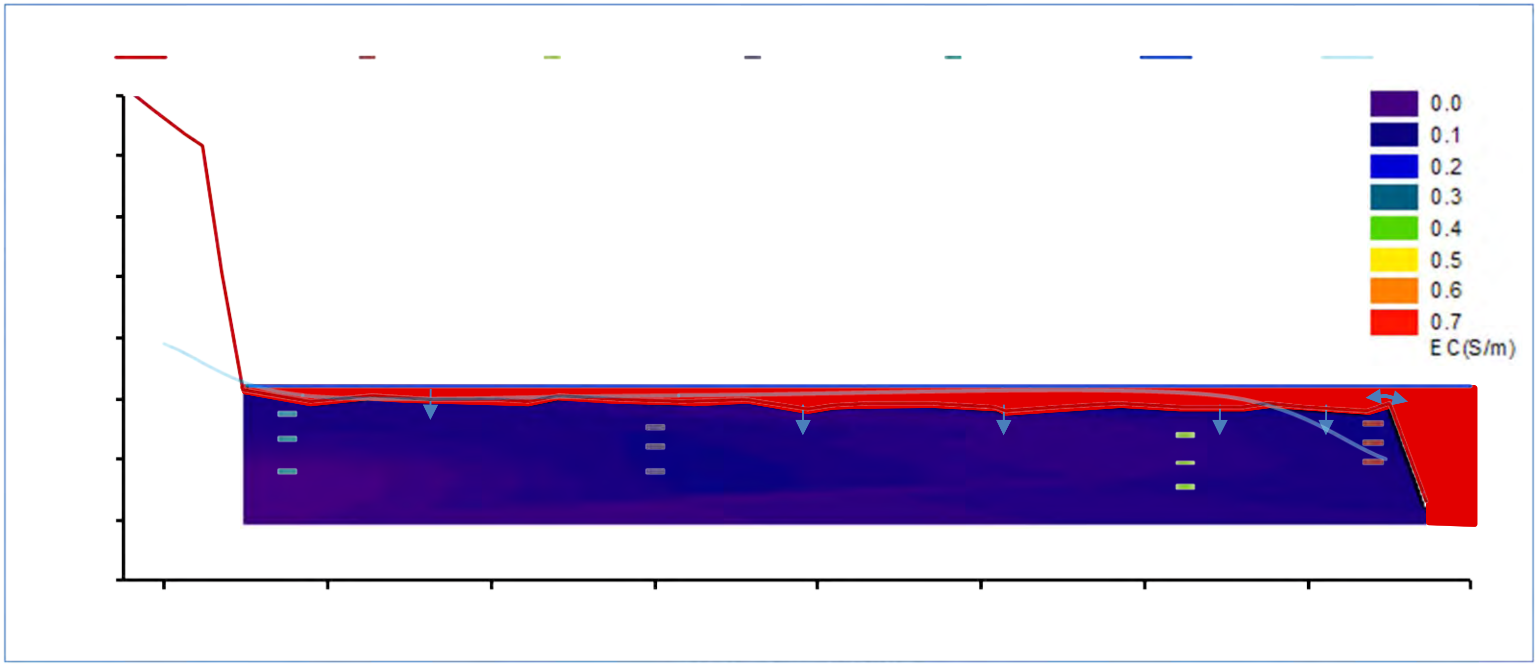



**Figure 2-30. Observed river stage and EC at RM 9.1 during the seventh time frame of a dry season tidal cycle**

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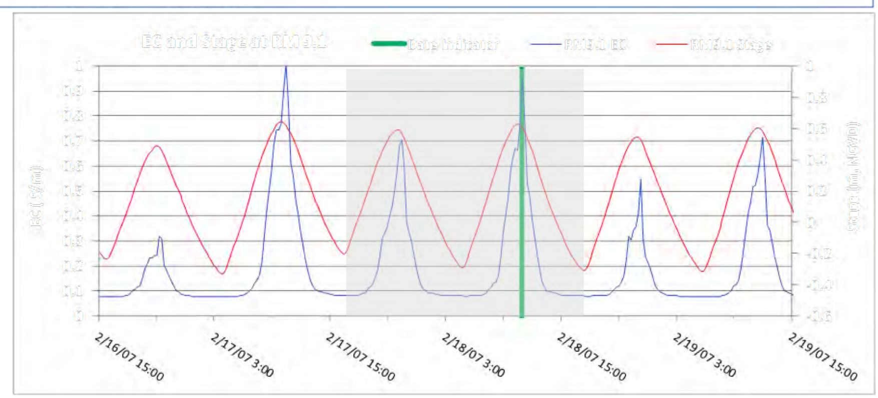
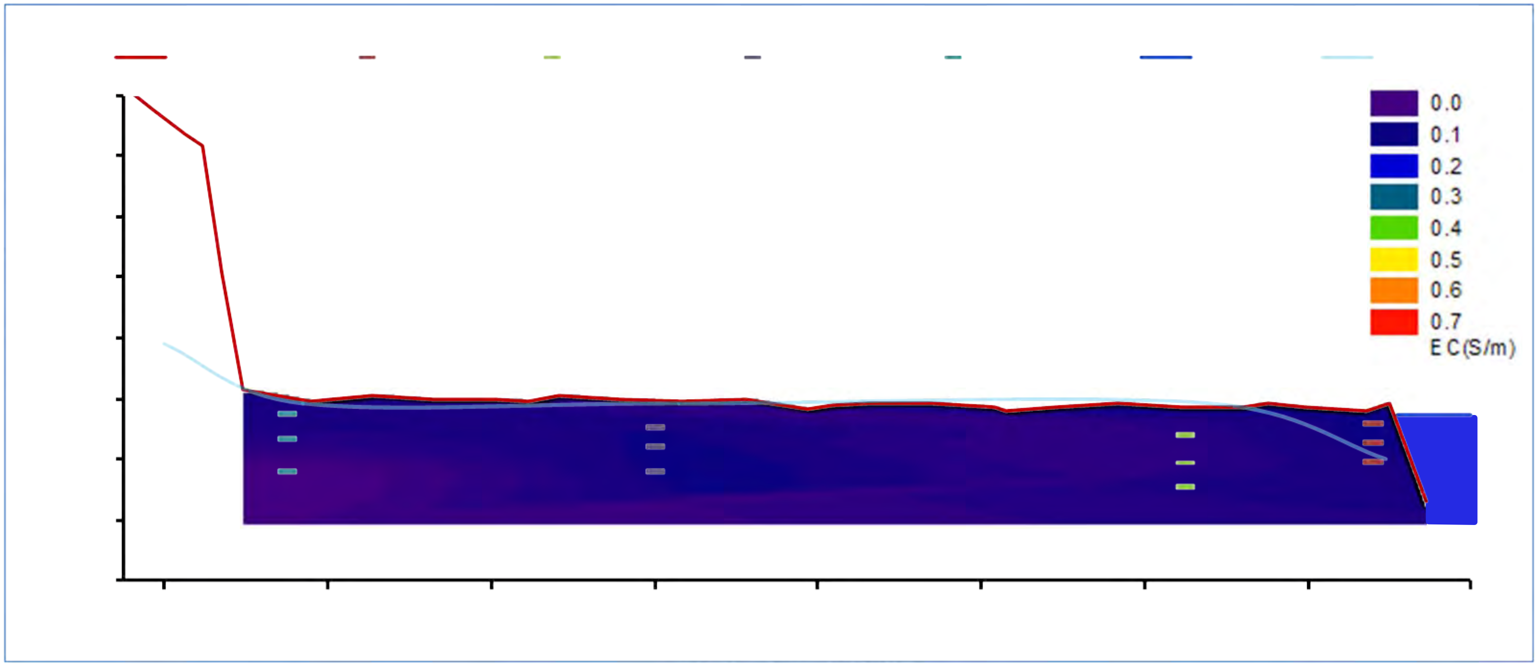



**Figure 2-31. Observed river stage and EC at RM 9.1 during the eighth time frame of a dry season tidal cycle**




02-018-2007: 11:00

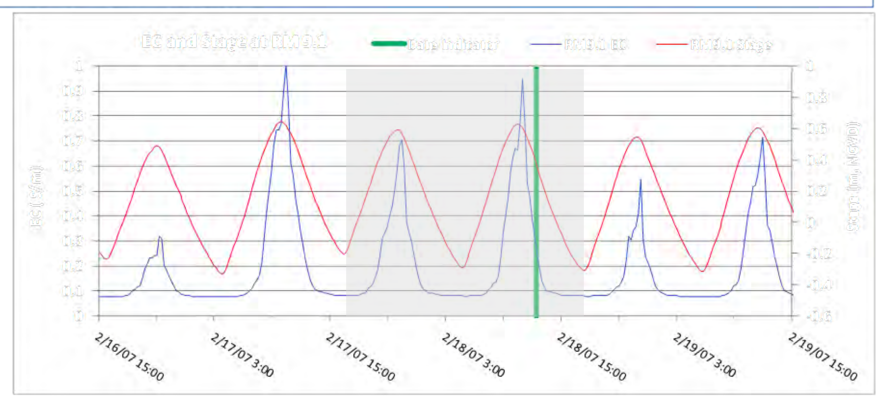
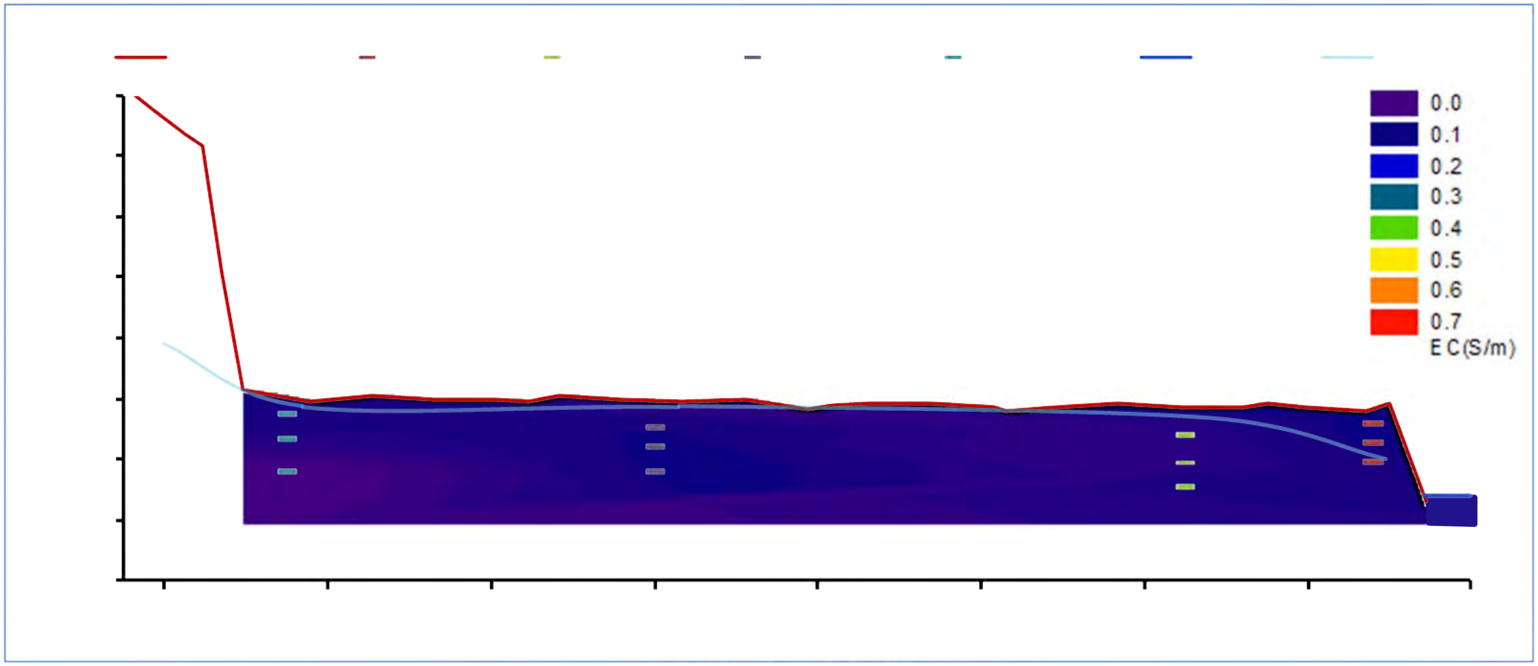



**Figure 2-32. Observed river stage and EC at RM 9.1 during the ninth time frame of a dry season tidal cycle**

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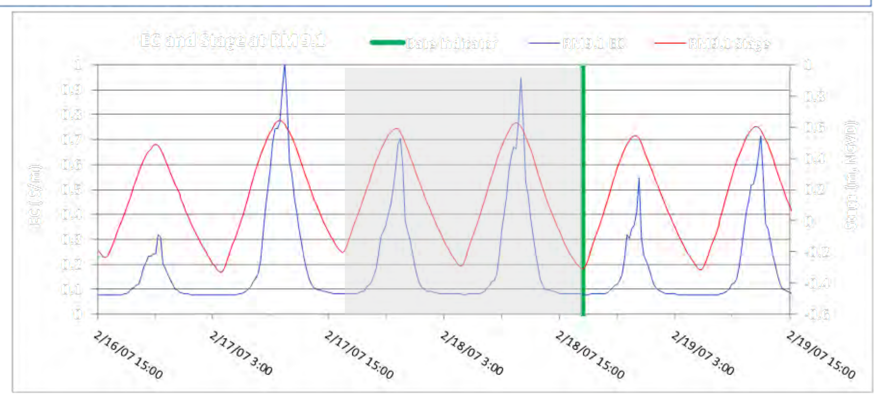



**Figure 2-33. Observed river stage and EC at RM 9.1 during the end of a dry season tidal cycle**

Wet Season Floodplain Inundation Process

**Figure 2-34** through **Figure 2-41** show the river stage and EC changes over a tidal cycle in the wet season (June 2, 2007 7:00 am to June 3, 2007 7:00 am). **Figure 2-34** to **Figure 2-35** and **Figure 2-37** to **Figure 2-38** show the river stage going up from low to high tide, while **Figure 2-35** to **Figure 2-37** and **Figure 2-39** to **Figure 2-41** show the river stage going down from high tide to low. In both low stage and high stage, the river EC was always low, since freshwater inflow from upstream (mainly from Lainhart Dam) is large enough to prevent saltwater intrusion. In other words, the water inundated in the floodplain was fresh water (low EC).

Porewater Salinity Dynamics on the Tidal Floodplain

The dry and wet season floodplain inundation processes observed above can be applied to explore seasonal floodplain porewater dynamics. Porewater EC contour maps for transect T7 were created and plotted along with river stage and EC to show that seasonal porewater EC varies along with river stage and EC (**Figure 2-42**). In this effort, a total of eight time points were selected to illustrate the porewater EC variation from dry season to wet season (**Figure 2-42c** to **j**). The river EC time series with rainfall and river stage time series were also plotted (**Figure 2-42a** and **b**). Time points selected for porewater EC variation illustration are indicated by red lines. The time points were selected with a time interval of 20 to 30 days. Due to variable data availability (there are some data gaps in time period of study due to lightning and other reason), some time intervals are less than 20 days or more than 30 days. The general rule for time point selection was to capture the pore water variation through both the dry and wet season.

From the dry season floodplain inundation analysis determined using field data collected along transect T7, it is known that the water inundating the floodplain has high EC. During inundation, which usually takes a few hours for one tidal cycle, the high EC water infiltrates into the floodplain soil. When high tide is over, the river stage recedes below bank height, and some high EC water stays in the floodplain because of the overall flat topographic elevation with depressions on the surface ground. This water infiltrates into the soil. The high EC water reaches the upper soil first, and then sinks to lower soil, which results in salinity increasing in the top soil first, then, after a lag time, into the lower soil. In addition, during the dry season, ET is greater than rainfall, intensifying the porewater salinity increase. **Figure 2-23c** to **f** show this dry season EC increase from February to June. This variation is not obvious through the short term, such as one tidal cycle, but this variation is apparent over days and months (**Figure 2-42c** to **i**).

In the wet season, the water inundating the floodplain is fresh water coming from the upstream watershed through Lainhart Dam and other tributaries. The low EC water in the floodplain infiltrates into the soil, washing the upper soil first and then the lower layer. In addition, in the wet season, rainfall is greater than ET, which also plays a role in washing soil from the top to the deep layers. This effect becomes apparent over days and months, but not during a short timeframe. **Figure 2-23c** to **f** shows porewater salinity decrease from late August to the end of the year. At stations T7-2 and T7-25, the salinity in the upper soil decreases earlier than the lower soil (**Figure 2-23c** and **d**). The salinity decrease with lag time in lower soil was not observed in the location of the floodplain furthest from the river (station T7-135, **Figure 2-23f** and **Figure 2-42c** to **j**) possibly due the high groundwater table in this area.

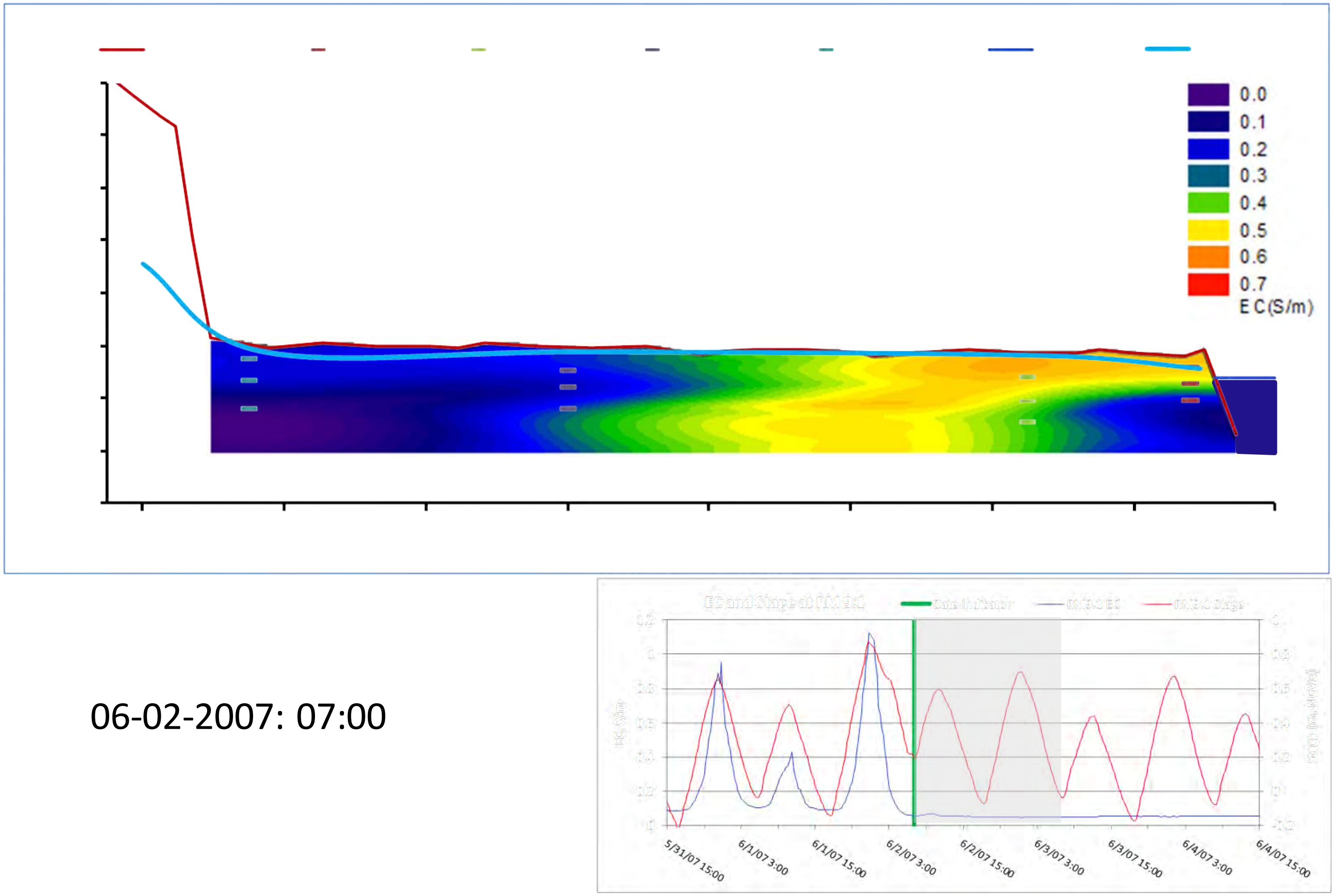



**Figure 2-34. Observed river stage and EC at RM 9.1 at the beginning of a wet season tidal cycle**

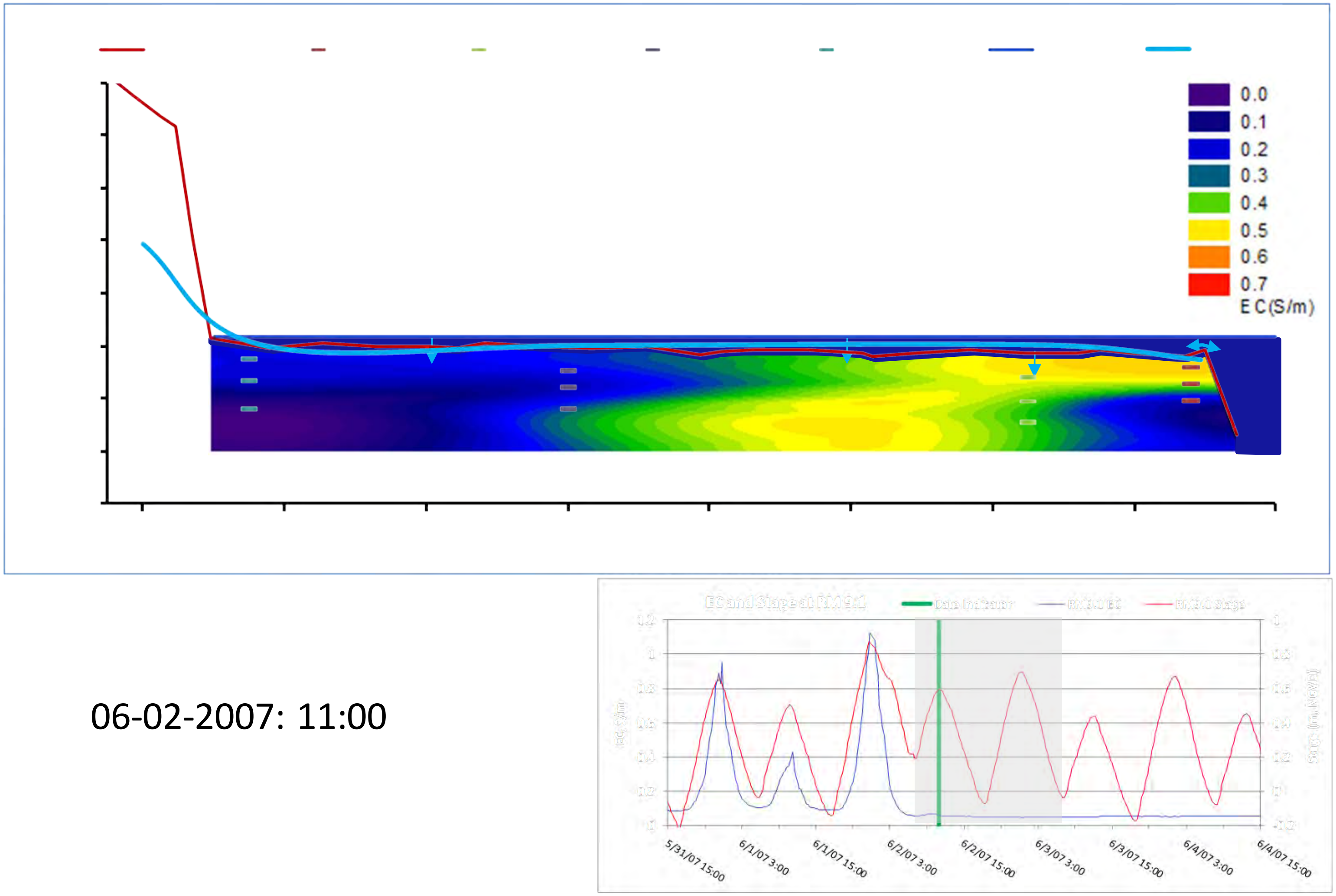



**Figure 2-35. Observed river stage and EC at RM 9.1 during the second time frame of a wet season tidal cycle**

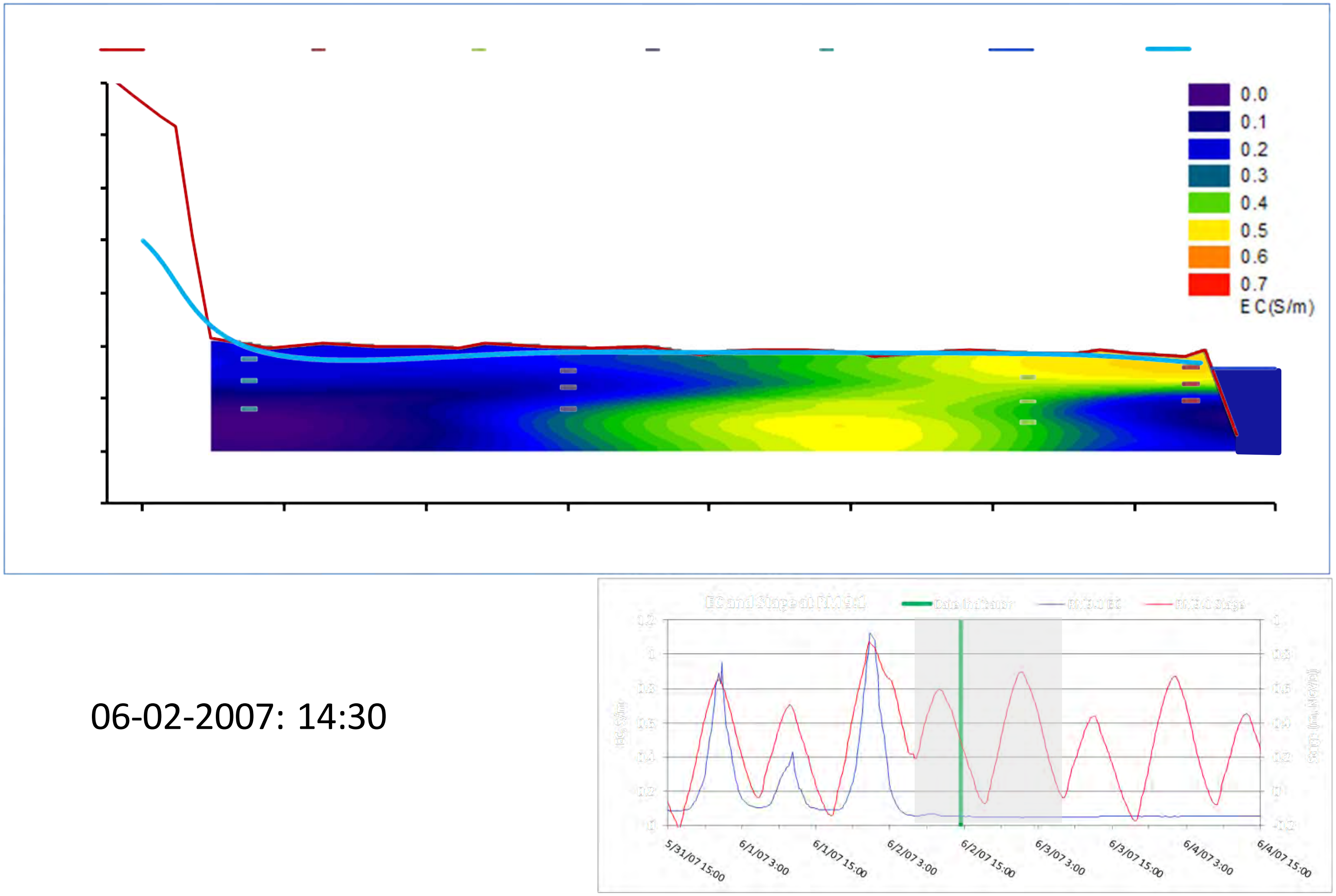



**Figure 2-36. Observed river stage and EC at RM 9.1 during the third time frame of a wet season tidal cycle**

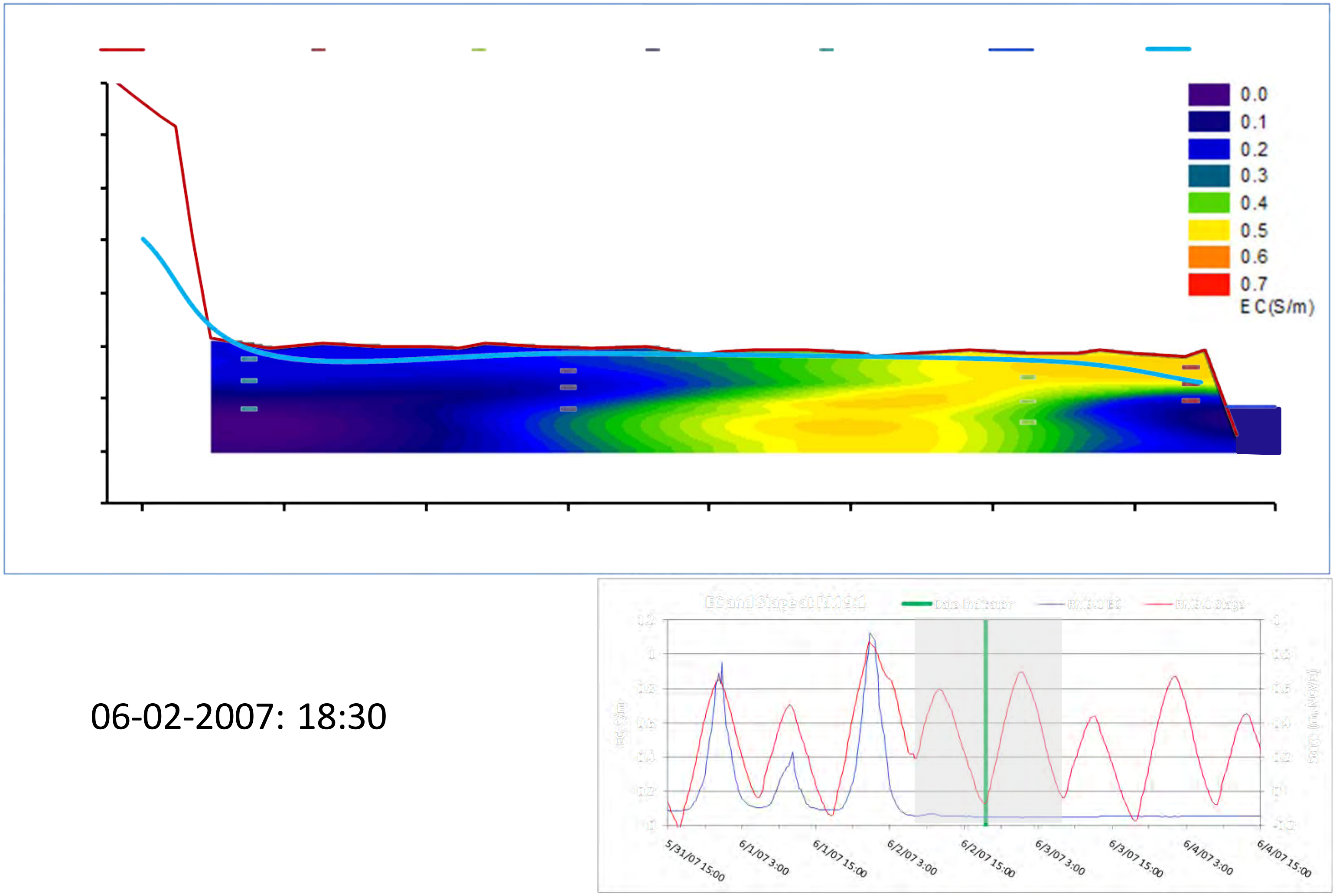



**Figure 2-37. Observed river stage and EC at RM 9.1 during the fourth time frame of a wet season tidal cycle**

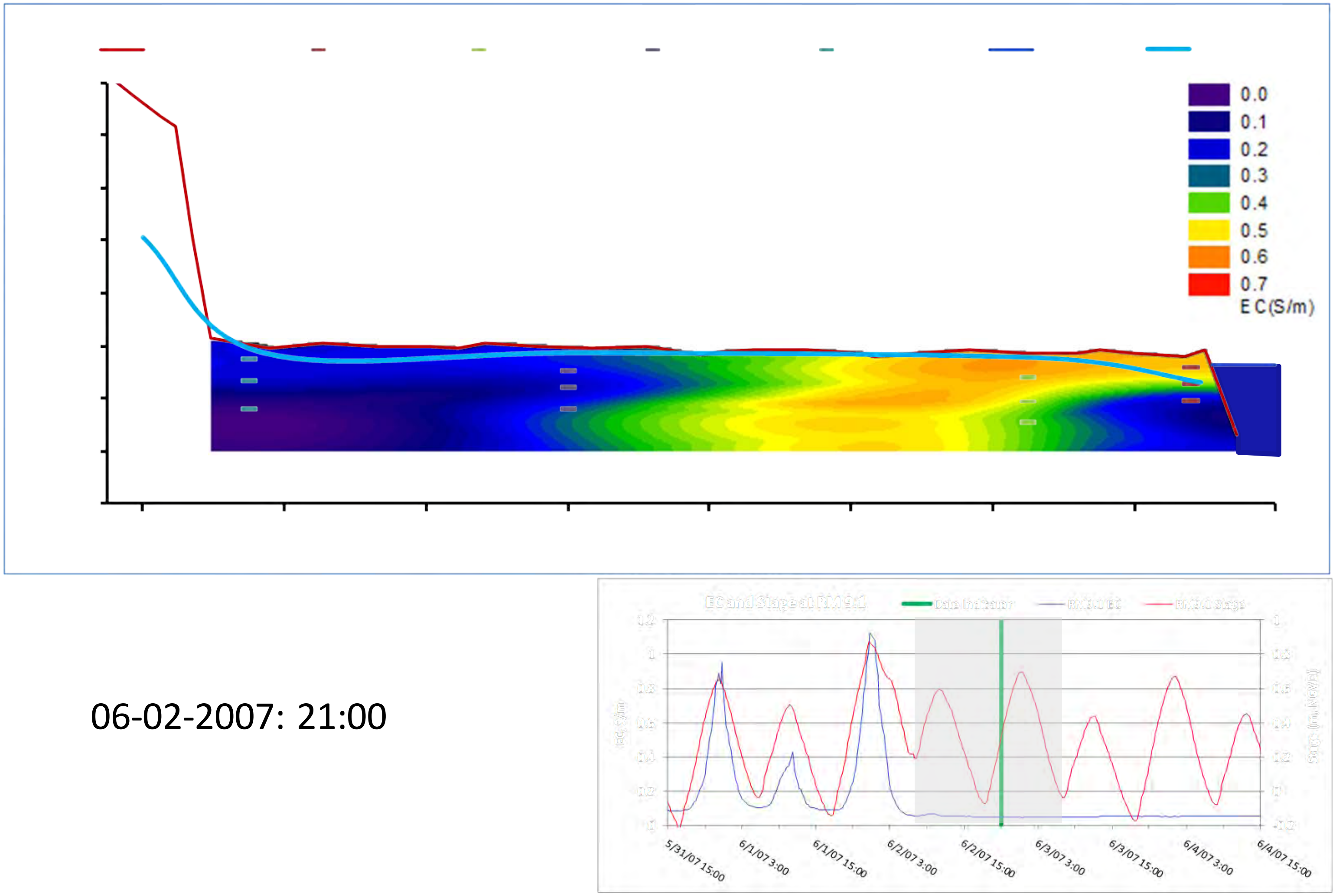



**Figure 2-38. Observed river stage and EC at RM 9.1 during the fifth time frame of a wet season tidal cycle**

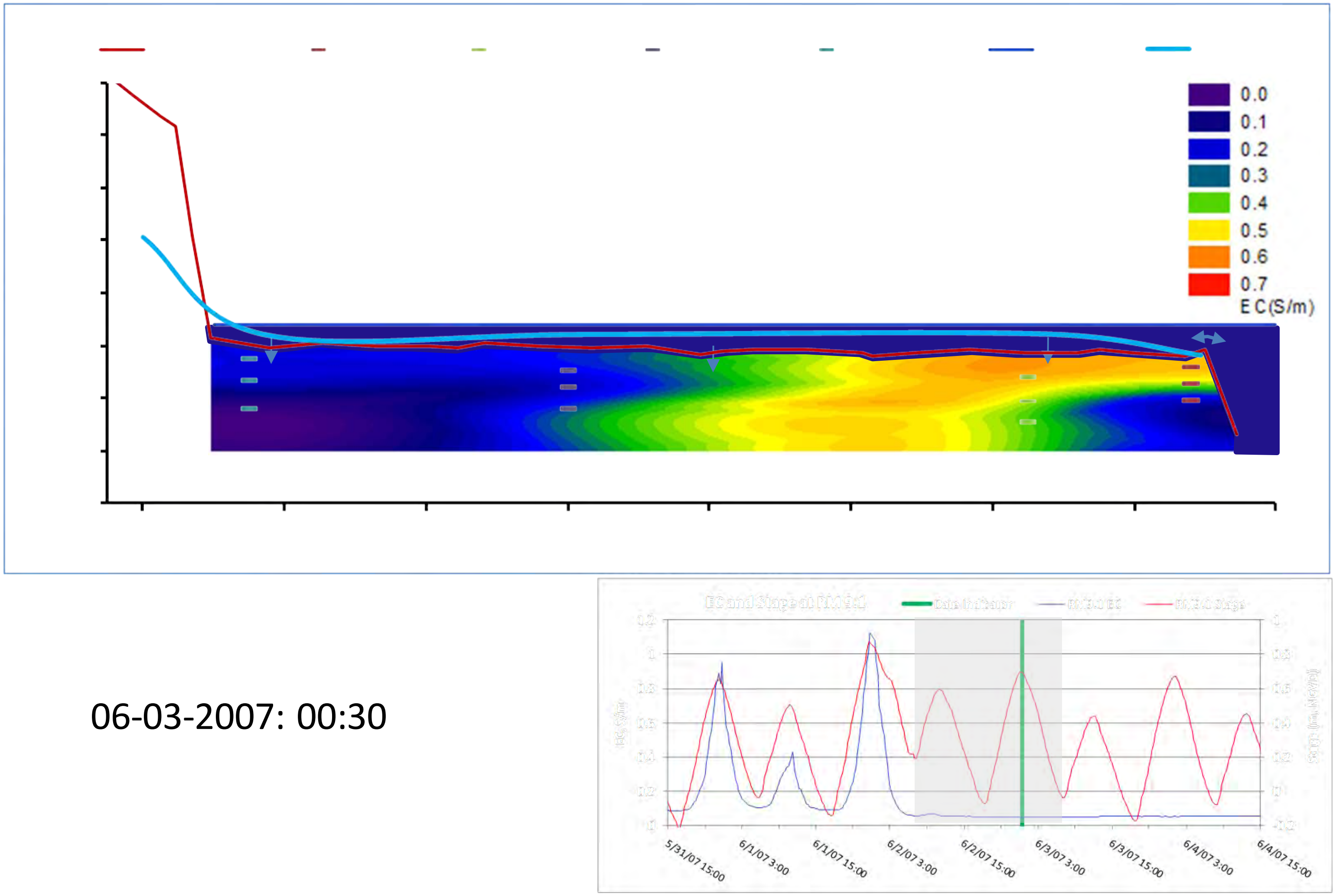
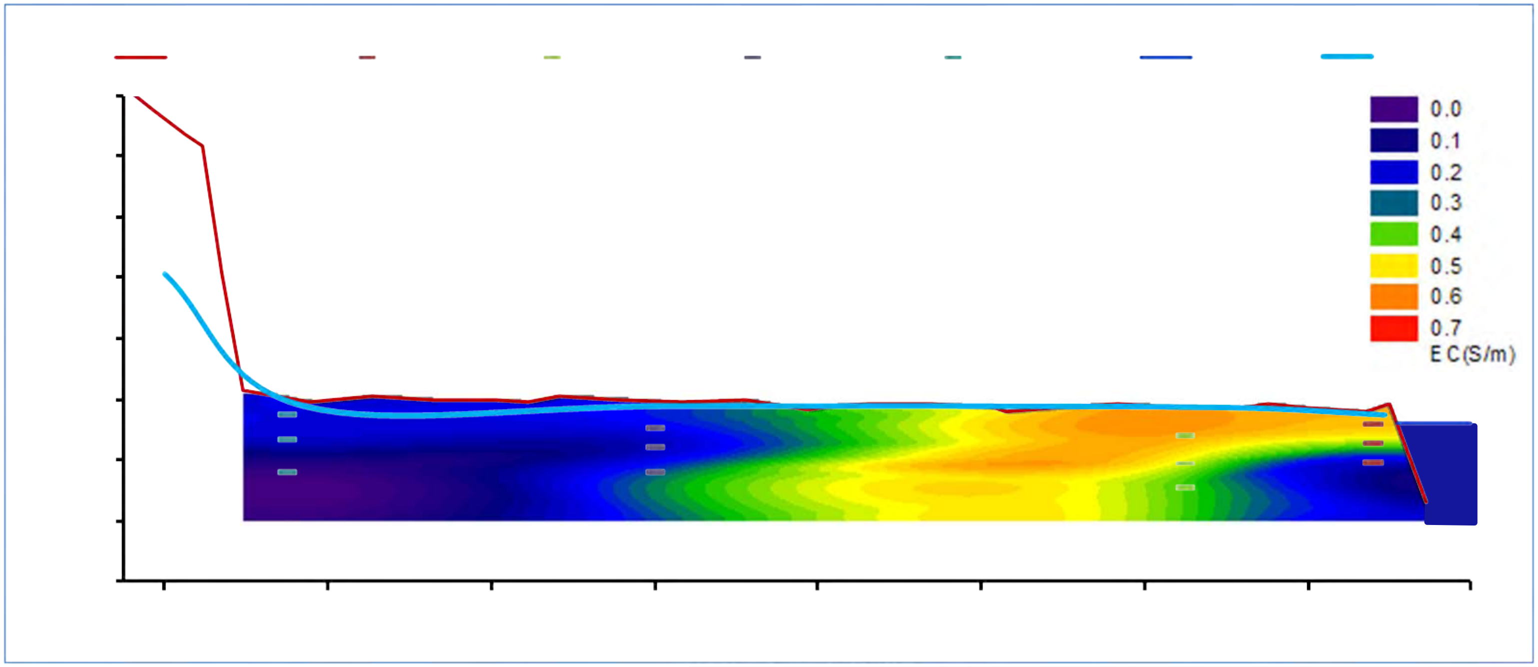



**Figure 2-39. Observed river stage and EC at RM 9.1 during the sixth time frame of a wet season tidal cycle**

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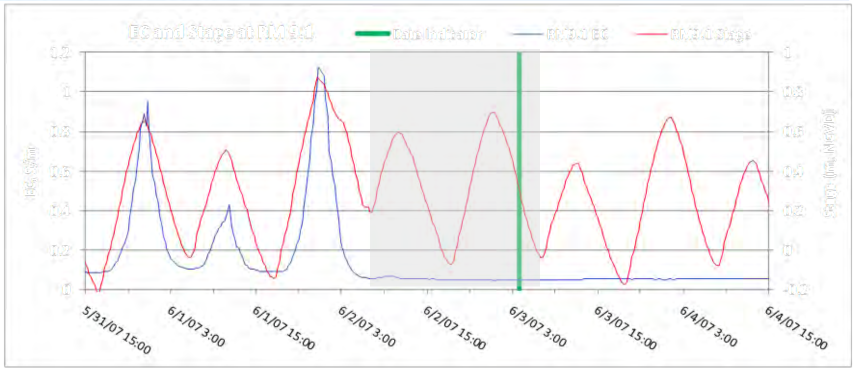


**Figure 2-40. Observed river stage and EC at RM 9.1 during the seventh time frame of a wet season tidal cycle**

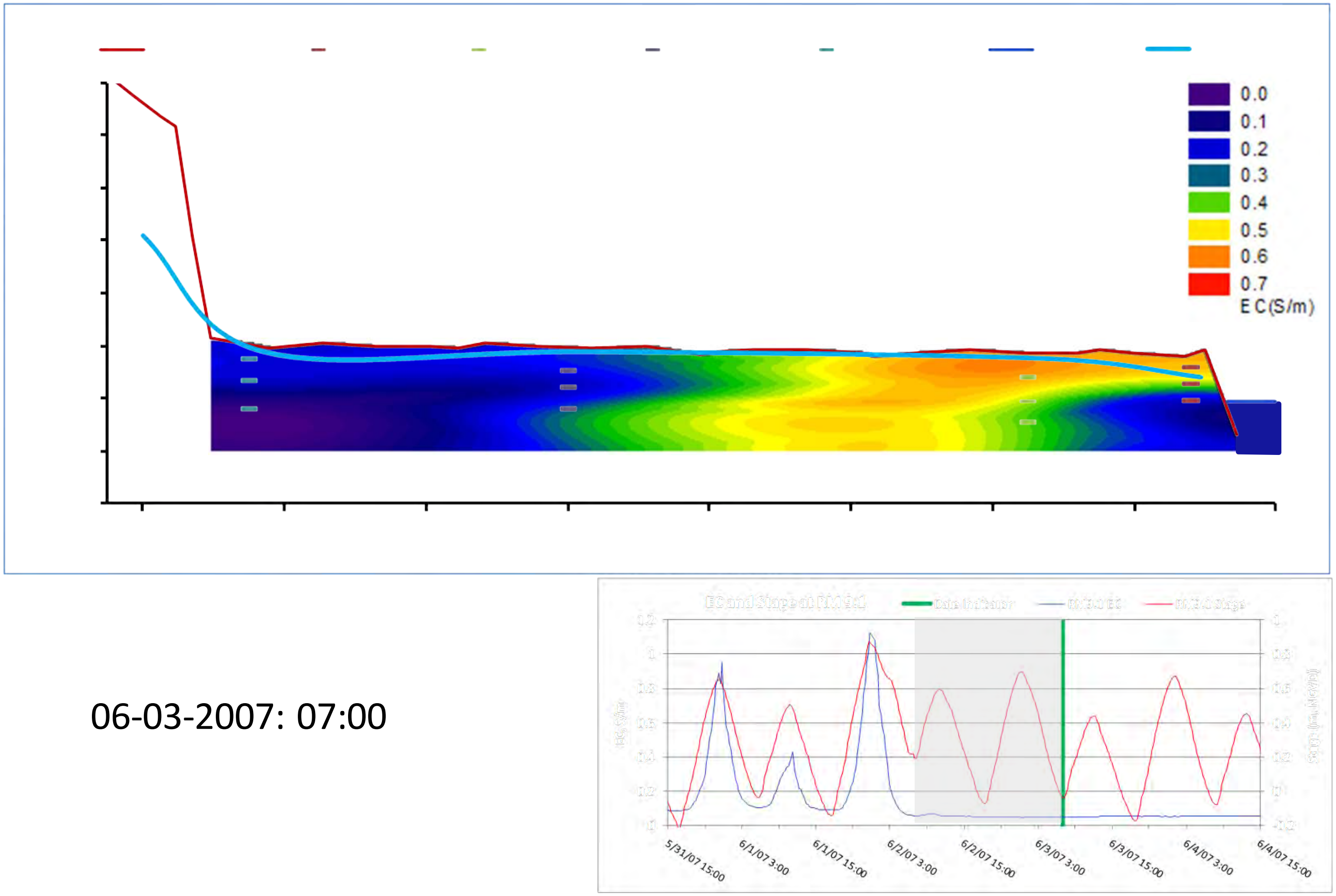


**Figure 2-41. Observed river stage and EC during RM 9.1 at the end of a wet season tidal cycle**

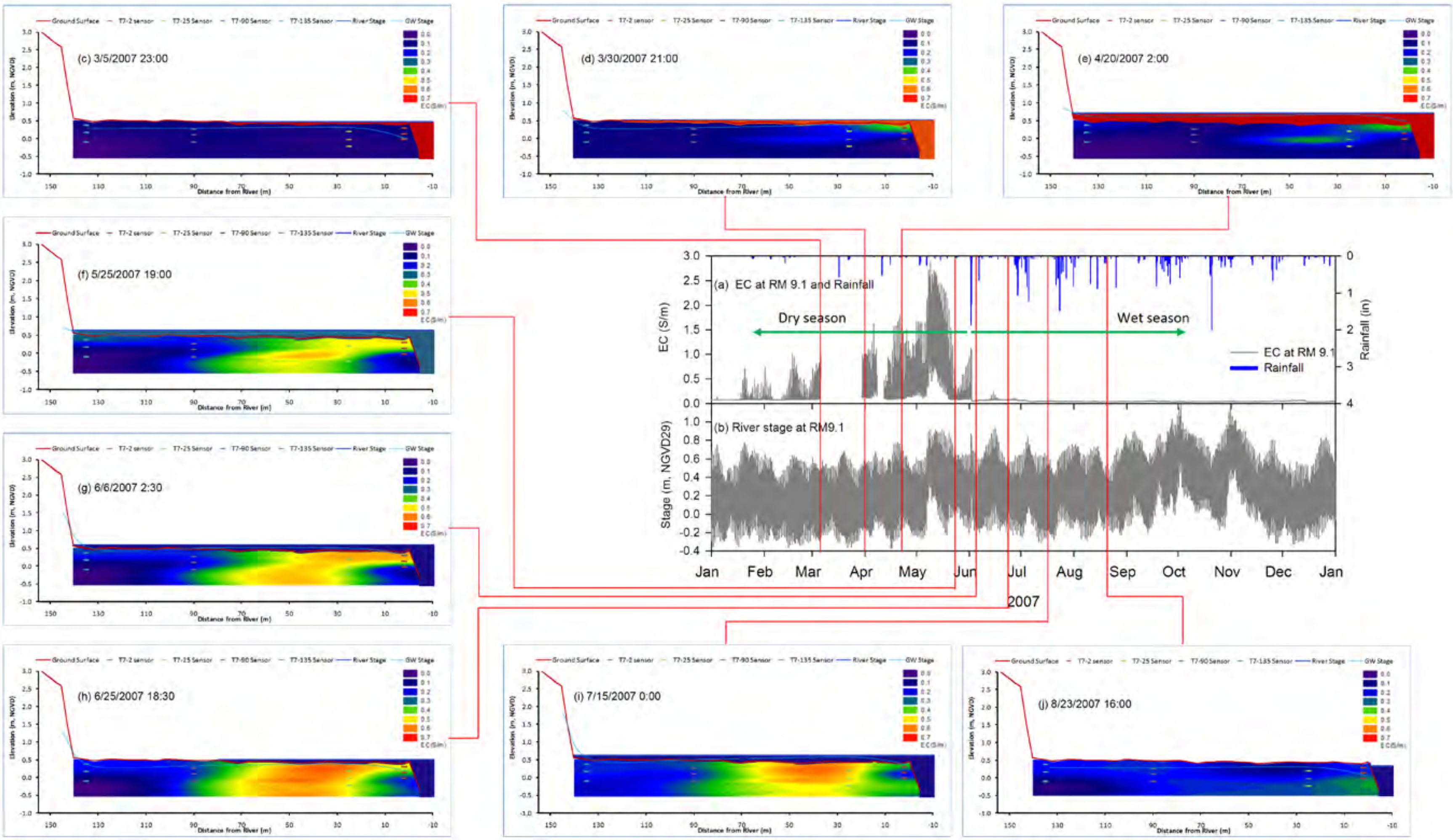


**Figure 2-42. T7 floodplain porewater EC contour showing EC variation from the dry season through the wet season**

At station T7-90, porewater salinity decreases with lag time is not obvious. It seems this station is a transition area between decrease with lag time and decreases without lag time (**Figure 2-23e**). In addition, porewater salinity contour maps show highest salinity was observed 30 to 70 m from the river bank but not the location closest to the river. This salinity distribution pattern may explain vegetation changes along the transect where white mangroves and pond apples grow between the river bank and T7-25, and red mangroves between T7-25 and T7-90. Porewater salinity exhibits a strong seasonal pattern increasing in the dry season and decreasing in the wet season, with a lag time of several months between the start of season and observed river water salinity change. Tidal cycles have very little impact on porewater salinity. The findings can be applied to the soil moisture and salinity management in the Northwest Fork, and links to vegetation patterns.

## 2.5 Flow-Stage Relationship

The *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006) established the flow-stage relationship for the Northwest Fork. Two field studies were conducted in 2004 to determine this hydrologic relationship. One study was a controlled release of 82 to 84 cfs of water over the Lainhart Dam with concurrent stage measurements at transects T1 through T4 (**Figure 3-1**). The other study focused on episodic stage measurements of the river under varying flow conditions in 2004. Further information on each study can be found in the restoration plan.

The flow-stage relationship has since been reevaluated focusing on the areas around the LOXR1 and LOXR3 stage recorders installed adjacent to transects T1 and T3, respectively (**Figure 2-43** and **Figure 2-44**). The first objective was to determine the elevation at each transect where inundation would begin. In 2003, surveyed transect lines were measured from the benchmark at the top of the floodplain to the edge of the river. These surveys are valuable but only show a slice of the topography. A more complete topographic representation was obtained by data collected in 2007 using terrestrial light detection and ranging (LIDAR). These data were processed into triangular irregular networks (TINS) (**Figure 2-43** and **Figure 2-44**). The LIDAR TINS proved to be a valuable tool to locate the low areas around the transects in the field, especially those descending to the river's edge connecting the floodplain to the river. The TINS were also useful in identifying flow impedances and isolated depressions.

Further analysis of the LIDAR data revealed its limitations due to its absolute vertical accuracy. Artifacts such as fallen trees and vegetation were left in the data, resulting in artificially higher elevations. The LIDAR TIN was compared to the 2003 survey data using the statistical approach of the root mean square error (RMSE) method, a method adopted by the Federal Emergency Management Agency. RMSE measures the square root of the average squared differences between the LIDAR data and the more accurate survey data at identical points. The LIDAR's RMSE resulted in an error of 1.04 ft at transect T1 and 0.76 ft at transect T3. An error of 1.04 ft is equivalent to approximately a 55 cfs difference in flow. Due to the magnitude of this error, elevations were measured in the low areas of each transect and in the areas of possible artifacts with a laser level by SFWMD staff (**Figure 2-45** and **Figure 2-46**). These measurements were used to ascertain the elevations where floodplain inundation would occur at various stages and to adjust the LIDAR data wherever possible with these measurements (**Figure 2-47** and **Figure 2-48**.)

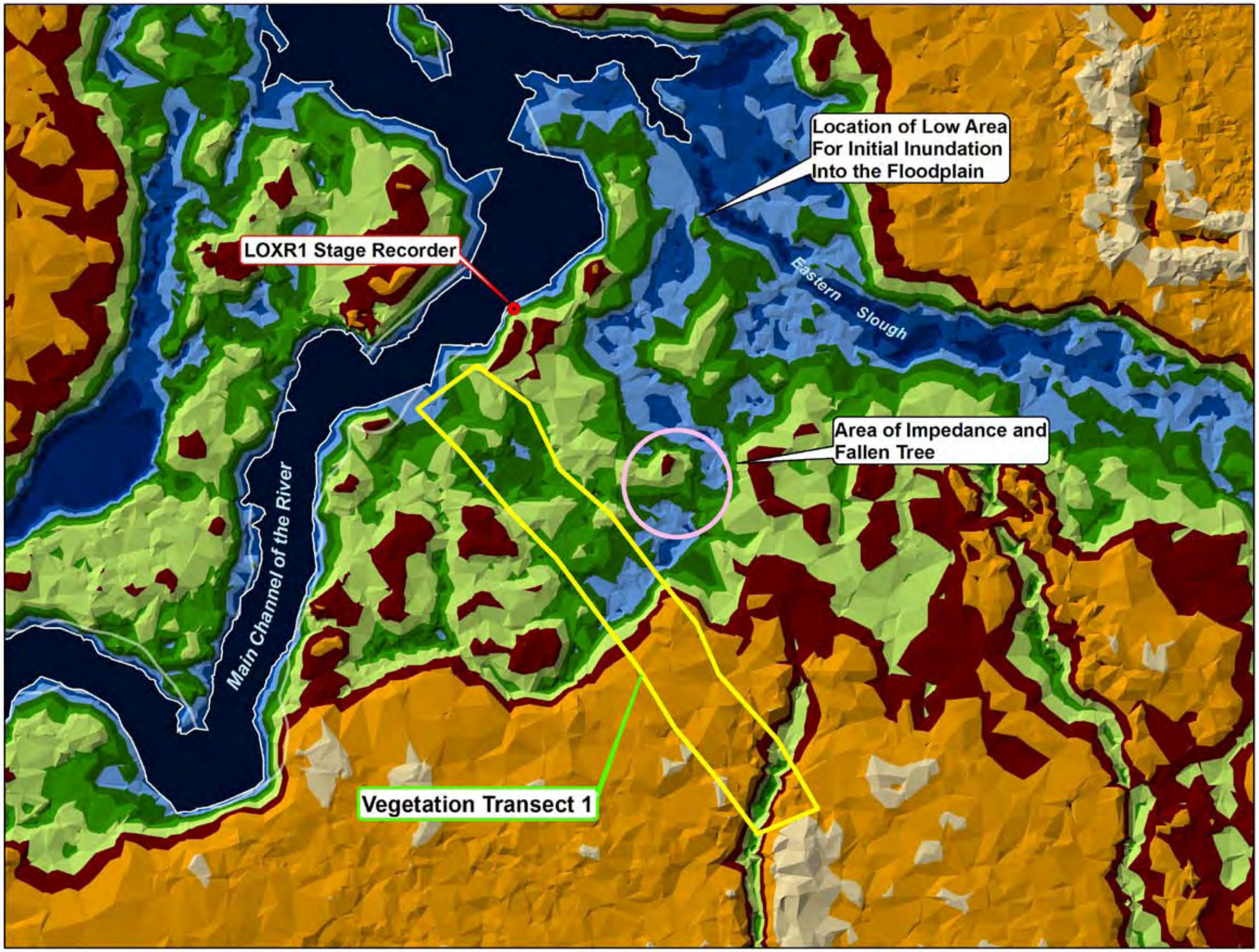


**Figure 2-43. LIDAR TIN around T1**

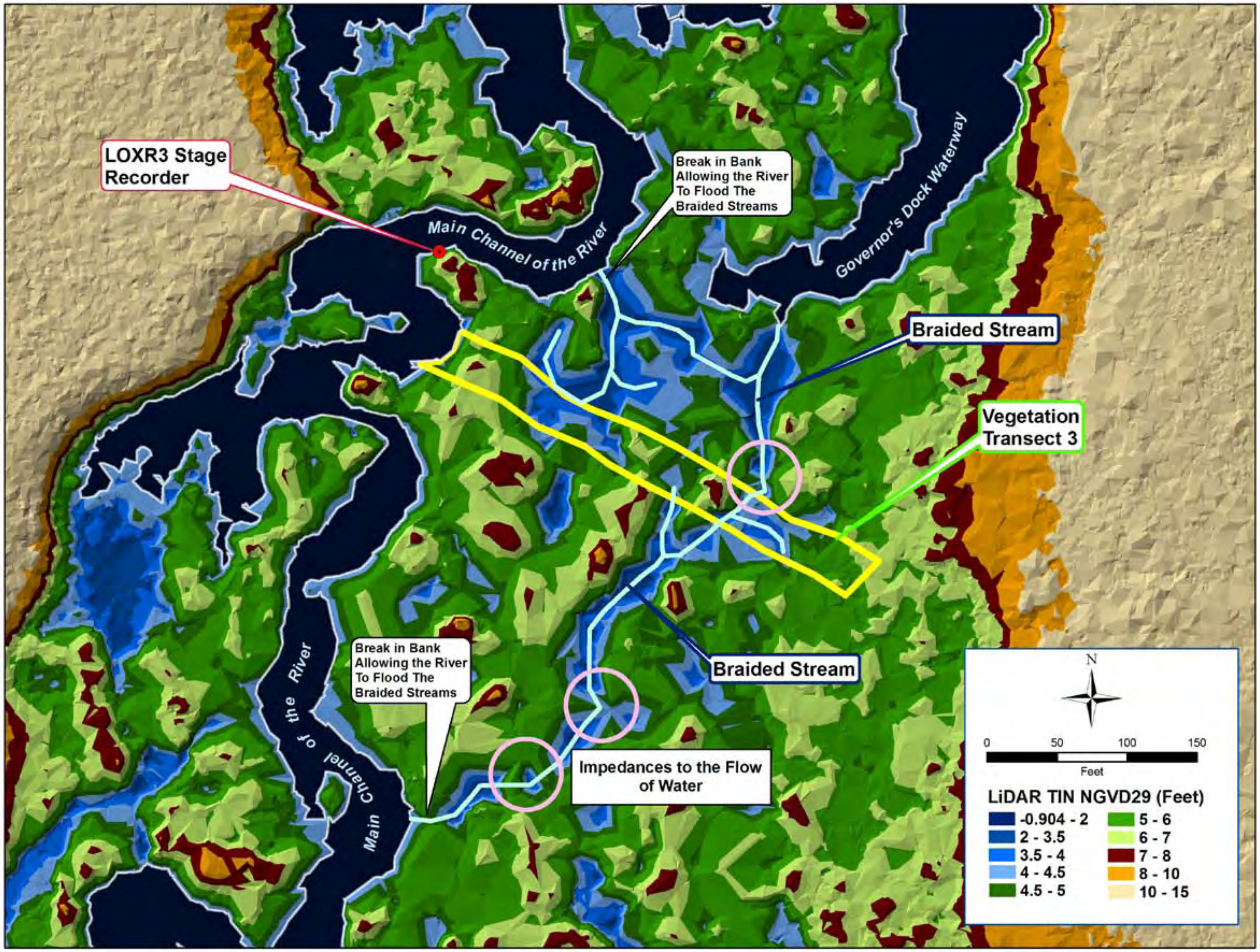


**Figure 2-44. LIDAR TIN around T3**

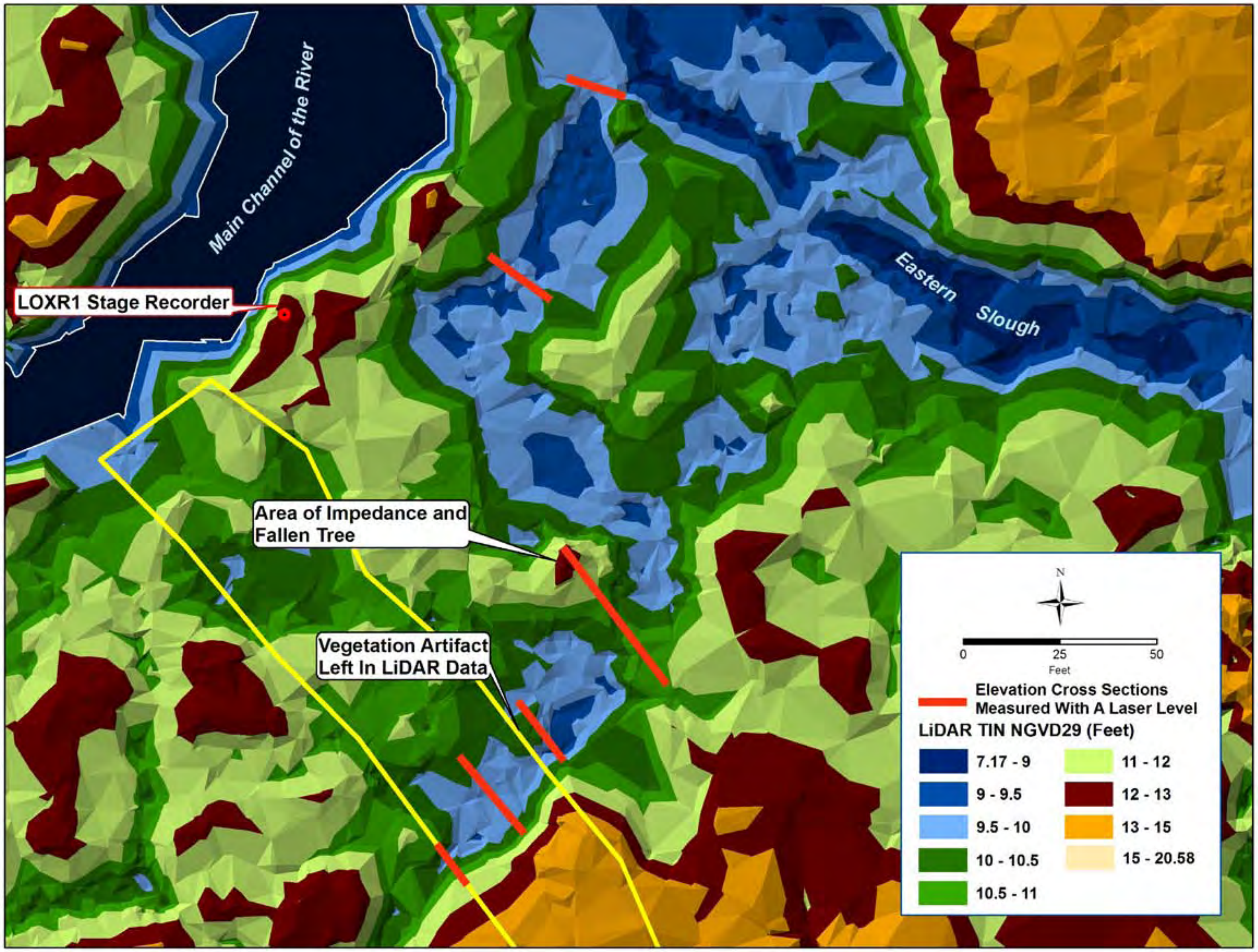


**Figure 2-45. LIDAR showing laser cross-sections around T1**

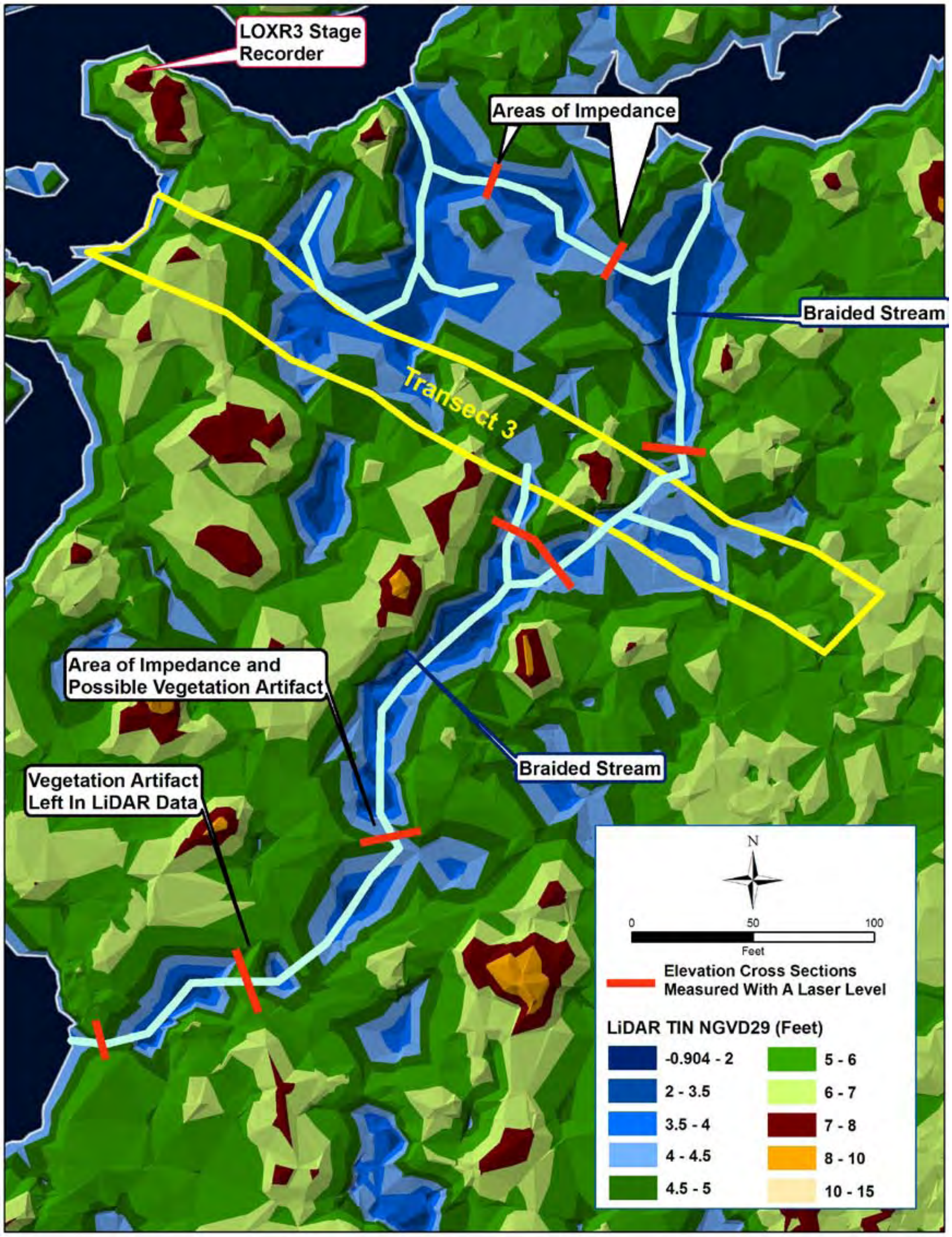


**Figure 2-46. LIDAR showing laser cross-sections around T3**

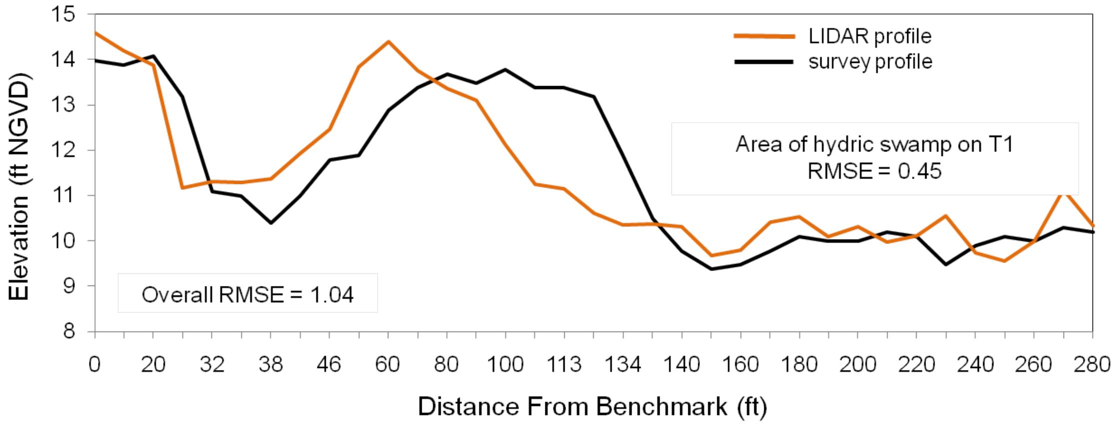


**Figure 2-47. Adjusted LIDAR data plotted against survey data for T1**

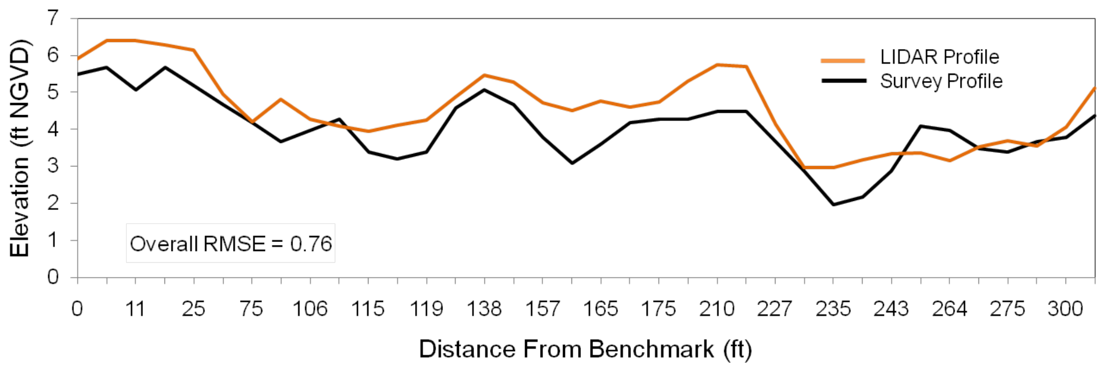


**Figure 2-48. Adjusted LIDAR data plotted against survey data for T3**

Due to the limitations of the LIDAR data, the adjusted LIDAR TINs were used only to approximate the area of inundation for different flow scenarios at each transect. One further note, after the LIDAR was adjusted at transect T1, the RMSE improved to 0.45 ft. in the area of the riverine swamp. Additional vegetation artifacts are left in the data, artificially raising the elevations at certain points. It would require more field measurements to further adjust the data.

At transect T1, the field measurements can be used to determine the river stage needed to reach 9.9 ft NGVD to flow into the transect. The stage data from LOXR1 was plotted against the Lainhart Dam flows (**Figure 2-49**). A flow of 110 cfs would create a stage of 9.95 ft NGVD, inundating first the midsection of the transect. In **Table 2-6**, the flow-stage relationship at transect T1 is listed for flows ranging from 85 to 300 cfs over the Lainhart Dam.

Transect T3 is traversed by lateral braided streams. The LIDAR results show these streams are connected to the river at three different sites, located outside of the vegetation transect (**Figure 2-44**). The LIDAR results also indicate several impedances to flow within these braided streams (**Figure 2-44** and **Figure 2-46**). SFWMD staff field verified the connections and measured cross sections at several locations including the locations of the impedances in the braided streams (**Figure** 2-46).

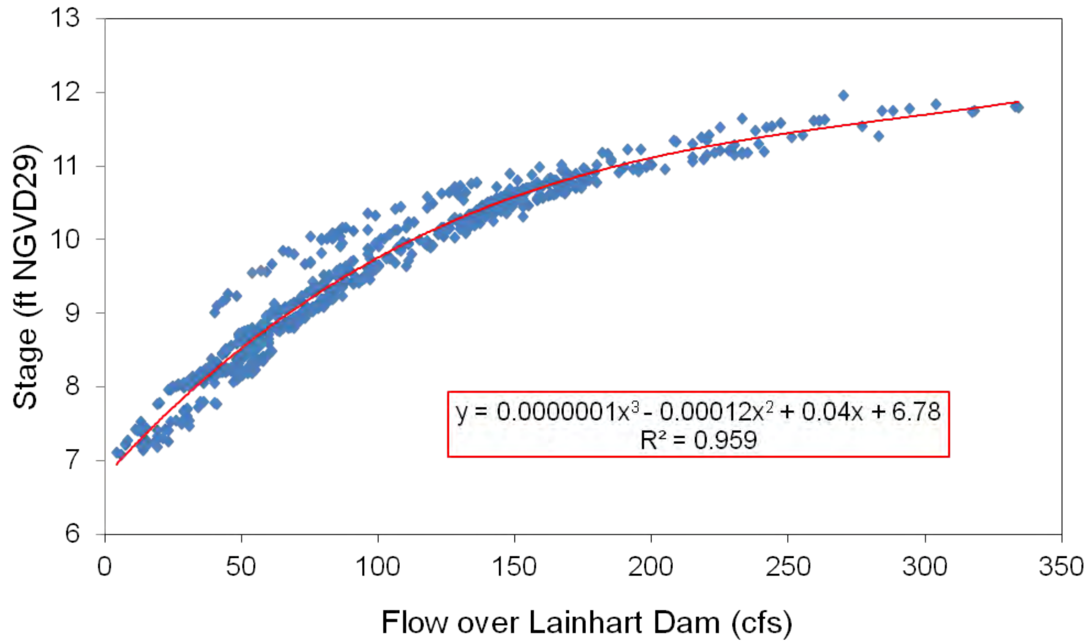


**Figure 2-49. Flow-stage relationship at T1 using LOXR1 stage recorder data with flows over the Lainhart Dam measured by the USGS**

**Table 2-6. T1 flow-stage relationship**

| Flow (cfs) | Stage (ft NGVD) | Flow (cfs) | Stage (ft NGVD) |
|---|---|---|---|
| 85 | 9.43 | 150 | 10.58 |
| 90 | 9.55 | 155 | 10.65 |
| 95 | 9.65 | 160 | 10.71 |
| 100 | 9.76 | 165 | 10.77 |
| 105 | 9.86 | 170 | 10.82 |
| 110 | 9.95 | 175 | 10.88 |
| 115 | 10.04 | 180 | 10.93 |
| 120 | 10.13 | 185 | 10.98 |
| 125 | 10.21 | 190 | 11.02 |
| 130 | 10.29 | 195 | 11.07 |
| 135 | 10.37 | 200 | 11.11 |
| 140 | 10.44 | 250 | 11.44 |
| 145 | 10.52 | 300 | 11.69 |

The floodplain around transect T3 is inundated not from the river's bank but from the river staging up into the braided streams and spilling over their banks onto the floodplain. The field measurements determined the braided streams would begin to be filled when the river reached a stage of 3.79 ft NGVD. The streams would overflow their banks at a stage ranging from 4.19 to 4.67 ft NGVD with an average elevation of 4.43 ft NGVD. When the stage data from LOXR3 was plotted against the flows of the Lainhart Dam (**Figure 2-50**), the braided streams would begin to fill from the river's stage at 90 cfs and overflow their banks at 110 cfs to 140 cfs. In **Table 2-7**, the flow-stage relationship at transect T3 is listed for flows ranging from 85 to 300 cfs over the Lainhart Dam. **Figure 2-51** through **Figure 2-56** show the approximate area of inundation under varying flows at each transect using the LIDAR TINS. In conclusion, the reevaluation of the flow-stage relationship at transects T1 and T3 builds upon and is consistent with the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006).

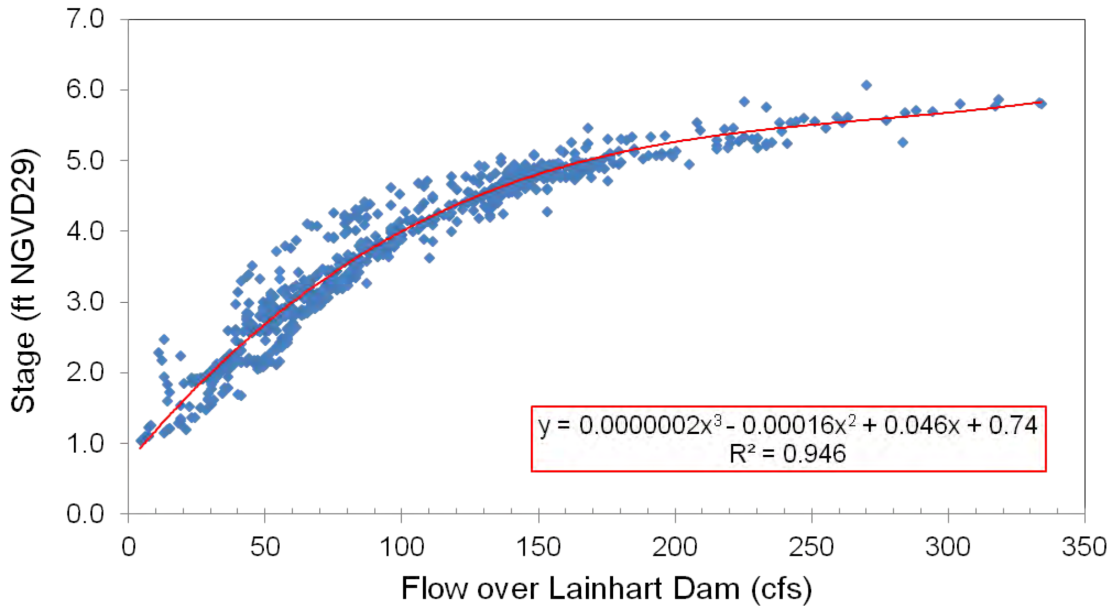


**Figure 2-50. Flow-stage relationship at T3 using LOXR3 stage recorder data with flows over the Lainhart Dam measured by the USGS**

NGVD29 – National Geodetic Vertical Datum of 1929

**Table 2-7. T3 flow-stage relationship**

| Flow (cfs) | Stage (ft NGVD) |
|---|---|
| 85 | 3.67 |
| 90 | 3.78 |
| 95 | 3.90 |
| 100 | 4.00 |
| 105 | 4.10 |
| 110 | 4.20 |
| 115 | 4.29 |
| 120 | 4.38 |

| Flow (cfs) | Stage (ft NGVD) |
|---|---|
| 131 | 4.55 |
| 135 | 4.61 |
| 140 | 4.68 |
| 150 | 4.81 |
| 175 | 5.07 |
| 200 | 5.27 |
| 250 | 5.51 |
| 300 | 5.68 |

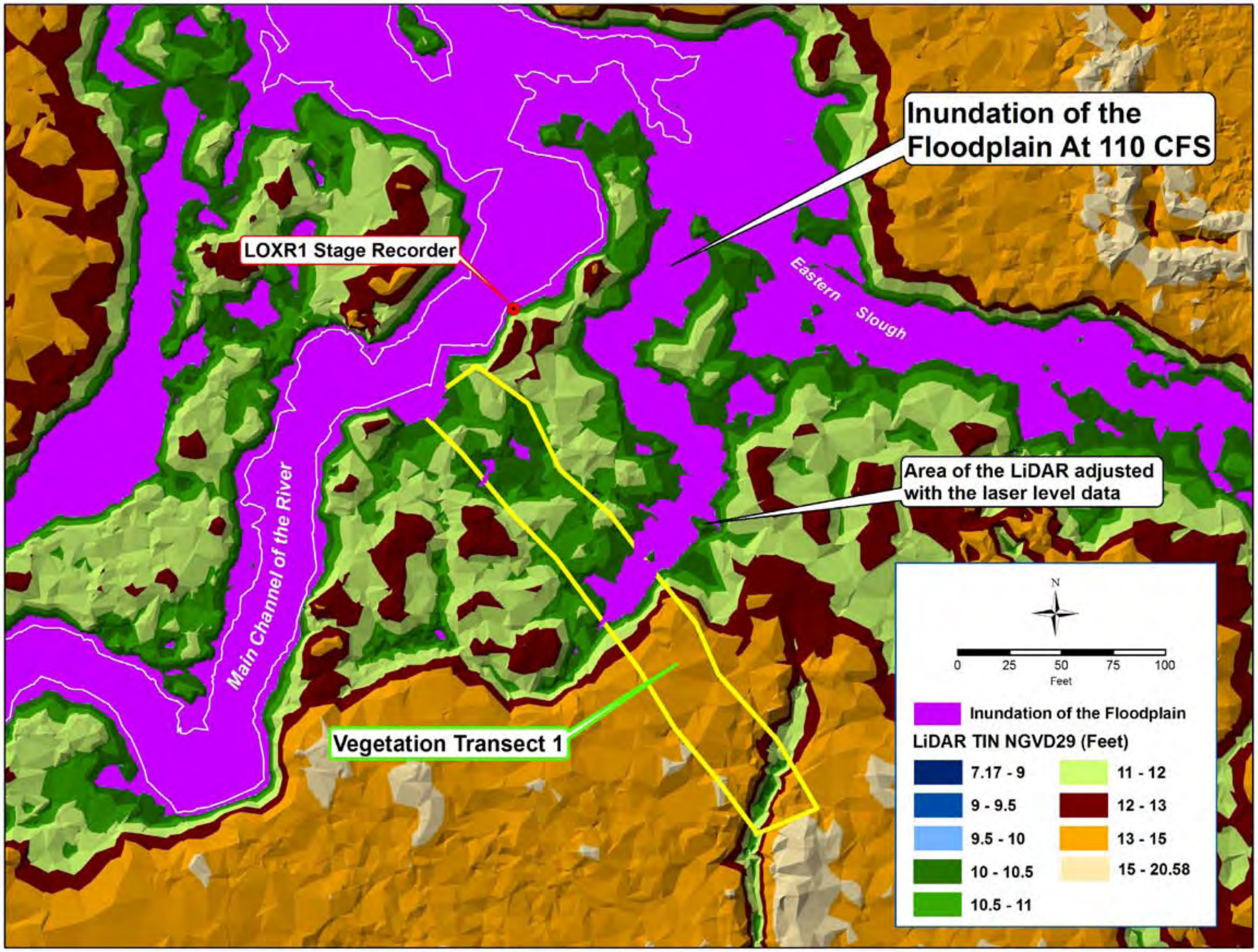


**Figure 2-51. T1 inundation when flow over the Lainhart Dam is 110 cfs**

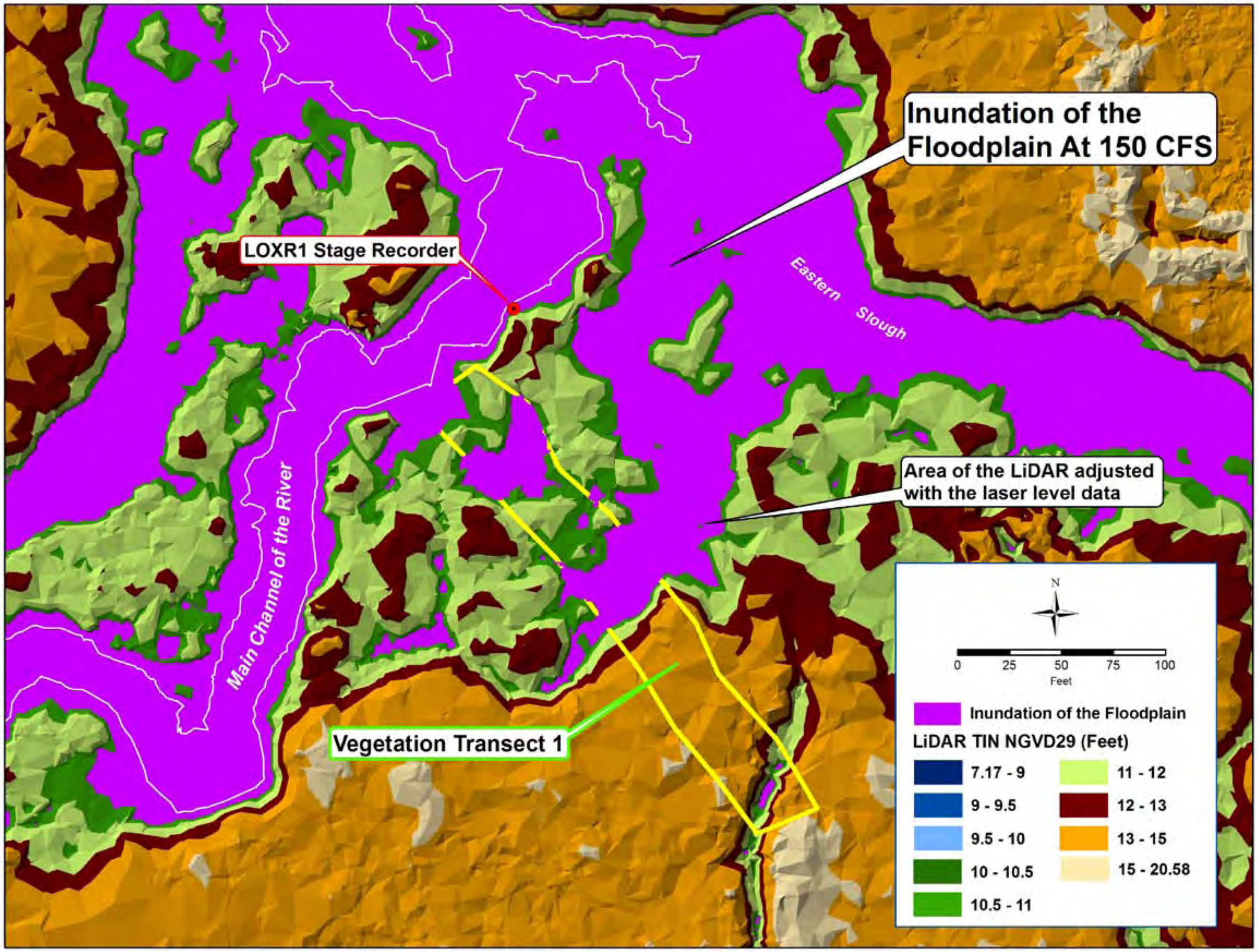


**Figure 2-52. T1 inundation when flow over the Lainhart Dam is 150 cfs**

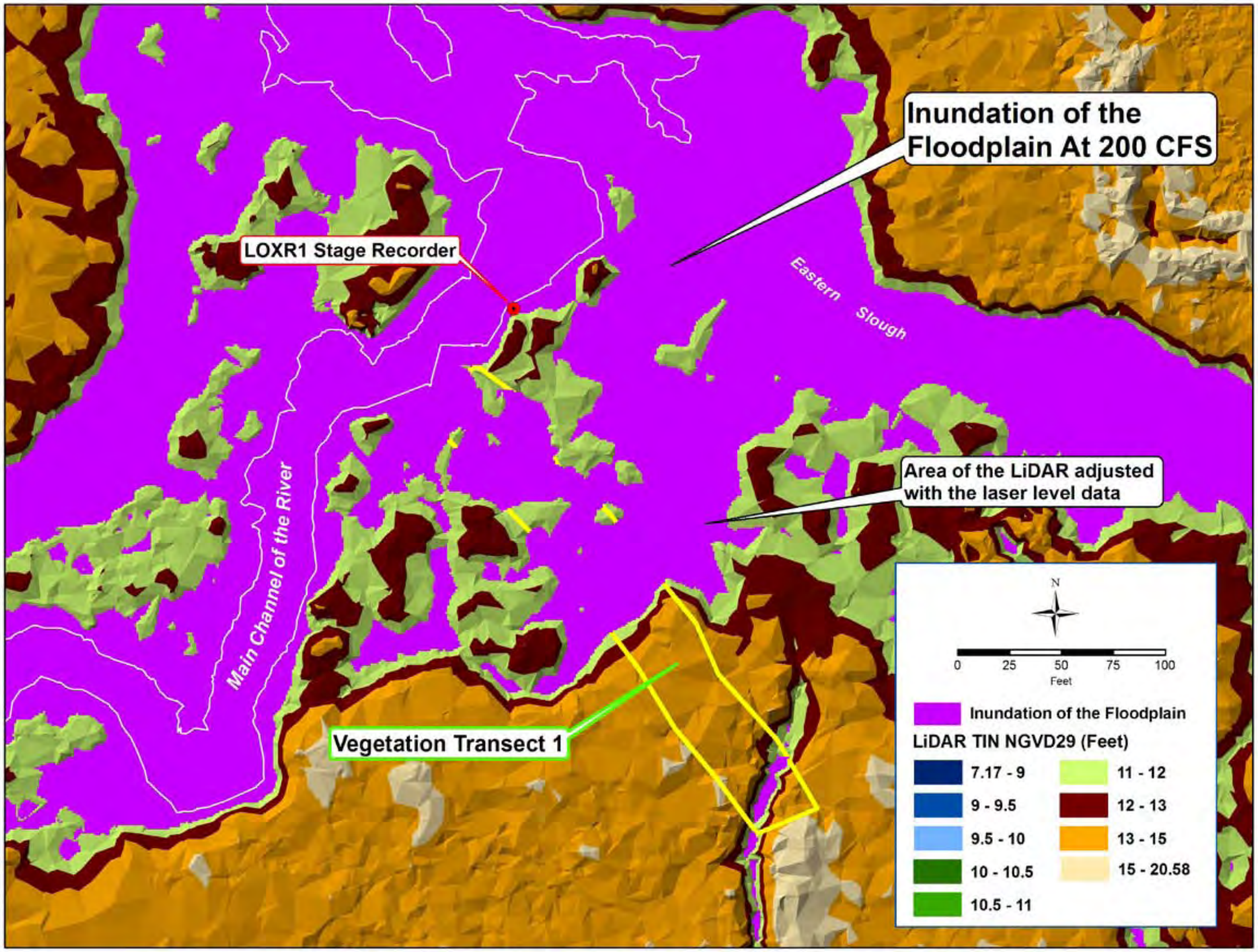


**Figure 2-53. T1 inundation when flow over the Lainhart Dam is 200 cfs**

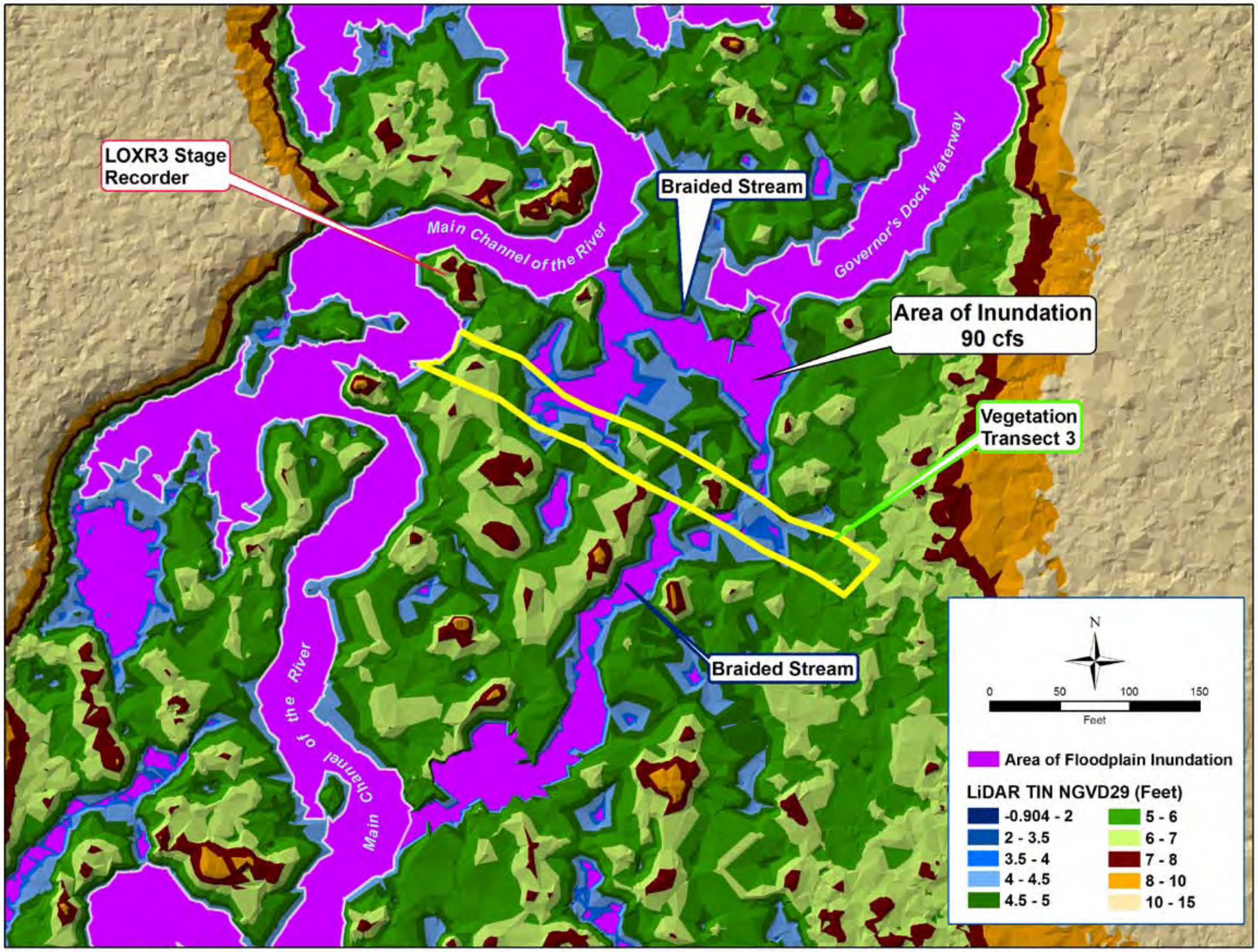


**Figure 2-54. T3 inundation when flow over the Lainhart Dam is 90 cfs**

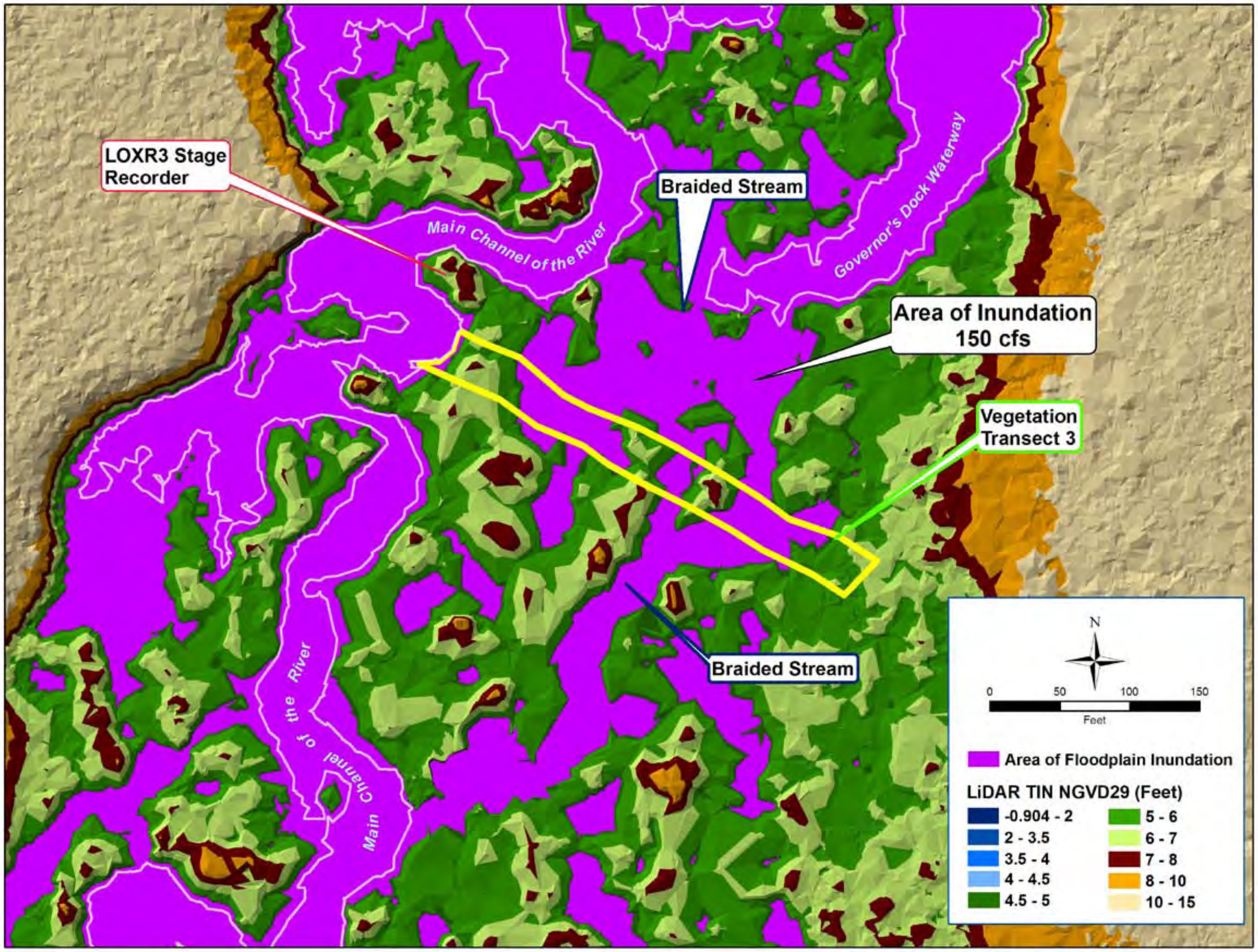


**Figure 2-55. T3 inundation when flow over the Lainhart Dam is 150 cfs**

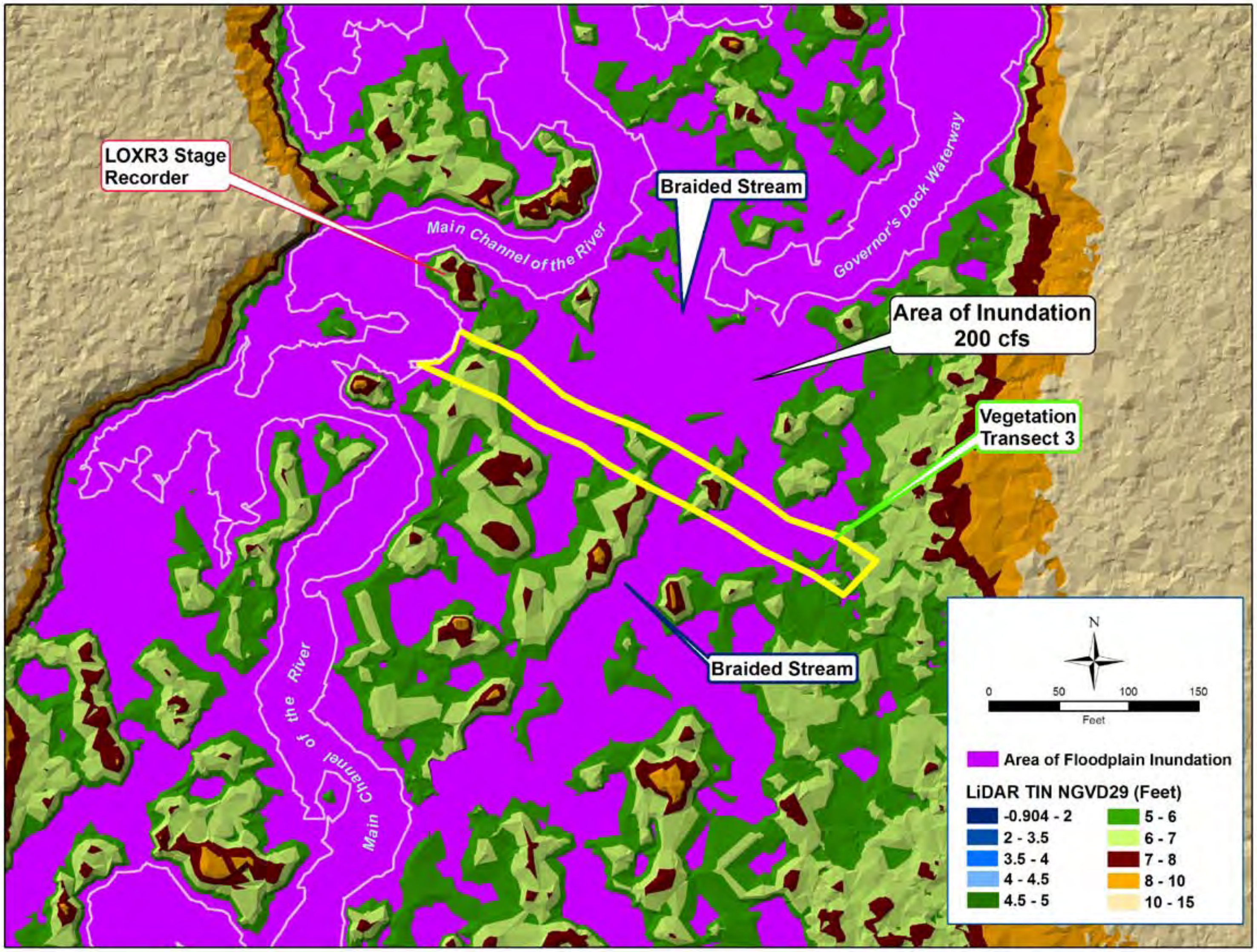


**Figure 2-56. T3 inundation when flow over the Lainhart Dam is 200 cfs**

# 3.0 RIVERINE AND TIDAL FLOODPLAIN VEGETATION INDICATORS

The floodplain plant communities on the Northwest Fork of the Loxahatchee River and its major tributaries were divided into three distinct reaches for study purposes: riverine, upper tidal and lower tidal (Figures 19 and 20 in SFWMD and FDEP FPS 2009). Hydroperiod influences the forest community composition in the riverine reaches, while salinity levels (e.g., saltwater intrusion and freshwater input) and tidal stage levels affect the forest community composition of the upper and lower tidal reaches of the river.

The major concerns regarding floodplain communities in the riverine reach are (1) minimal post-development inundation of the swamp community, (2) insufficient inundation to discourage the intrusion of transitional, upland and exotics plant species, (3) displacement of younger historic canopy species by multiple forest type communities, and (4) insufficient inundation for aquatic organisms to utilize floodplain swamp communities. A main goal of Northwest Fork restoration is the reestablishment of sufficient hydroperiods (frequency, duration and amplitude of duration) across riverine floodplain forest in the upper portions of the river.

Tidal portions of the river experienced higher salinity and greater tidal amplitude resulting in a loss of freshwater vegetation species, primarily bald cypress (*Taxodium distichum*), and created a dominant forest of red mangrove (*Rhizophora mangl*e) and white mangrove (*Laguncularia racemosa*) (Roberts et al. 2008). In addition, increases in salinity in tidal soils have resulted in an increase in hydrogen sulfide levels whereby organic sediment remains suspended in the water column instead of forming more solid layers of muck for healthier plant growth. Mesocosm and field studies on bald cypress seedlings collected from the Loxahatchee River have shown that bald cypress seedlings are stressed and may die at salinity above 2 practical salinity units (psu) as well as from prolonged flooding events (Li et al. 2006). Our emphasis on restoration in the tidal reaches is focused on reducing salinity to below 2 psu at the mouth of Kitching Creek.

Recommended hydroperiods for bald cypress swamp and hammock communities on the Loxahatchee River were established as 4–8 months and 1–2 months, respectively. In the tidal floodplain, the preferred restoration scenario will push the saltwater front from near River Mile (RM) 9.5, upstream of Hobe Grove Ditch, down to between RM 8, near Kitching Creek, and RM 7.5 (SFWMD 2006). This should improve recruitment of freshwater plant species in the mid-tidal reach of the river. For more details on this study, see the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006).

Sea level rise, climate change, land use and development, and water management are external drivers that result in ecological stressors including nutrients, hydrology and hydrodynamics, soil type, and other factors. An ecologic conceptual model (SFWMD et al. 2010) shows the effects caused by these stressors are salinity, saltwater intrusion, flow, altered hydroperiods, vegetative growth, hurricane, fire, lumbering, changes in light and canopy cover, and invasion of exotic vegetation species. The major concern in the riverine reach is the lack of post-development inundation. This lack of inundation encourages the intrusion of native transitional, upland and nonnative plant species; modifies the subcanopy vegetation into multiple types of forest communities; and reduces the utilization of the floodplain swamp by aquatic organisms. The tidal portions of the river have experienced a loss of freshwater plant species (i.e., bald cypress) and a shift to more saltwater tolerant plants (i.e., red and white mangroves) associated with increases in salinity and tidal amplitude (Roberts et al. 2008).

### 3.1 Vegetation Surveys

Vegetation surveys were conducted in 2003, 2007, 2009 and 2010. The canopy was surveyed in 2003 and 2009. Shrub and ground cover layers were surveyed in 2003, 2007 and 2010. The results of these summaries are discussed below. To survey vegetation, ten vegetative belt transects were established. Each transect runs from the uplands to the edge of the river channel. Transects were established in all three reaches of the river (**Figure 3-1**). Transects 1–5 are within the riverine reach, Transects 6–8 and 10 are within the upper tidal reach, and Transect 9 is within the lower tidal reach.

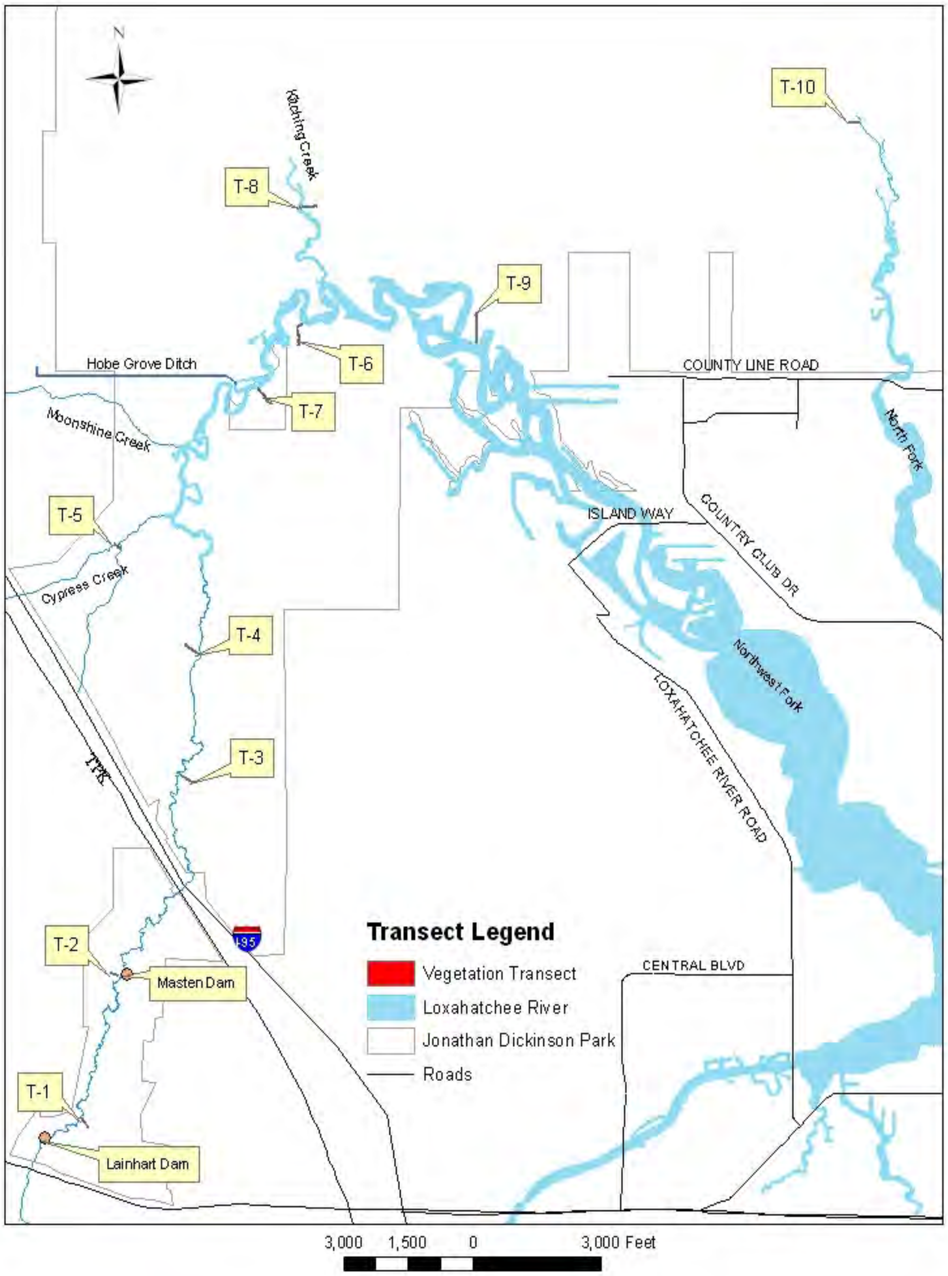


**Figure 3-1. Location of vegetation transects**

Major forest type categories were developed for the Loxahatchee River floodplain vegetative communities based on relative basal area of the canopy species present. Other forest composition factors examined include salinity, soil type, elevation, storm events, logging and fire history. These 17 forest types are summarized in **Table 3-1**. Rules for each forest type can be found in the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006) and *Riverine and Tidal Floodplain Vegetation of the Loxahatchee River and Its Major Tributaries* (SFWMD and FDEP FPS; see **Table 3-4** through **Table 3-6** later in this section). The five major community types were identified as swamp, bottomland hardwood, hydric or mesic hammocks, freshwater marsh, and upland. **Table 3-2** provides a summary of the number of plots of each community type found along each transect.

**Table 3-1. Forest type names and abbreviations**

| Reach | Forest Type | Forest Type Abbreviations |
|---|---|---|
| Riverine | Swamp | Rsw1 |
| | | Rsw2 |
| | Low bottomland hardwood | Rblh1 |
| | High bottomland hardwood | Rblh2 |
| | | Rblh3 |
| | Hammocks | MH |
| | | HH |
| | Uplands | U |
| Upper tidal | Swamps | UTsw1 |
| | | UTsw2 |
| | | UTsw3 |
| | | UTmix |
| | | Rsw1 |
| | | Rmix |
| | Hammocks | HH |
| | | MH |
| | Uplands | U |
| | Freshwater Marsh | M |
| Lower tidal | Swamp | LTsw1 |
| | | LTsw2 |
| | | LTmix |
| | Hammocks | HH |
| | Uplands | U |

**Table 3-2. Number of plots of each forest type along each transect**

| | Number of Plots | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Riverine | | | | | Upper Tidal | | | Lower Tidal | Upper Tidal |
| **Forest Type** | **T1** | **T2** | **T3** | **T4** | **T5** | **T6** | **T7** | **T8** | **T9** | **T10** |
| **Swamp** | | | | | | | | | | |
| Rsw1 | 9 | 4 | 2 | 5 | 4 | 1 | 2 | | | |
| Rsw2 | | | 7 | 1 | | | | | | |
| Rmix | | | | | | | 5 | 2 | | |
| UTsw1 | | | | | | 6 | 4 | 5 | | |
| UTsw2 | | | | | | | 3 | | | 1 |
| UTsw3 | | | | | | 6 | | | | |
| UTmix | | | | | | 1 | | 4 | | 4 |
| LTsw1 | | | | | | | | | 5 | |
| LTsw2 | | | | | | | | | 11 | |
| LTmix | | | | | | | | | 1 | |
| **Bottomland Hardwood** | | | | | | | | | | |
| Rblh1 | 1 | 1 | | | 1 | | | | | |
| Rblh2 | | | 2 | 3 | 5 | | | | | |
| Rblh3 | | | 1 | 1 | 1 | | | | | |
| **Hammock** | | | | | | | | | | |
| MH | 2 | 3 | | 1 | 1 | | | | | |
| HH | 2 | 2 | | | | | | 1 | 1 | 1 |
| **Other** | | | | | | | | | | |
| U | | | | | | 2 | | | 1 | |
| M | | | | | | | | | | 1 |
| **Combinations** | | | | | | | | | | |
| Rsw1/Rblh2 | | | | 1 | 1 | | | | | |
| MH/Rsw1 | | | | | | | 1 | | | |
| HH/Rsw1 | | 3 | | | | | | | | |
| HH/LTsw2 | | | | | | | | | 1 | |
| HH/Rblh3 | | | | | 1 | | | | | |
| HH/U | 1 | | 1 | | | | | | | |
| HH/M | | | | | | | | | | 1 |
| **Total** | **15** | **13** | **13** | **12** | **14** | **16** | **15** | **12** | **20** | **8** |

### 3.1.1 Summary of Methods

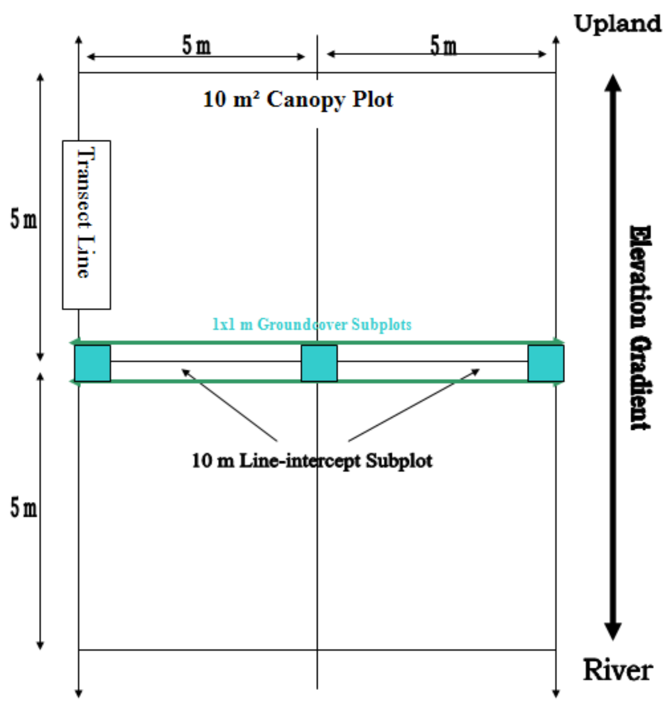


**Figure 3-2. Schematic of transect monitoring**

The methods used in the vegetation surveys were based largely on those defined by Ward (1993), Ward and Roberts (1996), and Light and Darst on the Suwannee River (Light et al. 2002, Darst et al. 2003). Each belt transect was 10 meters (m) wide and divided into adjacent 10 m by 10 m plots along its length (**Figure 3-2**). A total of 138 ten square meter ($m^2$) plots were established along the ten transects. Within each 10 m² plot, all trees with greater than 5 centimeters (cm) diameter at breast height (dbh) were identified by species and dbh was measured for canopy analysis. Shrub layer cover was measured by examining all plant species with a height greater than 1 m and dbh less than 10 cm within a 10 m line intercept nested within each 10 m² plot. Percent cover and stem counts of all herbaceous and woody plant species under 1 m were measured within three, 1 m² subplots nested within each 10 m² plot and recorded as ground cover data. Additional information collected within each vegetation plot included presence of hummocks, presence of cypress stumps, and estimates of percent open ground, percent exposed roots, percent leaf litter and percent fallen logs. Within each transect and vegetation plot, corresponding elevations and soil types were determined to investigate environmental factors affecting plant distribution and abundance. Field work was conducted by staff from the South Florida Water Management District (SFWMD) and the Florida Department of Environmental Protection's (FDEP) Florida Park Service (FPS) with assistance from student interns provided by the Student Conservation Association and Americorp, and a botanist from Palm Beach County Environmental Resources Management (**Appendix 3-1**).

Field data was analyzed using several categories. Canopy data was examined for abundance, basal area, dbh, frequency of occurrence, growth rate of select species, and dbh size frequency. The relative basal area of canopy species was used to determine forest type within each plot. The relative basal area was calculated by dividing the total basal area of a species (in $m^2$) by the total basal area of all species within a 10 $m^2$ plot.

The shrub layer data was reported by percent cover and frequency of occurrence by transect and forest type and included all plant species (Mueller-Dombois and Ellenberg 1974). Frequency of occurrence was determined for each species by counting the number of plots the species occurred in within a transect. In this case, each shrub line intercept and the three ground cover squares were considered a plot or sampling site. Percent cover was determined by summing the individual branch measurements of each species and dividing by the total measurement of all species along the intercept line of each plot.

With regards to the ground cover layer, percent cover and stem counts of all herbaceous and woody plant species shorter than 1 m were measured within three 1 $m^2$ subplots nested within each 10 $m^2$ plot. Ground cover data was analyzed for abundance of stems, percent cover and frequency of occurrence.

### 3.1.2 Rainfall and Freshwater Flow

Salinity, rainfall and freshwater flow are three effects shown to alter floodplain vegetation in the Loxahatchee River watershed. Salinity in the river and on the floodplain was discussed in more detailed in **Section 2.0**. However, it is important when discussing vegetation survey results to have a general understanding of rainfall and freshwater flow over at least the last 10 years.

The Loxahatchee River watershed generally receives about 61inches of rainfall annually (Dent 1997) although rainfall totals have ranged from 38 to 93 inches due to droughts and tropical storms. **Figure 3-3** illustrates total monthly rainfall at the S-46 water control structure on the Southwest Fork of the Loxahatchee River. As expected, heaviest precipitation occurred during the wet season from late spring to early fall (May through October) while low values were recorded for the dry season from November to April. A localized rainfall event occurred in October 2000 that produced 1.85 inches at S-46 while only 0.08 inches were recorded at the JDWX weather station located near Kitching Creek obtained from the SFWMD's hydrologic and water quality databases (DBHYDRO). Other events included Hurricanes Frances, Ivan and Jeanne in September 2004 resulting in a total of 19 inches of rainfall, Hurricane Wilma in October 2005 resulting in 8 inches of rainfall, and the severe drought during 2007.

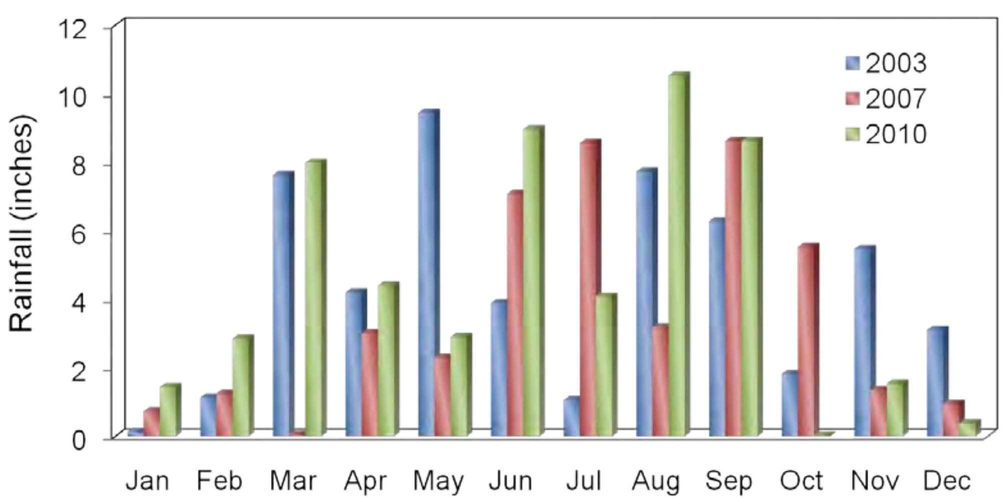


**Figure 3-3. Total monthly rainfall at S-46 during 2003, 2007 and 2010**

Dry and wet season freshwater flows over Lainhart Dam are assessed as a means of looking at hydrological conditions in the river channel and floodplain. **Figure 3-4** illustrates monthly dry and wet season flows at Lainhart Dam during the three years vegetation was monitored (2003, 2007 and 2010) along the river floodplain. The gold solid line represents 90 cubic feet per second (cfs), which is approximately the flow where stage at Transect (T1) is at the top of bank and the floodplain is still not inundated. At T1, the floodplain becomes inundated at

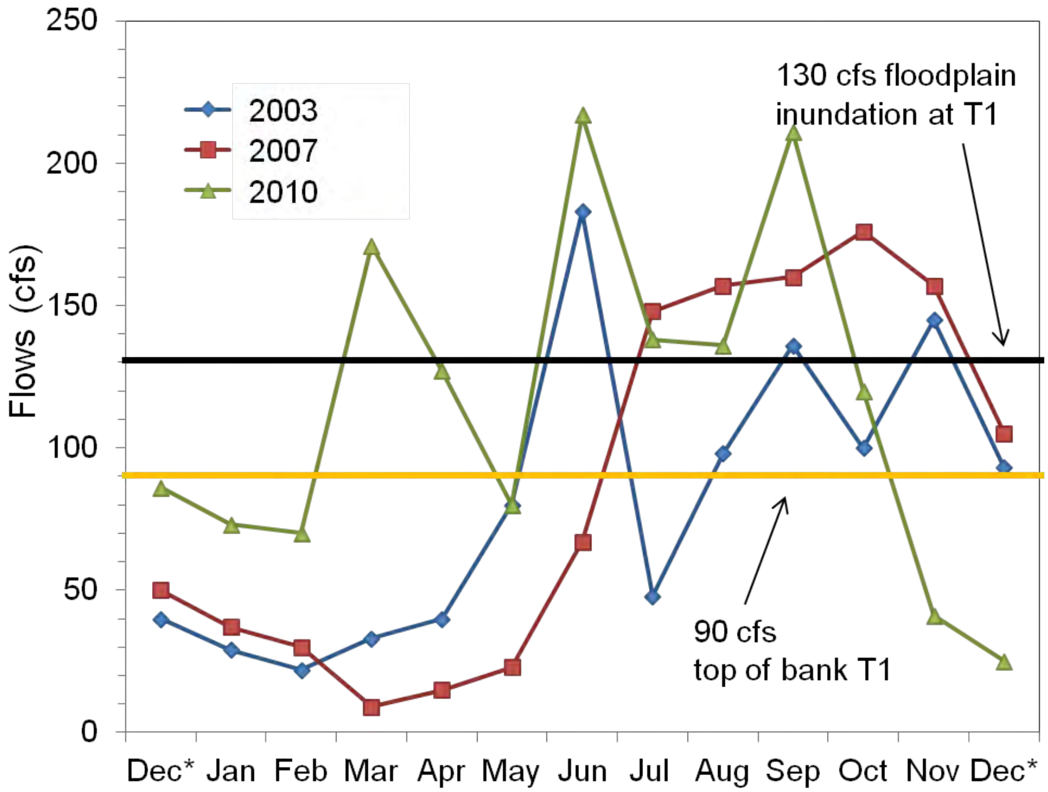


**Figure 3-4. Dry and wet season flows at Lainhart Dam during 2003, 2007 and 2010**

approximately 130 cfs. In 2010, both the dry and wet seasons had consecutive periods of several months of floodplain inundation. As will be discussed later in this section, freshwater vegetation numbers (abundance, frequency of occurrence, percent cover and stem counts) were high in spring 2010 following the wet dry season. On the other hand, 2007 salinity data from the pore water of T7, located at RM 9.1, were reportedly high during late winter and early spring. More details on this event are given in **Section 2.0**. In comparing flow for the vegetation monitoring periods, 2007 would be drought conditions and 2010 would be very wet conditions, while 2003 fell in between the two years with moderate hydrological conditions.

**Table 3-3** shows a more detailed view of mean monthly flow values at Lainhart Dam between 1999 and 2010. Red boxes are flow values less than 35 cfs, which is the current minimum flow target. Mean monthly flows ranged from 49 to 144 cfs. The 2007 shrub and ground cover survey was conducted between February and May, and flows were very low ranging from 9 to 30 cfs. The 2009 canopy survey was conducted between March and May with flows ranging from 45 to 126 cfs. The 2010 shrub and ground cover survey was conducted between March and June when flows ranged from 80 to 217 cfs. For almost all of the 2010 survey period, nontidal floodplain areas were inundated making it very hard to survey. In some plots, water was greater than a foot deep and an underwater view finder was used to enumerate vegetation on the ground. The impacts of these hydrological conditions on vegetative communities are discussed in more detail later.

**Table 3-3. Mean monthly flow values at Lainhart Dam 1999–2010**

| Years | Monthly Flow (cfs) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **January** | **February** | **March** | **April** | **May** | **June** | **July** | **August** | **September** | **October** | **November** | **December** | **Average** |
| 1999 | 182 | 84 | 43 | 6 | 8 | 106 | 140 | 130 | 158 | 221 | 120 | 80 | 107 |
| 2000 | 47 | 40 | 26 | 72 | 39 | 13 | 41 | 36 | 32 | 136 | 70 | 54 | 51 |
| 2001 | 24 | 19 | 14 | 27 | 17 | 43 | 130 | 210 | 258 | 272 | 259 | 94 | 114 |
| 2002 | 75 | 124 | 61 | 54 | 23 | 97 | 286 | 113 | 100 | 56 | 35 | 40 | 89 |
| 2003 | 29 | 22 | 33 | 40 | 80 | 183 | 48 | 98 | 136 | 100 | 145 | 93 | 84 |
| 2004 | 47 | 47 | 32 | 18 | 19 | 9 | 22 | 71 | 226 | 134 | 83 | 49 | 63 |
| 2005 | 23 | 94 | 73 | 66 | 167 | 151 | 146 | 180 | 180 | 119 | 110 | 109 | 112 |
| 2006 | 41 | 35 | 20 | 13 | 7 | 25 | 63 | 69 | 178 | 113 | 55 | 50 | 56 |
| 2007 | 37 | 30 | 9 | 15 | 23 | 67 | 148 | 157 | 160 | 176 | 157 | 105 | 91 |
| 2008 | 74 | 81 | 127 | 101 | 30 | 70 | 107 | 55 | 42 | 32 | 107 | 55 | 98 |
| 2009 | 42 | 32 | 45 | 49 | 126 | 145 | 114 | 132 | 47 | 86 | 48 | 86 | 76 |
| 2010 | 73 | 70 | 171 | 127 | 80 | 217 | 138 | 136 | 211 | 120 | 41 | 25 | 117 |
| Average | 58 | 57 | 55 | 49 | 52 | 93 | 116 | 116 | 144 | 130 | 103 | 70 | 90 |

**Legend**

| |
|---|
| < 35 cfs |
| < 65 cfs |
| ≥ 65 & ≤ 100 cfs |
| > 110 cfs |

**White outline denotes vegetation survey months**

2003 canopy, shrub and ground cover survey was conducted July–November 2003.

2007 shrub and ground cover survey was conducted February 22–May 10.

2009 canopy survey was conducted March 6–May 15.

2010 shrub and ground cover survey was conducted March 10–June 11.

### 3.1.3 Canopy Communities

The canopy trees of the floodplain forest are long-term indicators of hydrological conditions within the floodplain. The oldest and largest community by acreage on the Loxahatchee River floodplain is the bald cypress swamp community with some of the oldest trees estimated to be over 300 years old. The Loxahatchee River is the largest remaining bald cypress forest community in southeast Florida. *Riverine and Tidal Floodplain Vegetation of the Loxahatchee River and Its Major Tributaries* (SFWMD and FDEP FPS 2009) contains an analysis of the canopy data collected by transect in 2003. During the 2003 survey, 27 canopy species and one woody vine were encountered within the ten transects. During the 2009 canopy survey, five additional canopy species were reported: black mangrove (*Avicennia germinans*), coco plum (*Chrysobalanus icaco*), mulberry (*Morus rubra*), climbing cassia (*Senna pendula*) and poison ivy (*Toxicodendron radicans*). The majority of the species (i.e., relative abundance) observed in the 2009 canopy survey were white mangrove (29%), red mangrove (18%), pond apple (*Annona glabra*; 14%), cabbage palm (*Sabal palmetto*; 10%) and bald cypress (8%) (**Figure 3-5** and **Table 3-4**). Increases in abundance and relative abundance between 2003 and 2009 were mainly attributed to white mangrove (23 to 29%), red mangrove (14 to 18%) and pond apple (13 to 14%). Decreases in abundance were noticeable in bald cypress (9 to 8%), cabbage palm (12 to 10%), wax myrtle (*Myrica cerifera*; 6.6 to 3.63%), Brazilian pepper (*Schinus terebinthifolius*; 3 to 1%) and red maple (*Acer rubrum*; 4 to 2%). Decreases were generally attributed to damage from the 2004–2005 hurricanes, saltwater intrusion, and exotic removal programs within Jonathan Dickinson State Park.

Basal area reflects more of the nature of canopy cover than tree abundance. The bald cypress community dominated the floodplain of the Loxahatchee River and its major tributaries with a 40.2 percent basal area in 2003 and a 42.4 percent basal area in 2009 (**Table 3-5**). Cabbage palm was the next highest species with 22.8 percent in 2003 and 23 percent in 2009. The saltwater species white mangrove was next with 8.4 percent in 2003 and 8.1 percent in 2009 while red mangrove, the other saltwater species, occurred at only 1.6 and 2.6 percent in 2003 and 2009, respectively. Red maple decreased from 3.3 to 1.5 percent from 2003 to 2009 and water hickory (*Carya aquatica*) decreased from 8.0 to 7.6 percent. Pond apple increased from 2.5 to 3.3 percent.

Frequency of occurrence of the 2009 canopy species by transect is illustrated in **Table 3-6**. The saltwater species, white and red mangroves, occurred at the highest frequencies overall (29.4 and 18.0%, respectively) although they only occurred within the brackish tidal transects (T6–T10). Pond apple was the next highest with a 14.0 percent frequency. They occurred on seven of the ten transects; however, occurrences were much lower in the riverine reach than the tidal reaches. In the riverine reach, they were highest on T3, which features several small braided streams within the floodplain and, therefore, ground water levels may remain higher and more stable. Pond apple is a swamp species and needs inundation. This is another indication that hydroperiods on our riverine transects are not sufficient to support a variety of freshwater swamp species. This is also supported by the low numbers of freshwater swamp recruits in the riverine shrub and ground cover communities. Canopy bald cypress trees (7.3%) were observed on eight of the ten transects with the highest occurrences mostly in the Upper Tidal Reach where soil moisture levels never reach zero because of tidal inundation twice a day.

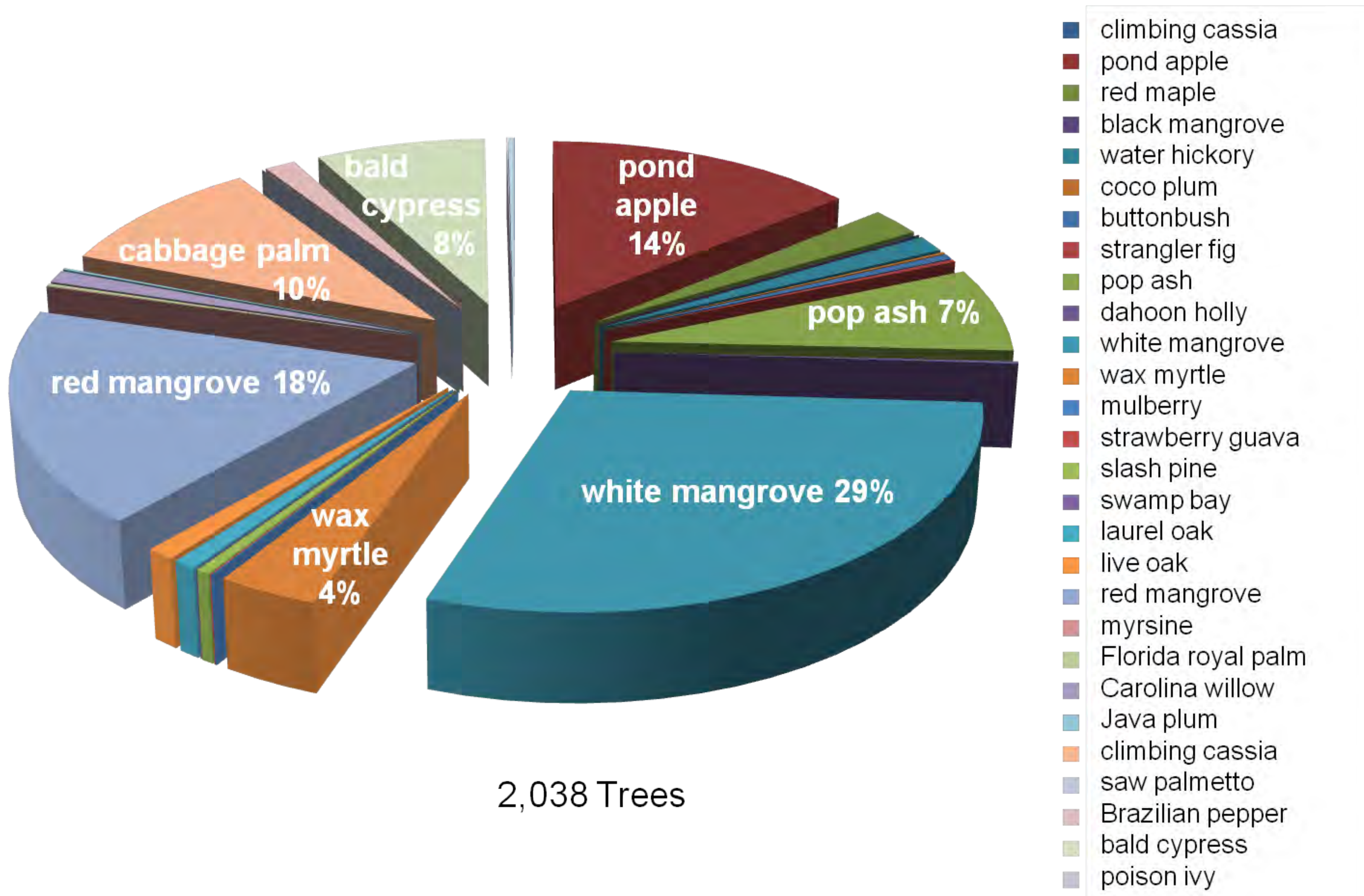


**Figure 3-5. Canopy species relative abundance in 2009**

Note: Scientific names are provided in **Appendix 3-2**.

**Table 3-4. Abundance and relative abundance of canopy species in 2003 and 2009**

| Common Name[1] | Abundance (total number) | | Relative Abundance (percent total) | |
|---|---|---|---|---|
| | 2003 | 2009 | 2003 | 2009 |
| Red maple | 61 | 48 | 3.50 | 2.35 |
| Pond apple | 228 | 285 | 13.00 | 14.00 |
| Black mangrove | | 1 | 0.00 | 0.05 |
| Water hickory | 33 | 29 | 1.90 | 1.40 |
| Buttonbush | 3 | 9 | 0.20 | 0.44 |
| Coco plum | | 3 | 0.00 | 0.15 |
| Wild orange[2] | 4 | 0 | 0.20 | 0.00 |
| Strangler fig | 5 | 5 | 0.30 | 0.24 |
| Pop ash | 139 | 143 | 7.90 | 7.02 |
| Dahoon holly | 5 | 4 | 0.30 | 0.20 |
| White mangrove | 396 | 598 | 22.50 | 29.34 |
| Mulberry | | 1 | 0.00 | 0.05 |
| Wax myrtle | 117 | 74 | 6.60 | 3.63 |
| Red bay | 6 | 0 | 0.30 | 0.00 |
| Swamp bay | 1 | 2 | 0.10 | 0.01 |
| Slash pine | 10 | 10 | 0.60 | 0.49 |
| Strawberry guava[2] | 4 | 1 | 0.20 | 0.05 |
| Laurel oak | 18 | 17 | 1.00 | 0.83 |
| Live oak | 24 | 21 | 1.40 | 1.03 |
| Myrsine | 1 | 1 | 0.10 | 0.05 |
| Red mangrove | 250 | 365 | 14.20 | 17.91 |
| Florida royal palm | 4 | 4 | 0.20 | 0.20 |
| Cabbage palm | 219 | 200 | 12.40 | 9.81 |
| Carolina willow | 19 | 21 | 1.10 | 1.03 |
| Brazilian pepper[2] | 49 | 29 | 2.80 | 1.40 |
| Climbing cassia[2] | 0 | 1 | 0.00 | 0.05 |
| Saw palmetto | 1 | 2 | 0.10 | 0.01 |
| Java plum[2] | 3 | 3 | 0.20 | 0.15 |
| Bald cypress | 158 | 156 | 9.00 | 7.65 |
| Poison ivy | 0 | 1 | 0.00 | 0.05 |
| Calloose grape[2] | 1 | 4 | 0.10 | 0.20 |
| **Total** | **1,760** | **2,038** | **100%** | **100%** |

[1]Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-5. Percent basal area by canopy species in 2003 and 2009**

| Common Name[1] | Percent Basal Area | |
|---|---|---|
| | 2003 | 2009 |
| Red maple | 3.3 | 1.5 |
| Pond apple | 2.5 | 3.3 |
| Black mangrove | 0.0 | <0.1 |
| Water hickory | 8.0 | 7.6 |
| Buttonbush | 0.1 | 0.1 |
| Coco plum | 0.0 | <0.1 |
| Wild orange[2] | 0.1 | 0.1 |
| Strangler fig | 1.0 | 0.1 |
| Pop ash | 3.6 | 3.6 |
| Dahoon holly | 0.1 | <0.1 |
| White mangrove | 8.4 | 8.1 |
| Mulberry | 0.0 | <0.1 |
| Wax myrtle | 0.8 | 0.7 |
| Red bay | 0.1 | <0.1 |
| Swamp bay | 0.0 | <0.1 |
| Slash pine | 2.1 | 1.7 |
| Strawberry guava[2] | 0.1 | <1.0 |
| Laurel oak | 3.0 | 2.8 |
| Myrtle Oak | 0.1 | 0.0 |
| Live oak | 1.5 | 1.1 |
| Myrsine | 0.1 | 0.1 |
| Red mangrove | 1.6 | 2.6 |
| Florida royal palm | 0.1 | 0.1 |
| Cabbage palm | 22.8 | 23.0 |
| Carolina willow | 0.1 | 0.2 |
| Brazilian pepper[2] | 0.5 | 0.3 |
| Climbing cassia[2] | 0.0 | <0.1 |
| Saw palmetto | 0.1 | 0.1 |
| Java plum[2] | 0.1 | <0.1 |
| Bald cypress | 40.2 | 42.4 |
| Poison ivy | 0.0 | <0.1 |
| Calloose grape[2] | 0.1 | 0.04 |
| **Total** | 100 | 100 |

[1]Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-6. Frequency of occurrence of canopy species by transect, total occurrence and percent total occurrence in 2009**

| Common Name[1] | Frequency of Occurrence per Transect | | | | | | | | | | Total Occurrence | Percent Total Occurrence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | | |
| Red maple | 2 | 3 | 7 | 19 | 5 | 1 | 10 | 1 | | | 48 | 2.4 |
| Pond apple | 5 | | 15 | | | 66 | 99 | 47 | 13 | 40 | 285 | 14.0 |
| Black mangrove | | | | | | | | | 1 | | 1 | 0.0 |
| Water hickory | | 1 | | 15 | 13 | | | | | | 29 | 1.4 |
| Buttonbush | | | | | | 2 | 3 | 4 | | | 9 | 0.4 |
| Coco plum | | | | | | | | | 3 | | 3 | 0.1 |
| Strangler fig | | | 3 | 1 | | | | | 1 | | 5 | 0.2 |
| Pop ash | | 8 | 57 | 35 | 1 | 6 | 32 | 4 | | | 143 | 7.0 |
| Dahoon holly | | | 2 | | | 2 | | | | | 4 | 0.2 |
| White mangrove | | | | | | 159 | 2 | 15 | 404 | 17 | 597 | 29.4 |
| Mulberry | 1 | | | | | | | | | | 1 | 0.0 |
| Wax myrtle | | | | 2 | | 18 | 35 | 13 | | 6 | 74 | 3.6 |
| Swamp bay | | | | | 1 | | | 1 | | | 2 | 0.1 |
| Slash pine | 3 | 1 | 1 | | | 2 | | | 2 | 1 | 10 | 0.5 |
| Strawberry guava[2] | | | | | | | | | | 1 | 1 | 0.0 |
| Laurel oak | 2 | 2 | 2 | 3 | 7 | | | | 1 | | 17 | 0.8 |
| Live oak | 3 | | | 6 | 2 | 2 | 8 | | | | 21 | 1.0 |
| Myrsine | | | | | | | 1 | | | | 1 | 0.0 |
| Red mangrove | | | | | | 181 | 53 | 1 | 130 | | 365 | 18.0 |
| Florida royal palm | | | | | 1 | 1 | 2 | | | | 4 | 0.2 |
| Cabbage palm | 30 | 48 | 10 | 2 | 8 | 6 | 31 | 4 | 26 | 46 | 211 | 10.4 |
| Carolina willow | | | | | | | 19 | 2 | | | 21 | 1.0 |
| Brazilian pepper[2] | | | | 1 | | 6 | | 7 | 4 | | 18 | 0.9 |
| Climbing cassia[2] | 1 | | | | | | | | | | 1 | 0.0 |
| Saw palmetto | | | | | | 1 | | 1 | | | 2 | 0.1 |
| Java plum[2] | | | | | | | 3 | | | | 3 | 0.1 |
| Bald cypress | 28 | 13 | 4 | 16 | 16 | 9 | 36 | 27 | | | 149 | 7.3 |
| Poison ivy | | | | | | | | | | | 1 | 0.0 |
| Calloose grape[2] | | | | | | | | | | | 4 | 0.2 |
| **Total** | **75** | **77** | **101** | **100** | **57** | **462** | **334** | **127** | **585** | **11** | **2,030** | **100.0** |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

In *Riverine and Tidal Floodplain Vegetation of the Loxahatchee River and Its Major Tributaries* (SFWMD and FDEP FPS 2009), an importance ranking that incorporated values for abundance, basal area and frequency of occurrence for canopy species was used. **Table 3-7** illustrates the importance values for the top fourteen canopy species in 2003 and 2009. Cabbage palm remained the highest ranked canopy species for both 2003 and 2009 while bald cypress shared the second highest ranking with white mangrove in 2009. Pond apple moved up from fourth to third in rank. Both pop ash (*Fraxinus caroliniana*) and water hickory moved up in rank (5.0 to 4.0 and 7.0 to 6.0, respectively) while red maple fell in rank from 6.5 to 7.5. Red mangrove also moved up in rank from 6.5 to 5.0. Overall, the freshwater species — cabbage palm, bald cypress and pond apple — remained high in the importance rankings; however, it is significant that the brackish water species appear to be increasing in importance. The canopy is scheduled to be monitored again in 2015.

**Table 3-7. Importance values for the top fourteen canopy species in 2003 and 2009**

| | Rankings | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Abundance | | Basal Area | | Frequency of Occurrence | | Total Rank | | Importance | |
| Common Name[1] | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 |
| Red maple | 8 | 8 | 6 | 10 | 6 | 7 | 20 | 25 | 6.5 | 7.5 |
| Pond apple | 3 | 3 | 8 | 6 | 3 | 3 | 14 | 12 | 4 | 3 |
| Water hickory | 10 | 9.5 | 4 | 4 | 9 | 10 | 23 | 23.5 | 7 | 6 |
| Pop ash | 6 | 6 | 5 | 5 | 4.5 | 5 | 15.5 | 16 | 5 | 4 |
| White mangrove | 1 | 1 | 3 | 3 | 5 | 4 | 9 | 8 | 3 | 2.5 |
| Wax myrtle | 7 | 7 | 13 | 12 | 4.5 | 6 | 24.5 | 25 | 8 | 7.5 |
| Slash pine | 14 | 14 | 9 | 9 | 13 | 12 | 36 | 35 | 12 | 11 |
| Laurel oak | 13 | 11.5 | 7 | 7 | 10 | 11 | 30 | 29.5 | 10 | 8 |
| Live oak | 11 | 10.5 | 11 | 11 | 10 | 11 | 32 | 32.5 | 11 | 10 |
| Red mangrove | 2 | 2 | 10 | 8 | 8 | 8 | 20 | 18 | 6.5 | 5 |
| Cabbage palm | 4 | 4 | 2 | 2 | 1 | 1 | 7 | 7 | 1 | 1 |
| Carolina willow | 12 | 10.5 | 14 | 14 | 15 | 15 | 41 | 39.5 | 13 | 12 |
| Brazilian pepper[2] | 9 | 9.5 | 13 | 13 | 7 | 9 | 29 | 31.5 | 9 | 9 |
| Bald cypress | 5 | 5 | 1 | 1 | 2 | 2 | 8 | 8 | 2 | 2.5 |

[1] Scientific names are provided in **Appendix 3-2**.

[2] Nonnative species.

Canopy Changes along Transects and Plots from 2003 to 2009

In both 2003 and 2009, percent relative basal area was calculated for each of the 138 vegetative plots that make up the 10 belt transects. **Appendix 3-3** contains a table for each transect by plot indicating these changes in biomass. Following is a summary of these data.

Within T1, located at RM 14.5 just downstream of Lainhart Dam (**Figure 3-1**), losses of laurel oak (*Quercus laurifolia*) and wild orange (*Citrus aurantium*) were observed (**Appendix 3-3**, **Table 3-3-1**). The wild orange trees were removed by FPS staff from the swamp and hydric hammock areas as part of a nonnative plant eradication program. New recruits to the canopy on this transect included red maple (5.7%), pond apple (4.0%), mulberry (0.6%), laurel oak (1.0%) and the nonnative climbing cassia (1.4%) primarily in the swamp habitat. Bald cypress lost basal area in some plots due to four tree deaths and two missing trees. Cabbage palm increased in almost every plot and every habitat including hammock (28.1 to 87.2%), bottomland hardwood (91.8%) and swamp (5.2 to 25.6%) habitats. We believe the cabbage palms are able to grow in the swamp habitat due to reduced periods of inundation of the floodplain and on some higher spots of elevation noted in the light detection and ranging (LIDAR) data at this transect.

T2 is located at RM 13.6 (**Figure 3-1**), which is near Masten Dam. It had few losses or gains in basal area (**Appendix 3-3**, **Table 3-3-2**). One swamp plot lost red maple and one plot gained red maple. Bald cypress and laurel oak showed mostly gains while cabbage palm showed primarily losses. No canopy size pond apple trees and very little pop ash (another swamp species) were found on this transect, although there were four swamp plots and one plot that was partially swamp.

T3 is located downstream of Interstate 95 and the Florida Turnpike at RM 12.1 (**Figure 3-1**). Unlike any of the other transects, canopy on this transect was dominated by the swamp species pop ash (**Appendix 3-3**, **Table 3-3-3**). This is probably attributed to the removal of some of the bald cypress for lumber, relatively low elevations and the presence of multiple braided channels that keep groundwater levels higher. In the northern part of the Florida peninsula, pop ash is generally more abundant in lower elevations (longer hydroperiods) than bald cypress. Also, this transect contained the largest specimens of pop ash observed in the Loxahatchee River floodplain. Some losses of laurel oak, cabbage palm and Brazilian pepper were observed. One new recruit, pond apple (1.1%), was also observed.

At T4 it appears that all species had some losses and some gains (**Appendix 3-3**, **Table 3-3-4**). This transect is located at RM 11.2 upstream of Cypress Creek and Trapper Nelson's Interpretive Site (**Figure 3-1**). Pop ash disappeared from one plot while new recruits of red maple, wax myrtle and Brazilian pepper appeared in three other plots. There were several dead and missing bald cypress and one very large missing water hickory (88.6 cm dbh from plot T4153, adjacent to the channel, relative basal area 50.9% reduced to 19.9%).

T5 was heavily impacted by the 2004–2005 hurricanes. Both wind damage and high flows, along with high water velocities impacted the canopy at this site, which is located just upstream of the mouth of Cypress Creek at RM 10.3 (**Figure 3-1**). The largest losses were in red maple and bald cypress (**Appendix 3-3**, **Table 3-3-5**). Three plots lost all of the red maple (10.6, 34.1 and 27.2 to 0.0) while two plots lost all of their bald cypress (52.2 and 20.9 to 0.0). Caloosa grape (*Vitis shuttleworthii*) was a new recruit to the canopy of this transect.

T6 is located near Ornamental Gardens at RM 8.4 in the upper tidal reach (**Figure 3-1**) and shows evidence of selective logging. It is characterized by a riverine plot of bald cypress adjacent to the uplands, followed by several plots of predominately upper tidal reach swamp forest type 3 (UTsw3) with a river fringe of upper tidal reach swamp forest type 1 (UTsw1). The major changes here were increases across the floodplain in white and red mangrove and decreases in pond apple and cabbage palm (**Appendix 3-3**, **Table 3-3-6**). One plot (T6178) went from a basal area of 42.8 to 0 percent for cabbage palm. Field notes reflected that most of these cabbage palms were dead or missing. This was probably a result of stress from a combination of saltwater intrusion, higher tidal stage levels and hurricane winds. Pond apples, which can tolerate higher salinity and higher tidal stages, appeared to be more stable on the outer plots closer to the river channel with moderate gains, unlike those at the back of the floodplain. There was also new recruitment of buttonbush (*Cephalanthus occidentalis*; 0.8%), dahoon holly (*Ilex cassine* 0.2%), wax myrtle (1.8%) and live oak (*Quercus virginiana*; 21.4%).

T7 is located directly across from the mouth of Hobe Grove Ditch at RM 9.1 (**Figure 3-1**). It was selectively logged of bald cypress. From the uplands to the river channel, this transect actually had one-half plot of mesic hammock (MH), 2.5 plots of riverine reach swamp forest type 1 (Rsw1) dominated by bald cypress, five plots of mixed riverine reach (Rmix) with 50 percent bald cypress and 50 percent cabbage palm dominance, four plots of UTsw1, and three plots of upper tidal reach forest type 2 (UTsw2). Forest types were adjusted on three of the white mangrove plots (T7192, T7193 and T7194) due to the presence of a noticeable subcanopy change. Both T7192 and T7193 contained two bald cypress trees each (19.5, 26.1, 35.0 and 17.8 cm dbh; **Appendix 3-3**, **Table 3-3-**1), which normally would have made these plots Rsw1; however, they also had a prominent subcanopy of pond apple and mangrove, particularly plot T7192. Plot T7194 had four bald cypress (43.8, 9.6, 10.6 and 21.2 cm dbh) and a subcanopy of several red maple, pond apple and pop ash. It was assumed that the larger bald cypress trees were probably from the unlogged forest while the remaining trees came in since 1940. However, in the 2009 field notes, it was mentioned that two new recruits of young bald cypress were found in the canopy since 2003 (12.2 cm dbh at T7186; 9.1 cm dbh at T7189).

Similar to T6, T7 also showed increases in white and red mangroves and decreases in cabbage palm and bald cypress (**Appendix 3-3**, **Table 3-3-7**). There were also small gains and losses of wax myrtle, pop ash, pond apple and Carolina willow (*Salix caroliniana*). Most of the losses were from the five bald cypress-cabbage palm mix plots (T7187 to T7191) and the adjacent first red mangrove plot (T7192). In this area of the floodplain, red maple dropped from 9.2 to 0.0 percent and pond apple dropped from 23.5 to 0.0 percent on plot T7192. One plot of bald cypress dropped from 15.5 to 0.0 percent (T7188). Plot T7192 also had an increase in red mangrove from 2.2 to 10.8 percent. Soil and pore water samples from this area indicated a lens of lingering high conductivity water during low flow conditions during the 2007 drought. In addition, a braided stream in this area may have caused the salts to linger and has, over time, produced a micro-community of mangroves in this area of mixed cabbage palm-bald cypress and mangroves (T7191, T7192). More detailed information on this observation is covered in **Section 2.0** and in Kaplan et al. (2010). Soil type changes were also observed with Immokalee fine sand in the hammock area, Terra Ceia variant inclusion in the riverine swamp and mixed plots, and Okeelanta variant muck in the outer upper tidal plots. Terra Ceia variant muck is more closely associated with inland muck, whereas Okeelanta variant muck is considered to be more of a coastal muck.

T8 is located on Kitching Creek at RM 8.1 (**Figure 3-1**). It is similar to T6 and T7 of the upper tidal reach; however, it has an understory of mangroves directly adjacent to the creek channel. Since 2003, both white and red mangroves, which only occurred in one plot each, have increased in basal area (**Appendix 3-3**, **Table 3-3-8**). Red mangrove in Plot T81108 increased from 1.5 to 6.4 percent while white mangrove increased from 20.8 to 31.0 percent in Plot T81107 and appeared as new recruits in five additional plots in 2009. In two of the plots, white mangrove jumped from 0.0 to 20.5 and 32.4 percent. There were losses of red maple, wax myrtle, buttonbush, dahoon holly, pop ash, red bay (*Persea borbonia*), Java plum (*Syzygium cumini*), cabbage palm and Brazilian pepper. Bald cypress appeared to be doing very well with basal area increases in almost every plot and one new recruit. In fact, bald cypress were present in every plot of T8 with the exception of one plot of upper tidal reach mixed forest type (UTmix; T81105), which is dominated by pond apple (60.6%), white mangrove (20.5%) and Brazilian pepper (18.8%).

T9 is the only transect that we monitor in the lower tidal reach since this area is dominated by mangrove communities. It is on a peninsula located at RM 6.5 (**Figure 3-1**), and has undergone tremendous changes in vegetative communities. Taylor Alexander established this transect in 1967 and documented the changes that he saw occurring in the floodplain (Alexander 1967). He observed dead, stressed and healthy bald cypress trees. His survey notes indicated that 67.0 percent of the bald cypress and 12.5 percent of the cabbage palms were dead due to saltwater intrusion. Also, in 1975 and again in 2004, bald cypress trees were surveyed on this peninsula by the FPS. In the 1975 survey of 100 bald cypress trees, only 21.0 percent were classified as healthy and no seedlings or saplings were reported. In the 2004 survey of these same trees and some additional trees, 98.0 percent of 168 trees were dead and the peninsula had been invaded by red and white mangroves. These changes in the plant communities were further documented in *Vegetational Responses to Saltwater Intrusion along the Northwest Fork of the Loxahatchee River within Jonathan Dickinson State Park* (Roberts et al. 2008). Although no canopy-sized bald cypress were observed in the 2009 survey of T9, several living trees were associated with the elevated trail that runs through this site.

Changes in the relative basal area of canopy species along the T9 transect between 2003 and 2009 are illustrated in **Appendix 3-3**, **Table 3-3-9**. The basal area of red and white mangroves increased in almost every plot although the 2004–2005 hurricanes caused some damage. Cabbage palm was totally lost from four plots and decreased in basal area in three others. Pond apple, strangler fig (*Ficus aurea*) and Brazilian pepper also had losses and gains while new recruits included black mangrove (0.6%) and laurel oak (5.2%). Groundwater well data from the three wells located along this transect had shown high levels of conductivity and sulfides particularly at the back of the floodplain. It was thought the old elevated trail may contribute to the poor exchange or flushing of tidal waters.

T10 is located on the North Fork of the Loxahatchee River (**Figure 3-1**) and is considered to be in the upper tidal reach. The North Fork comes into the embayment area of the river at RM 1.8. It was suggested in *Riverine and Tidal Floodplain Vegetation of the Loxahatchee River and Its Major Tributaries* (SFWMD and FDEP FPS 2009) that the upper North Fork was transitioning from a freshwater coastal marsh and hammock system to a young forested wetland system dominated by pond apple and white mangrove due to saltwater intrusion, rising tidal amplitude and reduced freshwater flow. Bald cypress were absent from T10 but a few could be seen close to the transect. The nontidal freshwater portion of the North Fork receives flow from the savannah system of the Atlantic Ridge area north of Bridge Road in Hobe Sound. This system flows into a forested system just south of Bridge Road and spreads out into freshwater marsh to the east and cypress sloughs to the west. The downstream portion of the North Fork is dominated by mangroves.

**Appendix 3-3**, **Table 3-3-10** illustrates changes in basal area on transect T10 between 2003 and 2009. There were losses and gains in most species indicating that the largest factor was probably hurricane impacts. In addition, the first two plots (marsh and hammock) from the upland were impacted by fire management. This probably accounted for the loss of red maple and wax myrtle. Plot T10132 went from 100 percent wax myrtle to a combination of 51.9 percent pond apple, 29.2 percent white mangrove, 19.0 percent Brazilian pepper, and no wax myrtle. Both pond apple and white mangrove increased in almost every plot.

<u>Canopy Species of Special Concern</u>

To further study trends in the floodplain canopy of the Loxahatchee River, several tree species were chosen for further investigation. These species included cabbage palm within the hydric hammock forest type; red maple, water hickory and laurel oak within the bottomland hardwood forest types; and pop ash, pond apple and bald cypress within the swamp forest types. Growth of these canopy trees was examined by using dbh size frequency analysis and by determining annual growth rates using dbh measurements from 2003 and 2009. The dbh size classes were 5–20 cm, 21–40 cm, 41–60 cm, 61–80 cm and 81–99+ cm. In *Riverine and Tidal Floodplain Vegetation of the Loxahatchee River and Its Major Tributaries* (SFWMD and FDEP FPS 2009), dbh size frequencies were used to observe recruitment, maturation and death between three decades using data from the 1983 (Worth 1984), 1995 (Ward and Roberts 1996), and 2003 canopy surveys. These histograms are expanded in **Appendix 3-4** of this document to include the 2009 size frequency data.

After initial losses of cabbage palm at T1 and T2 in the 21–40 cm class between 1984 and 1995, it remained fairly stable in this group (**Appendix 3-4**, **Figure 3-4-1**). However, little or no recruitment occurred and very few trees entered the 41–60 cm class, which is probably as large as cabbage palm can grow. Cabbage palm abundance was much lower on transects T3, T4 and T5 with very little recruitment.

The best recruitment (5–20 cm class) of red maple between 1984 and 2009 occurred along transect T4 (**Appendix 3-4**, **Figure 3-4-2**). The 21–40 cm and 41–60 cm classes showed declines and losses on all five transects. Red maples were highly impacted by the 2004–2005 hurricanes and were shown to generally have shallow root systems that leave them vulnerable to the high winds and flows of tropical storms.

Water hickory was not observed on transects T1 or T3 during any of the surveys. This bottomland hardwood species prefers elevations higher than the swamp species and perhaps was unable to compete in the primarily bald cypress and cabbage palm canopy because of the changes in hydroperiod. Recruitment was low and/or steadily declining on transects T2, T4 and T5 (**Appendix 3-4**, **Figure 3-4-3**). The 21–40 cm and 41–60 cm classes on transect T4 were fairly stable; however, losses were observed in the 61–80 cm and 81–99+ cm classes. Reverse trends in the 21–40 cm and 41–60 cm classes along transect T5 may be an indication of growth where trees leave one size class and move up to the next group. Growth rates also appear to be slower in the older trees (61–80 cm and 81–99+ cm).

Laurel oak is another bottomland hardwood species that appears to have low recruitment on all transects (**Appendix 3-4**, **Figure 3-4-4**). For the 2009 survey, only one new recruit to the 5–20 cm class was found along transect T1. Transects T4 and T5 each had only two additions to the 5–20 cm class. The 21–40 cm class declined or disappeared on all five transects except on T4, which remained the same.

Recruitment for pop ash, a swamp species, was much higher at all transects during the 1984 survey (**Appendix 3-4**, **Figure 3-4-5**). Even on transect T3, which has the most and largest pop ash, recruitment, is continuing to decline. It completely disappeared from transect T1 after the 1984 survey. Very few pop ash are reaching the 41–60 cm class.

Since the 1984 survey, pond apples have been rare in the riverine reach presumably because of the shortened hydroperiod (**Appendix 3-4**, **Figure 3-4-6**). Most of these swamp trees are found along the river bank where the groundwater table is more stable. Only pond apples within the 5–20 cm class were noted. In the 2009 survey, recruitment was observed only at transects T1 and T3 in the riverine reach and on all transects of the tidal reaches.

Bald cypress is the longest living and largest tree in the floodplain canopy of the Loxahatchee River. The river's floodplain forest has specimens of all five size classes. Overall, between the 2003 and 2009 surveys, 14 bald cypress were gained and 24 were lost (**Figure 3-6**; **Appendix 3-4**, **Figure 3-4-7**). These numbers have some overlap because growth of some trees moves them up to higher size frequencies. In looking at new recruits (5–20 cm), all transects remained the same with the exceptions of T5 and T7, which gained three trees each, and T4, which lost four trees. These trees do not appear to have moved up to the next size frequency, which also suffered one loss. With the exception of transect T2, all of the riverine transects lost trees (7 total) in the 21–40 cm class. T6 and T8 both gained a tree. In the 41–60 cm class, five trees were lost from transect T1 and one from transect T4. Transect T6 gained one tree. In the 61–80 cm class, seven trees were lost (3 in T1 and T5; 1 in T2) and two gained. Two of these trees definitely moved up to the 81–99+ cm class, which had a gain of two trees on transect T1 and no losses. As expressed in *Riverine and Tidal Floodplain Vegetation of the Loxahatchee River and Its Major Tributaries* (SFWMD and FDEP FPS 2009), the dip in bald cypress abundance and density at transects T2, T3 and T6 was probably a factor of past lumbering activities. Overall, transect T7 now has more bald cypress than transect T1, which had the most in 2003. Bald cypress trees were not present within plots along transects T9 or T10.

<u>Growth Analysis of Canopy Species</u>

Within the 138 10-$m^2$ vegetative plots, we were able to re-identify many of the individual canopy trees. When this was possible, we were able to obtain a growth for the tree using dbh measurements. **Table 3-8** is a summary of the ten species we were able to examine for growth rates between the 2003 and 2009 surveys. We did not examine growth rate by size because the N values (sample size) would have been even lower; however, averages and ranges in dbh and average growth rates and range of growth rates are given by species. White mangrove had the fastest growth rate at 0.36 cm per year (cm/yr) and cabbage palm had the slowest rate (0.10

cm/yr). Red maple, pond apple and pop ash had similar average growth rates (0.18, 0.16 and 0.12 cm/yr) while water hickory and bald cypress were similar (0.34 and 0.30 cm/yr, respectively).

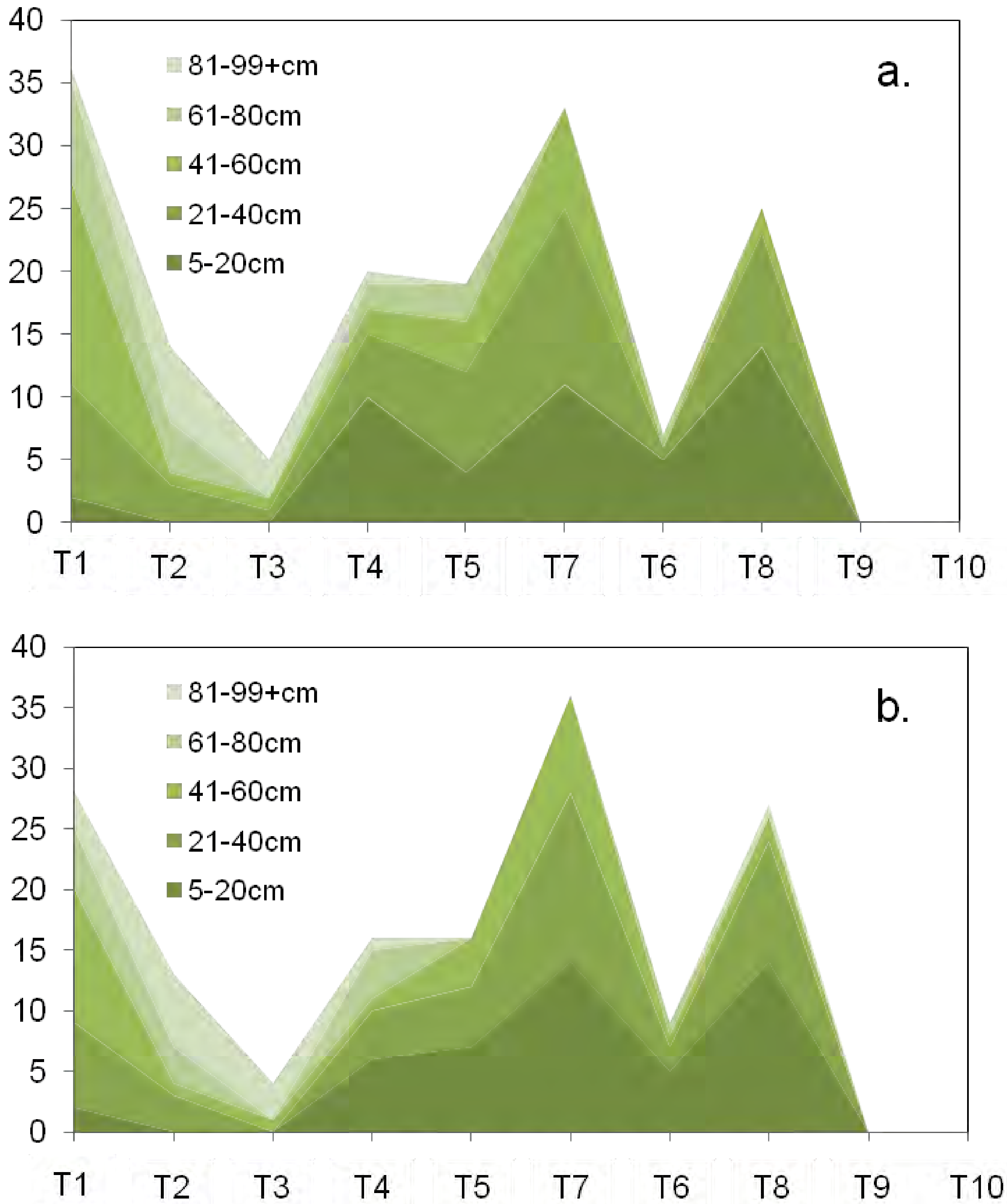


**Figure 3-6. Bald cypress canopy dbh surveys for a) 2003 and b) 2009**

**Table 3-8. Summary of canopy growth analysis between 2003 and 2009**

| Common Name[1] | Number | Average dbh (cm) | Range of dbh (cm) | Average Growth Rate (cm/yr) | Range of Growth Rate (cm/yr) |
|---|---|---|---|---|---|
| Red maple | 30 | 14.1 | 5.3–41.3 | 0.18 | 0.0–0.52 |
| Water hickory | 24 | 37.6 | 7.1–91.1 | 0.34 | 0.0–1.28 |
| Pop ash | 45 | 15.7 | 5.7–29.1 | 0.12 | 0.0–0.62 |
| Pond apple | 20 | 11.8 | 5.1–24.0 | 0.16 | 0.0–0.62 |
| White mangrove | 25 | 20.1 | 8.3–30.6 | 0.36 | 0.0–0.92 |
| Slash pine | 8 | 30.0 | 7.5–41.5 | 0.12 | 0.0–0.32 |
| Laurel oak | 15 | 34.3 | 9.0–72.5 | 0.28 | 0.0–0.88 |
| Live oak | 15 | 22.7 | 10.7–49.5 | 0.18 | 0.0–0.52 |
| Cabbage palm | 77 | 28.9 | 17.2–49.2 | 0.10 | 0.0–1.43 |
| Bald cypress | 105 | 40.4 | 5.8–152.4 | 0.30 | 0.0–1.45 |

[1] Scientific names are provided in **Appendix 3-2**.

Bald cypress growth rates are further broken down by transect in **Table 3-3-9**. Growth rates were generally higher for bald cypress in the riverine reach with the highest occurring on transect T4 (0.51 cm/yr); however, the ranges in values were large. The lowest growth rates were in the upper tidal reach on transect T6 (0.17 cm/yr) and transect T7 (0.19 cm/yr) while transect T8 (0.40 cm/yr) along Kitching Creek was more comparable to the growth rates in the riverine reach. **Figure 3-7a** illustrates the distribution growth rates of all 105 bald cypress trees surveyed. This is further broken down by reach (**Figure 3-7b** and **Figure 3-7c**). An increasing trend in the growth rate of those trees located in the riverine reach, and a decreasing trend in the growth rate trees from the upper tidal reach are apparent. Salinity may be the major factor in the distribution of these average growth rates for bald cypress in the Loxahatchee River floodplain. Visser and Sasser (1995) observed an average dbh growth rate of 1.63 millimeter per year (mm/yr) over a ten-year period in a bald cypress swamp forest off of the Mississippi River in southeastern Louisiana, and growth rates were significantly correlated with plot elevation. Mitsch and Ewel (1979) observed 0.2 to 3.3 mm/yr growth. Bald cypress are known to be slow growing and long lived with some existing trees estimated at 1,000 years old.

**Table 3-3-9. Growth analysis of bald cypress**

| Transect | Number | Average dbh (cm) | Range dbh (cm) | Standard Deviation | Average Growth Rate (cm/yr) | Range of Growth Rate (cm/yr) | Standard Deviation |
|---|---|---|---|---|---|---|---|
| T1 | 27 | 49.7 | 11.9–87.7 | 20.56 | 0.21 | 0.00–0.63 | 0.21 |
| T2 | 11 | 71.7 | 31.2–105.9 | 27.32 | 0.41 | 0.00–1.18 | 0.39 |
| T3 | 4 | 93.9 | 50.6–152.4 | 0.52 | 0.41 | 0.07–0.23 | 0.41 |
| T4 | 9 | 37.5 | 13.2–90.5 | 27.87 | 0.51 | 0.20–1.15 | 0.35 |
| T5 (Cypress Creek) | 9 | 30.1 | 10.7–59.2 | 15.00 | 0.19 | 0.00–0.68 | 0.23 |
| T6 | 8 | 30.6 | 14.9–73.5 | 20.24 | 0.17 | 0.00–0.43 | 0.15 |
| T7 | 32 | 29.6 | 8.0–50.5 | 12.77 | 0.79 | 0.00–0.68 | 0.23 |
| T8 (Kitching Creek) | 25 | 28.5 | 5.8–118.4 | 23.50 | 0.40 | 0.00–1.45 | 0.35 |

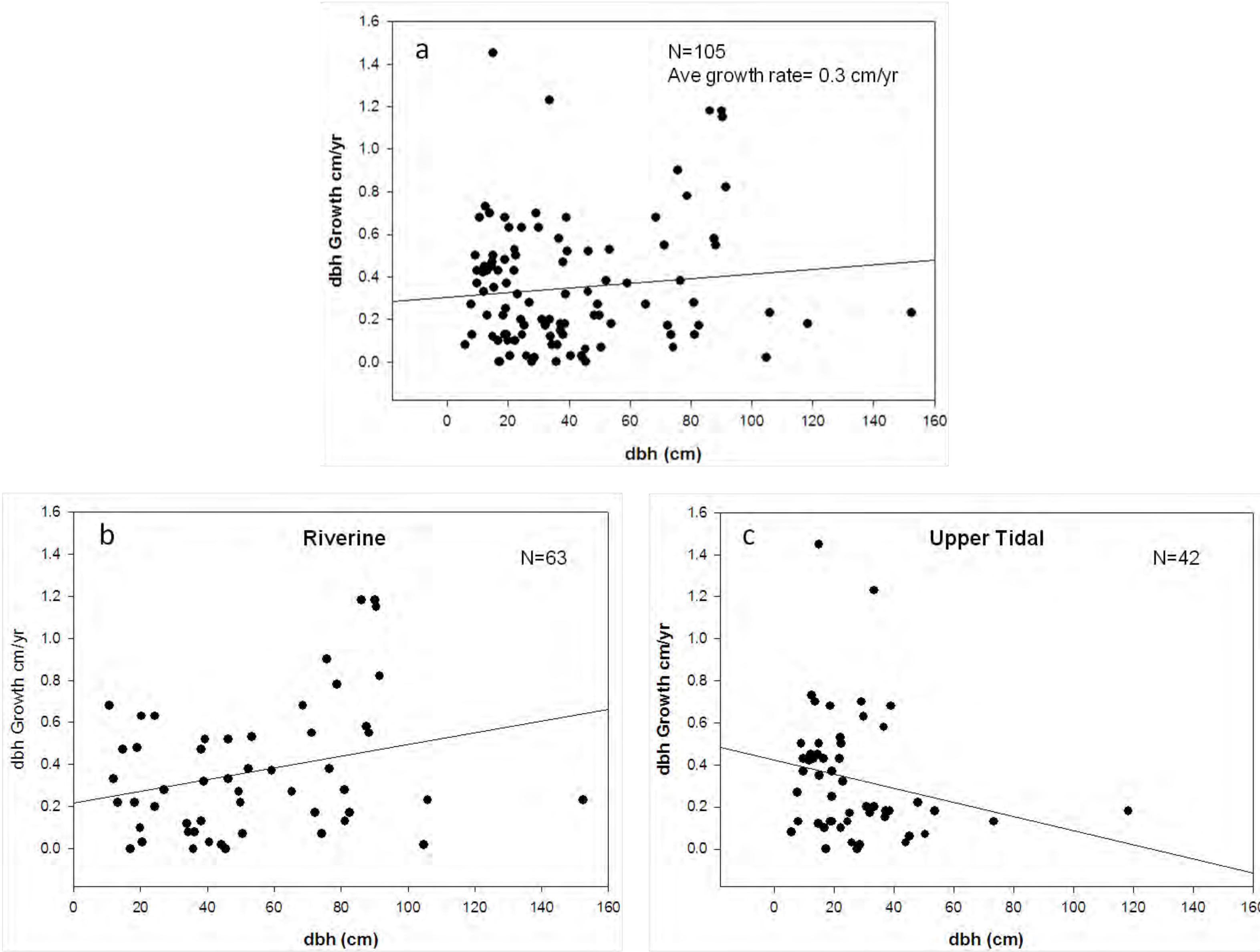


**Figure 3-7. Distribution of growth rates for (a) all 105, (b) riverine and (c) upper tidal bald cypress surveyed**

It was interesting to note in the Visser and Sasser (1995) study in Louisiana that over the ten-year study period, densities of bald cypress and water tupelo (*Nyssa aquatica*) in their 60 to 100 year old second growth forest stayed relative constant while red maple and ash (*Fraxinus* sp.) densities were rapidly declining. With regard to all four canopy tree species, mortality exceeded recruitment, particularly for red maple. Both maple and ash were less flood tolerant than bald cypress and water tupelo, and there was a general trend of increased flooding in the area (it was not mentioned whether this was due to sea level rise.). Death of maple and ash trees was also attributed to windthrow during storm events. Salinity was not an apparent factor in their study. Regarding recruitment, no maple seedlings were observed in their study area. Maple seeds reportedly lose their viability when submerged in water and, therefore, only become established if they fall on dry or moist soils or tree stumps. Seeds of bald cypress and water tupelo remain viable when submerged in water for longer periods of time and germinate readily when floodwaters recede. For their study area, Visser and Sasser concluded that a combination of high seed production and a relatively dry year is necessary for bald cypress to establish and fill occasional gaps in the forest. In our 2003 and 2009 canopy surveys on the Loxahatchee River, it is further interesting to note that red maple and pop ash also declined as they did in the Louisiana swamp study. In addition, storm damage was also a factor in changes in plant species composition.

Unlike the swamp in southeastern Louisiana, the Loxahatchee River floodplain forest was stressed by low freshwater flow, saltwater intrusion, increased tidal inundation, and an invasion of saltwater tolerant plant species. McWilliams and Rossen (1990) reported increases in salinity have been associated with losses of large forested wetland areas in the southeastern United States, which contains 650,000 hectares or more of bald cypress and water tupelo communities. Saltwater effects range from the total destruction and conversion of swamp forest to marsh and open water to the reduction of standing trees. Conner et al. (2007) stated that even small increases in salinity and prolonged flooding can have considerable impact. For example, in South Carolina and Louisiana, basal area was reduced from 87 to 44 $m^2$ per hectare in forest with no salinity to 36 to 23 $m^2$ per hectare in forests with 1.3 to 3.0 psu salinity. Increases in salinity were attributed to levees along rivers to prevent over bank flooding, dredging of canals, oil and gas exploration, recent trends in sea level rise, and temporary or permanent saltwater intrusion as a result of storm surges. Conner et al. (2007) stated that storm surge can extend tens of kilometers inland and to at least a meter in depth in some coastal forests while sea level rise may be as high as 0.90 to 0.88 m over the next 100 years. This would result in chronic shifts in tidal prisms and salinity distributions in coastal wetlands if we continue to reduce freshwater flow to river systems.

### 3.1.4 Shrub Communities

Shrub layers generally show an intermediate response to environmental changes in the floodplain community as compared with slow changes in canopy and rapid or seasonal changes in ground cover communities. Shrubs also help us identify whether we are getting restorative water levels and inundation periods to floodplain plant communities. Shrubs give us an idea of which plant species are surviving from the ground cover layer and which species will be recruiting soon to the canopy layer. In this study, shrub communities were examined for total number of species, percent cover, percent cover by forest type, and frequency of occurrence. Shrub communities were examined in 2003, 2007 and 2010.

For the three surveys combined, 100 shrubs species were recorded within the 138 vegetative plots. The 2003 survey had the fewest species with a total of 43 (**Figure 3-8**). The 2007 and 2010 surveys were very similar with 76 and 75 species, respectively. This was probably a direct response to the 2004–2005 hurricanes opening the canopy cover and allowing additional light to reach the floor of the floodplain. With the exceptions of transects T4 and T6, the total number of shrub species was considerably lower for 2003 compared to 2007 and 2010 (**Figure 3-9**). Along transects T4 and T6, totals for 2003 and 2010 were very similar with its moderate to high flow values. The 2007 survey with its drought conditions had the highest numbers of species. The highest number of shrub species were observed at transect T7 in the upper tidal reach (36 in 2007).

<u>Percent Cover of Shrub Species</u>

Because branches may overlap on the 10 m intercept lines, percent cover can be greater than 100 percent. General guidelines from a field perspective of abundance or cover would be **0.01 percent** very rare or very little present, **0.1 percent** common but not abundant, **1.0 percent** abundant and **10.0 percent** (our highest) dominant.

The shrub species with the highest percentage of cover were leather fern (*Acrostichum danaeifolium*), pond apple, swamp fern (*Blechnum serrulatum*), red mangrove, and tri-veined fern (*Thelypteris interrupta*). **Appendix 3-5** provides a summary of shrub coverage by transect for the three survey years (2003, 2007, 2010).

Leather fern was abundant on all transects except transect T5 where it probably could not compete with the nonnative grasses that came in after much of the canopy was destroyed by hurricanes. It is able to tolerate both fresh and brackish water habitats. Total percentages were 33.0 percent for 2003, 26.6 percent for 2007, and 26.9 percent for 2010 (**Figure 3-10**). It was the most robust along the brackish T6 transect (4.76, 6.90, 4.34%), T7 (6.21, 4.68, 3.75%), and T9 transect (9.66, 7.86, 8.75%) (**Figure 3-11**). Increased periods of tidal inundation and higher nutrient input may be a factor in this fern’s abundance and very large size on some tidal transects.

Pond apple percentages (10.25, 5.40, 9.29%) were lower for the riverine (0.02–0.48%) and higher for tidal reaches (0.43–3.17%) where soil moisture and groundwater levels were higher (**Figure 3-12** and **Figure 3-13**). In addition, we have learned that pond apple can be very tolerant of salt water (see **Section 3.3**). We have also observed that those pond apples found in brackish water have a tendency toward multiple trunks and over time are somewhat stunted in height but they do survive. They were also more exposed to freezing temperatures along the river channel corridor and defoliated rapidly when temperatures dropped. Other pond apples within the floodplain were less affected, probably due to the protection of the higher canopy.

Swamp fern (10.75, 5.06, 2.46%) appeared to have higher percent cover (0.05–5.37%) in the riverine reach during the 2007 drought period than the percentages (0.01–0.43%) observed in the tidal reaches (**Appendix 3-5**). This very common fern species was probably taking advantage of the dryer floodplain soils and appeared to have a low tolerance for brackish water. Along transect T5, swamp fern (5.37, 1.24, 0.57%) appeared to be declining.

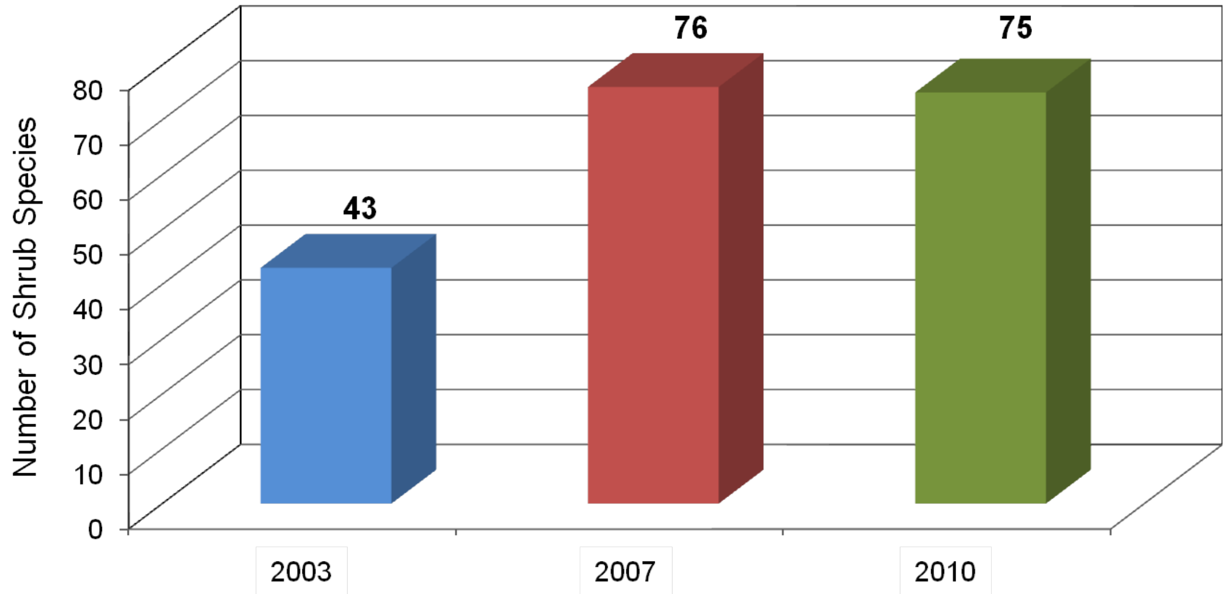


**Figure 3-8. Number of species observed in the shrub layer in each of the surveys**

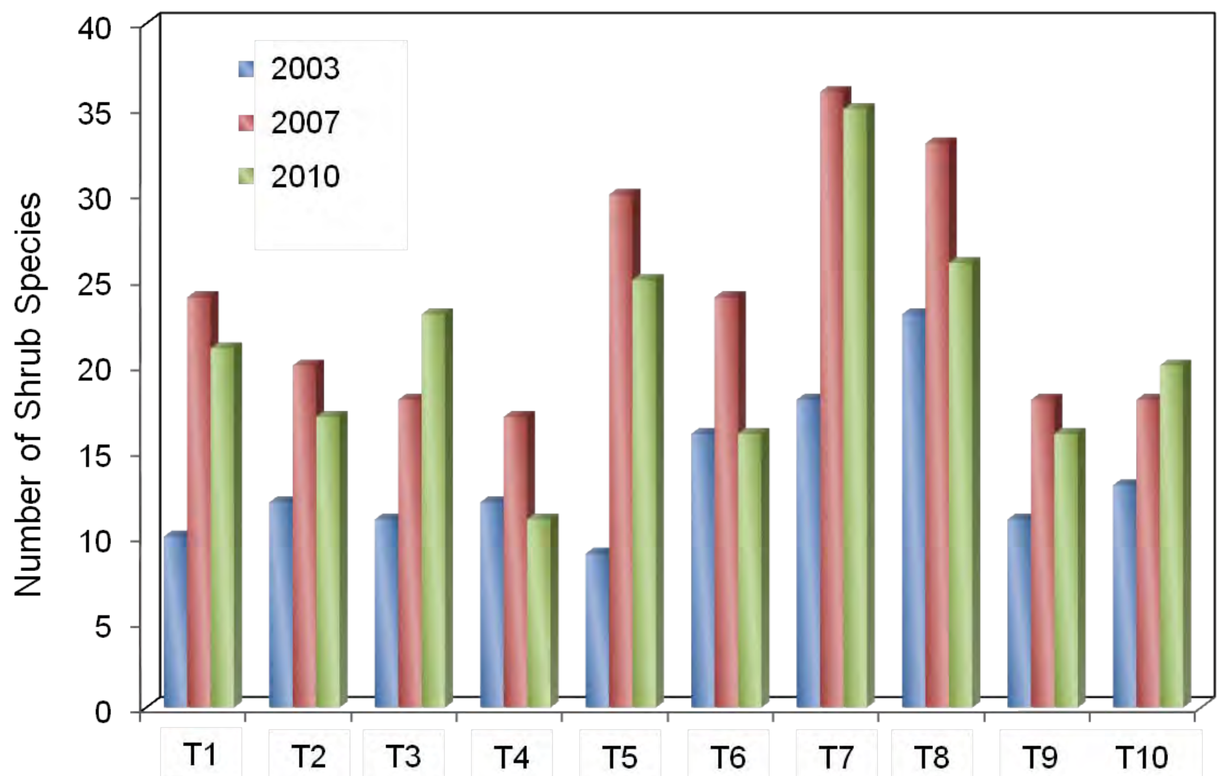


**Figure 3-9. Number of species observed along each transect in the shrub layer in each of the surveys**

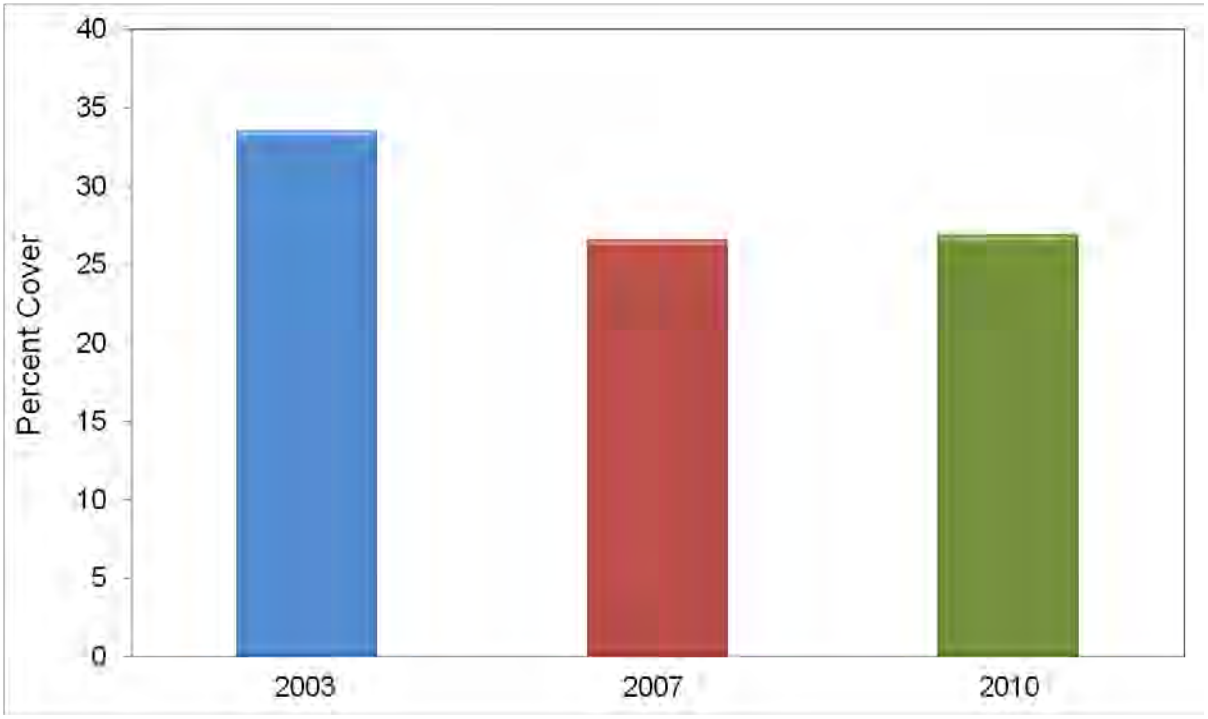


**Figure 3-10. Leather fern shrub layer percent cover**

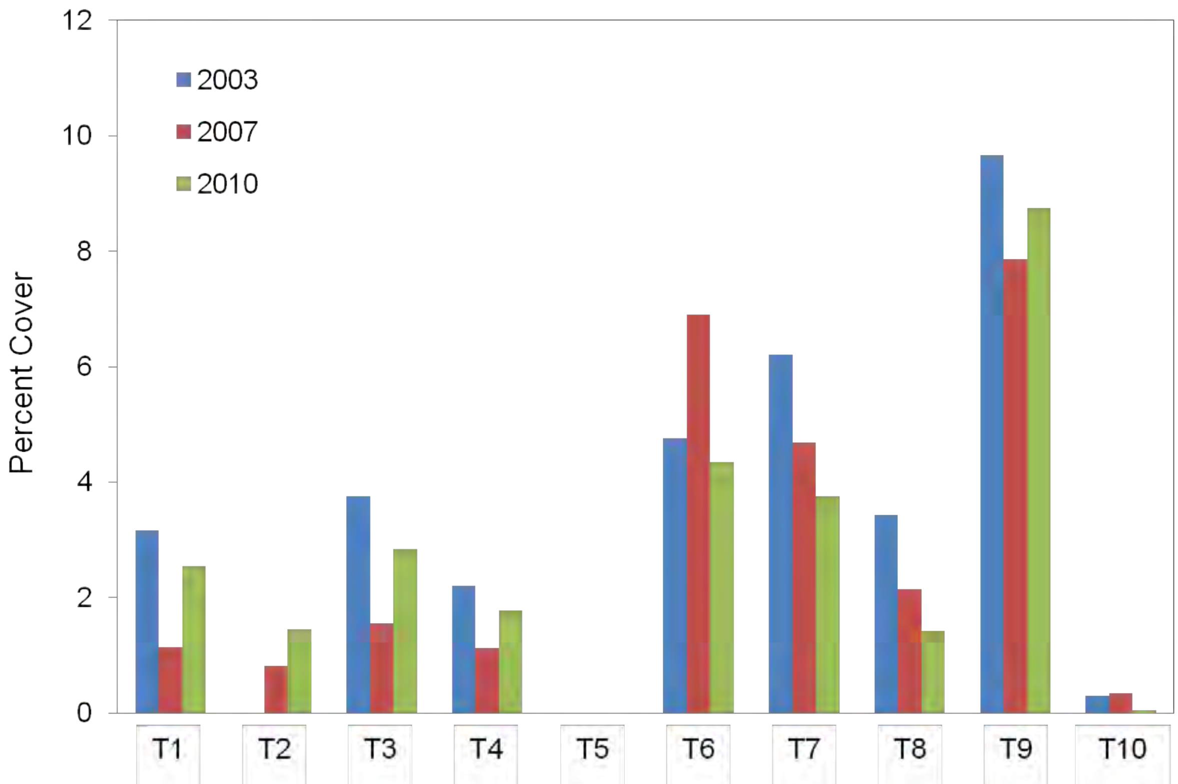


**Figure 3-11. Leather fern shrub layer percent cover of each transect**

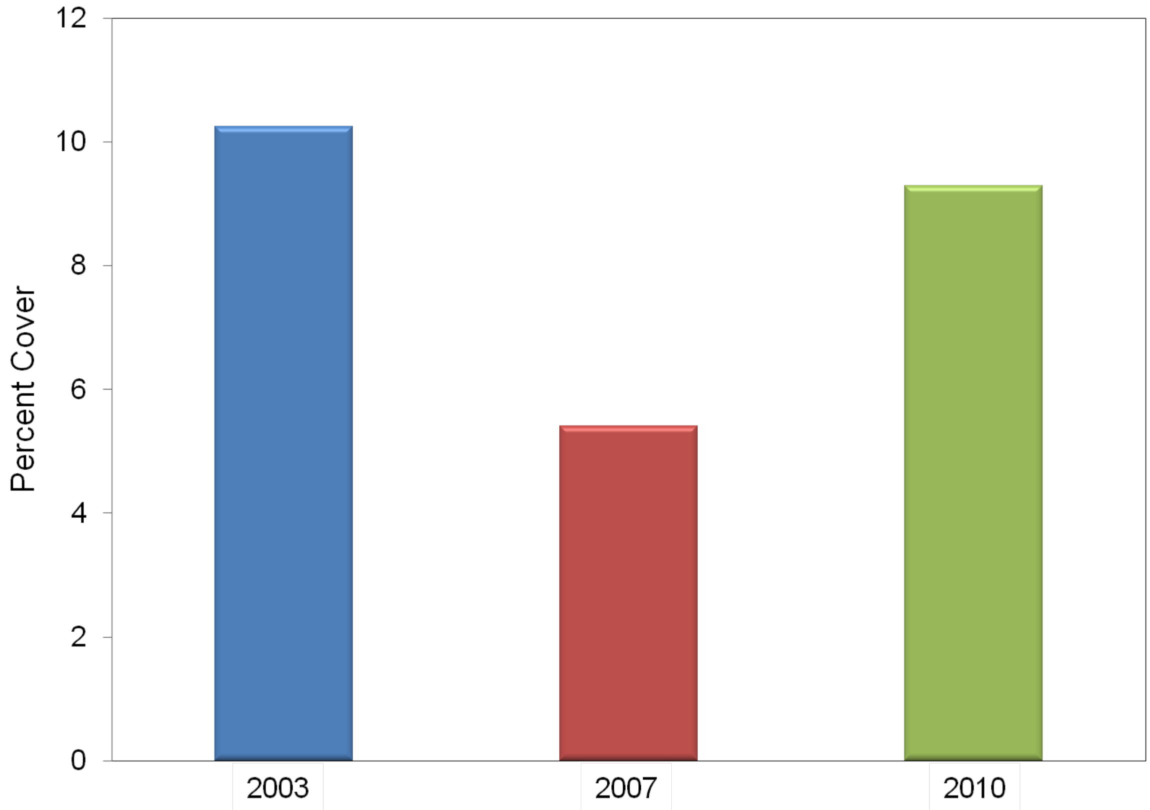


**Figure 3-12. Pond apple shrub layer percent cover for each survey year**

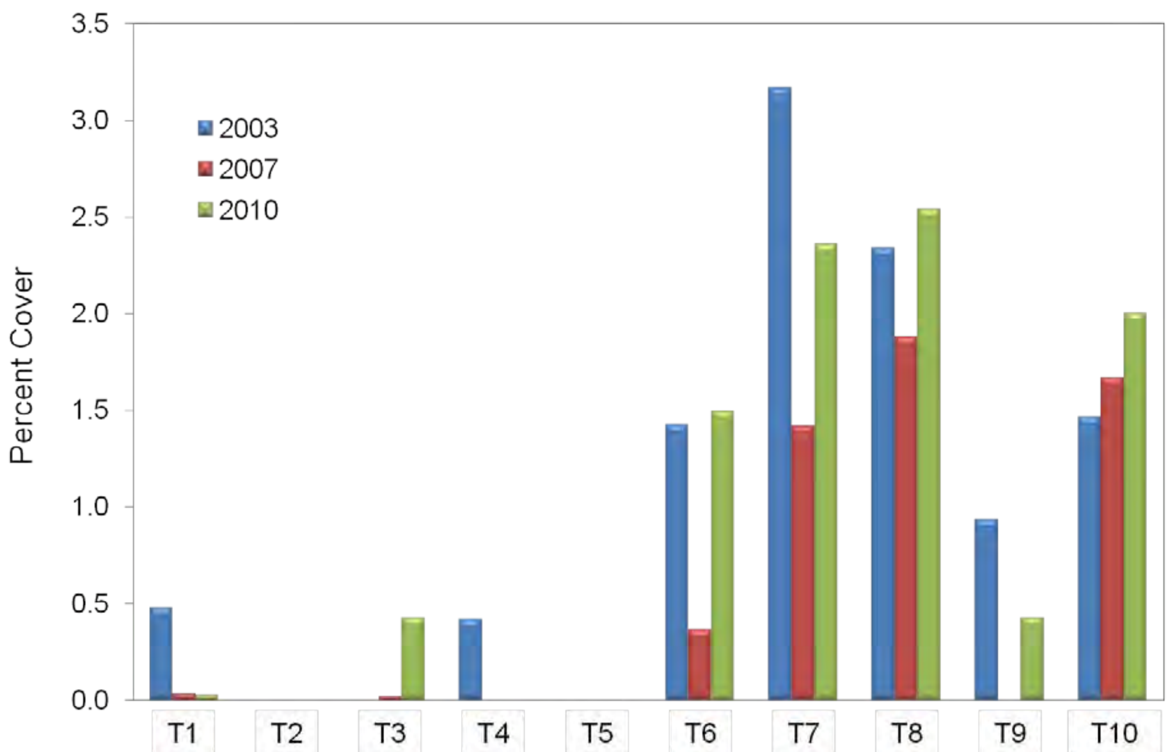


**Figure 3-13. Pond apple shrub layer percent cover for each transect for each survey year**

Where it was present, red maple shrubs showed primarily increases in percent cover between 2003 and 2010 (1.17, 1.45, 4.94%) (**Appendix 3-5**). In the riverine reach on transects T2 and T4, percent cover of red maple went from 0.51 to 1.22 percent on T2 and 0.57 to 1.82 percent on transect T4. They did not fare well in the tidal reaches, being absent from transects T6, T9 and T10 and disappearing in 2010 from transect T8. This shows that red maple has a low tolerance to salinity and flooding.

Tri-veined fern reacted positively to the 2007 drought and negatively to the higher flows in 2010). Percentage cover was 4.21 in 2003, 25.07 in 2007, and 3.60 in 2010 (**Figure 3-14**). It was most abundant during the 2007 survey along the riverine transects (3.73–5.97%) and even appeared in three of the tidal transects, T6 (0.10%), T7 (0.40%) and T8 (0.04%) in 2003 (**Figure** 3-15).

Pop ash is more of an incidental species in south Florida's wetland systems. Unlike northern Florida, we do not have forest communities of ash species, because it does not appear to be able to compete with bald cypress, pond apple, red maple or water hickory. Pop ash cover was 1.13 percent in 2003, 2.94 percent in 2007 and 6.01 percent in 2010 (**Appendix 3-5**). The most percent cover (2.77%) of pop ash was on transect T3 in the 2010 wet period. This area had the highest concentration and biggest specimens of pop ash on the Loxahatchee River's floodplain. This is attributed to historical lumbering activities, lower elevations and multiple braided channels within this transect.

The riverine reach also appeared to be too dry for wax myrtle. This plant only occurred on tidal transects (except T9), and was more abundant in the 2010 wet period. Wax myrtle may have been unable to compete with the shading from larger canopy species of the riverine reach.

White mangrove was present on all tidal transects and T5 (Cypress Creek). It showed a slight increase in percent cover during the 2007 drought and a decline during the 2010 wet period (2.13, 4.47, 3.35%) (**Figure 3-16** and **Figure 3-17**). White mangrove percent cover was the highest (2.74%) along transect T9 during the 2007 drought.

Percent cover of red mangrove, which was only present in the tidal reaches, was generally higher in 2007 and lowest in 2010 except on transect T9 where the floodplain community was composed primarily of red and white mangroves (**Appendix 3-5**). For example, along transect T7, percent cover of red mangroves was 0.12 in 2003, 0.37 in 2007, and 0.24 in 2010. Red mangrove shrubs are not yet present along transect T10.

Cabbage palm shrubs were most abundant on the riverine transects (0.05–1.79%) and responded negatively to the drought and positively to the 2010 increases in freshwater flow (3.11, 1.78, 5.54%) (**Figure 3-18** and **Figure 3-19**). Percentages on both the riverine and tidal transects were higher during the 2010 wet period.

Bald cypress shrubs were only observed on two transects: T1 (0.48% in 2007) and T8 (0.25% in 2010) (**Figure 3-20** and **Figure 3-21**). The cypress shrubs on transect T1 were gone in 2010. No new recruits were found on transect T1 in the 5–20 cm size class, so the young trees apparently did not survive. The new recruitment of bald cypress on transect T8 is a good sign that this tributary (Cypress Creek) is not being harmfully impacted by saltwater intrusion although the floodplain of upper Kitching Creek is suffering from reduced hydroperiods as a result of reduced freshwater flow.

Water hickory shrubs were only observed on transect T5 (**Appendix 3-5**). Percent cover of water hickory in the shrub layer was 0.06 during the 2007 drought and then 1.62 during the 2010 wet period.

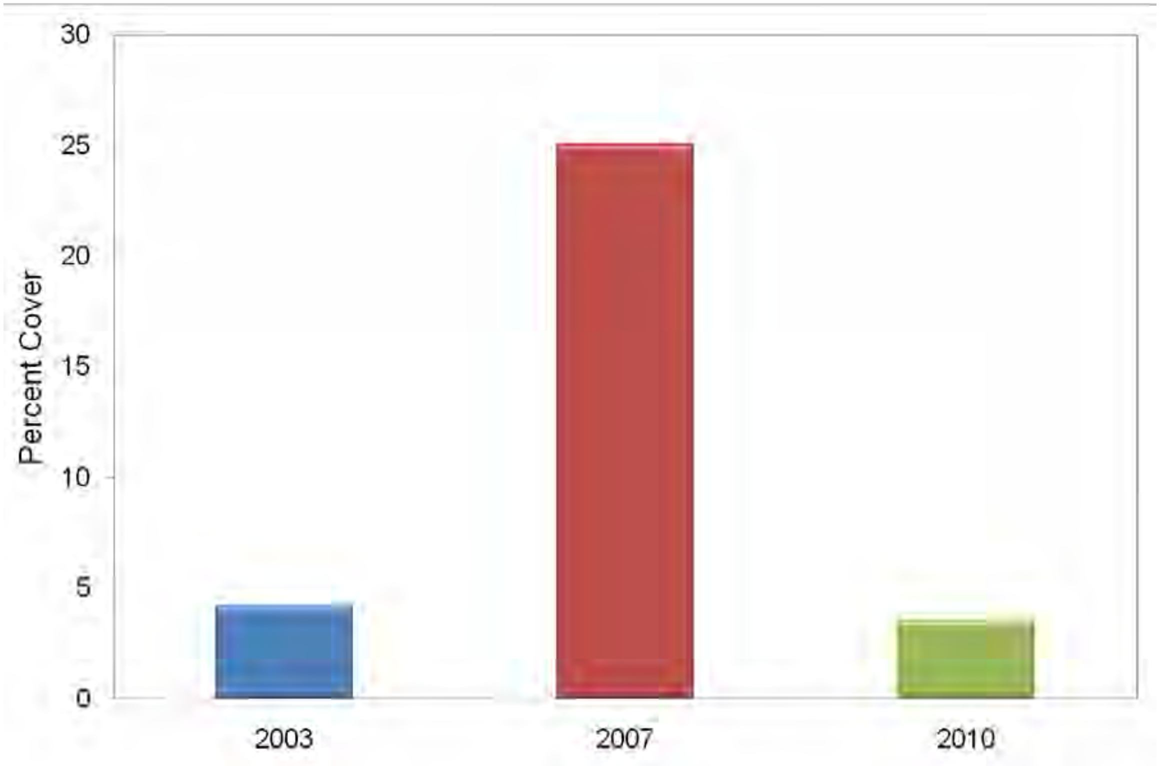


**Figure 3-14. Tri-veined fern shrub layer percent cover for each survey year**

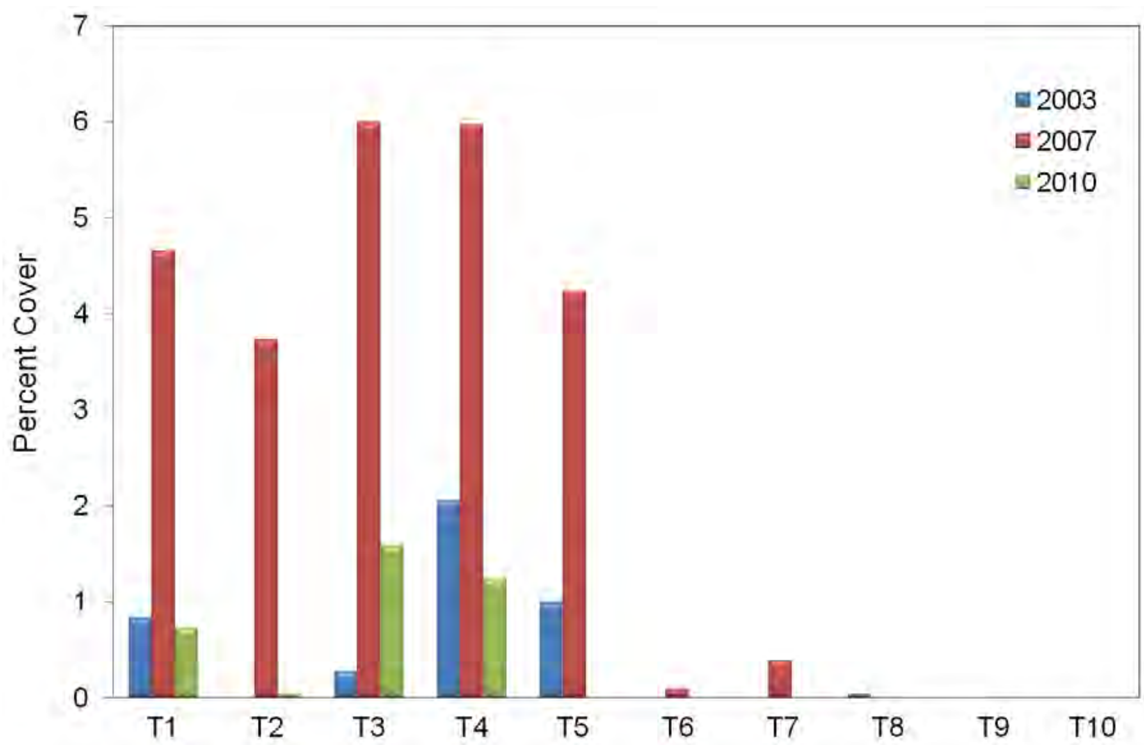


**Figure 3-15. Tri-veined fern shrub layer percent cover for each transect for each survey year**

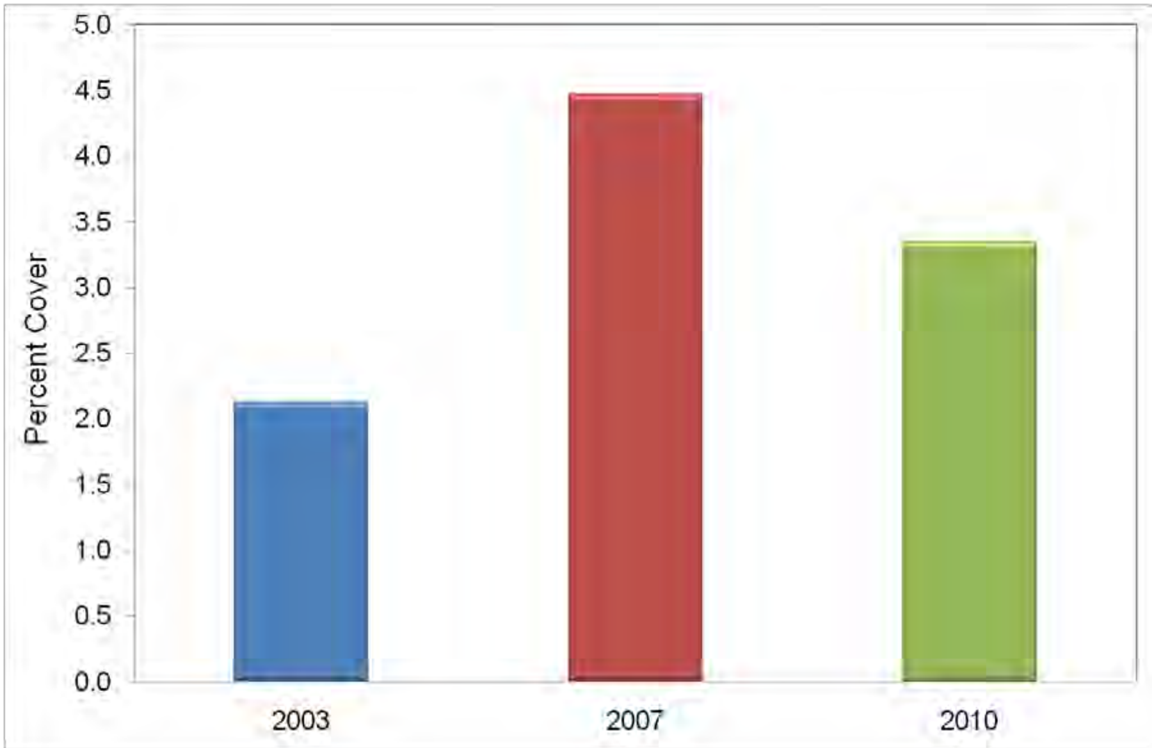


**Figure 3-16. White mangrove shrub layer percent cover for each survey year**

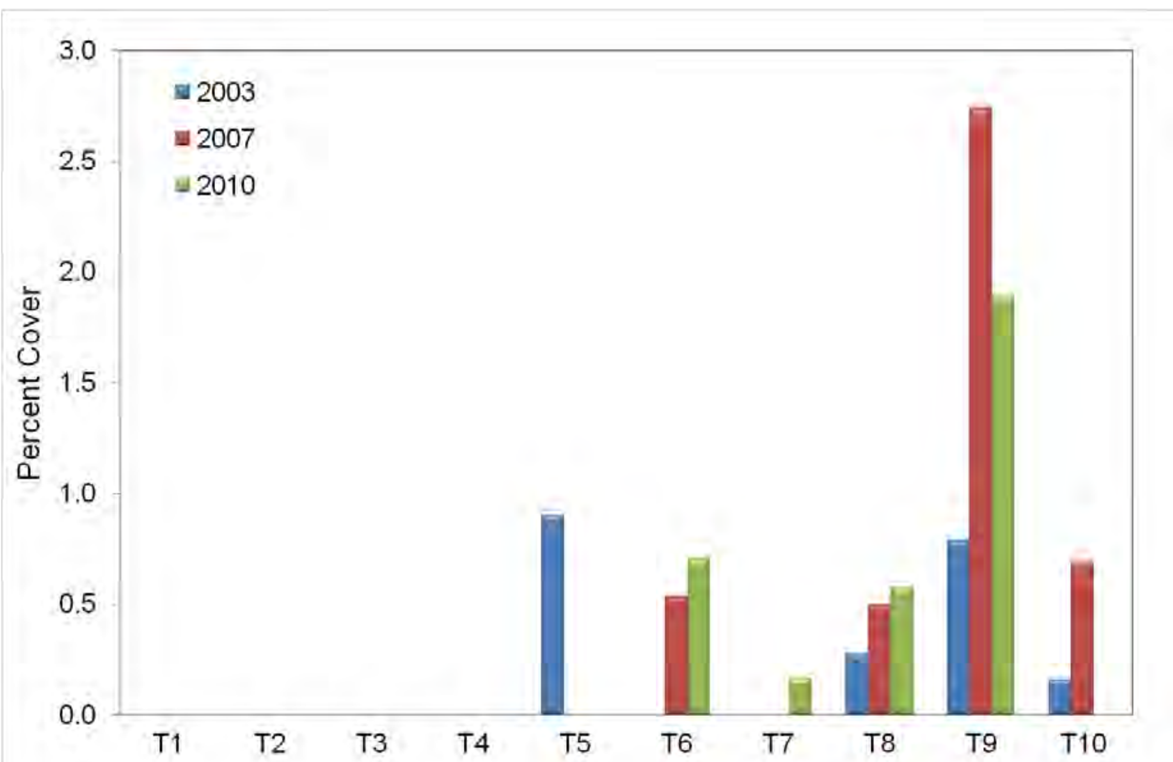


**Figure 3-17. White mangrove shrub layer percent cover for each transect for each survey year**

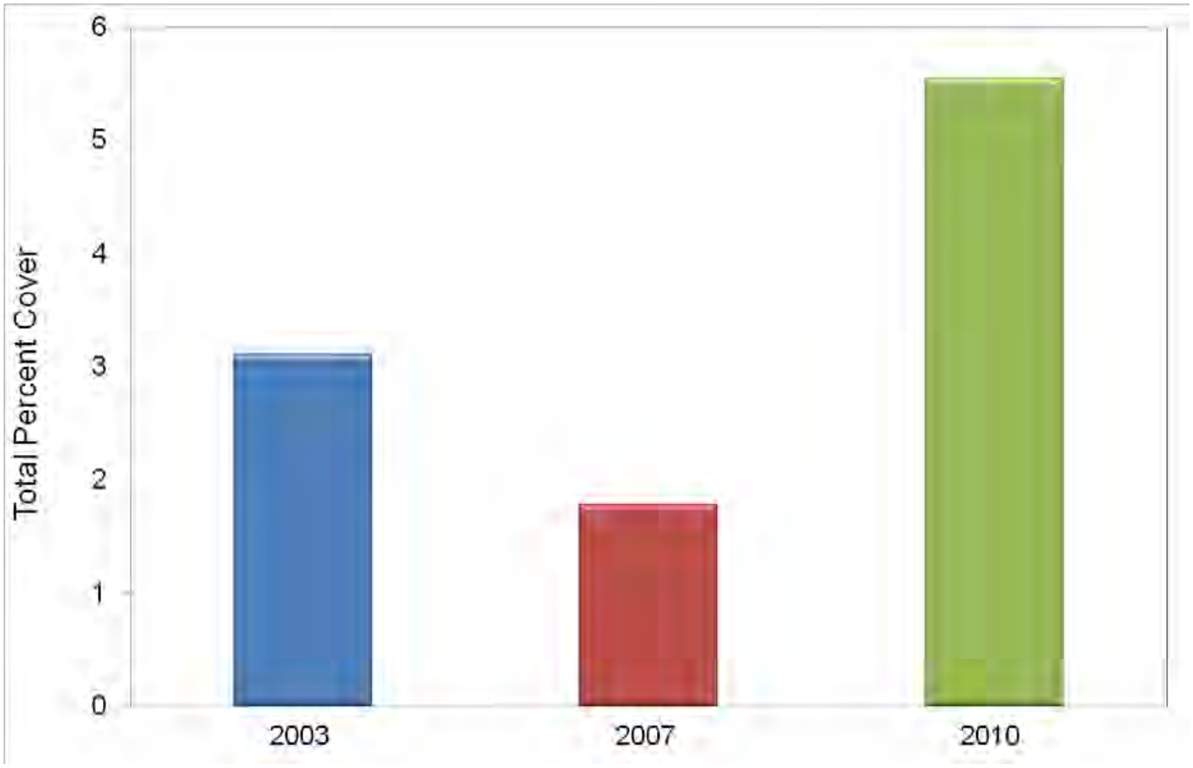


**Figure 3-18. Cabbage palm shrub layer percent cover for each survey year**

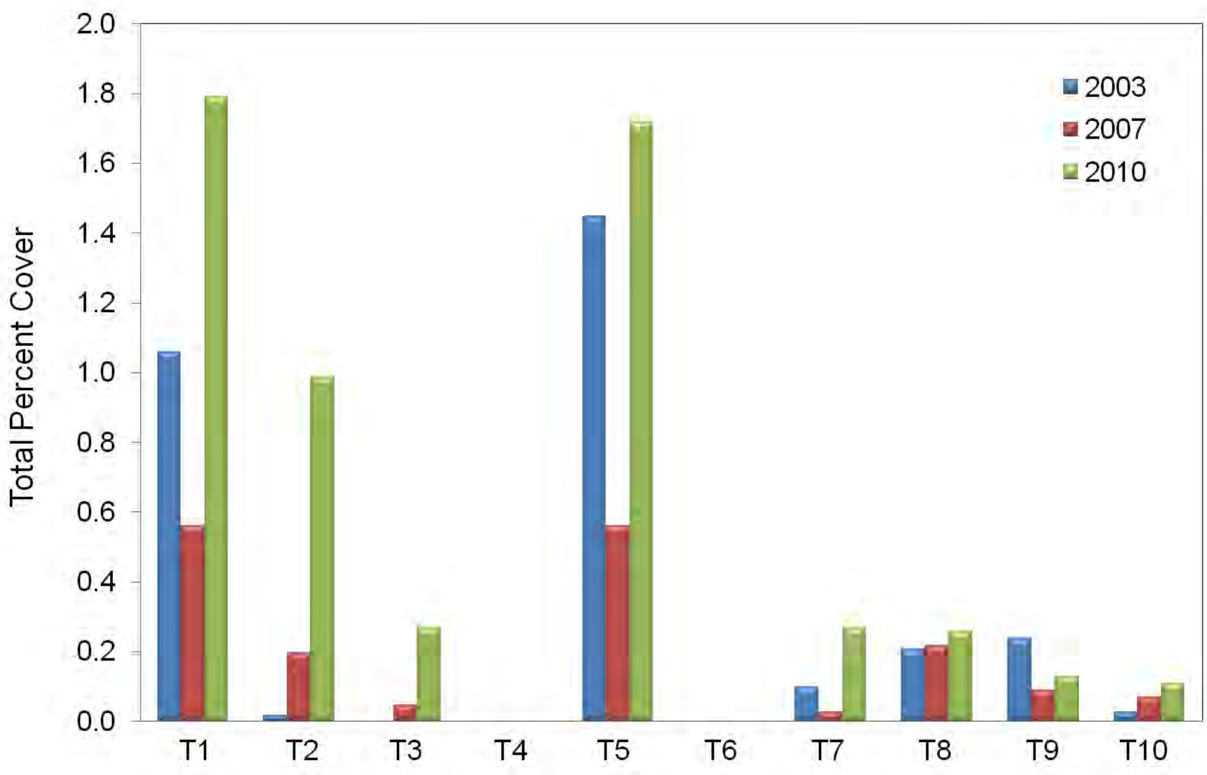


**Figure 3-19. Cabbage palm shrub layer percent cover for each transect for each survey year**

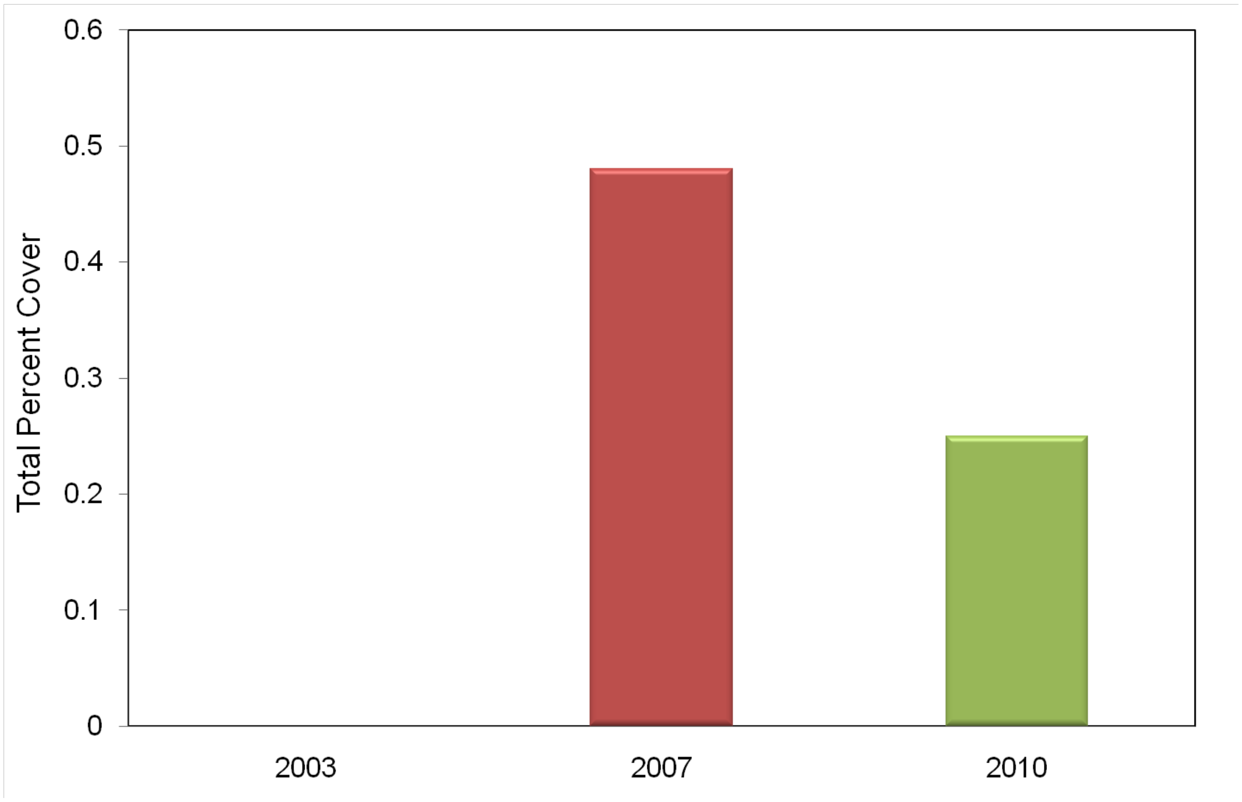


**Figure 3-20. Bald cypress shrub layer percent cover for each survey year**

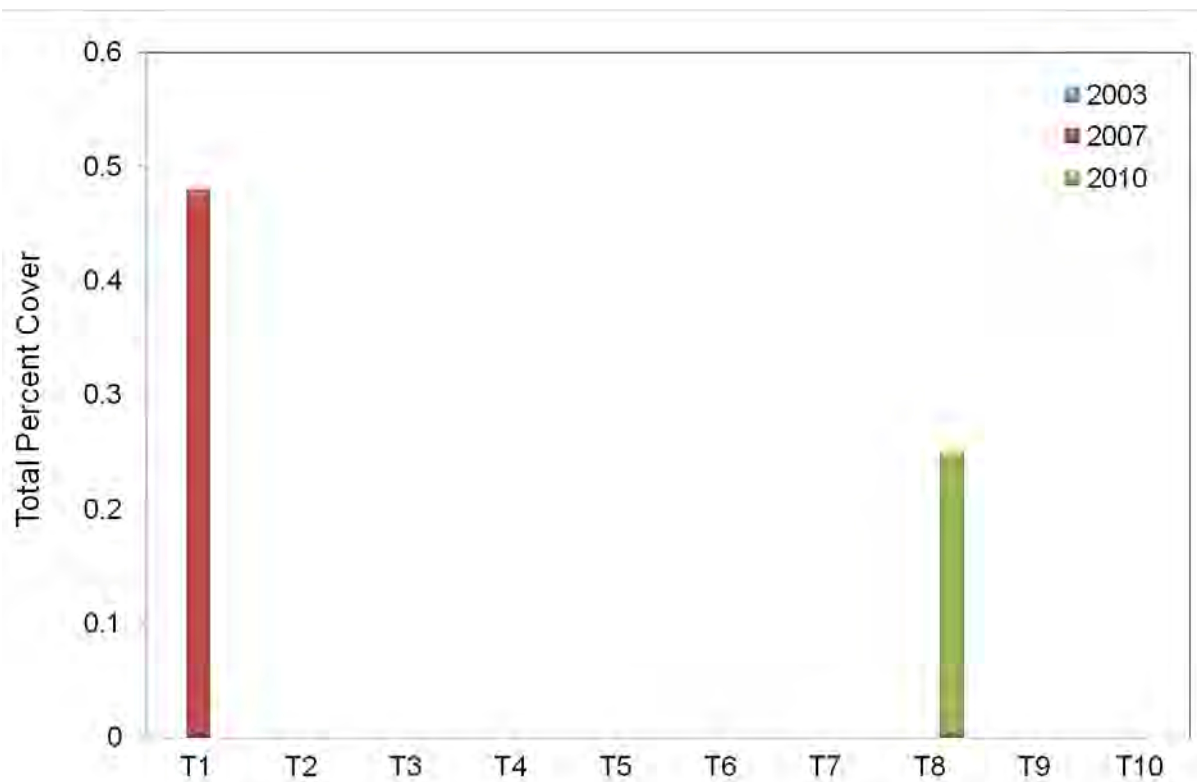


**Figure 3-21. Bald cypress shrub layer percent cover for each transect for each survey year**

Frequency of Occurrence of Shrub Species

**Appendix 3-6** provides a summary of percent frequency of occurrence of shrub species by transect for the three survey years (2003, 2007, 2010). Most of the shrub species appeared on less than 50 percent of the plots within the ten transects. The most frequently observed species were leather fern (0.13–0.87%), pond apple (0.06–0.75%), buttonbush (0.07–0.63%), swamp fern (0.05–0.57%), white mangrove (0.06–0.75%) and tri-veined fern (0.08–0.77%). Leather fern and pond apple were frequently observed on the tidal transects (T6– T10), and generally occurred in over 25 to 90 percent of the plots. The nonnative species wild taro (*Colocasia esculenta*) and Old World climbing fern (*Lygodium microphyllum*) were frequently observed on T1 (70%) and Old World climbing fern was frequently observed on T10 (63%). Wax myrtle was highly observed in all three surveys on T10 (100, 63, 88%). Finally, tri-veined fern occurred very frequently on transects T3 (77%) and T4 (83%) during the 2007 drought.

Percent Cover of Shrub Species by Forest Type

**Appendix 3-7** contains a series of tables displaying percent cover of shrubs by forest type along each transect for the three survey years (2003, 2007, 2010). The purpose of this analysis was to visually examine if species moved from one forest type to another with changes in hydrology. Forest types are generally presented from uplands (U) on the left to swamp and the river channel on the right.

In the hydric hammock forest type (HH) of transect T1 during the 2007 drought, no shrubs were observed at all while five species were present in 2003, and eight species were present in 2010 (**Appendix 3-7**, **Table 3-7-1**). Leather fern also disappeared from the Rsw1 plots on this transect in 2007 while it covered 3.17 percent in 2003 and 1.14 percent in 2010.

A number of shrub species recruited into the swamp plots of transect T2 during the 2007 drought (**Appendix 3-7**, **Table 3-7-2**): swamp fern (0.06%), moon vine (*Ipomoea alba,* 0.21%), blue morning glory (*Ipomoea indica*, 0.27%), hemp vine (*Mikania scandens*, 0.43%), and royal fern (*Osmunda regalis*, 0.27%). Tri-veined fern, generally a swamp species, also recruited into the HH and bottomland hardwood forest type 1 (Rblh1) plots with fairly high values of cover (1.63 and 1.26%, respectively).

Shrub species on transect T3 reacted positively to the 2007 drought and negatively to the increased freshwater flows in 2010 (**Appendix 3-7**, **Table 3-7-3**). Buttonbush totally disappeared from this transect in 2007 and came back to a 0.54 percent cover by 2010 in the riverine reach swamp forest type 2 (Rsw2). Leather fern also decreased in swamp plots (Rsw1, Rsw2) in 2007 (1.49, 0.06%) and returned with higher percentages (2.47, 0.37%) in 2010. For the most part, tri-veined fern and meniscium fern (*Thelypteris serrata*) reacted positively to the drought in several forest types: U/HH, Rblh1, bottomland hardwood forest types 2 and 3 (Rblh2 and Rblh3, respectively), Rsw1 and Rsw2. False nettle (*Boehmeria cylindrica*), moon vine and blue morning glory only appeared in the plots with swamp forest types during the 2007 drought.

Several species of shrub on transect T4 were only present during the drought (**Appendix 3-7**, **Table 3-7-4**). Red maple increased in 2007 and decreased in 2010 (0.5, 0.26, 0.0%) possibly due to the 2007 drought and then the prolonged inundation periods of the 2010 wet winter. Tri-veined fern increased its distribution during the drought while Virginia willow (*Itea virginica*) disappeared or decreased in percent cover. Swamp fern decreased in four forest types, Rblh3, Rblh2, Rsw2 and Rsw1, since 2003 and disappeared totally from three of the habitats by 2010. Old World climbing fern, blue morning glory, hemp vine and royal fern only appeared during the drought year.

Transect T5 results, located in Cypress Creek, stood out for the recruitment of water hickory on the floodplain in four different forest types in 2010 (HH/Rblh3, Rblh3, Rblh1 and Rsw1), and for many shrub species that were only recorded during the drought (**Appendix 3-7**, **Table 3-7-5**). These included false nettle, common dayflower (*Commelina diffusa*), Florida butterfly orchid (*Encyclia tampensis*), Indian laurel ficus (*Ficus microcarpa*), musty mint (*Hyptis alata*), moon vine, Mexican primrose willow (*Ludwigia octovalis*), Peruvian primrose willow (*Ludwigia peruviana*), hemp vine, cinnamon fern (*Osmunda cinnamomea*), Pouzolz's bush (*Pouzolzia zeylanica*), and summer grape.

Most of the transect T6 shrub community was located in the UTsw1 and UTsw3 plots closer to the river channel (**Appendix 3-7**, **Table 3-7-6**). Strawberry guava (*Psidium cattleianum*) was removed by FPS staff, which accounts for its absence in 2010, and probably the increase in saw palmetto (*Serenoa repens*; 1.00 to 2.00%). Within the Rsw1 plots at the back of the floodplain, shrubs were scarce in 2007 consisting of only two species, white vine (*Sarcostemma clausum*; 0.04%) and Brazilian pepper (0.35%). Leather fern, false indigo (*Amorpha fruticosa*), and buttonbush disappeared from Rsw1 plots during the drought and came back in 2010. Swamp fern disappeared from Rsw1 plots during the drought, but did not come back. Leather fern appeared in all other brackish water forest types and increased in percent cover out to the river channel. Red mangrove and pond apple also occurred in all of the brackish water forest types while white mangrove occurred only in the UTsw3 and in UTsw1 plots (2010 only). It appears that the back of the floodplain was either too dry or too saline for most freshwater shrub species on transect T6.

Most notable on transect T7 was the flip flop of the UTsw1 and UTsw2 plots (Kaplan et al. 2010). Generally, red mangrove communities are the closest to the river channel as on transect T9 in the lower tidal reach. Again, these forest types were based on canopy trees that have dbh greater than 5 cm. It was interesting to note that on transect T7, shrub-size red mangroves were only reported within the UTsw2 plots adjacent to the river (0.12, 0.37, 0.24%) and not in the UTsw1 plots (**Appendix 3-7**, **Table 3-7-7**). So the canopy/subcanopy of red mangroves in the UTsw1 plots must have been established for some period of time on perhaps a braided stream or depression. Shrub-sized white mangroves were only observed in 2010 (0.17%) in the UTsw2 plots adjacent to the river channel. Thus the UTsw1 plots must be inundated for too long for the white mangroves to establish. Many freshwater species such as red maple, false indigo, pond apple and buttonbush declined or disappeared, while other species only appeared during the 2007 drought, including marlberry (*Ardisia escallonoides*), salt bush (silverling) (*Baccharis glomeruliflora*) and downy shield fern (*Thelypteris dentata*).

Like transect T7, transect T8 has a braided stream approximately two plots away from the creek channel, which has increased the distribution of red mangroves in the vicinity of the stream; however, bald cypress remains as the dominant canopy species. The shrub community on transect T8 was dominated by leather fern, pond apple, buttonbush and wax myrtle (**Appendix 3-7**, **Table 3-7-8**). Red mangrove shrubs were only observed in the UTsw1plots in 2003 (0.25%)

while white mangrove shrubs were observed in the UTmix and UTsw1 plots in all three survey periods and had a high percent cover (35%). Leather fern had its highest percent coverage in the UTsw1 plots (2.22, 1.22, 1.01%). Since 2003, pond apple first decreased than increased in the UTmix plots (1.02, 0.33, 0.63%) and increased in the UTsw1 plots (1.32, 1.43, 1.91%) of transect T8. Wax myrtle appeared in all four forest types but had the highest percentages in the UTmix plots (0.79, 0.53 and 0.80%). The nonnative plant strawberry guava also appeared in all four forest types but never occurred any higher than 0.18 percent. Cabbage palm shrubs only occurred in the UTmix plots and ranged from 0.21 to 0.26 percent during the survey periods. Bald cypress shrubs were only found in the HH (0.10%) and UTsw1 (0.15%) forest types. Salt bush (silverling), persimmon (*Diospyros virginiana*), fire weed (*Erechitites hieraciifolius*), Peruvian primrose willow, red bay, saw palmetto and Spanish moss (*Tillandsia usneoides*) were only found during the 2007 drought.

Transect T9 is located on a peninsula near the Jonathan Dickinson State Park boat ramp at RM 6.46. This transect is dominated by cocoplum in the U and HH plots and red and white mangroves and leather fern in the swamp plots (**Appendix 3-7**, **Table 3-79**). Transect T9 had the highest percent coverage of leather fern observed within the Loxahatchee River floodplain. In the lower tidal reach forest type 2 (LTsw2), leather fern ranged from 8.17 percent in 2003, to 6.07 and 6.39 percent in 2007 and 2010, respectively. Pond apple disappeared from the plots during the drought after exhibiting a 0.89 percent cover in 2003 on the HH/LTsw2 plots and a 0.05 percent on the LTsw2 plots. False indigo, black mangrove, saw palmetto, laurel greenbrier (*Smilax laurifolia*), Spanish moss and muscadine grape (*Vitis rotundifolia*) were only observed during the drought while rosary pea (*Abrus precatorius*) was only observed in 2010. White mangrove shrubs were only observed in the LTsw2 plots, and were most abundant during the 2007 drought (2.74%). Red mangrove shrubs were found in the LTsw2 and lower tidal reach swamp forest type 1 (LTsw1) plots with the highest percent coverage in the LTsw1 plots.

As mentioned previously, transect T10 on the North Fork of the Loxahatchee River is transitioning from a freshwater coastal marsh and hammock system to a young forested wetland system dominated by pond apple and white mangrove. The most abundant shrubs were leather fern, pond apple, saw grass (*Cladium jamaicense*), wax myrtle and Brazilian pepper (**Appendix 3-7**, **Table 3-7-10**). Saw grass and wax myrtle were present on all five forest types. In the 2010 survey, leather fern, buttonbush, sawgrass and wax myrtle disappeared from the marsh forest type (M) and were replaced by pond apple (0.16%), white mangrove (0.11%), Old World climbing fern (0.37%), saw palmetto (0.07%) and broadleaf cattail (*Typha latifolia*; 0.02%). Pond apple remained about the same in the M, UTmix and UTsw2 forest types instead of showing an increase as it had on many of the tidal transects. Salt bush (groundsel tree) (*Baccharis halimifolia*) was only present during the 2010 survey in the HH/M and UTmix plots while swamp fern disappeared from the M, UTmix and UTsw2 plots in 2007. White mangroves appeared to be increasing in the M, UTmix and UTsw2 areas and even appeared in the HH in 2007 and 2010. Storm surge from the hurricanes may have taken the seedlings further inland and across the floodplain.

### 3.1.5 Ground Cover Communities

The ground cover community is our first link to subtle and quick changes in the floodplain forest. It responds quickly to rain events, flooding and drought. Therefore, many plant species may come and go entirely or change distribution in reaction to changes in hydrological, salinity or light conditions. This includes climate, seasonal reactions to the wet and dry seasons of south Florida, and long-term changes in water management within the river system. Ground cover was examined in 2003, 2007 and 2010.

The ground cover community within all ten transects and all 138 permanent vegetative plots were examined in 2003, 2007 and 2010 as proposed in the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006). Total number of ground cover species had increased since 2003. One hundred ground cover species were found in 2003 while 135 and 147, were found in 2007 and 2010, respectively (**Figure 3-22** and **Figure 3-23**). As with the shrub community, this is probably the result of increased sunlight reaching the floor of the floodplain following the 2004–2005 hurricanes. Transects T5 (37, 42, 60), T7 (36, 48, 50), and T8 (26, 38, 48) had the highest number of species in each survey year (2003, 2007, 2010) while transects T9 (18, 22, 28) and T10 (22, 20, 26) had the lowest number of species. Transect T5 had the highest number of species and also had the most physical damage of the five riverine transects after Hurricanes Frances and Jeanne in 2004 (Roberts et al. 2011).

Stem Counts

**Appendix 3-8** provides a summary of the stem count data set by transect and by survey (2003, 2007, 2010). Ground cover species with the highest stem counts were tri-veined fern (5006), white mangrove (3563), water hyssop (*Bacopa* spp.; 4525) and pennywort (*Hydrocotyle* spp.; 1986). Tri-veined fern was the most dominant (1038, 1794, 2174; **Figure 3-24** and **Figure 3-25**). Seedlings were highest along transect T1 (177, 544, 740). White mangrove showed a positive reaction to the 2007 drought conditions and a negative reaction to the increased freshwater flows in 2010 (251, 2976, 336; **Figure 3-26** and **Figure 3-27**). Transect T6 had the highest number of white mangrove seedlings (22, 1618, 123). Noteworthy was the first two red mangrove seedlings observed on transect T10 along the North Fork in 2010. Water hyssop (427, 2506, 1592) was not found in the riverine reach but occurred mostly in the upper tidal reach; it appears to be salt and flood tolerant. On the other hand, pennywort (362, 1153, 471) was found in all three reaches but mainly in the riverine reach. It occurred in the lower tidal reach only during the higher freshwater flows in 2010.

Bald cypress showed an increase in seed production with the 2010 freshwater flow levels (**Figure 3-28** and **Figure 3-29**). Cypress seedlings went up from a low of two in 2003 to 18 in 2007 and 295 in 2010. Most of these seedlings occurred on transects T7 (0, 12, 97) and T8 (1, 4, 165); however, it was significant that, for the first time in any survey, bald cypress seedlings were observed in the lower tidal reach on transect T9. Although only one seedling was recorded in a transect T9 plot, others were observed adjacent to the transect. **Table 3-10** provides a summary of other species that may have showed evidence of being effected by hydrological changes while others showed little correlation.

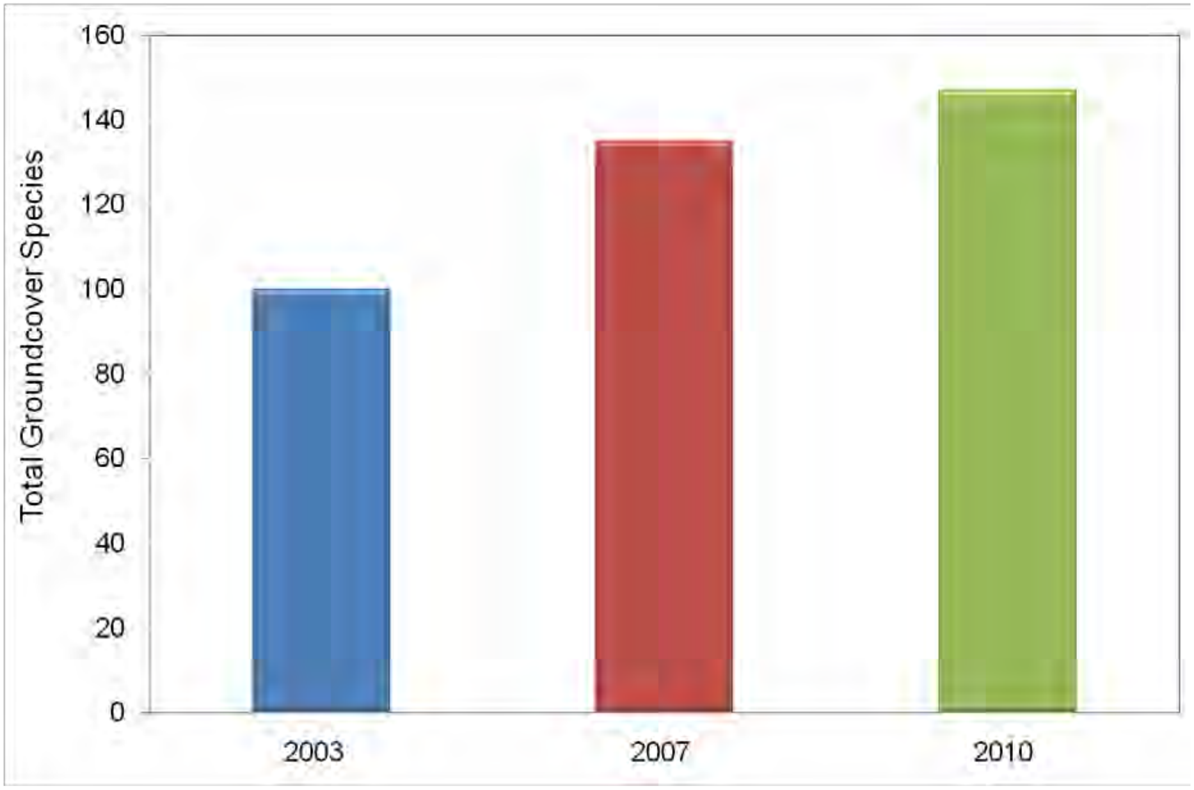


**Figure 3-22. Ground cover species richness for each survey year**

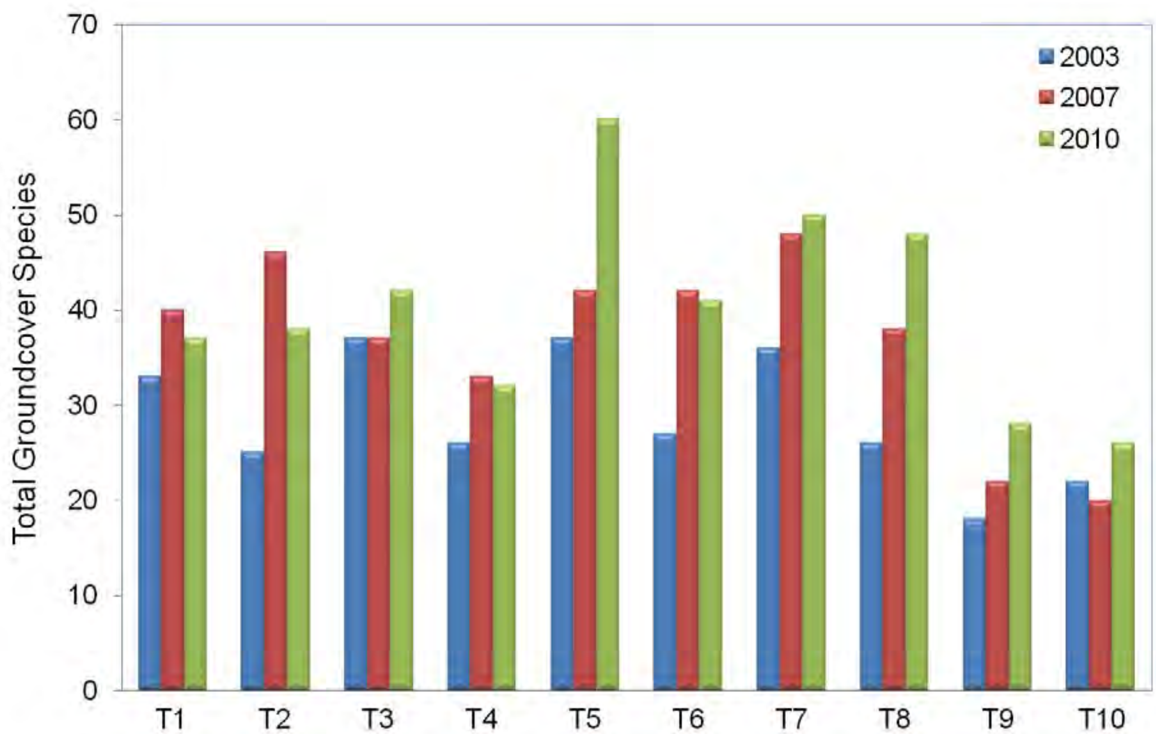


**Figure 3-23. Ground cover species richness for each transect for each survey year**

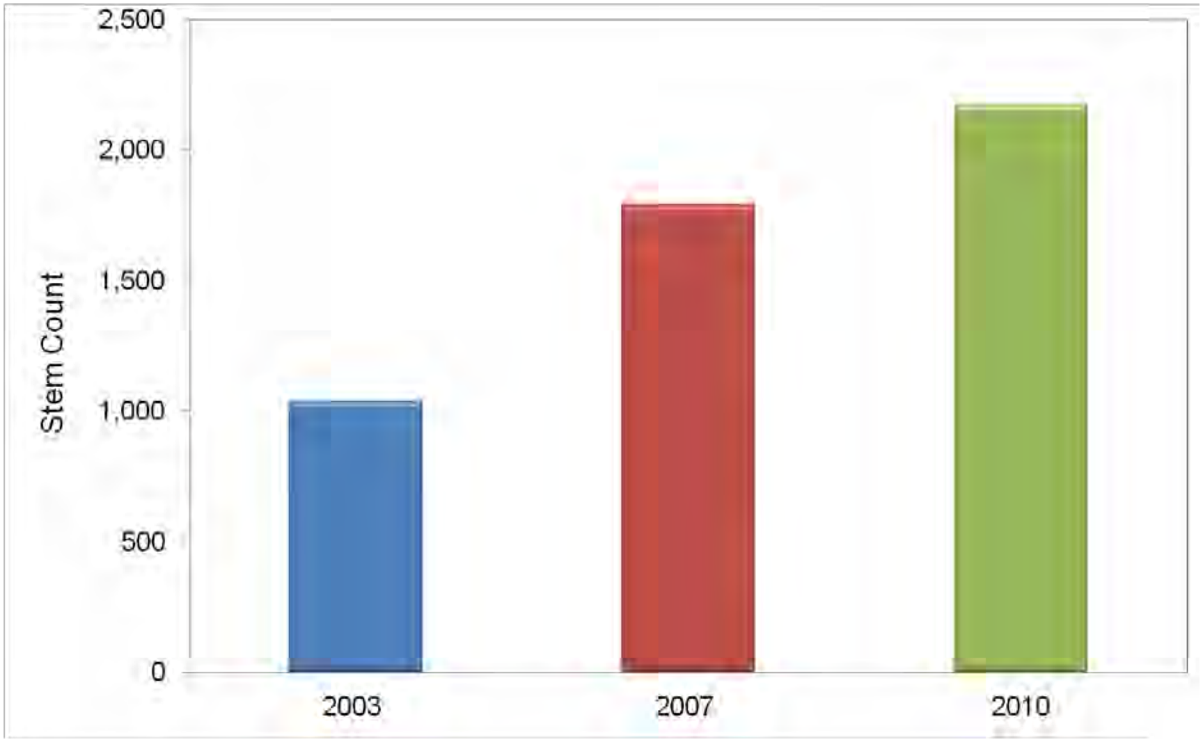


**Figure 3-24. Tri-veined fern ground cover stem count for each survey year**

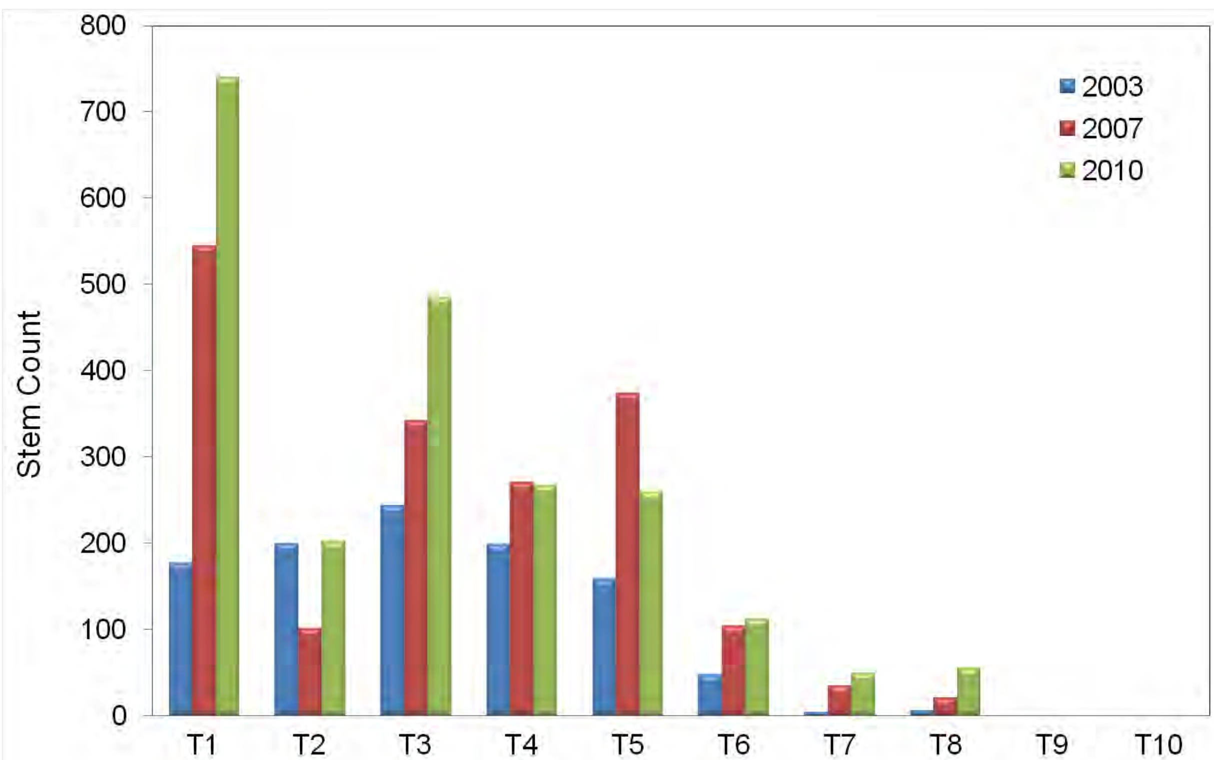


**Figure 3-25. Tri-veined fern ground cover stem count for each transect for each survey year**

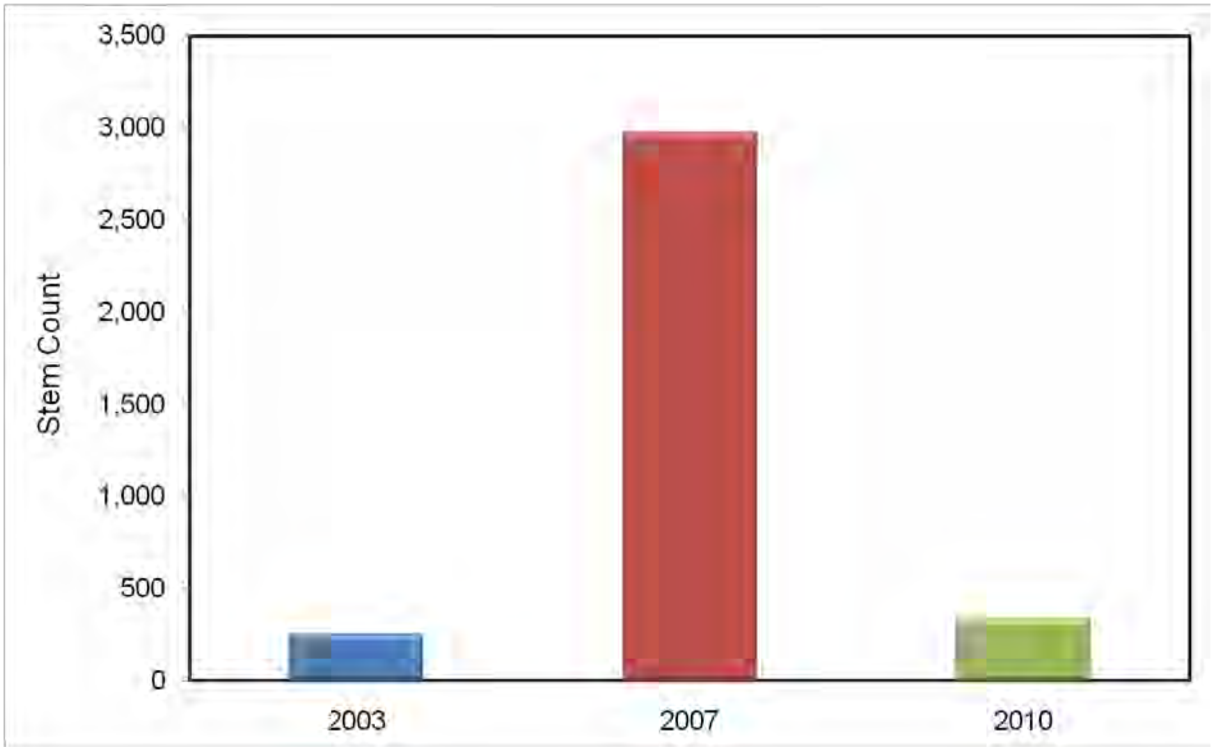


**Figure 3-26. White mangrove ground cover stem count for each survey year**

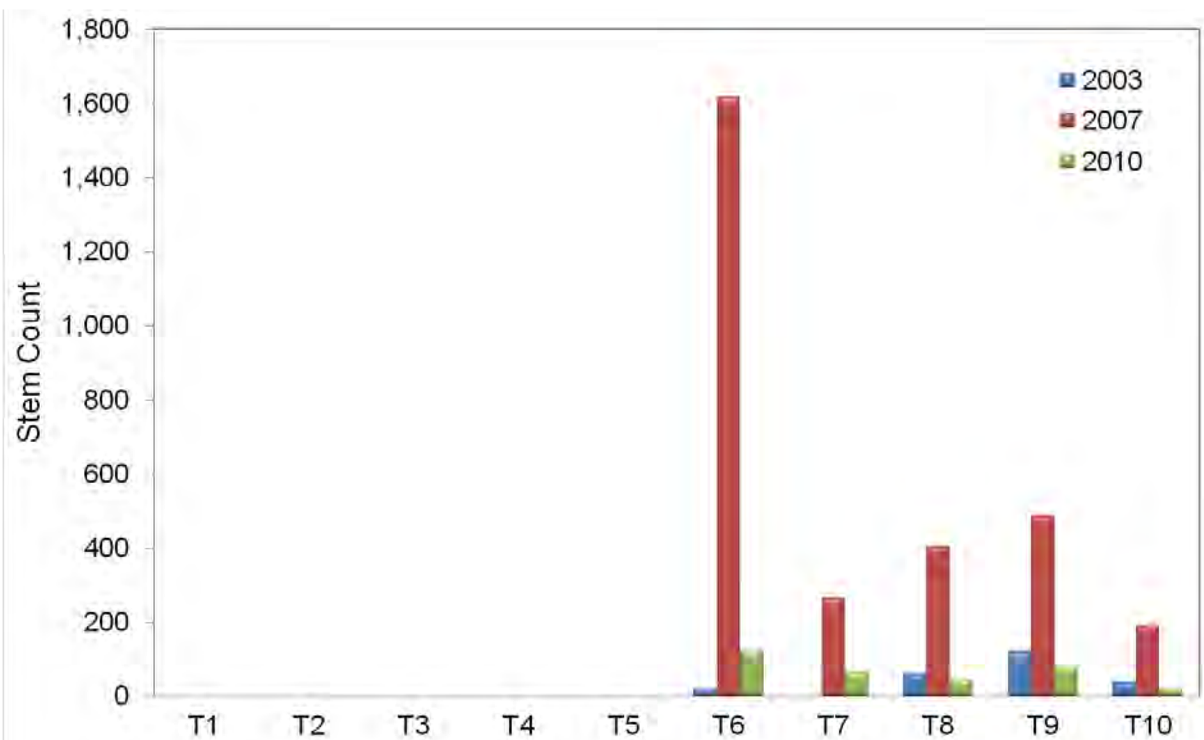


**Figure 3-27. White mangrove ground cover stem count for each transect for each survey year**

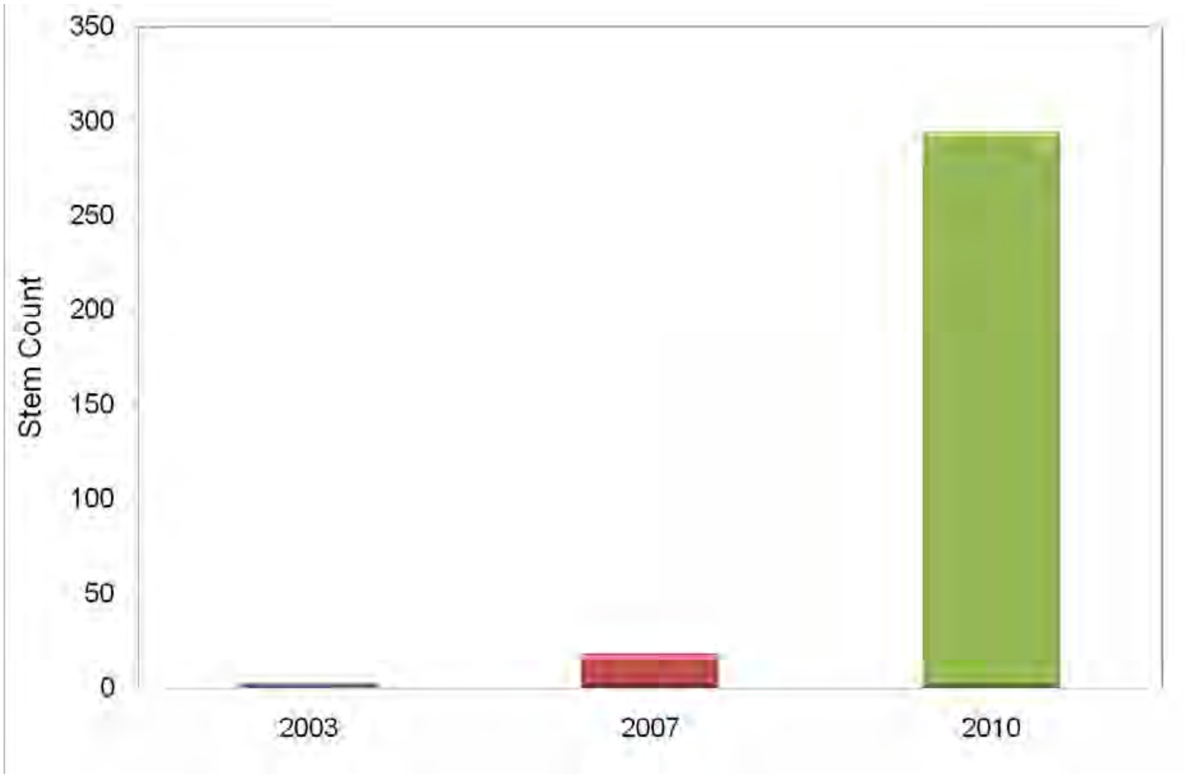


**Figure 3-28. Bald cypress ground cover stem count for each survey year**

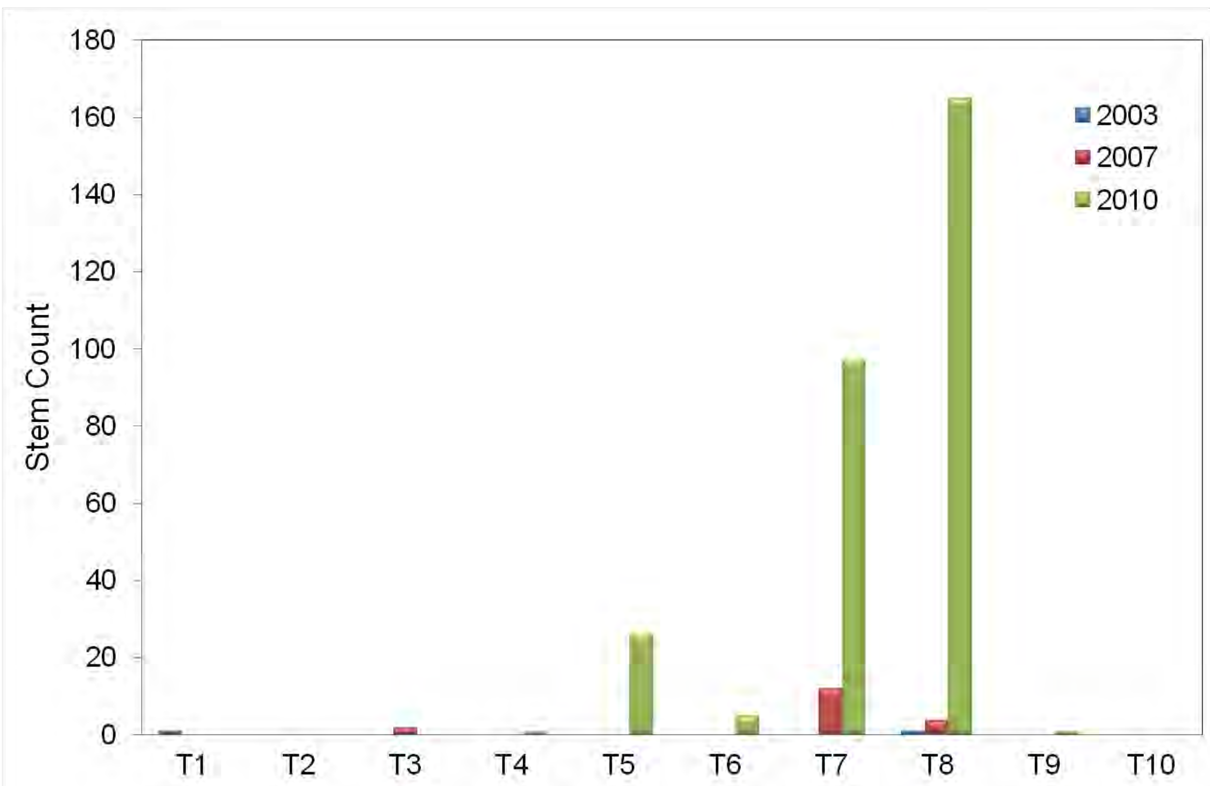


**Figure 3-29. Bald cypress ground cover stem count for each transect for each survey year**

**Table 3-10. Total ground cover stem counts for selected species**

| Common Name[1] | 2003 | 2007 | 2010 | Comments |
|---|---|---|---|---|
| Red maple | 35 | 25 | 64 | +2010–2007 |
| Leather fern | 95 | 186 | 210 | +2010 |
| Pond apple | 200 | 204 | 615 | +2010 |
| Swamp fern | 891 | 731 | 556 | declining |
| False nettle | 67 | 406 | 192 | +2007–2010 |
| Water hickory | 44 | 43 | 63 | +2010 |
| Common dayflower | 299 | 489 | 389 | +hurricanes |
| Swamp lily | 180 | 238 | 12 | +2007 |
| Variable witch grass | 343 | 408 | 444 | +hurricanes |
| Red mangrove | 635 | 119 | 58 | –hurricanes–2010 |

[1] Scientific names are provided in **Appendix 3-2**.

Percent Cover of Ground Cover Species

The highest total percent covers of ground species were of tri-veined fern, swamp fern, leather fern, pond apple and swamp lily (*Crinum americanum*). Tri-veined fern had the highest total percent cover of 949.5 percent on transect T1 and 806.5 percent on transect T3 in 2010 (**Figure 3-30** and **Figure 3-31**). Percentages for tri-veined fern were lower downstream. They were present on all transects but transects T9 and T10. They have been increasing since the hurricanes. **Appendix 3-9** summarizes the percent cover for all ground cover species by transect for all three survey years (2003, 2007, 2010).

Swamp fern was also present on all transects in 2007 except at transect T6. It had a total percentage of 319.5 percent on transect T1 in 2003 and 486 percent on transect T2 in 2010 while leather fern had 204 percent on transect T7. However, leather fern was totally missing from transects T3, T4 and T5 during all three surveys. In general, the percent cover of leather fern went down during the 2007 drought except on transect T1 (22.5, 2.5, 0.0%).

Swamp lily was present on all transects in almost every survey year. It was absent from transect T5 in 2003 and 2010 and absent from transect T9 in 2003 and 2007. Swamp lily had its highest percent cover on transects T8 (150.0, 40.0, 137.5%) and T1 (137.5, 37.5, 84.5). It was present at 15 percent cover in 2010 at transect T9 during the period of increased freshwater flow.

Percent cover of pond apple in ground cover was low in the riverine reach (2.5–7.5%) except on transect T3, which had 40.0 percent cover of pond apple in 2007. This is probably due to a lack of adequate inundation of the floodplain in the riverine reach. Transect T3, with its braided streams and low elevations, would have higher groundwater levels and more frequent inundation than the other riverine transects. In the tidal reaches, pond apple ranged from 332.0 to 0.0 percent on transect T6 between 2003 and 2007. This species reacted negatively to the 2007 drought and positively to increased freshwater flows in 2010.

Bald cypress was present on transects T2 (2.5% in 2003), T3 (2.5% in 2007), T4 (2.5% in 2010), T5 (37.5% in 2010), T6 (11.0% in 2010), T7 (12.5% in 2007; 82.5% in 2010), T8 (2.5, 7.5, 202.0%) and T9 (2.5% in 2010) (**Figure 3-32** and **Figure 3-33**).

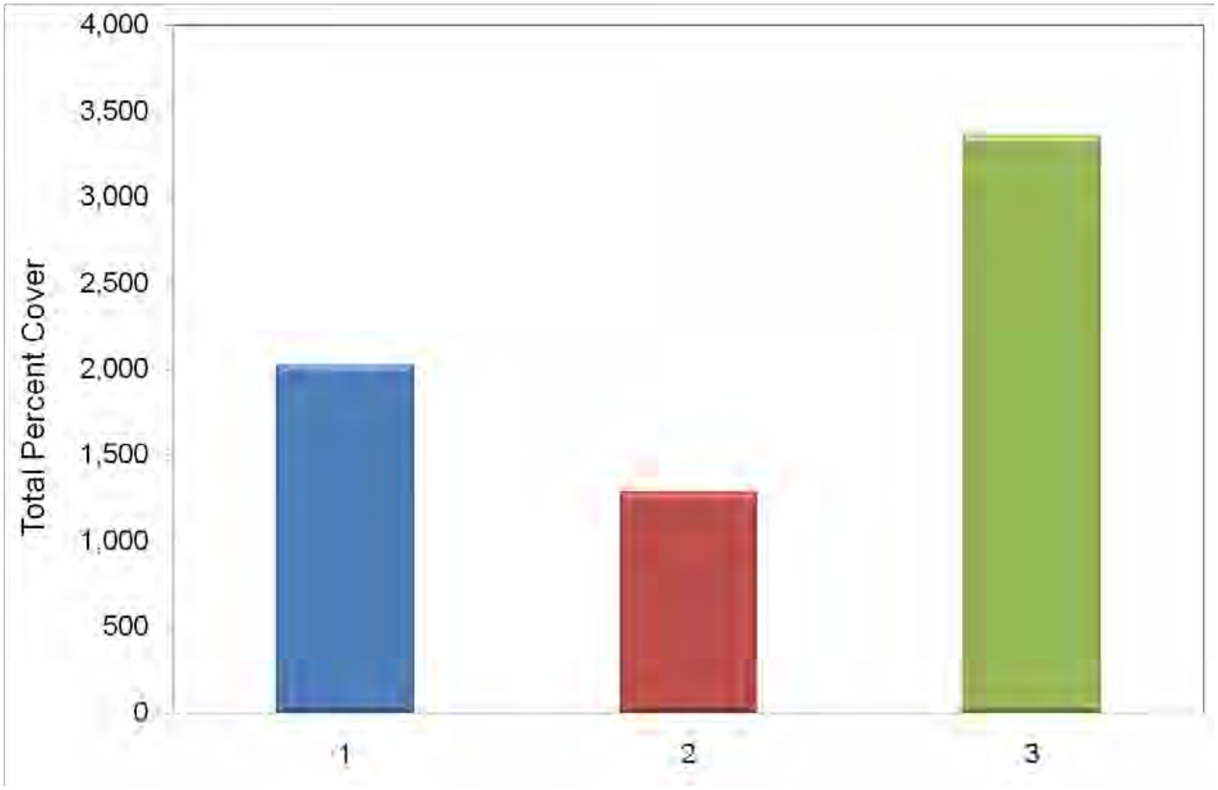


**Figure 3-30. Tri-veined fern ground cover percent cover for each survey year**

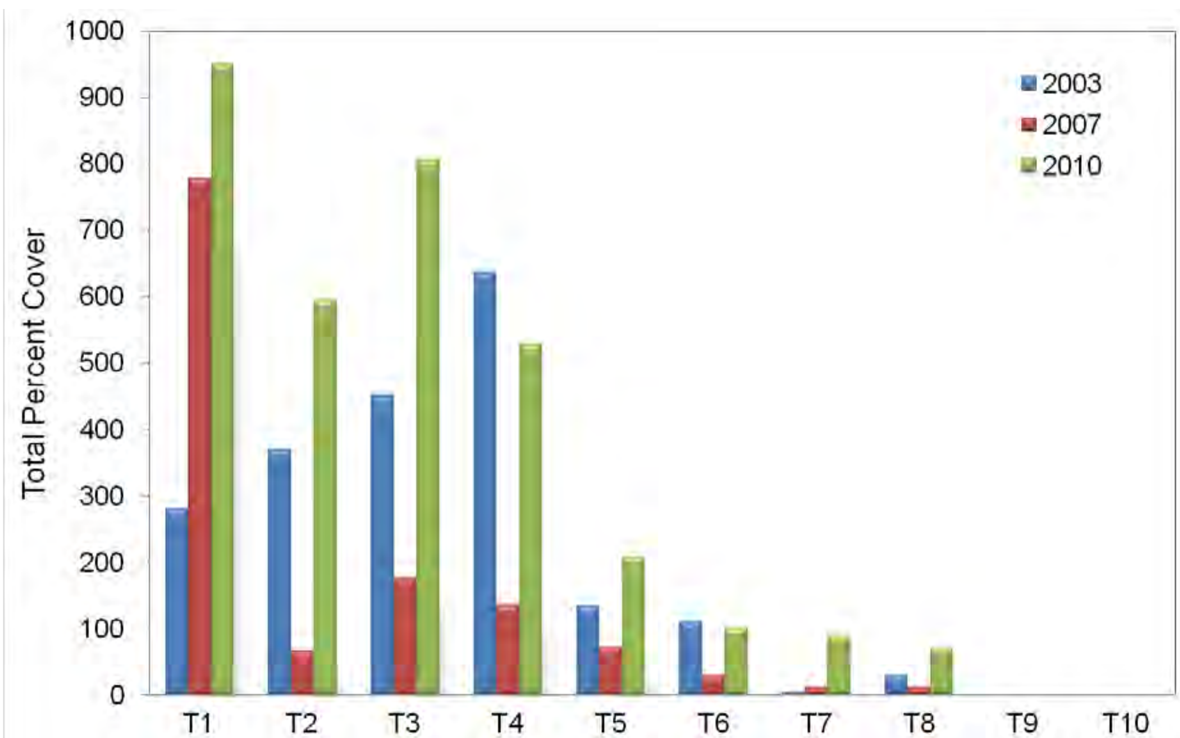


**Figure 3-31. Tri-veined fern ground cover percent cover for each transect for each survey year**

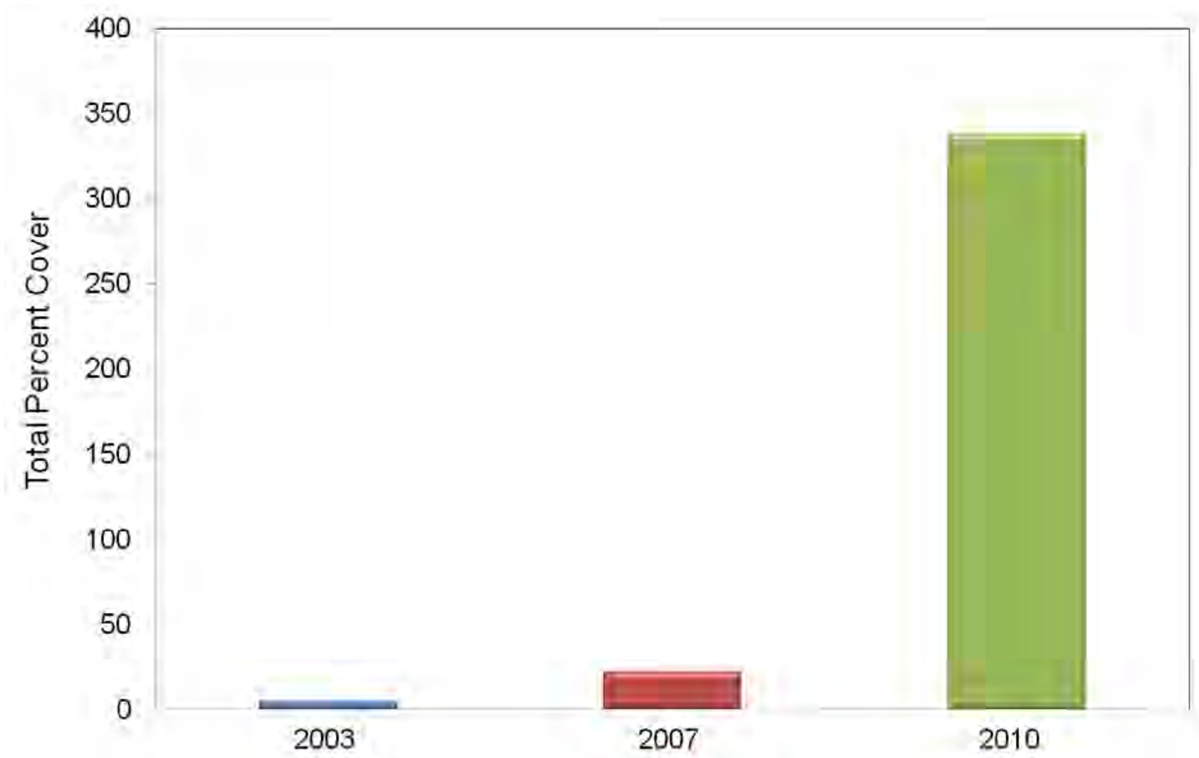


**Figure 3-32. Bald cypress ground cover total percent cover for all survey years**

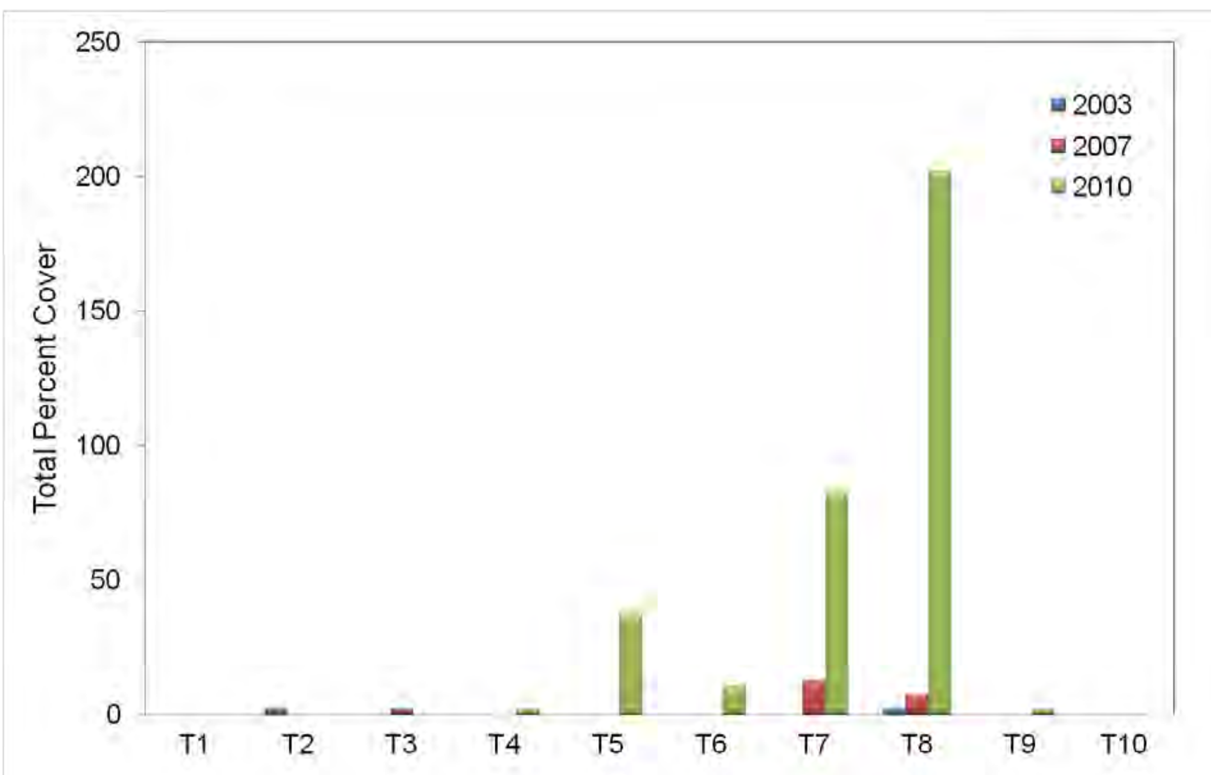


**Figure 3-33. Bald cypress ground cover percent cover for each transect for each survey year**

With regard to saltwater species, white mangrove occurred on all tidal transects during all three surveys (32.5–172.5%). The highest percent cover was on transects T6 (32.5, 172.5, 127.5%) and T9 (137.5, 130.0, 127.5%). Red mangrove was present on all tidal transects including T10 (5.0% in 2010) located in the North Fork and disappeared from transect T8 located in Kitching Creek after occurring at 2.5 percent in 2003. It was at its highest percent cover on transect T9 (125, 30, 85%) in the lower tidal reach.

Lizard's tail (*Saururus cernuus*) was also present along all ten transects except for T9 and T10. It decreased during the drought period and came back strong in 2010 with increased freshwater flows. It was highest on transect T8 (202.0, 57.5, 363.5%) and T3 (199.5, 52.5, 229.0%).

Additional percent cover and stem count figures for ground cover species are provided in **Appendix 3-12**.

<u>Percent Cover of Ground Cover Species by Forest Type</u>

Percent cover of ground cover species by forest type and survey year (2003, 2007, 2010) is provided for each transect in **Appendix 3-10**. Brief summaries of the species with the greatest coverage along with changes between survey years are provided here for each transect. Refer back to **Table 3-1** for descriptions of forest types and **Table 3-2** for a summary of forest types found within the plots along each transect.

Swamp fern occurred only in the HH plots and the plot of combined HH and U along transect T1 (**Appendix 3-10**, **Table 3-10-1**). It had the highest coverage in all three survey years in the HH plots (119.0, 106.5, 193.5%). Pellitory (*Parietaria floridana*) occurred both in the HH (89% in 2007) and Rsw1 (82% in 2007; 149.5% in 2010) plots, while tri-veined fern occurred in the MH (15% in 2003), Rlbh1 (64.5, 243.5, 99.5%) and Rsw1 (201.5, 534.5, 850.0%) plots. Caesar weed (*Urena lobata*) occurred in both HH (2.5–30.0%) and Rsw1 (5.0% in 2007) plots.

Swamp fern was found in all four forest types along transect T2 (**Appendix 3-10**, **Table 3-10-2**). Its highest percentages were in 2010 when it covered 109.0 percent of the MH, 129.0 percent of the HH plots and 119.0 percent of the combined HH/Rsw1 plot. In all habitats, swamp fern decreased during the 2007 drought and reacted with significant increases in 2010 with increased freshwater flow. For example, percent cover in Rsw1 plots were 17.5, 15.0 and 77.0 percent for 2003, 2007 and 2010, respectively. Lizard's tail responded similarly with 57.5, 12.5 and 143.5 percent cover in Rsw1 plots for 2003, 2007 and 2010, respectively. With regard to bald cypress, 2.5 percent was reported in Rblh1 plots, but disappeared and none was found in the later surveys.

Tri-veined fern in the Rsw1 plots had the highest percent cover on T3 (257, 70, 543%) in 2010 (**Appendix 3-10**, **Table 3-10-3**). Pop ash recruitment was low across this transect in all survey years but highest also in the Rsw1 plots (45.0, 12.5, 0.0%) in which the canopy is dominated by very large pop ash trees. Red maple and pond apple seedling coverage was also low, perhaps because the layer of ferns and lizard's tail may be preventing the recruitment of canopy species. Fakahatchee grass (*Tripsacum dactyloides*) was reported at 62.5 percent in 2007 in the Rblh1 forest type but was not observed in either of the other survey years.

Percent cover of swamp fern, lizard's tail and tri-veined fern decreased in 2007 in the bottomland hardwood and swamp forest types along transect T4 (**Appendix 3-10**, **Table 3-10-4**). Also, canopy seedlings were low in percent cover across this transect. Water hickory seedlings were present on the high bottomland hardwood (Rblh2, Rblh3) and swamp habitats. They were highest in the swamp (Rsw1, Rsw2) plots in each survey year (5.0, 15.0, 7.5%).

Swamp fern and Caesar weed were present along all transect T5 (Cypress Creek) forest types from MH to Rsw1 with 5.0 to 77.0 percent and 2.5 to 82.5 percent coverage, respectively (**Appendix 3-10**, **Table 3-10-5**). Common dayflower and tri-veined fern occurred in every habitat except MH. Several other species were abundant in many of the habitats including green flat sedge (*Cyperus virens*), witch grass (*Dichanthelium* spp.), guinea grass (*Panicum maximum*) and Pouzolz's bush reflecting the open canopy present after the hurricanes.

On tidal transect T6, tri-veined fern was limited to the Rsw1 and UTsw3 habitats at the back of the floodplain while swamp fern again was found on all habitats, but disappeared from the UTmix area after 2003 (**Appendix 3-10**, **Table 3-10-6**). White (5.0%) and red (2.5%) mangrove seedlings were found in all of the upper tidal plots and, in 2010, in the Rsw1 plots at low percentages at the back of the floodplain.

Creeping primrose willow (*Ludwigia repens*), swamp fern and bald cypress were found within plots of all forest types along transect T7 (**Appendix 3-10-7**). Leather fern and pond apple were found in all habitats with the exception of the MH/Rsw1 plot adjacent to the U forest type. On transect T7, bald cypress was found only after the hurricanes and peaked in 2010. The highest percent coverage was in the Rmix plots during 2010 (42%).

Pond apple, water hyssop (*Bacopa monnieri*), swamp fern, white mangrove, creeping primrose willow, hemp vine, swamp smartweed (*Polygonum hydropiperoides*), lizard's tail and bald cypress occurred within all of the forest types along transect T8 (Kitching Creek) ranging from HH to brackish water swamp (UTsw1). Tri-veined fern only occurred in the UTmix and UTsw1 plots closer to the river channel. In 2010, bald cypress occurred at 45 percent in HH, 57.5 percent in UTmix, and 92 percent (up from 2.5% in 2003) in the UTsw1 plots adjacent to the river channel. **Table 3-10-8** in **Appendix 3-10** lists coverages for all species in plots along transect T8**.**

Pond apple and white mangrove were present in all forest types except the U plot of transect T9 (**Appendix 3-10**, **Table 3-10-9**). Both were even present in the HH plots where they were carried as seeds or seedlings deeper into the floodplain during extreme high tides. Cabbage palm was found on most of the habitats, and was probably assisted by the additional elevation provided by hummocks in the tidal swamp. Many of the canopy cabbage palms appeared to be dead or dying from saltwater intrusion.

Pond apple, water hyssop, swamp fern and white mangrove occurred in all forest types along transect T10 (North Fork) including the HH plot, which was out in the middle of the floodplain on this transect (**Appendix 3-10**, **Table 3-10-10**). Old World climbing fern was found on all habitats except for the HH mock plots. Sawgrass was noted on the more inundated areas of UTmix and UTsw2 plots. Pond apple (15.0–45.0%), water hyssop (60.0–124.0%), swamp fern (54.5–122.5%) and white mangrove (10.0–40.0%) percent covers were highest on the UTmix plots while on the HH and UTsw2 plots closer to the channel, percentages were never higher than 17.5 percent.

Frequency of Occurrence of Ground Cover Species

**Appendix 3-11** summarizes the percent frequency of occurrence of ground cover species by transect for each survey year (2003, 2007, 2010). White mangrove, swamp fern, lizard's tail and tri-veined fern had the highest values. White mangrove showed a trend of increasing in frequency from upstream to downstream with percentages of 0.25, 0.60 and 0.60 on transect T7 to percentages of 0.75, 1.00 and 0.88 on transect T10. Red mangrove occurred at the highest frequency on transect T6 (0.69, 0.69, 0.63%), and was not correlated with changing hydrology. Swamp fern occurred the most on transects T2 (0.62, 0.69, 0.63%), T5 (0.93, 0.71, 0.43%), and T10 (1.00, 0.50, 0.63%). It appeared to be decreasing in frequency on most transects since 2003. Lizard's tail percent frequency was highest on transect T8 (0.91, 0.92, 0.83%) by appearing in almost every plot and occurring on all transects except transects T9 and T10. When it was present, little correlation was found with changing hydrology; it appeared to be more affected by salinity. Tri-veined fern also did not occur on transects T9 or T10. Its highest coverage occurred on transects T3 (0.85, 1.00, 0.92%) and T4 (1.00, 0.83, 0.92%).

### 3.1.6 Status of Nonnative Vegetation

Many nonnative plant species have a substantial time lag from when first observed to an explosive growth into the environment. Disturbance of natural areas has long been a part of south Florida's environment, providing an opportunity for nonnative species to spread into new areas. With human activities and multiple plant introductions, these species have invaded altered sites, often adversely affecting the natural complexity of the community (Roberts and Flanner 2010).

Of the introduced flora of Florida, 1,399 species have become pervasive and 155 species are listed by the Florida Exotic Pest Plant Council (FLEPPC) as invasive pest plants (Wunderlin and Henson 2008, FLEPPC 2009). In Jonathan Dickinson State Park, 180 nonnative plants are present, equaling 20 percent of the total plant species richness (Roberts et. al. 2006). Of these nonnative plants, 37 species are targeted for intensive control in the park's management plan (FDEP 2000).

During the 2003, 2007 and 2010 vegetational surveys, 30 species of vascular nonnative trees, shrubs, ground cover and vines were identified along the transects. These species are listed along with their occurrence and percent cover within the survey plots (**Table 3-11**). Percent basal area of trees from 2003 and 2009 are combined. Shrubs and ground cover are consolidated from 2003, 2007 and 2010 for their totals. Within the riverine reach, 21 nonnative species were recorded. Nine nonnative species were recorded in each of the upper tidal and lower tidal reaches. Three species were found in all reaches and 21 species were found in only one reach of the river.

A wetland indicator index is also provided in **Table 3-11**. The indicator index of wetland vascular plants places plants into five categories:

- Obligate – occurs almost always under natural conditions in wetlands
- Facultative wet – usually occurs in wetlands
- Facultative – equally likely to occur in wetlands or nonwetlands

- Facultative upland – usually occurs in nonwetlands
- Upland – occurs almost always in upland sites

**Table 3-11. List of nonnative trees, shrubs and ground cover and their percent cover**

| Common Name[1] | Layer or Vine | Wetland Indicator Index | FLEPPC Category | Species Occurrence by River Reach: Riverine | Upper Tidal | Lower Tidal | All Reaches | Percent Cover by Layer: Canopy | Shrub | Ground Cover |
|---|---|---|---|---|---|---|---|---|---|---|
| Rosary pea | vine | --- | 1 | √ | | √ | | | 0.55 | 77.5 |
| Blue mink | ground cover | facultative upland | --- | √ | | | | | | 90.0 |
| Alligator weed | ground cover | obligate | 2 | √ | | | | | | 94.5 |
| Sessile joyweed | ground cover | obligate | --- | √ | √ | | | | | 17.5 |
| Bishop wood | canopy | --- | 1 | √ | | | | | | 2.5 |
| Green shrimp plant | ground cover | facultative wet | 2 | √ | | | | | | 2.5 |
| Wild orange | canopy | facultative upland | --- | √ | | | | 0.20 | | |
| Wild taro | ground cover | obligate | 1 | √ | | | | | 2.12 | 431.5 |
| Common dayflower | ground cover | facultative wet | --- | √ | | | | | 0.13 | 1020.5 |
| Three-flower beggar weed | ground cover | facultative upland | --- | | √ | √ | | | | 2.5 |
| Indian laurel ficus | canopy | --- | 1 | | | √ | | | 0.61 | |
| Indian swamp weed | ground cover | obligate | 1 | √ | | | | | | 20.0 |
| Asian marsh weed | ground cover | obligate | 2 | √ | √ | | | | | 315.5 |
| Peruvian primrose willow | shrub | obligate | 1 | | | | √ | | | 27.5 |
| Old World climbing fern | vine | --- | 1 | | | | √ | | | 639.0 |
| Guinea grass | shrub | facultative | 2 | √ | | | | | | 200.5 |
| Elephant grass | shrub | facultative | 1 | √ | | | | | 0.57 | 15.0 |
| Pouzoulz's bush | ground cover | --- | --- | √ | | | | | 0.04 | 152.0 |
| Strawberry guava | canopy | facultative | 1 | | √ | √ | | 0.11 | 2.77 | 52.5 |
| Water spangles | ground cover | obligate | 1 | | | | | | | 2.5 |
| Brazilian pepper | canopy | facultative | 1 | | | | √ | 0.08 | 8.48 | 112.5 |
| Climbing cassia | canopy | --- | 1 | √ | | | | <0.01 | 0.84 | 2.5 |
| False buttonweed | ground cover | --- | --- | | | √ | | | | 15.0 |
| Smut grass | ground cover | facultative wet | --- | | | √ | | | | 15.0 |
| Creeping oxeye | ground cover | facultative | 2 | √ | | | | | | 2.5 |
| Nephthytis | vine | --- | 1 | √ | | | | | 0.06 | 75.0 |
| Java plum | canopy | facultative | 1 | | √ | | | 0.12 | 1.61 | 169.5 |
| Downy shield fern | ground cover | facultative wet | --- | √ | √ | | | | 0.35 | 292.5 |
| Caesar weed | ground cover | facultative | 2 | √ | | | | | 4.57 | 745.5 |
| Para grass | ground cover | facultative wet | 1 | √ | | | | | | 15.0 |

[1] Scientific names are provided in **Appendix 3-2**.

If applicable, the Florida Exotic Pest Plant Council (FLEPPC) category for each species is also provided in **Table 3-11**. Category 1 species are those nonnative plants that are altering native plant communities by displacing native species. Category 2 species are those that have not shown the extent of displacement as those in Category 1. Twenty species found in the plots are listed by the FLEPPC with 15 classified as Category 1 and five classified as Category 2.

The abundance of total canopy species is a measure of the number of individual trees (density) in a unit area. Total abundance of nonnative canopy species was measured in 2003 and 2009 (**Figure 3-34**). In the 2003 survey, the abundance of total canopy species numbers was exceedingly small for Brazilian pepper (2.8%). This demonstrates that past resource management activities, which utilized herbicides applied by contractors and FPS personnel, have obtained good results on this, as well as other, larger trees.

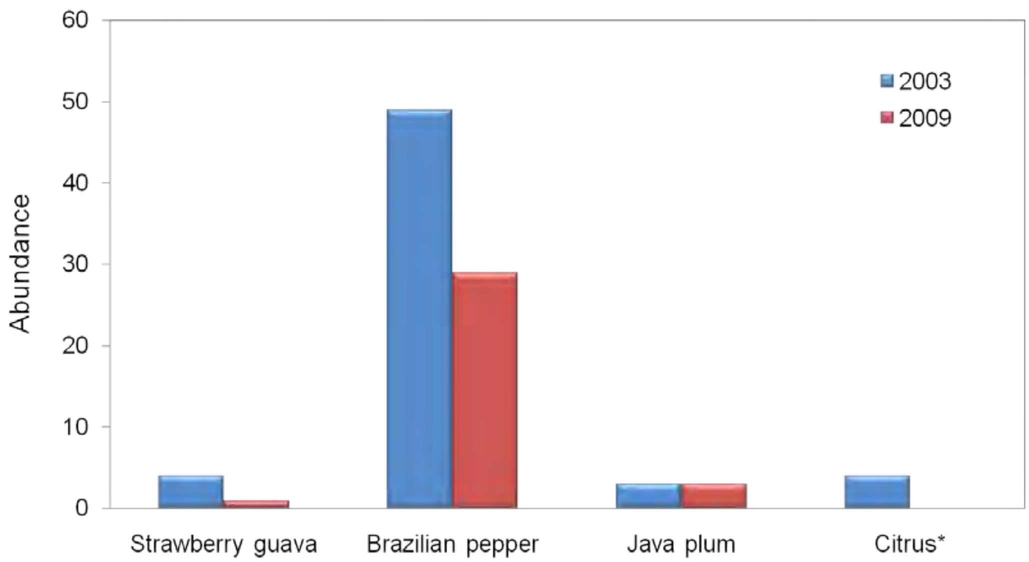


**Figure 3-34. Abundance of nonnative canopy trees**

The 2003, 2007 and 2010 nonnative shrub total percent cover was highest for Old World climbing fern, Brazilian pepper, Caesar weed, strawberry guava, wild taro, Java plum and Peruvian primrose willow in that order, followed by eight other shrub species (**Table 3-11**). Generally, shrub layer plants exhibit a more intermediate growth response between the tree canopy and ground cover. Results from this study show that the nonnative shrubs are becoming more established and spreading.

Ground cover vegetation reacts rapidly to changes in hydrological conditions. Their position within the topographical gradient can result in their being impacted by increased or decreased flows and inundation. Of the 28 nonnative plants documented in **Table 3-11** and found in the ground cover plots, the ten that have the largest percent cover were common dayflower, Caesar weed, Old World climbing fern, wild taro, Asian marsh weed (*Limnophila sessiliflora*), downy shield fern, guinea grass, Brazilian pepper, nephthytis (*Syngonium podophyllum*) and Indian swamp weed (*Hygrophila polysperma*). However, based on researching these sites and traversing areas of the floodplain, some of the percent cover totals, such as those for nephthytis and Indian swamp weed, are unexpectedly low.

To substantiate these ground cover observations, stem counts for the ten nonnative species with the largest percent cover were calculated for all three years. The total stem counts closely matched the same order for the percent cover, except for the two aquatic plants, Indian swamp weed (**Figure 3-35**) and Asian marsh weed (**Figure 3-36**), which were higher. The most widely distributed plants, Brazilian pepper (**Figure 3-37**) was found in all transects and Old World climbing fern (**Figure 3-38**) in nine transects. Neither species are actively controlled on transect T10 (North Fork). With the exception of downy shield fern (**Figure 3-39**) being found in transect T7, all the remaining ten selected species are only in the riverine reach of the river. It is the riverine reach area that contained the greatest concentration of nonnative vegetation.

Those nonnative plant species showing the greatest increase in stem count from 2003 to 2010 were Indian swamp weed (**Figure 3-35**), wild taro (**Figure 3-40**), guinea grass (**Figure 3-41**) and Caesar weed (**Figure 3-42**), in that order. Transect T5 was the most highly impacted from flows and hurricanes, and the greatest increases were guinea grass, Caesar weed and common dayflower (**Figure 3-43**). Again, there was a disparity between both the Indian swamp weed (**Figure 3-35**) and nephthytis (**Figure 3-44**) measured versus what was observed within the vicinity of the transect.

Although not included within the ten nonnative ground cover species with the greatest percent cover, an additional five plants pose serious threats, especially since four are FLEPPC-listed plants. They are Java plum (Category 1), Pouzoulz's bush (not FLEEPC-listed), alligator weed (*Alternanthera philoxeroides*; Category 2), strawberry guava (Category 1) and Peruvian primrose willow (Category 1). Pouzoulz's bush has shown some invasive tendencies wherein it can spread by seed and has an extensive root system (Rogers 2011).

The proliferation of many of these nonnative plants in the Northwest Fork contradicts the river's restoration and management goals of maintaining the river's existing native plant communities and restoring hydrological processes. Many of these plants are self-sustaining and are expanding their range, whereas others have not been deemed to be invasive in this environment. In the surveys, these plants were assessed according to those that were clearly detrimental in the existing environment and those that were expected to expand or contract with changes in the river's stage and flow relationship

For example, in the riverine reach during prolong periods of reduced flow and rainfall, the shortened hydroperiod facilitates more upland species (facultative and facultative upland) to germinate in areas otherwise too inundated with water for most of the year. Conversely, those areas with high flows and soil moisture are too wet for these nonnative plants. However, those species that can tolerate submersions can persist. This assumes no varied micro-topographical elevations within the floodplain, such as fallen logs, cypress knees or hummocks. These elevated sites will always be locations for diversity and seedling germination for both native and nonnative plants.

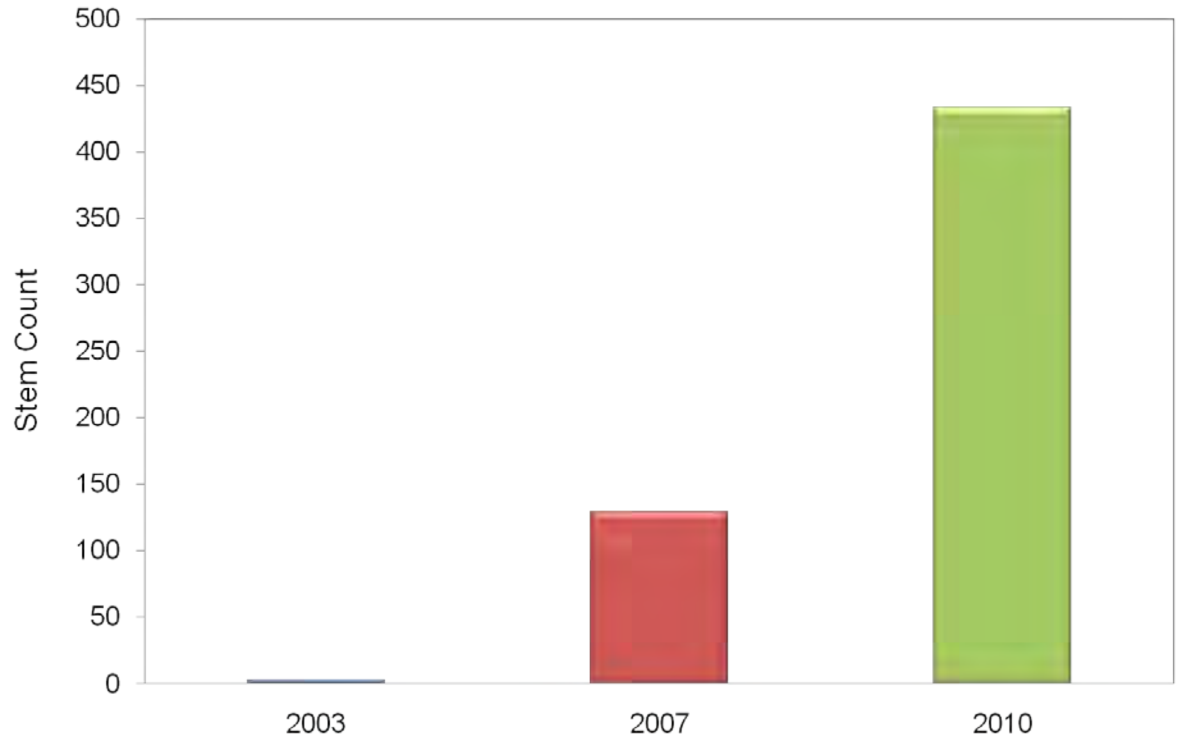


**Figure 3-35. Indian swamp weed stem counts for each survey year**

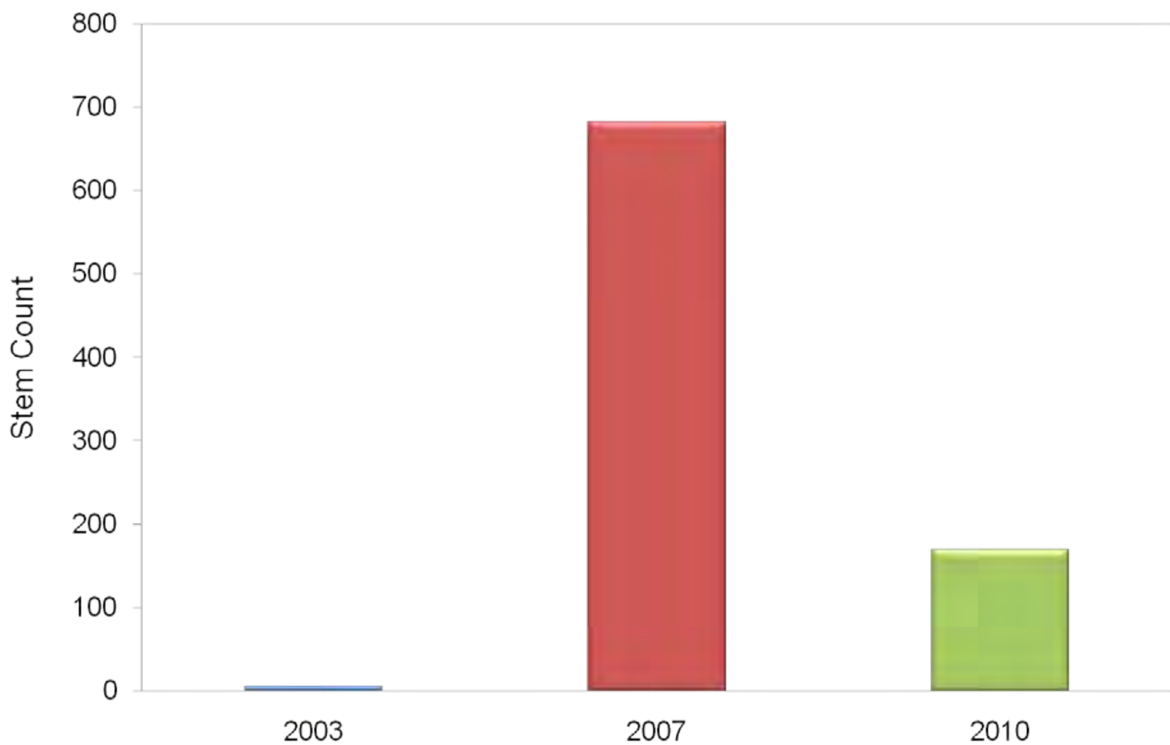


**Figure 3-36. Asian marsh weed stem counts for each survey year**

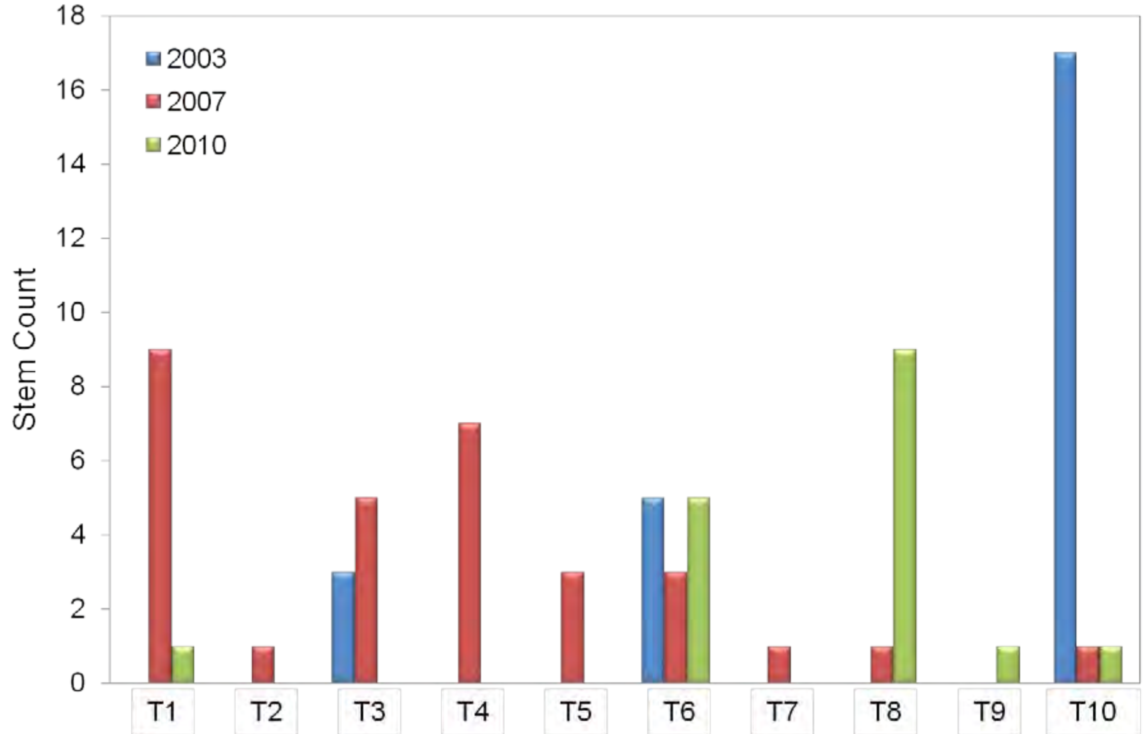


**Figure 3-37. Brazilian pepper stem counts for each transect for each survey year**

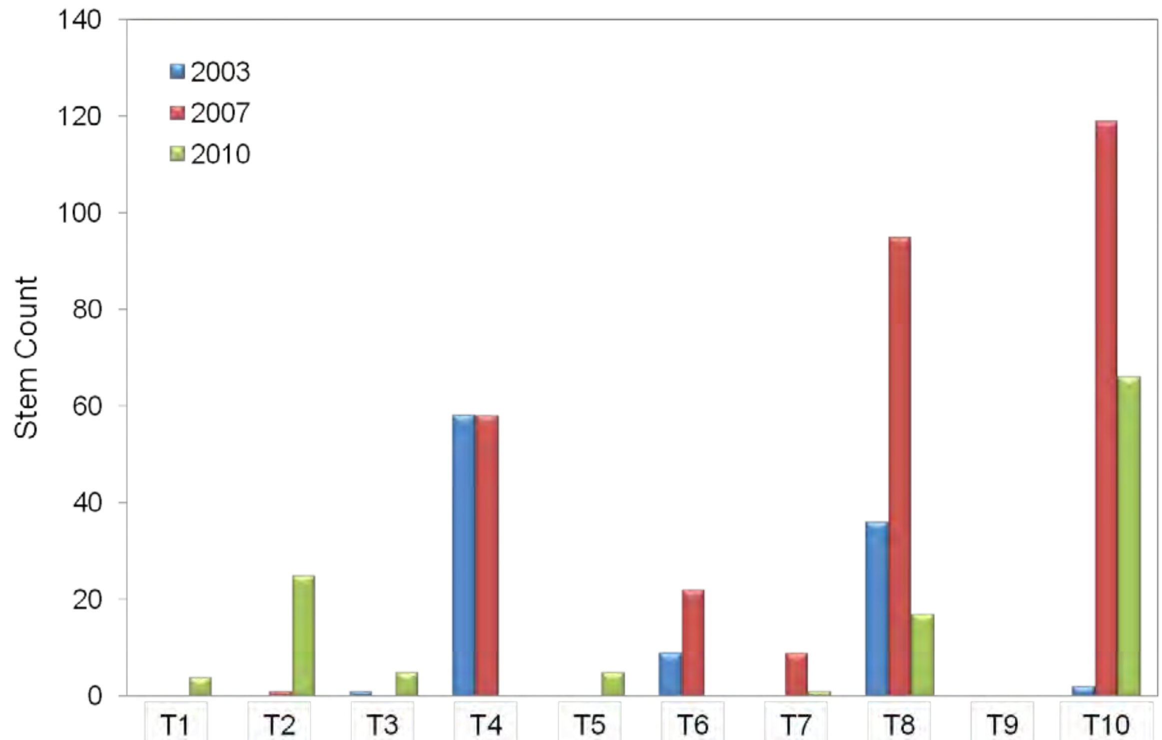


**Figure 3-38. Old World climbing fern stem counts for each transect for each survey year**

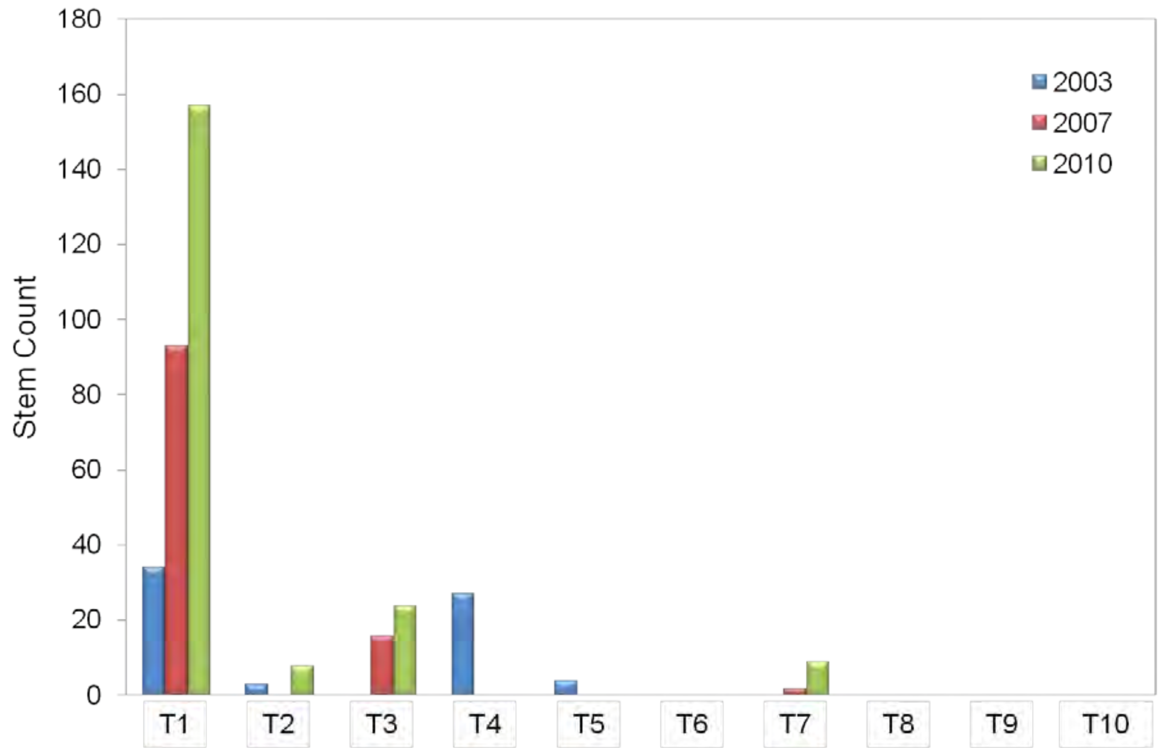


**Figure 3-39. Downy shield fern stem counts for each transect for each survey year**

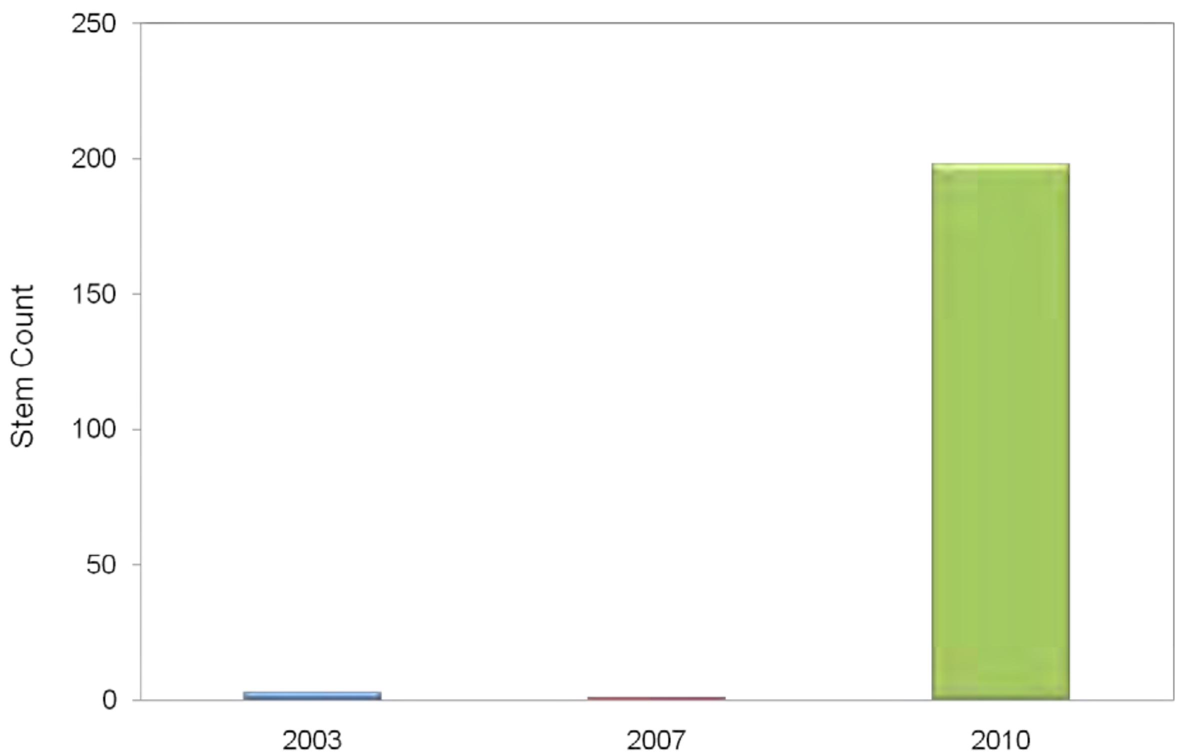


**Figure 3-40. Wild taro stem counts for each survey year**

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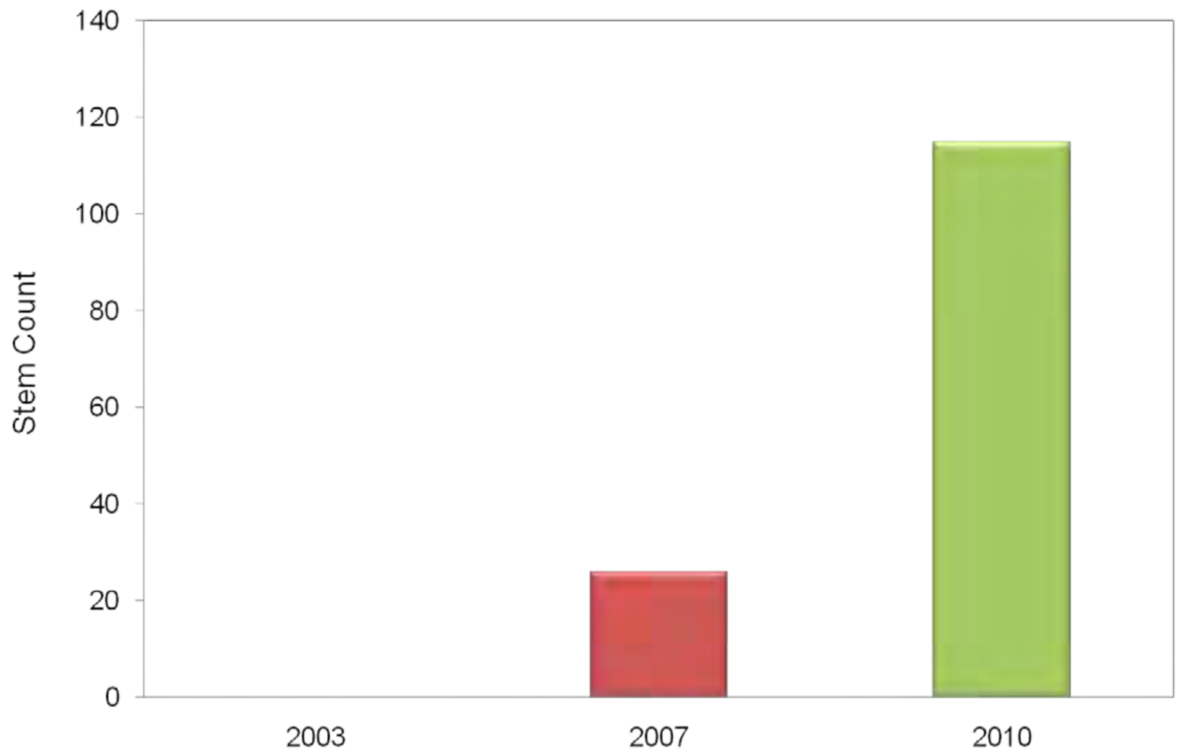


**Figure 3-41. Guinea grass stem counts for each survey year**

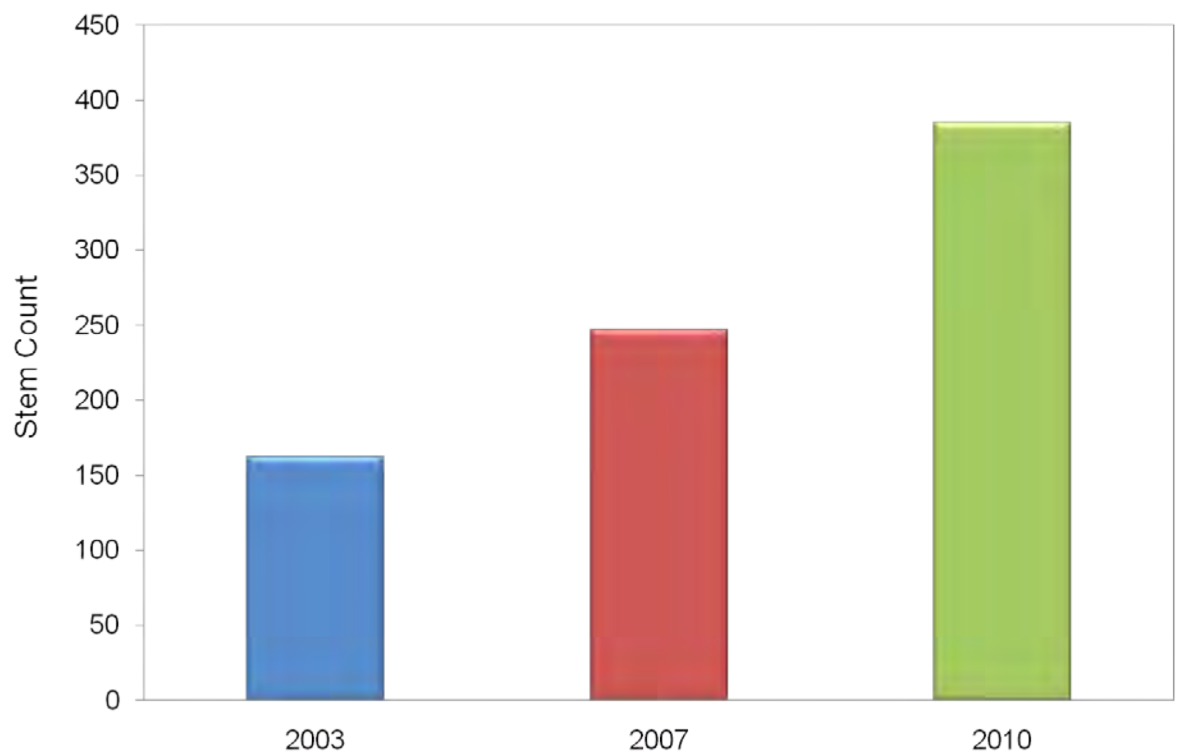


**Figure 3-42. Caesar weed stem counts for each survey year**

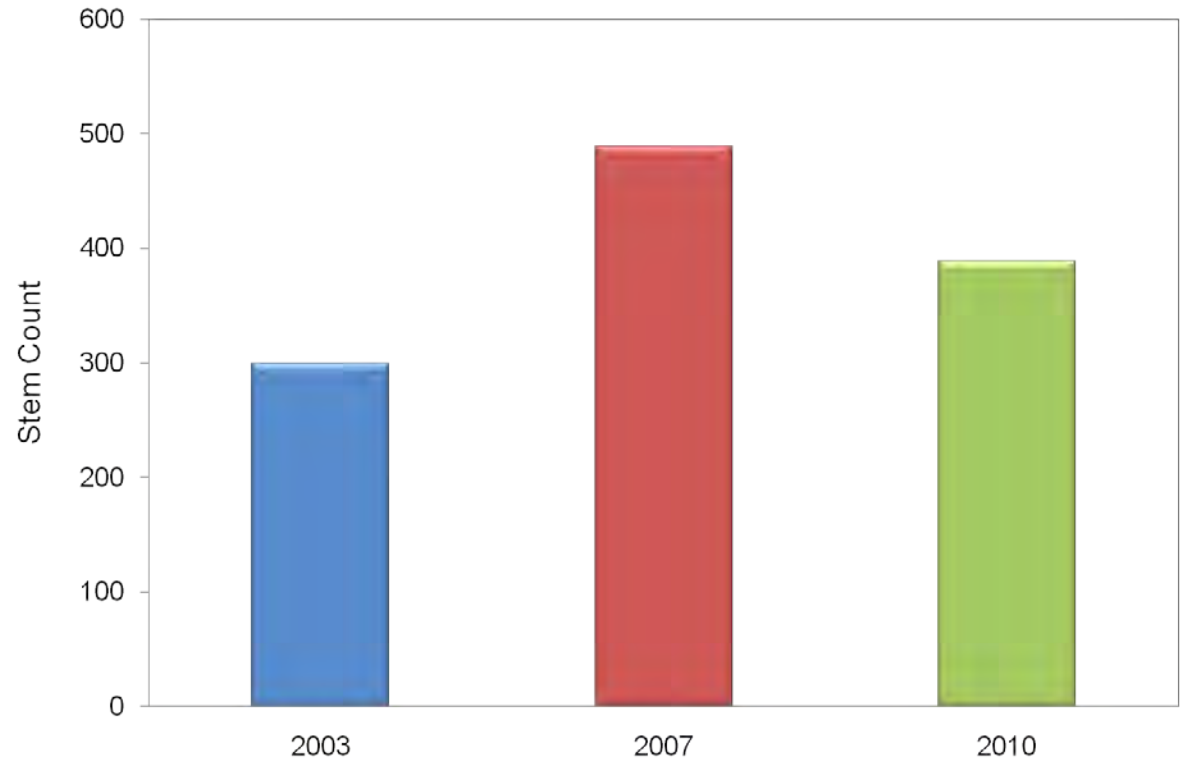


**Figure 3-43. Common dayflower stem counts for each survey year**

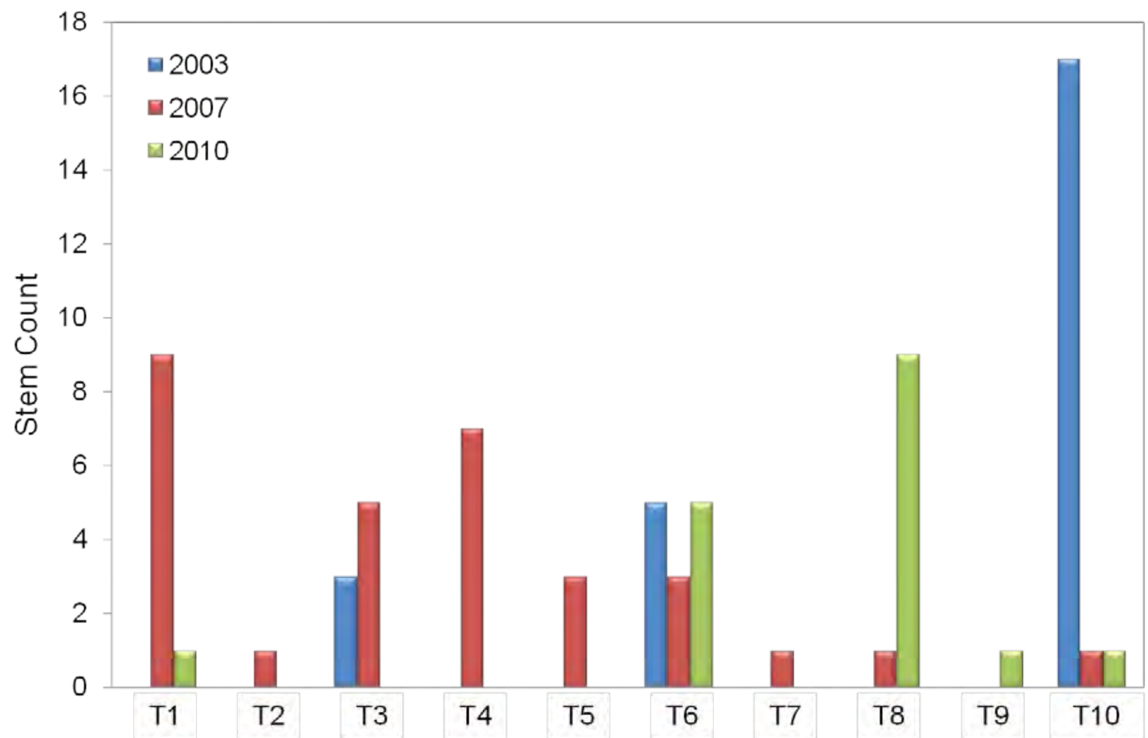


**Figure 3-44. Nephthytis stem counts for each transect for each survey year**

Those species expected to increase with reduced flows and soil moisture would include Caesar weed, guinea grass, Java plum, strawberry guava and elephant grass (*Pennisetum purpureum*). Both Java plum and strawberry guava are now prioritized species for control efforts. Strawberry guava is considered the worst pest plant in Hawaii, where it has invaded a variety of natural areas (Cronk and Fuller 1995). However, even with restored flows to the river and floodplain, the nonnative plants that are considered obligate or facultative wet species will persist even in this wetter environment (Tobe et al. 1998). These are common dayflower, wild taro, Asian marsh weed, downy shield fern, alligator weed, Peruvian primrose willow and Indian swamp weed. Only common dayflower and downy shield fern are not listed as either a Category 1 or 2 plant by the FLEPPC. Since the initial research on nephthytis in 1996, its control has been a persistent problem.

As discussed in *Riverine and Tidal Floodplain Vegetation of the Loxahatchee River and its Major Tributaries* (SFWMD and FDEP FPS 2009), disturbances are often associated with an increase of invasive species. However, disturbances do not have to be large or a result of human activity to promote these infestations (Marler 2000). Old World climbing fern, Brazilian pepper, nephthytis, strawberry guava, Java plum, wild taro, common dayflower, Indian swamp weed and Asian marsh weed have invaded relatively undisturbed sites and ecotones separating wetlands and uplands (Richard Roberts, FPS, personal observation)

## 3.2 Loxahatchee River Vegetational Demonstration Research Project

Natural and anthropogenic disturbances play a significant role in riverine forest dynamics, species diversity, and community composition. In the interpretation of the 1940 photograph by Alexander and Crook (1975) of the Northwest Fork of the Loxahatchee River, a significant shift from freshwater to more saltwater tolerant vegetation is evident. This was the result of the alteration of the natural hydrological system of the Loxahatchee's watershed by drainage activities associated with agriculture, urbanization, and a permanently opened Jupiter Inlet. These multiple impacts have brought about changes in the balance of the freshwater–saltwater interface, resulting in significant shifts in the distribution of vegetation along the river's floodplain (Roberts et al. 2006).

In 2004, a study to evaluate the restoration and enhancement of a small area of the upper tidal reach was conducted by the FPS in association with the mitigation of approximately 0.1 acres of mangroves that were adversely impacted by the reopening of the Jonathan Dickinson State Park swimming area. The site selected for mitigation (approximately 0.8 acres) is located within the park and the floodplain of the Loxahatchee National Wild and Scenic River area at RM 8.75 (**Figure 3-45**). The research plan included the eradication of nuisance and/or nonnative plant species and a study of the natural recruitment of native species under current hydrological flows. The target success criterion was to achieve 80 percent coverage of desired obligate and facultative wetland species (Tobe et al. 1998) after five years following nonnative vegetation removal.

The study area was divided into four sites. The sites were separated but in close proximity to each other and contained nonnative species. Sites One, Two and Four were predominately common screw-pine (*Pandanus utilis*). Site Three was populated by common bamboo (*Bambusa vulgaris*) (**Figure 3-46** and **Figure 3-47**). A few Brazilian pepper plants and many more strawberry guava plants were scattered throughout all locations.

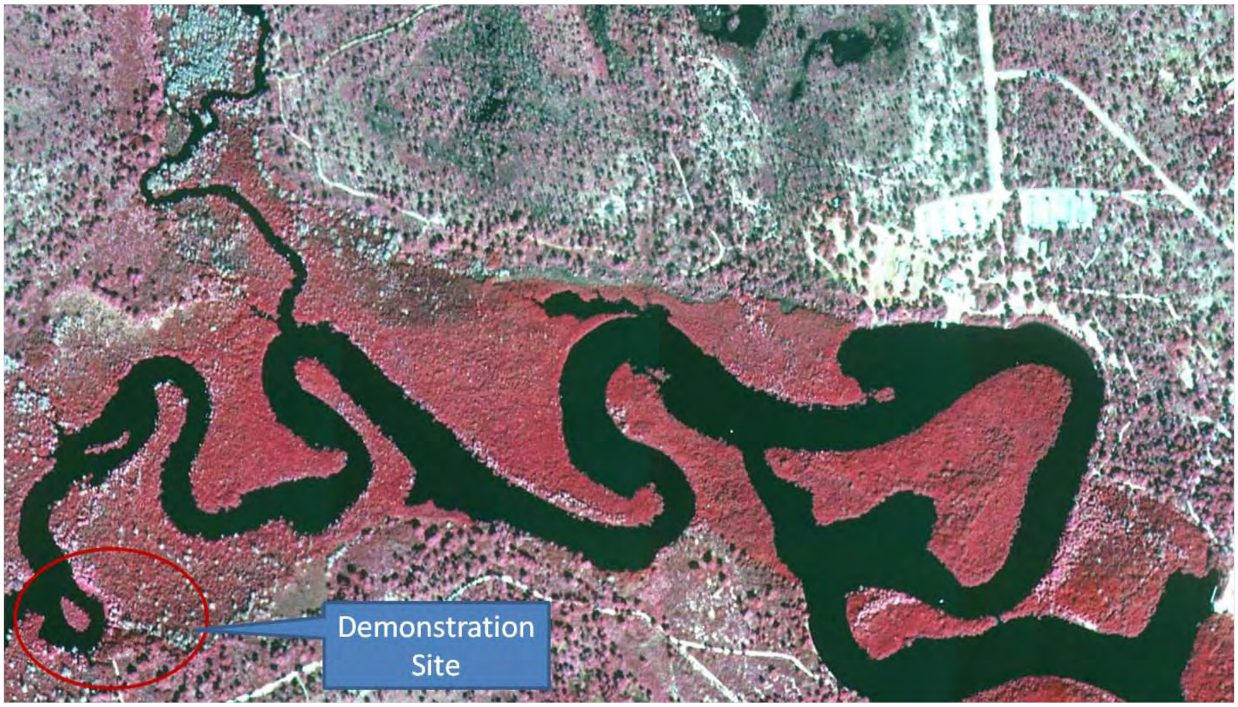


**Figure 3-45. Location of the Loxahatchee River Vegetational Demonstration Research Project within Jonathan Dickinson State Park (1985 infrared aerial)**

**Figure 3-46. Loxahatchee River Vegetational Demonstration Research Project one year after treatment for the removal of common screw pine and common bamboo; insert shows common screw pine removal**

**Figure 3-47. View of a cleared site from the river**

To evaluate the relative success of these mitigation efforts, a monitoring plan was developed to follow the elimination and restoration (i.e., natural recruitment) within these four very disturbed sites. Each 5 m by 5 m (25 $m^2$) plot was selected utilizing a superimposed grid that contained three randomly selected one-meter squares. Within each one-meter square, relative percent cover of desirable plant species, percent cover of nuisance and nonnative plant species, and random heights were recorded. The first survey of these four sites was completed in April 2004 and the final monitoring was conducted in May 2009. During this time interval, the nonnative vegetational species were removed either by hand or through the application of herbicide as part of Jonathan Dickinson State Park's invasive plant management program.

The study period began with the dry season in December 2003. Rainfall during the first survey (January–May) was 5.92 inches. In the intervening years, the lowest yearly rainfall was in 2006 with just 35.1 inches. During the first four months of 2009, total rainfall measured only 7.91 inches.

Natural recruitment began to occur across the site (**Figure 3-48**). In evaluating the target success criterion described above, nonnative species and native vines negatively impacting the site, such as hemp vine, climbing aster (*Symphyotrichum carolinianum*) and muscadine grape, were excluded. The resulting percent cover was 88 percent. However, if cabbage palm, which is a facultative species, was excluded, the total was 76 percent. The six species with the highest percent cover in 2009 were creeping primrose, cabbage palm, false hop sedge (*Carex lupuliformis*), swamp fern, pond apple and bald cypress. When comparing the two surveys for species richness in 2004, 20 species were found within the one-meter squares, with an additional

**Figure 3-48. Site 2 in May 2009; insert shows bald cypress and pond apple seedlings that naturally recruited to the site**

21 species within the total 5 m by 5 m squares. Of these plants, six were nonnatives. The last survey in 2009 showed 30 species within the one-meter squares and an additional 16 species found within the 5 m by 5 m squares. Five of the species were nonnatives. Excluding nonnative plants, this is an increase of six obligate, five facultative wetland, four facultative, one facultative upland and one upland species. Three obligate, two facultative wetland, six facultative and one facultative upland species were lost. For a description of these wetland indicator index categories see page 120.

The SFWMD and FDEP FPS (2009) used the importance values of canopy species to compare species in the sampling area based on the density, basal area and frequency of occurrence. Species with the highest importance values were considered to have the most influence on the composition and distribution of other species. Within the upper tidal reach of the river where the study sites are located, pond apple had the greatest importance value followed by white mangrove, red mangrove, cabbage palm, bald cypress, wax myrtle, pop ash, red maple, Brazilian pepper and Carolina willow. Within the one-meter squares of all four study sites, percent cover of plant species increased or stayed the same from 2004 to 2009 (**Table 3-12**).

As expected, percent coverage of some vines increased. These include coin vine (*Dalbergia ecastaphyllum*), hairy pod cowpea (*Vigna luteola*), hemp vine, muscadine grape and climbing aster.

**Table 3-12. Percent cover and average height of recruiting species between 2004 and 2009**

| Species[1] | Percent Cover 2004–2009 | Average Height 2004–2009 (cm) |
|---|---|---|
| Pond apple | 12–140% | 85.1 |
| White mangrove | 0–80% | 230.0 |
| Red mangrove | 0–16% | 40.3 |
| Cabbage palm | 24–151% | 254.2 |
| Bald cypress | 68–141% | 95.3 |
| Wax myrtle | 0–0% | 0.0 |
| Pop ash | 0–0% | 0.0 |
| Red maple | 0–0% | 0.0 |
| Brazilian pepper[2] | 2–4% | 3.0 |
| Carolina willow | 0–0% | 0.0 |

[1] Scientific names are provided in **Appendix 3-2**.

[2] Nonnative plant

The importance value results reflect the uniqueness of the upper tidal reach, with six of the ten top canopy species present. As compared to the importance value rankings in the riverine reach, five were included in this list: cabbage palm, bald cypress, pop ash, red maple and pond apple. It was significant to observe the large increases in cabbage palm, bald cypress and pond apple in this section of the upper tidal reach, which had previously showed signs of salinity stress and increases in saltwater species (i.e., mangroves).

With the impact of saltwater intrusion still having an effect on freshwater species' seed production and germination, seedling growth, and survival of adult trees, we have the ability to utilize this site to evaluate restoration and regrowth of freshwater vegetation under improved hydrological conditions over time.

**Appendix 3-13** provides the field plant list for the Loxahatchee River Vegetational Demonstration Research Project.

## 3.3 Bald Cypress and Pond Apple Seedling Studies

Three major seedling research efforts were conducted by staff from the University of Florida's Institute for Food and Agricultural Sciences (IFAS). Two projects were funded by the SFWMD and one was funded by the FPS. The purposes of these studies were to examine more closely the factors that were inhibiting the growth of bald cypress and pond apple, and target species for the Loxahatchee River floodplain community, as well as to recommend possible methods of reforestation of these species to support a more hands on approach to current and future restoration efforts. Since the survival of the bald cypress community on the Loxahatchee River is threatened by both salinity and flooding, attention was directed to tolerance levels of both stressors.

A 2004–2005 Bald Cypress Seedling Study consisted of laboratory experiments (controlled mesocosm) and field observations with the objective of determining the influence of salinity and altered hydroperiods on the growth and survival of bald cypress seedlings collected from the brackish water reach of the Loxahatchee River (Liu et al. 2005). Laboratory experiments were conducted at the Tropical Research and Education Center in Homestead, Florida, while field observations were conducted at the Loxahatchee River Vegetational Demonstration Research Project at RM 8.75 in Jonathan Dickinson State Park, which was discussed in the previous section.

**Figure 3-49. Bald cypress seedlings treated with 8 psu salinity for two weeks at different flooding levels**

Front row at 100% flooding level, middle row at 50 percent flooding level and back row at 0 percent flooding level

In the IFAS laboratory study, bald cypress seedlings tolerated 100 percent flooding (plant roots submerged in water) without salinity for as long as 30 days. All seedlings survived the 50 percent flooding (half root submerged in water) with exposure to 2, 4, 6 and 8 psu. All seedlings survived 50–100 percent flooding with 2 psu while 25–75 percent of the seedlings died under 100 percent flooding with 4–8 psu (**Figure 3-49**).

Six 1 $m^2$ plots were established within the Jonathan Dickinson State Park Loxahatchee River Vegetational Demonstration Research Project site in August 2004 for cypress seedling field study. However, all of plots were destroyed during Hurricanes Frances and Jeanne in September 2004. The experimental plots with eight 1 $m^2$ squares were reestablished again on February 3, 2005. Bald cypress seedlings in each of the set plots were counted and their heights were measured every month. Field observations showed that seedlings started growing in February or March and reached maximum growth rate in May 2005.

Also during the two-year study period, IFAS staff examined the effects of different chemicals or physical treatments on germination rates of bald cypress seeds. Seeds were soaked in a variety of treatments and were then sowed into cell trays containing Pro-Mix soil. Emerging seedlings were counted every day and then transplanted to one-gallon plastic pots. Heights of seedling were measured every week. Seedlings were later used in the salinity and altered hydrology experiments. Eight to twelve treatments of soaking the seeds in a one percent sodium hydroxide solution for five minutes and then in water for 24 hours produced the best germination rate. Fifty percent of the seedlings germinated (Liu et al. 2009). It was suggested that alkaline solutions may accelerate germination by neutralizing the acidity of the resins that surround bald cypress seeds. Physical treatment of mechanical cutting or heating negatively impacted germination rates.

In a 2007 continuation study, bald cypress seedlings were obtained from the North Carolina Division of Forest Sources Seedling Coordinator in Doldsboro, North Carolina, while pond apple seedlings were purchased from 3E Tree Farm Partners in Loxahatchee, Florida. In addition, 85 pond apple seedlings were collected from the Loxahatchee River floodplain. In a mesocosm experiment, both bald cypress and pond apple seedlings were exposed to 0, 3 or 9 psu salinity with no flooding or 100 percent flooding. Then four different treatments were applied: (1) none, (2) 20 grams fertilizer, (3) 50 milliliters three-percent hydrogen peroxide, and (4) 20 grams plus 50 milliliters three-percent hydrogen peroxide). In the field study, sixteen 1 $m^2$ plots were established on transects T6 and T7 (125 seedlings) along with 12 plots (96 seedlings) at the Loxahatchee River Vegetational Demonstration Research Project in Jonathan Dickinson State Park. A portion of the plots were fertilized with 20g of oxygen fertilizer. Water samples were collected from the field sites and tested for conductivity and pH, while soil samples were tested for sodium, potassium, calcium and magnesium. Metal detection was also examined from plant tissue taken from seedling leaves, stems and roots.

Some of the results of the 2007 bald cypress and pond apple study were as follows:

- Bald cypress seedlings started dying at 3 psu salinity (6.7% died) and 100 percent died at 15 psu.
- Pond apple seedlings tolerated 25 psu salinity and survived for one week at 35 psu (the same salinity level as seawater), but they lost most of their leaves.
- Solid oxygen fertilizer significantly increased the survival rate of cypress seedlings at 3 and 9 psu. The seedlings of bald cypress exposed to both flooding and 0, 3, or 9 psu salinity stress all survived with solid oxygen fertilization.
- Solid oxygen fertilizer significantly increase biomass of both cypress and pond apple seedlings exposed to flooding at 3 and 9 psu.
- Both cypress and pond apple seedlings survived during a 28-day research period when whole plants were submerged in water with or without 9 psu. Both species kept their leaves when salinity stress in water was absent; however, pond apple seedlings dropped all of their leaves when they were submerged in water with 9 psu salinity.
- Both solid oxygen fertilizer incorporated into soil or three-percent hydrogen peroxide added into water with or without 9 psu salinity significantly increased the biomass of both cypress and pond apple seedlings.

- Solid oxygen fertilizer significantly increased the growth of cypress seedlings in the twelve 1 $m^2$ square plots in the Loxahatchee River Vegetational Demonstration Research Project in Jonathan Dickinson State Park.

The objectives of the 2008 bald cypress and pond apple study were to (1) determine the range of flooding and salinity tolerance on the survival and growth of bald cypress seedlings in a controlled mesocosm experiment; (2) examine effects of oxygen fertilizers on improving the survival and growth of bald cypress seedlings in a controlled mesocosm experiment; and (3) examine effects of oxygen fertilizers on improving the survival and growth of bald cypress seedlings in field trials (Liu and Li 2008). To achieve these objectives, a field study, a screen house study and laboratory analyses were performed again at the IFAS lab and the vegetation demonstration site.

The mesocosm experiment consisted of placing bald cypress seedlings into flooding tubs and exposing them to 0 and 9 psu salinity while testing six different treatments consisting of root submergence (0, 50, and 100%) and applying different rates of solid oxygen fertilizer (26.1, 52.1, and 104.2 millimole bioavailable oxygen) (**Figure 3-50**).

**Figure 3-50. Mesocosms containing bald cypress seedlings at the IFAS lab**

Both screen house and laboratory studies were conducted to determine (1) appropriate application rates of oxygen fertilization to bald cypress seedlings, (2) soil redox potential in soils with or without oxygen fertilization and (3) plant physiological characterization of bald cypress seedlings exposed to flooding and/or salinity (**Figure 3-51**). The light density in the field study sites was measured with two light sensors (LI-COR, Model: Quantum) and a data logger (LI-COR, LI-1000) every

**Figure 3-51. Bald cypress seedlings at the IFAS lab**

15 minutes on September 11, 2008. Solid oxygen fertilizer was applied to some seedlings while others were used as control plants and did not receive solid oxygen fertilizer treatment. The growth increments of the treated and control seedlings were compared with each other.

Some of the results of the 2008 bald cypress study were as follows:

- Bald cypress seedlings significantly grew better in inundated conditions in the field with oxygen fertilization than without oxygen fertilization (**Figure 3-52**). No significant differences were observed in growth of seedlings in uninundated conditions with and without oxygen fertilization.

- In the mesocosm studies, 67 percent of bald cypress seedlings died of flooding and 9 psu salinity stresses when no oxygen fertilization was made while 26.1, 52.1 and 104.2 millimole bioavailable oxygen fertilization reduced the impact of stress on all treated seedlings.

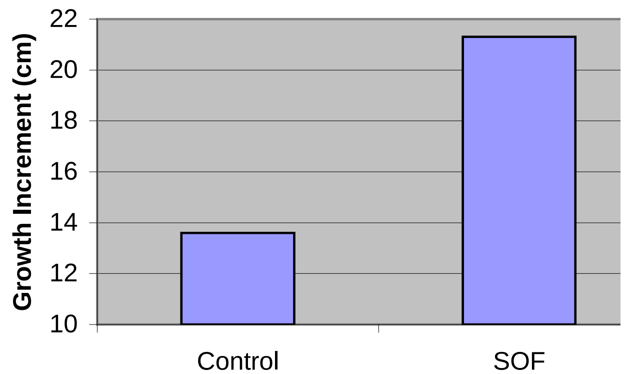


**Figure 3-52. The differences in plant heights of control and treated bald cypress seedlings March 17, 2008 to May 23, 2008**

SOF - solid oxygen fertilizer

- Biomass of the seedlings impacted from both flooding and 9 psu salinity was significantly smaller than that of any other treatments with either oxygen fertilization, no flooding, or 50 percent roots without flooding.

- Treatments with 26.1, 52.1 and 104 millimole bioavailable oxygen fertilization reduced the impact of stress on seedlings exposed to both flooding and 9 psu salinity.

- Fully submerged bald cypress seedlings were all killed at 9 psu salinity stress during two tests (1–4 days [**Figure 3-53**]; 1–4 weeks). The seedlings all survived after one week of full submergence at either 2 or 3 psu.

- Seedlings without leaves flooded in 9 psu brackish water survived and grew new shoots in weeks while those with leaves were killed within one week. Bald cypress seedling's transpiration was as much as twice that observed in pond apple seedlings.

**Figure 3-53. Bald cypress died after being fully submerged in 9 psu water for four days**

Results from these three studies can be used to address saltwater intrusion and altered hydroperiods issues on the Loxahatchee River. It will be almost impossible to address increased flooding with future rises in sea level without considering temporary or permanent barriers. With regard to saltwater intrusion, it was concluded from the 2004–2005 bald cypress study that 2 psu salinity was probably a safe level to adopt for cypress seedlings. The *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006) provided approximate locations at which salinity should be 1 psu (RM 7.5) and 2 psu (RM 7) to maintain a salinity distribution based on variable restorative flows of 90–60 cfs. With regard to flooding, no relationship appears to exist between flow and stage in the tidal reaches of the Northwest Fork due to the high variability of tidal influences. On the other hand, altered hydroperiods on the floodplain of the riverine reach may explain why recruitment of new bald cypress and pond apple was so low. With the lack of floodplain inundation and low soil moisture, germination of seeds was greatly reduced. Therefore, efforts to increase freshwater flow to the river should help to alleviate salinity stress on all freshwater species in the floodplain.

The 2007 bald cypress and pond apple seedlings study showed that pond apple seedlings can tolerate up to 35 psu for at least a week, although they may drop their leaves to conserve water. The content of potassium, calcium and magnesium was always greater in pond apple than in bald cypress seedlings, while sodium was always lower in pond apple than in bald cypress. This suggests that pond apple plants not only have a greater tolerance of salinity but may be able to better regulate the other essential elements. With regard to fully submerged plants, both bald cypress and pond apple seedlings showed that addition of the oxygen fertilizer alleviated the negative impacts of both flooding and salinity. Solid oxygen fertilizer was a vehicle for oxygen. Once dry soils meet wet conditions the bioavailable oxygen was released, and provided a growth boost to both bald cypress and pond apple seedlings and reduced the impact of flooding. In the future, problem areas in the floodplain could be treated with solid oxygen fertilizer to improve wetland plant production.

The 2008 bald cypress and pond apple seedling study provided more detailed information on the effects of different application rates in the laboratory and in the field regarding inundated and uninundated conditions. For future restoration efforts, the results suggest appropriate application rates for the oxygen fertilizer, and better explain the physiological responses of the seedlings including soil redox potential and root architecture (root to shoot ratio). The study basically illustrated again that bald cypress seedlings have a higher transpiration rate than pond apple seedlings, which probably accounts for their retreat in the lower tidal portions of the river. It illustrates how plants adjust their uptake of cations to anions in the rhizophere of the seedlings based on their physiological situation. In other words, the hypoxic plants were taking up more nitrate ions to ammonium ions than the aerobic plants. Oxygen fertilizer could be broadcast by helicopters in some problem areas along the river to improve growth. Reapplication may be necessary after significant flood events. In an economic analysis, it was shown that solid oxygen fertilizer kernel material cost about $3.50 per kilogram and one kilogram of kernel material can produce four kilograms of solid oxygen fertilizer for either pellets or plugs. It was estimated that this amount of fertilizer could save 50 to 100 two-gallon size trees in a one acre area. The study also suggested that it might be possible to reduce transpiration rates by applying anti-transpirants or anti-desiccants to accelerate ecological restoration.

## 3.4 Discussion and Conclusions

Since the 1940s, the Loxahatchee River has experienced considerable hydrologic change. Significant changes were made to the watershed that resulted in minimal post-development inundation of the floodplain swamp community and insufficient inundation to discourage the intrusion of transitional, upland and nonnative plant species. After the diversion of freshwater flow to the Southwest Fork in 1957–58 with the construction of C-18 Canal and the S-46 structure, bald cypress tree deaths were noted in the tidal reaches but not in the riverine reach of the Northwest Fork; however, they were probably stressed during very dry years. In the riverine reach, biologists and local residents reported the river channel would dry up for long stretches during the 1960s and 1970s, which was the most stressful period for bald cypress and other freshwater species in the tidal floodplain with regard to saltwater intrusion (Duever and McCollum 1983). Lainhart and Masten Dams may have provided some protection by impounding the fresh water from local rainfall upstream of the Florida Turnpike. Rainfall averages increased during the 1980s and 1990s and water was redirected back to the Northwest Fork via the G-92 structure, which was built in 1975. This is probably why today canopy tree deaths caused by saltwater intrusion seem reduced . However, in the lower tidal reach, the death of most of the remaining cabbage palms within the swamp and mixed plots of transect T9 was telling. Orem et al. (2006) identified high conductivity and high sulfides on portions of transects T9 and T6 probably due to poor flushing conditions at the back of the floodplain.

**Figure 3-54** illustrates the forever changing hydrology within riparian areas of the Loxahatchee River and its major tributaries. It is highly subjected to rainfall events and the management of major water control structures. The figure represents mean daily flow over Lainhart Dam collected by the United States Geological Survey from the beginning of dry seasons in December to the end of the wet seasons in November. With regard to our survey years, mean daily flows between November and May averaged 39.9 cfs in 2003, 31.3 cfs in 2007, and 93.6 cfs in 2010.

In 2007, conductivity measurements taken on transect T7 (RM 9.1) showed high salinity in pore water for about four months (See **Section 2.0** for details and Kaplan et al. 2010). Mean daily flows at Lainhart Dam did not go above the gold colored line in **Figure 3-54** (90 cfs) until June 2007. Vegetation data showed that the area of the highest and the most prolonged salinity event in the pore water was dominated by a subcanopy of red mangrove with a few live mature bald cypress trees while the adjacent area had more pond apple and white mangroves. This illustrates the direct effect saltwater intrusion has on plant community structure on the Loxahatchee River's floodplain. Continued monitoring of the pore water showed that when freshwater flows resumed in the wet season, surface water and soils were flushed of the salt water.

Mean daily flows ranged from 75 to 95 cfs between December and February 2010 (**Figure 3-54**). By mid-February mean daily flows rose to just above 200 cfs in March and then back down to about 90 cfs by May 2010 for an average of 93.6 cfs. Overall, the shrub and ground cover data for the 2010 survey showed a decline in red and white mangrove recruitment and increases in most, if not all, of the freshwater species that were present within each reach. Most importantly, bald cypress seedlings were encountered for the first time on T9 (RM 6.5) in the lower tidal reach. These observations illustrate the restorative nature of increasing freshwater flow and its impact on plant community structure on the Loxahatchee River floodplain. Additional flow will also provide added nutrients to the vegetation in the floodplain which should improve plant growth.

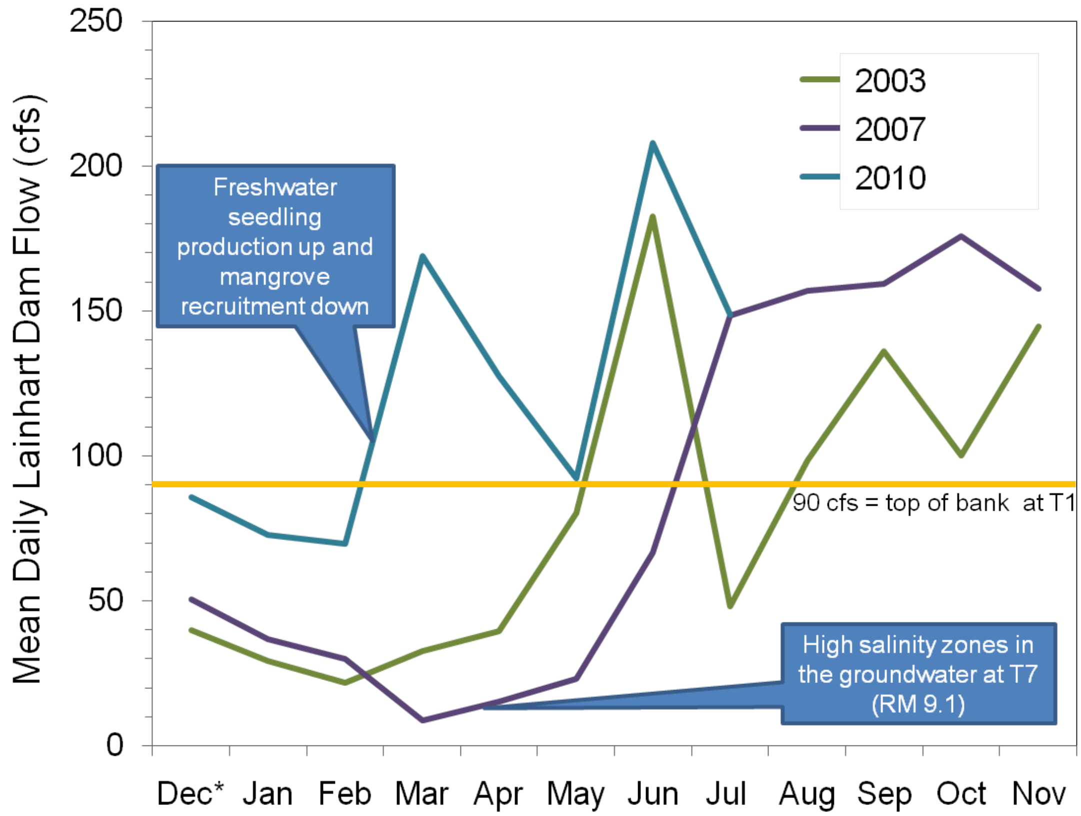


**Figure 3-54. Dry and wet season flows over Lainhart Dam indicating effects on vegetation**

Most environments can probably be managed to favor native species by altering resource levels and disturbance regimes so that native species performance is maximized relative to that of most nonnative invaders (Daehler 2003). In the case of riverine restoration, the promotion of the natural hydrological regimes and reduced anthropogenic disturbances should favor native vegetation. The specific management of nonnative plants along the Loxahatchee River's floodplain was initiated in 1996 (Richard Roberts, FPS, unpublished report). Since that time, the largest infestations of these plants have been controlled. To prevent the reestablishment of these invasive plants, constant maintenance must be continued and not just for FLEPPC Category I and II species. Regular monitoring is important for both early detection and prioritization for rapid response to deal with specific problems, as well as for continuing overall management (Luken 2004).

Examining the impacts of Hurricanes Frances and Jeanne provided insight into the physical impacts of severe weather, and a baseline for determining the amount of time needed for the floodplain plant community to recover. As demonstrated, hurricanes have the capability of opening the canopy of a forest and compounding hydrological complications within the river system by reducing soil moisture and providing more light to encourage the growth of ground cover species that perhaps may impede the recruitment of new canopy seedlings and saplings. The canopy continues to recover from the 2004 and 2005 hurricanes with new trees recruiting from the shrub layer.

While perpetuation of the floodplain plant communities is the primary focus of this study, we concluded bald cypress should be the primary species of concern for restoration and enhancement in the riverine swamp (Rsw1, Rsw2 and Rsw3), while red maple and water hickory should be the primary species of concern for bottomland hardwoods communities (Rblh1, Rblh2 and Rblh3) and cabbage palm for hydric hammocks. We continue to support the recommendations for hydroperiods and depths in floodplain swamp and hydric hammock communities established in Chapter 4 of the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006). For hydric hammocks, the performance measure was inundation of at least 30–60 days per year with 2–6 inches of water. For floodplain swamp, the performance measure was 4–8 months of inundation (100–300 days) with 18–30 inches of water. If hydroperiods in the floodplain are not adequate in depth and duration, these conditions allow for intrusion of nonhydric species and displacement of hydric species in floodplain forest communities.

Recommendations for future floodplain vegetation monitoring on the Loxahatchee River consists of examining canopy communities every six years and shrub and ground cover communities every three years. This schedule was presented in the 2006 restoration plan (SFWMD 2006) as a means to best utilize staff and allow the sites to recover from impacts created during sampling events. We continue to support this monitoring schedule for floodplain vegetation.

With the guidelines created for forest type identification and relative basal area databases for the Loxahatchee River canopy communities, future research will include working on a floodplain index (Darst and Light 2008). The floodplain index will be used to calculate and track changes in relative dryness in our current and future forest plot databases. As the various restoration projects are completed and operational and seasonal restorative freshwater flows become the norm, it will be essential to document how the Loxahatchee River floodplain community responds at canopy, shrub and ground cover levels.

## 4.0 FLOODPLAIN FISH AND WILDLIFE UTILIZATION

The periodic inundation of riparian floodplains is closely linked with the overall biological productivity of river ecosystems. Many fish and wildlife species associated with rivers utilize both instream and floodplain habitats, and inundation of the river floodplains greatly expands the habitat and food resources available to these organisms. Floodplain habitats support a variety of fish and wildlife species that differ greatly in their life histories and hydrologic requirements. On the Loxahatchee River, fish have experienced increasing salinity regimes as a result of ocean inlet stabilization and diminishing natural freshwater flows. Floodplain vegetation has changed from primarily freshwater species to brackish water communities. Restoration plans for the Northwest Fork are addressing both saltwater intrusion in the tidal reaches and diminished floodplain hydroperiods in the riverine reach.

### 4.1 Fish Monitoring

Much work is currently underway within Florida's five water management districts to address the issues of fish community dynamics and water management practices. Hill and Cichra (2002) prepared an annotated literature bibliography for water level effects on fish populations. Their report has shown the clear relationship between stream flow and water levels on fish reproduction, survival, growth and recruitment in freshwater, estuarine and coastal marine habitats. Christensen (1965) conducted an ichthyological survey of Jupiter Inlet and Loxahatchee River as part of his master's degree program at Florida State University in Tallahassee, Florida. However, all of his collections were made in the Embayment Area and surrounding brackish water habitats. Hedgepeth et al. (2001) examined four sites on the Loxahatchee River including the Embayment Area, lower Southwest Fork, mid and upper Northwest Fork, and lower and upper North Fork in the early 1980s. However, both the upper Northwest and upper North Forks were still in brackish water tidal areas. The Florida Fish and Wildlife Conservation Commission's (FWC) Florida Marine Research Institute (FMRI) has continued to conduct investigations over the past 20 years on the distribution, size and age structure of snook (*Centropomus* spp.) in the Loxahatchee River and Indian River Lagoon, while staff from the Freshwater and Exotic Fishery Programs have investigated fish populations in portions of Lake Okeechobee, the C-18 Canal, and associated canal systems. In February 2002, Florida Sportsman featured an article by Terry Gibson entitled "Wild and Scenic Bassing" that featured the freshwater reach of the Northwest Fork of the Loxahatchee River. As a boy, Gibson fished the river and reportedly captured many snook, tarpon (*Megalops atlanticus*) and mullet (*Mullus* spp.) throughout the river. He even observed sheepshead (*Archosargus probatocephalus*) under the cypress. At the Second Loxahatchee River Science Symposium in 2004, Mary Ridler (Loxahatchee River District [LRD]) and David Snyder (Continental Shelf Associates) presented data on fish assemblages in the southern Indian River Lagoon and the lower Loxahatchee River. From 1986 through 1988 and again in 2004, the South Florida Water Management District (SFWMD) investigated larval fishes in the low salinity zone at the head of the estuary. The results of this study were described in the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006). Greatest densities of larval fish were captured at salinity from 2 to 8 practical salinity units (psu). Reductions in flow were thought to decrease primary productivity, and in turn, secondary productivity (e.g., benthos and predatory fishes). On the other hand, too great a flow can flush planktonic organisms downstream and decrease productivity in the inner estuary. Information on baseline freshwater fish species and the use of freshwater habitats by estuarine fish species was clearly needed to better understand flow and water level requirements for fish habitat.

### 4.1.1 2007 Loxahatchee River Watershed Fish Survey

**Figure 4-1. A multi-agency task force conducted a 2007 fish survey**

A general fish survey was initiated to examine the major family groups utilizing the forested and channelized wetlands in the river and watershed. The project was a multi-agency field effort that included staff from SFWMD, Florida Department of Environmental Protection's (FDEP) Florida Park Service (FPS) and Southeast District Office, FWC, Palm Beach County Environmental Resources Management (PBCERM), United States Fish and Wildlife Service (USFWS), Student Conservation Association, and Continental Shelf Associates International, Inc. (**Figure 4-1**). Along with the survey, a literature review was conducted on freshwater fishes of South Florida with specific references to their water level needs. The survey also gave an opportunity to explore the current status of endangered, threatened, special concern, and exotic (nonnative) fish species on the river and its tributaries.

The watershed fish survey was conducted between June and December 2007. Sampling areas were divided into four components, riverine floodplain, riverine channel, tidal channel and tidal floodplain, and seven study areas: (1) upper Kitching Creek, (2) upper Cypress Creek, (3) upper North Fork, (4) C-14 and C-18 canals, (5) upper Northwest Fork, (6) upper and lower tidal and (7) Lainhart and Masten Dams. Fish sampling gear included seines, dip nets, backpack electroshockers, cast net, and underwater video camera.

As a result of the survey, a total of 593 fish of 26 species were obtained from the 14 sampling locations (**Table 4-1** and **Appendix 4-2**). The most abundant species were Eastern mosquito fish (*Gambusia holbrooki*), bluegill (*Lepomis macrochirus*), spotted tilapia (*Tilapia mariae*), Everglades pygmy sunfish (*Elassoma evergladei*), Mayan cichlid (*Cichlasoma urophthalma*) and brown hoplo (*Hoplosternum littorale*) (**Figure 4-2**). Eight additional species have been captured by FWC on the Loxahatchee River and PBCERM has captured an additional five species (**Table** 4-2) in the Loxahatchee Slough for a total of 40 species. The six exotic fish species are illustrated in red in **Figure 4-2** and included black acara (*Cichlasoma bimaculatum*), Mayan cichlid, walking catfish (*Clarias batrachus*), brown hoplo, sailfin catfish (*Pterygoplichthys multiradiatus*) and spotted tilapia. Oscars (*Astronotus ocellatus*) were not captured during the survey, but were observed at Lainhart Dam. The six exotic species are pictured in **Figure 4-3**. During the survey, no exotic species were returned to the water bodies. At the end of each sampling day, exotic fishes were donated for use as animal food to the Busch Wildlife Sanctuary in Jupiter, Florida. No species listed by the USFWS or the State of Florida as endangered, threatened or of special concern was collected during the survey.

**Table 4-1. Fish species collected during the 2007 Loxahatchee River Watershed Fish Survey**

| Common Name | Scientific Name | Total Number |
|---|---|---|
| Swordspine snook | *Centropomus ensiferus* | 1 |
| Common snook | *Centropomus undecimalis* | 2 |
| Black acara[1] | *Cichlasoma bimaculatum* | 7 |
| Mayan cichlid[1] | *Cichlasoma urophthalma* | 27 |
| Walking catfish[1] | *Clarias batrachus* | 4 |
| Everglades pygmy sunfish | *Elassoma evergladei* | 75 |
| Lake chubsucker / creek chubsucker | *Erimyzon oblongus* | 1 |
| Spotfin mojarra | *Eucinostomus argenteus* | 6 |
| Striped mojarra / stripped mojarra | *Eugerres plumieri* | 1 |
| Banded topminnow | *Fundulus cingulatus* | 4 |
| Golden topminnow | *Fundulus chrysotus* | 3 |
| Eastern mosquitofish | *Gambusia holbrooki* | 247 |
| Least killifish | *Heterandria formosa* | 2 |
| Brown hoplo[1] | *Hoplosternum littorale* | 22 |
| Flagfish | *Jordanella floridae* | 15 |
| Brook silverside | *Labidesthes sicculus* | 6 |
| Florida gar | *Lepisosteus platyrhincus* | 2 |
| Bluegill | *Lepomis macrochirus* | 91 |
| Redear sunfish | *Lepomis microlophus* | 8 |
| Largemouth bass | *Micropterus salmoides* | 2 |
| Striped mullet | *Mugil cephalus* | 11 |
| Sailfin molly | *Poecilia latipinna* | 10 |
| Black crappie | *Pomoxis nigromaculatus* | 2 |
| Sailfin catfish / armored catfish[1] | *Pterygoplichthys multiradiatus* | 1 |
| Spotted tilapia[1] | *Tilapia mariae* | 41 |
| Hogchoker | *Trinectes maculatus* | 2 |
| | **Total** | 593 |

[1]Nonnative species

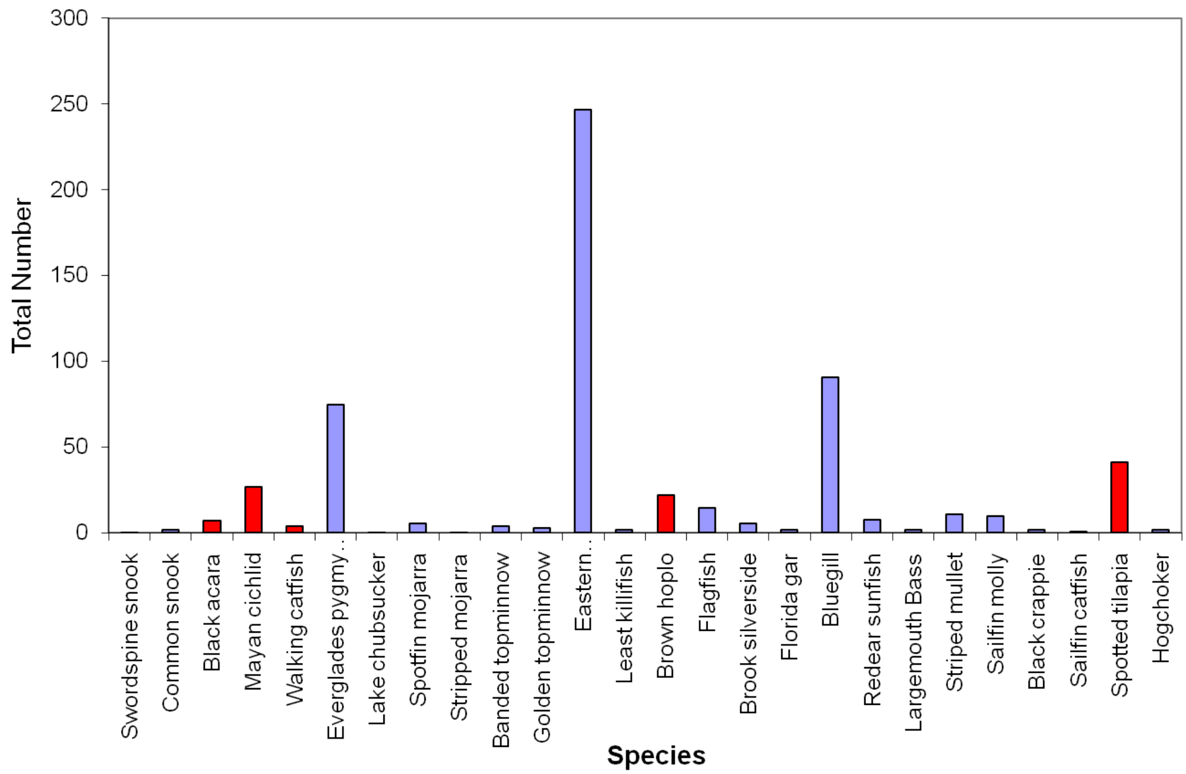


**Figure 4-2. Abundance of fish species[1] collected in the upper Loxahatchee watershed**

[1]Scientific names are provided in **Appendix 4-1**.

**Table 4-2. Data on fish species collected by electrofishing on Loxahatchee Slough Lake in May 2006[1]**

| Species[2] | Size Range Total Length (millimeter) | Total Number | Percent Composition | Number per Minute |
|---|---|---|---|---|
| Sport | | | | |
| Largemouth bass | 102–485 | 190 | 60 | 4.67 |
| Bluegill | 58–204 | 34 | 11 | 0.83 |
| Warmouth | 80–171 | 7 | 2 | 0.17 |
| Redear sunfish | 95–234 | 25 | 8 | 0.62 |
| Spotted sunfish | 80–166 | 15 | 5 | 0.37 |
| Other | | | | |
| Lake chubsucker | 250–250 | 1 | 0 | 0.03 |
| Spotted tilapia[3] | 167–200 | 2 | 1 | 0.05 |
| Bowfin | 44–632 | 19 | 6 | 0.47 |
| Florida gar | 238–465 | 21 | 7 | 0.53 |

[1]Additional species noted but not collected include eastern mosquitofish and oscar.
[2]Scientific names are provided in Appendix 4-1.
[3] Nonnative species.


**Figure 4-3. Exotic fish species[1] found in the Loxahatchee River in 2007**

[1]Scientific names are provided in **Appendix 4-1**.

Percent frequency of fish occurrence of the watershed survey is shown in **Figure 4-4**. The most widely distributed fishes were eastern mosquitofish (78.6%), bluegill (42.8%), spotted tilapia (26.7%), black acara (21.4%) and Mayan cichlid (21.4%). The most diverse site was Hobe Grove Ditch (water control structure) with 10 species collected. The fish were a combination of freshwater, estuarine and exotic species at this tidally inundated site. With regards to observed habitat differences, Everglades pygmy sunfish and walking catfish were often associated with isolated wetlands and sloughs rather than channelized areas. Video observations at both Lainhart and Masten Dams indicated the most frequent visitors to these structures were spotted tilapia.

The frequency and abundance of the top three exotic species are troublesome. Both spotted tilapia and Mayan cichlids are popular food fish with local sports fishermen. Of the six species, perhaps the major species of concern, but still in relatively low numbers during this survey, is the armored or sailfin catfish. Because of its thick armored skin, they are not popular to catch as a food fish, although otters at the Busch Wildlife Sanctuary devoured them. They are of concern in Lake Okeechobee, where they are abundant in some areas, because males burrow into the levee to create their nest and present an erosion threat. In addition, females can lay up to 2,000 eggs in a nest at one time. In addition, another species from the same genus, the vermiculated sailfin catfish (*Pterygoplichthys disjunctivus*), has also been reported in the Loxahatchee River. Fishermen are not encouraged to return exotic fish to our local water bodies (i.e., Florida's Sport Fishing Regulations). Aquarium releases are another issue that needs to be addressed at the state and federal regulatory level. These exotic fish species compete for local resources with our native fish species at all trophic levels.

During the winter cold waves of 2010–11, several exotic fish kills were noted throughout south Florida water bodies including the Loxahatchee River and Lake Okeechobee. The main species observed were Mayan cichlid and the armored catfish. Air temperatures reached down into the 30 degrees Fahrenheit range. Thus, cold waves may serve as nature's way of controlling exotic fishes on the Florida peninsular.

Recreational species such as snook and largemouth bass (*Micropterus salmoides*) were small in number and size during the survey; however, they were present in larger sizes in the channels and deeper pools examined in other studies. While electroshocking in 2006 in the Loxahatchee Slough, FWC observed nine species of fish including largemouth bass (**Table 4-2**). Sixty percent of their catch was largemouth bass. Length frequency of largemouth bass is shown in **Figure** 4-5. They ranged from 102 to 485 millimeters (mm) long. Approximately 40 percent of the bass were between 160 and 180 mm in length.

The composition of fish taken during the watershed survey indicated river channel, wet prairie, and tributary creeks supported common native freshwater species along with a few exotic species. With regards to size, the largest representatives of the fish community were snook and largemouth bass. Snook spawn downstream in the vicinity of Jupiter Inlet. Adult and juvenile snook both appear to be attracted to the additional freshwater habitat available in the upper Loxahatchee River and its tributaries. Inundation of the riverine floodplain allows snook and other marine species to travel around both Masten and Lainhart Dams. Largemouth bass generally reside and construct their nests in the deeper holes within the freshwater river system. Both snook and largemouth bass need adequate water levels to maintain fish passage within this river system.

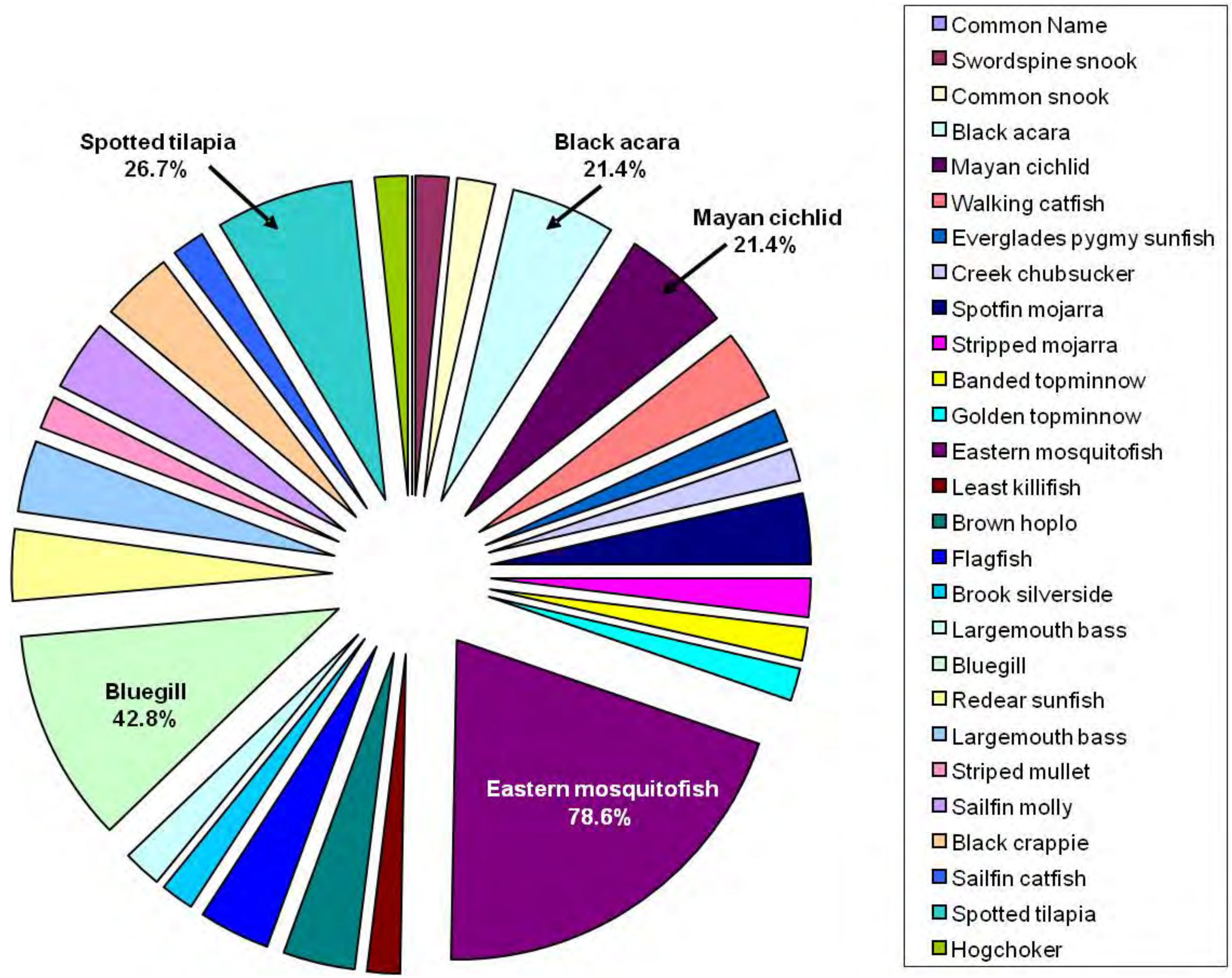


**Figure 4-4. Percent frequency of occurrence of fish species[1] in the upper Loxahatchee River watershed**

[1]Scientific names are provided in **Appendix 4-1.**

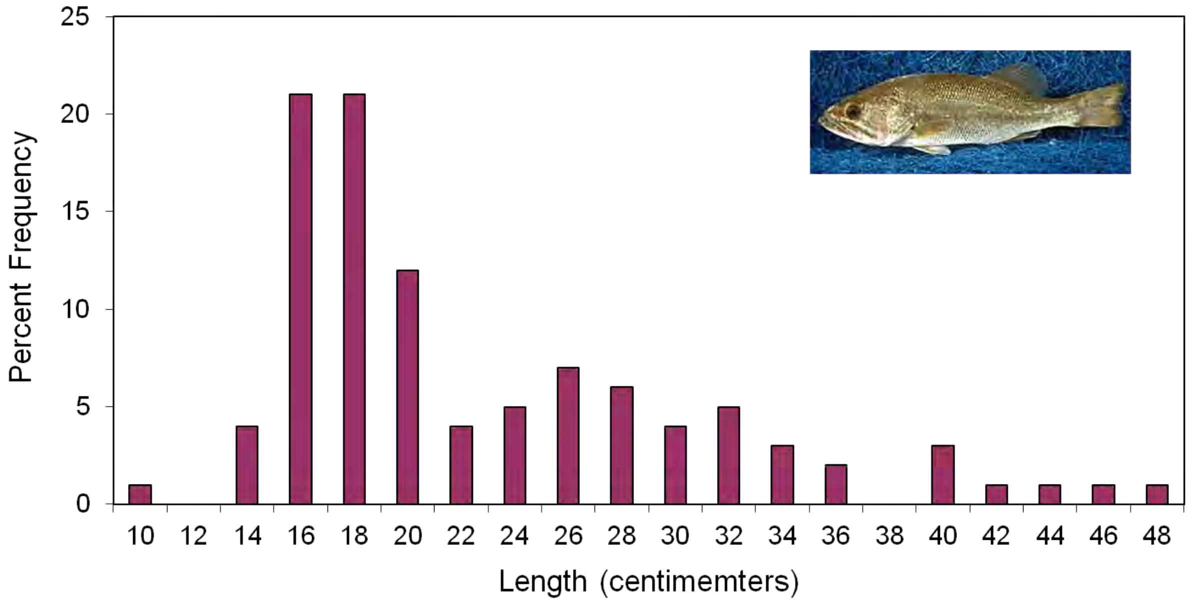


**Figure 4-5. Largemouth bass length frequencies from the 2006 sampling period**

The current minimum flow and level (MFL) criterion of 35 cubic feet per second (cfs) over Lainhart Dam reduces aquatic habitat to the bare minimum in the channel and some back creek areas, and provides no inundation of floodplain areas in the riverine reach upstream of Masten Dam. In fact, with regards to fish passage, larger fishes generally tend to congregate during periods of low water levels at bends in the river where deeper holes have formed from erosion. Dutterer and Allen's model simulation (2008) indicated that on three southwest Florida rivers, 0.3 meter reductions in average daily river stage could reduce habitat availability for spotted sunfish (*Lepomis punctatus*) by 20 to 70 percent across systems. In 2006 and 2007, Burgess (2008) looked at the connectivity between fish populations, floodplains and their connecting slough systems on freshwater segments of the Apalachicola River in northern Florida. Adult fishes including largemouth bass, spotted bass (*Micropterus punctulatus*), redear sunfish (*Lepomis microlophus*) and spotted suckers (*Minytrema melanops*) used both floodplain and main stem habitats during a given year. Strong evidence indicates these species use the floodplain as spawning grounds while juveniles use it as rearing grounds. Proposed restorative flows for the Northwest Fork of the Loxahatchee River would increase current dry season stage levels, which would be beneficial for both adult and juvenile fish and other aquatic communities.

### 4.1.2 Fish Assemblages and Dry Season Flow and Stage Levels

In 2008, a freshwater fish study was conducted by the SFWMD and Continental Shelf Associates International, Inc. to examine the relationships between fish assemblages and dry season flow and stage levels on the riverine reach of the Northwest Fork of the Loxahatchee River (CSA International Inc. 2009). The specific objectives of this study were to obtain data on fish abundance, biomass, size, body depth and species composition in response to flow and stage changes in the river channel during the dry season; examine habitat characteristics and environmental factors (e.g., temperature, conductivity, dissolved oxygen [DO]) associated with flow variation that may influence fish distribution in the river channel; and summarize the current status of endangered, threatened, special concern and exotic fish species. This was the first systematic fish sampling program undertaken in the upper Northwest Fork.

Sampling began in March 2008; however, persistent coastal rainfall resulted in above normal flows for much of the dry season (**Figure 4-6**). Sampling finally resumed in mid-April when rainfall subsided and flows dropped within target levels. Fish were sampled within four established reaches between river mile (RM) 12 and RM 15 (**Figure 4-7**; see **Figure 1-1** in **Section 1.0** for river mile locations). Three target flow ranges were sampled: (1) low - less than 35 cfs (< 1.0 cubic meters per second [$m^3$/sec]); (2) medium - 36 to 65 cfs (1.0 to 1.8 $m^3$/sec); and (3) 66 to 90 cfs (1.8 to 2.5 $m^3$/sec). A canoe-mounted electroshocker was used to sample fishes (**Figure 4-8**). Fish were identified, measured and weighed. For large adult individuals of largemouth bass, snook, tarpon and sunfishes (*Lepomis* spp.), body depth was measured to get an estimate of the minimum stage levels needed for movement in the channel. With the exception of exotics, all fish were released back into the channel. Habitat characteristics of the sampling reaches were assessed using the Qualitative Habitat Evaluation Index, which incorporates substrate, instream cover, channel morphology, riparian zone, pool/glide quality, and riffle/run quality variables. Water quality profiles included conductivity, temperature, DO and pH, which were recorded by the LRD.

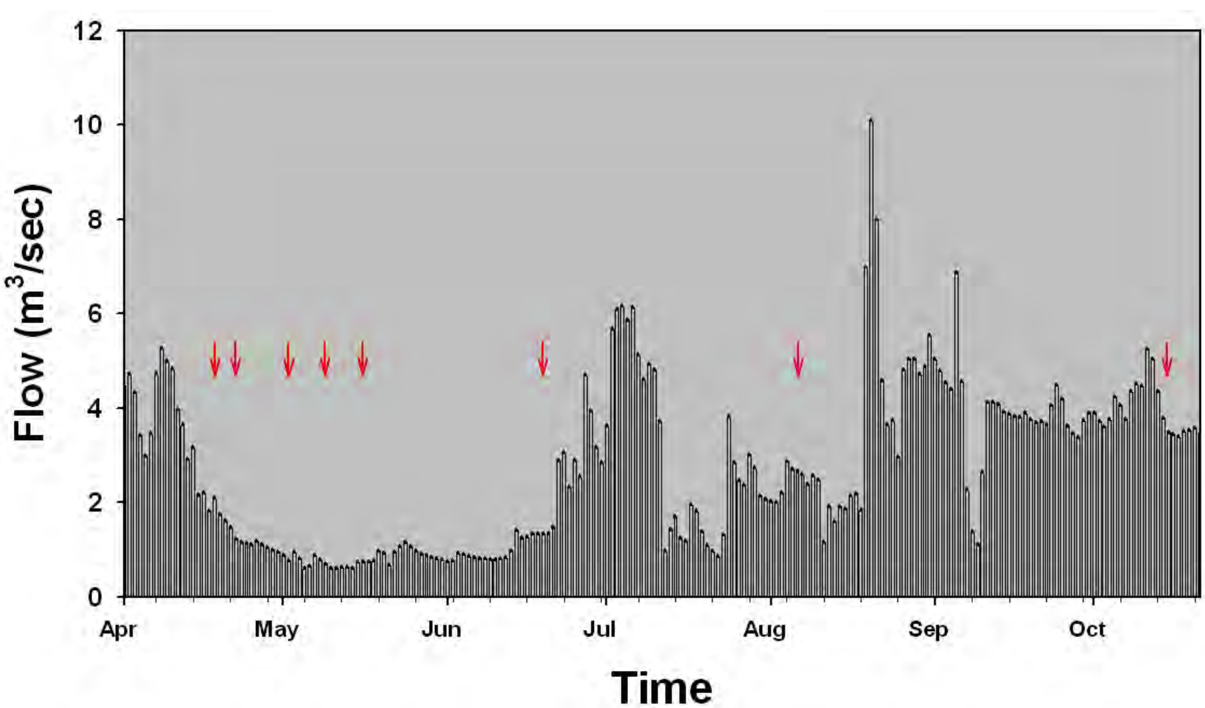


**Figure 4-6. Estimated daily flows over Lainhart Dam for the April – October 2008 study period with red arrows representing fish sampling days**

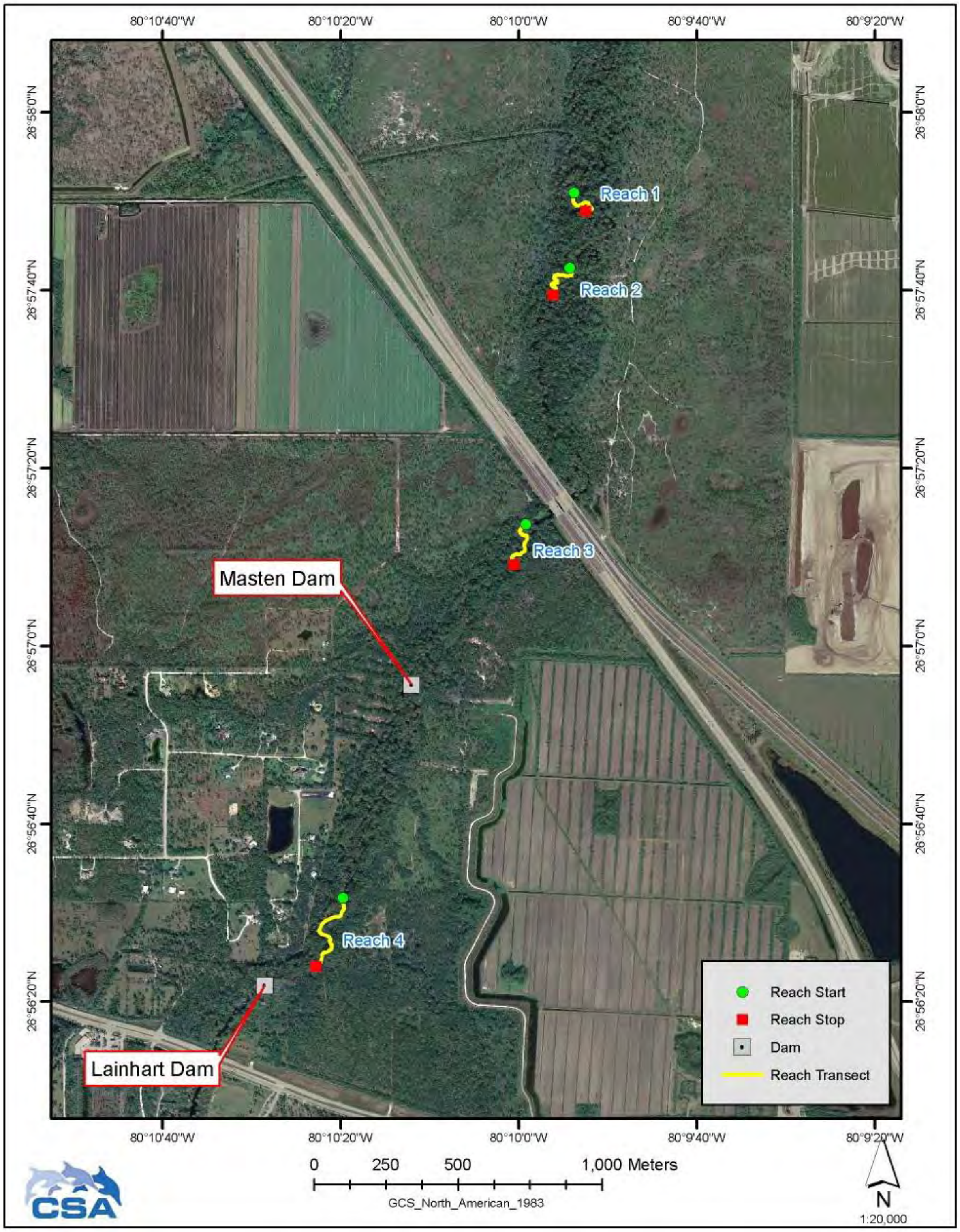


**Figure 4-7. Sampling reaches in the upper Northwest Fork of the Loxahatchee River**

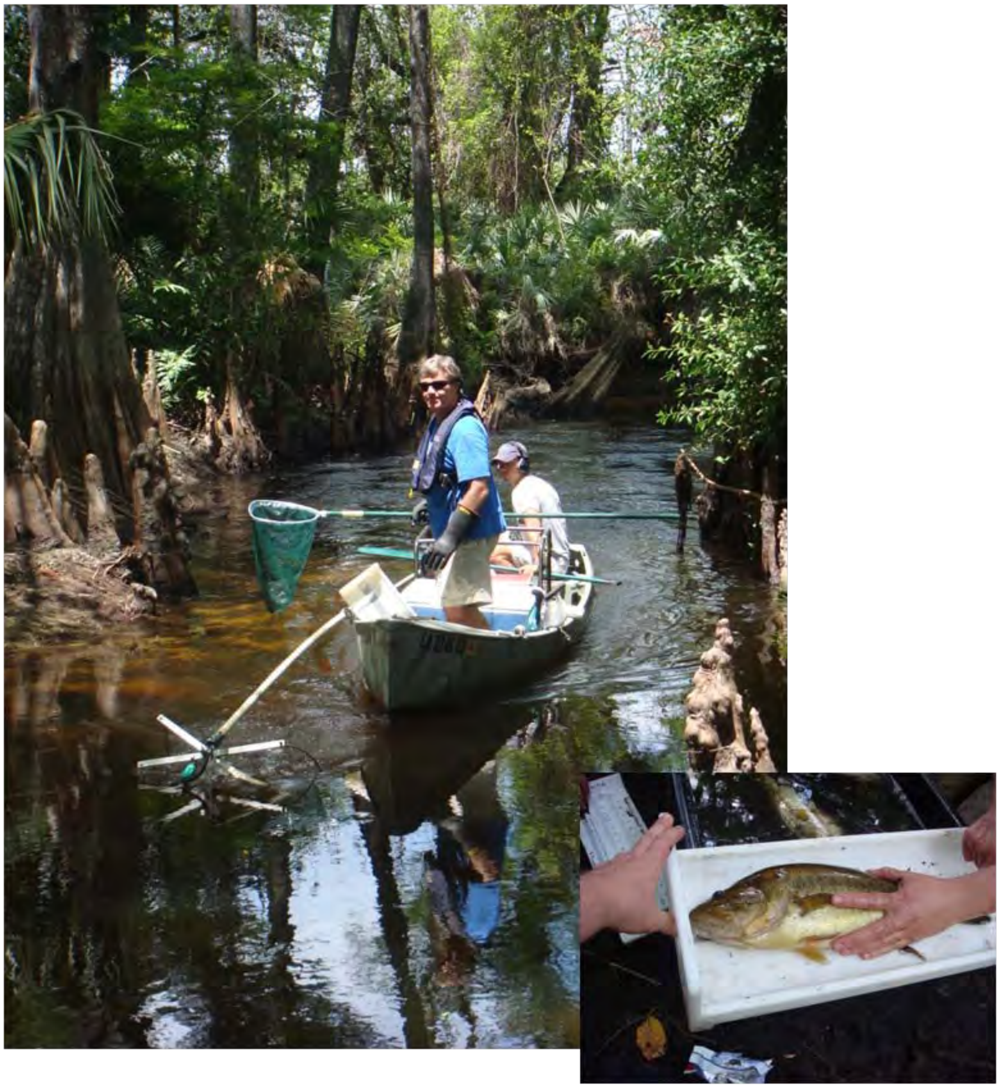

**Figure 4-8. Motorized canoe equipped with generator and single anode for electroshocking in the Northwest Fork**

A total of 32 fish species were collected during the study period (**Table 4-3**). The ichthyofauna of the upper Northwest Fork consisted of freshwater, marine, catadromous (living in fresh water and going to the sea to spawn), and exotic species. Notably, marine fishes included several tropical peripheral species with Caribbean origins. Species from this group included smallscale fat snook (*Centropomus parallelus*), burro grunt (*Pomadasys crocro*), river goby (*Awaous banana*), bigmouth sleeper (*Giobiomorus dormitor*) and mountain mullet (*Agonostomus monticola*). The most frequently occurring species overall were bigmouth sleeper (91.0%), spotted tilapia (82.6 %), Florida gar (*Lepisosteus platyrhincus*; 73.9%), vermiculated sailfin catfish (73.9%), striped mullet (*Mugil cephalus*; 70%), spotted sunfish (65.2%), bluegill (65.2%), and largemouth bass (65.2%). The most abundant species was the exotic spotted tilapia, which accounted for 16 percent of the 1,080 fishes collected during the survey. No individual of any species had a body length exceeding 200 mm.

**Table 4-3. Total numbers of fishes collected by electrofishing in the Northwest Fork in 2008**

| Type | Common Name[1] | Low Flow Reach | | | | Medium Flow Reach | | | | High Flow Reach | | | | Total | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | | |
| Freshwater | Spotted sunfish | 1 | 5 | 4 | 33 | | | 8 | 20 | 2 | 3 | 2 | 5 | 83 | 7.2 |
| | Bluegill | 2 | | | 24 | 1 | | 4 | 24 | 2 | 4 | | 12 | 73 | 6.3 |
| | Largemouth bass | 2 | 7 | 5 | 12 | 1 | | 15 | 9 | 5 | 1 | 1 | 6 | 64 | 5.6 |
| | Florida gar | 3 | 2 | 5 | 10 | 1 | | 3 | 7 | 7 | 3 | 3 | 4 | 48 | 4.2 |
| | Redear sunfish | 1 | 1 | | 19 | 3 | | | 11 | | 1 | | 1 | 37 | 3.2 |
| | Eastern mosquitofish | | | 19 | | | | 6 | 2 | | | | | 27 | 2.3 |
| | Bowfin | | | | 3 | | | | 2 | | | 2 | | 7 | 0.6 |
| | Warmouth | | | 2 | | | | 1 | | | | | | 3 | 0.3 |
| | Brown bullhead | | | | | | | | 1 | | | | | 1 | 0.1 |
| | Sailfin molly | | | | | | | 1 | | | | | | 1 | 0.1 |
| | Dollar sunfish | | | 1 | | | | | | | | | | 1 | 0.1 |
| Freshwater Total | | 9 | 15 | 36 | 101 | 6 | | 38 | 76 | 16 | 12 | 8 | 28 | 345 | 30.0 |
| Marine | Bigmouth sleeper | 13 | 30 | 15 | 47 | | | 26 | 20 | 9 | 12 | 9 | 5 | 186 | 16.2 |
| | Striped mullet | 14 | 10 | 5 | 4 | 6 | | 17 | 5 | 9 | 2 | 3 | 1 | 76 | 6.6 |
| | Smallscale fat snook | 4 | 1 | | 9 | | | | 15 | 3 | 2 | | 1 | 35 | 3.0 |
| | Mountain mullet | 1 | 3 | 5 | 6 | | | 4 | 7 | 2 | | 3 | 4 | 35 | 3.0 |
| | Striped mojarra | 2 | 4 | 2 | 2 | 5 | | 3 | 2 | 2 | 6 | 1 | | 29 | 2.5 |
| | Gray snapper | | 5 | 1 | 6 | 2 | | 5 | | | 3 | 2 | 1 | 25 | 2.2 |
| | Hogchoker | 2 | 4 | 1 | 8 | | | 3 | 5 | | | 1 | 1 | 25 | 2.2 |
| | Tidewater mojarra | | 2 | 3 | 2 | 3 | | 2 | | 8 | 1 | 2 | 2 | 25 | 2.3 |
| | Snapper | | 5 | 1 | 6 | 2 | | 5 | | 3 | 2 | 1 | | 25 | 2.2 |
| | Common snook | 5 | 1 | | 2 | 1 | | 6 | | 3 | 1 | 2 | 2 | 23 | 2.0 |
| | Fat sleeper | 2 | 3 | 9 | | | | 3 | | | 4 | | | 21 | 1.8 |
| | Largescale spinycheek sleeper | | 1 | 12 | | | | 3 | | 2 | 2 | | | 20 | 1.7 |
| | Burro grunt | 1 | 3 | 2 | | | | 1 | 1 | | 1 | | | 9 | 0.8 |
| | River goby | | | 1 | 1 | | | 4 | | | | | | 6 | 0.5 |
| | Sheepshead | 1 | | | | | | 1 | | | | 1 | | 3 | 0.3 |
| | Tarpon snook | | | | | | | | 1 | 1 | | | | 2 | 0.2 |
| | Tarpon | | | | | | | | | | 2 | | | 2 | 0.2 |
| Marine Total | | 45 | 67 | 56 | 87 | 17 | | 78 | 56 | 42 | 35 | 23 | 16 | 522 | 45.4 |
| Exotic | Spotted tilapia | 7 | 11 | 73 | 18 | | | 35 | 6 | 11 | 7 | 1 | 4 | 173 | 15.0 |
| | Vermiculated sailfin catfish | 2 | 5 | 2 | 7 | 3 | | 15 | 5 | 4 | 5 | 14 | 6 | 68 | 5.9 |
| | Walking catfish | | | 2 | | 1 | | 1 | | | | 2 | | 6 | 0.5 |
| | Mayan cichlid | | | 1 | 3 | | | | 1 | | | 1 | | 6 | 0.5 |
| Exotic Total | | 9 | 16 | 78 | 28 | 4 | | 51 | 12 | 15 | 12 | 18 | 10 | 253 | 22.0 |
| Catadromous | American eel | | 1 | 4 | 7 | | | 3 | 5 | 3 | 1 | 2 | 4 | 30 | 2.6 |
| Grand Total | | 63 | 99 | 174 | 223 | 27 | | 170 | 149 | 76 | 60 | 51 | 58 | 1,150 | |

[1]Scientific names are provided in **Appendix 4-1**.

In a one-way analysis of variance analysis (ANOVA), the highest catch rates in numbers per minute occurred during low flow sampling dates while the lowest catch rates occurred during high flow sampling dates (**Table 4-4**). Total number of species collected did differ significantly (ANOVA, F=5.66, p=0.011). Results presented in this report suggest fish assemblage response (both aggregate and compositional variables) to categorical flows in the upper Northwest during the dry season was subtle. Only the aggregate variables of total species and numbers per minute exhibited any statistically significant change in association with categorical flows. These data indicated that during low and medium flow sampling, more fishes were collected, which included a greater portion of smaller individuals. During high flows, fewer numbers of fishes were taken but larger (heavier) individuals continued to be collected. Fishes are obviously more concentrated and therefore more susceptible to capture during low flow conditions. Alternatively, during high flow conditions, fishes tend to be more widely dispersed and less vulnerable to capture. From a multivariate perspective, a principal coordinate analysis (PCA) did not reveal complete separation of samples from different flow categories or reaches, which would indicate appreciable compositional differences. However, canonical analysis of principal coordinates (CAP) confirmed very little difference occurred among numbers collected during medium and low flow samples. Overall sample sizes were small so additional monitoring is warranted.

Four exotic species were collected during the survey: walking catfish, vermiculated sailfin catfish, spotted tilapia and Mayan cichlid. Vermiculated sailfin catfish and spotted tilapia were among the highest contributors to total numbers (73.9 and 82.6%, respectively). Vermiculated sailfin catfish were commonly seen and collected around downed trees and in undercut portions of the bank. Although this species accounted for seven percent of the numbers of fishes caught, it appeared to be generally resistant to electroshocking. Thus, its relative abundance is likely to be accurate, but this method may have greatly underestimated its absolute abundance. Catfishes, in general, are less susceptible to electrical currents used in standard electroshocking. Spotted tilapia also appeared to be more resistant to the electrical current than the native marine or freshwater species. Consequently, these two exotic species were captured in proportion to their abundances relative to other species, but absolute abundances are likely much higher. The size range of fishes captured reflected what was observed in the river. Spotted tilapia adults were usually captured in groups around downed trees in pools whereas small juveniles were common in the grassy area west of the Florida Turnpike crossing (Reach 3). No species listed by the USFWS or the State of Florida as endangered, threatened, or of special concern was collected during the survey. However, smallscale fat snook, bigmouth sleeper and river goby are listed by the American Fisheries Society as species at risk for extinction (Musick et al. 2000).

From the multivariate perspective, PCA ordination did not reveal complete separation of samples from different flow categories (or reaches) that would indicate appreciable compositional differences. However, CAP plots did show some differences between groups of low and medium flow samples, which clustered together, and high flow samples that were separate, but highly variable, in ordination space. In this study, CAP confirmed species composition of fish collected during medium and low flow samples did not differ much. In addition, analysis of similarities (ANOSIM) tests failed to reject the null hypothesis of no difference in species composition based on numbers or biomass among flow categories or sampling reach. Species composition showed few differences among flow categories likely because most of the collected species are structure-associated and maintain their station around fallen trees and other three-dimensional features that

**Table 4-4. Phylogenetic listing of fishes collected by electrofishing in the Northwest Fork**

| Family | Common Name[1] | Freshwater | Marine | Exotic | Catadromous | Standard Length (mm) | Occurrence | Percent |
|---|---|---|---|---|---|---|---|---|
| Lepisosteidae | Florida gar | • | | | | 140–550 | 17 | 73.9 |
| Amiidae | Bowfin | • | | | | 450–680 | 4 | 17.4 |
| Megalopidae | Tarpon | | • | | | 470–520 | 1 | 4.3 |
| Anguillidae | American eel | | | | • | 130–560 | 12 | 52.2 |
| Ictaluridae | Brown bullhead | • | | | | 280–280 | 1 | 4.3 |
| Clariidae | Walking catfish | | | • | | 105–360 | 6 | 26.1 |
| Loricariidae | Vermiculated sailfin catfish[2] | | | • | | 93–354 | 17 | 73.9 |
| Poeciliidae | Eastern mosquitofish | • | | | | 20–36 | 4 | 17.4 |
| | Sailfin molly | • | | | | 40–40 | 1 | 4.3 |
| Centropomidae | Smallscale fat snook | | • | | | 40–480 | 8 | 34.8 |
| | Tarpon snook | | • | | | 415–465 | 1 | 4.3 |
| | Common snook | | • | | | 40–780 | 12 | 52.2 |
| Centrarchidae | Warmouth | • | | | | 95–130 | 3 | 13.0 |
| | Bluegill | • | | | | 52–190 | 15 | 65.2 |
| | Dollar sunfish | • | | | | 50–50 | 1 | 4.3 |
| | Redear sunfish | • | | | | 75–202 | 8 | 34.8 |
| | Spotted sunfish | • | | | | 45–168 | 15 | 65.2 |
| | Largemouth bass | • | | | | 160–581 | 15 | 65.2 |
| Lutjanidae | Snapper | | • | | | 135–230 | 12 | 52.2 |
| Gerreidae | Tidewater mojarra | | • | | | 45–103 | 13 | 56.5 |
| | Striped mojarra | | • | | | 92–280 | 12 | 52.2 |
| Haemulidae | Burro grunt | | • | | | 60–390 | 7 | 30.4 |
| Sparidae | Sheepshead | | • | | | 280–290 | 3 | 13.0 |
| Cichlidae | Mayan cichlid[2] | | | • | | 80–176 | 4 | 17.4 |
| | Spotted tilapia[2] | | | • | | 25–192 | 19 | 82.6 |
| Mugilidae | Mountain mullet | | • | | | 55–142 | 13 | 56.5 |
| | Striped mullet | | • | | | 180–440 | 16 | 69.6 |
| Electridae | Fat sleeper | | • | | | 25–78 | 8 | 34.8 |
| | Largescale spinycheek sleeper | | • | | | 54–111 | 7 | 30.4 |
| | Bigmouth sleeper | | • | | | 95–350 | 20 | 87.0 |
| Gobiidae | River goby | | • | | | 75–110 | 4 | 17.4 |
| Achiridae | Hogchoker | | • | | | 28–94 | 12 | 52.2 |
| **Total** | **32** | **11** | **16** | **4** | **1** | | | |

[1]Scientific names are provided in **Appendix 4-2**.
[2] Nonnative species.

provide a break from the flow. Future sampling should continue to increase overall sample size and, therefore, the power of univariate and multivariate statistical tests to confirm that the finding of no effect is real and not a consequence of sample size. Incorporating discrete habitat (micro or meso habitat) measurements into the sampling program would increase the resolution of this aspect of study.

### 4.1.3 Snook Behavior in Relation to Freshwater Inflows

Florida International University conducted a study in association with the SFWMD, LRD and FWC to determine if snook exhibit predictable movement patterns with respect to freshwater inflow (Layman 2009). As part of a 2008 pilot study, 16 common snook (*Centropomus undecimalis*) were acoustically tagged and tracked in the Loxahatchee River (**Figure 4-9**). Based on preliminary data obtained during the pilot study, upstream movements in common snook may be related to increases in freshwater discharge. Snook tagged in the lower section of the estuary frequently made forays into the upper reaches of all three river forks. It was not uncommon for snook to make roundtrip movements on the order of several miles in a single day. Brief migrations to upstream sections of the river were often observed in conjunction with periods of increased freshwater inflow.

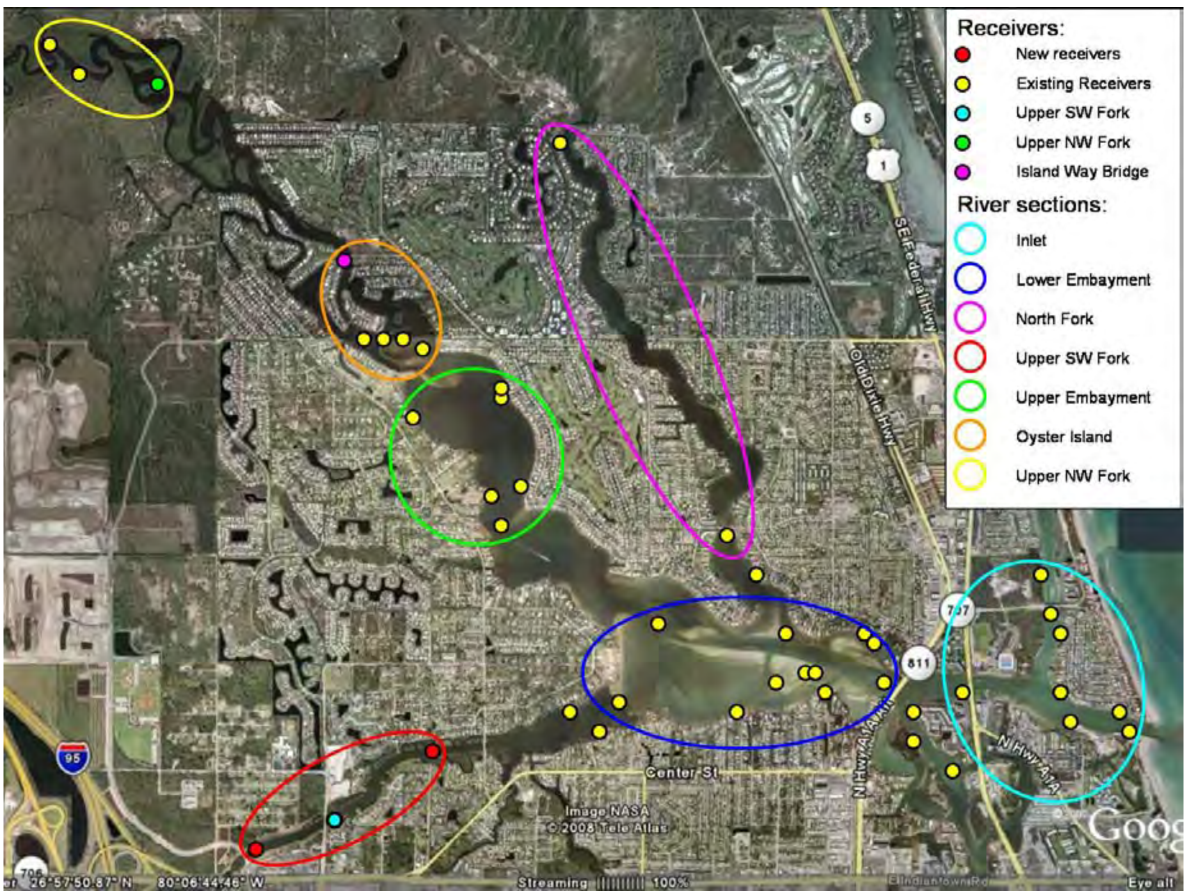


**Figure 4-9. Map of the Loxahatchee River Estuary showing the current location of all acoustic receivers used to examine snook movement patterns with respect to freshwater inflow**

To follow up on the preliminary findings, an additional ten common snook were acoustically tagged in late June and early July 2009. All of these fish were tagged in the upriver section of the Southwest Fork, immediately downstream of the S-46 structure. The number of individual snook present in the upper Southwest Fork during five-day time intervals was plotted against mean daily freshwater inflow through the S-46 structure from February 19 through August 3, 2004 (**Figure 4-10**). During the dry season, very few snook entered the Southwest Fork. Snook numbers began to increase following the first freshwater inflow event in early June. The greatest snook abundance in the upper Southwest Fork was observed in conjunction with the planned freshwater release event that occurred from July 6 through 8, 2009. Many of the snook that entered the Southwest Fork during the release event left shortly after freshwater inflow was cut off. In the Northwest Fork, changes to inflow level tend to occur more gradually and remain elevated during most of the wet season. The number of individual snook present during five-day time blocks in the lower Northwest Fork, near Island Way Bridge, was plotted against mean daily freshwater flow over Lainhart Dam from February 19 through July 30, 2009 (**Figure 4-11**). During the dry season, very few snook were present in either section of the Northwest Fork. As flow increased at the onset of the wet season, snook abundance in the Northwest Fork increased. This pattern was most apparent in the lower Northwest Fork; however, snook do appear to move further into the fork during periods of increased freshwater inflow. It is important to note that the maximum flow over Lainhart Dam during this study period was less than 180 cfs. Much greater flow levels can occur during storm events. The response of snook to unusually high flows has yet to be determined. Acoustic telemetry data suggest that common snook may respond to each increase in freshwater discharge, moving upriver during or shortly after periods of higher inflow.

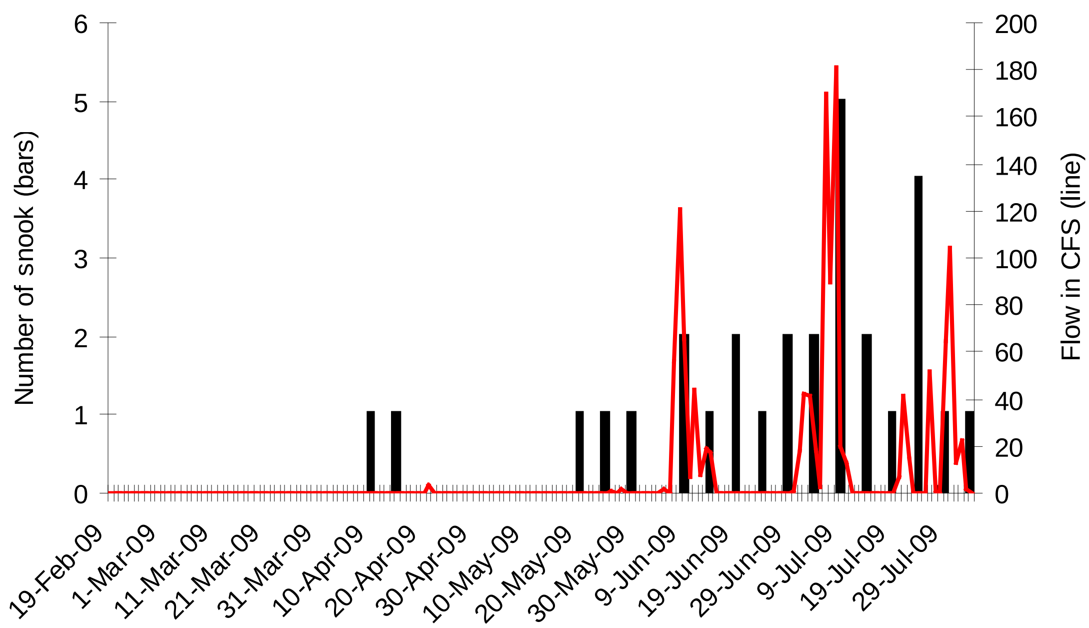


**Figure 4-10. Number (abundance) of acoustically-tagged snook[1] present in the upper reaches of the Southwest Fork of the Loxahatchee River plotted against mean daily freshwater inflow through the S-46 structure February 19 – August 3, 2009**

[1]Each vertical bar represents the total number of unique snook detected in the area over the previous five days.

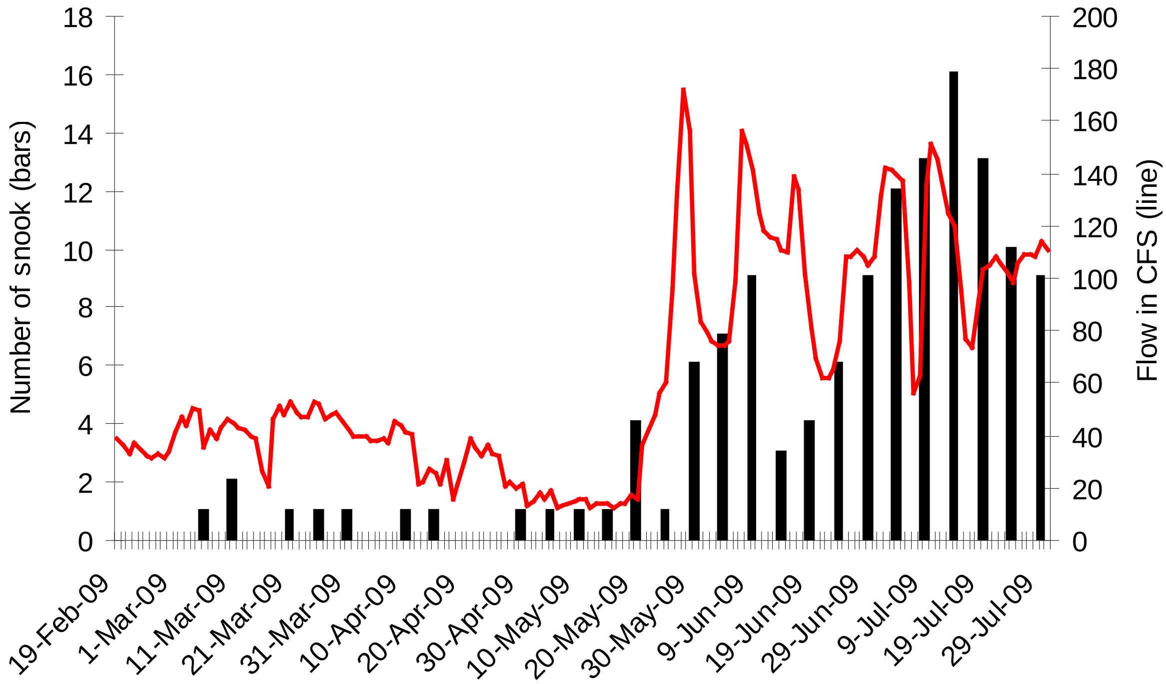


**Figure 4-11. Number (abundance) of acoustically-tagged snook[1] present in the lower Northwest Fork of the Loxahatchee River near Island Way Bridge plotted against mean daily freshwater flow over Lainhart Dam February 19 – July 30, 2009[1]**

[1]Each vertical bar represents the total number of unique snook detected in the area over the previous five days.

Additionally, fish were collected in the upper Southwest Fork with a 350 foot seine and examined for species composition, acoustic tagging and dietary analysis. Fish community structure was observed to change over time (**Figure 4-12**). In samples collected on June 30, 2009 (before any major freshwater inflow) and July 3, 2009 (during an initial period of low freshwater inflow), fish diversity and richness were high. A number of marine associated species were identified on these dates. During periods of high freshwater inflow (July 7 and July 9, 2009), most of the marine associated species were absent from the upper reaches of the Southwest Fork. It appears the initial pulse of fresh water through the system at the start of the wet season greatly affects fish community structure. Many of the species present prior to the reduction in salinity caused by freshwater inflow did not return to the upper Southwest Fork even after discharge had ceased on August 4. Richness and diversity were much lower following periods of freshwater inflow. Preliminary analysis has revealed snook diets were dominated by anchovies (*Anchoa* spp.), small herrings (Clupeidae) and Penaeid shrimp (Penaeidae). The largest snook examined frequently had empty stomachs. Large mullet were the most abundant prey item consumed by snook that were greater than 700 mm in length.

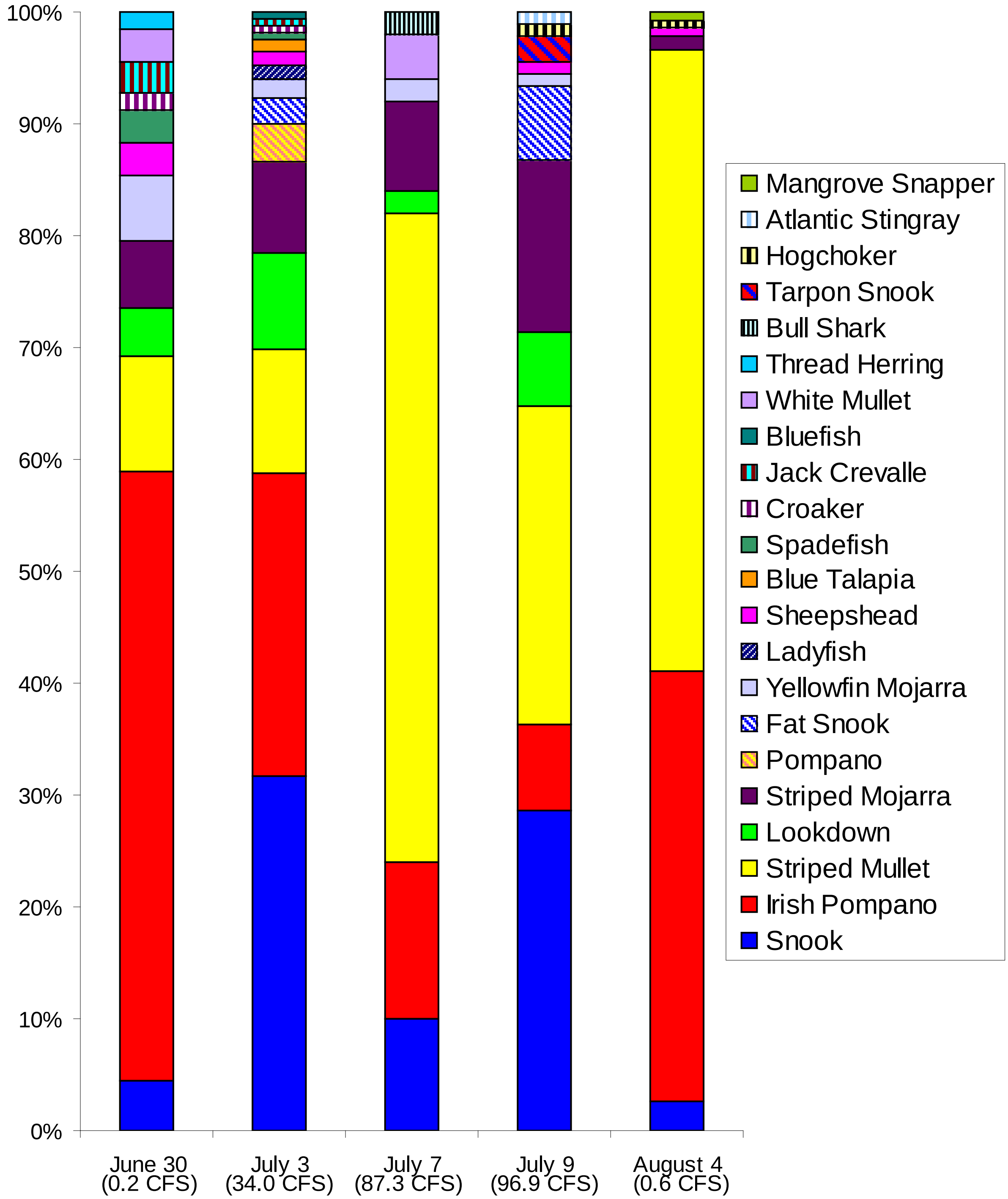


**Figure 4-12. Fish species[1] composition[2] in the upper Southwest Fork at varying levels of freshwater inflow[3]**

[1]Scientific names are provided in **Appendix 4-1**.

[2]Vertical bars represent the proportional contribution of each species to the total catch.

[3]Flow values refer to mean daily discharge over the previous 72 hours.

### 4.1.4 Snook and Largemouth Bass Habitat Utilization and Resource Partitioning

From May 2007 to March 2010, scientists from the FWC Fish and Wildlife Research Institute (FWRI) conducted bimonthly sampling in selected rivers of southeast Florida to collect ecological and biological information on largemouth bass and common snook (**Figure 4-13**). The objectives of this cooperative study were to determine how largemouth bass and common snook coexist and partition resources in three rivers (St. Lucie, Loxahatchee and Sebastian), and to describe habitat use, trophic dynamics and ecological interactions between these species. The findings from the current project, combined with findings from previous investigations, will expand the knowledge base necessary for sustainable management of these popular sport fishes.

**Figure 4-13. FWC electroshocking on the tidal portion of the river**

Observations were made and biological samples were collected using nonlethal electrofishing sampling techniques at randomly selected sites in the three rivers. In the Loxahatchee River, for the three years combined, a total of 58 largemouth bass (size range 63–532 mm total length [TL]) and 450 common snook (size range 38–1,070 mm TL) were sampled during the electrofishing surveys. Movements patterns and habitat utilization patterns will be described using recaptures of fish tagged with conventional external dart tags (sample size was 66 common snook and 34 largemouth bass) in the upstream habitats of the Loxahatchee River, in conjunction with data collected from common snook tagged with surgically implanted acoustic transmitters (sample size was 24, size range 808–1,052 mm TL) in Jupiter Inlet and the adjacent area. This ongoing tagging study is part of a FWRI comprehensive acoustic telemetry study to investigate common snook population dynamics along the southeast coast of Florida and determine the rates of exchange between the freshwater rivers and the higher salinity portions of estuaries and adjacent coastal areas. Data are being analyzed and results will be available shortly.

#### 4.1.5 Future Fish Monitoring

In the *Loxahatchee River Science Plan* (SFWMD et al. 2010), recommendations for monitoring of fishes as a bio-indicator group included the continuation of both riverine reach and low salinity zone studies to establish flow and salinity performance measures relating abundance and diversity of fishes in the river. The fish projects summarized in this chapter illustrate how channel and floodplain habitats support a variety of fish and wildlife on the Loxahatchee River and its watershed. The presence of major freshwater, marine and exotic species were documented; however, due to unusually wet conditions during that dry season, it was difficult to assess fish distribution and movement with regards to the effect of persistent low flows and low stage levels. By reexamining segments of the channel between Lainhart Dam (RM 14.7) and Hobe Grove Ditch (RM 9.1), fish utilization can be observed with regard to water level and fish passage in the channel, back creek and tidal floodplain areas in an attempt to answer questions regarding how flows and water levels affect the reproductive behavior of the fish community. Breeding seasons tend to be geared towards spring and summer months. Stage levels are affected not only by man-made manipulation of a water control structure, but also by direct storm water runoff, which can temporarily inundate the floodplain for short periods of time and then fall back into the channel. This scenario happens on the freshwater sections of the Loxahatchee River periodically during dry and wet seasons because adequate freshwater flow is not currently available to maintain seasonal stage levels. Rehage and Loftus (2008) found that in the southwestern Everglades, freshwater fishes would migrate from the freshwater habitat areas down into the mangrove creeks when stage levels were very low as a means of survival. With regards to low salinity zone studies, additional studies are needed to incorporate managed flows during the dry season to produce a productive low salinity zone in areas that will provide the best physical habitat for fish larvae and juveniles.

Additional fish studies are needed to compare with future species composition and abundances once additional water is received and hydroperiods are modified. These studies could also contribute to the state-wide survey of exotic and nuisance fish species that is conducted by the FWC. The results of this and future fish projects would be utilized by the Loxahatchee River Restoration Team and the Comprehensive Everglades Restoration Plan (CERP) Restoration Coordination and Verification Team (RECOVER). Results can also be used by the SFWMD is the development of MFLs and water reservations.

### 4.2 Wildlife

In the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006), a variety of data on terrestrial and aquatic vegetation, fish, oysters and water quality were presented as indicators of river health. A gap in knowledge identified in the plan was wildlife data. Of specific interest was wildlife use of the floodplain as a baseline to revisit in the future to determine success of restoration efforts. A second objective was to look at a variety of sites to determine current differences in distribution of vertebrates among the three reaches of the river defined as riverine, upper tidal and lower tidal. The third objective was to determine if any animals or groups of animals could serve as indicators for overall river health.

The examination of wildlife occurred in and around six of ten vegetation transects established along the Loxahatchee River (see **Figure 3-1** in **Section 3.0**) so vegetation, water quality and soil studies can be linked to the wildlife investigation. Transects T1, T2 and T3 are categorized as being within the riverine reach, which begins at RM 15.5 and ends at RM 9.5. Transects T6 and T7 are part of the upper tidal reach (RM 9.5 to 8.13) and transect T9 is an example of the lower tidal reach (RM 8.13 to 5.5).

A field trial began in 2006–07 to determine the feasibility of techniques and methodologies (Crossroads Environmental 2007, Cotleur and Hearing 2007). Following the field trial, from 2008 to 2010, birds, small mammals, frogs and alligators were monitored. Other groups of animals considered, but deemed to be impractical to work with included snakes, turtles, lizards and mid-size mammals.

Three specific recommendations regarding floodplain wildlife were made in the 2006 restoration plan (SFWMD 2006):

- Bird population monitoring is necessary to establish baseline studies and to evaluate the effects of restorative flows on habitat and associated wildlife.
- Small and mid-size mammals monitoring was recommended.
- Adult and metamorphic amphibian population monitoring was recommended.

These studies are discussed in the following sections. The data collected can be further scrutinized to determine seasonal occurrence and abundance. These data will also be presented in this document as a resource for future efforts.

### 4.2.1 Bird Monitoring

Birds are used as biological indicators for both upland and wetland ecosystems throughout the world (Gardali et al. 2006, Peak and Thompson 2006, Scholefield et al. 2011). The impact on bird communities of hydrological restoration in forested wetlands is potentially significant. Longer hydroperiods may increase chances of nesting success for some birds by preventing predator attacks and may increase food availability (Petranka et al. 2007, Hoover 2009). In some instances, changes in hydrology may also predict whether a particular species is present or absent (Desgranges et al. 2006). In addition to the direct impacts of hydroperiod on birds’ reproduction and foraging, it is very likely that, in the long-term, restoration would have indirect impacts on birds such as changes in vegetation type and structure, which would affect foraging and breeding sites. Examples of the influence of vegetation on bird assemblages occurring in the Loxahatchee River area are not something that was found in the literature specifically as it relates to the ecosystems found on the Loxahatchee River. However, the literature makes it clear that riparian vegetation structure has major impacts on bird assemblages (Stauffer and Best 1980, Desgranges et al. 2006, Peak and Thompson 2006), and that salinity is the driving factor that has altered the vegetation structure on the Loxahatchee River (Roberts et al. 2006).

In contrast to the vegetation surveys conducted starting in the 1960s and continuing to the present day (Roberts et al. 2008), little formal ornithological work has been done on the Loxahatchee River. The only exception is that osprey (*Pandion haliaetus*) surveys were conducted from 1988 to 2004 in the lower parts of the river (RM 10 to 6). These generally showed low productivity with a short-term trend for an increase in the number of nests towards the end of the 16 year study period (Roland 2004). In contrast to the osprey work, the monitoring effort described here was much more comprehensive in nature and is unlike anything previously done on the Loxahatchee River.

Bird monitoring was conducted using point count methodology, which involves using auditory and visual cues to identify birds (Buffington et al. 2000). Each transect had four equidistant points. Observations were made for 15 minute periods of birds no more than twenty meters from the observer's location. Surveys were repeated on each transect a minimum of three times per month starting at first light. If a bird could not be positively identified by the observer, it was not included in the data set. If a survey had to be abandoned for any reason, the survey for that morning was disregarded and repeated another morning.

Statistical analyses were calculated using the program JMP (2001) using repeated measures of analysis of variance. Transects T1, T2 and T3 were used as the control group and transects T6, T7 and T9 were used as the experimental group. A full factorial analysis was not possible because of the limited degrees of freedom associated with only three replicates per group. Treatment was considered the most important factor, followed by month, year and then the interaction of treatment and year. Analyses were done for species richness and total number of birds observed and by individual species abundance for those animals with enough observations. P-values of less than 0.05 were considered statistically significant.

A total of 98 of the 159 species known to be found in Jonathan Dickinson State Park were encountered along the river's floodplains during 6,273 total bird observations. The number of bird species and number of observations were higher in the upper parts of the river (p-value = 0.00026) versus the tidal portion (p-value < 0.0001) (**Table 4-5**).

**Table 4-4-6** breaks down commonly observed species by numbers of observations by river reach. Of the top 32 species observed, nine were more commonly found in the riverine reach and eight were more commonly found in the tidal river reach.

**Table 4-5. Number of bird species and number of observations in the riverine reach versus the tidal river reaches**

| | **Riverine** | **Tidal River** |
|---|---|---|
| Bird species | 8.45 ± 0.24 | 7.60 ± 0.18 |
| Bird observations | 12.98 ± 0.41 | 10.96 ± 0.30 |

**Table 4-4-6. The 32 most commonly observed bird species (>20 observations) in terms of numbers of observations ± standard error (SE) by river reach**

| Common Name | Scientific Name | Average Number of Observations ± SE | | P-value | Total Number of Observations |
|---|---|---|---|---|---|
| | | Riverine Reach | Tidal Reach | | |
| Northern cardinal | *Cardinalis cardinalis* | 8.70±0.59 | 7.57±0.45 | 0.11 | 1,318 |
| Pileated woodpecker | *Dryocopus pileatus* | 3.83±0.27 | 3.33±0.20 | 0.10 | 580 |
| Blue jay | *Cyanocitta cristata* | 2.85±0.42 | 2.99±0.28 | 0.73 | 473 |
| Blue-gray gnatcatcher | *Polioptila caerulea* | 3.94±0.34 | 1.54±0.18 | <0.0001 | 444 |
| Gray catbird | *Dumetella carolinensis* | 2.32±0.25 | 1.17±0.17 | <0.0001 | 283 |
| Common yellowthroat | *Geothlypis trichas* | 1.44±0.19 | 0.83±0.10 | 0.0029 | 184 |
| Yellow warbler | *Dendroica petechia* | 1.00±0.72 | 0.19±0.15 | 0.18 | 139 |
| Downy woodpecker | *Picoides pubescens* | 0.98±0.13 | 0.65±0.09 | 0.0291 | 132 |
| Osprey | *Pandion haliaetus* | 0.37±0.07 | 1.27±0.18 | <0.0001 | 131 |
| Mourning dove | *Zenaida macroura* | 0.37±0.08 | 1.21±0.16 | <0.0001 | 128 |
| Northern mockingbird | *Mimus polyglottos* | 0.64±0.11 | 0.44±0.09 | 0.14 | 88 |
| Black vulture | *Coragyps atratus* | 0.19±0.05 | 0.89±0.16 | <0.0001 | 87 |
| Barred owl | *Strix varia* | 0.59±0.12 | 0.47±0.08 | 0.39 | 86 |
| American crow | *Corvus brachyrhynchos* | 0.28±0.07 | 0.72±0.11 | 0.0007 | 82 |
| Limpkin | *Aramus guarauna* | 0.84±0.19 | 0.12±0.04 | 0.0002 | 78 |
| Palm warbler | *Dendroica palmarum* | 0.57±0.12 | 0.31±0.08 | 0.07 | 71 |
| Great blue heron | *Ardea herodias* | 0.22±0.06 | 0.60±0.11 | 0.0006 | 67 |
| Fish crow | *Corvus ossifragus* | 0.22±0.06 | 0.58±0.10 | 0.0017 | 65 |
| Common grackle | *Quiscalus quiscula* | 0.28±0.08 | 0.41±0.09 | 0.30 | 56 |
| Yellow-bellied sapsucker | *Sphyrapicus varius* | 0.37±0.09 | 0.28±0.06 | 0.43 | 53 |
| Red-shouldered hawk | *Buteo lineatus* | 0.49±0.11 | 0.15±0.05 | 0.0026 | 52 |
| Black-and-white warbler | *Mniotilta varia* | 0.43±0.13 | 0.17±0.06 | 0.0467 | 49 |
| White ibis | *Eudocimus albus* | 0.06±0.03 | 0.48±0.11 | 0.0002 | 44 |
| Northern parula | *Parula americana* | 0.32±0.08 | 0.21±0.05 | 0.25 | 43 |
| Great crested flycatcher | *Myiarchus crinitus* | 0.33±0.09 | 0.19±0.06 | 0.16 | 42 |
| White-eyed vireo | *Vireo griseus* | 0.34±0.07 | 0.16±0.05 | 0.0396 | 41 |
| Yellow-crowned night heron | *Nyctanassa violacea* | 0.05±0.02 | 0.41±0.08 | <0.0001 | 37 |
| Boat-tailed grackle | *Quiscalus major* | 0.27±0.08 | 0.15±0.04 | 0.16 | 34 |
| Red-bellied woodpecker | *Melanerpes carolinus* | 0.49±0.11 | 0.15±0.05 | 0.22 | 34 |
| Wood duck | *Aix sponsa* | 0.31±0.08 | 0.02±0.02 | 0.0003 | 27 |
| Pine warbler | *Dendroica pinus* | 0.12±0.04 | 0.20±0.06 | 0.33 | 26 |
| Belted kingfisher | *Megaceryle alcyon* | 0.19±0.05 | 0.11±0.04 | 0.26 | 24 |

In addition, total monthly observations of birds and bird species were found to be statistically significant (P-values of 0.0042 and 0.0028, respectively; F-ratio 2.66 and 2.78; sum squares 82.22 and 251.81). However, when individual months were compared to each other using Tukey's highly significant difference test, only the number of species found in September was found to be lower than March and April (**Figure 4-14**). No other differences were found. Data were furthered analyzed in terms of seasonal variation when looked at from a monthly perspective (**Table 4-7**).

**Table 4-7. Statistical results of the 32 most commonly observed bird species (>20 observations) in terms of monthly observations**

| Common Name | Scientific Name | P-value | Total Number of Observations |
|---|---|---|---|
| Northern cardinal | *Cardinalis cardinalis* | 0.0049 | 1,318 |
| Pileated woodpecker | *Dryocopus pileatus* | <0.0001 | 580 |
| Blue jay | *Cyanocitta cristata* | <0.0001 | 473 |
| Blue-gray gnatcatcher | *Polioptila caerulea* | 0.0004 | 444 |
| Gray catbird | *Dumetella carolinensis* | <0.0001 | 283 |
| Common yellowthroat | *Geothlypis trichas* | 0.0004 | 184 |
| Yellow warbler | *Dendroica petechia* | <0.0001 | 139 |
| Downy woodpecker | *Picoides pubescens* | <0.0001 | 132 |
| Osprey | *Pandion haliaetus* | 0.0201 | 131 |
| Mourning dove | *Zenaida macroura* | 0.0100 | 128 |
| Northern mockingbird | *Mimus polyglottos* | 0.07 | 88 |
| Black vulture | *Coragyps atratus* | 0.15 | 87 |
| Barred owl | *Strix varia* | 0.16 | 86 |
| American crow | *Corvus brachyrhynchos* | 0.52 | 82 |
| Limpkin | *Aramus guarauna* | 0.28 | 78 |
| Palm warbler | *Dendroica palmarum* | 0.09 | 71 |
| Great blue heron | *Ardea herodias* | <0.0001 | 67 |
| Fish crow | *Corvus ossifragus* | 0.44 | 65 |
| Common grackle | *Quiscalus quiscula* | 0.49 | 56 |
| Yellow-bellied sapsucker | *Sphyrapicus varius* | 0.28 | 53 |
| Red-shouldered hawk | *Buteo lineatus* | 0.0229 | 52 |
| Black-and-white warbler | *Mniotilta varia* | 0.0002 | 49 |
| White ibis | *Eudocimus albus* | 0.41 | 44 |
| Northern parula | *Parula americana* | 0.69 | 43 |
| Great crested flycatcher | *Myiarchus crinitus* | 0.0027 | 42 |
| White-eyed vireo | *Vireo griseus* | 0.54 | 41 |
| Yellow-crowned night heron | *Nyctanassa violacea* | 0.0192 | 37 |
| Boat-tailed grackle | *Quiscalus major* | 0.11 | 34 |
| Red-bellied woodpecker | *Melanerpes carolinus* | 0.20 | 34 |
| Wood duck | *Aix sponsa* | 0.0009 | 27 |
| Pine warbler | *Dendroica pinus* | 0.07 | 26 |
| Belted kingfisher | *Megaceryle alcyon* | 0.0071 | 24 |

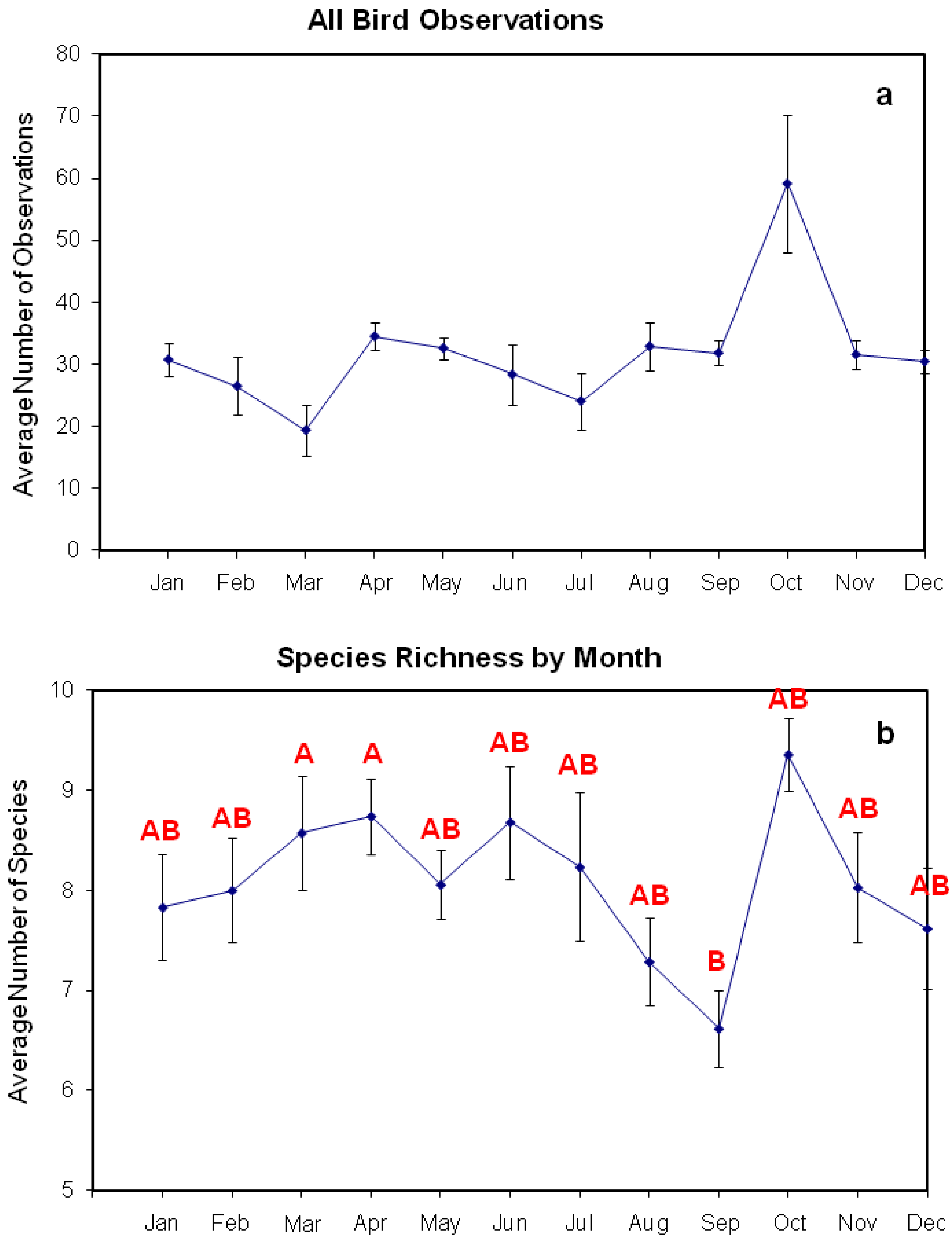


**Figure 4-14. Seasonal variation of (a) total number of bird observations and (b) species richness[1] (number of species) by month with standard error bars**

[1]Each month that is different from another does not share a common letter.

Overall, bird monitoring revealed higher numbers of birds and number of species of birds observed in riverine reaches versus the tidal reaches (**Table 4-5**). When looking at the more detailed species by species account, five of nine species that occur more commonly in the freshwater reaches of the river are passerines (**Table 4-4-6**). Three of the eight species more commonly found in the tidal reaches of the river are wading birds. However, limpkins (*Aramus guarauna*) were more commonly found in the riverine reach, which can be anecdotally attributed in large part to the abundance of salt intolerant, island apple snails (*Pomacea insularum*). In the recent past (2005, 2006), limpkins were not commonly observed along the riverine reaches of the river, but the appearance of the nonnative snails seems to coincide with the more common observations of limpkins. Ospreys only nest in areas where the channel of the river is not covered by canopy vegetation, which starts around RM 10.2 and explains why they were more commonly found in tidal reaches versus the riverine reach (Roland 2004). Black vultures (*Coragyps atratus*) are commonly seen roosting in flocks along the upper and lower tidal reaches of the river.

The differences in the avifauna, when looking at individual species, between the riverine and tidal reaches of the river indicate at least three patterns: different species use the tidal portion of the river because they require the more open river channel (i.e., osprey and wading birds; Poole 1989); some species may prefer the vegetation associated with the riverine or tidal reaches of the river (i.e., downy woodpecker [*Picoides pubescens*], and some species preferentially use parts of the river because of an abundance of food (i.e., limpkin). Explanations are not readily available for all the species found more commonly in one part of the river than the other such as the red-shouldered hawk (*Buteo lineatus*), downy woodpecker and wood duck (*Aix sponsa*), which were more commonly observed in the riverine reach or mourning doves (*Zenaida macroura*), fish crows (*Corvus ossifragus*) and American crows (*Corvus brachyrhynchos*), which were more commonly found in the tidal reaches of the river. However, overall abundance and species richness were higher in the riverine reach versus the tidal reach of the river, indicating that the two reaches of the river provide different and unequal types of habitat for birds.

In addition to abundances along the river by reach, many birds were found to be more abundant during different seasons. Winter residents were belted kingfisher (*Megaceryle alcyon*), black-and-white warbler (*Mniotilta varia*), gray catbird (*Dumetella carolinensis*) and blue-gray gnatcatcher (*Polioptila caerulea*). Great crested flycatchers (*Myiarchus crinitus*) are summer residents and yellow warblers (*Dendroica petechia*) migrate through in the fall and spring. Other birds are year-round residents but are seasonally much more common. These include the northern cardinal (*Cardinalis cardinalis*), pileated woodpecker (*Dryocopus pileatus*), blue jay (*Cyanocitta cristata*), common yellowthroat (*Geothlypis trichas*), downy woodpecker, osprey, mourning dove, great blue heron (*Ardea herodias*), red-shouldered hawk, yellow-crowned night heron (*Nyctanassa violacea*) and wood duck. Figures showing the average number of observations by month for many of these species can be found in **Appendix 4-3**.

Restorative flows are likely to lead to a variety of changes in habitat for the avifauna of the Northwest Fork and future updates of the science plan should provide follow-up data to this baseline work. Of particular interest would be the response of the birds that are now more commonly observed in the tidal portions of the river and the adaptation of the birds that currently reside in the riverine reaches of the river.

### 4.2.2 Small Mammal Monitoring

Small mammals are important links between primary production and predators such as snakes, birds of prey, and larger mammals in food webs (Wike et al. 2000). Studies of small mammal populations and their responses to flooding vary from positive to negative. In one study, a species in the genus *Antechinus* stayed in the floodplain by using unsubmerged, downed trees as refugia (Lada et al. 2008). In other places, small mammals are fully adapted to very wet marsh conditions (i.e., marsh rice rat, *Oryzomys palustris*; Whitsitt and Tappe 2009). In other studies small mammals are found to move in and out of the floodplain with rising waters (Shepe 1972, Andersen et al. 2000).

Some small mammals are herbivores or omnivores and have significant impacts on recruitment of plants in all types of ecosystems (Asquith et al. 1997, Manson et al. 2001, Gough et al. 2008, Gedan et al. 2009). In a case study in the western United States, a lack of floodplain inundation was shown to reduce recruitment of trees because of increased mortality caused by small mammal foraging (Andersen and Cooper 2000). It is possible these impacts are occurring in the Loxahatchee River floodplain on plant species of high interest.

Mammal surveys in the Northwest Fork of the Loxahatchee River targeted small mammals using Sherman traps. The pilot study showed that raccoon interference, cold weather and high water were obstacles to successful small mammal trapping (Crossroads Environmental 2007). To minimize raccoon interference, two techniques were used: (1) Sherman traps were encased in rectangular cages built of wood and chicken wire and secured to substrate above the high tide mark and (2) three larger traps were set alongside the Sherman traps to minimize raccoon interference. The traps were baited with peanut butter and lined with straw as bedding material. Traps were checked at first light to reduce heat stress on the animals and reset just before dusk.

Statistical analyses were calculated using the program JMP (2001) using repeated measures analysis of variance. As with the analysis of bird survey data, transects T1, T2 and T3 were the control group and transectsT6, T7 and T9 were labeled as the experimental group. A full factorial analysis was not possible because of the limited degrees of freedom associated with only three replicates per group. Treatment was considered the most important factor, followed by month, year, and then the interaction of treatment and year. Analyses were done for each species. P-values of less than 0.05 were considered statistically significant.

Small mammal trapping resulted in the finding of two species: cotton mice (*Peromyscus gossypinus*) and cotton rats (*Sigmodon hispidus*). None were ever found in the lower tidal reach, few in the upper tidal reach, and about 18 percent of the time either cotton mice or cotton rats were found in traps in the riverine reach of the river (**Table 4-8**).

Small mammal trapping resulted in the finding of two species of small mammals commonly found in the riverine reach of the Northwest Fork, generally during nonwinter months when the river levels were low. However, the tidal reaches had almost no detectable small mammal activity. These results were similar to the findings in 2007 and 2008 although many more cotton rats were found at that time (35 captures in 139 trap nights in riverine areas, 25%, versus 1 capture in 132 trap nights, <1%; Crossroads Environmental 2007). Andersen et al. (2000) reveals that flooding may preclude small mammal mortality on saplings of floodplain tree species. It is possible, but as yet unknown, if any of these effects are occurring on the Loxahatchee River.

Further investigation through experimentation may be fruitful because of the minimal amount of bald cypress (*Taxodium distichum*) recruitment occurring in the floodplain. In addition to possible small mammal damage to native vegetation, other mammals, particularly wild pigs (*Sus scrofa*), are known to severely damage native vegetation (Campbell and Long 2009). With increases in water levels, it is possible these animals would be pushed out of the floodplain and damage to native vegetation recruitment would be minimized. An approach by which to test this theory could use experimental exclosures (i.e., Gough et al. 2008).

**Table 4-8. Small mammal trap success by river reach**

| Common Name | Scientific Name | Riverine | Tidal River | P-value |
|---|---|---|---|---|
| Cotton mouse | *Peromyscus gossypinus* | 14.81% | 0.74% | 0.0004 |
| Hispid cotton rat | *Sigmodon hispidus* | 3.33% | 0.37% | 0.13 |
| Total | | 18.15% | 1.11% | 0.0002 |

### 4.2.3 Frog Monitoring

Amphibians are declining worldwide for a variety of reasons including disease, pollutants, nonnative animals, and habitat destruction and degradation (Lotters et al. 2009). In addition, successful breeding in frog populations can be extremely variable from year to year, and are tied to rainfall and the resultant hydroperiod (Semlitsch et al. 1996). However, other factors such as predation may also have key impacts on successful breeding (Semlitsch et al. 1996, Petranka et al. 2007). Creation and restoration of wetlands has been clearly demonstrated as an effective tool to manage for pond ecosystems (Petranka et al. 2007, Rannap et al. 2009). However, examples of amphibian responses to hydrological restoration in stream ecosystems in the southeastern United States are less clear cut (Weller 1995). Collecting sufficient data of high quality on the Loxahatchee River could provide major insight into how hydrological restoration impacts stream breeding frogs.

Frog monitoring was conducted using nocturnal auditory surveys. Auditory surveys were completed on the same six transects as the other wildlife monitoring (transects T1, T2, T3, T6, T7 and T9). Each survey was conducted bimonthly at night for a total of 40 surveys between June 2008 and May 2010. Nocturnal surveys were conducted on two points per transect for 15 minutes at a time. One point was located at the start of the transect and the other was located at the end of the transect close to the river. At each point, the observer identified the call to species and the intensity of the call (e.g., individual call, 2 to 5 individuals calling, and chorus of frogs calling). All six transects were visited on the same night. Temperature, humidity and wind speed were recorded at each transect. If a survey had to be abandoned for any reason, the survey data for that night was disregarded.

Statistical analyses were done using the program JMP (2001) using repeated measures analysis of variance and Excel. As with both the bird and small mammal data analyses, transects T1, T2 and T3 were the control group and transects T6, T7 and T9 constituted the experimental group. A full factorial analysis was not possible because of the limited degrees of freedom associated with only three replicates per group. Treatment was considered the most important factor, followed by month and year, and then the interaction of treatment and year. Analyses were done for total number of frogs observed and for individual species abundance for those animals with enough observations. P-values of less than 0.05 were considered statistically significant. Overall abundances for frogs did not yield any significant differences by river reach (P-value 0.61). On each transect, 14 species of frogs were found.

**Table 4-9** shows the most common species by river reach in percentages of times found during surveys. Combined frog abundances were significant for month (P-value <0.0001; F-Ratio 10.75; sum of squares 23985.84) (**Figure 4-15**). However, when the Tukey's highly significant difference test was run, not any one month was different than another. **Figure 4-16** illustrates the total number of frog calls with total monthly rainfall measured at the S-46 structure and mean monthly flow at Lainhart Dam. Total frog calls (5,609) peaked as expected during the wet seasons of July 2008 (528), and July (744) and September (456) 2009 when flows were at or above 100 cfs. They declined to their lowest levels during the late wet season and dry season (November 2008, 46; January and December 2009, 0 and 61) when flows were below 100 cfs. A Person correlation between rainfall and flow was 0.28, which is poor probably because of the delay and evaporation between rainfall events and basin flow. A better correlation (0.38) was noted between rainfall and total number of frog calls. This relationship is probably distorted by the various lengths of metamorphosis (0 to 365 days) among area frog species. Also, flow appeared to be affected by the management of the G-92 structure.

A striking feature of the findings of the surveys is the relatively uncommon encounters with southern leopard frogs (*Lithobates sphenocephalus utricularius*) and the very rare observations of pig frogs (*Lithobates grylio*) in the floodplain on any reach of the river (**Table 4-9**). Both of these native species require longer inundation periods than any of the other species, with pig frogs requiring at least 360 days of inundation and southern leopard frogs requiring at least 90 days. While southern leopard frogs were more common than pig frogs, they were still scarce, having been found less than 10 percent of the time. During the period in which frogs were monitored, March 1, 2008 to June 1, 2010 (823 days), the river flowed out of its channel[2] on 307 days. Out-of-channel flow occurred on 28 occasions, 17 of which were of less than 10 days duration, seven of which were between 11 and 20 days duration, three of which were between 21 and 29 days duration. The longest period of inundation was 67 days. **Figure 4-17** contrasts the difference in rainfall and the abundance of southern leopard frog and the exotic Cuban tree frog (*Osteopilus septentrionalis*), which has a short metamorphosis period of 21 to 28 days. Although they were not present in high numbers, southern leopard frog calls were generally present when total monthly rainfall was over one inch (note also, flows were or had been above 100 cfs). Southern leopard frog calls peaked in summer 2008 and in June 2009 while Cuban tree frogs clearly took advantage of each wet season. In the future, when more water is available to bring to the Loxahatchee River, it will be important to inundate the floodplain for longer periods, perhaps using the time to metamorphosis of the southern leopard frog as a benchmark. In addition, the quantification of restoration is important because little is known on how frogs will react to the type of stream restoration proposed by the SFWMD (SFWMD 2006, Petranka et al. 2007, Rannap et al. 2009).

[2] The river is considered to be flowing out of its channel when water is flowing at 100 cubic feet per second over the Lainhart Dam based on SFWMD data.

**Table 4-9. The 13 most commonly encountered species of frogs organized by percent chance of encounter on any given survey date and frog call abundance by month**

| Common Name[1] | Percent Chance of Encounter | | | | P-value for Call Abundance by Month |
|---|---|---|---|---|---|
| | Riverine | Tidal River | P-value | Days to Metamorphosis | |
| Cricket frog | 86.20% | 91.15% | 0.065 | 41 to 90 | <0.0001 |
| Cuban treefrog | 66.15% | 64.32% | 0.0009 | 21 to 28 | <0.0001 |
| Greenhouse frog | 59.11% | 54.69% | 0.0011 | 0[1] | <0.0001 |
| Pinewoods treefrog | 45.31% | 41.93% | 0.25 | 50 to 75 | 0.0002 |
| Squirrel treefrog | 39.06% | 47.14% | 0.0001 | 40 to 60 | 0.0489 |
| Southern toad | 19.79% | 18.75% | 0.79 | 30 to 60 | 0.11 |
| Green treefrog | 18.49% | 19.01% | 0.0471 | 24 to 45 | <0.0001 |
| Southern leopard frog | 11.20% | 9.11% | 0.0245 | > 90 | 0.0068 |
| Oak toad | 8.59% | 9.90% | 0.52 | 30 | <0.0001 |
| Narrowmouth toad | 7.03% | 7.29% | 0.66 | 20 - 70 | 0.0987 |
| Little grass frog | 5.21% | 7.55% | 0.17 | 45 -70 | 0.0155 |
| Barking treefrog | 5.21% | 5.73% | 0.39 | 41 -160 | <0.0001 |
| Pig frog | 2.34% | 1.82% | 0.18 | 365 to 730 | 0.0020 |
| Average number of total observations | 478.67 | 484.67 | 0.61 | | |

[1]Scientific names are provided in **Appendix 4-4**.

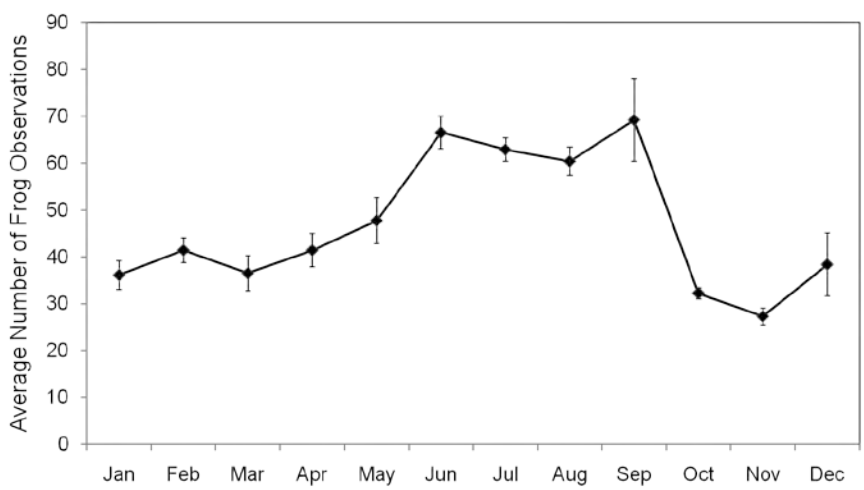


**Figure 4-15. Frog call abundance by month with standard error bars**

Month was a significant factor in the repeated measures of ANOVA (p-value <0.0001) but, using Tukey's highly significant difference test, any one particular month is not different compared to another.

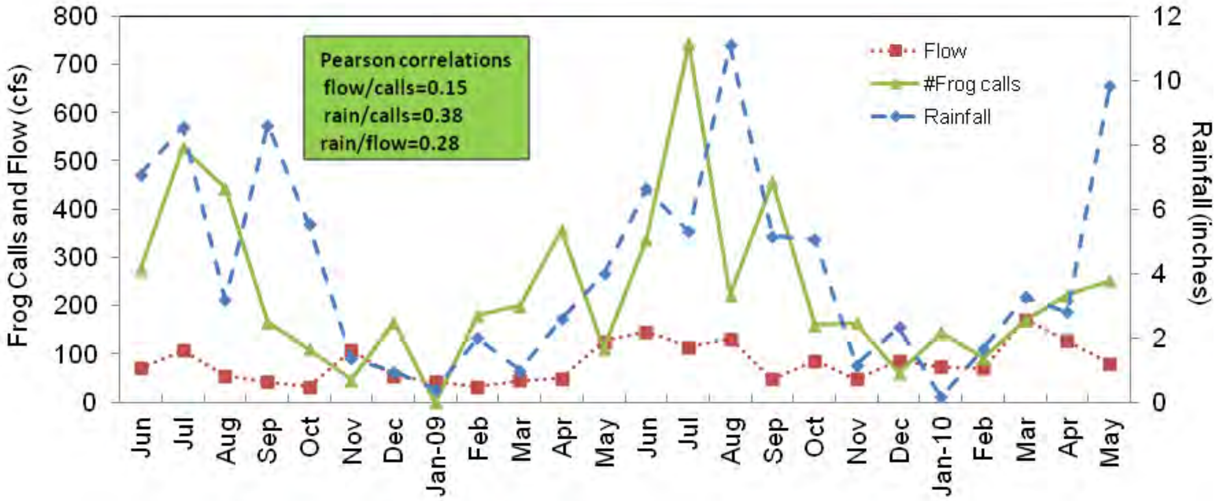


**Figure 4-16. Total number of all frog calls with mean monthly flow at Lainhart Dam and total monthly rainfall at S-46**

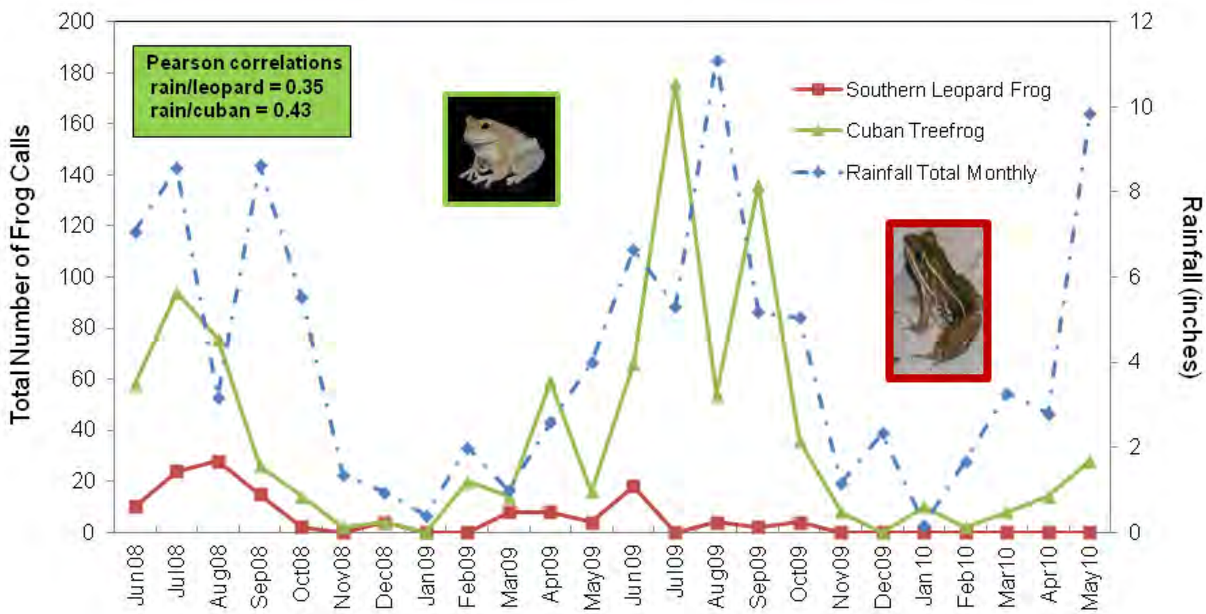


**Figure 4-17. A comparison of total monthly rainfall and the abundance of southern leopard frog and nonnative Cuban tree frog calls.**

Monthly data was also looked at by species (**Figure 4-18–Figure 4-20**; **Table 4-9**). All species except southern toads (*Anaxyrus terrestris*) were found to have a monthly variation in call abundances.

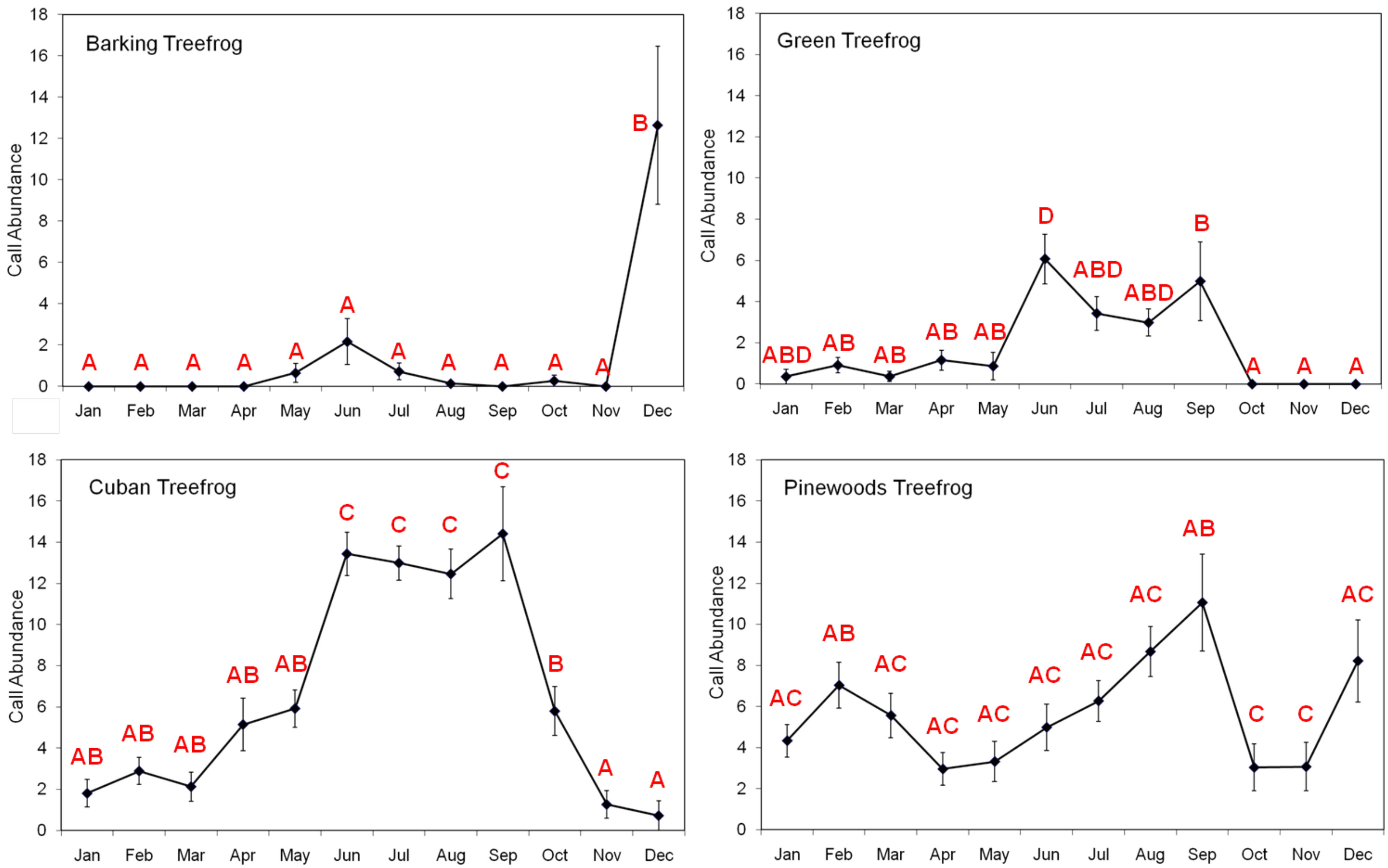


**Figure 4-18. Breakdown of four frog species call abundance by month**

Letters assigned to each month indicate statistically significant differences by month. When a point shares a letter, the values for that month are not statistically different than the other number. Conversely, if two points do not share a value they have statistically different values according to Tukey's highly significant difference test.

Scientific names are provided in **Appendix 4-4**.

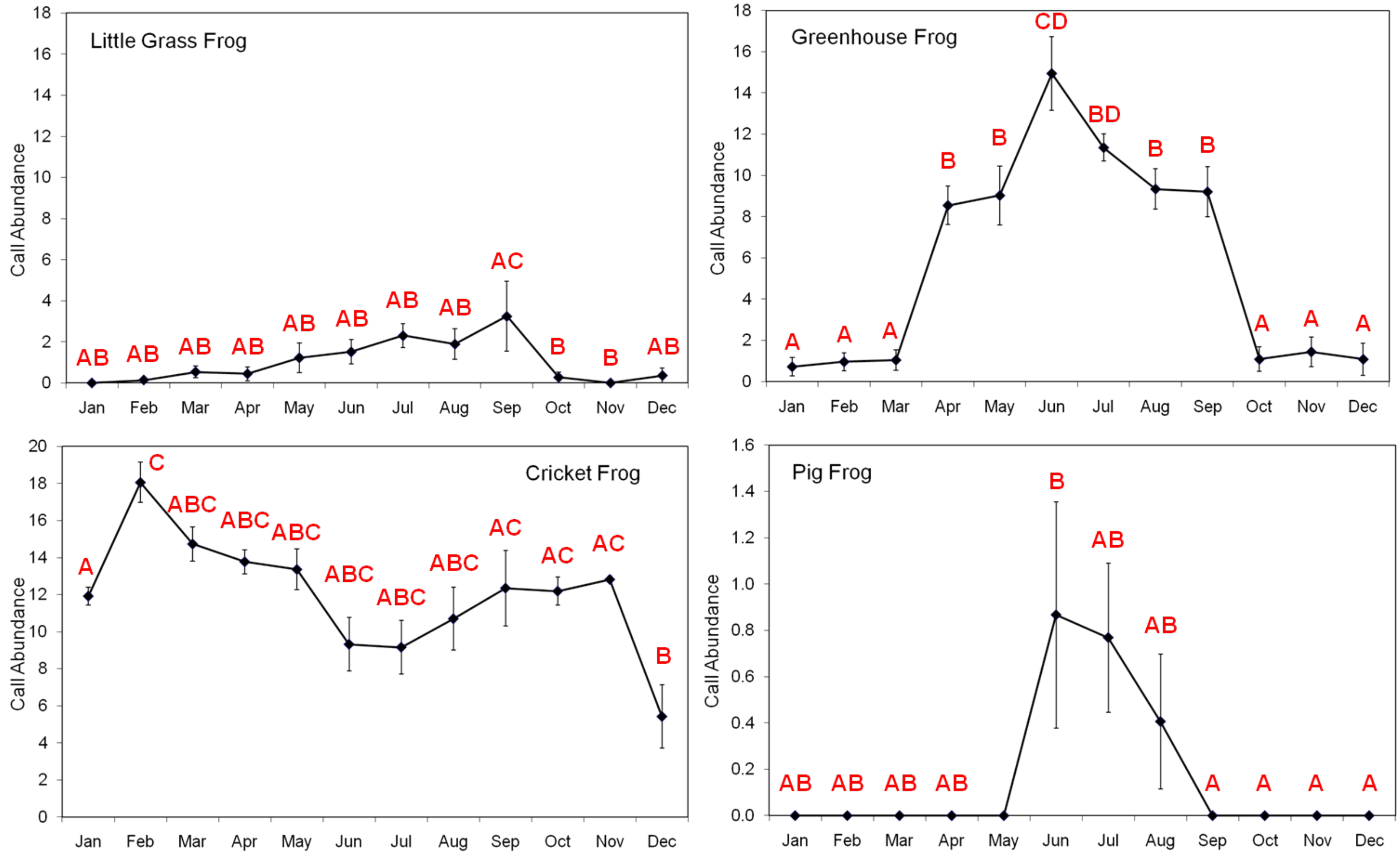


**Figure 4-19. Breakdown of four frog species call abundance by month**

Letters assigned to each month indicate statistically significant differences by month. When a point shares a letter, the values for that month are not statistically different than the other number. Conversely, if two points do not share a value they have statistically different values according to Tukey's highly significant difference test.

Scientific names are provided in **Appendix 4-4**.

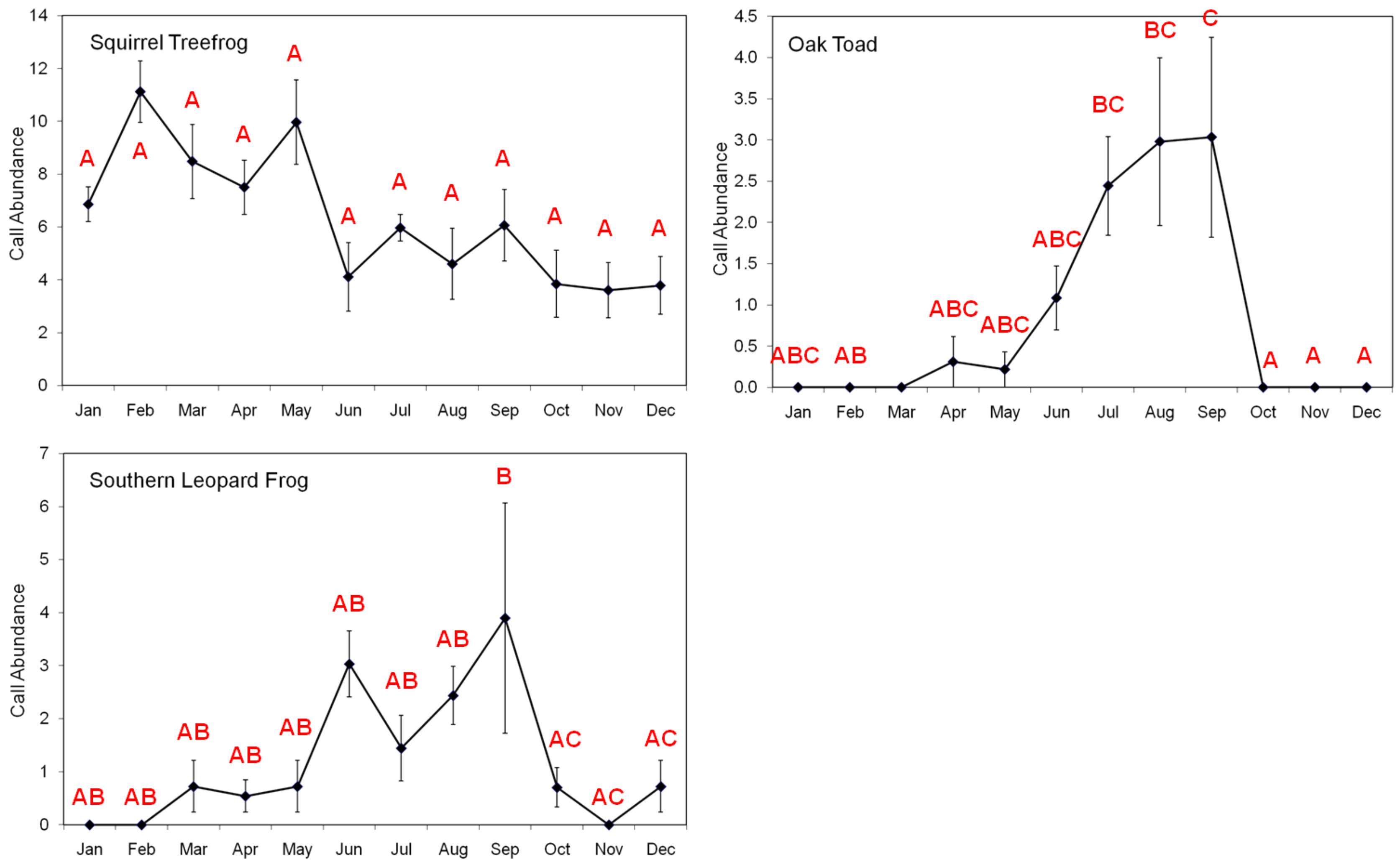


**Figure 4-20. Breakdown of three frog species call abundance by month**

Letters assigned to each month indicate statistically significant differences by month. When a point shares a letter the values for that month are not statistically different than the other number. Conversely, if two points do not share a value they have statistically different values according to Tukey's highly significant difference test.

Scientific names are provided in **Appendix 4-4**.

### 4.2.4 Alligator Monitoring

Reptile monitoring as outlined in an initial proposal was impractical. A pilot of snake surveying in the floodplain yielded little results for the amount of time spent searching transects (Cotleur and Hearing 2007). In addition, turtle trapping attracted alligators and no turtles were caught in this manner.

American alligators (*Alligator mississippiensis*) are used as indicators for Everglades ecosystem (DeAngelis et al. 1998, Sergio 2008, Mazzotti et al. 2009). In the Everglades, alligators are not only top predators and ecosystem engineers (Sergio 2008), they also have indirect positive influences on other invertebrates and vertebrates through their feeding habits (Bondavalli and Ulanwicz 1999). For these reasons alone, alligators are an important part of the ecosystems in which they live.

Mazzotti et al. (2009) studied the effects of hydrology on alligators in the Everglades. Unnatural releases of water may flood alligator nests. Unnatural droughts in both frequency and duration may also decrease the total amount of area that can be used by alligators and can have such negative impacts on food for alligators that they cannot survive. Lastly and perhaps most importantly, alligators prefer fresh water and brackish water to salt water. Saltwater intrusion has limited the distribution of alligators in the Everglades (Mazzotti et al. 2009). It is unclear what, if any, of these problems are occurring in the Loxahatchee River, but it is likely alligators are being affected.

Alligator surveys were conducted mostly by kayak on the upper part of the river from RM 14.8 to RM 10.2, and by kayak or motorized boat on the lower part of the river from RM 10.2 to RM 6.2. Alligators were located using a spot light (portable 500,000 candlepower light) that results in a reflection from the eyes of alligators. When an alligator was spotted, it was approached and, where possible, approximate size was determined (Webb et al. 2009). Also, when each of the alligators was located, water salinity, water temperature, and global positioning satellite (GPS) coordinates measures were taken. Sampling was conducted once a month after dusk for both the lower (RM 10.2 to RM 6.2) and upper (RM 14.8 to RM 10.2) parts of the river. Surveys were not conducted on the upper part of the river when river flows were too low to continue kayaking down the river. Seventeen surveys were completed on the upper part of the river and 26 surveys were completed on the lower part of the river between February 2008 and May 2010.

Data were collected in such a way that the most logical analysis was a multiple regression model. River mile at which the alligators were found were plotted against water temperature, salinity, length of the alligator, and average flow over Lainhart Dam for the survey date. The result of the multiple regression revealed an overall significant model (P-value <0.0001) with an $R^2$ of 0.17. Of the four factors in the regression model, both salinity and temperature were highly significant in predicting where alligators were found along the river (**Table 4-10**; **Figure 4-21**). Number observations by salinity alone is shown in **Table 4-11**.

**Table 4-10. Results of the multiple regression with respect to the variable of the river mile where the alligators were found**

| Factor | P-value |
|---|---|
| Temperature (ºFahrenheit) | 0.0020 |
| Salinity (psu) | 0.0002 |
| Flow over Lainhart Dam (cfs) | 0.2201 |
| Body size (feet) | 0.3590 |

**Table 4-11. American alligator observations by salinity**

| Salinity Range (psu) | Number of Observations | Percentage of Observations |
|---|---|---|
| 0.00–0.49 | 132 | 74% |
| 0.50–0.99 | 15 | 8% |
| 1.00–1.49 | 6 | 3% |
| 1.50–1.99 | 3 | 2% |
| 2.00–4.99 | 9 | 5% |
| 5.00–9.99 | 9 | 5% |
| 10.00–14.99 | 3 | 2% |
| 15.00 plus | 1 | 1% |
| Total | 178 | 100% |

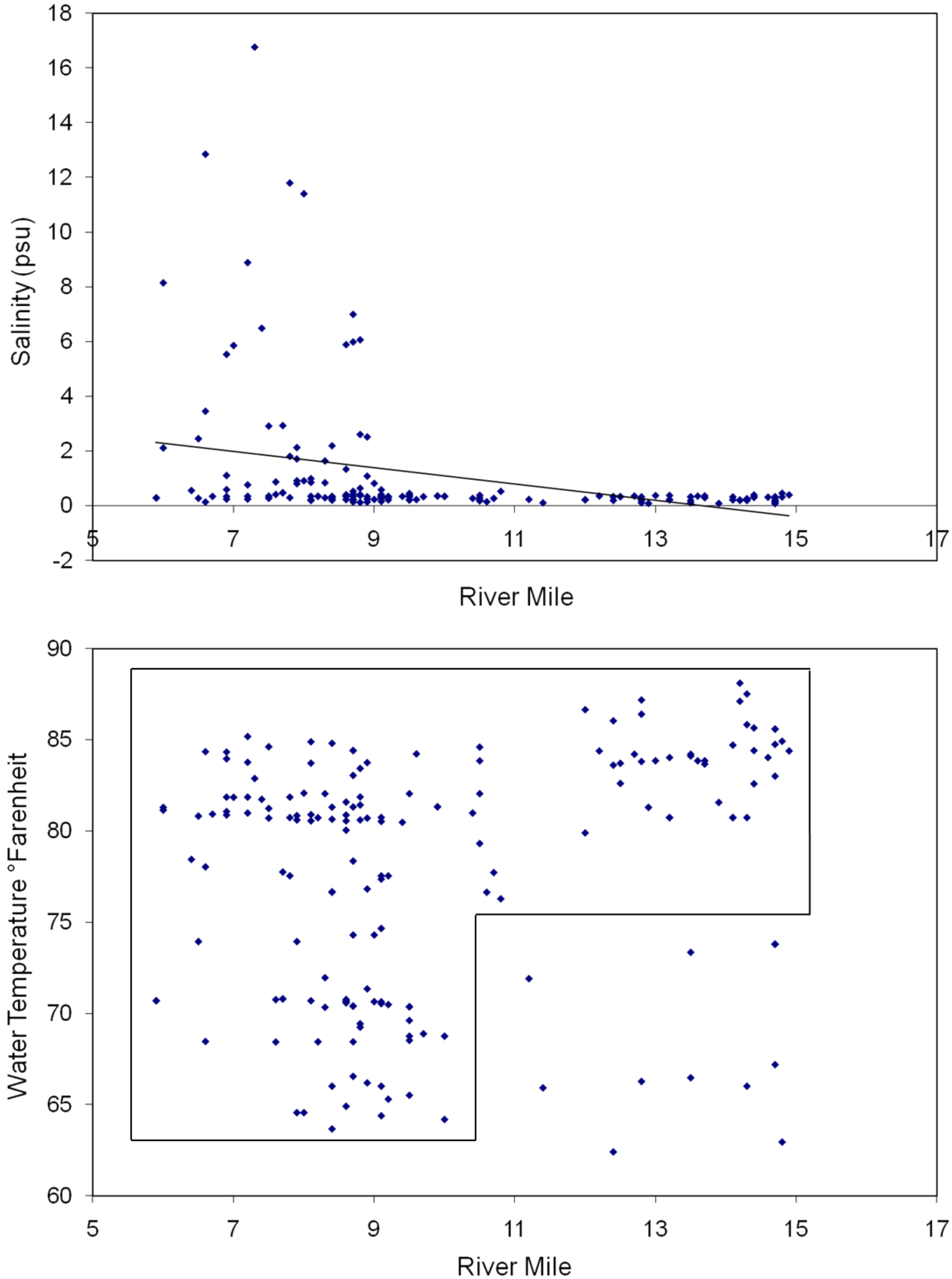


**Figure 4-21. The two significant factors in the multiple regression to determine what factors were important in where alligators were found along the river (river mile) were salinity and water temperature**

The regression model does not explain very much of the variability. While there are several reasons why for this, salinity can still be a major explanatory factor of how alligators are distributed along the river. In the regression model, river mile is used to explain the four factors measured: water temperature, salinity, size of the alligator and flow over Lainhart Dam. Salinity changes through the course of the year according to flow over the dam and is also compounded by tides. This may be why river mile where alligators were found and salinity are by themselves a poor explanation of why an alligator occurs in a certain area. However, when looking only at salinity (**Table 4-11**), these animals occur almost exclusively in fresh water and particularly in salinity of less than 1 psu (82% of all observations). Surveys were conducted in all periods of the year, during dry and wet times, and in all parts of the river. In addition, the literature is clear that American alligators prefer fresh or brackish water (Pidcock et al. 1997, Mazzotti et al. 2009). Scientific literature is less clear about the mechanism of why alligators do not venture much into marine water environments. To further test this hypothesis, additional monitoring could be conducted on the river, especially during periods of drought. The implication of these data is that with restorative freshwater flows, the saltwater wedge would be pushed further downstream for longer periods of time, and alligators to be more common in the lower parts of river. Further investigation into this issue is recommended as alligator distribution and salinity seem to have a very clear relationship.

### 4.2.5 Wildlife Conclusions

Much data were collected on various wildlife species along the Northwest Fork between spring 2008 and early summer 2010, and the results described in this report. The purpose of this monitoring, to obtain baseline data on wildlife using the Northwest Fork, was fulfilled and will be very useful for comparison once restoration is complete. Frog observations after restorative flows reach the river will be very interesting. In this study, few observations were made of pig frogs and southern leopard frogs, frogs with longer metamorphic life cycles, indicating perhaps that water levels were not sufficient in the observed years to adequately sustain them. Perhaps this will change with restorative flows and the system could be managed in the future to have an excess of 90 days of inundation in the floodplain, while monitoring is conducted to see if these frogs will respond. Alligators are using the freshwater (≤1 psu) portions of the river much more than the lower tidal reaches of the river. Reversal of higher salinity may create more suitable habitat for alligators. Bird surveys indicate the riverine reach of the river supports a wider variety of species perhaps due to the older and more complex vegetation community structure created by the vegetation of the riverine reach of the river. Drying out of the riverine reach of the river allows for small mammals to utilize this part of the floodplain for longer periods of time; however it is more important for aquatic species to have an inundated floodplain for their life cycle events. It is important that once restorative flows reach the river floodplain that this work be revisited for the sake of comparison. No one species or set of species were found to be clear cut candidates as potential indicators of river health, but alligators, frogs and small mammals seem to have the clearest relationship with fresh water in the river and water in the floodplain and therefore they are recommended for further study.

# 5.0 ESTUARINE VEGETATION AND WILDLIFE

## 5.1 Seagrass

### 5.1.1 Background

Seagrass is a valued ecosystem component (VEC) of the polyhaline zone of the Loxahatchee River Estuary. All seven seagrass species found in Florida have been documented in the Loxahatchee River Estuary: shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), turtle grass (*Thalassia testudinum*), Johnson's seagrass (*Halophila johnsonii*), paddle grass (*Halophila decipiens*), star grass (*Halophila engelmanni*) and widgeon grass (*Ruppia maritima*). Scientists and managers use seagrass condition and distribution to assess the health and condition of the estuary. Further, seagrass data will be used to assess restoration success following modified freshwater inflows resulting from implementation of the Comprehensive Everglades Restoration Plan (CERP) and the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006).

The restoration plan provided a summary of available seagrass distribution information based on maps produced by various agencies for 1981, 1985, 1990, 1994, 1996, 2000, 2003 and 2004. Although mapping methods and project boundaries were not consistent, several general conclusions were reached:

- Seagrass beds have been a persistent feature of the estuary since at least the early 1980s.
- Seagrass tends to grow in very shallow water in the Loxahatchee River Estuary (typically less than 1 meter deep).
- Shoal grass and Johnson's seagrass are the dominant species in the Loxahatchee River Estuary.
- High rainfall in 1994–1995 may have caused the large loss of seagrass documented in 1996.
- A general trend of increasing seagrass acreage was documented from 1996 through 2003.
- Core seagrass beds persisted in all map years; however, the size and shape of the beds varied considerably.
- Seagrass distribution changes were attributed to changes in shifting and accreting sediments in shoal areas of the Central Embayment and to lower salinity, greater salinity variation, and darker water in the upper estuary and river forks.

Understanding seagrass species distribution, not just changes in seagrass cover, is important for water management considerations because the species found in the Loxahatchee River Estuary

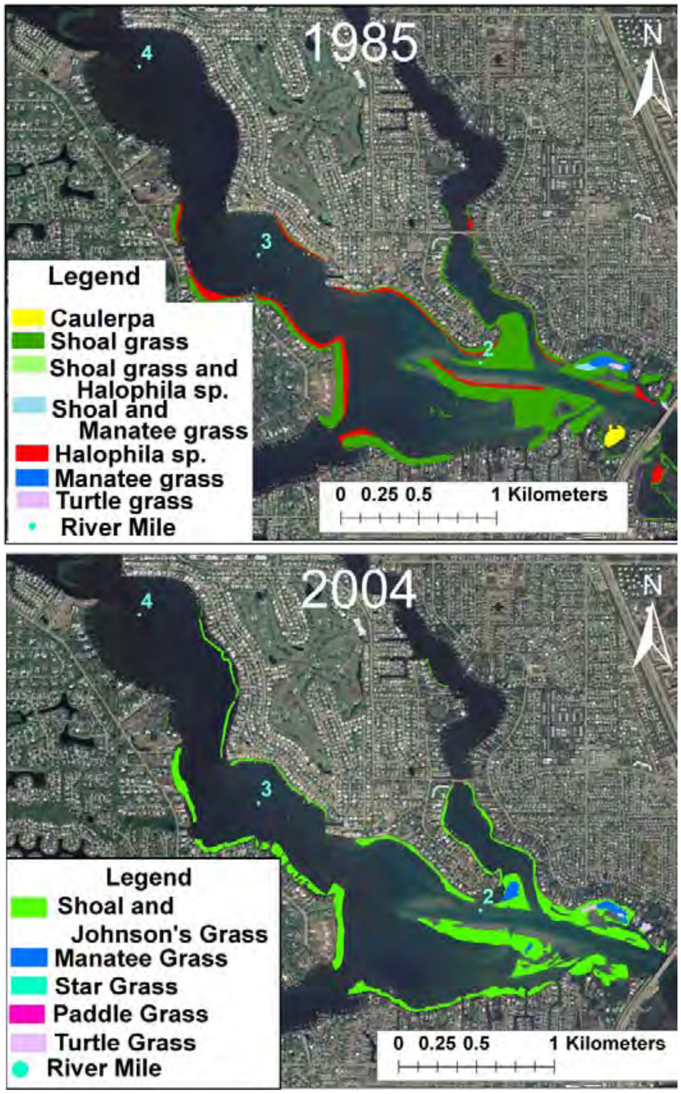


**Figure 5-1. Seagrass maps created nearly 20 years apart reveal similar species distributions**

have species specific salinity thresholds (SFWMD 2006). Once restoration projects are completed, species shifts may occur.

At the time the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006) was completed, only two detailed species-level mapping efforts had been completed for the Loxahatchee River Estuary. These efforts were conducted by Klemm and Vare (1985) and the Loxahatchee River District [LRD] (2004a). Methods and project area varied, but a visual comparison of these maps revealed very similar seagrass species distributions (**Figure 5-1**). Shoal grass and *Halophila* species (Johnson's seagrass and paddle grass) were found throughout the estuary. Turtle grass and manatee grass were present but not abundant and were located in the lower estuary downstream of River Mile (RM) 2. In 2004, manatee grass was found approximately 0.3 mile upstream of its location in 1985. Species diversity was highest downstream of RM 2 in both years. During the 2004 map field work, widgeon grass was found near RM 6.5 and two patches of star grass (first documentation of this species in the estuary) were found just upstream of the railroad bridge in coves along both shores.

Following the completion of the restoration plan, several other mapping projects were conducted: (1) three seagrass mapping projects based on interpretation of aerial photographs were completed in 2004, 2006 and 2007, (2) two detailed species-level mapping projects were completed in 2007 and 2010, and (3) a natural resource inventory that included seagrass species distribution information was completed in 2005. Additionally, seagrass monitoring along the estuary's salinity gradient was initiated in summer 2003 and continues today. The seagrass mapping and monitoring efforts completed since 2003 and preliminary comparisons with available water quality data are summarized below providing insights into the ecology and dynamics of seagrass in the Loxahatchee River Estuary.

### 5.1.2 Mapping Projects

<u>Maps Based on Aerial Photographs</u>

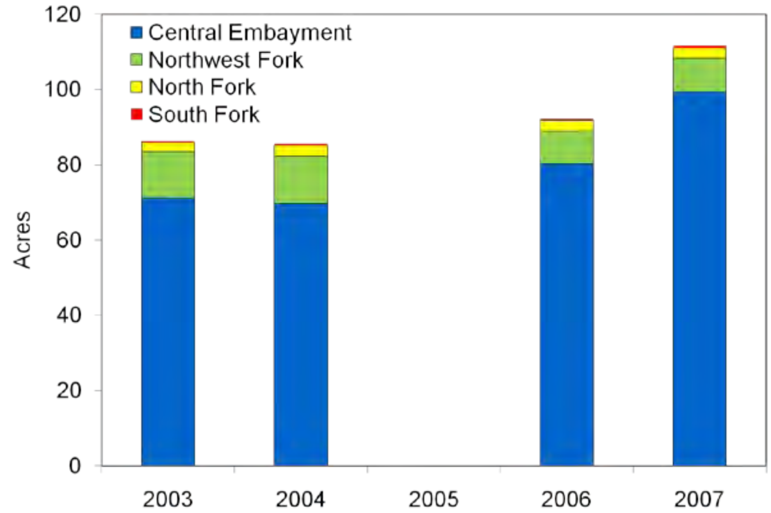


**Figure 5-2. Seagrass maps for 2003–2007 were created by interpreting benthic signatures on aerial photographs**

Methods were consistent for all years, making acreage comparisons possible. Acreages shown represent areas of the estuary upstream of the railroad bridge.

Maps of Loxahatchee River Estuary seagrass distribution created from the interpretation of aerial photographs were completed under direction of the South Florida Water Management District (SFWMD) for 2003, 2004, 2006 and 2007. Methodology included using 1:4,800 scale imagery, flying imagery during high tides to ensure that Central Embayment benthic features would be visible on the imagery, using submeter accuracy global position system (GPS)-guided field checks to ground truth questionable photographic signatures, and using state of the art mapping methods to generate geographic information system (GIS) data. The quality and timing of the imagery allowed photo interpretation upstream to approximately RM 3. From 2003 to 2007, the Central Embayment supported the greatest seagrass acreage, with an apparent increase from 2004 through 2007 (**Figure 5-2**). Since different mapping methods were used prior to 2003, it is not appropriate to compare acreage changes where methods were not consistent. However, it is interesting that both efforts suggest an increasing trend in Loxahatchee River Estuary seagrass coverage over time.

Areas of seagrass gain, loss and no change from 2003 through 2007 are shown on **Figure 5-3**. As past mapping indicated (SFWMD 2006), seagrass bed shapes and sizes are dynamic in the Loxahatchee River Estuary. From 2003 to 2004, losses (primarily in the Central Embayment) and gains (typically on the deep edges of beds throughout the estuary) tended to balance each other out resulting in similar total acreages for both years. A slight increase in acreage occurred from 2004 to 2006, but acreage losses still occurred in some locations such as the downstream end of the Northwest Fork and near the Sand Bar seagrass bed. However, for this time period, overall acreage gains throughout the estuary were greater than losses.

Significant gains in acreage were observed from 2006 to 2007, primarily in the Central Embayment. Detailed field data (discussed in greater detail below) was available from summer 2007. Comparison of those data points with mapped areas of seagrass gain revealed that the areas mapped as seagrass “gain” were dominated by Johnson’s seagrass, at times mixed with shoal grass. Both species are opportunistic species that can rapidly colonize suitable substrate. Since much of the acreage gain from 2006 to 2007 occurred along shoal areas in the

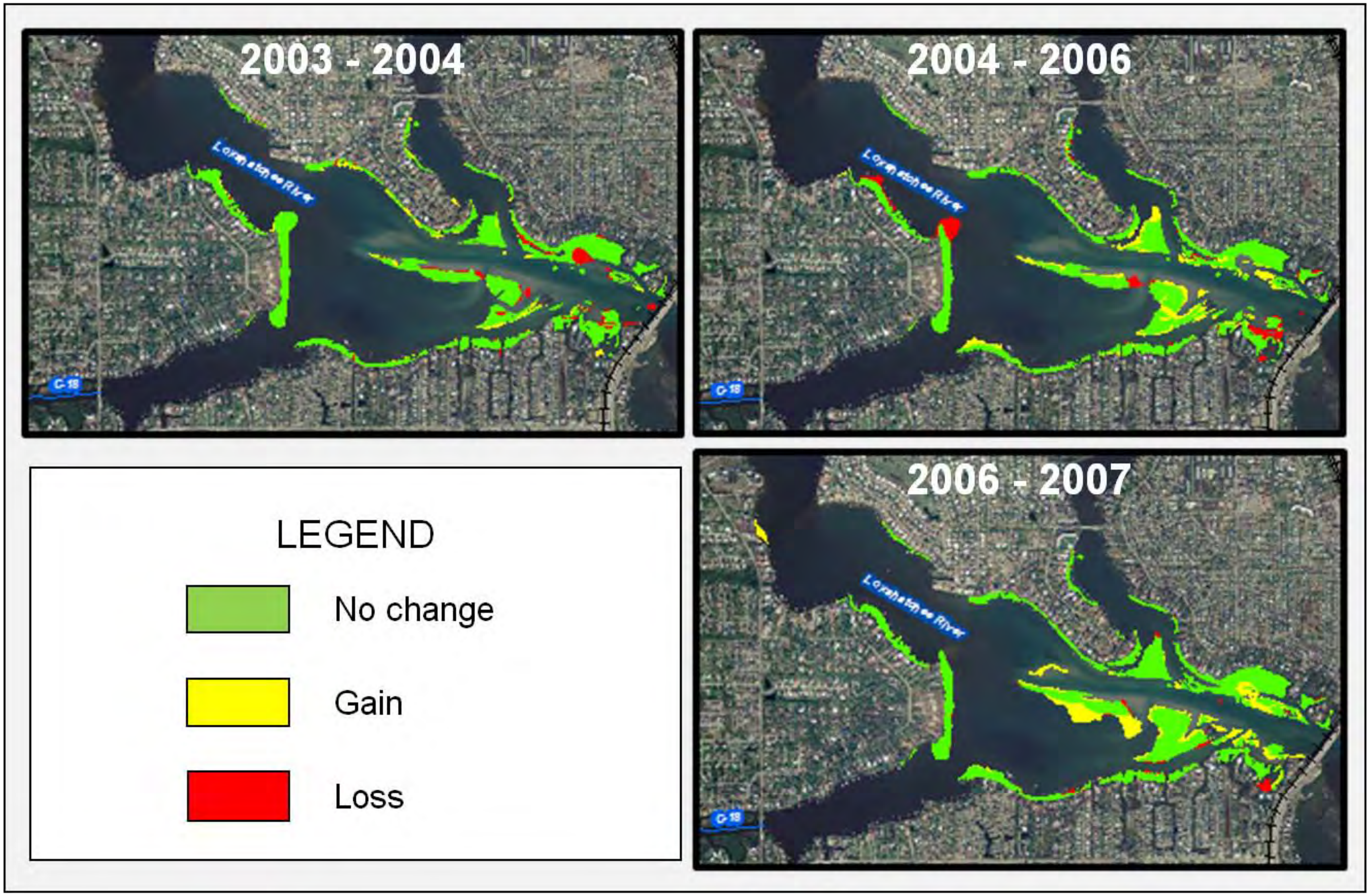


**Figure 5-3. Areas of change in seagrass distribution between 2003–2004, 2004–2006 and 2006–2007**

Central Embayment, it is possible that increases in seagrass acreage reflect suitable seagrass substrate created from movement of the sediments and/or continued recovery following the hurricane impacts of 2004. Evaluation of available bathymetric data may help assess acreage increases.

The 2003–2007 maps were prepared using consistent, state-of-the-art methods, and the data are available for analysis in Arc Map GIS. Comparison of the four GIS data sets provides insight into variations in distribution and acreage over time. **Figure 5-4** shows areas where seagrass beds were consistently mapped (persistent, core seagrass beds documented in all four years) and where seagrass coverage varied. As indicated in past mapping efforts (SFWMD 2006) seagrass "bed" distribution is dynamic in the Loxahatchee River Estuary and sediment shifts may play an important role in seagrass distribution.


**Figure 5-4. Seagrass distribution in the Loxahatchee River Estuary varied over time**

Green areas define persistent seagrass beds from 2003 to 2007. The yellow areas show where seagrass cover fluctuated outside of the core beds over the 2003–2007 timeframe.

Maps Based on Detailed Field Inspections

*Seagrass Mapping Using GPS*

While the maps created from aerial photos provide valuable landscape-scale information on trends in the seagrass bed distribution, they do not provide species information and cannot capture very sparse seagrass and/or seagrass distribution in the upper reaches of the forks where dark water and/or very sparse seagrass distribution preclude mapping from imagery. During the summers in 2003–2004, 2007 and 2010, LRD staff mapped Loxahatchee River Estuary seagrass to the species level. In the 2003–2004 study (LRD 2004a), seagrass beds were snorkeled, bed edges were marked with buoys, bed outlines were captured with a mapping-grade GPS providing submeter accuracy, and species composition was recorded. As noted in the 2006 restoration plan (SFWMD 2006), the species mapping effort revealed seagrass upstream of previous maps for the Northwest Fork of the Loxahatchee River (**Figure 5-1**).

A 2005 natural resource inventory of the Loxahatchee River Estuary was conducted for the Jupiter Inlet District (Taylor Engineering 2005). This project provided important post-hurricane documentation of Loxahatchee River Estuary seagrass and mangrove distribution. Maps were developed using aerial photo interpretation with extensive ground-truthing, which included using differential GPS to record the edges of the seagrass beds. In areas where no seagrass was noted on aerials, divers were towed behind a boat along transects spaced 150 feet apart. Where seagrass was present on shoals, the bed edge was walked and recorded using differential GPS. Where visibility was poor (i.e., river forks) staff traversed shore perpendicular transects spaced less than 100 feet apart. Their results were in general agreement with the LRD's 2004 map. Shoal and Johnson's seagrass were the most abundant species and were distributed throughout the estuary. Manatee grass was found near RM 2, as in the LRD's 2003–2004 findings, but not in the Sand Bar area. The 2005 report compared mapped acreage from 2000 through 2005 (similar methods used), and found that species composition was "relatively the same" except that isolated patches of turtle grass were found along the southeast shore. Additionally, they estimated an acreage increase from 2000 through 2005. The increase was mostly due to increased seagrass acreage in the North and Northwest Forks.

*Quadzilla Mapping*

In 2007 and 2010, species mapping methods were further refined and included quantifying seagrass occurrence and density using a random stratified design that located sampling points throughout the estuary (**Figure 5-5**). Each point on **Figure 5-5** represents a 3 meter by 3 meter quadrat (dubbed a "quadzilla") subdivided into nine, 1 meter by 1 meter quadrants. Presence-absence scores (0–9) for each species were recorded at each sampling point. In 2010, substrate type and muck depth were also documented. Results from these projects provide unprecedented, species-specific assessments of seagrass in the Loxahatchee River Estuary. Details of these efforts, including methods, results and detailed maps, can be found at www.loxahatcheeriver.org/reports.php and are summarized below.

In 2007, 849 of 1,085 points contained seagrass. In 2010, 979 of 1,667 points contained seagrass. With the exception of paddle grass, the distributions of other grasses (Johnson's seagrass and shoal, manatee and turtle grasses) were generally similar in 2007 and 2010 (**Figure 5-5**). The distribution of paddle grass showed marked changes between the surveys, expanding into the North Fork but declining greatly in the area south of the Sand Bar site where it was a dominant species in 2007. Johnson's seagrass, a federally-listed threatened species, was the most frequently encountered seagrass in 2007 and 2010 (**Figure 5-6**). Shoal grass was the second most encountered species in both years. **Figure 5-7** shows an example of how the seagrass data points can be interpolated to create seagrass habitat maps.

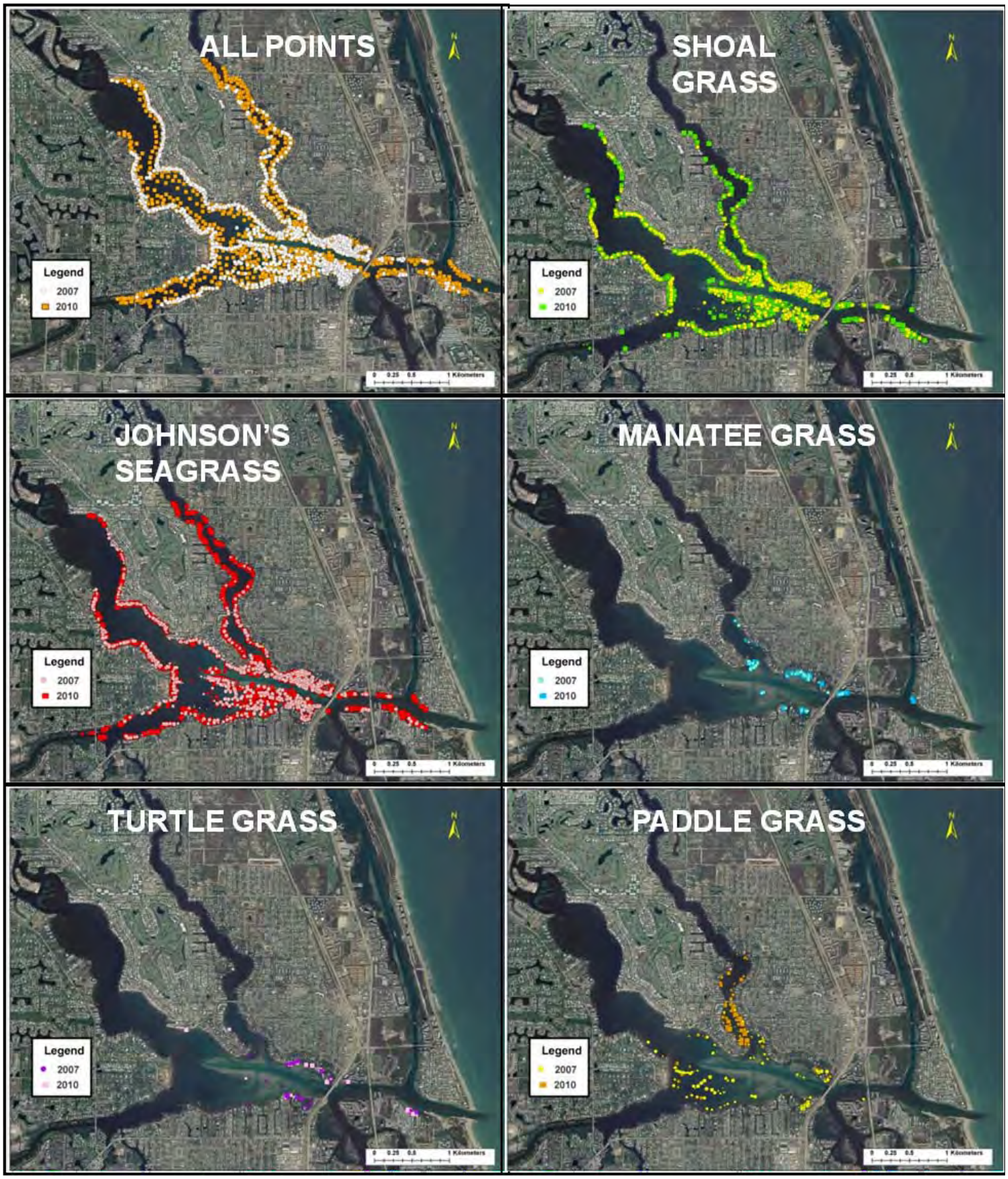


**Figure 5-5. Species maps of all points monitored in 2007 and 2010 as well as points containing each seagrass species**

Each point represents a 3 meter by 3 meter quadrat. The points are not to scale; they are drawn larger than actual size so colors can been distinguished.

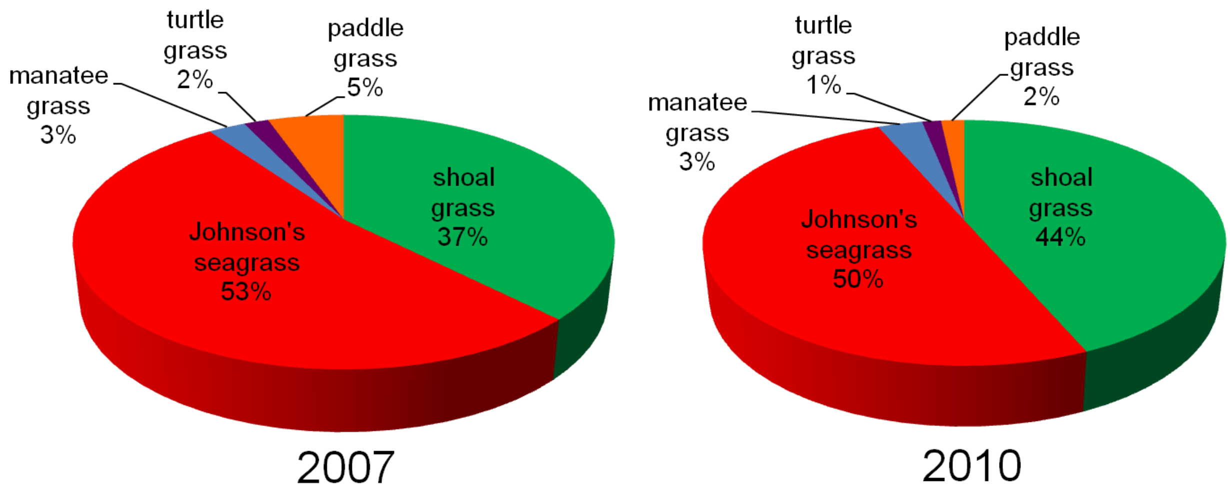


**Figure 5-6. Of the sample points containing seagrass, at least 50 percent were occupied by Johnson's seagrass in both years with shoal grass being the second most abundant**

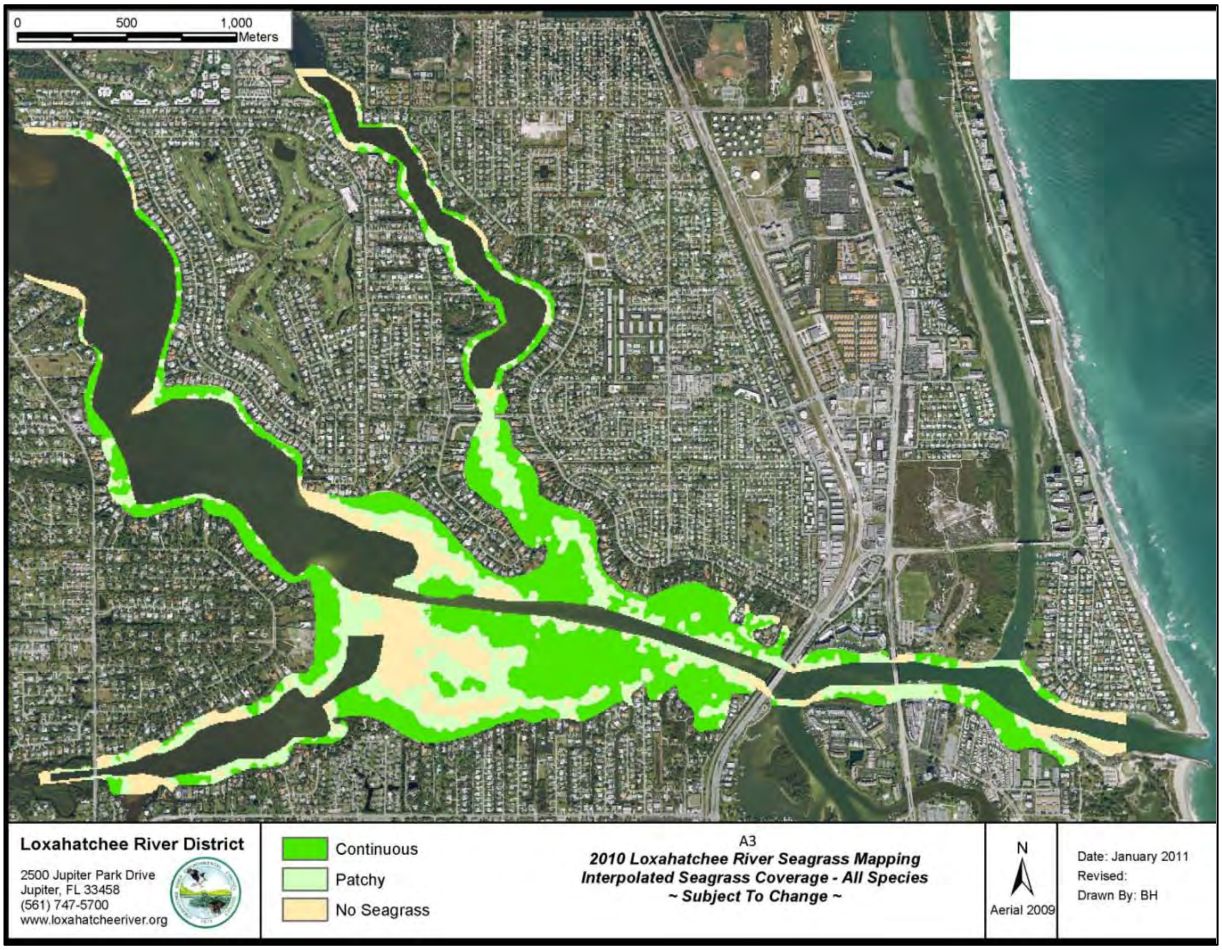


**Figure 5-7. Interpolation of the 1,667 sample points in 2010 identifies where seagrass habitat occurs in the Loxahatchee River Estuary**

The 2010 survey included water depth measurements and sediment characterization at each sample point, and when present, muck depth was recorded. Comparisons of seagrass density with water depth concurred with past assessments that indicated seagrass typically grows in very shallow water in the Loxahatchee River Estuary (**Table 5-1**). Additionally, the data suggests a strong negative relationship between seagrass occurrence and water and muck depth.

**Table 5-1. Seagrass density compared with muck and water depth**

| Seagrass Density | Water Depth (cm) | | Muck Depth (cm) |
|---|---|---|---|
| | Muck Bottom | Sand Bottom | |
| Absent | 153 | 160 | 31 |
| Patchy | 128 | 136 | 16 |
| Continuous | 74 | 81 | 11 |

cm - centimeters

<u>Mapping Methods Comparison</u>

Maps from aerial photographs facilitate evaluation of seagrass bed trends over time. These types of maps represent conditions at the time of imagery acquisition, and are limited to areas of the estuary where the water is clear enough for the imagery to capture benthic features and where seagrass density is typically greater than 10 percent. Accordingly, dark water areas such as areas upstream of RM 3 in the Northwest Fork and areas of the estuary where seagrass is relatively sparse (<10% cover) are not mapped from aerial photographs. Since most of the seagrass resources are found in the Central Embayment where water clarity on incoming tides allows for imagery to capture benthic features, this method is an excellent tool for tracking the core Loxahatchee River Estuary seagrass beds over time. The Comprehensive Everglades Restoration Plan Restoration Verification and Coordination (RECOVER) Team recommended conducting this type of mapping at five-year intervals.

To understand species distribution, detailed field work is necessary. The quadzilla method does an excellent job of defining species distribution within the estuary at the time of field inspections. Additionally, this method provides critical information on the upstream extent of seagrass distribution by being able to document seagrass presence in dark water areas. Additionally, this method can document areas where seagrass is present but too sparse to map from aerial imagery. Maps generated from the field points are dependent on point distribution and interpolation method. The LRD intends to conduct this type of mapping at three-year intervals.

The abundance of opportunistic seagrass species in the Loxahatchee River Estuary can complicate results of both mapping methods. For example, paddle grass was abundant south of the Sand Bar site during the 2007 quadzilla mapping. Presence of seagrass beds in this area was not documented in the 2007 map produced from aerial photographs. Because paddle grass has a rapid growth rate and is typically not present throughout the year, timing of imagery and field inspections can impact map results. It is possible paddle grass was present in densities not observable from the imagery or that it was not yet present at the time the imagery was taken.

These two possibilities result in considerable differences in the map results. Additionally, the two dominant Loxahatchee River Estuary seagrass species, Johnson's seagrass and shoal grass, can also rapidly colonize areas.

In summary, both mapping methods have their benefits and limitations, but certainly complement each other. Maps created from interpolated points may overestimate seagrass coverage where maps from aerial photographs likely underestimate seagrass coverage by being unable to capture very sparse seagrass signatures or grasses present in dark water areas. The quadzilla method provides species-specific distribution data that cannot be obtained with aerial photo interpretation. It also provides significantly more robust data when water color values are high (dark water). It is recommended that future mapping include both methods conducted as close in time as feasible to ensure accurate documentation of Loxahatchee River Estuary seagrass resources, especially considering the dominance of opportunistic species in this system. The next aerial image acquisition is scheduled for 2012 and the next quadzilla mapping is scheduled for 2013. To provide the best possible documentation of Loxahatchee River Estuary seagrasses, it is recommended that the aerial images be acquired in 2013 to coincide with the quadzilla mapping effort.

### 5.1.3 Monitoring Efforts

**Figure 5-8** shows seagrass and associated water quality monitoring locations in the Loxahatchee River Estuary and a nearby "reference" location in Hobe Sound not influenced by freshwater discharges to the estuary. Water quality results are detailed in reports that can be found at www.loxhatcheeriver.org/reports.php and generally compared with seagrass results below.

In summer 2003, the LRD began a transect-based seagrass monitoring program conducted monthly at three locations in the estuary: Pennock Point, Sand Bar and North Bay (**Figure 5-8**). The primary purpose of the study was to document seasonal changes in seagrass along the salinity gradient within the Loxahatchee River Estuary. The transect methodology was replaced in 2007 with a patch-scale, quadrat-based methodology recommended by the RECOVER program. Since October 2007, the RECOVER methods have been used to monitor seagrass every other month at the three sites used in the transect study plus a site in the Northwest Fork of the river and a reference site (Hobe Sound) in the Southern Indian River Lagoon (**Figure 5-8**). Comparisons of transect and patch-scale quadrat data have demonstrated similar results. Therefore, data sets are combined in **Figure 5-9**. For methodology details please visit: www.loxahatcheeriver.org/reports.php.

Hurricanes in 2004 greatly impacted the Loxahatchee River Estuary seagrass resources. Subsequent monitoring continues to document seagrass recovery (**Figure 5-9**). During the most recent monitoring year, October 2009–September 2010, seagrass in the Loxahatchee River Estuary appeared to be relatively healthy, though percent cover values for some species and monitoring sites remain below those observed prior to the September 2004 hurricanes. Comparison of seagrass conditions in the Loxahatchee River against those of the reference site and across the upstream-downstream gradient help explain Loxahatchee River Estuary seagrass dynamics. Preliminary results and observations are presented below from upstream to downstream sites, following the salinity gradient.


**Figure 5-8. Seagrasses are currently monitored bimonthly at four locations in the Loxahatchee River Estuary and one "reference" location in Hobe Sound**

The green polygons represent the actual size and shape of the seagrass bed monitored at each location. Associated water quality stations are also shown. The seagrass transects (orange lines) are part of a St. Johns River Water Management District monitoring network. While results are not presented in this report, locations are shown so that all known seagrass studies in the area are represented. Results from the St. Johns River Water Management District monitoring agree with mapping and monitoring data presented in this addendum.

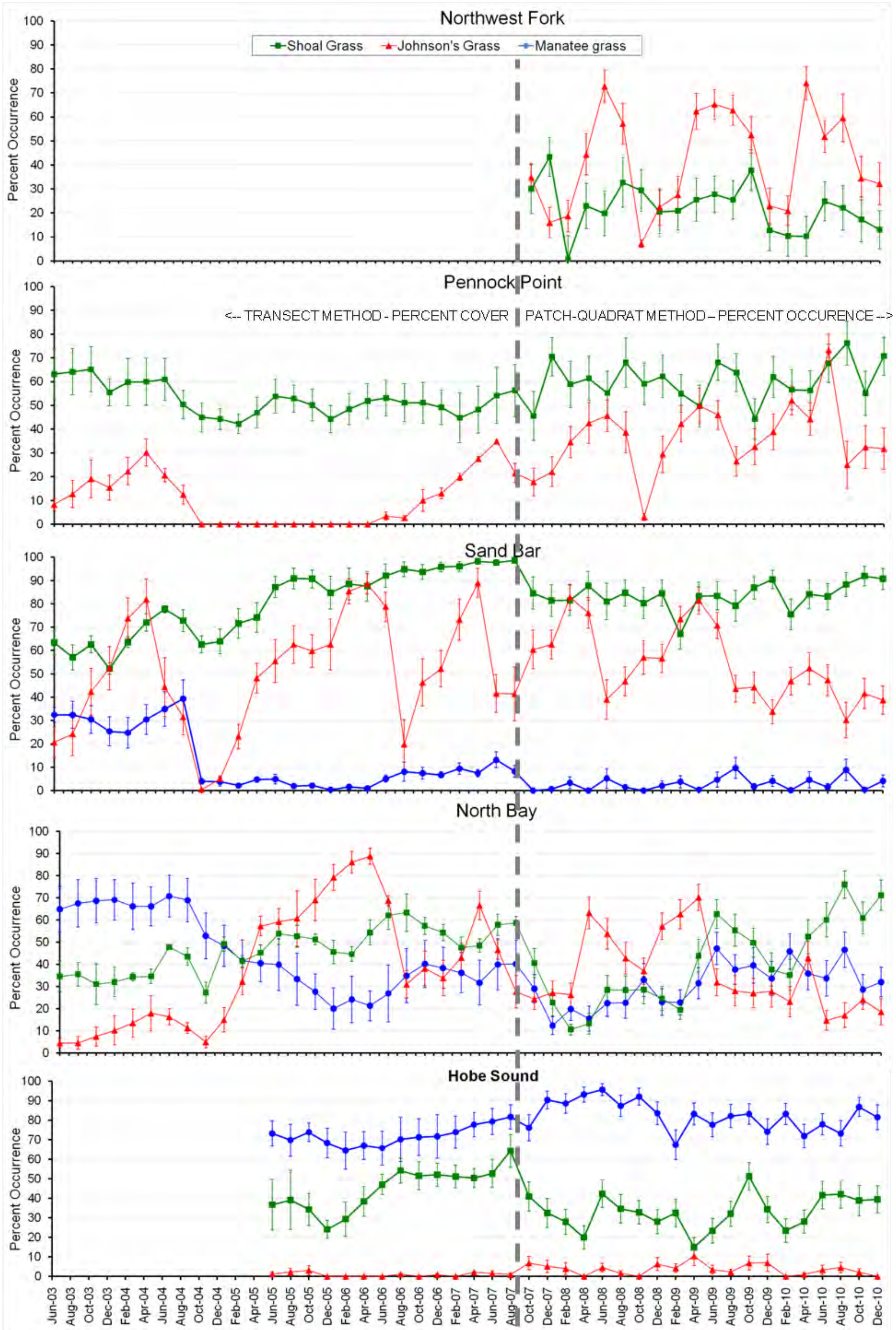


**Figure 5-9. Results from four Loxahatchee River Estuary seagrass monitoring sites and the Hobe Sound reference site**

Northwest Fork

The most upstream seagrass site is in the Northwest Fork at RM 3.4. It is adjacent to River Keeper water quality station 60. Monitoring of seagrass at this location began in October 2007. Johnson's seagrass and shoal grass are the only seagrass species that have been observed at this location. During 2010, Johnson's seagrass consistently had the greatest percent cover of the two species, reaching as high as 70 percent in April 2010. Shoal grass percent cover was consistently between 10 and 20 percent. Average canopy height was typically less than 10 centimeter (cm). Because of freshwater flowing down the Northwest Fork of the Loxahatchee River, hydrologic stressors include the highest average water color, lowest light penetration, lowest average salinity condition and most variable salinity conditions among the seagrass sites sampled (**Figure 5-10**).

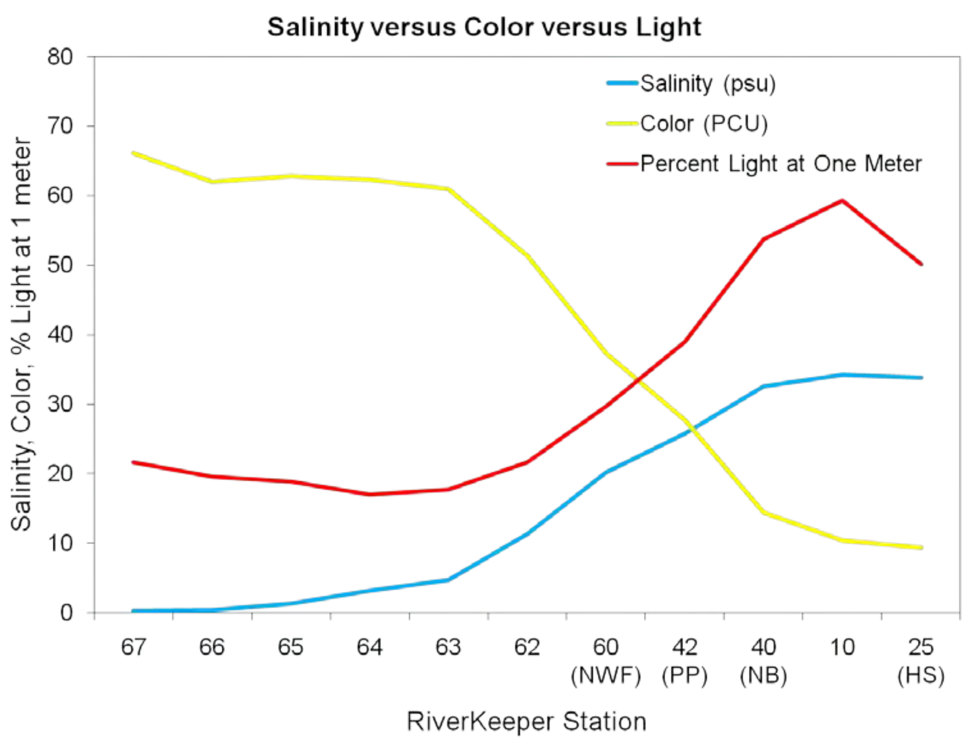


**Figure 5-10. Mean salinity, color and light values plotted from upstream to downstream along a salinity gradient**

In the legend, PCU is platinum-cobalt units. Along the x-axis, NWF is Northwest Fork, PP is Pennock Point, NB is North Bay, and HS is Hobe Sound.

Pennock Point

At RM 2.5, the Pennock Point seagrass bed has been monitored since June 2003. It is adjacent to River Keeper water quality station 42. As with the Northwest Fork site, only Johnson's seagrass and shoal grass occur at this location. Unlike the Northwest Fork location, this site was monitored prior to the 2004 hurricanes, providing the opportunity to document impacts and recovery. Seagrass resources at this location appear to have fully recovered. In 2010, shoal grass occupied roughly 60 percent of the seagrass patch and Johnson's seagrass occupied 30 to 70 percent of the seagrass patch. Johnson's seagrass has exhibited a pronounced increase in occurrence especially since 2008. Average seagrass canopy height is similar to the Northwest Fork site; typically less than 10 cm. Hydrologic stressors at this location include low average salinity that varies over a wide range, as well as elevated color resulting in low light (**Figure** 5-10) and may contribute to factors preventing colonization and persistence by manatee grass at this location. A datasonde, recording salinity at 15 minute intervals, is co-located with the seagrass monitoring site and has been in place since January 2004. LRD's 2010 report (www.loxahatcheeriver.org/reports.php) provides salinity envelope analysis that illustrates the variability in salinity at this station and along the salinity gradient in the estuary. Clearly, the Pennock Point and North Bay seagrass stations are subject to greater fluctuations in salinity, relative to the downstream stations (Sand Bar and North Bay).

<u>Sand Bar</u>

The Sand Bar site is located at RM 1.8. As at Pennock Point, both shoal grass and Johnson's seagrass appear to have made a full recovery. Manatee grass occurred in 30 to 40 percent of Sand Bar samples prior to the 2004 hurricanes, but was only found in small, sparse patches occupying less than 10 percent of samples in 2010. Reasons for manatee grass' lack of recovery at the Sand Bar site may include sand deposition, resulting in the former manatee grass location in the bed now becoming exposed at extreme low tides (i.e., too shallow to support manatee grass). Water quality has been stable at this site since the hurricanes so should not preclude manatee grass recovery. Johnson's seagrass has a pronounced seasonality at this site with annual peaks typically occurring in April, though peak abundance in 2008 occurred in February. In general, seagrass canopy height averages around 10 cm at the Sand Bar except for patches that contain manatee grass where canopy height peaks around 20 cm. Since this site is closer to the influence of the Jupiter Inlet, hydrologic stressors discussed for the upstream sites are not as pronounced at this site. Heavy human use, as well as shallow depths, may play a role in seagrass species composition at this location.

<u>North Bay</u>

The North Bay site, the most downstream Loxahatchee River Estuary seagrass monitoring location, is located at RM 1.5. Prior to the 2004 storms, this seagrass bed was dominated by manatee grass. While manatee grass appears to be mounting a slow and steady recovery, the present occurrence of manatee grass remains about 50 percent of its predisturbance occurrence. Shoal grass has occurred in approximately 70 percent of North Bay samples since August 2010. Johnson's seagrass showed significant increases in occurrence the two years following hurricane impacts, but declined to near predisturbance occurrence levels (approximately 20 percent) in 2010 as canopy forming species moved in. Maximum canopy height within the North Bay was generally around 30 cm, with manatee grass forming the tallest canopy. This site has the most stable salinity regime of the Loxahatchee River Estuary sites, which may explain why manatee grass is more successful here than anywhere else in the Central Embayment. A data sonde recording salinity at 15 minute intervals is co-located with the seagrass monitoring site and has been in place since January 2004. The less variable and generally higher salinity at this site (www.loxahatcheeriver.org/reports.php) provides insight into the salinity tolerances for manatee grass, turtle grass and, to a lesser extent, paddle grass.

Hobe Sound

Located north in the Intracoastal Waterway the reference seagrass bed in Hobe Sound continued to exhibit relatively stable seagrass community composition. It is adjacent to River Keeper and data sonde water quality station 25. Manatee grass occupied nearly 80 percent of the bed throughout the year. Shoal grass occupied around 40 percent of the bed for most of the year, and Johnson's seagrass generally occupied less than five percent of the seagrass bed. Canopy height at Hobe Sound was generally found to be 30 to 40 cm with manatee grass as the dominant canopy species. Analysis of the data sonde data ((January 2006 – February 2008; www.loxahatcheeriver.org/reports.php) indicates very stable and relatively high salinity conditions at this site due to the lack of freshwater inflows. As such, manatee grass, a canopy forming species sensitive to salinity fluctuations, has uniformly dominated this site through time.

### 5.1.4 Conclusions

Tremendous gains have occurred in our knowledge of the seagrass resources of the Loxahatchee River Estuary since the completion of the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006):

- Detailed species mapping results confirmed that shoal grass and Johnson's seagrass are the dominant seagrass species throughout the estuary.
- Maps from aerial photographs revealed the dynamic nature of the core seagrass beds, especially in the Central Embayment.
- An apparent increasing trend in seagrass bed acreage that can be mapped from aerial photographs upstream of the railroad bridge was documented from 2003 through 2007.
- Water quality comparisons with seagrass beds along a salinity gradient show that only shoal grass and Johnson's seagrass are successful in the darker water areas with the greatest salinity variations.
- Seagrass species diversity increases downstream of RM 2 because of more stable and higher salinity.
- Post-hurricane recovery has been documented at most of the monitoring locations. However, manatee grass has not recovered at the Sand Bar site (Ridler et al. 2006). Because water quality seems suitable for recovery and source plants are nearby, other factors may be important. It is possible that changes in bathymetry over time and heavy human use of the area preclude recovery.
- The dynamic nature of the sediments in the Loxahatchee River Estuary, especially the lower portion of the Central Embayment, may play important roles in seagrass distribution including species distribution.

### 5.1.5 Recommendations

Recommendations related to seagrass restoration in the Loxahatchee River Estuary are as follows:

- Continue bimonthly seagrass and associated water quality data collection programs to further characterize variability in seagrass distributions relative to the spectrum of water quality conditions.

- Further investigate and evaluate existing seagrass and water quality data. Additional analysis and insight will provide a better understanding of differences in salinity regimes and profiles among seagrass patches and provide essential information for adaptive management of future restoration activities.

- Continue the landscape-scale species-specific mapping at three-year intervals to further assess and document the extent of seagrass species variation and distribution under the present spectrum of water quality conditions.

- Continue mapping from aerial photographs on a five-year interval as recommended by the CERP Monitoring and Assessment Plan (RECOVER 2009). Aerial photographs are scheduled to be taken in 2012. However, it is recommended that the next image acquisition take place in conjunction with the 2013 quadzilla mapping field work and that field work, especially south of the Sand Bar site, be conducted as close to the date of imagery acquisition as possible.

- Locate and evaluate all available bathymetric data for seagrass dominated areas of the Loxahatchee River Estuary. Evaluation of this data may help our understanding of the dynamic seagrass bed shifts (size and shape) and species distribution in the Loxahatchee River Estuary.

## 5.2 Oysters

Oysters have also been selected as VEC candidates within the estuarine portion of the Loxahatchee River watershed. According to historical accounts, during the late nineteenth and early twentieth centuries, the Loxahatchee River Estuary supported a large and robust oyster population within the Central Embayment, only a few miles from the Jupiter Inlet. Changes in water quality and volumes, and bottom sediment composition over the past sixty years have served to greatly alter and diminish the quality of environmental conditions.

### 5.2.1 1991 Survey

In 1991, Law Environmental, Inc. conducted an evaluation of live oysters within the estuary for the Jupiter Inlet District (Law Environmental, Inc. 1991). The report documented minimal presence of oyster bars in the Central Embayment and the north prong, but a more substantial presence near the mouths of the Northwest and Southwest Forks. During that study, two species of oyster were observed to be living within the estuary, the eastern oyster (*Crassostrea virginica*) and the flat tree oyster (*Isognomon alatus*). While both species were documented, the dominant species found in both the Northwest and Southwest Forks of the Loxahatchee River was the eastern oyster. The flat tree oyster was found closest to the inlet, within the Central Embayment and not found concentrated in bars, but rather living on seawalls and pilings. The estuarine portion of the North Fork supported no oyster beds, limiting the areas of oyster presence to the seawalls and pilings.

### 5.2.2 2003 Survey

Another study completed by LRD (2004b) had the following objectives:

- Identify the composition of the oyster community and record the environmental conditions present.
- Define and map the distribution patterns of the oysters in each of the major segments of the estuary.
- Evaluate the health and viability of the observed oysters by documenting oyster size, density and viability.

The study area is shown in **Figure 5-11**. The study resulted in the identification of 72 oyster beds, typically small in size and covering approximately ten acres in total. These beds were mapped. Oyster sampling points were established on twelve of the beds, including four in the Northwest Fork and eight in the Southwest Fork. The beds were almost exclusively composed of eastern oysters with flat tree oysters appearing at only four sites and never contributing more

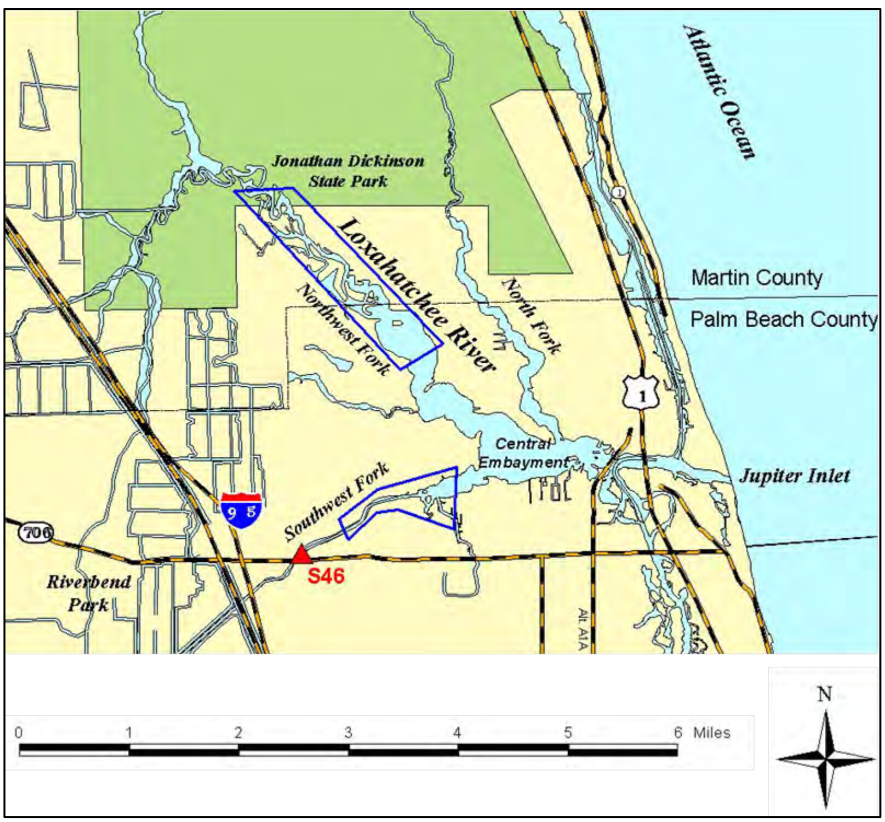


**Figure 5-11. Oyster bed study area**

From LRD 2004b

than seven percent of the individuals. The greatest number of beds, largest spatial distribution and highest living densities were recorded within the Northwest Fork. The oysters observed in both forks were generally small in size (less than 5 cm) and the percentage of live oysters typically exceeded 75 percent of all individuals counted.

Northwest Fork

**Figure 5-12** shows the 48 oyster beds within the Northwest Fork. All were found within seven miles of the Jupiter Inlet. Relative extent of oyster bar distribution of areas of greater than one square meter, supporting greater than five live oysters was described as approximately nine total acres (LRD 2004b). **Figure 5-12** also identifies the four oyster monitoring stations located in the Northwest Fork where specific data regarding size, density and viability was obtained.

The eastern oyster was found exclusively at each of three sampling points in the Northwest Fork. Flat tree oysters accounted for less than 0.5 percent of the individuals observed at station 4. The recorded densities in the Northwest Fork ranged from 167 to 901 oysters per square meter ($/m^2$) of oyster bar habitat.

Oyster size and the percentage of live organisms compared to total count of live oysters and oyster shell were assessed to evaluate the health and viability of oysters. Over three-quarters of the oysters observed at the four monitoring sites fell into the smallest size category. Class size counts included: 1,672 individual live oysters measured less than 5 cm, 503 were sized between 5 and 10 cm and only four oysters were greater than 10 cm in size. The relationship of live versus dead oysters for the four monitoring stations ranged from 61 percent live oysters found at station 5 to 88 percent of live oysters recorded at station 4.

Southwest Fork

**Figure 5-13** shows the observed oyster beds and the specific sampling points located in the Southwest Fork and associated tributaries of Jones and Sims Creeks. During the study, 24 oyster beds were documented within this area (LRD 2004b). These oyster beds were characterized as substantially smaller than those observed in the Northwest Fork and covering less than one acre in total, including one very small bed found 0.5 miles upstream (station 1). The beds were mainly distributed within a 0.5 mile reach of the channelized portion of the Southwest Fork and approximately 0.3 miles into Jones and Sims Creeks. Approximately 3.5 miles from the Jupiter Inlet was the eastern most extent where oyster reefs were identified.

The eastern oyster was the sole species identified at five of the eight stations and predominant species found within this reach. The very limited population, of which flat tree oysters consisted of less than seven percent, was identified at stations 3, 5 and 7. The densities, in numbers of live oysters, recorded at each of the eight monitoring stations in the Southwest Fork and tributary streams range from 23 to 457 organisms/$m^2$.

Approximately 58 percent of the individuals fell within the less than 5 cm group, while nearly 40 percent were in the 5 to 10 cm category. A small percentage, 1.9 percent of the oysters, was greater than 10 cm in size.


**Figure 5-12. Oyster beds and selected monitoring sites on the Northwest Fork**

From LRD (2004b).

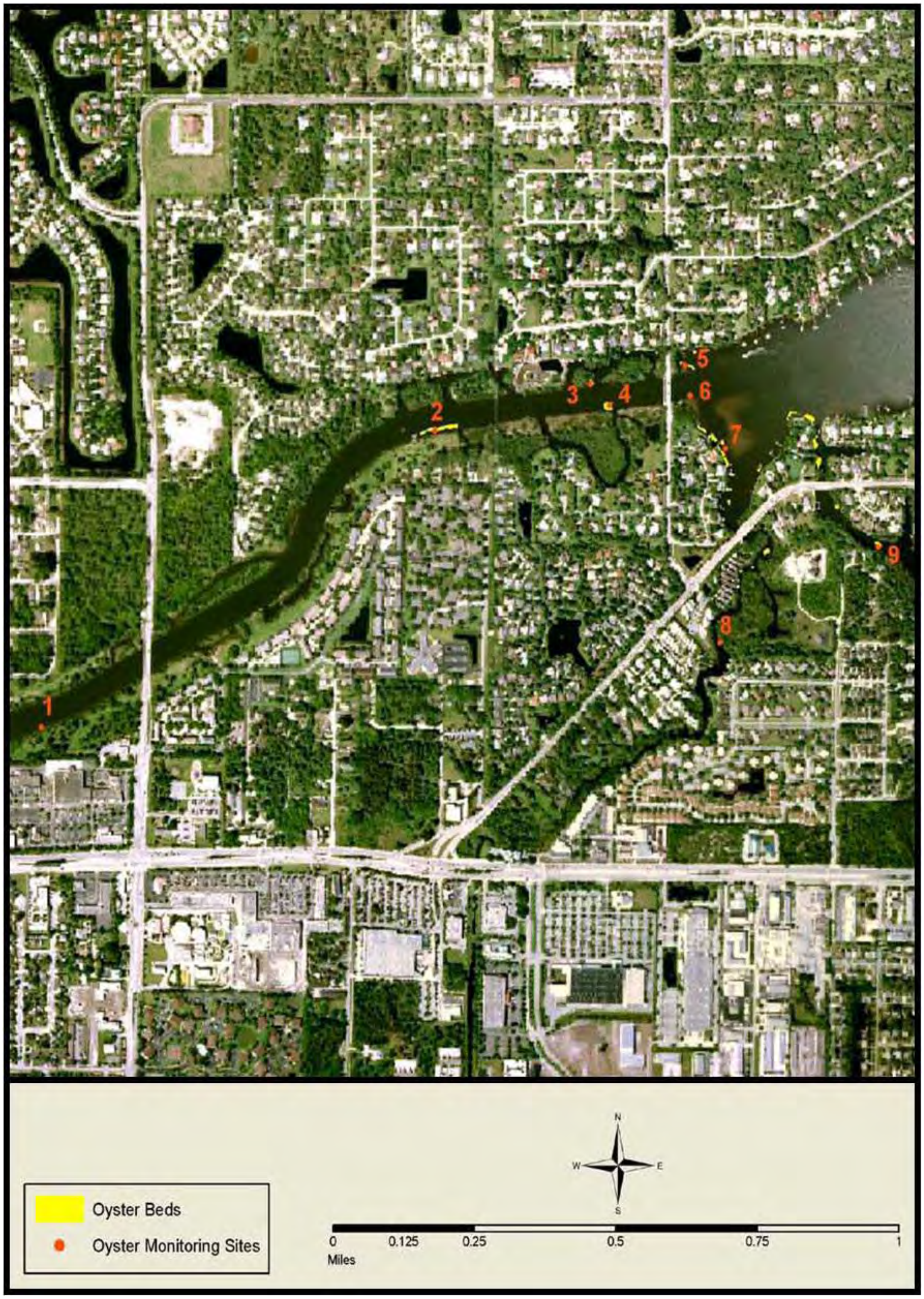


**Figure 5-13. Oyster beds and selected monitoring sites on the Southwest Fork and its tributaries**

From LRD (2004b).

### 5.2.3 2008 Survey

In 2008, LRD staff mapped a total of 91 oyster reefs, with a total area of over 15 acres, throughout the Northwest and Southwest Forks (**Figure 5-14**) (LRD 2008). The 56 oyster reefs in the Northwest Fork comprised over 90 percent of the total acreage mapped in 2008 (**Table** 5-2). While 35 oyster reefs were identified in the Southwest Fork, these smaller reefs totaled only 1.2 acres in area. Overall, the 2008 survey was able to identify nearly 50 percent more acreage of oyster reefs than were observed during the survey in 2003.

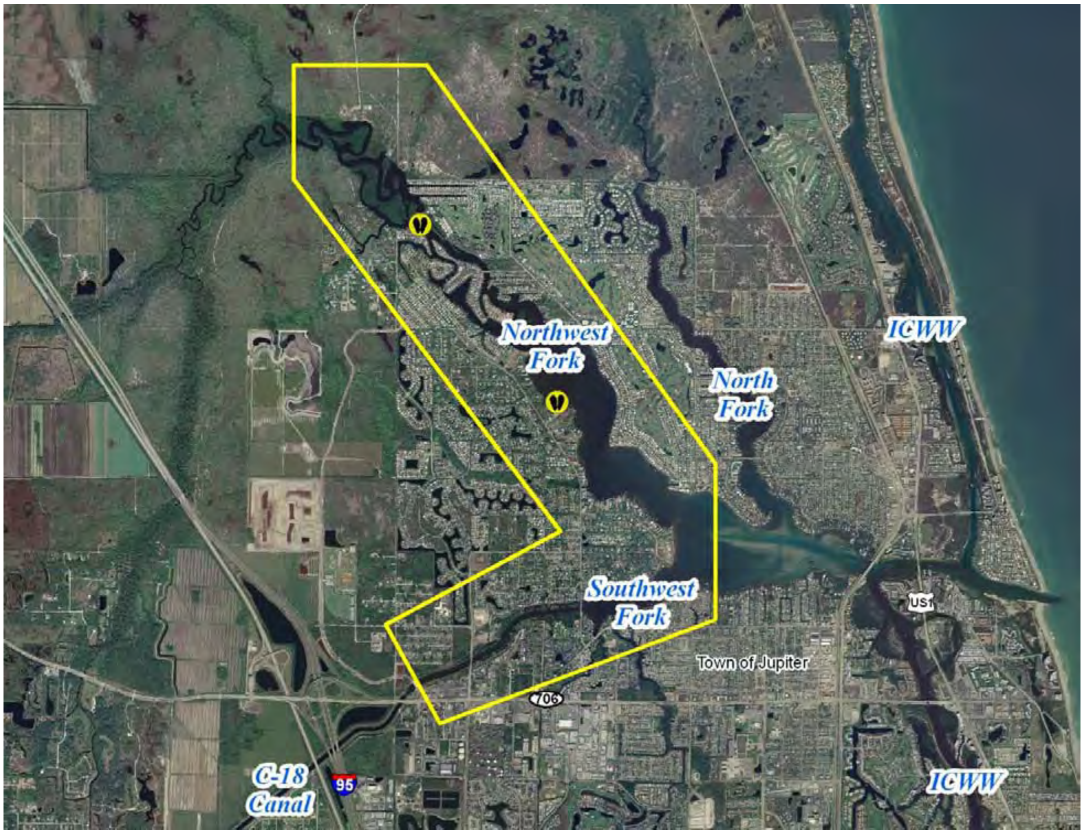


**Figure 5-14. Oyster reef mapping and assessment project area in the Loxahatchee River 2008 survey**

From LRD (2008)

**Table 5-2. Number and acres of oyster reefs within the Loxahatchee River**

| | | 2003 | 2008 |
|---|---|---|---|
| Northwest Fork | Number of reefs | 48 | 56 |
| | Acres | 9.5 | 13.9 |
| Southwest Fork | Number of reefs | 24 | 35 |
| | Acres | 0.7 | 1.2 |
| Total | Number of reefs | 72 | 91 |
| | Acres | 10.2 | 15.1 |

<u>Density</u>

Eastern oyster density was calculated via summary statistics excluding oysters with a shell height less than 2.5 cm. When the small, newly recruited oysters were excluded from the density calculations, oyster density between the Northwest and Southwest Forks was similar. This may suggest more recruitment occurred in the Northwest Fork or may have been a sampling artifact due to surveys of more Northwest Fork sites during high recruitment months.

Excluding newly recruited oysters, that is, those smaller than 2.5 cm, approximate eastern oyster density was 120/m$^2$. Of these smaller oysters, approximately 79 percent were alive, with similar results in the Northwest and Southwest Forks at 80 and 74 percent, respectively.

In general, oyster reefs in the Northwest Fork had highest densities of live oysters between RM 4 and RM 6 (**Figure 5-15**). Many of the long lived and well studied oyster reefs in the vicinity of the mangrove islands south of the Island Way Bridge showed moderate densities ranging from 50 to 150 live oysters/m$^2$. Oyster densities in the Southwest Fork showed similar spatial variability in live oyster density (**Figure 5-16**). Most apparent is the lack of high density oyster reefs (greater than 150 live oysters/m$^2$) in the Southwest Fork (LRD 2008).

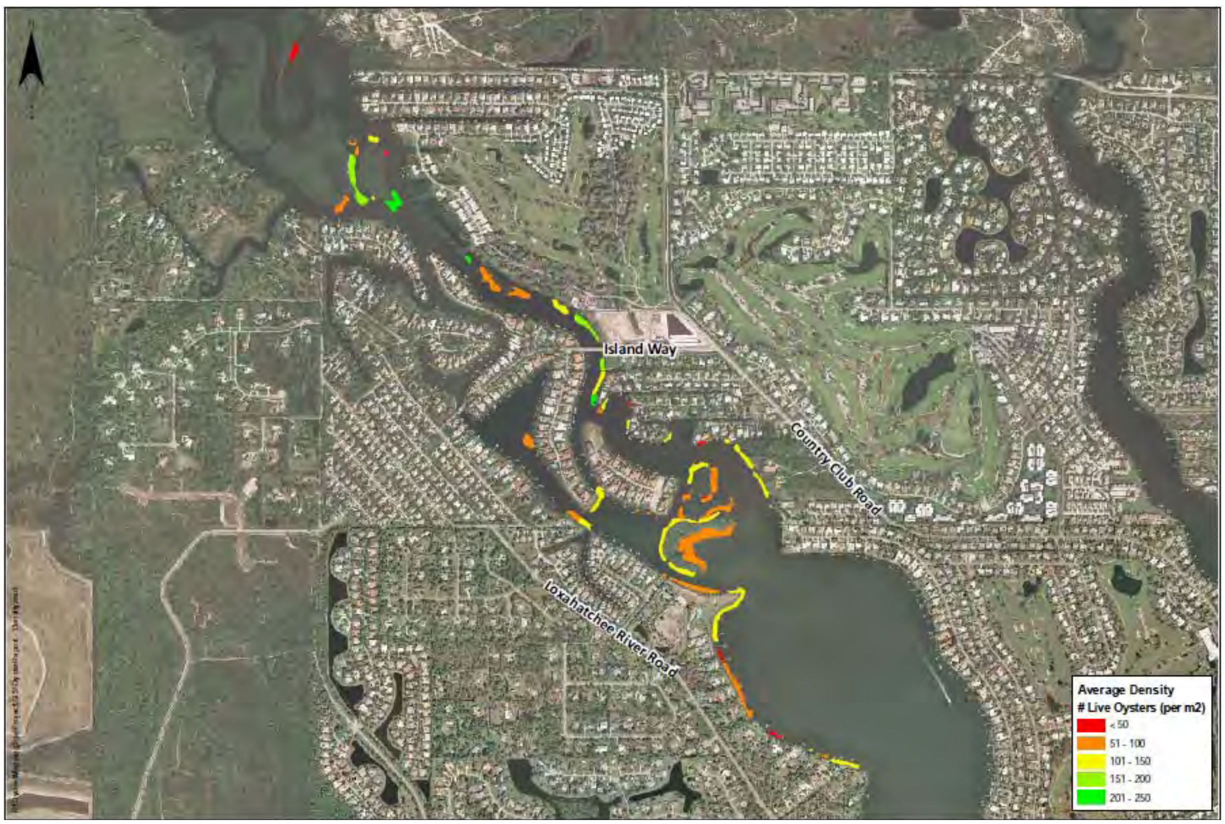


**Figure 5-15. Average live oyster density per square meter in each reef mapped in 2008 in the Northwest Fork of the Loxahatchee River**

Excludes small (<2.5 cm) new recruits.

From LRD (2008).


**Figure 5-16. Average live oyster density per square meter in each reef mapped in 2008 in the Southwest Fork of the Loxahatchee River**

Excludes small (<2.5 cm) new recruits.

From LRD (2008)

In the Northwest Fork, the lowest proportion of live oysters was found in the reefs furthest up- and downstream (**Figure 5-17**). In the Southwest Fork, the upstream oyster reefs had similar findings but with substantially more spatial variability in the percentage of live oysters throughout the area (**Figure 5-18**).

Size

As was done when determining oyster density, overall eastern oyster size was calculated via summary statistics excluding oysters with a shell height less than 2.5 cm. Across the entire Loxahatchee River, eastern oyster average size (i.e., shell height) was 3.2 cm, or 4.8 cm when newly recruited oysters (less than 2.5 cm) were excluded. Oysters in the Southwest Fork were generally larger than those in the Northwest Fork, at 4.4 and 5.7 cm, when excluding the new recruits.

Oysters in the Northwest Fork were generally smaller in the reefs upstream of the Island Way Bridge. The reefs containing the largest oysters were found along the south shoreline, south of the Island Way Bridge. In the Southwest Fork, distribution of the generally larger, live oyster shells was scattered.


**Figure 5-17. Percentage of live oysters in each reef in 2008 in the Northwest Fork**


**Figure 5-18. Percentage of live oysters in each reef in 2008 in the Southwest Fork**

Both figures are from LRD (2008).

Recruitment

Monthly oyster spat monitoring by the LRD showed variable settlement patterns at the upstream and downstream monitoring sites in the Northwest and Southwest Forks as indicated in **Figure** 5-19 and **Figure 5-20**. The data suggest oyster recruitment peaks in the spring and summer in the Loxahatchee River, but some degree of oyster recruitment occurs most months. The highest oyster spat settlement occurred in September 2007 at the downstream site with an average of more than 20 oyster spat per shell. The monitoring data from the Southwest Fork was also variable with the highest recruitment occurring in October 2008, January 2009, April 2009, August/September 2009, May 2010, August/September 2010, May 2011 and September 2011. These findings were consistent with those obtained by the Fish and Wildlife Research Institute (FWRI) recruitment findings at sites located between LRD's upstream and downstream sampling sites.

In 2009, monthly oyster spat monitoring by the LRD showed variable settlement patterns as indicated in **Figure 5-21** and **Figure 5-22** for the Northwest and Southwest Forks, respectively. In general, these results show oyster recruitment occurred every month sampled except February.

The oyster spat recruitment counts were significantly lower in the Southwest Fork, with typically less than half the spat settlement measured in Northwest Fork sampling sites. The lower oyster recruitment may be due to less oyster seed source from the fewer naturally occurring oysters or more variable conditions than those found in the Northwest Fork. For example, salinity in the Southwest Fork is consistently higher (between 25–35 practical salinity units [psu]) than in the Northwest Fork during the dry season (winter months). In contrast, the Southwest Fork can experience extreme freshwater influences during the summer wet season as a result of substantial freshwater discharges from the S-46 water control structure draining water from the C-18 Canal.

### 5.2.4 2009 FMRI Long-term Study

The Florida Marine Research Institute (FMRI), a division of the Florida Fish and Wildlife Conservation Commission (FWC), conducted oyster monitoring on the Northwest and Southwest Forks of the Loxahatchee River in 2009. Monitoring included four aspects of oyster ecology and health: (1) spatial and size distribution patterns of adult oysters, (2) reproduction and recruitment, (3) juvenile oyster growth and (4) distribution and frequency patterns of the oyster diseases *Perkinsus marinus* (dermo) and *Haplosporidium nelsoni* (MSX). Coordinates for each sampling reef are provided in **Table 5-3**.

**Table 5-3. CERP oyster monitoring sites in the Loxahatchee River**

| Fork | Station | Latitude °N | Longitude °W |
|---|---|---|---|
| Northwest Fork | 1 | 26 58.164 | 80 07.688 |
| | 2 | 26 58.237 | 80 07.649 |
| | 3 | 26 58.370 | 80 07.686 |
| Southwest Fork | 1 | 26 56.574 | 80 07.112 |
| | 2 | 26 56.630 | 80 07.280 |

°N is degrees north. °W is degrees west.
Adapted from FWC (2010).

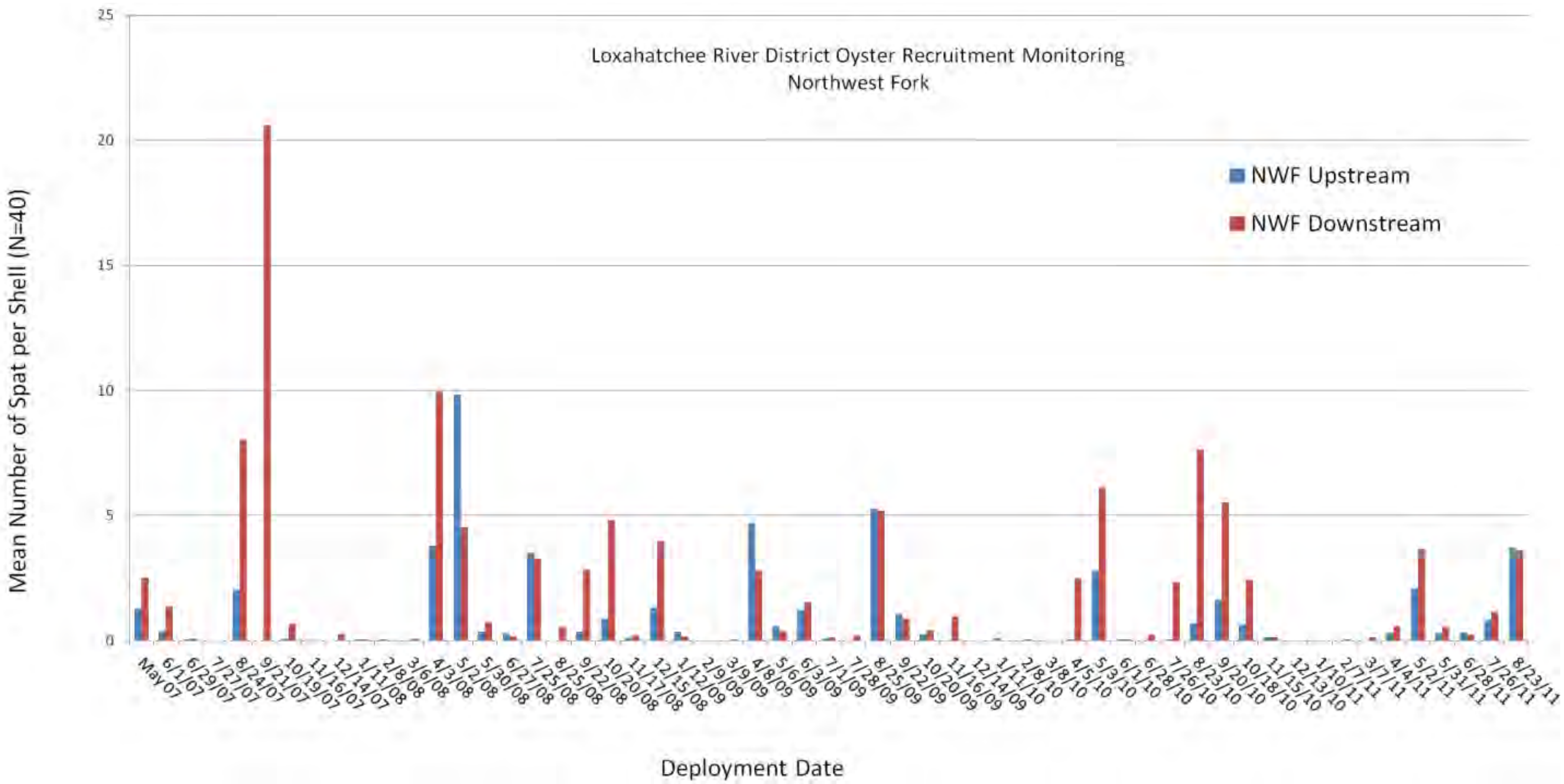


**Figure 5-19. Mean monthly oyster spat in the Northwest Fork of the Loxahatchee River**

From LRD (2011)

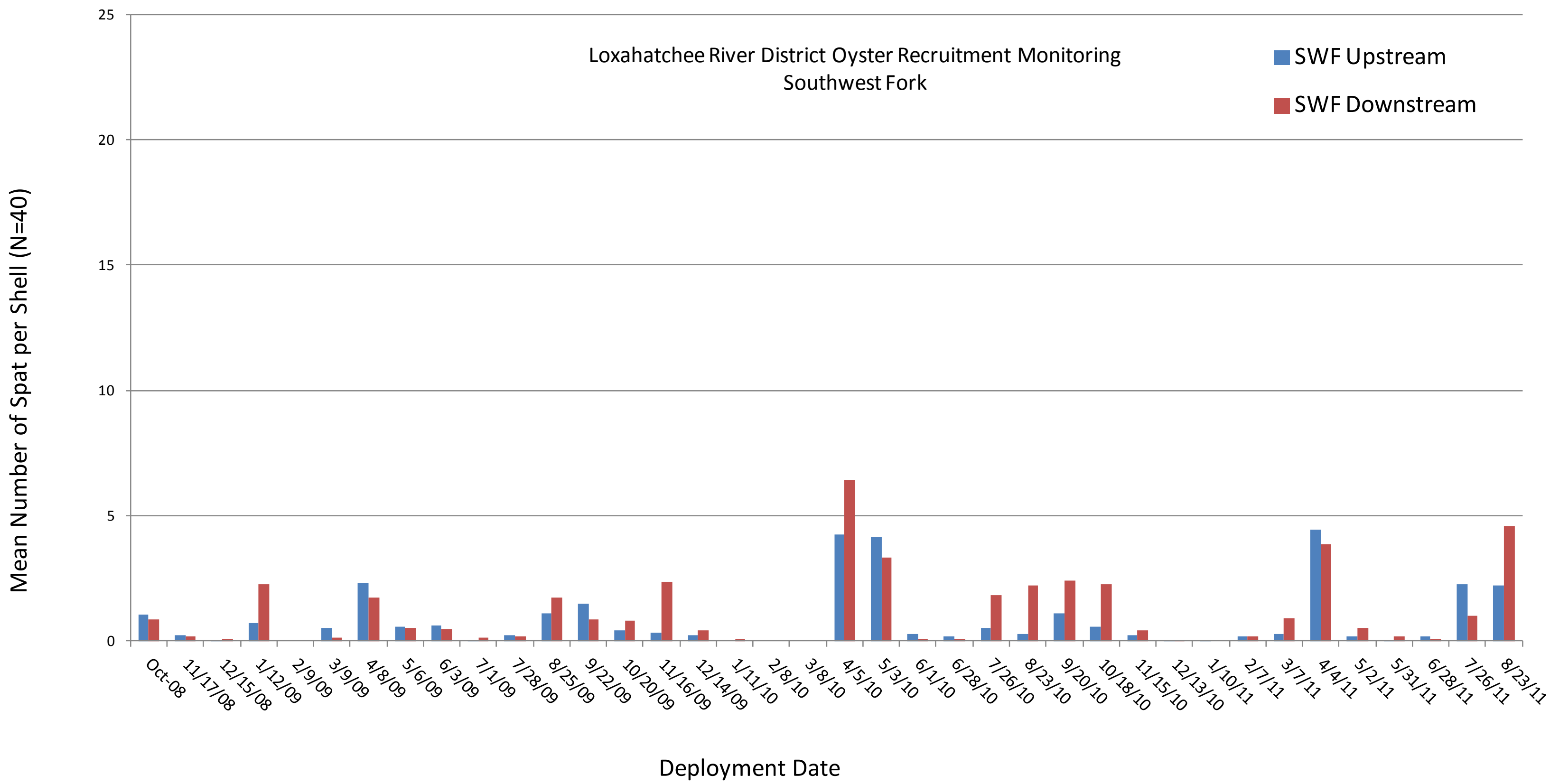


**Figure 5-20. Mean monthly oyster spat in the Southwest Fork**

From LRD (2011)

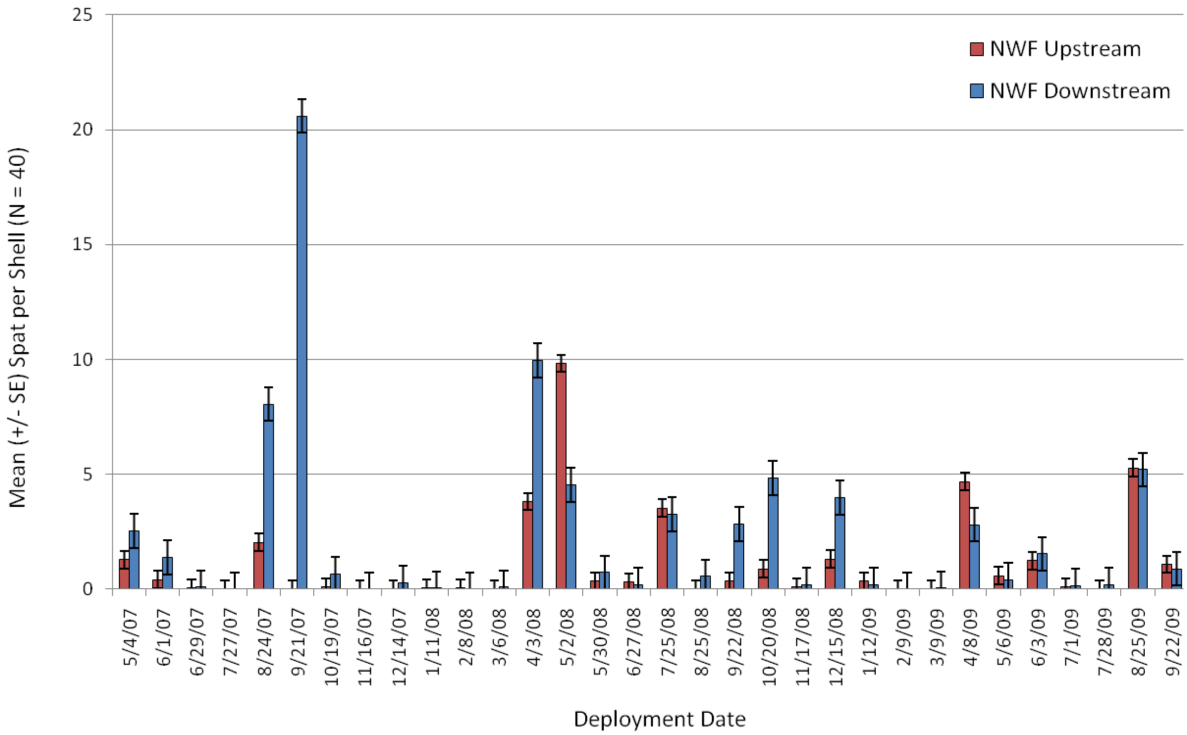


**Figure 5-21. Mean (± standard error) oyster spat recruitment using "oyster Ts" in the Northwest Fork**

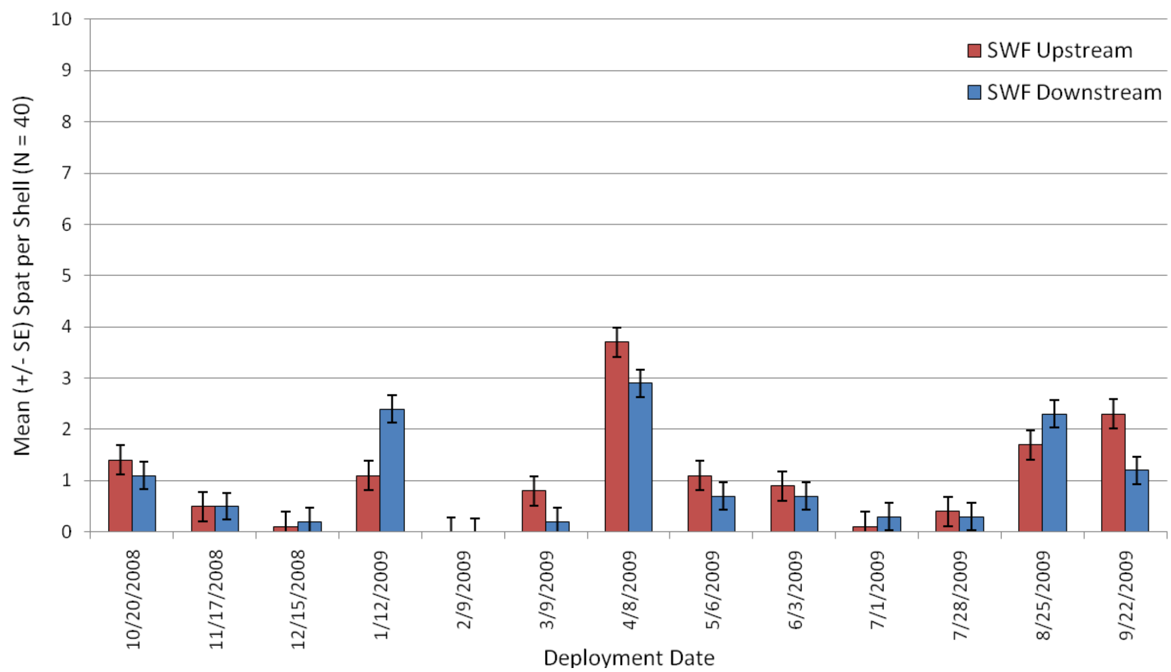


**Figure 5-22. Mean (± standard error) oyster spat recruitment using "oyster Ts" in the Southwest Fork**

SE - standard error; N - sample size; NWF - Northwest Fork; SWF - Southwest Fork

From LRD (2008)

Salinity

The eastern oyster thrives in salinity from 10 to 30 psu, but does poorly when salinity falls below 5 psu for a period of from one to five months (Shumway 1996). Salinity continues to be the driving force behind changes in oyster survival, abundance and health in the study sites. Although oysters in each estuary were subjected to large variations in salinity, 2009 had no extreme rainfall events or prolonged freshwater releases.

Density

Oyster densities exhibited similar patterns to those seen in the 2008 survey discussed above. Mean live oyster densities exceeded 400/m$^2$ in the spring and increased significantly to over 700/m$^2$ in the fall (**Figure 5-24**) (FWC 2010). Doubling of oyster density doubling was also seen in the Northwest Fork in 2008, but at slightly lower densities with 250/m$^2$ in the spring versus 500/m$^2$ in the fall. In contrast, in the Southwest Fork, live oyster densities were similar between spring and fall at stations 1 and 2 with a nonsignificant decrease in station 3 counts only. Fall 2009 mean shell heights in the Northwest Fork ranged from 35 to 37 millimeters (mm) and in the Southwest Fork from 29 to 41 mm (**Figure 5-23**). Dead oyster density patterns were similar between seasons and reflected those seen in previous years (**Figure 5-24**) (FWC 2010).

Despite the fact that the Loxahatchee River sites are rarely impacted by low salinity events, local salinity regimes do influence density patterns both directly and indirectly. In 2009, oyster densities in the Northwest Fork increased from spring to fall while densities in the Southwest Fork were similar between seasons. Salinity at the Northwest Fork site was relatively lower and closer to the optimal range for maximal oyster survival and recruitment success throughout the year (annual average of 18.5 psu) allowing densities to increase between seasons. In contrast, salinity in the Southwest Fork site was much higher, reaching annual averages of 25 psu or greater. While the average salinity is within the tolerance range for oysters (10–30 psu), it is important to note that salinity at the site was near or exceeded 30 psu for six months of the year. As a consequence, oyster densities were likely kept in check by a resultant increase in predation and/or disease incidence related to the high salinity (FWC 2010).

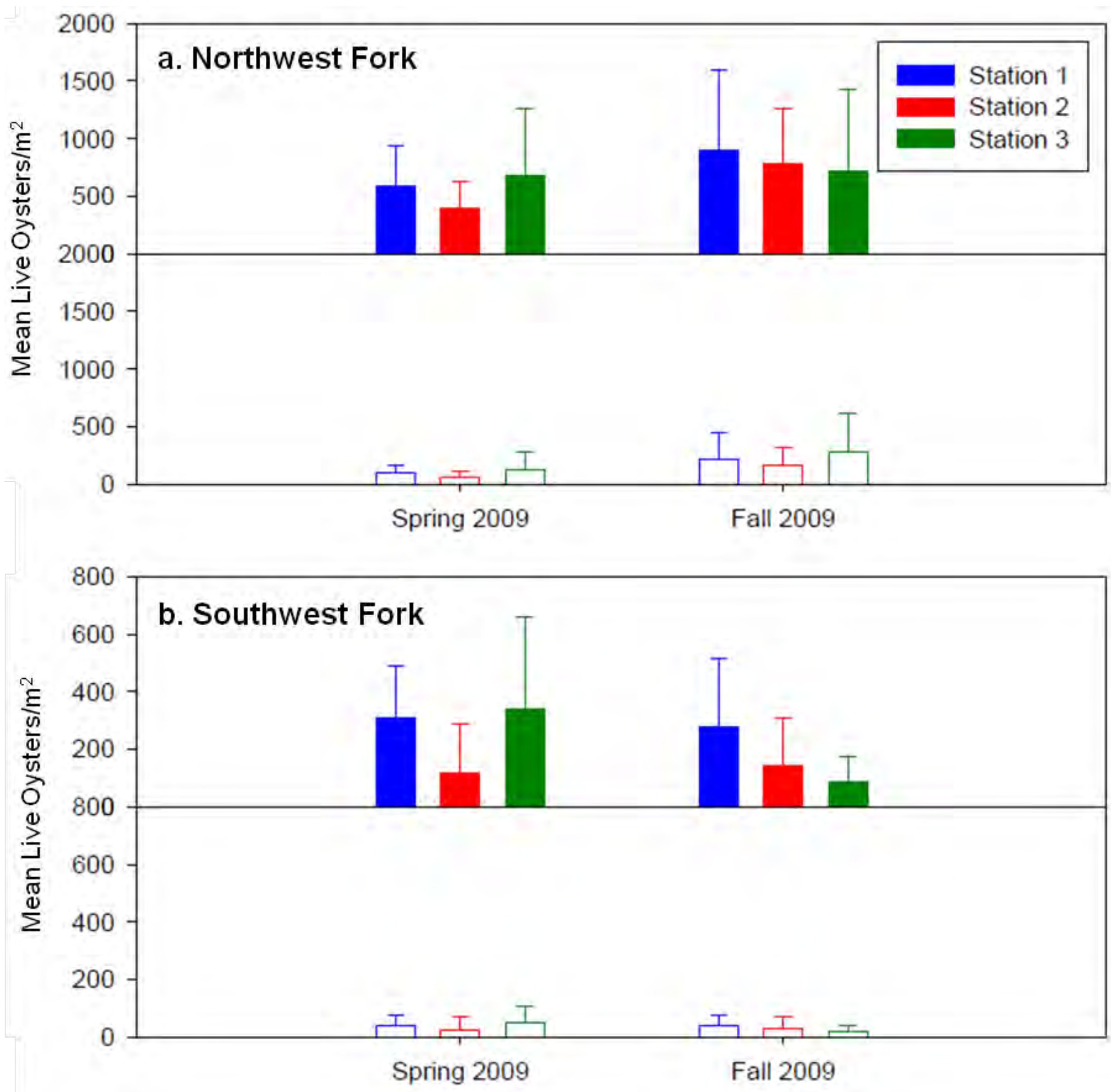


**Figure 5-23. Mean shell height (+ standard deviation) of live oysters present at (a) Northwest Fork and (b) Southwest Fork study sites during the spring and fall 2009 surveys**

Filled bars represent the number of live oysters and the hollow bars represent the number of dead oysters with articulated shells. Please note the differences in the y-axis range between the two study sites.

Adapted from FWC (2010).

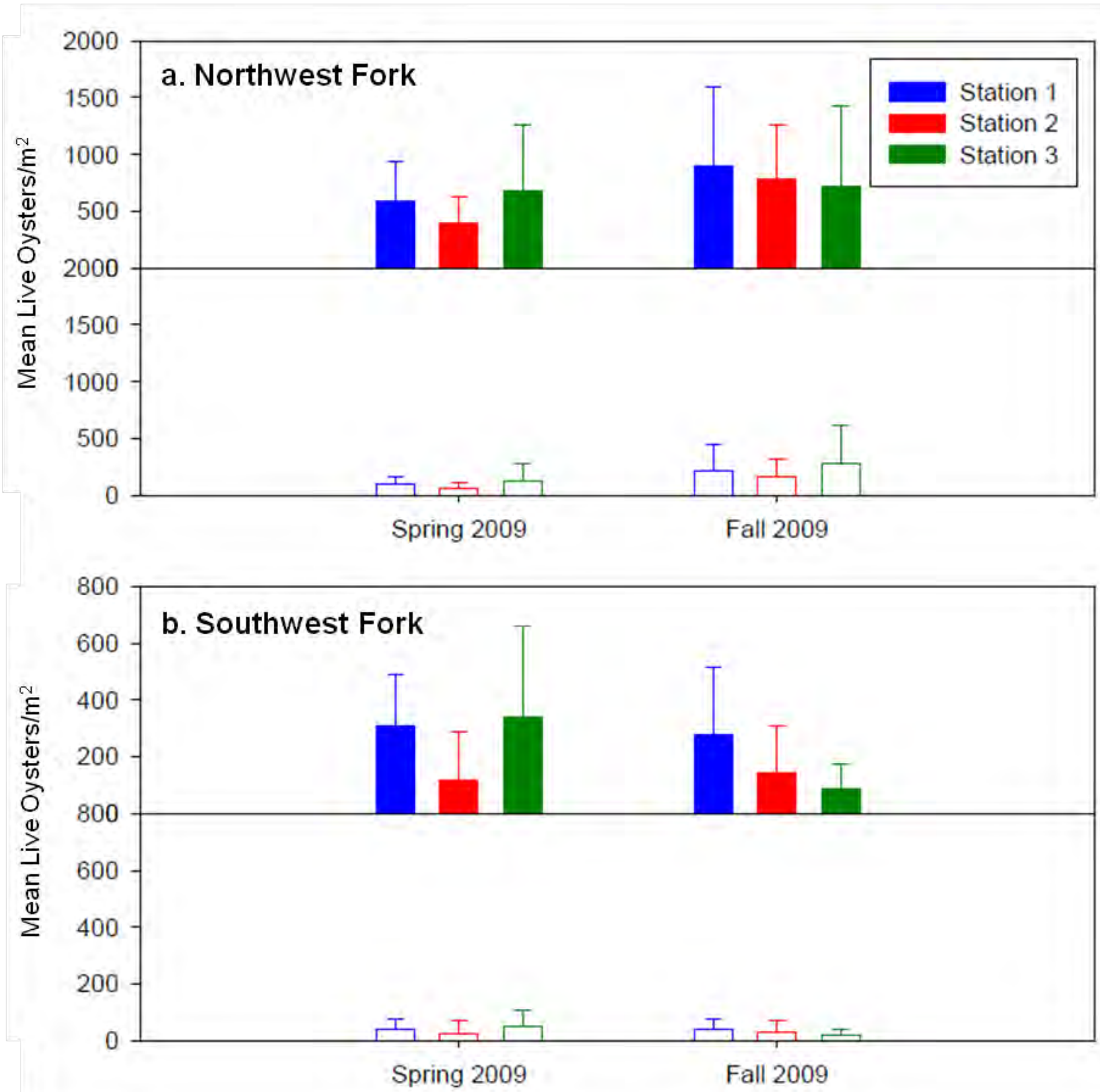


**Figure 5-24. Mean number (+ standard deviation) of live and dead oysters present (density) at (a) Northwest Fork and (b) Southwest Fork study sites during the spring and fall 2009 surveys**

Filled bars represent the number of live oysters and the hollow bars represent the number of dead oysters with articulated shells. Please note the differences in the y-axis range between the two study sites.

Adapted from FWC (2010).

<u>Reproduction</u>

Each sample was assigned a reproductive stage following the classification scheme provided in **Table 5-4**, which is modified from the work of Fisher et al. (1996) and FWC (2010). For graphical presentation, the 11 reproductive stages have been simplified by combining them into four different categories: (1) indifferent stage, (2) developing stage, (3) ripe/spawning stage and (4) spent/recycling stage.

**Table 5-4. Reproductive staging criteria for oysters collected from Florida waters**

<table>
<tr><th>Value</th><th>Observations</th><th>Simplified<br>Stage Categories</th></tr>
<tr><td>0</td><td>Neuter or resting stage with no visible signs of gametes</td><td>Indifferent stage</td></tr>
<tr><td>1</td><td>Gametogenesis has begun with no mature gametes</td><td rowspan="4">Developing stage</td></tr>
<tr><td>2</td><td>First appearance of mature gametes to approximately one-third mature gametes in follicles</td></tr>
<tr><td>3</td><td>Follicles have approximately equal proportions of mature and developing gametes</td></tr>
<tr><td>4</td><td>Gametogenesis progressing, but follicles dominated by mature gametes</td></tr>
<tr><td>5</td><td>Follicles distended and filled with ripe gametes, limited gametogenesis, ova compacted into polygonal configurations, and sperm have visible tails</td><td rowspan="2">Ripe/spawning stage</td></tr>
<tr><td>6</td><td>Active emission (spawning) occurring, general reduction in sperm density or morphological rounding of ova</td></tr>
<tr><td>7</td><td>Follicles one-half depleted of mature gametes</td><td rowspan="3">Spent/recycling stage</td></tr>
<tr><td>8</td><td>Gonadal area is reduced, follicles two-thirds depleted of mature gametes</td></tr>
<tr><td>9</td><td>Only residual gametes remain, some cytolysis evident</td></tr>
<tr><td>10</td><td>Gonads completely devoid of gametes, and cytolysis is ongoing</td><td>Indifferent stage</td></tr>
</table>

Adapted from FWC (2010).

Analysis of gonadal tissues indicated that most oysters were in various stages of reproductive development including gametogenesis, active spawning and gonadal recycling throughout most of 2009 (**Figure 5-25**). However, oysters classified as either developing or ripe/spawning were more prevalent during the summer months in the Northwest Fork and during the first few months of 2009 in the Southwest Fork. In the fall, reproductive development began decreasing as more oysters entered the winter resting stage.

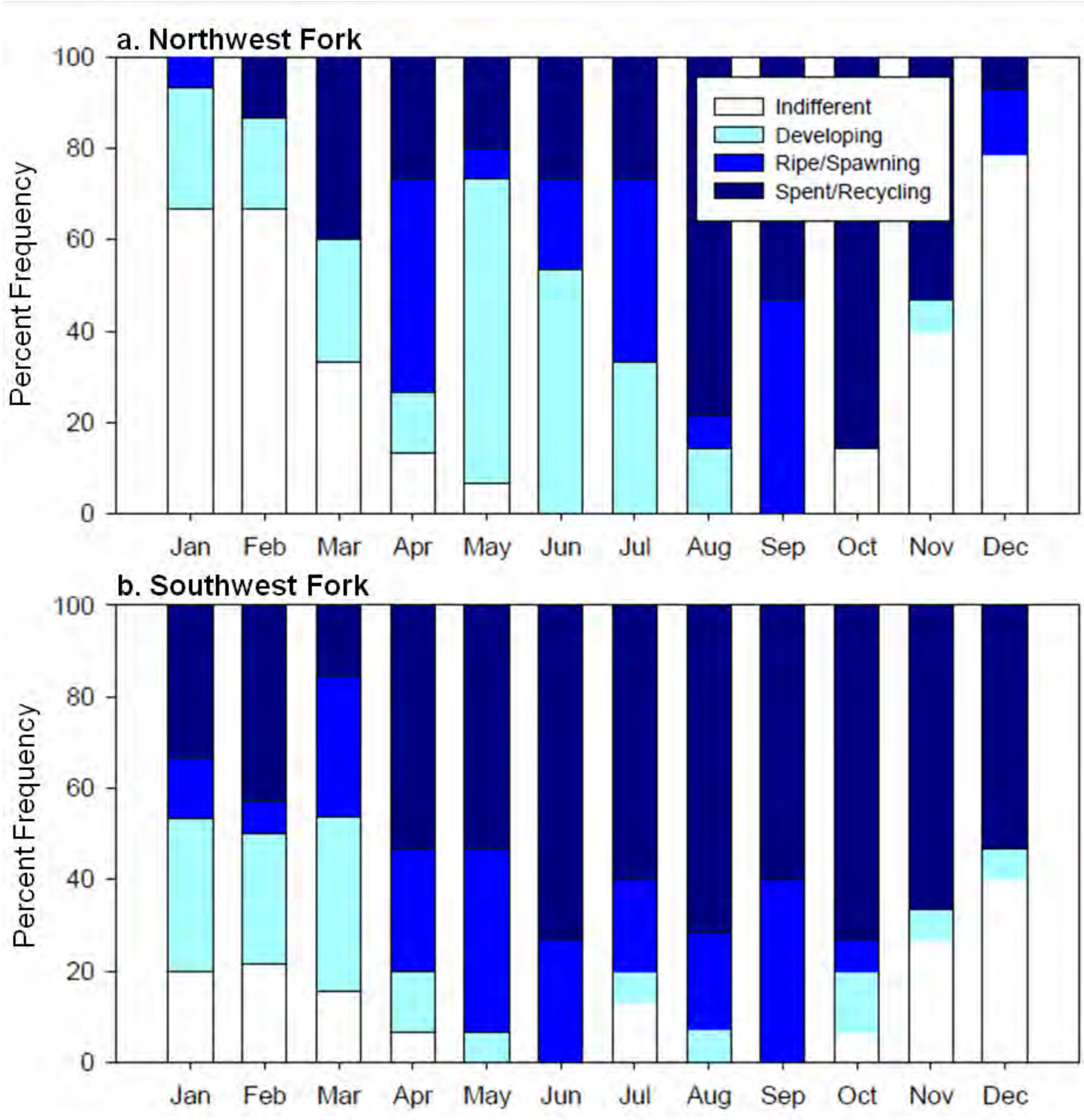


**Figure 5-25. Reproductive development of oysters collected from the (a) Northwest Fork and (b) Southwest Fork study sites during 2009**

Adapted from FWC (2010).

In general, those oysters in what is considered developmental or fully ripe stages were most prevalent during the spring and summer months while most oysters collected in January, February and December were classified as indifferent, completely devoid of gametes or resting. The Southwest Fork sites also had some indifferent stage oysters present in mid-summer. These may represent young-of-the-year oysters that have not matured, or could represent early spawning oysters that were completely spent by the end of spring.

Condition

Changes in physiological condition reflected these reproductive patterns in that peak condition index values in the Northwest Fork occurred between April and July 2009, coinciding with the greatest percentage of reproductively developing oysters (**Figure 5-26**). Similarly, Southwest Fork condition index values were maximal from January through March 2009, also coinciding with the time period of greatest reproductive development. In 2009, physiological condition began the year high and gradually declined, representative of the transfer of energetic reserves into gamete production.

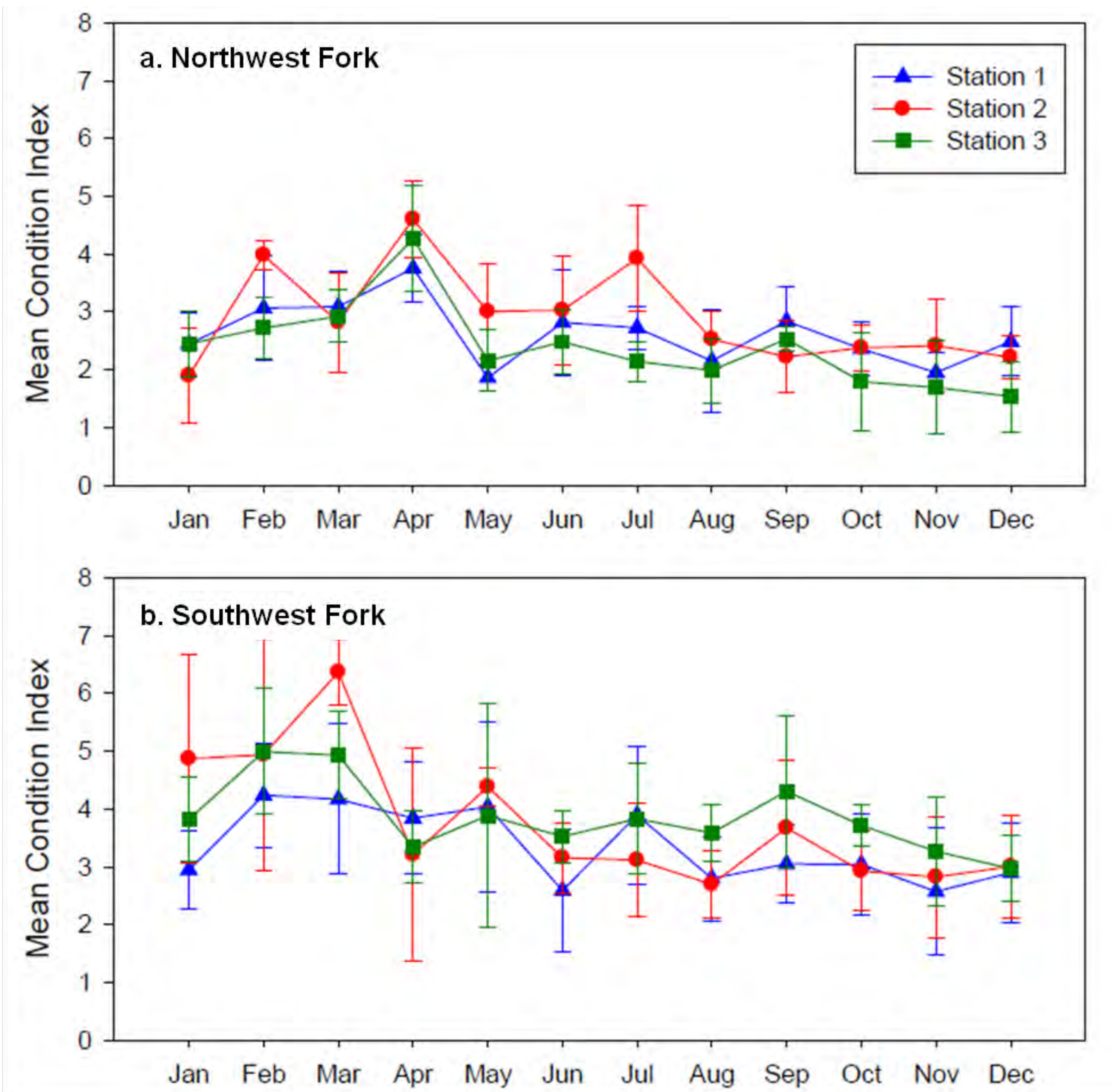


**Figure 5-26. Monthly mean condition index (± standard deviation) of oysters collected from (a) Northwest Fork and (b) Southwest Fork study sites during 2009**

Adapted from FWC (2010).

<u>Recruitment</u>

Spat monitoring arrays were deployed and retrieved at each station on a monthly schedule at each study site and mean numbers of spat per shell per month were calculated for each reef (FWC 2010). In 2009, recruitment rates peaked twice in both study sites the Loxahatchee River. Recruitment peaked in May and October in the Northwest Fork, while in the Southwest Fork, the peaks occurred in May and September (**Figure 5-27**). In both study sites, recruitment occurred continuously from April through December 2009. Overall, the peaks and duration of the recruitment season are comparable to rates seen in previous years.

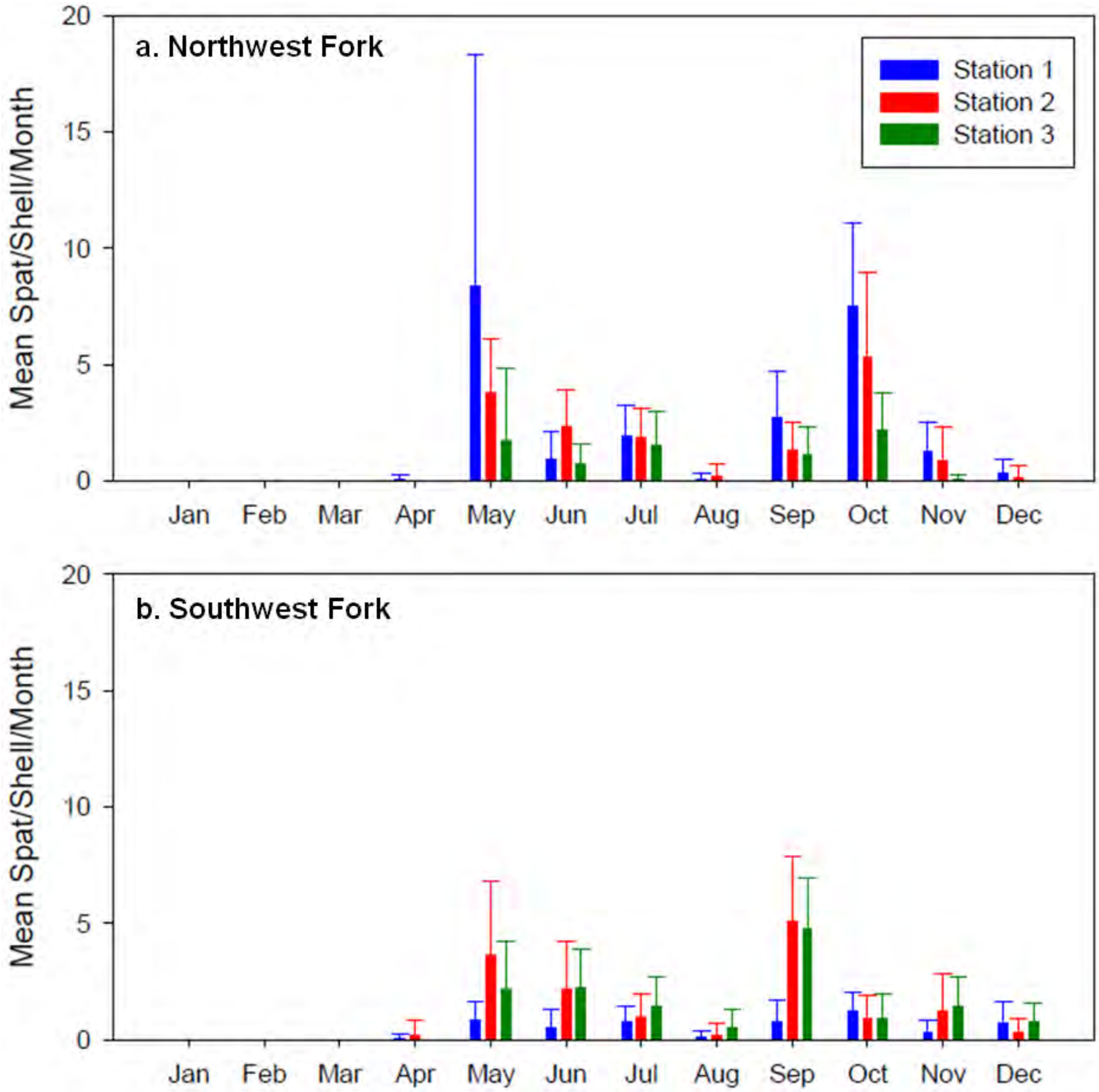


**Figure 5-27. Mean number (+ standard deviation) of oyster recruits collected per shell each month from (a) Northwest Fork and (b) Southwest Fork study sites during 2009**

Adapted from FWC (2010).

In 2009, recruitment commenced as early as April and continued for the remainder of the year. However, each site had two strong recruitment peaks. Both sites had strong spring peaks in May, but in the fall, peaks occurred in September in the Southwest Fork and October in the Northwest Fork. This bimodal pattern of recruitment is typical of oysters in other Florida waters such as Apalachicola Bay (Ingle 1951) and has been observed in other study sites in past years (Arnold et al. 2008).

Growth

Juvenile growth monitoring was conducted at each study site from March 2009 until March 2010. Juvenile oysters first appeared in the Southwest Fork in April and in the Northwest Fork in May (**Figure 5-28**). This corresponds to the spat recruitment results in that the first recruits

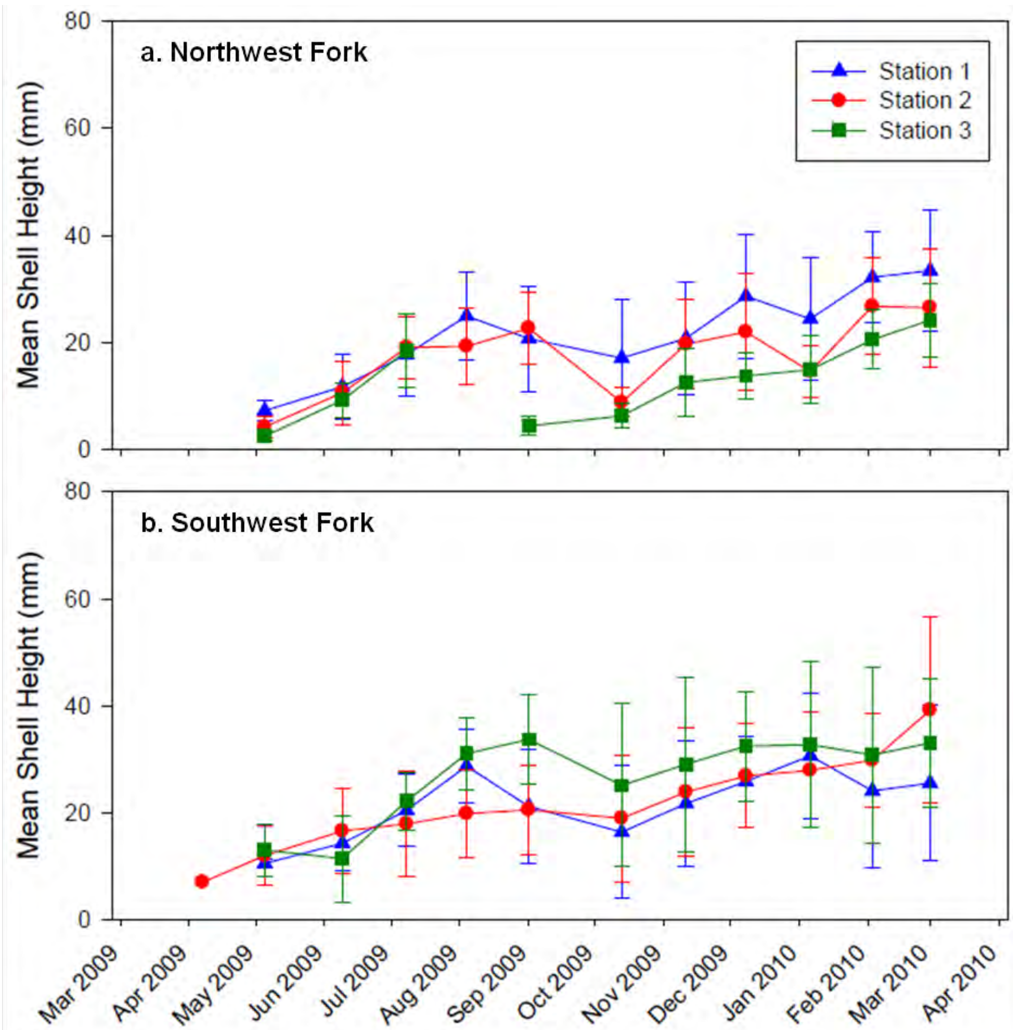


**Figure 5-28. Monthly mean shell height (± standard deviation) of wild juvenile oysters settled onto growth arrays at (a) Northwest Fork and (b) Southwest Fork study sites**

Months with no data indicate months when no juvenile oysters were present on the growth arrays.

Adapted from FWC (2010).

recorded in each study site were found in April. Juvenile oysters at both sites exhibited moderate growth rates, adding an average of approximately 2 mm shell height per month. When the study was completed in March 2010, the juvenile oysters had reached a mean size of approximately 28 mm shell height in the Northwest Fork and 33 mm shell height in the Southwest Fork.

Juvenile growth rate was moderate. These growth rates are typical of oysters in the southeastern United States and particularly in the Gulf of Mexico, but are more rapid than those typically reported for more northern populations (Shumway 1996). Consistent with other bivalves, the more rapid growth of oysters in southern latitudes may be attributed to the longer growing season rather than to an inherently more rapid growth rate (Jones et al. 1990). This distinction is important, because factors other than temperature also influence growth rate. In particular, oysters do not grow well at salinity less than 10 psu (Loosanoff 1953). Ramifications of growth variation can be significant, as faster growing oysters will more quickly escape the ravages of size-limited predators and also would be expected to reallocate energy from growth to reproduction at an earlier age.

Disease Prevalence and Intensity

Using the Mackin scale, parasite density (infection intensity) can be ranked (**Table 5-5**). Average parasite densities were calculated for each individual sample and from those values. Mean *Perkinsus marinus* infection intensity and prevalence were calculated for each station within each site.

**Table 5-5. Mackin scale showing different stages of *Perkinsus marinus* infection**

| Stage | Category | Cell Number | Notes |
|---|---|---|---|
| 0 | Uninfected | No cells detected | |
| 0.5 | Very light | <10 cells in entire preparation | |
| 1 | Light | 11–100 cells in entire preparation | Cells scattered or in localized clusters of 10–15 cells |
| 2 | Light–moderate | Cells distributed in local concentrations of 24–50 cells or uniformly distributed so that 2–3 cells occur in each field at 100 times magnification | |
| 3 | Moderate | 3 cells in all fields at 100 times magnification | Masses of 50 cells may occur |
| 4 | Moderate–heavy | Cells present in high numbers in all tissues | Less than half of tissue appears blue-black macroscopically |
| 5 | Heavy | Cells in enormous numbers | Most tissue appears blue-black macroscopically |

Adapted from FMRI (2010).

Prevalence of the *Perkinsus marinus* infection was moderate to high with 20 to 80 percent of oysters from the Northwest Fork and 33 to 80 percent from the Southwest Fork infected each month (**Figure 5-29**) (FWC 2010). But while *Perkinsus marinus* infection was present throughout the year in oysters collected from both the Northwest and Southwest Forks, levels were relatively low, rarely exceeding a score of 1 (light infection) on the Mackin scale (**Figure** 5-30) (FWC 2010). *Haplosporidium nelsoni* (MSX) infection was not evident in any of the oysters.

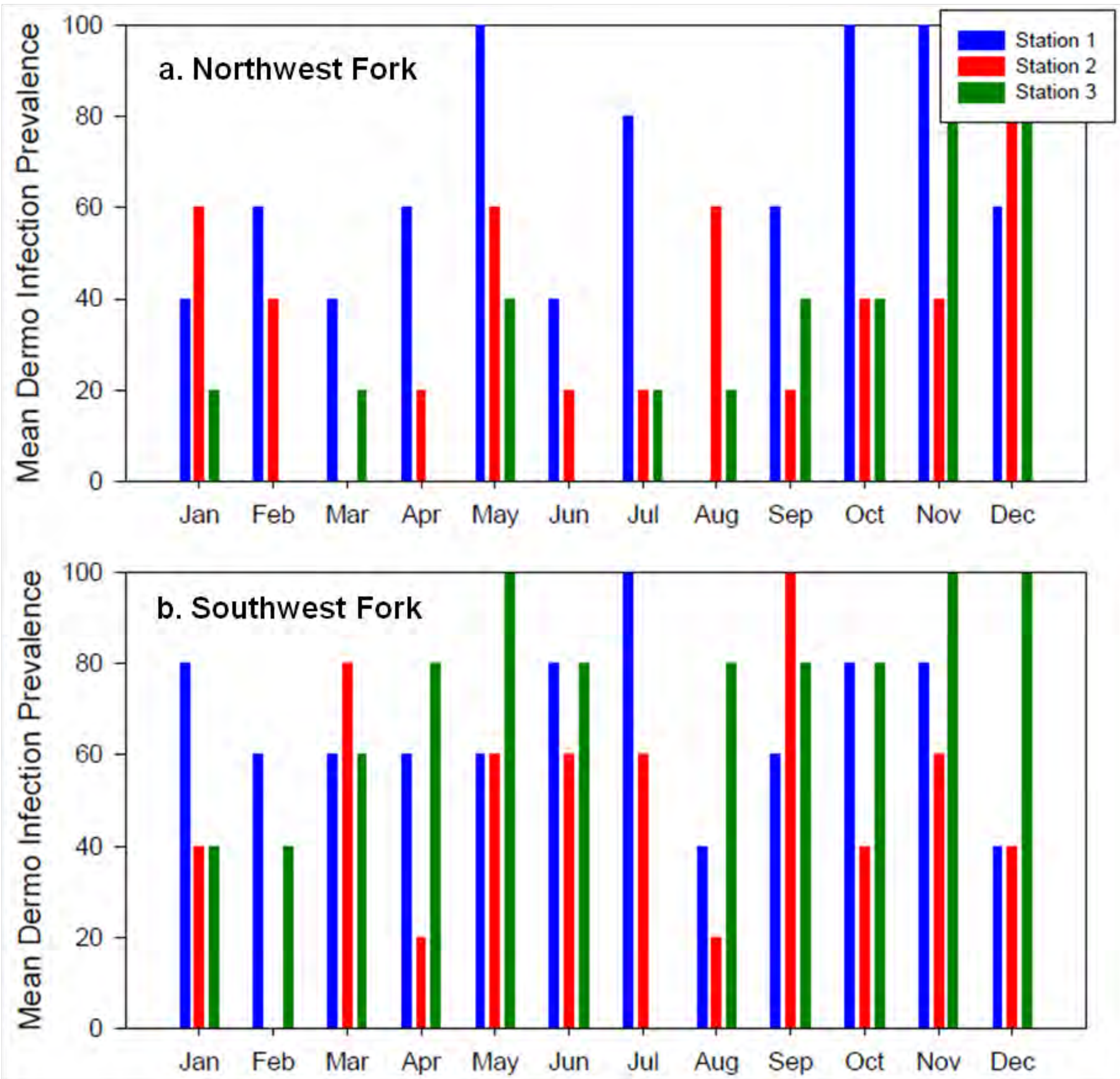


**Figure 5-29. Monthly mean prevalence (percent) of oysters infected with *Perkinsus marinus* at (a) Northwest Fork and (b) Southwest Fork study sites during 2009**

Adapted from FWC (2010).

In 2009, both intensity and prevalence of disease were much higher where salinity was both higher and more stable. It is well established that low temperature and low salinity are correlated with reduced levels of infection (Craig et al. 1989). Infection levels rarely exceeded 1 on the Mackin scale even though the intensity levels in the Loxahatchee River are high because the estuary experiences longer periods of high salinity. To date, the MSX parasite has not detected in any samples collected from the Loxahatchee River Estuary.

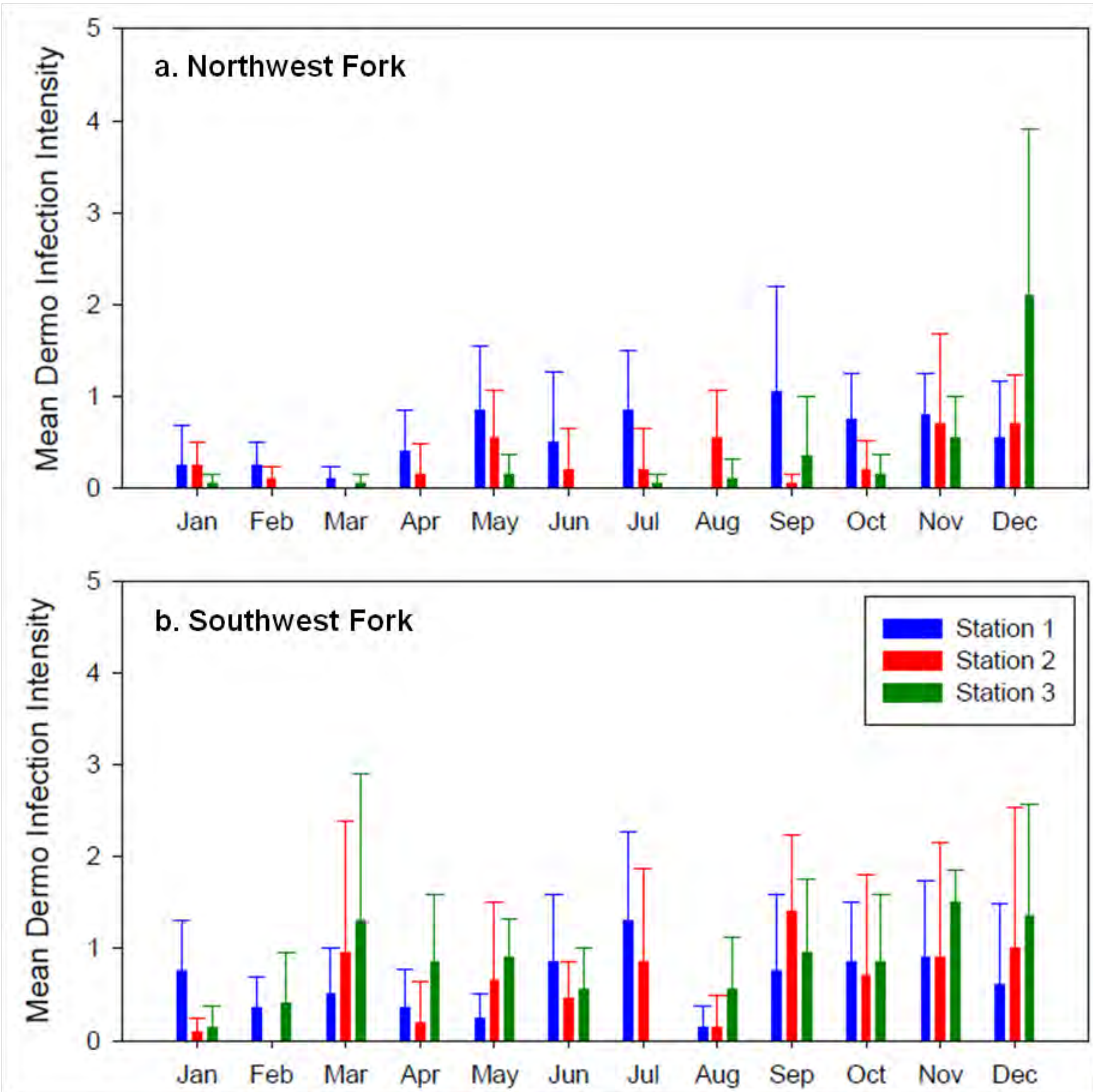


**Figure 5-30. Monthly mean infection intensity (+ standard deviation) of oysters infected with *Perkinsus marinus* at stations in the (a) Northwest Fork and (b) Southwest Fork study sites during 2009**

Adapted from FWC (2010).

Conclusion

Results from 2009 indicate that the patterns of oyster abundance, health and population ecology within the Loxahatchee River Estuary generally fell within the bounds expected for central and south Florida oyster populations. It is apparent that freshwater releases must be carefully considered with respect to their impact on a host of downstream organisms, but particularly oysters. Because one of the benefits of the oysters includes habitat engineering, impacts to oyster populations can have uniquely broad-ranging consequences for a host of ancillary organisms and for the oysters themselves, whose recovery from such events may be serially degraded to the point of no return.

### 5.2.5 Oyster Reef Restoration and Monitoring

The LRD has an ongoing oyster reef restoration pilot study that involves local property owners permitting the construction of nine artificial reefs under their residential docks. In addition, a large-scale (5.8 acre) oyster reef habitat restoration project was initiated on June 21, 2010 near RM 4.2 in the Northwest Fork by the LRD, National Oceanic and Atmospheric Administration (NOAA) and Martin County (**Figure 5-31** and **Figure 5-32**). Funding for this restoration project was made available through an American Recovery and Reinvestment Act of 2009 stimulus grant. It is hoped that the increase in suitable substrate will ultimately increase the overall

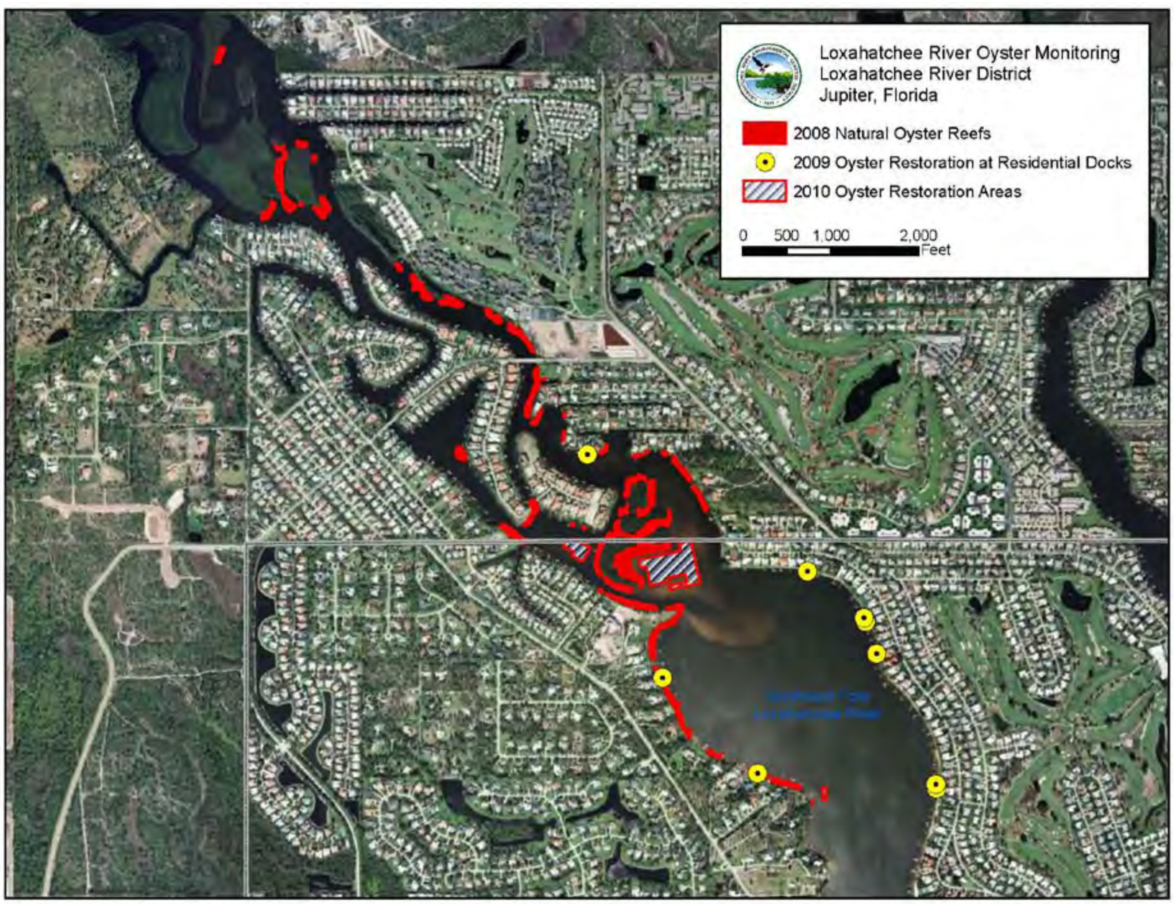


**Figure 5-31. Natural reef and oyster reef restoration sites in the Loxahatchee River**
Image courtesy of the LRD.

acreage of oyster reefs in this area. An approximately six-inch layer of substrate, comprised of rock and shell (the by-product of Palm Beach County's Juno Beach Renourishment Project) was deposited in water with an average subtidal water depth between two to five feet. This river reach presently supports some oyster reefs with moderate densities (50 to 150/$m^2$), which suggests suitable substrate is the factor most likely limiting oyster occurrence and densities in this area.


**Figure 5-32. 2010 Oyster reef restoration sites in the Northwest Fork**

Image courtesy of the LRD.

To assess the success of the oyster reef restoration projects, the LRD has conducted bi-annual (summer and winter) monitoring at each of the residential dock and NOAA restoration sites since August 2009. Summer samples were collected during August/September, and winter samples were collected during January/February. Monitoring of both the residential dock and NOAA restoration sites commenced following project completion. Quantifying the trajectory of restoration success, that is, the change in oyster density and size over time, and the relative functionality of various restoration materials (clutch) were the primary objectives of these monitoring efforts.

The LRD initially monitored the residential dock restoration sites by collecting and evaluating new oyster settlement from shells collected from the shell bags used in the restoration. However, due to extensive recruitment and growth of new oysters, the LRD began quantifying oyster density using a quarter-square meter quadrat sampling method in summer 2010. This quadrat method was less invasive and has been applied consistently at all of the oyster restoration sites within the Loxahatchee River.

<u>Quarter-Square Meter Quadrat Sampling</u>

Each summer and winter since 2010, LRD scientists collected and evaluated new oyster settlement occurring within the quarter-square meter quadrats. Within each quadrat, shells were excavated to a depth of six inches, or until no additional live oysters were present. All live and dead oysters were counted and measured within each quadrat. Two quadrat samples were collected at each dock site, with one sample haphazardly collected from the nearshore half of the dock and one sample collected from the offshore half of the dock. At the NOAA restoration sites, multiple sites were randomly sampled throughout the restoration areas, with the number of samples varying by the size of the restoration site (i.e., 10 samples were collected at site N8, 16 samples were evaluated at Site 13, and 21 samples evaluated at Site 14). For all new spat/oysters within each quadrat (sample), the following parameters were quantified:

- Number of live (post-settlement) oysters
- Number of dead oysters
- Oyster size (i.e., shell height)
- Restoration substrate (e.g., shell, rock, fossil shell if identifiable)
- Water depth
- Location (GPS coordinates)

<u>Results and Discussion</u>

Both the dock and NOAA oyster reef restoration projects have had rapid and dense oyster settlement. At the dock sites, approximately 12–24 months after construction, median densities ranged from 1,000 to 2,500 post-settlement spat and/or oysters per $m^2$ (**Figure 5-33a**). For the NOAA sites, six and 12 months after construction, median densities were roughly 500 oyster/$m^2$). The range of oyster spat densities at the older dock sites reached over 4,000 spat/$m^2$. The ranges of spat densities were generally lower at the newer NOAA sites than the dock sites, but several samples exceeded 1,000 spat/$m^2$ on the NOAA sites. It is likely that the construction methodology used under the docks (i.e., placing bags of oyster shell) contributed to the

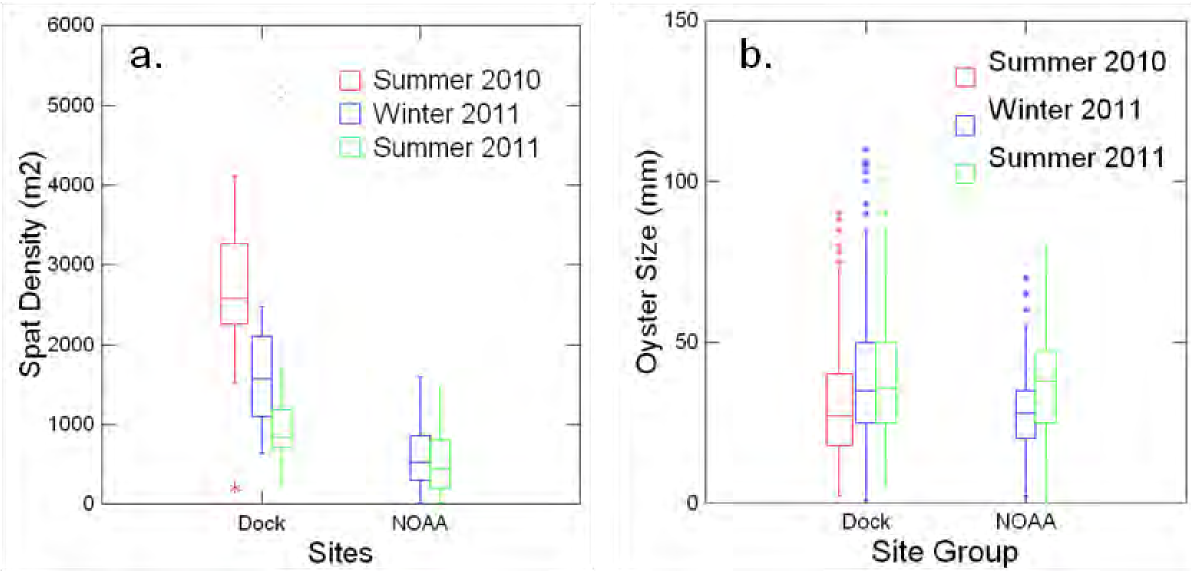


**Figure 5-33. Oyster (a) density and (b) size over time at restoration sites**

m2 = square meter

significantly higher oyster spat densities observed under the docks, because placement of bagged oyster shell creates a larger amount of vertical habitat space. Also, it seems the higher spat densities may simply be more larval oysters settling on a larger amount of available space. Nonetheless, the age and size of the restoration sites also may contribute to the varying oyster densities observed among the restoration projects.

Median size of live, post-settlement oysters at the restoration sites gradually increased over time (**Figure 5-33b**). At dock sites, median oyster size was 25 mm, though some oysters exceeded 75 mm only 12 months after construction. Several oysters exceeded 100 mm within 24 months following construction. At the NOAA restoration sites, median oyster size was over 25 mm, with several oysters over 60 mm just six months after construction. As the restored oyster reefs mature, we have observed oyster densities decline while oyster size has increased (**Figure 5-33**). Monitoring results clearly show several oyster recruitment events over time. Based on the 2011 winter and summer monitoring of the dock sites, which occurred 12 and 18 months after construction, the restored reefs in the Loxahatchee River quickly matured with median oyster size approximately 40 mm (**Figure 5-33b**). This median size is comprised of juvenile oysters settling on and growing over older oysters with only a few oysters able to grow larger than 75 mm. It will be valuable to continue to monitor these restored oyster reefs to better understand their relative health relative to existing, mature, natural oyster reefs.

Another key question for these restoration projects was the performance of the various cultch materials used. The materials used for the dock sites included oyster shell from area restaurants or fossilized shell, or a combination of both. The cultch material used in the NOAA project was limestone rock and shell, a by-product from Palm Beach County's Juno Beach Renourishment Project. At the NOAA sites, the delineation of the mixed base material (rock or shell) was discontinued following the winter 2011 sampling because the extensive growth of new oysters had obscured the original cultch material. Preliminary results are shown in **Figure 5-34** and suggest that all of these calcium carbonate materials provide good cultch for restoration work in the Loxahatchee River. Moreover, these data suggest oyster restoration using fossilized shell, fresh oyster shell from restaurants, or limestone rock and shell from beach renourishment projects all provided equally high quality substrate (cultch) rapidly colonized by oyster larvae.

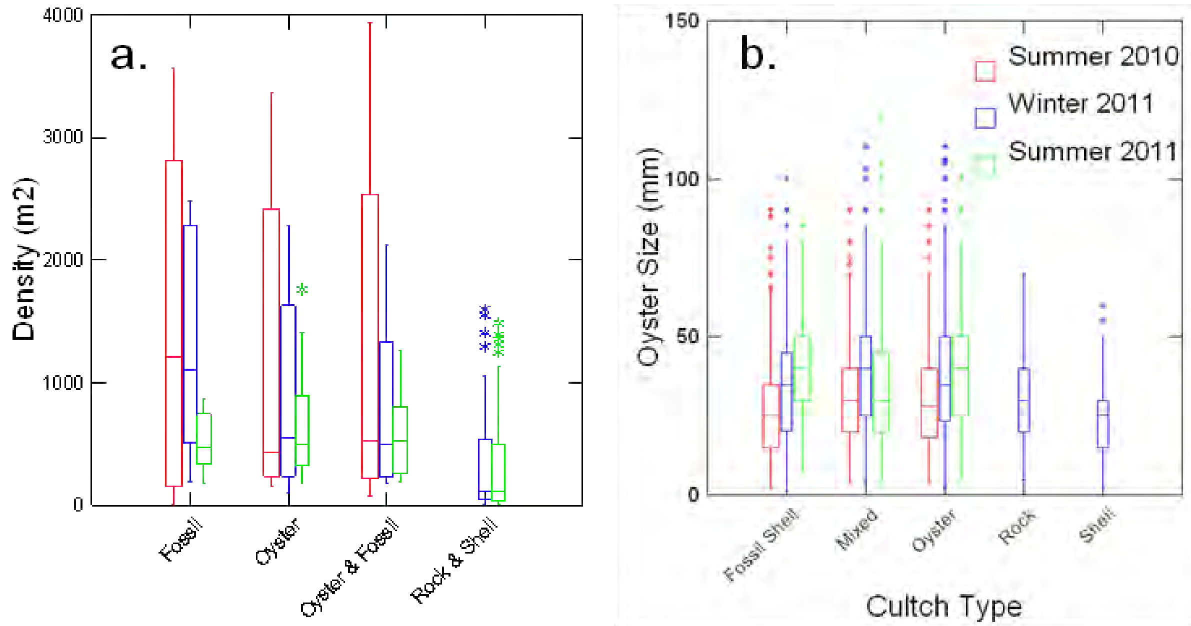


**Figure 5-34. Oyster (a) density and (b) size over time for each type of substrate used for restoration sites**

m2 = square meter

# 6.0 WATER QUALITY

## 6.1 Loxahatchee River Water Quality Monitoring

### 6.1.1 Introduction

Since 1971 the Loxahatchee River District (LRD) has been fulfilling its mission to preserve and protect the Loxahatchee River through an innovative wastewater treatment and reuse program and an active water quality monitoring program. LRD staff have monitored water quality in the surface waters of the Loxahatchee River and associated waters (**Figure 6-1** and **Figure 1-1** in **Section 1.0**) in an effort to document the ecological health of the river, and to determine the location and extent of water quality issues that need to be addressed. Over these past 35 years, the LRD has contributed significantly to the understanding of the ecology of this river. While numerous reports have been written regarding the Loxahatchee River, perhaps none are as comprehensive as the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006). This document characterizes the watershed, discusses various restoration alternatives, and identifies the preferred restoration flow scenarios. In particular, Table 10-1 of

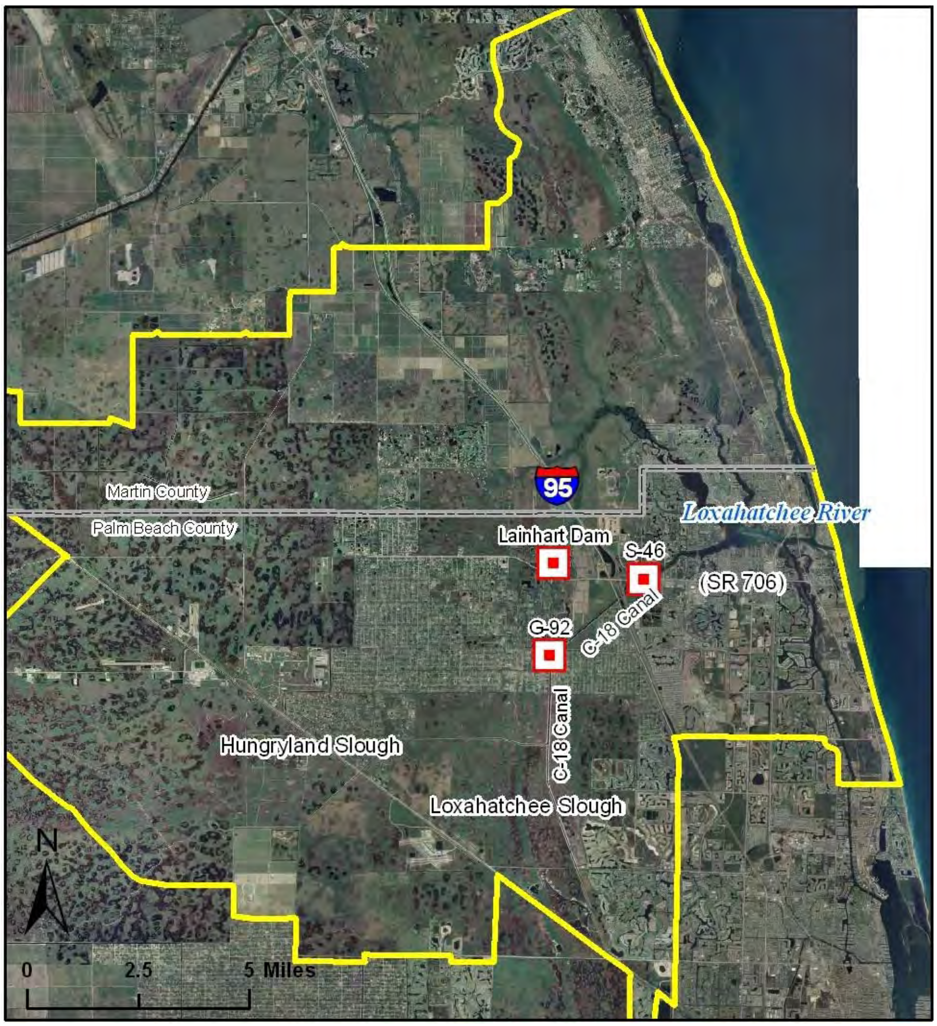


**Figure 6-1. Loxahatchee River watershed and associated features**

the restoration plan includes the water quality targets for the marine (salinity >30 practical salinity units [psu]), polyhaline (salinity 18–30 psu), meso/oligohaline (salinity 5–18/0.5–5 psu), Wild and Scenic (salinity <5 psu), and freshwater tributaries (salinity <5 psu) zones of the Loxahatchee River. These water quality targets (i.e., nondegradation standards) were established by LRD and South Florida Water Management District (SFWMD) scientists using bimonthly water quality data collected by LRD over the five-year period from 1998 to 2002. Using this model, the numbers of monitoring sites were expanded within each of the above categories with additional supplemental analysis group categories for freshwater canals and brackish tributaries. **Figure 6-2** and **Table 6-1** illustrate water quality sampling sites, analysis group categories, and sampling frequency.

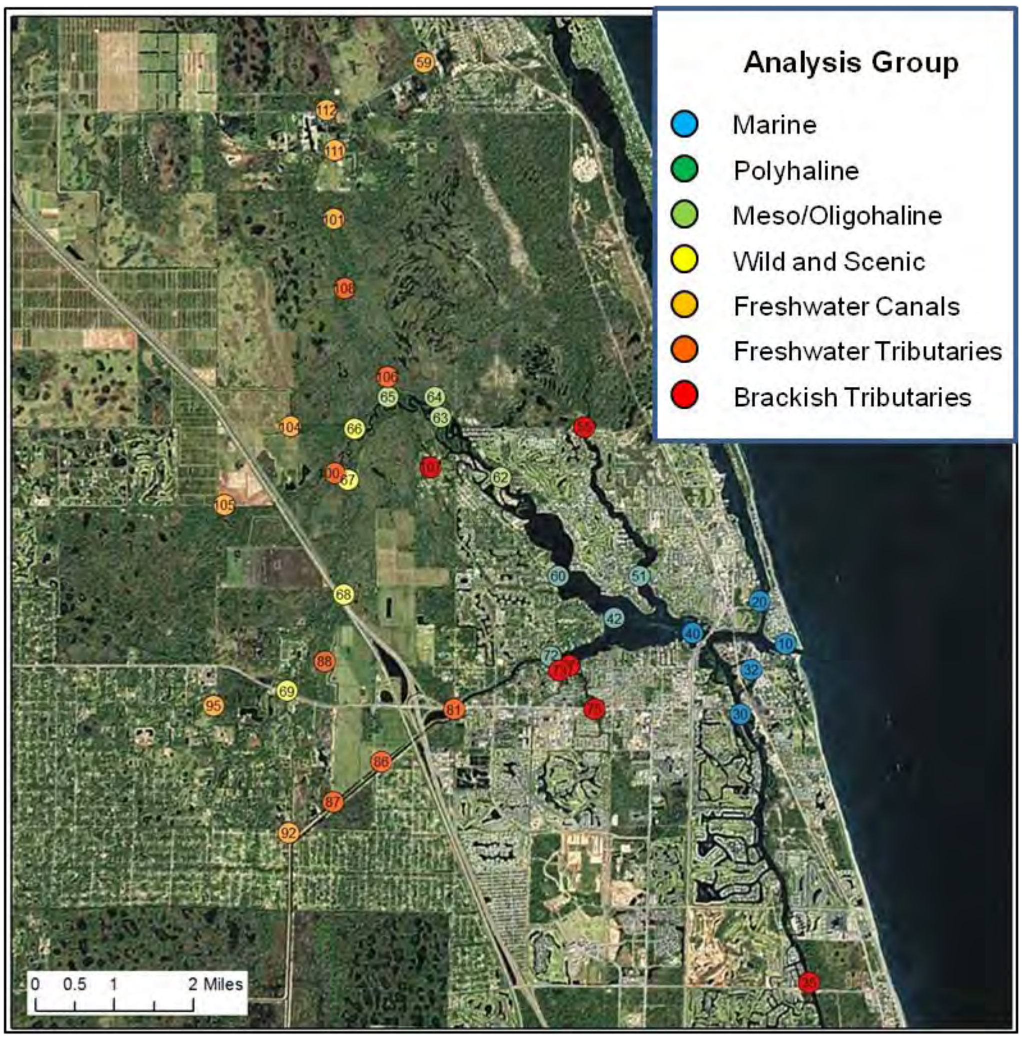


**Figure 6-2. LRD's water quality monitoring stations in the Loxahatchee River and associated waters color coded by analysis group**

**Table 6-1. River Keeper sampling sites**

| Station | Analysis Group | Restoration Plan Zone[1] | Sampling Frequency | Northing[2] | Easting[2] | Latitude[3] | Longitude[3] |
|---|---|---|---|---|---|---|---|
| 10 | Marine | Marine | Monthly | 950,408 | 957,903 | 26 56.7206 | -80 04.4293 |
| 20 | Marine | Marine | Bimonthly | 953,238 | 956,193 | 26 57.1897 | -80 04.7404 |
| 25 | Marine | | Bimonthly | 972,837 | 950,720 | 27 00.4308 | -80 05.7224 |
| 30 | Marine | Marine | Bimonthly | 945,745 | 954,896 | 26 55.9546 | -80 04.9892 |
| 32 | Marine | | Bimonthly | 948,686 | 955,606 | 26 56.4391 | -80 04.8546 |
| 35 | Brackish Tributary | | Bimonthly | 927,816 | 959,468 | 26 52.9901 | -80 04.1717 |
| 40 | Marine | | Monthly | 951,108 | 951,709 | 26 56.8435 | -80 05.5690 |
| 42 | Polyhaline | | Bimonthly | 952,109 | 946,497 | 26 57.0148 | -80 06.5275 |
| 51 | Polyhaline | Polyhaline | Bimonthly | 954,927 | 948,122 | 26 57.4780 | -80 06.2246 |
| 55 | Brackish Tributary | | Bimonthly | 964,841 | 944,439 | 26 59.1185 | -80 06.8901 |
| 59 | Freshwater Canal | | Bimonthly | 989,168 | 933,755 | 27 03.1456 | -80 08.8280 |
| 60 | Polyhaline | Polyhaline | Monthly | 954,920 | 942,739 | 26 57.4831 | -80 07.2160 |
| 62 | Meso/Oligohaline | Meso/Oligohaline | Monthly | 961,525 | 938,899 | 26 58.5776 | -80 07.9148 |
| 63 | Meso/Oligohaline | Meso/Oligohaline | Bimonthly | 965,503 | 934,848 | 26 59.2387 | -80 08.6561 |
| 64 | Meso/Oligohaline | Meso/Oligohaline | Bimonthly | 966,884 | 934,503 | 26 59.4670 | -80 08.7179 |
| 65 | Meso/Oligohaline | | Monthly | 966,873 | 931,330 | 26 59.4687 | -80 09.3025 |
| 66 | Wild and Scenic | | Bimonthly | 964,747 | 929,142 | 26 59.1202 | -80 09.7082 |
| 67 | Wild and Scenic | Wild and Scenic | Monthly | 961,353 | 928,662 | 26 58.5606 | -80 09.8008 |
| 68 | Wild and Scenic | Wild and Scenic | Bimonthly | 953,689 | 928,384 | 26 57.2960 | -80 09.8613 |
| 69 | Wild and Scenic | Wild and Scenic | Monthly | 947,259 | 924,583 | 26 56.2389 | -80 10.5691 |
| 71 | Brackish Tributary | | Bimonthly | 948,947 | 943,456 | 26 56.4965 | -80 07.0916 |
| 72 | Polyhaline | Polyhaline | Monthly | 949,554 | 942,258 | 26 56.5981 | -80 07.3114 |
| 73 | Brackish Tributary | | Bimonthly | 948,621 | 942,812 | 26 56.4434 | -80 07.2106 |
| 75 | Brackish Tributary | | Bimonthly | 946,078 | 945,127 | 26 56.0211 | -80 06.7876 |

[1] From the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006)
[2] State Plane, Florida East, in feet
[3] World Geodetic System 1984, in degrees and decimal minutes

## Table 6-1. continued

| Station | Analysis Group | Restoration Plan Zone[1] | Sampling Frequency | Northing[2] | Easting[2] | Latitude[3] | Longitude[3] |
|---|---|---|---|---|---|---|---|
| 81 | Freshwater Tributary | Freshwater Tributary | Bimonthly | 946,035 | 935,787 | 26 56.0246 | -80 08.5075 |
| 86 | Freshwater Tributary | | Bimonthly | 942,562 | 930,899 | 26 55.4568 | -80 09.4118 |
| 87 | Freshwater Tributary | | Bimonthly | 939,867 | 927,701 | 26 55.0155 | -80 10.0039 |
| 88 | Freshwater Tributary | | Bimonthly | 949,254 | 927,103 | 26 56.5654 | -80 10.1026 |
| 92 | Freshwater Canal | | Bimonthly | 937,810 | 924,731 | 26 54.6793 | -80 10.5531 |
| 95 | Freshwater Canal | Freshwater Tributary | Monthly | 946,288 | 919,695 | 26 56.0839 | -80 11.4703 |
| 100 | Freshwater Tributary | Freshwater Tributary | Monthly | 961,807 | 927,804 | 26 58.6365 | -80 09.9583 |
| 101 | Freshwater Canal | | Bimonthly | 978,724 | 927,740 | 27 01.4285 | -80 09.9494 |
| 104 | Freshwater Canal | | Bimonthly | 964,884 | 924,842 | 26 59.1475 | -80 10.5002 |
| 105 | Freshwater Canal | | Bimonthly | 959,657 | 920,431 | 26 58.2895 | -80 11.3190 |
| 106 | Freshwater Tributary | | Bimonthly | 968,197 | 931,290 | 26 59.6873 | -80 09.3082 |
| 107 | Brackish Tributary | | Bimonthly | 962,186 | 934,199 | 26 58.6920 | -80 08.7798 |
| 108 | Freshwater Tributary | | Bimonthly | 974,119 | 928,465 | 27 00.6677 | -80 09.8215 |
| 111 | Freshwater Canal | | Bimonthly | 983,296 | 927,764 | 27 02.1831 | -80 09.9395 |
| 112 | Freshwater Canal | | Bimonthly | 985,981 | 927,200 | 27 02.6268 | -80 10.0401 |

**<u>Alternate Analysis Groupings</u>**
Longitudinal (downstream to upstream): 10, 40, 42, 60, 62, 63, 64, 65, 66, 67, 68, 69, 92, 81
Indian River Lagoon: 20, 25
Lake Worth Lagoon: 30, 32, 35
South Indian River Water Control District: 95
Kitching Creek: 101, 106, 108, 111, 112
Brackish Tributaries: 55, 71, 73, 75, 107

[1] From the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006)
[2] State Plane, Florida East, in feet
[3] World Geodetic System 1984, degrees - decimal minutes

The water quality monitoring program, entitled “River Keeper”, was developed to identify long-term trends and make comparisons to the established water quality targets. Furthermore, ongoing results are used to establish baseline conditions prior to modification of freshwater inflows resulting from the implementation of the Comprehensive Everglades Restoration Plan (CERP) and the *Northwest Fork of the Loxahatchee Restoration Plan* (RECOVER 1999, SFWMD 2006).

The purpose of this report is to provide a simplified characterization and overview of the water quality conditions in the Loxahatchee River. Water quality results are summarized throughout the watershed at three levels: (1) a high-level stoplight approach by analysis group; (2) a temporal and spatial assessment by analysis group and (3) annual comparisons of individual sampling sites relative to target levels.

### 6.1.2 Study Area

The Loxahatchee River Estuary encompasses approximately 700 hectares (1,000 acres) and drains a watershed of approximately 700 square kilometers (370 square miles) located in northeastern Palm Beach County and southeastern Martin County (**Figure 6-1**). Freshwater discharges into the estuary from the North Fork, the Northwest Fork, and the Southwest Fork of the Loxahatchee River. The hydrology of the basin has been substantially altered by flood control efforts since the 1950s. Historically (pre-1950) most surface water runoff reaching the estuary originated in Loxahatchee and Hungryland Sloughs and flowed gradually to the Northwest Fork. In the 1930s the Lainhart Dam, a small fixed-weir dam, was constructed in the Northwest Fork at river mile (RM) 14.5 to reduce “over” drainage of upstream reaches of the Northwest Fork during dry seasons. In 1958 a major canal (C-18) and flood control structure (S-46) were constructed to divert flows from the Northwest Fork to the Southwest Fork, which increased the intensity and decreased the duration of storm-related discharge to the estuary. Furthermore, since 1947 Jupiter Inlet, the eastern link to the ocean, was expanded through ongoing dredging projects. These hydraulic modifications promoted increased saltwater to intrude into the previously freshwater portions of the Northwest Fork. Ongoing restoration efforts seek to increase base freshwater flows to the Northwest Fork while not compromising the ecological integrity of downstream reaches (i.e., estuary), nor impairing valued ecosystem components of the estuary such as oysters and seagrasses (SFWMD 2006).

### 6.1.3 Methods

LRD scientists collected water quality samples monthly or every other month at the stations identified in **Table 6-1**. At each station, physical water quality conditions (e.g., temperature, pH, conductivity, salinity and dissolved oxygen [DO]) were evaluated using a multi-probe water quality instruments near the water surface (0.3 meter depth). At stations 60 through 66, the river reach most likely to experience a halocline (salinity stratification), the mid-depth was sampled, and approximately 20 centimeters (cm) above the river bottom.

Nutrient, bacteriological, chlorophyll a, turbidity, total suspended solids (TSS) and water color samples were processed following standard methods by the LRD’s WildPine Laboratory. The WildPine Laboratory has been certified (#E56026) under the National Environmental Laboratory Accreditation Program since 2000. Prior to 2000, the WildPine lab was a state certified laboratory. Photosynthetically active radiation was assessed by simultaneously logging at least three replicates using three LI-COR spherical sensors (4 $\pi$) fixed at 20 cm, 50 cm, and 100 cm below the water surface.

A key distinction in this report and analysis is the removal of problematic nitrogen data, including total kjeldahl nitrogen (TKN), total nitrogen (TN) and dissolved organic nitrogen, collected prior to January 1, 2005. Prior to 2005 the WildPine laboratory employed a laboratory analysis technique for nitrogen that used mercury. Unfortunately, saline waters caused interference making the results unreliable. These problems were remedied in 2005 though the use of an analysis technique utilizing copper. As a precaution to eliminate spurious results, the nitrogen data for all samples collected prior to 2005 where salinity was greater than 10 psu, have not been included in this analysis.

For consistency in analyses, the "annual" period is set at October 1 through September 30. For example, the data group named "2010" includes all data collected between October 1, 2009 through September 30, 2010. The five-year target period group from 1998 to 2002 included all data collected from October 1, 1997 through September 30, 2002.

Results are summarized using a stoplight approach to provide a simplified, integrated assessment of annual observed water quality conditions for key nutrient measures including TN, total phosphorus (TP) and chlorophyll a as measured by annual geometric mean. The annual geometric mean relative to target water quality values (1998–2002) are compared for each of the seven river reaches: marine, polyhaline, mesohaline, Wild and Scenic, freshwater tributaries, brackish tributaries and freshwater canals. The geometric mean statistic is also utilized in the Florida Department of Environmental Protection (FDEP) and United States Environmental Protection Agency (USEPA) analytical approaches, and it is the more appropriate measure of central tendency for these types of skewed data. Analytical results for each river reach were divided into three categories (red, yellow and green), which can be interpreted similar to the colors in a traffic signal. **Appendix 6-1** presents the decision rules and results. In general terms, the annual geometric means relative to the 75th and 90th percentiles are evaluated from the data collected during the target period (1998–2002). Green indicates good or acceptable conditions — no degradation is occurring. Yellow indicates caution should be observed — degradation may or may not be occurring (i.e., there may be causes for concern). Red indicates degradation is likely occurring, and resource managers should seek to identify the source of the problem and determine what actions might be employed to remedy the observed degradation in water quality. A more comprehensive and thorough temporal and spatial assessment was also conducted using box-and-whisker plots to compare water quality conditions for all parameters among the following periods: the target period (1998–2002), the subsequent five-year period (2003–2007), and then annually from 2008 through 2010.

Results are compared to values given in *Water Quality Standards for the State of Florida's Lakes and Flowing Waters* (40 CFR §131; USEPA 2010a) and the USEPA numeric nutrient criteria for stream protection of streams in Florida's peninsula region (40 CFR §131.43; USEPA 2010a, 2010b). To compliment the comparisons to the nutrient criteria, comparisons are included for the non-freshwater analysis groups to the 1998–2002 target period using the stoplight method described above. These comparisons provide a more detailed stoplight assessment of annual water quality conditions for each sampling site for TN, TP, chlorophyll a, DO and fecal coliform bacteria. Results are also summarized in maps showing all sampling sites symbolized by the

2010 stoplight scores developed from the previously described comparisons to USEPA or FDEP numeric nutrient criteria or the 1998–2002 target period.

### 6.1.4 Results and Discussion

During the period from October 2009 through September 2010, 374 water quality samples were collected and analyzed for 29 parameters resulting in over 6,000 analytical results. Because water quality is closely related to the hydrologic conditions in the region, an assessment of rainfall and resulting river flows is provided. Results from the SFWMD's hydrological and water quality database (DBHYDRO) were used. Water managers have established minimum flow criteria designed to provide sufficient flows to protect the river's freshwater ecosystems from saltwater intrusion migrating up the river.

Rainfall and River Flows

Total annual rainfall for the period from October 1, 2009 through September 30, 2010 was the highest observed since 2003. The increased rainfall and effective flood control management resulted in moderate but consistent river flows measured at Lainhart Dam. In 2010, 70 inches of rainfall was recorded at the LRD's treatment plant in Jupiter, compared to 60, 59 and 64 inches for the same period (October–September) in 2009, 2008 and 2007 (**Table 6-2**). Annual average daily flows at Lainhart Dam during the same period were also moderate at 89 cubic feet per second (cfs) in 2010 compared to 77, 106 and 80 cfs for 2009, 2008 and 2007, respectively. Daily flows over the Lainhart Dam were less than 35 cfs, the minimum target flow established in the *Restoration Plan for the Northwest Fork of the Loxahatchee* (SFWMD 2006), for only 11 total days in 2010 compared to 45, 48 and 162 days during 2009, 2008 and 2007, respectively.

**Table 6-2. Summary of annual rainfall and river flows[1]**

| Year (October 1– September 30) | Annual Average Rainfall (inches) | Annual Average Daily Flow (cfs) | Number of Days Lainhart Flow <35 cfs |
|---|---|---|---|
| 2010 | 70.0 | 89.1 | 11 |
| 2009 | 60.1 | 76.7 | 45 |
| 2008 | 59.4 | 105.8 | 48 |
| 2007 | 64.4 | 80.0 | 162 |
| 2006 | 56.7 | 89.4 | 143 |
| 2005 | 44.8 | 109.9 | 77 |
| 2004 | 63.9 | 79.3 | 143 |
| 2003 | 56.2 | 72.4 | 103 |

[1] Rainfall is measured at the LRD Treatment Plant. Flow is measured at Lainhart Dam.

**Figure 6-3** illustrates the daily rainfall and elevated flows in 2010, with fewer low flow conditions compared to 2008 and 2009. For the first time since 1997, the minimum flows and levels (MFL) criteria were not violated in the Northwest Fork. This was the result of increased rainfall during the 2009–2010 dry season and sound water management operations.

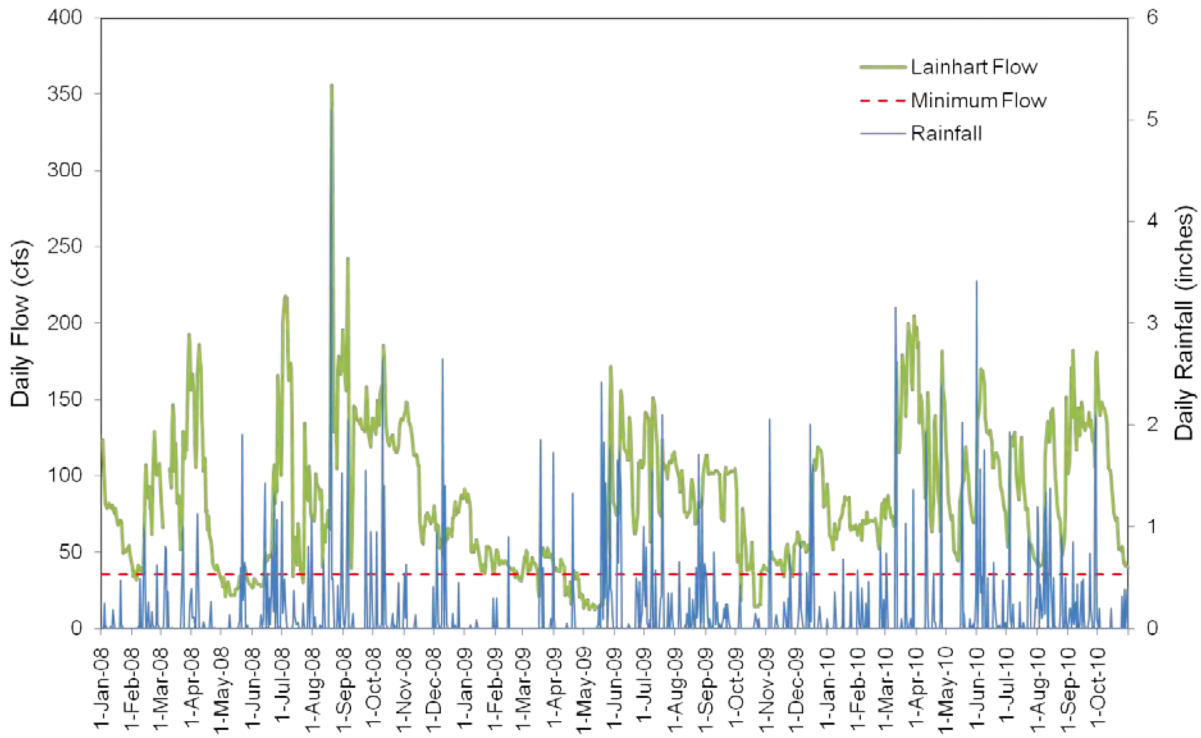


**Figure 6-3. Daily flow at Lainhart Dam and daily rainfall at the LRD Treatment Plant January 2008 – October 2010**

Stoplight Assessment

When compared against the water quality targets (i.e., nondegradation standards), water quality in the Loxahatchee River for 2010 (October 2009–September 2010) scored green, or good, within all analysis groups for TN and TP (**Table 6-3**). Two analysis groups, meso/oligohaline and brackish tributaries, showed elevated chlorophyll a values suggesting possible impairment of these waters, meaning a stoplight score of yellow, relative to the 1998–2002 target values. A preliminary review of chlorophyll a over time suggests a trend of increasing concentrations relative to the 1998–2002 target period (**Table 6-3**). However, more detailed analyses of these data are needed to determine if these are significant trends, or artifacts due to changes in sampling frequency (monthly prior to 2007 versus bimonthly since 2007), variations in duration of the reference period, or some other cause. The marine and polyhaline analysis groups continue to show the greatest overall health. Semi-diurnal tides flush these downstream sites twice a day with relatively high quality (e.g., has low nutrient concentrations) sea water flowing from the Atlantic Ocean through the Jupiter Inlet.

In order to provide a historical perspective on water quality throughout the watershed, scores for several previous years beginning with 2003 are included (**Table 6-3**). Using these scoring thresholds, the river appears relatively healthy. Increased nutrient levels and the subsequent yellow scores during the years labeled 2005 and 2006 correspond with the heavier tropical storm activity during that period. Chlorophyll a values in the meso/oligohaline and brackish tributaries analysis groups are more frequently higher than the target values than the other analysis groups. The temporal and spatial assessment sections (discussed below) provide additional detail into these observations. These data are somewhat perplexing. The observed increase in chlorophyll a appears to have occurred without an increase in either nitrogen or phosphorus. It is conceivable that the observed increase in chlorophyll a is due to an increase in availability of some other limiting nutrient. Presently, sufficient data to evaluate this hypothesis is not available.

**Table 6-3. Stoplight summary relative to the 1998–2002 reference period**

| | Marine | Polyhaline | Meso/ Oligohaline | Wild and Scenic | Freshwater Tributaries | Brackish Tributaries | Freshwater Canals |
|---|---|---|---|---|---|---|---|
| **Total Nitrogen** | | | | | | | |
| 2003 | Green | Green | Yellow | Green | Green | Yellow | Green |
| 2004 | Green | Green | Green | Green | Green | Green | Green |
| 2005 | Green | Green | Red | Yellow | Yellow | Green | Yellow |
| 2006 | Green | Green | Green | Yellow | Yellow | Green | Yellow |
| 2007 | Green | Green | Green | Green | Green | Green | Yellow |
| 2008 | Green | Green | Green | Green | Green | Green | Green |
| 2009 | Green | Green | Green | Green | Green | Green | Green |
| 2010 | Green | Green | Green | Green | Green | Green | Green |
| **Total Phosphorus** | | | | | | | |
| 2003 | Green | Green | Green | Green | Green | Green | Green |
| 2004 | Green | Green | Green | Green | Green | Green | Green |
| 2005 | Green | Green | Green | Green | Green | Green | Green |
| 2006 | Green | Green | Green | Green | Green | Green | Green |
| 2007 | Green | Green | Green | Yellow | Green | Green | Green |
| 2008 | Green | Green | Green | Green | Green | Green | Green |
| 2009 | Green | Green | Green | Green | Green | Green | Green |
| 2010 | Green | Green | Green | Green | Green | Green | Green |
| **Chlorophyll a** | | | | | | | |
| 2003 | Green | Green | Yellow | Green | Green | Green | Yellow |
| 2004 | Green | Green | Green | Green | Green | Green | Green |
| 2005 | Green | Yellow | Yellow | Green | Green | Red | Green |
| 2006 | Green | Green | Green | Green | Green | Green | Green |
| 2007 | Green | Green | Green | Green | Green | Green | Green |
| 2008 | Green | Green | Yellow | Green | Green | Yellow | Green |
| 2009 | Green | Green | Red | Yellow | Green | Green | Green |
| 2010 | Green | Green | Yellow | Green | Green | Yellow | Green |

Temporal Assessment

In addition to the previous stoplight assessment, box-and-whisker plots for each parameter are given in **Appendix 6-2**. These plots facilitate comparisons of water quality for all parameters among five temporal periods: the target period (1998–2002), five years following the target period (2003–2007), then 2008, 2009 and 2010 (October–September for all). The following provides a brief summary of noteworthy results from 2010, relative to the target period (1998–2002) for each parameter.

Alkalinity values measured in 2010 were above the target values in the polyhaline and brackish tributaries analysis groups. Chlorophyll a values from 2010 in the meso/oligohaline analysis groups were higher relative to the target period, but down from last year's high. Median chlorophyll values in the brackish tributaries reached a new high, and are well above the target values. Conductivity and salinity values in 2010 were notably lower than the targets in the important, saline sensitive meso/oligohaline and Wild and Scenic analysis groups. The lower salinity is likely a result of the favorable river flows and higher annual rainfall during the dry season. Median DO values in 2010 in the Wild and Scenic analysis group were slightly lower than the target period and similar to 2008. In contrast, the median DO for 2010 was higher than historical observations in the freshwater canals analysis groups. Median fecal coliform values were highest in the brackish tributaries, while all other analysis groups were similar to previous observations. Percent light transmission readings in 2010 were higher than previous years, meeting or exceeding median target periods in nearly all river analysis groups. An important observation is that despite heavier flows into the river, nitrogen related values (nitrate + nitrite, TKN, TN, organic nitrogen and ammonia) are generally similar to previous years, and in line with target values. Note that comparisons of nitrogen related values (TKN, TN and organic nitrogen) in the marine analysis groups prior to 2005 are based on substantially reduced sample sizes because of data redaction (see methods section for details). Median pH values in 2010 were elevated relative to the target period in the marine, polyhaline and brackish tributaries analysis groups. Despite record cold water temperatures during January and February 2010, the cooler temperatures are not reflected in the median or low range of the River Keeper sampling relative to the target period. This finding reinforces the benefits of high frequency sampling using instrumentation because the timing of monthly or bimonthly sampling might not capture significant events. Similar to the 2010 nitrogen-related parameters, phosphorus values (orthophosphorus and TP) also did not show substantial increases relative to the target period despite higher river flows and rainfall. While individual sites show higher values (see discussion below), the combination of sites that comprise an analysis group appear to be relatively healthy and similar to the target period values. In 2010, TSS and turbidity values in 2010 were lower in nearly all analysis groups relative to the target periods and previous observations.

Assessment of Individual Sampling Sites

An additional level of detail is given at individual sampling sites throughout the watershed for five key parameters (TN, TP, chlorophyll a, DO and fecal coliform bacteria). This analysis provides insight into the water quality at specific sampling sites within the analysis groups described above. The annual geometric mean of TN and TP are compared to the USEPA numeric nutrient criteria for freshwater streams in Florida for the stations within the Wild and Scenic, freshwater tributaries and freshwater canals analysis groups. For the other analysis groups (marine, polyhaline, meso/oligohaline and brackish tributaries), means were compared to the annual geometric means from the 1998–2002 targets. For chlorophyll a, we compared the station geometric mean relative to the 1998–2002 analysis group targets. Observed DO concentrations were compared to FDEP Class III surface water criteria. Lastly, for the fecal coliform bacteria, the annual geometric means were compared to USEPA and FDEP thresholds for recreational waters. **Appendix 6-3** provides spatial plots of the five water quality parameters.

TN values in 2010 were elevated (greater than 75% of the numeric nutrient criteria limit) at the majority of sampling stations within Kitching Creek (**Table 6-4** and **Figure 6-3-1** in **Appendix 6-3**). Station 59, a canal tributary in the northern part of the watershed, exceeded the numeric nutrient criteria value of 1.54 milligrams per liter (mg/L) (**Table 6-4**). All other stations were below the 1998–2002 target or the numeric nutrient criteria (**Table 6-4**, **Table 6-5** and **Figure 6-3-1**).

TP values were elevated at several sampling stations within the meso/oligohaline and brackish tributary analysis groups (**Table 6-7** and **Figure 6-3-2**). Two sampling sites (88 and 104) exceeded the numeric nutrient criteria for phosphorus (**Table 6-6** and **Figure 6-3-2**).

Chlorophyll a values were elevated at more stations (17 total) than any other parameter. These elevated levels were distributed throughout the various analysis groups (**Table 6-8** and **Figure 6-3-3**). Seven of the stations measured values greater than the 90th percentile of the target period for the respective analysis group. Clearly, chlorophyll a is a parameter that needs to be monitored closely and further evaluated to gain a better understanding of the causes driving the increasing concentrations.

Observed DO values relative to FDEP Class III surface water criteria were moderately low for fourteen stations and below the criteria at five stations (**Table 6-9** and **Figure 6-3-4**). The annual geometric means for each station were scored green (good) for DO values that exceeded the 5 mg/L criterion; yellow (caution) for values less than 5 mg/L, but greater 3 mg/L, the lower limit for agricultural water supplies, and red (poor) for values less than 3 mg/L. All of the stations in the Wild and Scenic analysis group scored yellow, but these DO values are not surprising considering the connectivity between the river channel and the floodplain swamp. Similarly, low DO values in the meso/oligohaline stations may be attributed to the significant groundwater inputs into this segment of the river documented in studies by the United States Geological Survey (USGS). While the DO values for these analysis groups are concerning relative to FDEP criteria, the values are generally comparable to the 1998–2002 targets using the previously described stoplight criteria. The freshwater canals, tributaries, and brackish tributaries each have stations that score yellow or red and do not meet the state's criteria for DO. While these stations have historically experienced low oxygen levels because of the nature of the sites (e.g., stagnant ditches, canals, etc.), they do not meet FDEP criteria.

Fecal coliform bacteria counts were high at two stations (107 and 73), and moderately high at two stations (106 and 75) (**Table 6-10** and **Figure 6-3-5**). The LRD has invested significant effort in converting existing development from the use of onsite wastewater treatment systems (i.e., septic systems) to the regional sanitary sewer system. Nonetheless, the homes along the banks of the river near station 107 continue to rely on septic systems for their wastewater treatment, so this might be a source.

**Table 6-4. TN annual geometric means for freshwater analysis groups color coded by USEPA numeric nutrient criteria for Florida streams**

| River Analysis Group | Site | Total Nitrogen (mg/l) 1998–2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Wild and Scenic | 66 | 1.07 | 1.27 | 0.98 | 1.33 | 1.49 | 1.09 | 0.88 | 0.98 | 0.74 |
| | 67 | 0.93 | 1.07 | 1.00 | 1.22 | 1.34 | 1.10 | 0.97 | 1.05 | 0.85 |
| | 68 | 0.97 | 1.01 | 1.03 | 1.38 | 1.37 | 1.37 | 0.96 | 1.02 | 0.91 |
| | 69 | 0.88 | 1.09 | 0.97 | 1.37 | 1.30 | 1.11 | 0.99 | 1.05 | 0.93 |
| Freshwater Tributaries | 81 | 0.90 | 1.02 | 0.96 | 1.34 | 1.18 | 1.29 | 0.91 | 1.10 | 0.87 |
| | 86 | | | | | | | 0.64 | 1.06 | 0.89 |
| | 87 | | | | | | | 0.62 | 1.11 | 0.87 |
| | 88 | | | | | | | 1.30 | 1.45 | 1.17 |
| | 100 | 1.07 | 1.14 | 0.95 | 1.45 | 1.32 | 1.09 | 0.98 | 1.02 | 0.89 |
| | 106 | 1.18 | 1.44 | 0.98 | 1.48 | 1.91 | 1.09 | 1.15 | 1.04 | 1.24 |
| | 108 | | | | | 2.14 | 1.34 | 0.94 | 1.34 | 1.22 |
| Freshwater Canals | 59 | 1.20 | 1.05 | 1.47 | 1.60 | 2.05 | 1.95 | 1.42 | 2.24 | 1.89 |
| | 92 | 0.97 | 0.92 | 0.98 | 1.44 | 1.32 | 1.37 | 1.01 | 1.18 | 0.90 |
| | 95 | 0.85 | 0.95 | 0.87 | 1.52 | 1.27 | 1.48 | 0.88 | 1.10 | 0.93 |
| | 101 | 1.23 | 1.38 | 1.11 | 1.95 | 2.10 | 2.02 | 1.19 | 1.62 | 1.52 |
| | 104 | 1.37 | 1.77 | 1.26 | 1.93 | 1.42 | 1.14 | 0.99 | 1.13 | 1.08 |
| | 105 | 1.11 | 1.14 | 0.97 | 1.51 | 1.52 | 1.09 | 0.88 | 1.02 | 1.05 |
| | 111 | | 1.23 | 1.15 | 1.54 | 1.86 | 1.65 | 0.87 | 1.79 | 1.50 |
| | 112 | | 1.23 | 1.65 | 1.42 | 2.08 | 1.81 | 1.38 | 1.38 | 1.41 |

**Color Code**
Yellow >1.16 (75% of USEPA numeric nutrient limit) and ≤1.54 (USEPA numeric nutrient limit)
Red >1.54 (USEPA numeric nutrient limit)

**<u>Alternate Analysis Groupings</u>**
Longitudinal (downstream to upstream): 66, 67, 68, 69, 92, 81
South Indian River Water Control District: 95
Kitching Creek: 101, 106, 108, 111, 112

**Table 6-5. TN annual geometric means for estuarine and marine analysis groups color coded by LRD 1998–2002 target value**

| | | Total Nitrogen (mg/l) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **River Analysis Group** | **Site** | **1998-2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| Marine | 10 | | 0.85 | | 0.60 | 0.45 | 0.15 | 0.16 | 0.12 | 0.16 |
| | 20 | | 0.78 | | 0.59 | 0.28 | 0.17 | 0.18 | 0.16 | 0.15 |
| | 25 | | 0.82 | | 0.73 | 0.37 | 0.12 | 0.12 | 0.16 | 0.11 |
| | 30 | | 0.95 | | 0.68 | 0.47 | 0.18 | 0.22 | 0.18 | 0.21 |
| | 32 | | | | 0.67 | 0.54 | 0.17 | 0.17 | 0.12 | 0.19 |
| | 40 | 1.44 | 0.63 | | 0.69 | 0.38 | 0.20 | 0.19 | 0.11 | 0.11 |
| | Thresholds not available because of limited data | | | | | | | | | |
| Brackish Tributaries | 35 | | 1.17 | | 0.65 | 0.42 | 0.22 | 0.33 | 0.18 | 0.16 |
| | 55 | 1.26 | 1.46 | 1.75 | 1.41 | 0.65 | 0.75 | 0.37 | 0.47 | 0.45 |
| | 71 | 1.23 | 2.40 | 1.24 | 1.14 | 0.63 | 0.39 | 0.56 | 0.27 | 0.38 |
| | 73 | 1.28 | 2.47 | 0.81 | 0.79 | 0.71 | 0.65 | 0.66 | 0.49 | 0.58 |
| | 75 | | | | | | 0.49 | 0.62 | 0.58 | 0.82 |
| | 107 | 1.20 | 1.62 | 1.20 | 2.26 | 1.81 | 0.60 | 1.01 | 0.99 | 0.91 |
| | **Color Code** - yellow >1.46 and ≤1.79; red >1.79 | | | | | | | | | |
| Polyhaline | 42 | | | 1.62 | 0.78 | 0.57 | 0.37 | 0.36 | 0.18 | 0.25 |
| | 51 | 0.54 | 1.86 | | 0.78 | 0.50 | 0.30 | 0.30 | 0.23 | 0.15 |
| | 60 | 1.77 | 1.06 | 2.09 | 1.25 | 0.76 | 0.35 | 0.55 | 0.54 | 0.30 |
| | 72 | 1.41 | 2.49 | 0.86 | 1.22 | 0.78 | 0.55 | 0.56 | 0.40 | 0.49 |
| | **Color Code** - yellow >1.95 and <2.32; red >2.32 | | | | | | | | | |
| Meso/Oligohaline | 62 | 1.46 | 1.78 | 2.18 | 2.73 | 0.97 | 0.62 | 0.77 | 0.58 | 0.72 |
| | 63 | 1.33 | 1.83 | 1.15 | 2.01 | 1.49 | 0.52 | 1.29 | 0.77 | 0.91 |
| | 64 | 1.26 | 2.16 | 1.07 | 1.86 | 1.69 | 0.69 | 1.18 | 0.84 | 0.87 |
| | 65 | 1.13 | 1.68 | 0.99 | 1.43 | 1.64 | 0.98 | 0.93 | 0.94 | 0.89 |
| | **Color Code** - yellow >1.54 and ≤1.91; red >1.91 | | | | | | | | | |

**Alternate Analysis Groupings:** Longitudinal (downstream to upstream): 10, 40, 42, 60, 62, 63, 64, 65; Indian River Lagoon: 20, 25; Lake Worth Lagoon: 30, 32, 35; Brackish Tributaries: 55, 71, 73, 75, 107

**Table 6-6. TP annual geometric mean for freshwater analysis groups color coded by USEPA numeric nutrient criteria for Florida streams**

| | | Total Phosphorus (mg/l) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **River Analysis Group** | **Site** | **1998-2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| Wild and Scenic | 66 | 0.055 | 0.058 | 0.061 | 0.059 | 0.062 | 0.072 | 0.051 | 0.061 | 0.056 |
| | 67 | 0.043 | 0.046 | 0.048 | 0.045 | 0.049 | 0.080 | 0.060 | 0.051 | 0.044 |
| | 68 | 0.040 | 0.042 | 0.040 | 0.036 | 0.042 | 0.080 | 0.046 | 0.053 | 0.047 |
| | 69 | 0.033 | 0.032 | 0.030 | 0.033 | 0.032 | 0.054 | 0.043 | 0.041 | 0.038 |
| Freshwater Tributaries | 81 | 0.028 | 0.037 | 0.016 | 0.025 | 0.026 | 0.029 | 0.026 | 0.024 | 0.027 |
| | 86 | | | | | | | 0.027 | 0.040 | 0.027 |
| | 87 | | | | | | | 0.038 | 0.028 | 0.034 |
| | 88 | | | | | | | 0.350 | 0.587 | 0.492 |
| | 100 | 0.059 | 0.058 | 0.045 | 0.065 | 0.060 | 0.070 | 0.058 | 0.058 | 0.065 |
| | 106 | 0.068 | 0.077 | 0.081 | 0.052 | 0.088 | 0.081 | 0.086 | 0.085 | 0.069 |
| | 108 | | | | | 0.105 | 0.087 | 0.063 | 0.089 | 0.068 |
| Freshwater Canals | 59 | 0.060 | 0.040 | 0.076 | 0.054 | 0.101 | 0.070 | 0.080 | 0.223 | 0.076 |
| | 92 | 0.031 | 0.031 | 0.027 | 0.031 | 0.033 | 0.057 | 0.039 | 0.040 | 0.040 |
| | 95 | 0.038 | 0.042 | 0.043 | 0.050 | 0.041 | 0.088 | 0.074 | 0.069 | 0.057 |
| | 101 | 0.067 | 0.058 | 0.038 | 0.064 | 0.090 | 0.086 | 0.051 | 0.078 | 0.068 |
| | 104 | 0.085 | 0.094 | 0.095 | 0.105 | 0.121 | 0.080 | 0.107 | 0.108 | 0.144 |
| | 105 | 0.058 | 0.061 | 0.059 | 0.057 | 0.075 | 0.085 | 0.035 | 0.055 | 0.064 |
| | 111 | | 0.053 | 0.041 | 0.033 | 0.052 | 0.054 | 0.036 | 0.102 | 0.055 |
| | 112 | | 0.031 | 0.057 | 0.021 | 0.067 | 0.037 | 0.050 | 0.067 | 0.040 |

**Color Code**
Yellow >0.09 (75% of USEPA numeric nutrient limit) and ≤0.12 (USEPA numeric nutrient limit)
Red >0.12 (USEPA numeric nutrient limit)

**<u>Alternate Analysis Groupings</u>**
Longitudinal (downstream to upstream): 66, 67, 68, 69, 92, 81
South Indian River Water Control District: 95
Kitching Creek: 101, 106, 108, 111, 112

**Table 6-7. TP annual geometric mean for estuarine and marine analysis groups color coded by LRD 1998–2002 target value**

| | | Total Phosphorus (mg/l) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **River Analysis Group** | **Site** | **1998-2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| Marine | 10 | 0.017 | 0.012 | 0.012 | 0.043 | 0.013 | 0.009 | 0.016 | 0.014 | 0.014 |
| | 20 | 0.013 | 0.008 | 0.010 | 0.034 | 0.010 | 0.004 | 0.008 | 0.011 | 0.008 |
| | 25 | 0.019 | 0.014 | 0.012 | 0.022 | 0.022 | 0.013 | 0.015 | 0.013 | 0.012 |
| | 30 | 0.030 | 0.022 | 0.027 | 0.031 | 0.033 | 0.024 | 0.021 | 0.022 | 0.027 |
| | 32 | | | | 0.029 | 0.029 | 0.019 | 0.020 | 0.022 | 0.023 |
| | 40 | 0.022 | 0.015 | 0.013 | 0.031 | 0.023 | 0.008 | 0.019 | 0.013 | 0.015 |
| | **Color Code** - yellow >0.033 and ≤0.043; red >0.043 | | | | | | | | | |
| Brackish Tributaries | 35 | 0.034 | 0.029 | 0.029 | 0.032 | 0.030 | 0.022 | 0.026 | 0.024 | 0.023 |
| | 55 | 0.042 | 0.037 | 0.049 | 0.042 | 0.045 | 0.043 | 0.039 | 0.040 | 0.040 |
| | 71 | 0.048 | 0.041 | 0.052 | 0.044 | 0.047 | 0.031 | 0.046 | 0.034 | 0.044 |
| | 73 | 0.055 | 0.049 | 0.066 | 0.052 | 0.049 | 0.040 | 0.065 | 0.048 | 0.047 |
| | 75 | | | | | | 0.067 | 0.079 | 0.074 | 0.088 |
| | 107 | 0.208 | 0.179 | 0.232 | 0.115 | 0.091 | 0.107 | 0.101 | 0.110 | 0.118 |
| | **Color Code** - yellow >0.080 and ≤0.150; red >0.150 | | | | | | | | | |
| Meso/Oligohaline | 62 | 0.049 | 0.045 | 0.062 | 0.050 | 0.051 | 0.056 | 0.057 | 0.048 | 0.052 |
| | 63 | 0.054 | 0.055 | 0.062 | 0.059 | 0.059 | 0.062 | 0.064 | 0.058 | 0.069 |
| | 64 | 0.053 | 0.062 | 0.065 | 0.057 | 0.065 | 0.064 | 0.064 | 0.062 | 0.066 |
| | 65 | 0.056 | 0.064 | 0.066 | 0.055 | 0.068 | 0.072 | 0.063 | 0.061 | 0.066 |
| | **Color Code** - yellow >0.066 and ≤0.081; red >0.081 | | | | | | | | | |
| Polyhaline | 42 | | | 0.031 | 0.028 | 0.025 | 0.021 | 0.024 | 0.018 | 0.026 |
| | 51 | 0.027 | 0.020 | 0.026 | 0.030 | 0.028 | 0.016 | 0.023 | 0.023 | 0.024 |
| | 60 | 0.037 | 0.030 | 0.035 | 0.038 | 0.041 | 0.056 | 0.038 | 0.031 | 0.037 |
| | 72 | 0.041 | 0.032 | 0.042 | 0.043 | 0.037 | 0.031 | 0.038 | 0.030 | 0.035 |
| | **Color Code** - yellow >0.044 and ≤0.070; red >0.070 | | | | | | | | | |

**Alternate Analysis Groupings:** Longitudinal (downstream to upstream): 10, 40, 42, 60, 62, 63, 64, 65; Indian River Lagoon: 20, 25; Lake Worth Lagoon: 30, 32, 35; Brackish Tributaries: 55, 71, 73, 75, 107

## Table 6-8. Chlorophyll a annual geometric means for analysis groups color coded by LRD 1998–2002 target value

| | | Chlorophyll a | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **River Analysis Group** | **Site** | **1998-2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| Wild and Scenic | 66 | 3.5 | 3.8 | 3.6 | 4.6 | 3.0 | 4.1 | 1.9 | 5.4 | 3.2 |
| | 67 | 2.2 | 1.2 | 1.3 | 4.0 | 1.6 | 3.7 | 3.5 | 3.8 | 2.3 |
| | 68 | 1.8 | 1.3 | 1.1 | 3.2 | 1.5 | 2.8 | 4.1 | 3.2 | 3.0 |
| | 69 | 2.6 | 3.7 | 2.8 | 5.2 | 2.1 | 5.7 | 7.1 | 9.6 | 8.6 |
| | | **Color Code** - yellow >4.4 and ≤8.3; red >8.3 | | | | | | | | |
| Freshwater Tributaries | 81 | 5.0 | 10.5 | 3.8 | 6.4 | 2.4 | 12.5 | 6.9 | 7.0 | 9.0 |
| | 86 | | | | | | | 10.0 | 12.4 | 12.2 |
| | 87 | | | | | | | 11.2 | 10.3 | 12.6 |
| | 88 | | | | | | | 49.5 | 48.2 | 19.5 |
| | 100 | 2.8 | 3.2 | 2.3 | 3.7 | 1.4 | 4.0 | 2.7 | 3.1 | 2.9 |
| | 106 | 4.4 | 6.7 | 9.9 | 4.0 | 5.2 | 4.0 | 10.4 | 7.3 | 5.5 |
| | 108 | | | | | 5.2 | 3.3 | 7.5 | 4.6 | 3.5 |
| | | **Color Code** - yellow >8.0 and ≤12.8; red >12.8 | | | | | | | | |
| Freshwater Canals | 59 | 6.3 | 13.3 | 2.5 | 6.0 | 15.7 | 6.8 | 10.1 | 14.5 | 11.9 |
| | 92 | 4.5 | 10.1 | 3.6 | 8.4 | 3.4 | 9.1 | 7.3 | 10.9 | 11.0 |
| | 95 | 3.1 | 4.5 | 3.8 | 6.4 | 2.0 | 10.0 | 8.4 | 11.0 | 7.8 |
| | 101 | 10.6 | 27.3 | 10.8 | 13.5 | 8.3 | 13.9 | 7.1 | 9.8 | 21.6 |
| | 104 | 11.3 | 11.7 | 9.7 | 21.1 | 7.7 | 3.4 | 17.3 | 20.0 | 12.8 |
| | 105 | 3.5 | 3.6 | 2.4 | 4.5 | 2.3 | 1.2 | 2.7 | 4.0 | 4.4 |
| | 111 | | 19.1 | 9.0 | 7.1 | 5.2 | 9.4 | 7.3 | 12.1 | 9.6 |
| | 112 | | 16.2 | 12.3 | 6.6 | 8.5 | 7.0 | 9.8 | 7.0 | 5.5 |
| | | **Color Code** - yellow >11.0 and ≤26.5; red >26.5 | | | | | | | | |
| Marine | 10 | 1.9 | 2.3 | 2.3 | 3.3 | 0.9 | 1.0 | 2.4 | 1.6 | 2.0 |
| | 20 | 1.5 | 1.8 | 1.9 | 2.9 | 0.9 | 0.5 | 3.4 | 1.2 | 1.1 |
| | 25 | 2.8 | 4.0 | 3.4 | 4.7 | 2.5 | 1.7 | 3.7 | 1.8 | 2.2 |
| | 30 | 4.4 | 6.0 | 8.9 | 6.3 | 4.6 | 5.4 | 8.4 | 5.6 | 7.9 |

## Table 6-8. continued

| River Analysis Group | Site | Chlorophyll a 1998-2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Marine (continued) | 32 | | | | 4.7 | 4.3 | 4.9 | 7.3 | 5.5 | 5.7 |
| | 40 | 2.6 | 3.5 | 2.7 | 4.1 | 2.0 | 2.2 | 3.9 | 2.4 | 2.6 |
| | **Color Code** - yellow >4.2 and <6.9; red >6.9 | | | | | | | | | |
| Brackish Tributary | 35 | 3.4 | 3.8 | 7.5 | 8.0 | 4.5 | 5.5 | 8.5 | 6.0 | 7.9 |
| | 55 | 5.6 | 8.4 | 4.6 | 13.8 | 5.0 | 11.2 | 5.3 | 10.1 | 8.7 |
| | 71 | 7.3 | 9.6 | 9.9 | 16.2 | 6.2 | 10.5 | 12.3 | 11.3 | 12.6 |
| | 73 | 8.4 | 16.9 | 14.2 | 22.0 | 5.8 | 11.1 | 17.8 | 12.6 | 15.2 |
| | 75 | | | | | | | 16.0 | 11.6 | 20.1 |
| | 107 | 3.6 | 5.4 | 4.4 | 14.4 | 5.7 | 5.0 | 4.0 | 4.0 | 7.0 |
| | **Color Code** - yellow >8.9 and ≤13.7; red >13.7 | | | | | | | | | |
| Meso/Oligohaline | 62 | 4.1 | 6.9 | 6.2 | 7.6 | 6.9 | 5.6 | 8.8 | 9.4 | 8.1 |
| | 63 | 4.2 | 8.8 | 4.6 | 7.6 | 5.3 | 5.6 | 8.9 | 8.7 | 7.9 |
| | 64 | 4.0 | 10.3 | 3.8 | 7.6 | 4.0 | 3.2 | 8.1 | 7.0 | 8.5 |
| | 65 | 3.7 | 7.5 | 4.5 | 5.3 | 3.1 | 4.7 | 5.6 | 8.5 | 5.6 |
| | **Color Code** - yellow >5.8 and ≤8.3; red >8.3 | | | | | | | | | |
| Polyhaline | 42 | | | 4.5 | 7.2 | 3.0 | 5.6 | 6.8 | 4.4 | 7.1 |
| | 51 | 3.7 | 5.6 | 10.3 | 7.7 | 3.2 | 4.2 | 6.0 | 5.0 | 5.4 |
| | 60 | 4.2 | 6.8 | 4.0 | 10.6 | 5.8 | 4.9 | 7.4 | 8.4 | 7.3 |
| | 72 | 9.9 | 15.7 | 13.4 | 17.0 | 6.5 | 13.3 | 12.8 | 11.7 | 14.8 |
| | **Color Code** - yellow >9.3 and ≤14.5; red >14.5 | | | | | | | | | |

**<u>Alternate Analysis Groupings</u>**
Longitudinal (downstream to upstream): 10, 40, 42, 60, 62, 63, 64, 65, 66, 67, 68, 69, 92, 81
Indian River Lagoon: 20, 25
Lake Worth Lagoon: 30, 32, 35
South Indian River Water Control District: 95
Kitching Creek: 101, 106, 108, 111, 112
Brackish Tributaries: 55, 71, 73, 75, 107

**Table 6-9. DO annual geometric means for all analysis groups color coded by FDEP criteria for Class III waters**

| | | Dissolved Oxygen (mg/l) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **River Analysis Group** | **Site** | **1998-2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| Wild and Scenic | 66 | 5.63 | 5.46 | 4.88 | 6.05 | 4.39 | 4.27 | 4.97 | 4.86 | 4.85 |
| | 67 | 5.67 | 5.40 | 4.55 | 4.91 | 3.93 | 4.10 | 4.57 | 4.61 | 4.95 |
| | 68 | 5.75 | 5.64 | 6.67 | 4.70 | 4.45 | 4.17 | 4.52 | 4.78 | 4.87 |
| | 69 | 4.41 | 4.08 | 5.00 | 3.99 | 4.05 | 3.25 | 4.02 | 4.19 | 3.81 |
| Freshwater Tributaries | 81 | 6.73 | 6.42 | 6.00 | 5.40 | 6.09 | 5.49 | 5.46 | 6.79 | 5.88 |
| | 86 | | | | | | | 6.44 | 6.58 | 6.37 |
| | 87 | | | | | | | 6.90 | 6.18 | 6.24 |
| | 88 | | | | | | | 1.16 | 0.69 | 1.60 |
| | 100 | 6.17 | 6.24 | 5.91 | 6.15 | 4.88 | 5.23 | 5.71 | 5.39 | 5.17 |
| | 106 | 3.68 | 3.53 | 4.66 | 3.98 | 4.59 | 4.30 | 4.03 | 3.52 | 4.27 |
| | 108 | | | | | 3.92 | 2.75 | 3.21 | 3.83 | 4.82 |
| Freshwater Canals | 59 | 0.50 | 0.53 | 0.49 | 1.35 | 1.79 | 0.88 | 0.36 | 0.36 | 2.77 |
| | 92 | 5.26 | 4.55 | 5.16 | 4.21 | 4.52 | 2.80 | 4.60 | 4.38 | 4.37 |
| | 95 | 5.30 | 4.73 | 4.29 | 4.39 | 4.73 | 3.32 | 4.15 | 4.59 | 4.51 |
| | 101 | 0.74 | 0.58 | 1.77 | 2.28 | 2.12 | 1.01 | 1.09 | 2.36 | 2.67 |
| | 104 | 6.33 | 4.77 | 6.72 | 5.96 | 5.54 | 4.84 | 5.29 | 6.45 | 6.49 |
| | 105 | 4.69 | 3.12 | 5.68 | 4.91 | 4.91 | 3.40 | 3.83 | 4.00 | 5.42 |
| | 111 | | 2.18 | 1.86 | 1.78 | 1.33 | 1.39 | 1.19 | 1.43 | 2.81 |
| | 112 | | 0.81 | 1.32 | 3.08 | 2.31 | 2.81 | 1.18 | 3.14 | 4.05 |
| Marine | 10 | 6.49 | 6.33 | 6.13 | 6.64 | 6.32 | 6.62 | 6.51 | 6.72 | 6.96 |
| | 20 | 6.66 | 6.63 | 6.41 | 6.61 | 6.18 | 6.56 | 6.64 | 6.79 | 7.06 |
| | 25 | 6.62 | 6.33 | 6.07 | 6.44 | 6.32 | 6.24 | 6.41 | 6.59 | 6.59 |
| | 30 | 6.00 | 5.96 | 5.80 | 6.44 | 5.41 | 5.88 | 5.96 | 6.06 | 6.22 |
| | 32 | | | | 6.14 | 5.34 | 5.89 | 5.93 | 5.94 | 6.20 |
| | 40 | 6.65 | 6.53 | 6.36 | 6.62 | 6.45 | 6.65 | 6.54 | 6.85 | 7.09 |

**Table 6-9. continued**

| River Analysis Group | Site | Dissolved Oxygen | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1998-2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| Brackish Tributaries | 35 | 5.61 | 5.50 | 5.81 | 6.03 | 5.82 | 5.72 | 5.70 | 6.01 | 5.93 |
| | 55 | 4.94 | 3.51 | 3.67 | 5.30 | 4.22 | 4.27 | 4.22 | 4.22 | 4.98 |
| | 71 | 5.28 | 4.64 | 4.18 | 5.76 | 5.59 | 5.70 | 4.68 | 5.52 | 5.69 |
| | 73 | 4.86 | 4.30 | 3.75 | 5.36 | 4.99 | 5.50 | 4.40 | 4.95 | 5.94 |
| | 75 | | | | | | 3.01 | 2.91 | 2.72 | 2.95 |
| | 107 | 4.40 | 2.90 | 5.07 | 4.37 | 4.00 | 3.99 | 4.58 | 4.12 | 3.40 |
| Meso/Oligohaline | 62 | 5.40 | 5.12 | 4.86 | 5.71 | 5.04 | 4.61 | 5.26 | 5.48 | 5.57 |
| | 63 | 5.14 | 4.73 | 3.56 | 5.23 | 4.23 | 4.10 | 4.65 | 4.60 | 4.64 |
| | 64 | 5.22 | 4.75 | 3.21 | 5.17 | 4.11 | 4.46 | 4.92 | 4.54 | 4.82 |
| | 65 | 4.99 | 3.81 | 2.91 | 5.60 | 3.15 | 3.50 | 5.00 | 3.46 | 4.75 |
| Polyhaline | 42 | | | 6.50 | 6.51 | 6.08 | 6.04 | 5.86 | 6.27 | 6.62 |
| | 51 | 6.25 | 5.91 | 5.80 | 6.27 | 6.16 | 5.92 | 6.35 | 6.28 | 6.85 |
| | 60 | 6.20 | 5.86 | 6.27 | 6.34 | 5.78 | 5.61 | 6.04 | 6.22 | 6.28 |
| | 72 | 6.16 | 5.31 | 5.48 | 6.31 | 6.06 | 5.22 | 5.95 | 5.93 | 5.30 |

**Color Code**
Yellow >3.0 and ≤5.0
Red ≤ 3.0

**<u>Alternate Analysis Groupings</u>**

Longitudinal (downstream to upstream): 10, 40, 42, 60, 62, 63, 64, 65, 66, 67, 68, 69, 92, 81
Indian River Lagoon: 20, 25
Lake Worth Lagoon: 30, 32, 35
South Indian River Water Control District: 95
Kitching Creek: 101, 106, 108, 111, 112
Brackish Tributaries: 55, 71, 73, 75, 107

**Table 6-10. Fecal coliform annual geometric means for estuarine analysis groups color coded by FDEP criteria for Class II waters**

| River Analysis Group | Site | Fecal Coliform (colony forming units 100 per m/l) 1998-2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Marine | 40 | 5 | 6 | 6 | 10 | 10 | 3 | 11 | 1 | 3 |
| Brackish Tributaries | 71 | 84 | 68 | 139 | 125 | 136 | 50 | 158 | 97 | 150 |
| | 73 | 145 | 202 | 346 | 513 | 194 | 254 | 922 | 441 | 520 |
| Meso/Oligohaline | 62 | 73 | 66 | 40 | 142 | 46 | 61 | 149 | 51 | 90 |
| | 63 | 117 | 115 | 188 | 120 | 115 | 76 | 276 | 63 | 127 |
| | 64 | 129 | 132 | 121 | 102 | 92 | 91 | 187 | 79 | 156 |
| Polyhaline | 42 | | | 61 | 10 | 36 | 9 | 49 | 8 | 30 |
| | 51 | 12 | 6 | 11 | 14 | 17 | 8 | 33 | 5 | 9 |
| | 60 | 40 | 20 | 30 | 18 | 15 | 17 | 53 | 14 | 31 |
| | 72 | 53 | 59 | 57 | 145 | 52 | 97 | 197 | 67 | 121 |

**Color Code**
White ≤ 43
Yellow > 43 and ≤ 200
Red > 200

In **Figure 6-4** is a synthesis of the results in a spatial plot. When considering all five parameters, station 88, a freshwater tributary/ditch flowing into the Northwest Fork; station 75 at Jones Creek, a brackish tributary flowing into the Southwest Fork; and station 107, a brackish tributary flowing into the Northwest Fork are the most degraded sampling sites in the watershed. Station 88 is a surface water outfall that delivers water from a fallow agriculture area to the floodplain of the Northwest Fork just upstream of Masten Dam. During the dry season, this site (i.e., culvert) is dry. During the wet season, low flows are observed at this site following rainfall events. Station 75 is in Jones Creek, a drainage tributary for an extensive urban area of Jupiter. The Town of Jupiter, in partnership with the Loxahatchee River Preservation Initiative, continues

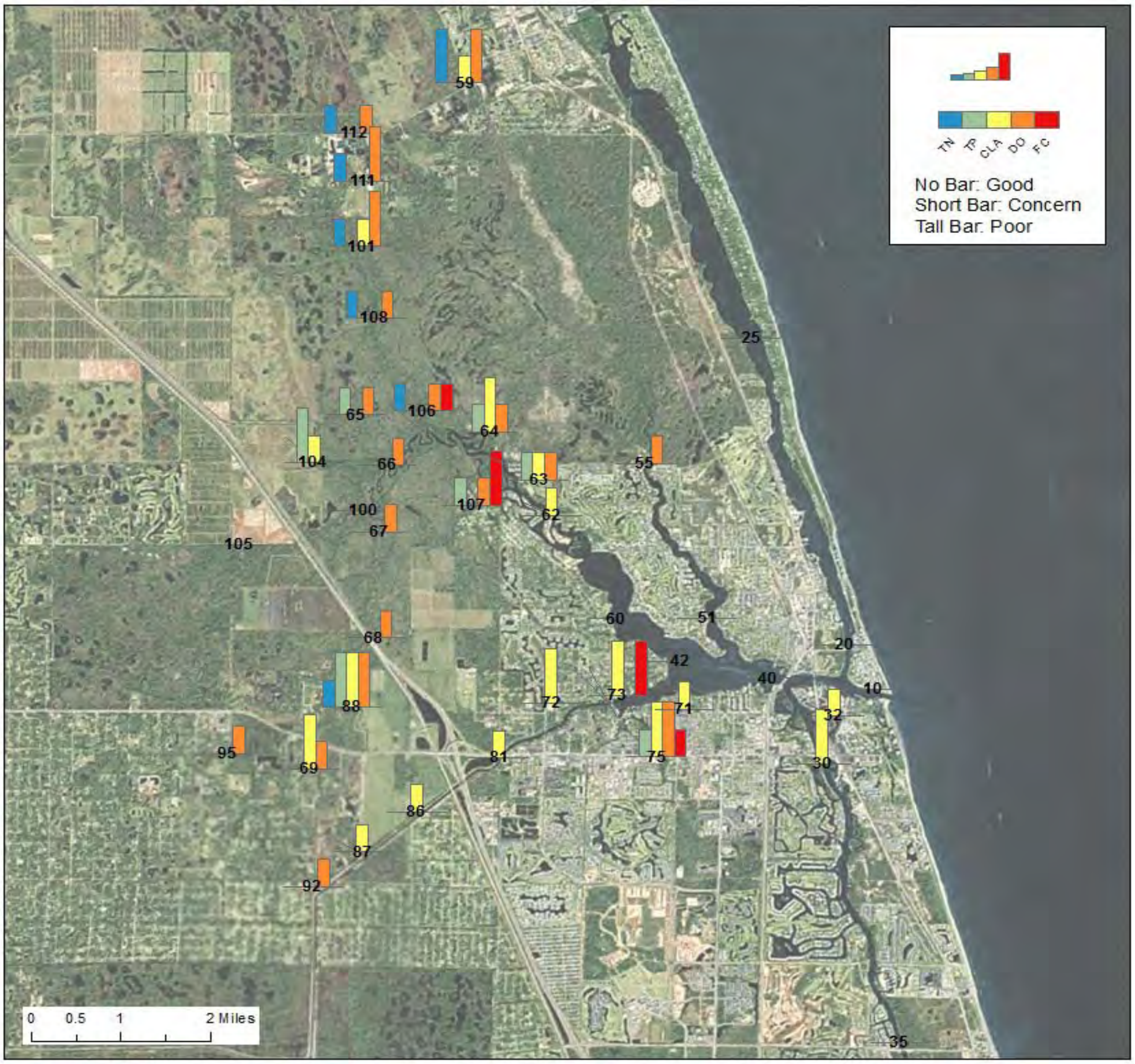


**Figure 6-4. Synthesis of 2010 water quality stoplight scoring by sampling site for TP, TN, chlorophyll a, DO and fecal coliform combined**

Bar height corresponds to the stoplight score relative to the LRD 1998–2002 target period, or the USEPA numeric nutrient criteria or FDEP criteria for Class II or III Waters. No bar is equivalent to green (good), short bar is equivalent to yellow (caution) and tall bar is equivalent to red (poor).

work on a variety of stormwater improvement projects that may improve water quality within this subbasin. Station 107 is in a tributary of the Northwest Fork referred to as Ketter Creek. This tributary provides drainage from an older residential community that relies on septic systems for wastewater treatment as well as a new development on former agriculture fields. These three sampling sites clearly present opportunities for restoration that would further improve surface water quality within the Loxahatchee River watershed.

### 6.1.5 Conclusions

In conclusion, water quality in the Loxahatchee River during 2010 was generally good. These findings are encouraging because the river experienced greater base flows than observed over the past several years. In fact, during the 2009–2010 dry season, river flows measured at Lainhart Dam fell below the 35 cfs target for only 11 days total, and it was the first year since 1997 that the minimum flow criterion was not violated. Higher than usual rainfall, particularly during the dry season, and improved water management within the basin were key contributors to improved flows.

Despite the increased flows, TN and TP values were generally below target values established by the USEPA numeric nutrient criteria and the targets established by the LRD. Elevated chlorophyll a concentrations, particularly in the meso/oligohaline and brackish water tributaries, continue to exhibit values higher than the LRD targets. Further investigation into the causes and potential consequences of the elevated chlorophyll a concentrations is needed.

This report provides a historical assessment of water quality for five key parameters by river analysis group and by individual sampling station, relative to USEPA numeric nutrient criteria, FDEP Class II and III water quality criteria, and LRD targets. Fortunately, the vast majority of sampling sites in the Loxahatchee River watershed meet the numeric nutrient criteria for nitrogen and phosphorus. In general, many of the parameters with elevated concentrations correspond with significant weather events observed in 2004 and 2005. Elevated chlorophyll a and low DO levels were observed at sampling sites throughout the watershed. The causes of the elevated chlorophyll values are not clear. While there are some logical explanations for the lower DO observations, water quality does not consistently meet FDEP criteria for Class III waters. Three sampling sites present consistently poor water quality and these subbasins should be targeted for restoration work to improve water quality.

The River Keeper water quality monitoring project continues to be an excellent and efficient approach to monitor water quality in the Loxahatchee River watershed. Because of the LRD's long standing commitment to assess water quality in the Loxahatchee River watershed, an excellent historical record has been established. As restoration efforts continue to move forward in the watershed, water quality conditions should continue to be evaluated, and compared to the USEPA numeric nutrient criteria, FDEP Class II and III water quality criteria, established LRD target conditions and pre-restoration conditions, thereby providing a comprehensive measure of project success. Such across-time comparisons can be valuable for adaptively managing the resource. Finally, it should be noted that while much work has been done in the Loxahatchee River watershed (e.g., the numerous Loxahatchee River Preservation Initiative projects), there continue to be water quality issues that need to be addressed.

A summary of recommendations for future work include the following:

- Continue the River Keeper monitoring project to assess long- and short-term trends in water quality in the Loxahatchee River. These data provide essential information for adaptive management of restoration activities.

- Further assess causes and potential consequences of elevated chlorophyll a concentrations observed at various sites throughout the watershed.

- Where water quality concerns are identified, resource managers should identify the source of the degradation and develop and implement projects to remedy the source of water quality degradation.

- The River Keeper data should be used to the greatest extent possible by the FDEP under their efforts to assess total maximum daily loads for the Loxahatchee River and its tributaries.

## 6.2 Estimates of Nutrient Loads

### 6.2.1 Introduction

A preferred restoration flow scenario was proposed in the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006). The development of this flow scenario was based primarily on the response of salinity levels to freshwater inflow. The restoration goal was to provide salinity levels needed to support a wide spectrum of ecological resources including freshwater riverine and tidal floodplain vegetation. However, the response of water quality to freshwater flow and associated nutrient loads was not given much consideration during the development of the preferred restoration flow scenario. Water quality response is critically important to appropriately evaluate the effects of freshwater inflow on estuaries (Alber 2002). In addition, an assessment of responses of an estuary to nutrient loads has been the focus in recent federal and state efforts such as the development of total maximum daily loads and the derivation of numeric nutrient criteria (USEPA 2010c).

One of the reasons for this gap of information was the lack of concurrent measurements of flow and water quality data, making it difficult to estimate loading of nutrients to the river. To address this gap, flow measurements made by the USGS and SFWMD and water quality data collected by the LRD are combined. The objectives of analyses were to (1) quantify freshwater flows and nutrient loads, (2) determine the sources of the flows and loads and (3) examine water quality responses in the Northwest Fork to freshwater and nutrient loads. The estimated nutrient loads and riverine responses will provide baseline information to evaluate impacts of ongoing and future CERP projects on the hydrology and ecosystem of this area.

### 6.2.2 Materials and Methods

The Loxahatchee River is composed of three forks — Southwest, North and Northwest (See **Figure 1-1** in **Section 1.0**). The Northwest Fork has the longest reach and provides the largest freshwater inflow, most of which is through the Lainhart Dam, Kitching Creek and Cypress Creek (**Figure 6-5**) and other tributaries, such as Hobe Grove Ditch (Mcpherson and Sonntag

1984, SFWMD 2006). The Southwest Fork is linked to the C-18 Canal, which is another main source of fresh water and nutrients to the Loxahatchee River Estuary. Flow from the C-18 Canal into the Southwest Fork is controlled by the S-46 structure.

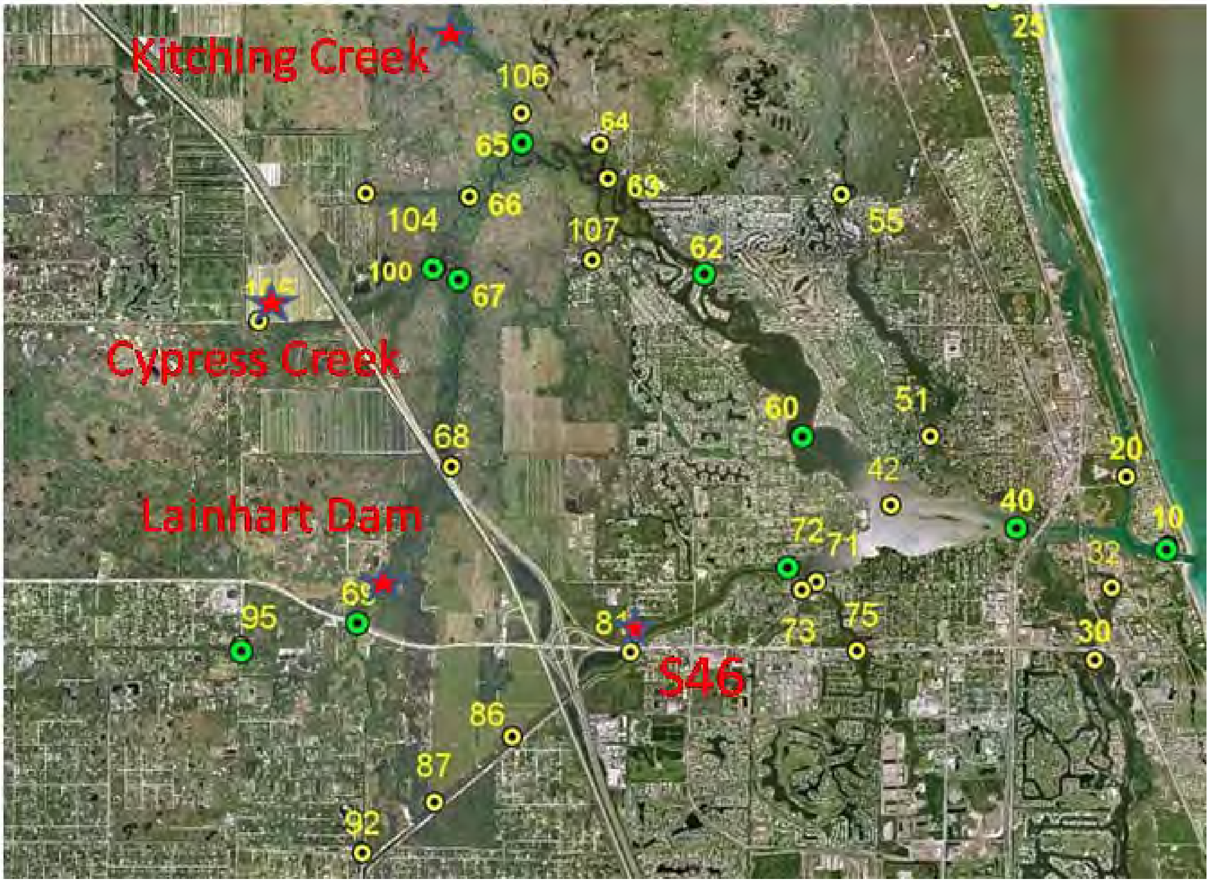


**Figure 6-5. Gauges (stars) at which freshwater flow is monitored by the USGS and SFWMD and water quality stations (circles) monitored by the LRD**

Green circles indicate the station is sample monthly.

Yellow circles indicate the station is sampled bimonthly (every other month).

The focus of this analysis is primarily on fresh water and associated nutrient loads flowing into the Northwest Fork from Lainhart Dam, Cypress Creek and Kitching Creek because of their relative contributions and the availability of flow and water quality data. The daily flow data were downloaded from the USGS website (http://waterdata.usgs.gov/fl/nwis/). The nutrient concentration, measured as TN, TP, dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) or orthophosphate, were taken on a monthly or bimonthly (every other month) basis by the LRD, and linearly interpolated into daily concentrations from bimonthly samples. Finally, daily nutrient loads were estimated by multiplying daily flows and interpolated daily nutrient concentrations to determine wet season (May–October), dry season (November–April), and annual loads.

In a river dominated estuary, water quality is driven by magnitudes of freshwater discharge and materials within these discharges, and varies with geographic distance from discharge. To account for spatial differences in responses of water quality to freshwater flows and nutrient loads, two reaches in the Northwest Fork were chosen. The first is the Wild and Scenic reach (stations 67 and 68 on **Figure 6-5**), which relates to freshwater discharges and nutrient loads from Lainhart Dam. The other is the mesohaline reach or oligahaline ecozones (stations 62, 63 and 64), which relate to discharges and loads from all three tributaries. The stations located further downstream were not included in this study because water quality is potentially impacted by discharges from the C-18 Canal through the S-46 structure.

The parameters examined were salinity, chlorophyll a, DO concentration and saturation, percentage of surface light at a depth of one meter, nutrient concentrations (TN, TP, DIN and DIP) and their molar ratios, color, TSS and fecal coliform bacteria. These same divisions of reaches, stations and parameters were used to develop water quality targets in the 2006 restoration plan (Table 10-1 in SFWMD 2006). Average daily discharge and total daily nutrient loads were related to averaged water quality at each reach on the same water quality sample dates. On the average, slightly over 60 percent of the total volume of the estuary is flushed on each tide (Mcpherson and Sonntag 1984). A daily time period was chosen because of this short flushing time of the river and because this timescale yielded a higher flow-salinity relationship and captured well the responses of the river and estuary to freshwater inflow (Wan and Hu 2006).

The Mann-Whitney rank test was used to examine statistical differences in means of seasonal nutrient concentrations and their molar ratios from the three tributaries. Spearman's rank correlation was used to relate the water quality responses to freshwater discharges and nutrient loads. Differences or corrections are statistically significant when p is less than 0.05.

### 6.2.3 Results

<u>Hydrological Load</u>

Freshwater inflow or hydrologic load to the Northwest Fork of the Loxahatchee River shows distinct seasonal and interannual variations (**Figure 6-6a**). The total annual inflow from Kitching Creek, Cypress Creek and Lainhart Dam to the Northwest Fork ranges from 100 million cubic meters per year (2006) to approximately 260 million cubic meters per year (2005). This large interannual variation is related to the hurricanes experienced during 2004 and 2005 (Hu and Wan 2006). In each year, about 70 percent of the fresh water was delivered to the Northwest Fork in the wet season (May–October) (**Table 6-11**). Overall, flows were delivered via the Lainhart Dam (~48%) and Cypress Creek (~44%) with only eight percent flowing from Kitching Creek and these relative contributions varied over different seasons and years. Inflows at these three tributaries account for about 80 percent of the entire watershed that discharged into the Loxahatchee River during the study period (Wan and Hu 2006). Another tributary flowing into the Northwest Fork Hobe Grove Ditch was not included in this study.

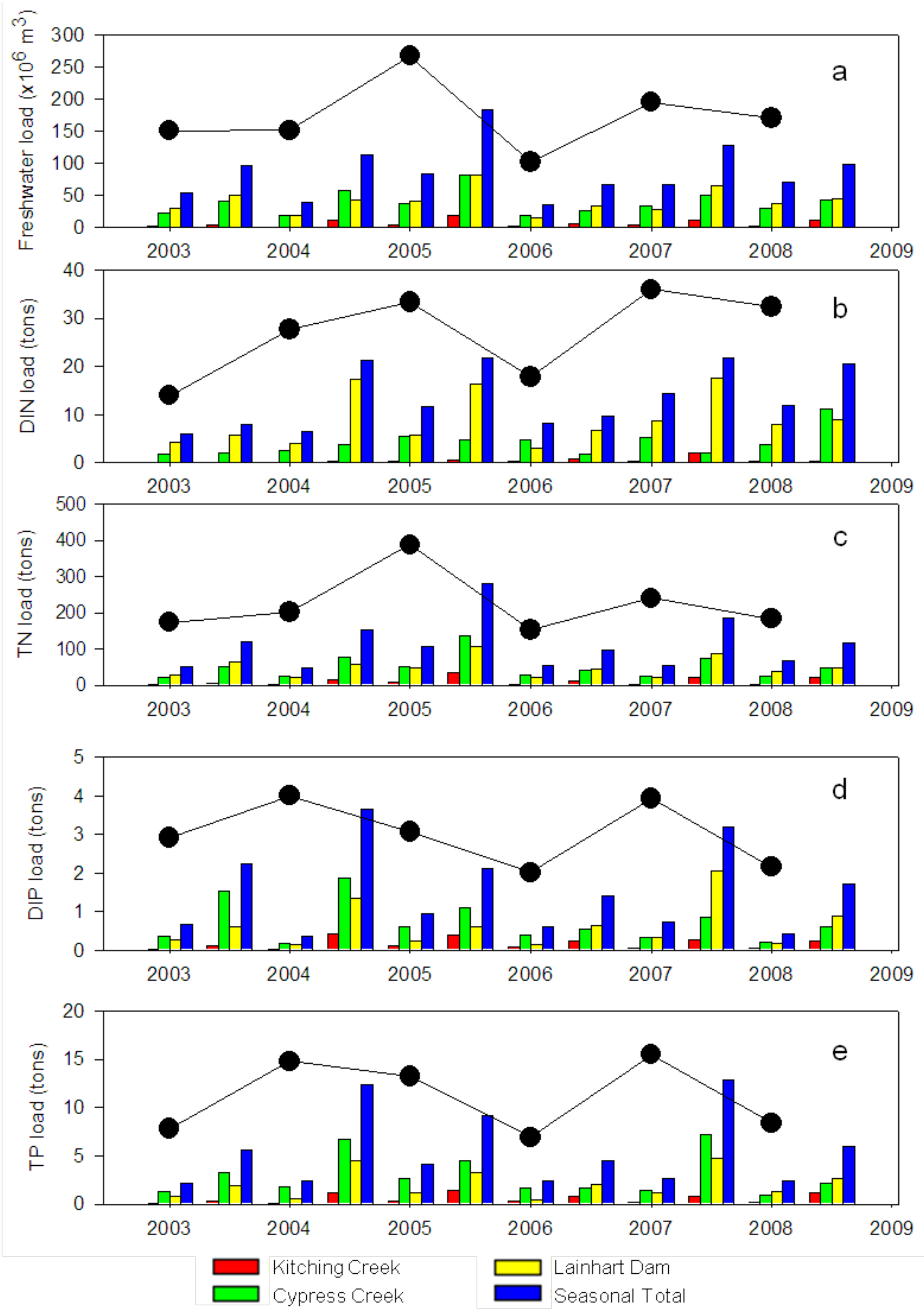


**Figure 6-6. Annual flows and loads (filled circles) and (a) freshwater inflows and (b) DIN, (c) TN, (d) DIN and (e) TP loads to the Northwest Fork from each tributary and for seasons during the 2003–2008 period.**

"x $10^6$ $m^3$" indicates the numbers on the y-axis are multiplied by one million cubic meters.

**Table 6-11. Ranges of annual freshwater flow and nutrient loads to the Northwest Fork from three tributaries and their average seasonal and individual (geographic) contributions**

| Parameters | Ranges | Mean ± Standard Deviation | Seasonal Contribution | | Geographic Contribution | | |
|---|---|---|---|---|---|---|---|
| | | | Dry | Wet | Kitching Creek | Cypress Creek | Lainhart Dam |
| Total flows (million cubic meters per year) | 102–267 | 172 ± 55 | 33% | 66% | 8% | 44% | 48% |
| DIN (tons per year) | 17.8–36.0 | 26.8 ± 9.0 | 36% | 64% | 3% | 31% | 65% |
| TN (tons per year) | 153.0–389.0 | 223.0 ± 86.2 | 28% | 72% | 10% | 45% | 44% |
| DIP (tons per year) | 2.0–4.0 | 4.0 ± 0.8 | 21% | 79% | 11% | 47% | 41% |
| TP (tons per year) | 6.9–15.5 | 11.1 ± 3.8 | 24% | 76% | 10% | 52% | 37% |

Nutrient Loads and Compositions

Nutrient loads to the Northwest Fork mimic the temporal variations of freshwater inflows with clear interannual and seasonal signals (**Figure 6-6**). On a seasonal scale, freshwater inflows account for about 65, 94, 51 and 62 percent of DIN, TN, DIP and TP variations in loads, respectively, and more than 70 percent of nutrients were delivered to the Northwest Fork during the wet season. TN loads range from 150 to 390 metric tons per year with relative contributions from the tributaries similar to those of flows (**Figure 6-6c**; **Table 6-11**), whereas DIN loads are 17 to 36 tons per year with more contribution from the Lainhart Dam (>66%) than Cypress Creek (31%) and Kitching Creek (3%) (**Figure 6-6b**). TP and DIP loads are 6 to 15 tons and 2 to 4 tons per year, respectively, with major contributions from Cypress Creek (>50%) rather than Lainhart Dam (~40%) (**Figure 6-6c** and **d**; **Table 6-11**).

The differences in the contributions are likely due to the different concentrations in the tributaries (**Figure 6-7**). Kitching Creek has the highest concentration of all the nutrients except for DIN. But due to the relatively small freshwater inflow from Kitching Creek, the focus is on comparisons of nutrients between Lainhart Dam and Cypress Creek, which have similar freshwater inflows. Mann-Whitney rank tests showed that Cypress Creek has statistically higher TP ($p < 0.01$) and lower DIN ($p < 0.001$) than Lainhart Dam with no statistical differences in DIP and TN (**Table 6-12**), consistent with estimated differences in contributions mentioned above. Furthermore, examination of relationships between nutrient concentrations and flows showed nutrient concentrations are mostly independent of flows, indicating the increases in estimated nutrient loads are mainly associated with flow increases. However, the DIP and TP in the Lainhart Dam was found to have a positive correlation ($p < 0.05$) with inflows (figure not shown), indicating that phosphorus load from the Lainhart Dam increases not only with higher flows but also from increased concentrations as well. These differences in concentrations and relationships with flows further lead to different compositions of nutrient loads from different tributaries (**Table 6-12**). Both molar ratios of DIN to DIP and percentages of DIN to TN are statistically different among these three tributaries, while no difference was found in percentages of DIP to TP among them. The molar ratio of TN to TP from the Lainhart Dam was statistically higher than those from Kitching Creek and Cypress Creek. Overall, the waters from the Lainhart Dam have a higher N to P ratio than that of the waters from Kitching and Cypress Creeks.

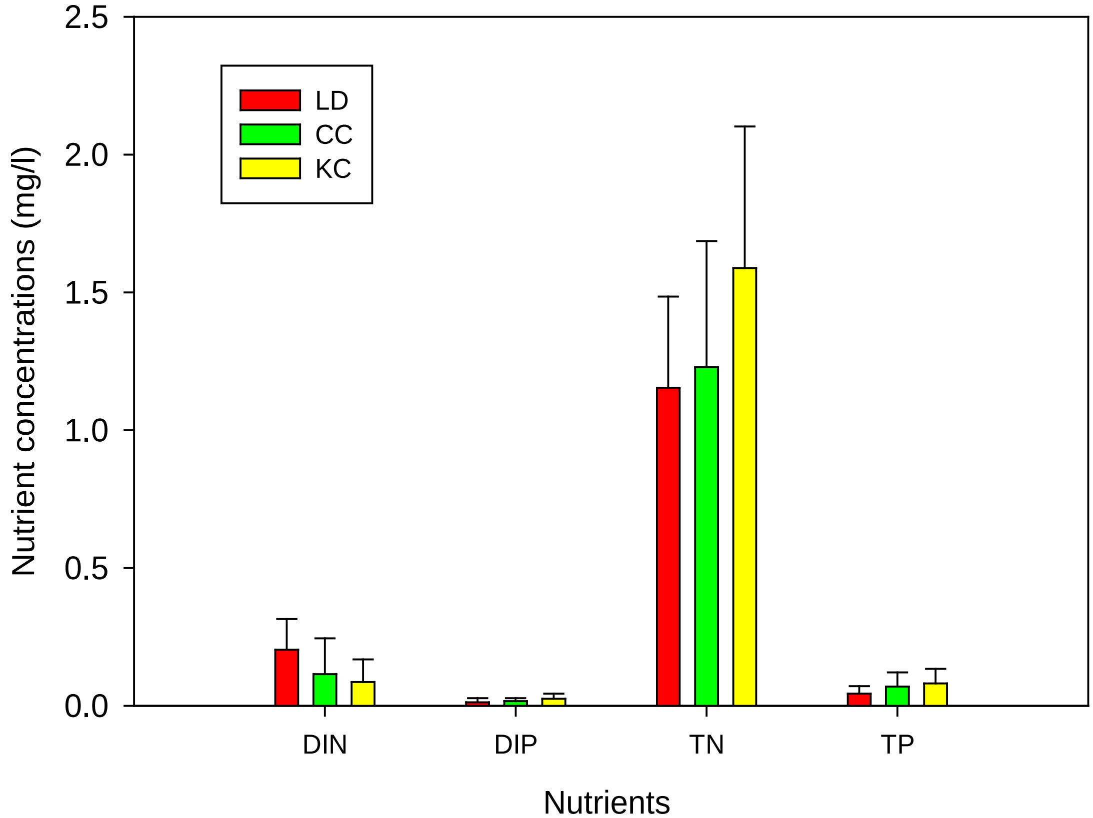


**Figure 6-7. Mean concentrations (+ standard deviation) of nutrients measured in three tributaries from 2003 to 2008**

mg/l - milligrams per liter

**Table 6-12. Differences in molar ratios of TN to TP and DIN to DIP and percentages of dissolved forms to TN and TP concentrations from three tributaries[1]**

| | **Means ± Standard Deviations** | | | |
|---|---|---|---|---|
| **Tributaries** | **TN:TP Molar Ratio** | **DIN:DIP Molar Ratio** | **DIN:TN (%)** | **DIP:TP (%)** |
| Cypress Creek | 42.2 ± 13.2 | 19.5 ± 14.5 | 10.7 ± 7.1 | 25.4 ± 9.3 |
| Kitching Creek | 47.5 ± 11.7 | 7.2 ± 5.4 | 5.0 ± 7.1 | 31.4 ± 6.4 |
| Cypress + Kitching Creeks | 44.8 ± 12.5 | | | 28.4 ± 8.4 |
| Lainhart Dam | 64.5 ± 23.7 | 43.7 ± 23.6 | 18.5 ± 7.6 | 28.2 ± 7.7 |
| Statistical Differences | No difference between Cypress and Kitching Creeks but both different from Lainhart Dam | All three different | All three different | None different |

[1] If Kitching and Cypress Creeks are not statistically different, then averaged ratios or percentages were calculated.

Water Quality Responses to Freshwater Flow and Nutrient Loads

Analysis indicated various correlations between water quality and freshwater discharges and nutrient loads. Some parameters (color, DIN, DIP, TN, TP and water clarity) showed positive correlation with flows or loads, while some parameters (DO, salinity and TSS) were inversely correlated with discharges and loads (**Table 6-13**). The results suggest that higher freshwater inflows and associated nutrient loads tended to increase nutrient concentrations, and reduce DO content and water clarity in the Northwest Fork. Conversely, chlorophyll was not statistically correlated with flows in both reaches, indicating variations in phytoplankton biomass in the Northwest Fork are not associated with discharge induced higher nutrient concentrations. Furthermore, relationships varied between the reaches. For example, neither fecal coliform nor TSS showed statistically significant correlation with flows in the Wild and Scenic reach, but both showed significant correlation in the mesohaline reach, indicating discharges other than those from Lainhart Dam affected water quality in the downstream portions of the river. In contrast, an inverse correlation between flow and DIN to DIP ratio observed in the upper stream of the river became insignificant downstream. The inverse correlation at stations 67 and 68 is consistent with increasing phosphorus with increasing flow at the Lainhart Dam. These varying relationships for each reach indicate water quality may change as a function of both total discharges and their sources. Finally, phosphorus concentrations were generally better correlated with TP loads or freshwater flow than nitrogen, although nitrogen loads are better correlated with discharge (**Table 6-13**). This difference indicates a more complex biogeochemical cycle of nitrogen than phosphorus in the river, leading to no correlation between the TN to TP ratios and flows or loads in both reaches.

**Table 6-13. Spearman's rank correlation coefficient and statistical significance ($p < 0.05$) between daily mean discharge (in cubic feet per second), total daily loads (in tons) from three tributaries, and water quality in two reaches of the Northwest Fork.**

| Parameters | Mesohaline Reach (stations 62, 63 and 64) | | Wild and Scenic Reach[2] (stations 67 and 68) | |
|---|---|---|---|---|
| Flow vs. percentage of light at one meter | -0.78 | | -0.38 | not significant |
| Flow vs. oxygen saturation | -0.70 | | -0.65 | |
| Flow vs. salinity | -0.69 | | -0.84 | |
| Flow vs. oxygen | -0.56 | | -0.64 | |
| Flow vs. TSS | -0.41 | | -0.11 | not significant |
| Flow vs. chlorophyll a | -0.26 | not significant | 0.07 | not significant |
| Flow vs. TN:TP molar ratio | -0.06 | not significant | -0.21 | not significant |
| Flow vs. DIN:DIP molar ratio | 0.07 | not significant | -0.42 | |
| Flow vs. fecal coliform | 0.44 | | -0.15 | not significant |
| Flow vs. color | 0.47 | | 0.49 | |
| TN load:TN concentration | 0.48 | | 0.07 | not significant |
| DIN load vs. DIN concentration | 0.68 | | 0.45 | |
| DIP loads:DIP concentration | 0.71 | | 0.58 | |
| TP load vs. TP concentration | 0.74 | | 0.47 | |

### 6.2.4 Discussion

Using gauged flow rates and water quality monitoring data collected near the gauges, freshwater inflow and associated nutrient loads to the Northwest Fork were successfully estimated for the first time using data from 2003 to 2008. The estimated hydrological and nutrient loads provided overall load ranges, showed clear interannual and seasonal variation, and relative contributions of three tributaries to total freshwater flow and nutrient loads. However, the results are only rough estimates of these loads due to high spatial and temporal variations in nutrient concentrations. Nutrient concentrations are not sampled at exactly the same locations as the hydrology gauges, thus spatial differences in nutrient concentrations may give rise to different nutrient loads. For example, a close examination of nutrient concentrations between stations 67, 68 and 69 indeed showed spatial differences in concentrations, and thus introduce some uncertainties in estimated nutrient loads (data not shown here). In addition, water quality was sampled, at best, on a monthly basis and then linearly interpolated into daily concentrations from these monthly values. This approach temporally under-samples water quality and may introduce large uncertainties in the estimated loads. Mcpherson and Sonntag (1984) found that storm related nutrient loads could account for more than 50 percent of nutrient loads during their 1981 study period. Spikes in loads are likely missed in some monthly sampled data. Thus, the estimated nutrient loads in this study could be an underestimate relative to realistic loads to the Northwest Fork. What is striking, however, is that the average TN and TP loads to the Northwest Fork obtained in this study are nearly double during the 2003–2008 period as compared to TN and TP estimates in 1981 (Table 3 in Mcpherson and Sonntag 1984). It is not clear if the differences indicate a long-term increase in nutrient loads from 1981 to 2008 or are due to different approaches used in estimation.

Analyses indicated that increased flows and associated nutrient loads will generally increase nutrient concentrations and reduce oxygen content and water clarity in the downstream areas, but no discernable increase in chlorophyll was observed. In the preferred restoration flow scenario proposed in the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006), only the impact of flow on salinity is quantified with no consideration of other impacts such as oxygen content and water clarity. Furthermore, only freshwater quantity was taken into consideration in determining the restoration scenario defined in the plan. Other constituents associated with discharges and their possible impacts on water quality in the downstream river were not considered. The analyses presented here clearly indicates that different water sources are composed of different nutrient constituents and quantities, and some water quality parameters in the downstream river changed as a function of fresh water inputs and the relative contributions of nutrients. More importantly, given the short flushing time in the system (Mcpherson and Sonntag 1984), the relationship between freshwater and nutrient loads and water quality responses is likely complex. On the one hand, increased freshwater inflow and nutrient load will likely increase nutrient concentration and color, but phytoplankton growth may be depressed due to strong flush out effects as observed in other freshwater tidal reaches tributaries (Lionard et al. 2008). On the other hand, reduced flows and nutrient loads may be associated with high phytoplankton biomass due to increased residence time such that phytoplankton growth is stimulated. Thus a scientific evaluation of responses of water quality to variations in flows and nutrient sources is warranted.

# 7.0 RESTORATION PROGRESS

## 7.1 Loxahatchee River Watershed Restoration Project

The Loxahatchee River Watershed Restoration Project is a component of the Comprehensive Everglades Restoration Plan (CERP) that encompasses northern Palm Beach and southern Martin Counties. It was formerly called the North Palm Beach County Project - Part 1. The project incorporates many of the elements or projects that were identified in the *Northern Palm Beach County Comprehensive Water Management Plan* (SFWMD 2002b), with additional elements that have been included because of the larger regional scope and the 50-year design horizon of the CERP.

One of the primary goals of the Loxahatchee River Watershed Restoration Project is to provide storage of runoff from the L-8 basin during wet conditions, and to divert the water to provide benefits to the ecological systems of the Loxahatchee River, while reducing flows from the L-8 basin directly to tide. Storage provided by the L-8 Reservoir should increase water availability for improved hydroperiods in the Loxahatchee Slough, and provide restorative flows to the Northwest Fork of the Loxahatchee River. It will be necessary to design and construct infrastructure that reconnect and manage the water flows and levels within the Grassy Waters Preserve and Loxahatchee Slough. The wetland systems, which provided the historic flow of water to the river, have been severed by the construction of canals, roads and railways in the project area. In addition to capturing and rerouting water to benefit wetlands and the river, the project is anticipated to attenuate some problematic stormwater discharges to the Lake Worth Lagoon, and also provide for flood control improvements in the Indian Trail Improvement District. A pilot project of this system was conducted in 2011.

The South Florida Water Management District (SFWMD) recognized that many of the elements within the Loxahatchee River Watershed Restoration Project are essential to deliver necessary dry season restorative flows to the Northwest Fork. Therefore, in parallel with the United States Army Corps of Engineers (USACE) CERP planning process, the SFWMD has completed the acquisition of the L-8 Reservoir, and expects to move forward with the design and construction of the pump station and inflow structure that is necessary to capture and deliver flows to the system. The SFWMD has completed design and construction of both the Loxahatchee Slough (G-160) and Northlake Boulevard (G-161) water control structures, facilities that are necessary to provide the connectivity between the river and its historic headwaters. The SFWMD has also partnered with Palm Beach County and the City of West Palm Beach to design the Northlake Boulevard Bridge, which will provide additional hydrological connectivity between Grassy Waters Preserve and the Loxahatchee Slough during high water level stages. Other related improvements, such as the widening of the M-Canal, and the relocation and expansion of the Control 2 (Loxahatchee) Pump Station, will also take place on this expedited path in partnership with the City of West Palm Beach. In addition to the components noted above, the project includes an analysis of an alternative route to deliver water more directly through the C-18 Canal west leg. This could provide for significant watershed restoration activities within the Cypress Creek basin to reduce flood flows and reroute water to restore groundwater levels and wetlands.

The SFWMD will continue to coordinate with the USACE during the planning process to ensure the work performed by the SFWMD is included in the alternatives analysis and incorporated, where appropriate, in the selected plan, which will be documented in a project implementation report expected to be completed in 2013. It is anticipated that many of the components identified in the *Northern Palm Beach County Comprehensive Water Management Plan* (SFWMD 2002b) will continue to demonstrate their worth through the analysis of the project implementation report effort, and will be included in the recommendation to Congress for cost-sharing consideration.

The amount, timing and distribution of restoration flows to be delivered by the Loxahatchee River Watershed Restoration Project elements have been identified. These restoration flow targets have being incorporated into a model simulation analysis to evaluate alternative designs for water delivery to the Northwest Fork. The project implementation report currently being developed will identify the means and methods necessary to meet these future requirements. The effort is led by the SFWMD and USACE and supported by other public and private organizations.

## 7.2 The L-8 Reservoir Pilot Test

The L-8 Reservoir Pilot Test was a collaborative effort between the SFWMD, City of West Palm Beach, Palm Beach County, and Loxahatchee River District (LRD). This pilot test was implemented successfully for a total of 50 days from March 1 to April 19, 2011 during the dry season. Its initial purpose was to begin the process of lowering water levels within the L-8 Reservoir in anticipation of planned future construction for a new pump station. The objectives changed prior to implementation to take advantage of additional data collection opportunities and provide operational testing of the existing facilities to deliver flows to the Northwest Fork.

### 7.2.1 Existing Infrastructure

The pilot test utilized an existing 75 cubic feet per second (cfs) pump located within the L-8 Reservoir that discharges to the L-8 Canal where it mixes with gravity inflows from Lake Okeechobee (**Figure 7-1**). This water is then pumped from the L-8 Canal eastward via the L-8 Tieback Canal utilizing the City of West Palm Beach's Control 2 pump station (150 cfs pumping capacity) to the M-Canal a distance of 9.4 miles east into Grassy Waters Preserve. Grassy Waters Preserve is a 20 square mile preserve area comprised of wetland and upland habitat that serves as a water supply source for the City of West Palm Beach. A portion of this water was routed north through Grassy Waters Preserve to the G-161, G-160 and G-92 structures and ultimately delivered to the Northwest Fork (**Figure 7-1**). Part of the water was also delivered into the City of West Palm Beach's Lake Mangonia and Clear Lake via the M-Canal and Control 4 structure for public water supply.

The project included the water storage and conveyance features currently owned by the SFWMD and City of West Palm Beach, including but not limited to the L-8 Reservoir; L-8 Canal; L-8 Tieback Canal; Control 2 pump station; Control 3 and Control 4 structures; M-Canal; Grassy Waters Preserve; G-161, G-160 and G-92 structures; and Lainhart Dam.

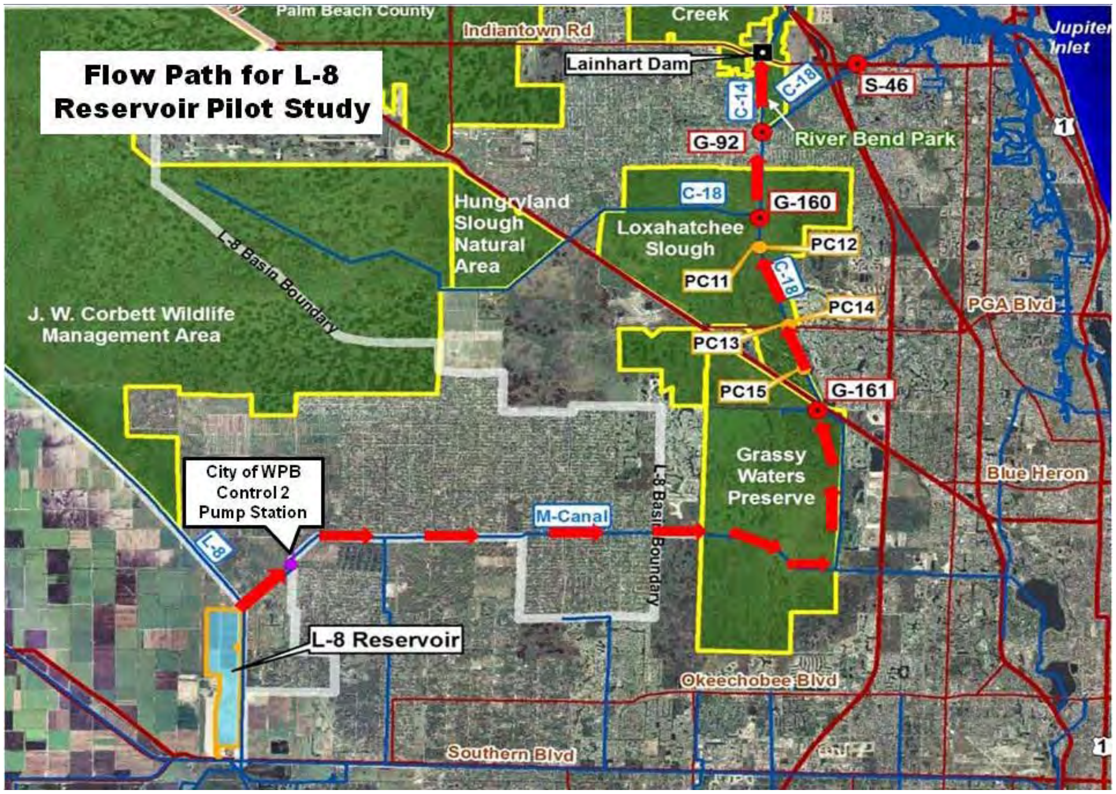


**Figure 7-1. Flow path for the delivery of L-8 Reservoir water to Grassy Waters Preserve and the Northwest Fork**

WPB – West Palm Beach

### 7.2.2 Data Collection and Major Findings

Flow and water quality data (total phosphorus [TP] and chlorides) were collected at critical water control structures and selected locations within Grassy Waters Preserve. The data were analyzed and results will be reported in a technical report being prepared by the project team (SFWMD 2011). System operation, water budget, phosphorus and chloride transport, and compliance were evaluated. Some of the major findings were summarized below.

The data collected during the pilot test demonstrated that water deliveries from the L-8 Reservoir to the Northwest Fork via Grassy Waters Preserve can be accomplished under extreme drought conditions. However, this water delivery proved to be challenging in part because of the long delivery distance of 28.8 miles, multiple control structures along the conveyance route, and limitations of the existing pump facilities. Over the 50 day pilot test period, the Control 2 pump station (150 cfs) delivered 13,640 acre-feet of water to the M-Canal and Grassy Water Preserve. Over 3,005 acre-feet of water was released from Grassy Waters Preserve via G-161 to the Northwest Fork. Approximately 60 percent of the total volume coming into Grassy Waters Preserve was lost to evapotranspiration and seepage. The balance of the remaining water was delivered to the City of West Palm Beach via the M-Canal and Control 4 structure for water supply. One of the major successes of the project was meeting the minimum flows and levels (MFL) criteria for the Northwest Fork of the Loxahatchee River, which was met for 48 days during the 50 day test period.

The water quality dynamics within the L-8 Reservoir and Grassy Waters Preserve are complex and are dependent upon a multitude of factors such as rainfall, seepage, basin inflows, mineral content and mixing that affect chloride concentrations. During the test period, the average concentration of TP coming from Lake Okeechobee decreased as water pumped from the L-8 Reservoir and L-8 Canal was delivered towards Grassy Waters Preserve and mixed along the conveyance route. During the pilot test, the average TP concentration was 95 micrograms per liter (µg/L) for Lake Okeechobee water and 17 µg/L for the L-8 Reservoir water.

Chloride concentrations varied at different locations during and after the pilot test. The pilot test was suspended on April 19, 2011 in response to concerns related to increasing chloride concentrations upstream of Control 4. These increasing concentrations had the potential to affect the City of West Palm Beach's public water supply. However, the highest residual chloride concentration of 134 milligrams per liter (mg/L) at the compliance point (Lake Mangonia) occurred after the test was completed, and was well below the compliance target of 250 mg/L.

The initial water stage within Grassy Waters Preserve (18.69 feet National Geodetic Vertical Datum [NGVD]) was critical to the success of the test so that sufficient mixing of water occurred to comply with the water quality target for chlorides. The availability of sufficient dilution water, managing chloride concentrations, and maintaining stage elevations within Grassy Waters Preserve were the most constraining factors associated with the test. Chloride concentrations were found to be closely correlated with stage elevations, pump operation, rainfall, and availability of dilution water within the regional system. The pilot test also resulted in the removal of nearly 4,000 metric tons of chlorides from the L-8 Reservoir.

The pilot test concluded that delivering "dedicated water" from the L-8 Reservoir to Grassy Waters Preserve and the Northwest Fork has a multitude of complexities and constraints related to operations, water quality, wildlife concerns, public water supply and water losses (evapotranspiration and seepage). The data collected from this pilot test will be used to make refinements to a pilot test planned for the 2011–2012 dry season. The results will also be used to assist with updating the assumptions in the modeling tool used for the final design of the L-8 pump station.

## 7.3 The Loxahatchee River Preservation Initiative

The Loxahatchee River is the southernmost tributary of the Indian River Lagoon and includes the Northwest Fork, the first federally designated Wild and Scenic River in Florida (see **Figure 1-1** in **Section 1**). This historic watershed, which once covered over 750 square miles, has been reduced by flood control basins and drainage districts to approximately 277 square miles in southern Martin and northern Palm Beach Counties. The region's population is nearing 100,000, with most of the residents living in the coastal communities of Hobe Sound, Tequesta, Jupiter, Palm Beach Gardens and Juno Beach.

Water quantity and quality influence the aquatic and wetland ecosystems in the watershed. Water is a limited resource necessary, not only for public use, but to conserve natural areas and protect wetlands. Fresh water that historically reached the Wild and Scenic River portion of the Northwest Fork began being diverted at the turn of the last century to provide drinking water to Palm Beach. In the 1950s, the headwaters of the river were drained for agriculture and other urban land uses. Today, even more water is being diverted for human consumption. Over the past

50 years, about four river miles of cypress swamp have been replaced by mangroves due to saltwater intrusion resulting from diminished freshwater flow. Wetlands have been intentionally drained and/or filled, or simply degraded through water diversion and a lowered water table. Changes in hydrology have allowed invasive exotic plants to move into areas that were once high quality wetlands. Meanwhile, the environmental quality of the Loxahatchee River has been negatively influenced by pollution entering waterways via point and nonpoint sources. Some of the waterways in the river system are impaired waters and do not meet their designated uses.

The Loxahatchee River Preservation Initiative is the outgrowth of a watershed management effort that the Florida Department of Environmental Protection spearheaded in 1996. The initiative was formed in 2000 with the single purpose of seeking out funding assistance for projects that would improve and protect the natural resources within the watershed. Several key projects, critical to preserving the long-term health of the Loxahatchee River, have not been implemented due to lack of resources and other regional priorities taking precedence. Urban stormwater improvements and the restoration of other tributaries including the estuarine portion of the river system are emphasized in the Loxahatchee River Preservation Initiative. Urban residents and river users will be the primary beneficiaries of efforts to improve the water quality of the Loxahatchee River. Over the past six years, the Loxahatchee River Preservation Initiative has been instrumental in kick starting over $34 million dollars in water quality enhancement projects.

## 7.4 Watershed Restoration Projects

Ongoing and planned watershed restoration activities will improve surface water storage, groundwater recharge and increase native biodiversity. The entities that are either implementing or have planned restoration activities are Martin and Palm Beach Counties, SFWMD and USACE. The following is a summary of priority projects including those that will fulfill research objectives and should be considered for additional monitoring and assessment. The locations of many of the areas discussed below can be found in **Figure 1-1** in **Section 1** of this document.

### 7.4.1 Moonshine Creek Tributary and Hobe Grove Ditch Restoration

Hobe Grove Ditch was excavated through uplands in the 1960s to drain flood waters from newly planted citrus groves into the Northwest Fork. Runoff from the surrounding groves was directed to Hobe Grove Ditch instead of Moonshine Creek. The groves have been purchased by the SFWMD and Martin County. These agencies are planning to restore the area to its natural condition of pine flatwoods and wet prairies. The hydroperiod of the floodplain forest community on Moonshine Creek will be restored and more treatment of the surface waters will be provided prior to its entry into the Loxahatchee River.

**Table 7-1. Loxahatchee River Preservation Initiative Projects 2005–2009**

| Title | Initiated | Status |
|---|---|---|
| Urban Stormwater Management System Rehabilitation - Phase I | 2005 | Completed |
| Data Sonde Monitoring in the Loxahatchee River | 2005 | Completed |
| Loxahatchee River Water Quality Event Sampling Project | 2005 | Completed |
| Wild and Scenic River Corridor Exotic/Pest Plant Control - Phase 1 | 2005 | Completed |
| Little Club Stormwater Quality Retrofit Project | 2005 | Completed |
| Hydrologic Restoration of Sawfish Bay Park (formerly known as Harborview Park) | 2005 | Completed |
| Limestone Creek Restoration - South | 2005 | Completed |
| Wildlife Utilization of the Flood Plain of the Loxahatchee River Prior to Restoration Efforts | 2005 | Completed |
| Exotic Vegetation Removal | 2005 | Completed |
| Loxahatchee River Water Quality Trends and Standards | 2005 | Completed |
| Loxahatchee River Monthly Seagrass/Algae Monitoring | 2005 | Completed |
| Loxahatchee River Oyster/Benthic Indicator Data Monitoring | 2005 | Completed |
| Wild and Scenic River Corridor Exotic/Pest Plant Control - Phase 2 | 2006 | Completed |
| Atlantic Ridge Hydrologic Restoration - Phase 1 | 2006 | Completed |
| Cypress Creek Restoration - Phase II | 2006 | Completed |
| Cypress Creek | 2006 | Completed |
| Kitching Creek Restoration - Phase IV | 2006 | Completed |
| Delaware Scrub Natural Area Restoration | 2006 | Completed |
| Limestone Creek Restoration - Phase II | 2006 | Completed |
| Urban Stormwater Management System Rehabilitation - Phase II | 2006 | Completed |
| Loxahatchee River Water and Biological Monitoring | 2006 | Completed |
| Muck Removal in SFWMD Canal and Removal of Exotics in Right-of-ways | 2006 | Completed |
| Jones Creek Parcel Hydrological Restoration | 2006 | Completed |
| Surface Water Recharge System Improvement | 2006 | Completed |
| Loxahatchee River Preservation Initiative Public Outreach Project | 2006 | Completed |
| Loxahatchee Septic Tank Maintenance Program | 2006 | Completed |
| Kitching Creek - Phase V | 2006 | Completed |
| Limestone Creek Restoration - Phase III | 2006 | Completed |
| Cypress Creek/Loxahatchee Project - Phase III (2007) | 2006 | Completed |
| Sandhill Crane East - Loxahatchee Slough Restoration Project - Phase I | 2007 | Completed |
| Urban Stormwater Management System Rehabilitation - Phase III | 2007 | Completed |
| Loxahatchee River Water Quality and Biological Monitoring | 2007 | Completed |
| Wild and Scenic River Corridor Exotic/Pest Plant Control - Phase 1 | 2007 | Completed |
| Loxahatchee River Public Outreach Project II | 2007 | Completed |
| Limestone Creek Septic to Sewer Conversion | 2007 | Completed |
| Loxahatchee River Public Outreach Project III | 2007 | Completed |
| Urban Stormwater Management System Rehabilitation - Phase IV | 2008 | Completed |
| Cypress Creek/Loxahatchee Project - Phase IV | 2008 | Ongoing |
| Sandhill Crane East - Loxahatchee Slough Restoration Project - Phase II | 2008 | Ongoing |
| Delaware Scrub Natural Area Restoration Project - Phase II | 2008 | Ongoing |
| Wild and Scenic River Water Quality and Biological Monitoring | 2008 | Completed |
| Loxahatchee River Water Quality and Biological Monitoring | 2008 | Completed |
| Cypress Creek East Restoration Project | 2009 | Ongoing |
| Loxahatchee River Neighborhood Sewer Project | 2009 | Completed |
| Urban Stormwater Management System Rehabilitation - Phase V | 2009 | Completed |
| Loxahatchee River Water Quality and Biological Monitoring | 2009 | Completed |
| Wild and Scenic River Corridor Exotic/Pest Plant Control - Phase III | 2009 | Completed |

Before upstream restoration can be completed, an engineering study is required to examine the best structural methods to reconnect Moonshine Creek, maintain or reduce existing drainage levels, and fill in Hobe Grove Ditch. As part of this engineering study, the quantity and quality (nutrient loads) of water within Moonshine Creek and Hobe Grove Ditch will be monitored to obtain baseline information. The measured data will then be analyzed to quantify improvements to water quantity and quality resulting from creek and upstream restoration activities.

### 7.4.2 Cypress Creek Restoration

The Cypress Creek Restoration project area covers approximately 4,000 acres and is equally divided between Martin and Palm Beach Counties as the county line bisects the property. The area provides approximately one-third of the historic flow to the Northwest Fork. This area is important because it has a direct drainage connection to the Northwest Fork through Cypress Creek. The area is interspersed with numerous marshes, cypress swamps and wet prairies. The protection and restoration of the wetlands in the Cypress Creek area will be extremely beneficial in improving the supply of fresh water to the Northwest Fork. These actions will assist in reducing saltwater intrusion. Other benefits include floodwater attenuation, protection of fish and wildlife habitat, and enhancement of water quality.

The project area has been heavily impacted by agricultural practices and development. Construction of drainage ditches in the early 1950s impacted the sites hydrology, creating favorable conditions for nonnative invasive species to flourish. Currently, the floodplain of the creek experiences abnormal dryness and sedimentation problems. The floodplain needs to be analyzed in relation to the bathymetric depth of the channel and floodplain inundation. Restoration activities to eradicate nonnative invasive vegetation began in 1999. To date, over 1,600 acres have been treated within the project area. Hydrologic activities began in spring 2007 and have resulted in over six miles of ditch filling and plugging.

The Cypress Creek Restoration project is funded by Martin and Palm Beach Counties and the Loxahatchee River Preservation Initiative, which is discussed in more detail in the previous section. It entails construction that will provide for redistribution, storage and timed delivery of basin stormwater. It is anticipated that existing conveyances and the creation of a large stormwater treatment area on land currently owned by Martin County and the SFWMD will provide the needed facilities. Flows from the Pal Mar basin will be delivered to the Northwest Fork to assist in ecosystem restoration. The redistribution of seasonal flows will also reduce channel erosion and its impact on the floodplain. Its connection with Flow Way 3 of the Loxahatchee River Watershed Restoration Project (discussed above) will also enhance the benefit of the project.

To date, nuisance non-native plants have been removed from the Martin County portion of Cypress Creek. A proposal to plug ditches and install two water control structure on the same lands to restore the hydrology is being considered, which is consistent with already completed efforts on the Palm Beach County portion of the project.

### 7.4.3 Kitching Creek Restoration

The historic flows that fed Kitching Creek provided key freshwater contributions to the Northwest Fork. Urban development of the upper watershed has diverted and affected the timely distribution of these flows to Jonathan Dickinson State Park and the Northwest Fork. The Kitching Creek Restoration project entails the restoration of the historical discharges of the headwaters of the Kitching Creek watershed. The project area is located south of Cove Road, east of the South Fork of the St. Lucie River and west of U.S. Highway 1 in southern Martin County. The project is designed to improve water quality and quantity by enhancing surface water deliveries to Kitching Creek and restore up to 1,000 acres of habitat in the upper Kitching Creek watershed. This will create rehydration of the historical portion of Kitching Creek that has been dewatered by a ditch to the east on Kitching Creek Road. Rehydration of this watershed should also increase nesting and roosting by wading birds, improve habitat for fish, invertebrates and other riverine-dependent species, and lead to improved water quality. To date all permits have been received for the eastern and middle flow ways. Martin County staff is awaiting an assessment by the Federal Emergency Management Agency for possible cost sharing.

### 7.4.4 Pal Mar East Restoration

Pal Mar East covers 3,100 acres in southern Martin County. Martin County and the SFWMD, in conjunction with the Natural Resources Conservation Service of the United States Department of Agriculture are currently developing a restoration plan for the 1,350 acre portion of Pal Mar East within the conservation easement. The plan is being implemented as part of CERP's Loxahatchee River Watershed Restoration Project (discussed in earlier in the section), and should only be considered an interim step in the restoration of Pal Mar East. The Natural Resources Conservation Service plan will focus on those areas within the conservation easement but will also include some restoration measures for the entire site.

Flow Way 3 is a component of one the Loxahatchee River Watershed Restoration Project's alternatives (**Figure 7-1**). Flow Way 3, if carried forward as part of the selected plan, will help to reestablish sheet flow and hydrological connectivity across areas in the northern section of the project boundary, and help ensure adequate and timely flows to the Loxahatchee River. The Flow Way 3 portion of the project includes measures to restore several former agricultural and ranch lands back to wetlands, improve hydroperiods in existing wetlands, provide improved water deliveries to the Loxahatchee River via Cypress Creek, and improve flood protection for Ranch Colony; all of which rely in part on being able to successfully promote sheet flow through Pal Mar East.

To date, all exotic plant removal and phase one of hydrological restoration have been completed. Additionally, portions of the area have been subjected to a prescribed burn. The area has been opened for passive recreation and some limited hunting in coordination with the Florida Fish and Wildlife Conservation Commission.

### 7.4.5 Culpepper Ranch Restoration

The most recent acquisition in the Cypress Creek watershed, the Culpepper Ranch, also referred to as the Pal Mar addition, comprises 1,280 acres of land formally in cattle ranching and, before that, in dairy farming. The land was purchased with a combination of SFWMD and Martin County funds. The county has completed a full sweep of exotic plant removal on the entire property. Additionally, the county has recently completed the first phase of hydrological restoration by plugging of agricultural ditches and breaching berms formally used to hydrologically isolate the property from the rest of Hungryland and Pal Mar. All parties are currently discussing opening the property for passive recreation and limited hunting, which is consistent with the remainder of Hungryland.

### 7.4.6 Loxahatchee Slough Natural Area Restoration

The Loxahatchee Slough Natural Area is the Palm Beach County's largest natural area, a total of 12,836 acres. The slough serves as the headwaters for the Wild and Scenic Loxahatchee River. To date, hydrologic restoration activities include backfilling over 15 miles of agricultural ditches and an extensive eradication program targeting exotic and nuisance plant species. Palm Beach County currently has surface water staff gauges located within specific wetlands and data is recorded on a monthly basis.

### 7.4.7 Pine Glades Natural Area Restoration

The Pine Glades Natural Area includes 3,124 acres of pine flatwoods, wet prairies and freshwater marshes. The area supplies water to the federally designated Wild and Scenic portion of the Northwest Fork. Large portions of the project area have either been drained for development or channelized through the construction of large canal systems. The restoration of the wetland and upland systems within Pine Glades will improve the ecological conditions within the watershed and ultimately the river.

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# Addendum to the Restoration Plan for the Northwest Fork of the Loxahatchee River

## APPENDICES

## February 2012

South Florida Water Management District
West Palm Beach, FL

Loxahatchee River District
Jupiter, FL

Florida Department of Environmental Protection
Florida Park Service
Fifth District
Hobe Sound, FL

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## ACRONYMS AND UNITS OF MEASUREMENT

| | |
|---|---|
| µg/L | micrograms per liter |
| C | degrees Celcius |
| cfu/100 ml | colony forming units per 100 milliliters |
| cm | centimeters |
| dbh | diameter breast height |
| DBH | diameter breast height |
| HH | hydric hammock forest type |
| LTmix | lower tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| LTsw1 | lower tidal reach swamp forest type 1 |
| LTsw2 | lower tidal reach swamp forest type 2 |
| LTsw3 | lower tidal reach swamp forest type 3 |
| M | marsh forest type |
| m | meters |
| mg/L | milligrams per liter |
| mg-N/L | milligrams nitrogen per liter |
| mg-P/L | milligrams phosphorus per liter |
| MH | mesic hammock forest type |
| NTU | nephelometric turbidity unit |
| PCU | platinum-cobalt units |
| ppt | parts per thousand |
| psu | practical salinity units |
| Rblh1 | bottomland hardwood forest type 1 |
| Rblh2 | bottomland hardwood forest type 2 |

| | |
|---|---|
| Rblh3 | bottomland hardwood forest type 3 |
| Rmix | riverine forest type with canopy dominance 50 percent bald cypress and 50 percent cabbage palm |
| Rsw1 | riverine reach swamp forest type 1 |
| Rsw2 | riverine reach swamp forest type 2 |
| Rsw3 | riverine reach swamp forest type 3 |
| T# | denotes a vegetation transect |
| T#W# | denotes a groundwater monitoring well along a vegetation transect |
| U | uplands forest type |
| μmho/cm | micro Siemens per centimeter |
| UTmix | upper tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| UTsw1 | upper tidal reach swamp forest type 1 |
| UTsw2 | upper tidal reach swamp forest type 2 |
| UTsw3 | upper tidal reach swamp forest type 3 |

# APPENDIX 3-1
# MEMBERS OF THE VEGETATION CREW

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*Students from the Student Conservation Association and Americorp

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# APPENDIX 3-2
# PLANT LISTS

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**Table 3-2-1. Canopy species list**

| Scientific Name | Common Name |
|---|---|
| *Acer rubrum* | red maple |
| *Annona glabra* | pond apple |
| *Avicennia germinans* | black mangrove |
| *Carya aquatica* | water hickory |
| *Cephalanthus occidentalis* | buttonbush |
| *Chrysobalanus icaco* | coco plum |
| *Citrus aurantium*[1] | wild orange |
| *Ficus aurea* | strangler fig |
| *Fraxinus caroliniana* | pop ash |
| *Ilex cassine* | dahoon holly |
| *Laguncularia racemosa* | white mangrove |
| *Morus rubra* | mulberry |
| *Myrica cerifera* | wax myrtle |
| *Persea borbonia* | red bay |
| *Persea palustris* | swamp bay |
| *Pinus elliottii* | slash pine |
| *Psidium cattleianum*[1] | strawberry guava |
| *Quercus laurifolia* | laurel oak |
| *Quercus myrtifolia* | myrtle oak |
| *Quercus virginiana* | live oak |
| *Rapanea punctata* | myrsine |
| *Rhizophora mangle* | red mangrove |
| *Roystonea regia* | Florida royal palm |
| *Sabal palmetto* | cabbage palm |
| *Salix caroliniana* | Carolina willow |
| *Schinus terebinthifolia*[1] | Brazilian pepper |
| *Senna pendula*[1] | climbing cassia |
| *Serenoa repens* | saw palmetto |
| *Syzygium cumini*[1] | Java plum |
| *Taxodium distichum* | bald cypress |
| *Toxicodendron radicans*[2] | poison ivy |
| *Vitis shuttleworthii*[1] | calloose grape |

[1] Nonnative species
[2] Vine

**Table 3-2-2. Shrub and ground cover species**

| Scientific Name | Common Name |
|---|---|
| *Abrus precatorius*[1],[2] | rosary pea |
| *Acer rubrum* | red maple |
| *Acrostichum danaeifolium* | leather fern |
| *Ageratum houstonianum*[1] | blue mink |
| *Alternanthera philoxeroides*[1] | alligator weed |
| *Alternanthera sessilis*[1] | sessile joyweed |
| *Alternanthera* spp.[1] | joy weed |
| *Ammannia latifolia* | toothcup #1 |
| *Amorpha fruticosa* | false indigo |
| *Annona glabra* | pond apple |
| *Apios americana* | groundnut |
| *Ardisia escallonoides* | marlberry |
| *Avicennia germinans* | black mangrove |
| *Baccharis glomeruliflora* | salt bush (silverling) |
| *Baccharis halimifolia* | salt bush (groundsel tree) |
| *Baccharis* spp. | Baccharis species |
| *Bacopa monnieri* | water hyssop |
| *Bacopa* spp. | water hyssop species |
| *Bambusa vulgaris*[1] | common bamboo |
| *Bejaria racemosa* | tar flower |
| *Bidens alba* | beggar ticks |
| *Bischofia javanica*[1] | bishop wood |
| *Blechnum serrulatum* | swamp fern |
| *Blechum pyramidatum*[1] | green shrimp plant |
| *Boehmeria cylindrica* | false nettle |
| *Callicarpa americana* | American beautyberry |
| *Canna flaccida* | golden canna |
| *Cardamine pensylvanica* | bitter cress |
| *Carex lupuliformis* | false hop sedge |
| *Carex* spp. | hop sedge species |
| *Carya aquatica* | water hickory |
| *Cephalanthus occidentalis* | buttonbush |
| *Chamaecrista fasciculata* | partridge pea |
| *Chromolaena odorata* | Jack-in-the-bush |
| *Chrysobalanus icaco* | coco plum |

[1] Nonnative species
[2] Vine

**Table 3-2-2. continued**

| Scientific Name | Common Name |
|---|---|
| *Cladium jamaicense* | sawgrass |
| *Colocasia esculenta*[1] | wild taro |
| *Commelina diffusa*[1] | common dayflower |
| *Crinum americanum* | swamp lily |
| *Crotalaria pallida* | mucronate rattlebox |
| *Cynoglosum zeylanicum* | Ceylon hound's tongue |
| *Cyperus haspan* | flat sedge |
| *Cyperus ligularis* | false sawgrass |
| *Cyperus retrorsus* | pine barren flat sedge |
| *Cyperus* spp. seedling | sedge seedling |
| *Cyperus virens* | green flat sedge |
| *Dalbergia ecastaphyllum*[2] | coin vine |
| *Desmodium tortuosum*[1] | Florida beggar weed |
| *Desmodium triflorum*[1] | three-flower begger weed |
| *Dichanthelium commutatum* | variable witch grass |
| *Dichanthelium dichotomum* | cypress witch grass |
| *Dichanthelium ensifolium* | dwarf cypress witch grass |
| *Dichanthelium laxiflorum* | open flower witch grass |
| *Dichanthelium* spp. | witch grass species |
| *Diospyros virginiana* | persimmon |
| *Eclipta prostrata* | false daisy |
| *Eleocharis baldwinii* | road grass |
| *Encyclia tampensis* | Florida butterfly orchid |
| *Erechtites hieraciifolius* | fire weed |
| *Erythrina herbacea* | coral bean |
| *Eupatorium capillifolium* | dog fennel |
| *Eupatorium compositifolium* | Yankee weed |
| *Eupatorium* spp. | Thoroughwort species |
| *Ficus aurea* | strangler fig |
| *Ficus microcarpa*[1] | Indian laurel ficus |
| *Fraxinus caroliniana* | pop ash |
| *Galactia* spp. | milk pea |
| *Galium tinctorium* | bed straw |
| *Gamochaeta antillana* | Caribbean purple everlasting |
| *Gamochaeta pensylvanica* | cud weed |

[1] Nonnative species
[2] Vine

**Table 3-2-2. continued**

| Scientific Name | Common Name |
|---|---|
| *Hydrocotyle* spp. | pennywort species |
| *Hydrocotyle umbellata* | many flower marsh pennywort |
| *Hydrocotyle verticillata* | whorled marsh pennywort |
| *Hygrophila polysperma*[1] | Indian swamp weed |
| *Hymenocallis palmeri* | alligator lily |
| *Hypericum cistifolium* | roundpods St. John's wort |
| *Hypericum* spp. | St. John's wort species |
| *Hypericum tetropetalum* | four petal St. John's wort |
| *Hyptis alata* | musky mint |
| *Ilex cassine* | dahoon holly |
| *Ilex glabra* | gallberry |
| *Ipomoea alba* | moon vine |
| *Ipomoea indica* | blue morning glory |
| *Itea virginica* | Virginia willow |
| *Juncus marginatus* | shore rush |
| *Laguncularia racemosa* | white mangrove |
| *Limnophila sessiliflora*[1] | Asian marsh weed |
| *Ludwigia alata* | winged water primrose |
| *Ludwigia octovalis* | Mexican primrose willow |
| *Ludwigia peruviana*[1] | Peruvian primrose willow |
| *Ludwigia repens* | creeping primrose willow |
| *Ludwigia* spp. | primrose willow species |
| *Ludwigia* spp. seedlings | primrose willow seedling |
| *Lygodium microphyllum*[1] | Old World climbing fern |
| *Lyonia fruticosa* | stagger bush |
| *Lyonia lucida* | fetterbush; shiny lyonia |
| *Melanthera nivea* | square stem |
| *Melothria pendula*[2] | creeping cucumber |
| *Micranthemum glomeratum* | baby tears |
| *Mikania scandens*[2] | hemp vine |
| *Mimosa quadrivalvis* | sensitive brier |
| *Mitreola petiolata* | horn pod |
| *Morus rubra* | mulberry |
| *Myrica cerifera* | wax myrtle |
| *Nephrolepis cordifolia* | tuberous sword fern |

[1] Nonnative species
[2] Vine

**Table 3-2-2. continued**

| Scientific Name | Common Name |
|---|---|
| *Nephrolepis exaltata* | Wild Boston fern |
| *Oplismenus hirtellus* | woods grass |
| *Osmunda cinnamomea* | cinnamon fern |
| *Osmunda regalis* | royal fern |
| *Panicum maximum*[1] | guinea grass |
| *Panicum rigidulum* | redtop panicum |
| *Panicum spp.* | panic grass species |
| *Panicum virgatum* | switch grass |
| *Parietaria floridana* | pellitory |
| *Parthenocissus quinquefolia* | Virginia creeper |
| *Pennisetum purpureum*[1] | elephant grass |
| *Persea borbonia* | red bay |
| *Phlebodium aureum* | golden polypody |
| *Phytolacca americana* | American pokeweed |
| *Pinus elliottii* | slash pine |
| *Pistia stratiotes* | water lettuce |
| *Pityopsis graminifolia* | silk grass |
| *Pleopeltis polypodioides* | resurrection fern |
| *Pluchea odorata* | marsh fleabane |
| *Pluchea* spp. | fleabane species |
| *Polygonum hydropiperoides* | swamp smartweed |
| *Polygonum punctatum* | dotted smartweed |
| *Polygonum* spp. | smartweed species |
| *Pontederia cordata* | pickerelweed |
| *Pouzolzia zeylanica*[1] | Pouzolz's bush |
| *Proserpinaca pectinata* | combleaf mermaid weed |
| *Psidium cattleianum*[1] | strawberry guava |
| *Psilotum nudum* | whisk-fern |
| *Psychotria nervosa* | wild coffee |
| *Psychotria sulzneri* | shortleaf wild coffee |
| *Pteridium aquilinum* | bracken fern |
| *Pteris tripartita* | giant brake fern |
| *Ptilimnium capillaceum* | mock bishops weed |
| *Quercus laurifolia* | laurel oak |
| *Quercus geminata* | sand live oak |

[1] Nonnative species

**Table 3-2-2. continued**

| Scientific Name | Common Name |
|---|---|
| *Quercus myrtifolia* | myrtle oak |
| *Quercus* spp. seedling | oak seedling |
| *Quercus virginiana* | live oak |
| *Rapanea punctata* | myrsine |
| *Rhabdadenia biflora*[2] | rubber vine |
| *Rhizophora mangle* | red mangrove |
| *Rhus copallinum* | winged sumac |
| *Rhynchospora inundata* | horned beak sedge |
| *Rhynchospora rariflora* | few flower beak sedge |
| *Rhynchospora* spp. | beak sedge species |
| *Rivira humilis* | rouge plant |
| *Rotala ramosior* | tooth cup #2 |
| *Rubus trivialis* | blackberry |
| *Rumex verticillatus* | swamp dock |
| *Sabal palmetto* | cabbage palm |
| *Sabatia calycina* | coastal rose gentian |
| *Sagittaria lancifolia* | bull tongue arrowhead |
| *Sagittaria latifolia* | broadleaf arrowhead |
| *Salix caroliniana* | Carolina willow |
| *Salvinia minima*[1] | water spangles |
| *Samolus valerandi* | pineland pimpernel |
| *Sarcostemma clausum*[2] | white vine |
| *Saururus cernuus* | lizard's tail |
| *Schinus terebinthifolia*[1] | Brazilian pepper |
| *Senna pendula*[1] | climbing cassia |
| *Serenoa repens* | saw palmetto |
| *Sesuvium maritimum* | sea purslane |
| *Sida ulmifolia* | wire weed |
| *Smilax auriculata* | earleaf greenbrier |
| *Smilax bona-nox*[2] | saw greenbrier |
| *Smilax laurifolia*[2] | laurel greenbrier |
| *Smilax* spp. | greenbrier species |
| *Smilax* spp. seedling | greenbrier seedling |
| *Solanum americanum* | common nightshade |
| *Solidago odora* var. *chapmanii* | Chapman's goldenrod |

[1] Nonnative species
[2] Vine

**Table 3-2-2. continued**

| Scientific Name | Common Name |
|---|---|
| *Solidago* spp. | goldenrod species |
| *Sonchus oleraceus* | common sow thistle |
| *Spermacoce verticillata*[1] | false buttonweed |
| *Sphagneticola trilobata*[1] | creeping oxeye; wedelia |
| *Sporobolus indicus*[1] | smut grass |
| *Stenotaphrum secundatum* | St. Augustine grass |
| *Symphyotrichum carolinianum*[2] | climbing aster |
| *Syngonium podophyllum*[1, 2] | nephthytis |
| *Syzygium cumini*[1] | Java plum |
| *Taxodium distichum* | bald cypress |
| *Taxodium distichum* seedling | bald cypress seedling |
| *Thelypteris dentata*[1] | downy shield fern |
| *Thelypteris interrupta* | tri-veined fern |
| *Thelypteris kunthii* | maiden fern |
| *Thelypteris palustris* | marsh fern |
| *Thelypteris serrata* | meniscium fern |
| *Thelypteris* spp. juvenile | juvenile fern |
| *Tillandsia fasciculata*[3] | cardinal airplant |
| *Tillandsia setacea*[3] | needleleaf airplant |
| *Tillandsia usneoides*[3] | Spanish moss |
| *Toxicodendron radicans*[2] | poison ivy |
| *Triglochin striata* | arrow grass |
| *Tripsacum dactyloides* | Fakahatchee grass |
| *Typha domingensis* | narrowleaf cattail |
| *Typha latifolia* | broadleaf cattail |
| *Urena lobata*[1] | Caesar weed |
| *Urochloa mutica*[1] | para grass |
| *Vigna luteola*[2] | hairypod cowpea |
| *Vitis aestivalis*[2] | summer grape |
| *Vitis rotundifolia*[2] | muscadine grape |
| *Vitis shuttleworthii*[1] | calloose grape |
| *Vittaria lineata* | shoestring fern |
| *Xanthosoma sagittifolium*[1] | elephant ear |
| *Ximenia americana* | tallow wood |

[1] Nonnative species
[2] Vine
[3] Airplant

**Table 3-2-2. continued**

| Scientific Name | Common Name |
|---|---|
| *Xyris* spp. | yelloweyed grass species |
| Unidentified Cyperceae | unidentified sedges |
| Unidentified Poaceae | unidentified grass |
| | unidentified fern |
| | unidentified juvenile fern |
| | unidentified seedling |
| | unidentified species |

# APPENDIX 3-3

# RELATIVE BASAL AREA COMPARISONS OF SPECIES IN THE CANOPY LAYER BETWEEN 2003 AND 2009

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## FOREST TYPE DEFINITIONS

| | |
|---|---|
| HH | hydric hammock forest type |
| LTmix | lower tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| LTsw1 | lower tidal reach swamp forest type 1 |
| LTsw2 | lower tidal reach swamp forest type 2 |
| LTsw3 | lower tidal reach swamp forest type 3 |
| M | marsh forest type |
| MH | mesic hammock forest type |
| Rblh1 | bottomland hardwood forest type 1 |
| Rblh2 | bottomland hardwood forest type 2 |
| Rblh3 | bottomland hardwood forest type 3 |
| Rmix | riverine forest type with canopy dominance 50% bald cypress and 50% cabbage palm |
| Rsw1 | riverine reach swamp forest type 1 |
| Rsw2 | riverine reach swamp forest type 2 |
| Rsw3 | riverine reach swamp forest type 3 |
| U | uplands forest type |
| UTmix | upper tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| UTsw1 | upper tidal reach swamp forest type 1 |
| UTsw2 | upper tidal reach swamp forest type 2 |
| UTsw3 | upper tidal reach swamp forest type 3 |

Some plots contain more than one forest type. For example, HH/Rsw1 indicates the plot contains both hydric hammock and riverine reach swamp forest type 1.

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**Table 3-3-3. Percent relative basal area comparisons between 2003 and 2009 for Transect 1**

| **Plot** | **T111** | | **T112** | | **T113** | | **T114** | | **T115** | | **T116** | | **T117** | | **T118** | | **T119** | | **T1210** | | **T1211** | | **T1212** | | **T1213** | | **T1214** | | **T1215** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | **MH** | | **MH** | | **HH/U** | | **HH** | | **Rsw1** | | **Rsw1** | | **Rsw1** | | **Rsw1** | | **Rsw1** | | **Rblh1** | | **Rsw1** | | **Rsw1** | | **Rsw1** | | **Rsw1** | | **HH** | |
| **Species[1]** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** |
| Red maple | | | | | | | | | | | | | 1.2 | 1.0 | | | | | | | 0.0 | 5.7 | | | | | | | | |
| Pond apple | | | | | | | | | | | | | | | | | | | 3.1 | 8.2 | 0.0 | 3.3 | 0.0 | 0.7 | | | | | | |
| Wild orange[2] | | | | | | | | | | | | | | | | | | | | | 1.9 | 0.0 | | | | | | | 6.5 | 0.0 |
| Mulberry | | | | | | | 0.0 | 0.6 | | | | | | | | | | | | | | | | | | | | | | |
| Slash pine | 31.9 | 33.3 | | | 25.6 | 24.0 | 74.9 | 71.3 | | | | | | | | | | | | | | | | | | | | | | |
| Laurel oak | | | 9.4 | 0.0 | 20.4 | 20.9 | | | | | | | | | | | | | | | 0.0 | 1.0 | | | | | | | | |
| Live oak | 10.5 | 11.2 | 39.7 | 41.5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cabbage palm | 57.6 | 55.5 | 50.9 | 58.5 | 54.1 | 55.1 | 25.1 | 28.1 | | | 14.7 | 18.8 | 9.7 | 25.6 | 5.2 | 5.2 | 6.8 | 7.3 | 96.9 | 91.8 | | | 5.8 | 7.6 | | | | | 80.2 | 87.2 |
| Climbing cassia[2] | | | | | | | | | | | | | | | | | | | | | 0.0 | 1.4 | | | | | | | | |
| Bald cypress | | | | | | | | | 100.0 | 100.0 | 85.3 | 81.2 | 89.1 | 73.4 | 94.8 | 94.8 | 93.2 | 92.7 | | | 98.1 | 88.6 | 94.2 | 91.7 | 100.0 | 100.0 | 100.0 | 100.0 | 13.3 | 12.8 |

**Legend**

(yellow) The species was a new occurrence in 2009.

(red) The species disappeared between 2003 and 2009.

**Summary of Changes**

Plot T112 lost one live oak (29.2 centimeters [cm]) and gained one cabbage palm (19.9 cm) between 2003 and 2009.
Plot T114 gained one mulberry (5.8 cm) between 2003 and 2009.
Plot T119 had one dead bald cypress (37.1 cm) in 2009.
Plot T1211 lost one wild orange (6.9 cm) and gained two pond apples (5.6, 8.3 cm), one red maple (13.1 cm), one laurel oak (5.4 cm), and one climbing cassia (6.4 cm) between 2003 and 2009.
Plot T1212 had two dead bald cypress (58.0, 70.5 cm) in 2009. It gained two pond apples (5.5, 5.6 cm) between 2003 and 2009.
Plot T1213 had two missing bald cypress in 2009.
Plot T1214 had one dead bald cypress (25 cm) in 2009.
In Plot T1215, three wild orange (16.3, 13.3, 10.2 cm) were removed by Florida Park Service staff between 2003 and 2009.

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-4. Percent relative basal area comparisons between 2003 and 2009 for Transect 2**

| **Plot** | **T2116** | | **T2117** | | **T2118** | | **T2119** | | **T2120** | | **T2121** | | **T2122** | | **T2223** | | **T2224** | | **T2225** | | **T2226** | | **T2227** | | **T2228** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | **Rblh** | | **Rsw1** | | **HH/Rsw1** | | **Rsw1** | | **HH/Rsw1** | | **HH** | | **HH** | | **MH** | | **MH** | | **MH** | | **HH/Rsw1** | | **Rsw1** | | **Rsw1** | |
| **Species[1]** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** |
| Red maple | 8.8 | 5.6 | 0.0 | 6.1 | | | | | | | | | | | | | | | | | | | | | 17.4 | 0.0 |
| Water Hickory | 0.7 | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Pop ash | 0.3 | 0.3 | | | | | | | 10.3 | 13.0 | | | 1.7 | 2.3 | | | | | | | | | | | 6.9 | 7.9 |
| Slash pine | | | | | | | | | | | | | | | 28.4 | 28.0 | | | | | | | | | | |
| Laurel oak | | | | | | | | | | | | | 9.9 | 12.6 | 26.0 | 24.2 | | | | | | | | | | |
| Cabbage palm | 7.4 | 7.6 | 5.1 | 3.4 | 31.8 | 26.0 | | | 89.7 | 87.0 | 100.0 | 100.0 | 88.4 | 85.0 | 45.6 | 47.9 | 100.0 | 100.0 | 100.0 | 100.0 | 18.0 | 17.0 | | | 11.9 | 12.9 |
| Bald cypress | 82.8 | 85.6 | 94.9 | 90.5 | 68.1 | 74.0 | 99.1 | 98.3 | | | | | | | | | | | | | 82.0 | 83.0 | 100.0 | 100.0 | 63.8 | 79.5 |
| Calloose grape[2] | | | | | | | 1.3 | 1.7 | | | | | | | | | | | | | | | | | | |

**Legend**

| | |
|---|---|
| (yellow) | The species was a new occurrence in 2009. |
| (red) | The species disappeared between 2003 and 2009. |

**Summary of Changes**

Plot T2116 had one dead red maple in 2009.
Plot T2223 had one dead laurel oak (24.4 cm) in 2009.
Plot T2225 had one dead cabbage palm in 2009.
Plot T2228 was missing two pop ash and one red maple (59.6 cm) in 2009.

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-5. Percent relative basal area comparisons between 2003 and 2009 for Transect 3**

| **Plot** | **T3129** | | **T3130** | | **T3131** | | **T3132** | | **T3133** | | **T3134** | | **T3135** | | **T3136** | | **T3137** | | **T3138** | | **T3139** | | **T3240** | | **T3241** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | **Rblh2** | | **Rblh3** | | **Rsw2** | | **Rsw2** | | **Rsw1** | | **Rsw2** | | **Rsw2** | | **Rsw1** | | **Rsw2** | | **Rsw2** | | **Rsw2** | | **U/HH** | | **Rblh2** | |
| **Species**[1] | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** |
| Red maple | 90.6 | 100.0 | 0.5 | 0.7 | | | | | | | | | | | | | | | | | | | | | 40.4 | 30.3 |
| Pond apple | | | | | | | 0.8 | 1.3 | | | 7.6 | 9.9 | 2.0 | 3.2 | 0.2 | 0.4 | 0.0 | 1.1 | | | | | | | | |
| Strangler fig | | | | | | | | | | | | | 0.8 | 0.8 | 1.6 | 1.7 | | | | | | | | | | |
| Pop ash | | | | | 78.3 | 100.0 | 99.2 | 98.7 | 11.1 | 19.5 | 92.4 | 90.1 | 16.4 | 14.1 | 1.5 | 2.0 | 100.0 | 98.9 | 62.3 | 62.5 | 100.0 | 100.0 | | | | |
| Dahoon holly | | | | | | | | | | | | | | | | | | | | | | | | | 0.5 | 1.4 |
| Slash pine | | | | | | | | | | | | | | | | | | | | | | | 56.9 | 56.2 | | |
| Laurel oak | 9.4 | 0.0 | 82.9 | 84.5 | | | | | | | | | | | | | | | | | | | | | | |
| Cabbage palm | | | 16.6 | 14.8 | 21.7 | 0.0 | | | | | | | | | | | | | 37.7 | 37.5 | | | 43.1 | 43.8 | 59.1 | 68.2 |
| Brazilian pepper[2] | | | | | | | | | | | | | | | 1.3 | 0.0 | | | | | | | | | | |
| Bald cypress | | | | | | | | | 88.9 | 80.5 | | | 80.8 | 81.9 | 95.5 | 95.9 | | | | | | | | | | |

**Legend**

(yellow) The species was a new occurrence in 2009.

(red) The species disappeared between 2003 and 2009.

**<u>Summary of Changes</u>**

Plot T3129 was missing one laurel oak (5.8 cm) in 2009.
Plot T3131 had one dead cabbage palm (31 cm) in 2009.
Plot T3132 was missing four pop ash in 2009.
Plot T3133 gained one pop ash between 2003 and 2009.
Plot T3134 gained two pond apple (5.1, 5.3 cm) and two pop ash (7.2, 8.2 cm) between 2003 and 2009.
Plot T3135 gained three pond apple (5.4, 5.6, 6.2 cm) between 2003 and 2009.
Plot T3136 was missing three Brazilian pepper (6.8, 6.1, 16.1 cm) in 2009. It gained one pond apple (7.1 cm) and one pop ash (5.4 cm) between 2003 and 2009.
Plot T3137 was missing one pop ash in 2009. It gained one pond apple (5.5 cm) between 2003 and 2009.
Plot T3138 was missing one pop ash in 2009.
Plot T3241 had one dead cabbage palm and was missing three red maples in 2009. It gained one dahoon holly (5.0 cm) between 2003 and 2009.

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-6. Percent relative basal area comparisons between 2003 and 2009 for Transect 4**

| Plot | T4142 | | T4143 | | T4144 | | T4145 | | T4146 | | T4147 | | T4148 | | T4149 | | T4150 | | T4151 | | T4152 | | T4153 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | **MH** | | **Rsw1** | | **Rsw1/Rblh2** | | **Rblh2** | | **Rsw1** | | **Rsw1** | | **Rsw1** | | **Rblh2** | | **Rblh3** | | **Rsw2** | | **Rsw1** | | **Rblh2** | |
| **Species[1]** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** |
| Red maple | | | 0.0 | 0.0 | 10.4 | 11.1 | 18.7 | 10.8 | | | | | 1.5 | 4.9 | 7.8 | 11.0 | | | | | 2.1 | 2.8 | 5.5 | 8.5 |
| Water hickory | | | 7.7 | 4.6 | 9.5 | 9.3 | 81.3 | 89.2 | | | 29.1 | 21.1 | 8.5 | 13.6 | 70.4 | 80.3 | 74.9 | 77.8 | | | | | 50.9 | 19.9 |
| Strangler fig | | | | | | | | | | | | | | | | | | | | | | | 0.1 | 0.6 |
| Pop ash | | | | | | | | | 48.3 | 54.8 | 19.1 | 13.1 | 30.9 | 30.4 | 1.7 | 2.7 | | | 54.3 | 60.4 | 0.9 | 0.0 | 0.6 | 1.0 |
| Wax myrtle | 0.0 | 1.1 | | | 0.5 | 0.4 | | | | | | | | | | | | | | | | | | |
| Laurel oak | 2.3 | 3.8 | | | | | | | | | | | | | | | | | | | 9.8 | 8.9 | 1.1 | 1.8 |
| Live oak | 97.7 | 95.5 | | | | | | | | | | | | | | | | | | | | | | |
| Cabbage palm | | | | | | | | | | | | | | | | | 25.1 | 22.2 | 45.7 | 39.6 | | | | |
| Brazilian pepper[2] | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.4 |
| Bald cypress | | | 92.3 | 94.7 | 79.6 | 79.2 | | | 51.7 | 45.2 | 51.8 | 65.8 | 59.1 | 51.0 | 20.1 | 6.0 | | | | | 87.2 | 88.4 | 41.7 | 67.7 |

**Legend**

- (yellow) The species was a new occurrence in 2009.
- (red) The species disappeared between 2003 and 2009.

**Summary of Changes**

Plot T4143 was missing one bald cypress (17.1 cm) in 2009. It gained one red maple (6.6 cm) between 2003 and 2009.
Plot T4144 gained one red maple (5.6 cm) between 2003 and 2009.
Plot T4145 was missing one red maple (19 cm) in 2009.
Plot T4146 gained one red maple (5.7 cm) between 2003 and 2009.
Plot T4147 gained one water hickory (24.6 cm). Bald cypress increased from 56.4 to 71.5 cm between 2003 and 2009.
Plot T4148 gained one red maple (5.7 cm) between 2003 and 2009.
Plot T4149 had one dead bald cypress and was missing two bald cypress in 2009. It gained one pop ash (5.4 cm) between 2003 and 2009.
Plot T4151 gained one pop ash (12.1 cm) between 2003 and 2009.
Plot T4152 was missing one pop ash (7.2 cm) in 2009.
Plot T4153 was missing one water hickory (88.6 cm) and one bald cypress (8.6 cm) in 2009. It gained one Brazilian pepper (7.8 cm) between 2003 and 2009.

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-7. Percent relative basal area comparisons between 2003 and 2009 for Transect 5**

| Plot | T5154 | | T5155 | | T5156 | | T5157 | | T5158 | | T5259 | | T5260 | | T5261 | | T5262 | | T5263 | | T5264 | | T5265 | | T5266 | | T5267 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | **MH** | | **HH/Rblh3** | | **Rblh3** | | **Rsw1** | | **Rsw1/Rblh2** | | **Rblh1** | | **Rsw1** | | **Rsw1** | | **Rsw1** | | **Rblh2** | | **Rblh2** | | **Rblh2** | | **Rblh2** | | **Rblh2** | |
| **Species[1]** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** |
| Red maple | | | | | 19.3 | 19.3 | | | 10.6 | 0.0 | 63.1 | 79.3 | 34.1 | 0.0 | 27.2 | 0.0 | | | | | | | 4.6 | 7.8 | | | | |
| Water hickory | | | 29.6 | 28.2 | 45.6 | 45.1 | 42.0 | 100.0 | 80.6 | 99.4 | | | | | | | 1.6 | 0.0 | 100.0 | 100.0 | | | 87.2 | 55.8 | 92.5 | 97.4 | 81.8 | 83.2 |
| Pop ash | | | | | | | | | | | 4.0 | 5.9 | | | | | | | | | | | | | | | | |
| Dahoon holly | | | | | | | | | | | | | | | 2.1 | 0.0 | | | | | | | | | | | | |
| Red bay | | | | | | | | | | | | | | | | | | | | | | | | | | | 2.2 | 0.0 |
| Swamp bay | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 2.6 | | |
| Laurel oak | | | 70.4 | 71.8 | | | | | 0.8 | 0.0 | 12.0 | 14.7 | | | | | | | | | 36.6 | 36.4 | | | | | | |
| Live oak | 100.0 | 100.0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Royal palm | | | | | | | | | | | | | | | | | | | | | 3.2 | 7.3 | | | | | | |
| Cabbage palm | | | | | | | 5.8 | 0.0 | | | | | 5.4 | 14.7 | | | | | | | 58.9 | 52.7 | 8.3 | 35.5 | 7.5 | 0.0 | 15.1 | 15.3 |
| Bald cypress | | | | | 35.0 | 35.6 | 52.2 | 0.0 | 8.0 | 0.6 | 20.9 | 0.0 | 60.5 | 85.3 | 70.7 | 100.0 | 98.4 | 98.7 | | | 1.4 | 3.5 | | | | | | |
| Calloose grape[2] | | | | | | | | | | | | | | | | | 0.0 | 1.3 | | | | | | | | | 0.9 | 1.5 |

**Legend**

(yellow) The species was a new occurrence in 2009.

(red) The species disappeared between 2003 and 2009.

**Summary of Changes**

Plot T5157 had one dead bald cypress (66.6 cm) and one dead cabbage palm (25 cm) in 2009.
Plot T5158 lost one red maple (32.1 cm), one laurel oak (8.9 cm) and one bald cypress (27.9 cm), and gained one bald cypress (6.7 cm) between 2003 and 2009.
Plot T5259 lost one bald cypress (22.7 cm) between 2003 and 2009.
Plot T5260 lost two bald cypress and three very large red maples (52.3, 47.4, 37.2 cm) between 2003 and 2009.
Plot T5261 had one dead red maple (45.6 cm) and was missing one dahoon holly (13.3 cm) in 2009. It gained one bald cypress (13.8 cm) between 2003 and 2009.
Plot T5262 had one dead bald cypress (31.8 cm) and one dead dahoon holly (9.6 cm) in 2009; and gained one calloose grape (8.0 cm) between 2003 and 2009.
Plot T5263 was missing one water hickory (5.7 cm) in 2009.
Plot T5265 lost two water hickory (15.9, 45.7 cm) between 2003 and 2009.
Plot T5266 lost two water hickory (59.2, 53.5 cm) and gained one swamp bay (5.3 cm) between 2003 and 2009.
Plot T5267 lost two red bay (5.5, 15.5 cm) and gained one calloose grape (8.1 cm) between 2003 and 2009.The bays may have been misidentified in Plot T5267.

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-8. Percent relative basal area comparisons between 2003 and 2009 for Transect 6**

| Plot | T6168 | | T6169 | | T6170 | | T6171 | | T6172 | | T6173 | | T6174 | | T6175 | | T6176 | | T6177 | | T6178 | | T6179 | | T6180 | | T6281 | | T6282 | | T6283 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | U | | U | | Rsw1 | | UTsw3 | | UTsw3 | | UTsw3 | | UTsw3 | | UTsw3 | | UTmix | | UTsw1 | | UTsw1 | | UTsw1 | | UTsw1 | | UTsw3 | | UTsw1 | | UTsw1 | |
| **Species[1]** | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 |
| Red maple | | | | | 4.3 | 5.1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pond apple | | | | | | | 15.2 | 2.4 | 3.3 | 0.0 | 0.0 | 0.6 | 2.3 | 0.0 | 1.8 | 0.0 | | | 44.7 | 25.0 | 1.9 | 3.5 | 9.8 | 10.8 | 5.9 | 1.2 | 26.7 | 31.6 | 13.8 | 17.8 | 40.7 | 39.4 |
| Buttonbush | | | | | 0.5 | 0.3 | | | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | | | | |
| Pop ash | | | | | | | | | | | | | | | | | | | 3.8 | 4.4 | 3.2 | 3.3 | 1.2 | 0.0 | | | | | | | | |
| Dahoon holly | | | 2.8 | 8.3 | | | | | 0.0 | 0.2 | | | | | | | | | | | | | | | | | | | | | | |
| White mangrove | | | | | | | 52.4 | 73.6 | 35.4 | 45.4 | 94.5 | 93.8 | 95.4 | 92.8 | 67.7 | 85.1 | 11.0 | 18.6 | 26.9 | 37.5 | 8.5 | 19.2 | 26.9 | 35.7 | 19.2 | 16.4 | 56.9 | 57.6 | | | | |
| Wax myrtle | | | | | 0.6 | 0.6 | 1.2 | 3.0 | 4.6 | 0.8 | 5.5 | 5.0 | 2.3 | 4.2 | 0.0 | 1.8 | 4.3 | 0.9 | 2.5 | 0.0 | | | 5.7 | 4.1 | | | | | 1.2 | 1.4 | 1.5 | 1.0 |
| Red bay | | | 12.1 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Slash pine | 94.0 | 94.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Live oak | 6.0 | 5.8 | 0.0 | 21.4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Red mangrove | | | | | | | 6.3 | 5.6 | 9.7 | 26.1 | 0.0 | 0.6 | 0.0 | 3.0 | 4.6 | 13.2 | 1.0 | 15.5 | 18.7 | 33.2 | 34.6 | 62.8 | 52.5 | 48.3 | 35.4 | 20.4 | 10.8 | 10.8 | 11.7 | 17.5 | 35.5 | 39.5 |
| Royal palm | | | | | | | | | | | | | | | | | | | | | 9.0 | 11.1 | | | | | | | | | | |
| Cabbage palm | | | | | | | 18.0 | 0.0 | 47.0 | 25.9 | | | | | 25.9 | 0.0 | 63.6 | 42.8 | | | 42.8 | 0.0 | | | 36.7 | 45.8 | | | 15.8 | 15.0 | 19.4 | 14.4 |
| Brazilian pepper[2] | | | | | | | | | | | | | | | | | 3.0 | 0.0 | 3.3 | 0.0 | | | 3.9 | 1.1 | 2.8 | 6.5 | 0.0 | 0.0 | 9.2 | 0.0 | 3.0 | 5.6 |
| Saw palmetto | | | 85.1 | 70.3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bald cypress | | | | | 94.7 | 93.9 | 7.0 | 15.4 | | | | | | | | | 17.2 | 22.2 | | | | | | | | | | | 48.3 | 48.3 | | |

**Legend**

| | |
|---|---|
| Yellow | The species was a new occurrence in 2009. |
| Red | The species disappeared between 2003 and 2009. |

**Summary of Changes**

Plot T6169 lost two saw palmetto and gained one live oak (10.6 cm) between 2003 and 2009.
Plot T6170 had one dead cabbage palm fall into the plot in 2009. It and gained one wax myrtle between 2003 and 2009.
Plot T6171 gained a bald cypress between 2003 and 2009. In 2003, a 17.3 cm bald cypress was present; in 2009, two bald cypress (17.3, 16.7 cm) were present.
Plot T6172, lost two cabbage palm (25, 26 cm) between 2003 and 2009.
In Plot T6173, a cabbage palm (36.5 cm) present in 2003 may not have been present in the plot in 2009. Seven trees were incorrectly recorded in the 2003 data set. They need to be changed to white mangroves and the relative basal area recalculated.
Plot T6175 had one dead cabbage palm (27 cm) in 2009.
Plot T6176 had one dead cabbage palm in 2009. It lost three wax myrtle and gained 16 red mangroves between 2003 and 2009.
Plot T6177 lost one pond apple and one wax myrtle and gained one pop ash and 11 red mangrove between 2003 and 2009.
Plot T6178 gained one pond apple, one white mangrove and 15 red mangrove between 2003 and 2009.
Plot T6180 gained three pond apple and four white mangrove, and lost four red mangrove between 2003 and 2009.
Plot T6281 gained six pond apple, nine white mangrove and one red mangrove between 2003 and 2009.
Plot T6282 gained four pond apple between 2003 and 2009.
Plot T6283 gained two pond apple and three red mangrove between 2003 and 2009.

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-9. Percent relative basal area comparisons between 2003 and 2009 for Transect 7**

| **Plot** | **T7184** | | **T7185** | | **T7186** | | **T7187** | | **T7188** | | **T7189** | | **T7190** | | **T7191** | | **T7192** | | **T7193** | | **T7194** | | **T7195** | | **T7196** | | **T7197** | | **T7198** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | **MH/Rsw1** | | **Rsw1** | | **Rsw1** | | **Rmix** | | **Rmix** | | **Rmix** | | **Rmix** | | **Rmix** | | **UTsw1** | | **UTsw1** | | **UTsw1** | | **UTsw1** | | **UTsw2** | | **UTsw2** | | **UTsw2** | |
| **Species[1]** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** |
| Red maple | | | 0.4 | 0.5 | | | 9.2 | 0.0 | | | 7.0 | 5.9 | | | 6.1 | 7.7 | 4.1 | 5.1 | | | 1.3 | 1.8 | | | | | | | | |
| Pond apple | | | | | | | | | 0.0 | 1.4 | 0.3 | 0.3 | | | 0.5 | 2.0 | 23.5 | 0.0 | 8.3 | 8.3 | 3.8 | 7.7 | 28.6 | 30.5 | 47.9 | 49.8 | 28.3 | 26.4 | 15.3 | 16.0 |
| Buttonbush | | | | | | | 0.4 | 0.3 | 0.0 | 1.4 | | | | | | | | | | | | | | | | | | | | |
| Pop ash | | | | | | | 0.5 | 0.5 | 1.9 | 4.3 | 1.7 | 0.4 | 0.9 | 2.2 | 2.9 | 0.6 | 6.7 | 9.4 | 0.0 | 5.3 | 11.0 | 9.4 | 11.2 | 5.4 | 6.0 | 3.3 | 4.6 | 3.2 | 1.5 | 1.5 |
| White mangrove | | | | | | | | | | | | | | | 1.2 | 4.0 | | | | | | | | | | | 1.6 | 3.9 | 1.2 | 2.7 |
| Wax myrtle | 2.1 | 0.0 | 0.0 | 0.4 | 3.2 | 3.6 | 6.8 | 4.2 | 9.5 | 11.1 | 5.5 | 6.3 | 7.7 | 5.5 | 1.2 | 0.0 | 7.4 | 0.0 | 3.9 | 2.4 | | | | | 1.7 | 2.2 | 4.2 | 2.2 | | |
| Live oak | 44.6 | 49.8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Myrsine | | | 0.3 | 0.5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Red mangrove | | | | | | | | | | | | | | | | | 2.2 | 10.8 | | | | | | | 4.4 | 12.0 | 12.5 | 14.5 | 10.1 | 18.1 |
| Royal palm | | | | | 0.5 | 0.7 | | | | | 1.0 | 1.7 | | | | | | | | | | | | | | | | | | |
| Cabbage palm | | | | | 17.6 | 17.9 | 54.3 | 61.6 | 73.1 | 81.9 | 39.1 | 34.5 | 66.6 | 65.2 | 43.9 | 31.7 | | | | | | | | | 31.5 | 22.2 | 48.9 | 49.8 | 72.0 | 61.6 |
| Carolina willow | | | | | | | | | | | | | | | | | | | 7.8 | 7.0 | | | 28.0 | 31.4 | 8.4 | 10.5 | | | | |
| Pop ash | | | 0.0 | 0.7 | 1.2 | 0.0 | | | | | | | | | 1.2 | 1.6 | | | 7.8 | 7.0 | 1.3 | 0.9 | 28.0 | 31.4 | 8.4 | 10.5 | 4.6 | 3.2 | | |
| Brazilian pepper[2] | | | | | 0.6 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Java plum | | | | | | | | | | | | | | | 1.2 | 1.6 | | | | | 0.0 | 0.9 | | | | | | | | |
| Bald cypress | 53.3 | 50.2 | 99.3 | 98.0 | 77.0 | 77.8 | 28.8 | 33.4 | 15.5 | 0.0 | 45.4 | 50.9 | 24.8 | 27.1 | 43.0 | 51.6 | 56.1 | 74.7 | 80.0 | 77.1 | 82.7 | 80.1 | 32.2 | 32.6 | | | | | | |

**Legend**

(yellow) The species was a new occurrence in 2009.

(red) The species disappeared between 2003 and 2009.

**<u>Summary of Changes</u>**

Plot T7184 lost two wax myrtle between 2003 and 2009.
Plot T7185 had one dead bald cypress (25.8 cm) and gained one wax myrtle between 2003 and 2009.
Plot T7186 lost two wax myrtle and gained one bald cypress (12.2 cm) between 2003 and 2009.
Plot T7187 lost two red maple and two wax myrtle between 2003 and 2009.
Plot T7189 lost three pop ash, and gained one bald cypress (9.1 cm) and five wax myrtle between 2003 and 2009.
Plot T7190 gained two pop ash and one wax myrtle between 2003 and 2009.
Plot T7191 had one dead cabbage palm in 2009. It lost one wax myrtle between 2003 and 2009.
Plot T7192 lost two pond apple, three wax myrtle and three red mangrove, and gained one pop ash between 2003 and 2009.
Plot T7193 lost one Carolina willow and gained two pond apple, three pop ash and two wax myrtle between 2003 and 2009.
Plot T7194 lost one Carolina willow and two pop ash, and gained six pond apple, one Java plum and two bald cypress between 2003 and 2009.
Plot T7195 had one dead pop ash and it gained nine pond apple and three Carolina willow.
Plot T7196 gained two pop ash, three red mangrove and one Carolina willow between 2003 and 2009.
Plot T7197 lost three pond apple, two pop ash and three wax myrtle between 2003 and 2009.
Plot T7198 gained three pond apple, one pop ash and 14 red mangrove between 2003 and 2009.

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[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-10. Percent relative basal area comparisons between 2003 and 2009 for Transect 8**

| Plot | T8199 | | T81100 | | T81101 | | T81102 | | T81103 | | T81104 | | T81105 | | T81106 | | T81107 | | T81108 | | T81109 | | T81110 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | **Rmix** | | **HH** | | **Rmix** | | **Utmix** | | **UTmix** | | **UTsw1** | | **UTmix** | | **UTsw1** | | **UTmix** | | **UTsw1** | | **UTsw1** | | **UTsw1** | |
| **Species[1]** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** |
| Red maple | | | 11.6 | 5.0 | | | 14.3 | 0.0 | | | | | 5.9 | 0.0 | | | | | | | | | | |
| Pond apple | | | | | | | 26.2 | 32.8 | 5.4 | 9.0 | 3.8 | 6.7 | 33.9 | 60.6 | 0.8 | 0.8 | 2.5 | 1.1 | 67.2 | 48.2 | 0.0 | 0.6 | 16.0 | 11.0 |
| Buttonbush | | | 0.0 | 14.9 | 1.8 | 0.0 | 0.0 | 3.8 | | | | | | | | | | | | | | | | |
| Pop ash | | | | | | | 3.3 | 7.2 | | | | | | | | | | | 4.8 | 7.1 | 2.0 | 0.0 | 0.0 | 1.1 |
| White mangrove | | | | | | | | | | | 0.0 | 1.8 | 0.0 | 20.5 | 0.0 | 0.1 | 20.8 | 31.0 | 0.0 | 32.4 | 0.0 | 0.6 | | |
| Wax myrtle | | | 81.8 | 48.8 | 38.7 | 1.7 | 33.7 | 16.9 | 7.3 | 2.5 | 2.0 | 0.0 | 5.5 | 0.0 | 1.8 | 1.8 | 1.3 | 0.0 | | | | | 4.0 | 0.0 |
| Red bay | | | | | 6.2 | 0.0 | 11.6 | 0.0 | | | | | | | | | | | | | | | | |
| Swamp bay | | | 0.0 | 7.5 | | | | | | | | | | | | | | | | | | | | |
| Strawberry guava[2] | | | | | | | | | 1.3 | 0.0 | 0.7 | 0.0 | 7.4 | 0.0 | | | | | | | | | | |
| Red mangrove | | | | | | | | | | | | | | | | | | | 1.5 | 6.4 | | | | |
| Cabbage palm | | | | | | | | | 36.3 | 21.8 | | | | | | | 19.6 | 0.0 | 26.6 | 0.0 | 39.9 | 28.9 | 39.8 | 34.5 |
| Carolina willow | | | | | | | | | | | | | | | 5.5 | 2.0 | | | | | | | | |
| Brazilian pepper[2] | | | | | | | 7.1 | 14.3 | 5.5 | 1.3 | | | 47.3 | 18.8 | 1.9 | 0.0 | | | 0.0 | 2.9 | | | | |
| Saw palmetto | 1.9 | 1.7 | | | | | | | | | | | | | | | | | | | | | | |
| Bald cypress | 98.1 | 98.3 | 6.5 | 23.7 | 53.3 | 98.3 | 3.8 | 24.9 | 44.2 | 65.4 | 93.6 | 91.5 | | | 89.9 | 96.3 | 55.8 | 67.9 | 0.0 | 2.9 | 57.9 | 69.9 | 40.2 | 53.4 |

**Legend**

The species was a new occurrence in 2009.

The species disappeared between 2003 and 2009.

**<u>Summary of Changes</u>**

Plot T81100 lost one red maple and six wax myrtle, and gained three buttonbush and one swamp bay between 2003 and 2009.
Plot T81101 lost one buttonbush, seven wax myrtle and one red bay, and gained one bald cypress between 2003 and 2009.
Plot T81102 had two dead wax myrtle and one dead pop ash in 2009. It lost two red maple and two red bay, and gained one pop ash between 2003 and 2009.
Plot T81103 had two dead wax myrtle in 2009. It lost one Brazilian pepper and gained two pond apple between 2003 and 2009.
Plot T81104 lost two wax myrtle and one strawberry guava, and gained five pond apple and two white mangrove between 2003 and 2009.
Plot T81105 had two dead red maple in 2009. It gained four pond apple and three white mangrove between 2003 and 2009.
Plot T81106 lost one wax myrtle and one Brazilian pepper between 2003 and 2009.
Plot T81107 had one dead cabbage palm in 2009. It lost one pond apple, one white mangrove and one wax myrtle between 2003 and 2009.
Plot T81108 had one dead cabbage palm in 2009. It lost seven pond apple and one pop ash between 2003 and 2009.
Plot T81109 had one dead cabbage palm in 2009. It lost one pop ash and gained one pond apple and one white mangrove between 2003 and 2009.
Plot T81110 lost two pond apple and three wax myrtle, and gained one pop ash between 2003 and 2009.

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-11. Percent relative basal area comparisons between 2003 and 2009 for Transect 9**

| **Plot** | **T91111** | | **T91112** | | **T91113** | | **T91114** | | **T91115** | | **T91116** | | **T91117** | | **T91118** | | **T91119** | | **T91120** | | **T91121** | | **T91122** | | **T91123** | | **T91124** | | **T91125** | | **T91126** | | **T91127** | | **T91128** | | **T91129** | | **T91130** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Forest Type** | **U** | | **HH** | | **LTsw2** | | **LTsw2** | | **LTsw2** | | **LTmix** | | **HH/LTsw2** | | **LTsw2** | | **LTsw2** | | **LTsw2** | | **LTsw2** | | **LTsw2** | | **LTsw2** | | **LTsw2** | | **LTsw2** | | **LTsw1** | | **LTsw1** | | **LTsw1** | | **LTsw1** | | **LTsw1** | |
| **Species[1]** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** | **2003** | **2009** |
| Pond apple | | | 2.6 | 6.6 | | | | | | | | | | | 1.4 | 0.7 | 3.8 | 2.9 | 2.2 | 1.5 | 1.5 | 5.0 | 1.8 | 3.0 | 0.0 | 2.2 | | | | | 0.0 | 0.5 | 1.1 | 0.0 | | | | | | |
| Black mangrove | | | | | | | | | | | | | | | 0.0 | 0.6 | | | | | | | | | | | | | | | | | | | | | | | | |
| Coco plum | | | 0.0 | 7.3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Strangler fig | | | | | 0.0 | 0.8 | | | | | | | | | | | | | | | | | | | 0.7 | 0.0 | | | | | | | | | | | | | | |
| White mangrove | | | 12.9 | 13.3 | 65.5 | 92.8 | 94.7 | 100.0 | 58.3 | 59.0 | 12.3 | 53.2 | 5.5 | 3.8 | 52.1 | 53.4 | 60.1 | 97.1 | 94.8 | 96.2 | 80.8 | 95.0 | 97.2 | 96.4 | 98.7 | 95.3 | 92.3 | 97.3 | 94.8 | 95.1 | 90.2 | 86.7 | 46.0 | 51.5 | 55.1 | 22.8 | 55.3 | 41.8 | 5.4 | 24.0 |
| Slash pine | 100.0 | 94.8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Laurel oak | 0.0 | 5.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Red mangrove | | | | | 5.0 | 6.4 | | | | | | | | | | | | | | | 0.6 | 0.0 | 0.0 | 3.3 | | | 1.9 | 0.5 | 5.2 | 4.9 | 9.8 | 11.3 | 36.1 | 32.7 | 44.9 | 77.2 | 44.7 | 58.2 | 94.6 | 76.0 |
| Cabbage palm | | | 84.4 | 72.7 | 28.1 | 0.0 | 4.6 | 0.0 | 41.7 | 41.0 | 87.7 | 46.8 | 94.1 | 96.2 | 34.0 | 45.3 | 36.1 | 0.0 | | | 14.5 | 0.0 | | | | | | | | | | | 16.8 | 15.8 | | | | | | |
| Brazilian pepper[2] | | | | | 0.4 | 0.0 | 0.7 | 0.0 | | | | | 0.3 | 0.0 | 12.6 | 0.0 | | | 3.0 | 2.3 | 2.5 | 0.0 | 0.9 | 0.0 | 0.7 | 2.5 | 5.8 | 2.1 | | | 0.0 | 1.5 | | | | | | | | |

**Legend**

(yellow) The species was a new occurrence in 2009.

(red) The species disappeared between 2003 and 2009.

**Summary of Changes**

Fire management had impacted Plot T91111 in 2009.
Plot T91111 had one dead laurel oak in 2009.
Plot T91112 lost one pond apple and three cabbage palm, and gained three coco plum and two white mangrove between 2003 and 2009.
Plot T91113 had two dead cabbage palm in 2009. It lost one red mangrove and one Brazilian pepper, and gained one strangler fig and two white mangrove between 2003 and 2009.
Plot T91114 had one dead cabbage palm and two dead white mangrove in 2009. It lost one Brazilian pepper between 2003 and 2009.
Plot T91115 lost two white mangrove between 2003 and 2009.
Plot T91116 had three dead cabbage palm in 2009. It gained nine white mangrove between 2003 and 2009.
Plot T91117 lost three white mangrove and one Brazilian pepper between 2003 and 2009.
Plot T91118 lost two Brazilian pepper and gained 15 white mangrove between 2003 and 2009.
In Plot T91119, all four cabbage palm and two white mangrove were dead in 2009.
Plot T91120 lost one pond apple and gained 17 white mangrove between 2003 and 2009.
Plot T91121 lost one red mangrove and one cabbage palm, and gained one pond apple and 12 white mangrove between 2003 and 2009.
Plot T91122 lost one Brazilian pepper, and gained 21 white mangrove and one red mangrove between 2003 and 2009.
Plot T91123 lost one strangler fig, and gained one pond apple and 10 white mangrove between 2003 and 2009.
Plot T91124 lost two Brazilian pepper and gained 29 white mangrove between 2003 and 2009.
Plot T91125 lost two red mangrove and gained 10 white mangrove between 2003 and 2009.
Plot T91126 gained one pond apple, three white mangrove, three red mangrove and one Brazilian pepper between 2003 and 2009.
Plot T91127 lost one pond apple, one white mangrove and one red mangrove between 2003 and 2009.
Plot T91128 lost one white mangrove and gained 12 red mangrove between 2003 and 2009.
Plot T91129 gained 15 red mangrove between 2003 and 2009.

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-3-12. Percent relative basal area comparisons between 2003 and 2009 for Transect 10**

| Plot | T10131 | | T10132 | | T10133 | | T10134 | | T10135 | | T10136 | | T10137 | | T10138 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forest Type | HH/M | | M | | UTsw2 | | UTmix | | HH | | UTmix | | UTmix | | UTmix | |
| Species[1] | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 | 2003 | 2009 |
| Red maple | 53.9 | 0.0 | | | | | | | | | | | | | | |
| Pond apple | | | 0.0 | 51.9 | 87.6 | 83.5 | 11.7 | 12.6 | 0.0 | 1.7 | 24.3 | 11.4 | 6.2 | 3.8 | 0.0 | 10.3 |
| Dahoon holly | | | | | 2.3 | 0.0 | | | 0.5 | 0.0 | | | | | | |
| White mangrove | | | 0.0 | 29.2 | 0.0 | 10.1 | 0.0 | 0.6 | | | 0.0 | 2.0 | 0.0 | 1.0 | 5.1 | 6.4 |
| Wax myrtle | 46.1 | 0.0 | 100.0 | 0.0 | 3.0 | 0.0 | 2.3 | 3.5 | 4.2 | 0.6 | | | 1.2 | 0.0 | 1.8 | 0.0 |
| Red bay | | | | | | | | | 0.7 | 0.0 | | | | | | |
| Slash pine | | | | | | | 0.6 | 1.2 | | | | | | | | |
| Strawberry guava[2] | | | | | | | | | 0.3 | 0.5 | | | | | | |
| Laurel oak | | | | | | | | | 13.6 | 0.0 | | | | | | |
| Cabbage palm | | | | | | | 85.4 | 82.0 | 80.0 | 96.9 | 75.0 | 86.0 | 92.3 | 93.6 | 89.6 | 79.7 |
| Brazilian pepper[2] | | | 0.0 | 19.0 | 7.2 | 6.4 | | | 0.6 | 0.0 | 0.7 | 0.6 | 0.0 | 1.7 | 3.5 | 3.6 |
| Bald cypress | | | | | | | | | 0.0 | 0.3 | | | | | | |
| Poison ivy | | | | | | | | | 0.0 | 0.3 | | | | | | |

**Legend**

| | |
|---|---|
| (yellow) | The species was a new occurrence in 2009. |
| (red) | The species disappeared between 2003 and 2009. |

**<u>Summary of Changes</u>**

Plot T10131 was impacted by fire management, which may account for the loss of wax myrtle and red maple between 2003 and 2009.

Plot T10132 was impacted by fire management. It lost two wax myrtle and gained three pond apple, two white mangrove and one Brazilian pepper between 2003 and 2009.

Plot T10133 lost three pond apple and one dahoon holly, and gained three white mangrove between 2003 and 2009.

Plot T10134 lost two pond apple, and gained one white mangrove and one wax myrtle between 2003 and 2009.

Plot T10135 had three dead wax myrtle, one dead red bay and one dead laurel oak in 2009. It lost one dahoon holly, one additional wax myrtle and one Brazilian pepper, and gained two pond apple and one poison ivy between 2003 and 2009.

Plot T10136 had two dead pond apples and two dead wax myrtle in 2009, and it had lost two additional pond apples and gained three white mangrove between 2003 and 2009.

Plot T10137 lost three wax myrtle and gained two white mangrove and three Brazilian pepper between 2003 and 2009.

Plot T10138 had two dead wax myrtle in 2009. It gained 12 pond apple and one Brazilian pepper between 2003 and 2009.

1 Scientific names are provided in **Appendix 3-2**.
2 Nonnative species.

# APPENDIX 3-4

# DBH SIZE CLASS FREQUENCIES OF SELECT CANOPY SPECIES

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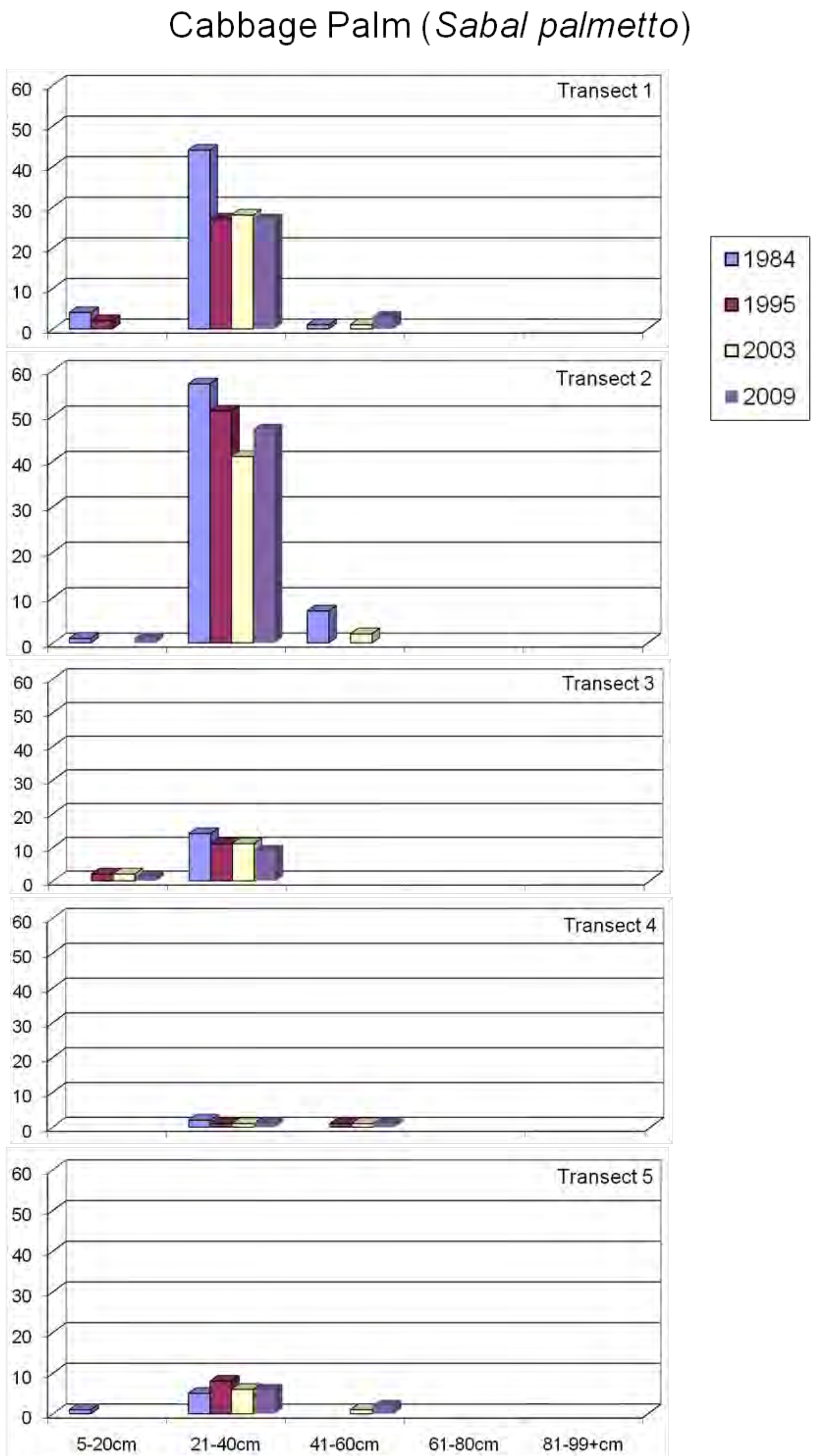


**Figure 3-4-1. Cabbage palm (*Sabal palmetto*) DBH size class frequencies for the riverine reach transects**

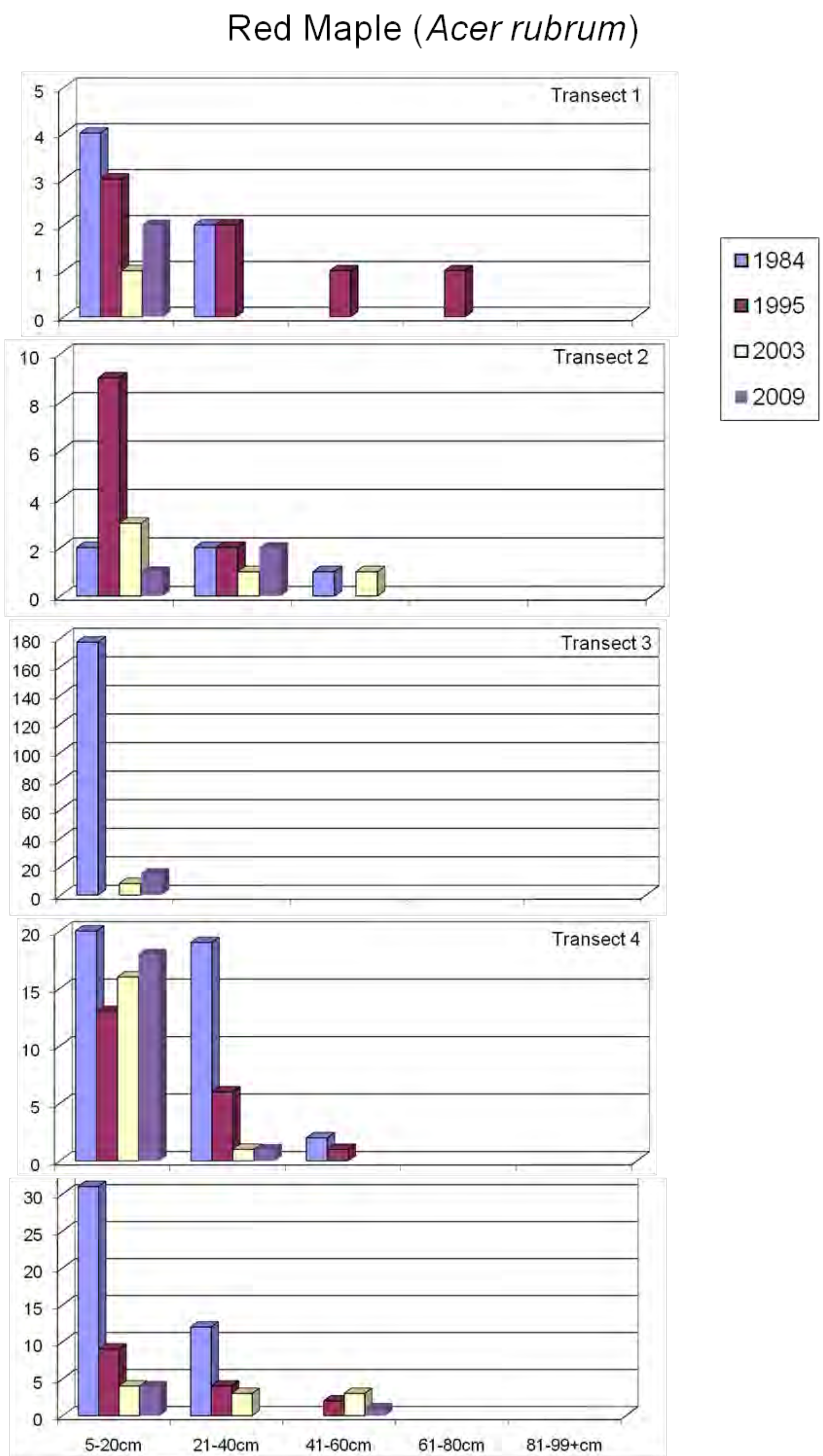


**Figure 3-4-2. Red maple (*Acer rubrum*) DBH size class frequencies for the riverine reach transects**

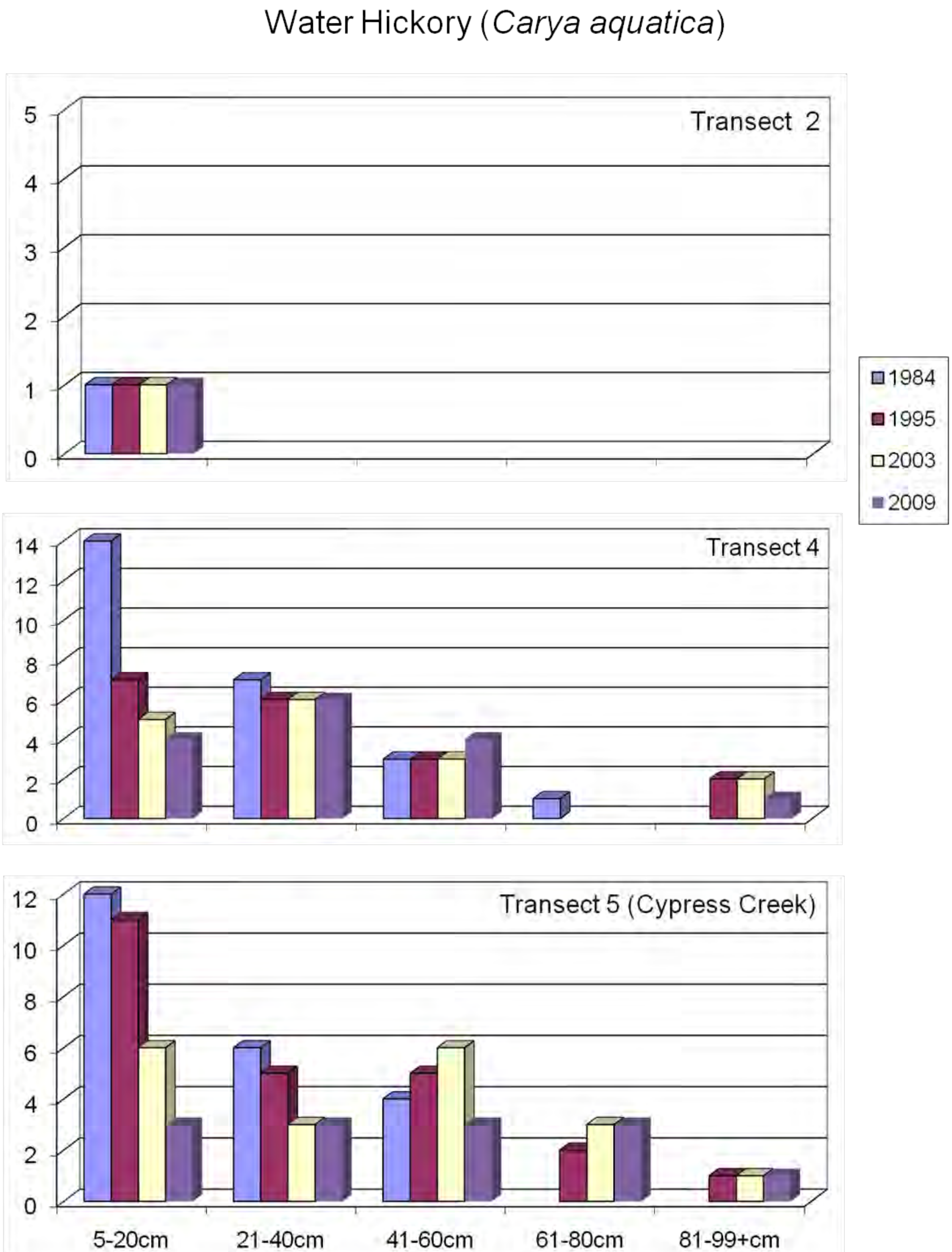


**Figure 3-4-3. Water hickory (*Carya aquatica*) DBH size class frequencies for three of the riverine reach transects**

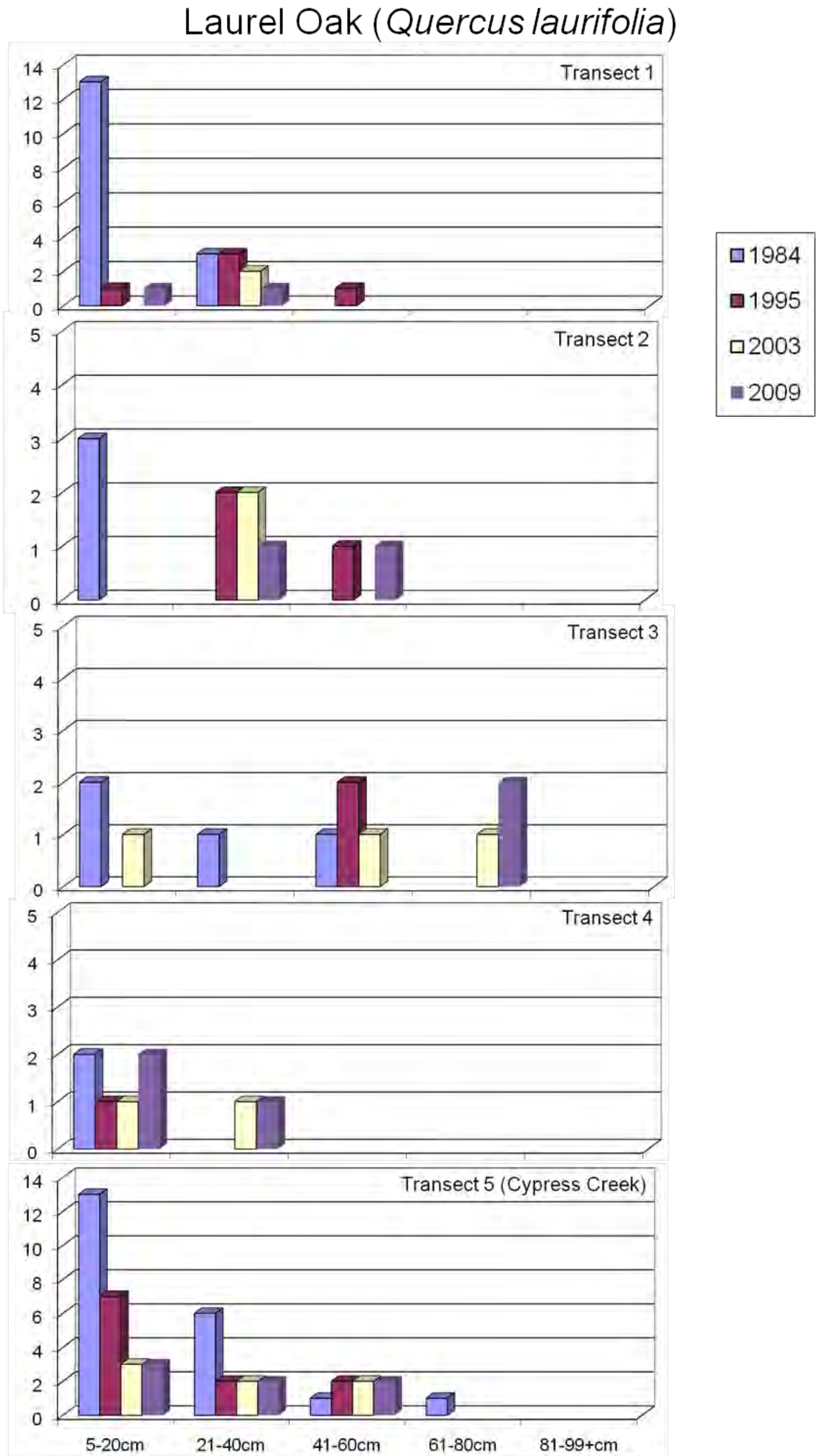


**Figure 3-4-4. Laurel oak (*Quercus laurifolia*) DBH size class frequencies for the riverine reach transects**

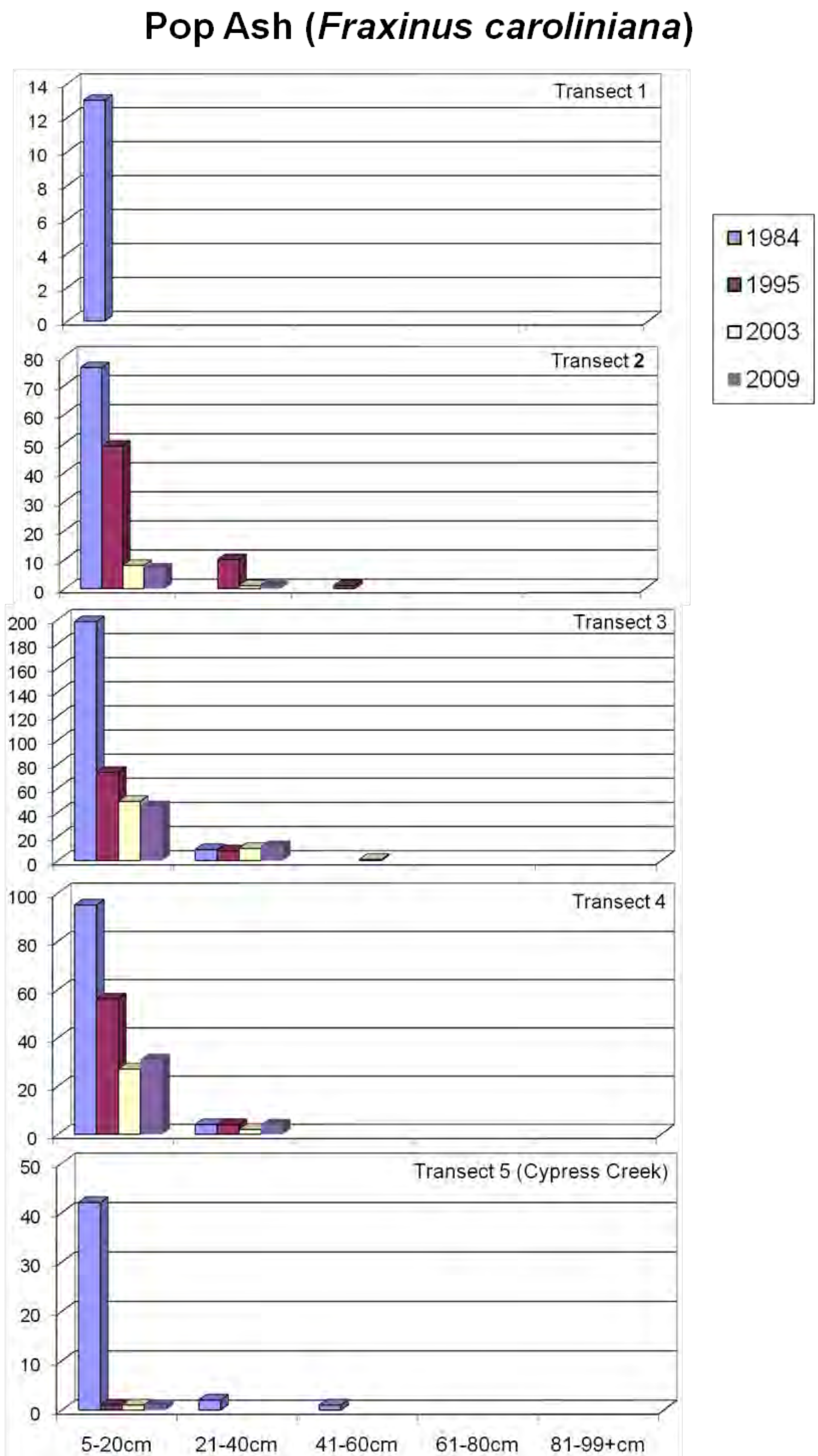


**Figure 3-4-5. Pop ash (*Fraxinus caroliniana*) DBH size class frequencies for the riverine reach transects**

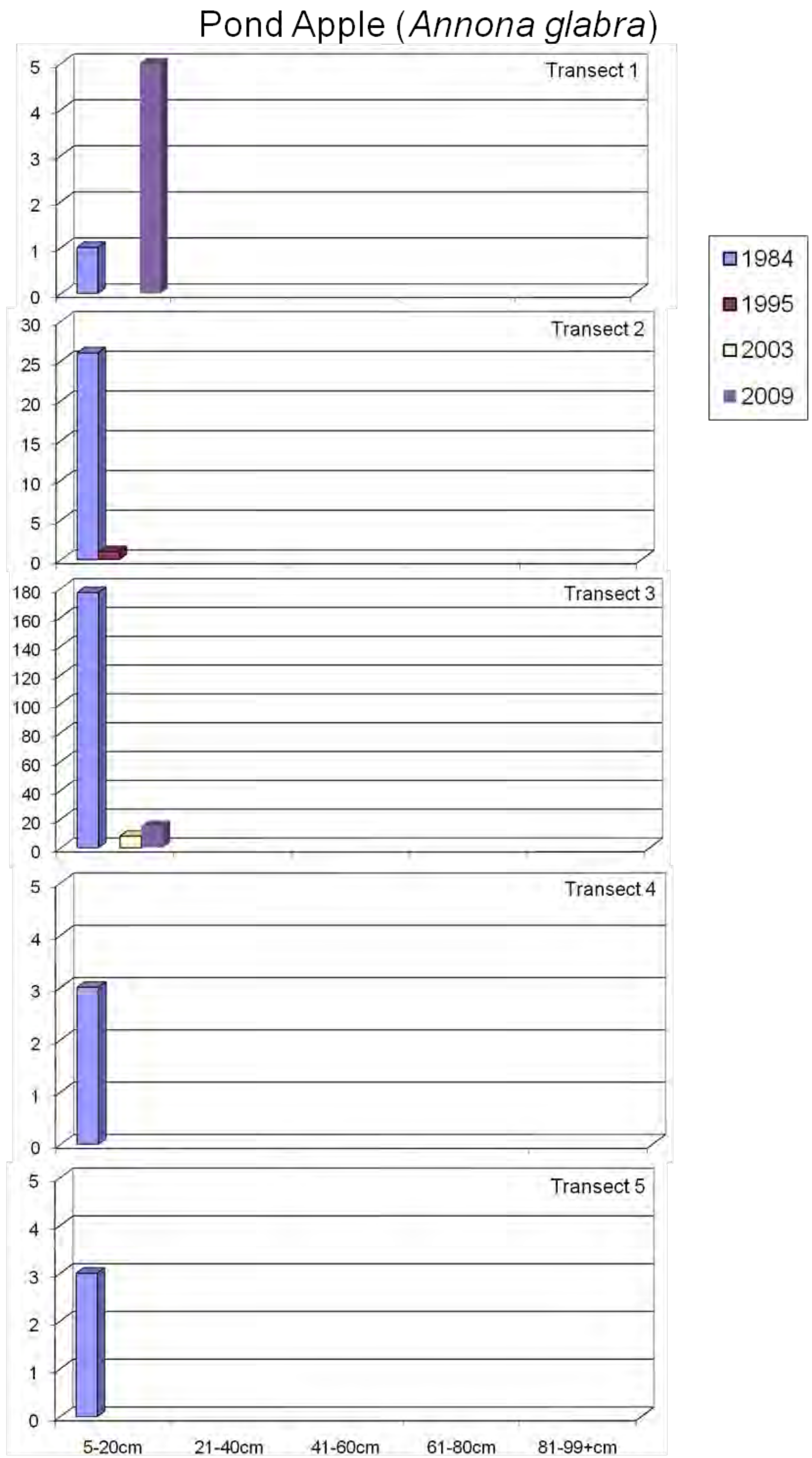


**Figure 3-4-6. Pond apple (*Annona glabra*) DBH size class frequencies for the riverine reach transects**

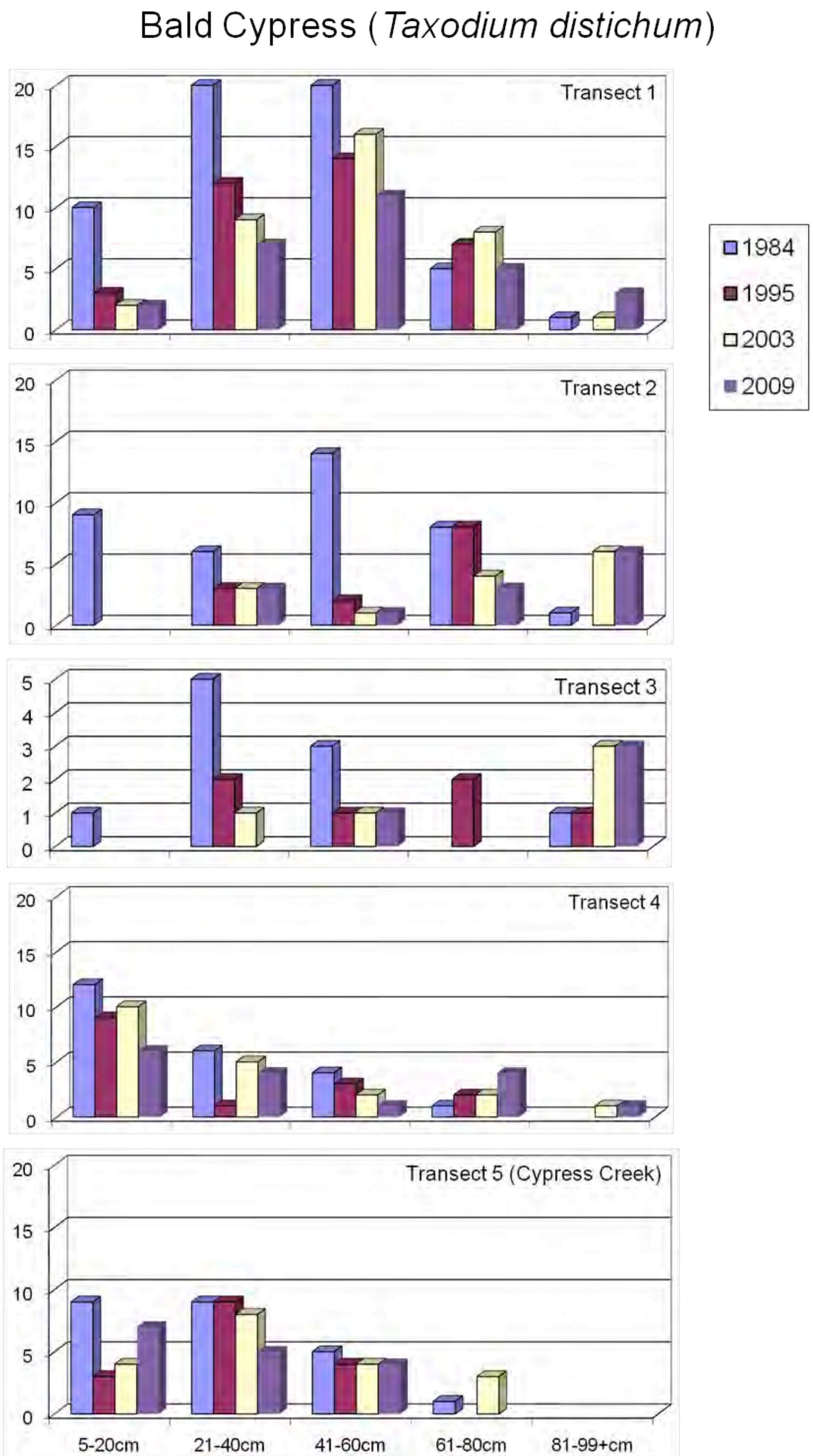


**Figure 3-4-7. Bald cypress (*Taxodium distichum*) DBH size class frequencies for the riverine reach transects**

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# APPENDIX 3-5
# SHRUB PERCENT COVER FOR EACH TRANSECT

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## Table 3-5-13. Percent cover of shrubs by transect between 2003 and 2010

| | Percent Cover | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | | T2 | | | T3 | | | T4 | | | T5 | | | T6 | | | T7 | | | T8 | | | T9 | | | T10 | | |
| **Common Name[1]** | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Rosary pea[2] | | | | | | | | | | | | | | | | | | | | | | | | | | 0.04 | 0.51 | | | |
| Red maple | | | | 0.51 | 0.31 | 1.22 | | 0.33 | 0.78 | 0.57 | 0.60 | 1.82 | | 0.01 | 0.79 | | | | | 0.06 | 0.33 | 0.09 | 0.14 | | | | | | | |
| Leather fern | 3.17 | 1.14 | 2.54 | | 0.82 | 1.45 | 3.75 | 1.55 | 2.84 | 2.2 | 1.12 | 1.78 | | | | 4.76 | 6.9 | 4.34 | 6.21 | 4.68 | 3.75 | 3.43 | 2.15 | 1.42 | 9.66 | 7.86 | 8.75 | 0.30 | 0.34 | 0.025 |
| False indigo | | | | | | | | | | | | | | | | 0.28 | 0.14 | 0.25 | 0.13 | 0.08 | 0.36 | 0.05 | 0.46 | 0.45 | | | | | | |
| Pond apple | 0.48 | 0.04 | 0.03 | | | | | 0.02 | 0.43 | 0.42 | | | | | | 1.43 | 0.37 | 1.50 | 3.17 | 1.42 | 2.36 | 2.34 | 1.88 | 2.54 | 0.94 | | 0.43 | 1.47 | 1.67 | 20 |
| Groundnut | | | | | | | | | 0.10 | | | | | | | | | | | | | | | | | | | | | |
| Marlberry | 0.03 | | 0.18 | 2.37 | 0.86 | 1.39 | | | | | | | 0.32 | 0.08 | 0.30 | | | | | 0.03 | | 0.07 | | | | | | | | |
| Black mangrove | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | | |
| Salt bush (silverling) | | | | | | | | | | | | | | | | | | | | 0.05 | | | 0.12 | | | | | | | |
| Salt bush (groundsel tree) | | | | | | | | | | | | | | | | | | | 0.66 | 0.05 | | 0.58 | 0.24 | | | | | | | |
| Baccharis species | | | | | | | | | | | | | | | | | | | | | 0.29 | | | 0.03 | | | | | | 0.02 |
| Swamp fern | 1.05 | 2.04 | 1.25 | 0.31 | 0.46 | 0.22 | 0.05 | 0.10 | 0.10 | 2.25 | 0.96 | 0.08 | 5.37 | 1.24 | 0.57 | 0.26 | 0.08 | | 0.27 | 0.17 | 0.06 | 0.36 | 0.01 | 0.03 | 0.43 | | 0.10 | 0.40 | | 0.05 |
| False nettle | | 0.2 | 0.02 | | 0.02 | | | 0.02 | | | | 0.06 | | 0.56 | | | | | | 0.01 | 0.05 | 0.05 | | 0.05 | | | | | | |
| American beautyberry | 0.64 | 0.41 | 0.19 | 0.57 | 1.12 | 0.45 | | | | | | | | 0.36 | 0.45 | | | | | | | | | | | | | | | |
| Water hickory | | | | | | | | | | | | | | 0.06 | 1.62 | | | | | | | | | | | | | | | |
| Buttonbush | 0.54 | 0.28 | 0.41 | 0.48 | 0.06 | 0.12 | 0.15 | | 0.54 | 0.28 | 0.26 | 0.95 | | 0.19 | 0.23 | 0.78 | 0.84 | 1.49 | 1.32 | 0.77 | 1.17 | 0.88 | 1.63 | 2.61 | | | | 0.36 | 0.60 | 0.34 |
| Jack-in-the-bush | | | | | | | | | | | | | | 0.16 | 0.06 | | | | | | | | | | | | | | | |
| Coco plum | | 0.39 | 0.84 | 0.56 | 0.08 | 0.32 | | | | | | | | | | | | | | | | 0.04 | 0.06 | | 1.49 | 1.36 | 0.88 | | | |
| Sawgrass | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1.16 | 1.40 | 0.47 |
| Wild taro[2] | | 0.68 | 1.44 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Common dayflower[2] | | 0.12 | | | | | | | | | | | | 0.10 | | | | | | | | | | | | | | | | |
| Swamp lily | | | 0.14 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| False sawgrass | | | | | | | | | | | 0.12 | | | | | | | | | | | | | | | | | | | |
| Green flat sedge | | | | | | | | | | | | | | | 0.68 | | | | | | | | | | | | | | | |
| Coin vine | | | | | | | | | | | | | | | | | | 0.03 | | 0.33 | 0.08 | | 0.06 | 0.08 | | 1.30 | 1.06 | | 0.13 | 0.40 |
| Persimmon | | | | | | | | | | | | | | | | | | | | | | | 0.03 | | | | | | | |
| Florida butterfly orchid | | | | | | | | | | | | | | 0.10 | | | | | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-5-13. continued

| Common Name[1] | Percent Cover | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | | T2 | | | T3 | | | T4 | | | T5 | | | T6 | | | T7 | | | T8 | | | T9 | | | T10 | | |
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Fire weed | | | | | | | | | | | | | | | | | | | | | | | 0.02 | | | | | | | |
| Coral bean | | | | | | | | | | | | | | | 0.16 | | | | | | | | | | | | | | | |
| Indian laurel ficus[2] | | | | | | | | | | | | | | 0.24 | | | | | | | | | | | | 0.35 | 0.20 | | | |
| Pop ash | | | 0.03 | | 0.01 | 1.20 | | 2.16 | 2.77 | 0.39 | 0.46 | 0.83 | | | 0.37 | 0.39 | 0.10 | 0.40 | 0.35 | 0.21 | 0.41 | | | | | | | | | |
| Musky mint | | | | | | | | | | | | | | 0.01 | | | | | | | | | | | | | | | | |
| Dahoon holly | | | | | | | | | | | | | | 0.05 | 0.26 | | | | | 0.08 | 0.06 | | | | 0.09 | | | | 0.02 | 0.10 |
| Moon vine | | 0.54 | | | 0.21 | | | 0.09 | | | | | | 1.24 | | | | | | | | | | | | | | | | |
| Blue morning glory | 0.13 | 0.48 | | | 0.80 | | | 0.37 | | | 0.02 | | | 0.02 | 0.02 | | | | | | | | | | | | | | | |
| Virginia willow | | | | 2.68 | 1.76 | 1.77 | | | | 2.12 | 0.08 | 2.70 | | | | | | | | 0.18 | 0.09 | 0.02 | | | | | | | | |
| White mangrove | | | | | | | | | | | | | 0.90 | | | | 0.54 | 0.71 | | | 0.17 | 0.28 | 0.50 | 0.58 | 0.79 | 2.74 | 1.89 | 0.16 | 0.69 | |
| Mexican primrose willow | | | | | | | | | | | | | | | | | | | | | | | 0.45 | | | | | | | |
| Peruvian primrose willow[2] | | | | | | | | | | | | | | 0.44 | | | 0.16 | | | 0.13 | | | 0.23 | | | | | | | |
| Creeping primrose willow | | | | | | | | | | | | | | | | | | | | | 0.11 | | | | | | | | | |
| Primrose willow species | | | | | | | | | | | | | | | | | | | | | 0.01 | | | | | | | | | |
| Old World climbing fern[2] | | 0.46 | 0.36 | | | | | | 0.07 | | 0.47 | | | | | | 0.19 | | | | 0.01 | 0.94 | 0.61 | 0.94 | | | | | 0.71 | 6.85 |
| Stagger bush | | | | | | | | | | | | | | | | | | | 0.03 | 0.02 | | | | | | | | | | |
| Square stem | | | | | | | | 0.96 | | | | | | | | | | | | | | | | | | | | | | |
| Creeping cucumber | | 0.09 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hemp vine | | 0.15 | | | 0.43 | | | | | | 0.14 | | | 0.04 | | | 0.11 | 0.08 | | 0.45 | 0.35 | | 0.12 | 0.09 | | | | | | |
| Sensitive brier | | | | | | | | | | | | | | | | | | | | | 0.04 | | | | | | | | | |
| Wax myrtle | | | | | | | | | | | | | | | | 0.69 | 0.85 | 1.07 | 0.68 | 0.69 | 1.31 | 1.43 | 1.14 | 1.2 | | | | 2.40 | 0.92 | 1.32 |
| Wild Boston fern[2] | | | | | | 0.09 | | | | | | | | | | | | | 0.27 | 0.01 | | | | | | | | | | |
| Cinnamon fern | | | | | | | | | | | | | | 0.07 | | | | | 0.2 | 0.43 | 0.36 | | | | | | | | | |
| Royal fern | | | | | 0.27 | | | | | | 0.12 | | | | | 0.13 | 0.02 | 0.07 | 0.26 | 0.41 | 0.38 | 0.04 | | | | | | | | |
| Guinea grass[2] | | | | | | | | | | | | | | | 0.75 | | | | | | | | | | | | | | | |
| Redtop panicum | | | | | | | | | | | | | | | | | | | | | | | 0.22 | | | | | | | |
| Panic grass species | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.12 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-5-13. continued

| Common Name[1] | Percent Cover | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | | T2 | | | T3 | | | T4 | | | T5 | | | T6 | | | T7 | | | T8 | | | T9 | | | T10 | | |
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Elephant grass[2] | | | | | | | | | | | | | | 0.29 | 0.28 | | | | | | | | | | | | | | | |
| Red bay | | | | | | | | | | | | | | | | | | | | | 0.03 | | 0.05 | | | | | 0.11 | 0.05 | |
| American pokeweed | | | | | | 0.15 | | | | | | | | | | | | | | | | | | | | | | | | |
| Marsh fleabane | | | | | | | | | | | | | | | | | | | | | | | 0.01 | 0.09 | | | | | | |
| Pouzolz's bush[2] | | | | | | | | | | | | | | 0.04 | | | | | | | | | | | | | | | | |
| Strawberry guava[2] | | | | | | | | | | | | | | | | 0.75 | 0.17 | | | | | 0.49 | 0.29 | 0.33 | | 0.02 | 0.01 | 0.41 | 0.17 | 0.13 |
| Wild coffee | 0.23 | 0.13 | 0.20 | | | | 0.39 | 0.12 | 0.22 | 0.33 | 0.29 | 1.00 | 0.41 | | 0.10 | | | | | | | 0.15 | | | | | | | | |
| Shortleaf wild coffee | | 0.21 | 0.15 | | | 0.51 | 0.38 | 0.31 | 0.08 | | | | 0.05 | 0.17 | 0.06 | | | | | | | | | | | | | | | |
| Giant brake fern[2] | | | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | |
| Laurel oak | | | | | | | | | 0.13 | | | | 0.21 | | | | | | | | | | | | 0.33 | 0.19 | | | | |
| Myrtle oak | | | | | | | | | | | | | | | | | | | | | | | | | | 0.08 | 0.10 | | | |
| Live oak | | | | | | | | | | | | | | | | 0.88 | | | | | | | | | | | | | | |
| Rubber vine | | | | | | | | | | | | | | | | | 0.74 | 0.23 | | 0.01 | 0.08 | | 0.11 | 0.01 | 0.13 | 0.15 | 0.61 | | 0.04 | 0.12 |
| Myrsine | | | | | | | 0.56 | 0.42 | 0.38 | | | | | | | 0.14 | 0.11 | 0.11 | 0.21 | 0.26 | 0.11 | | 0.08 | 0.13 | | | | 0.28 | 0.11 | 1.32 |
| Red mangrove | | | | | | | | | | | | | | | | 3.96 | 1.49 | 2.42 | 0.12 | 0.37 | 0.24 | 0.25 | | | 3.5 | 3.85 | 4.54 | | | |
| Swamp dock | | | | | | | | | | | | | | | 0.43 | | | | | | | | | | | | | | | |
| Cabbage palm | 1.06 | 0.56 | 1.79 | 0.02 | 0.20 | 0.99 | | 0.05 | 0.27 | | | | 1.45 | 0.56 | 1.72 | | | | 0.10 | 0.03 | 0.27 | 0.21 | 0.22 | 0.26 | 0.24 | 0.09 | 0.13 | 0.03 | 0.07 | 0.11 |
| Broadleaf arrowhead | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.10 |
| Carolina willow | | | | | | | | | | | | | | | | | | | | 0.46 | 0.06 | | | | | | | | | |
| White vine | | | | | | | | | 0.01 | | | | | 0.02 | | | 0.05 | 0.01 | | 0.09 | 0.04 | | 0.02 | 0.04 | | | | | | |
| Lizard's tail | | 0.11 | | | | | | 0.01 | 0.02 | | | | | | | | | | | 0.01 | | | 0.01 | 0.06 | | | | | | |
| Brazilian pepper[2] | | | | | | | | | | 0.21 | | | | | | 0.49 | 0.72 | | 0.02 | | 0.06 | 0.22 | 0.38 | 0.65 | 2.27 | 0.64 | 0.58 | 0.84 | 0.90 | 0.50 |
| Climbing cassia[2] | | | 0.84 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Saw palmetto | | | | 0.72 | 0.47 | 0.35 | | | | 1.00 | 0.83 | 0.99 | 1.18 | 0.44 | 0.65 | 0.95 | 1.00 | 2.00 | 0.74 | 0.72 | 0.61 | 0.06 | 0.01 | | | 0.16 | 0.18 | | | 0.07 |
| Wire weed | | | | | | | | | | | | | | 0.37 | 0.31 | | | | | | | | | | | | | | | |
| Earleaf greenbrier | | | | | | | | | 0.02 | | | | | | | | | | | | | | | | | | | | | |
| Laurel greenbrier | | 0.04 | 0.17 | | | | | | | | | | | | | | 0.08 | | | 0.02 | 0.01 | | | | | 0.02 | | | | |
| Chapman's goldenrod | | | | | | | | | | | | | | | 1.00 | | | | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-5-13. continued**

| Common Name[1] | Percent Cover | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | | T2 | | | T3 | | | T4 | | | T5 | | | T6 | | | T7 | | | T8 | | | T9 | | | T10 | | |
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Climbing aster | | | | | | | | | | | | | | | | | | | | 0.02 | | | | 0.01 | | | | | | |
| Nephthytis[2] | | | 0.06 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Java plum[2] | | | | | | | | | | | | | | | | | | | 0.56 | 1.05 | | | | | | | | | | |
| Bald cypress | | 0.48 | | | | | | | | | | | | | | | | | | | | | | 0.25 | | | | | | |
| Downy shield fern[2] | | | 0.23 | | | | | | 0.11 | | | | | | | | | | | 0.01 | | | | | | | | | | |
| Tri-veined fern | 0.83 | 4.65 | 0.73 | 0.02 | 3.73 | 0.05 | 0.27 | 5.99 | 1.59 | 2.05 | 5.97 | 1.23 | 1.00 | 4.23 | | | 0.10 | | | 0.40 | | 0.04 | | | | | | | | |
| Marsh fern | | | | | | | | | | | | | | | | 0.02 | | | | | | | | | | | | | | |
| Fern species | | | | 0.24 | 0.15 | | 1.30 | 0.24 | 0.15 | 0.19 | | | | | | | | | | | | | | | | | | | | |
| Cardinal airplant | | | | | | | | | | | | | | | | | | | | | 0.07 | | | | | | | | | |
| Needleleaf airplant | | | | | | | | | | | | | | | | | | | | | 0.04 | | | | | | | | | |
| Spanish moss | | | | | | | | | | | | | | | | | | | | | | | 0.27 | | | 0.01 | | | 0.02 | |
| Poison ivy | | | | | | | | | 0.18 | | 0.04 | | | | 0.23 | | 0.66 | 1.05 | | 1.05 | 0.82 | 0.02 | 0.11 | 0.10 | | | | | 0.07 | 0.42 |
| Fakahatchee grass | | | | | | | 1.00 | 0.15 | 1.52 | | | | | | | | | | | | | | | | | | | | | |
| Narrowleaf cattail | | | | | | | | | | | | | | | | | | | | | | | 0.18 | | | | | | | |
| Broadleaf cattail | | | | | | | | | | | | | | | | | | | | | | | | 0.01 | | | | | | |
| Caesar weed[2] | | 0.71 | | 0.41 | 0.41 | 0.04 | 1.00 | 0.09 | | | 0.04 | | 1.00 | 0.38 | 0.49 | | | | | | | | | | | | | | | |
| Para grass | | | | | | | | | | | | | | | 0.01 | | | | | | | | | | | | | | | |
| Hairy pod cowpea | | 0.06 | | | | | | | | | | | | | | | 0.02 | | | 0.22 | 0.09 | | | 0.07 | | | | | | |
| Summer grape | | | | | | | | | | | | | | 0.54 | | | | | | | | | | | | | | | | |
| Muscadine grape | | 0.03 | 0.03 | | | 0.19 | 0.14 | | 0.20 | | 0.03 | 0.01 | | 0.27 | 0.24 | | 0.59 | | | 0.05 | 0.07 | | 0.17 | 0.08 | | 0.11 | 0.02 | | | |
| Unidentified grass | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.07 | |
| Unidentified species | | | | | | | | | | | | | 1.00 | | | | | | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

# APPENDIX 3-6

# FREQUENCY OF OCCURRENCE OF SHRUB SPECIES BY TRANSECT

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## Table 3-6-14. Frequency of occurrence of shrub species by transect between 2003 and 2010

| | Frequency of Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | | T2 | | | T3 | | | T4 | | | T5 | | | T6 | | | T7 | | | T8 | | | T9 | | | T10 | | |
| **Common Name**[1] | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Rosary pea[2] | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | 0.05 | | | |
| Red maple | | | | 0.08 | 0.15 | 0.15 | | 0.15 | 0.08 | 0.25 | 0.33 | 0.15 | | 0.07 | 0.14 | | | | | 0.07 | 0.13 | 0.08 | 0.08 | | | | | | | |
| Leather fern | 0.27 | 0.13 | 0.27 | 0.23 | 0.23 | 0.23 | 0.38 | 0.38 | 0.46 | 0.33 | 0.25 | 0.31 | | | | 0.81 | 0.81 | 0.69 | 0.87 | 0.93 | 0.87 | 0.83 | 0.50 | 0.58 | 0.80 | 0.75 | 0.90 | 0.50 | 0.50 | 0.25 |
| False indigo | | | | | | | | | | | | | | | | 0.06 | 0.06 | 0.06 | 0.13 | 0.13 | 0.2 | 0.08 | 0.33 | 0.25 | | | | | | |
| Pond apple | 0.13 | 0.07 | 0.06 | | | | | 0.08 | 0.08 | 0.08 | | | | | | 0.25 | 0.19 | 0.38 | 0.27 | 0.40 | 0.53 | 0.50 | 0.58 | 0.58 | | | 0.15 | 0.63 | 0.75 | 0.75 |
| Groundnut | | | | | | | | | 0.15 | | | | | | | | | | | | | | | | | | | | | |
| Marlberry | 0.13 | | 0.06 | 0.23 | 0.31 | 0.38 | | | | | | | 0.14 | 0.14 | 0.14 | | | | | | | 0.08 | | | | | | | | |
| Black mangrove | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | | |
| Salt bush (silverling) | | | | | | | | | | | | | | | | | | | | 0.07 | | | 0.08 | | | | | | | |
| Baccharis species | | | | | | | | | | | | | | | | | | | 0.13 | 0.07 | 0.20 | 0.42 | 0.08 | 0.08 | | | | | | 0.25 |
| Swamp fern | 0.2 | 0.33 | 0.33 | 0.15 | 0.38 | 0.15 | 0.08 | 0.15 | 0.08 | 0.33 | 0.50 | 0.15 | 0.57 | 0.50 | 0.21 | 0.13 | 0.06 | | 0.40 | 0.33 | 0.20 | 0.42 | 0.08 | 0.17 | 0.05 | | 0.05 | 0.5 | | 0.25 |
| False nettle | | 0.20 | 0.06 | | 0.08 | | | 0.08 | | | | 0.08 | | 0.28 | | | | | | 0.07 | 0.20 | 0.17 | | 0.08 | | | | | | |
| American beautyberry | 0.13 | 0.07 | 0.06 | 0.23 | 0.23 | 0.15 | | | | | | | | 0.07 | 0.07 | | | | | | | | | | | | | | | |
| Water hickory | | | | | | | | | | | | | | 0.07 | 0.36 | | | | | | | | | | | | | | | |
| Buttonbush | 0.07 | 0.07 | 0.06 | 0.08 | 0.08 | 0.08 | 0.08 | | 0.15 | 0.08 | 0.17 | 0.15 | | 0.07 | 0.07 | 0.25 | 0.19 | 0.31 | 0.47 | 0.40 | 0.53 | 0.33 | 0.42 | 0.58 | | | | 0.38 | 0.63 | 0.38 |
| Jack-in-the-bush | | | | | | | | | | | | | | 0.07 | 0.07 | | | | | | | | | | | | | | | |
| Coco plum | | 0.07 | 0.13 | 0.08 | 0.08 | 0.15 | | | | | | | | | | | | | | | | 0.08 | 0.08 | | 0.15 | 0.15 | 0.10 | | | |
| Sawgrass | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.63 | 0.75 | 0.63 |
| Wild taro[2] | | 0.70 | 0.20 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Common dayflower[2] | | 0.70 | | | | | | | | | | | | 0.28 | | | | | | | | | | | | | | | | |
| Swamp lily | | | 0.13 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| False sawgrass | | | | | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | |
| Green flat sedge | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| Coin vine | | | | | | | | | | | | | | | | | | 0.06 | | 0.20 | 0.27 | | 0.17 | 0.17 | | 0.20 | 0.20 | | 0.13 | 0.13 |
| Persimmon | | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | | | | | |
| Florida butterfly orchid | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | | |
| Fire weed | | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-6-14. continued

| Common Name[1] | Frequency of Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | | T2 | | | T3 | | | T4 | | | T5 | | | T6 | | | T7 | | | T8 | | | T9 | | | T10 | | |
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Coral bean | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| Indian laurel ficus[2] | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | 0.05 | 0.05 | 0.05 | | | |
| Pop ash | | | 0.06 | | 0.08 | 0.15 | | 0.46 | 0.46 | 0.17 | 0.17 | 0.15 | | | 0.07 | 0.13 | 0.06 | 0.13 | 0.27 | 0.07 | 0.33 | | | | | | | | | |
| Musky mint | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Dahoon holly | | | | | | | | | | | | | | 0.07 | 0.07 | | | | | 0.07 | 0.06 | | | | | | | 0.13 | 0.13 | 0.13 |
| Moon vine | | 0.13 | | | 0.08 | | | 0.08 | | | | | | 0.43 | | | | | | | | | | | | | | | | |
| Blue morning glory | 0.07 | 0.20 | | | 0.23 | | | 0.31 | | | 0.08 | | | 0.07 | 0.07 | | | | | | | | | | | | | | | |
| Virginia willow | | | | 0.31 | 0.31 | 0.23 | | | | 0.5 | 0.33 | 0.46 | | | | | | | | 0.20 | 0.20 | 0.08 | | | | | | | | |
| White mangrove | | | | | | | | | | | | | | | | 0.19 | 0.13 | 0.25 | | | 0.06 | 0.25 | 0.25 | 0.42 | 0.10 | 0.30 | 0.40 | 0.13 | 0.50 | 0.75 |
| Mexican primrose willow | | | | | | | | | | | | | | | | | | | | | | | 0.17 | | | | | | | |
| Peruvian primrose willow [2] | | | | | | | | | | | | | | 0.07 | | | 0.06 | | | 0.27 | 0.13 | | 0.08 | | | | | | | |
| Primrose willow species | | | | | | | | | | | | | | | | | | | | | 0.06 | | | | | | | | | |
| Old World climbing fern[2] | | 0.70 | 0.13 | | | | | | 0.08 | | 0.18 | | | | | | 0.13 | | | | 0.06 | 0.08 | 0.33 | 0.42 | | | | | 0.63 | 0.63 |
| Stagger bush | | | | | | | | | | | | | | | | | | | 0.07 | 0.07 | | | | | | | | | | |
| Square stem | | | | | | | | 0.15 | | | | | | | | | | | | | | | | | | | | | | |
| Creeping cucumber | | 0.70 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hemp vine | | 0.70 | | | 0.08 | | | | | | 0.42 | | | 0.07 | | | 0.06 | 0.06 | | 0.53 | 0.6 | | 0.25 | 0.17 | | | | | | |
| Sensitive brier | | | | | | | | | | | | | | | | | | | | | 0.06 | | | | | | | | | |
| Wax myrtle | | | | | | | | | | | | | | | | 0.13 | 0.25 | 0.38 | 0.47 | 0.47 | 0.40 | 0.42 | 0.50 | 0.58 | | | | 1.00 | 0.63 | 0.88 |
| Wild Boston fern[2] | | | | | | 0.08 | | | | | | | | | | | | | 0.07 | 0.07 | | | | | | | | | | |
| Cinnamon fern | | | | | | | | | | | | | | 0.07 | | | | | 0.07 | 0.13 | 0.13 | | | | | | | | | |
| Royal fern | | | | | 0.08 | | | | | | 0.08 | | | | | 0.07 | 0.06 | 0.06 | 0.27 | 0.13 | 0.27 | 0.08 | | | | | | | | |
| Guinea grass[2] | | | | | | | | | | | | | | | 0.14 | | | | | | | | | | | | | | | |
| Redtop panicum | | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | | | | | |
| Panic grass species | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.25 |
| Elephant grass[2] | | | | | | | | | | | | | | 0.07 | 0.07 | | | | | | | | | | | | | | | |
| Red bay | | | | | | | | | | | | | | | | | | | | | 0.06 | | 0.08 | | | | | 0.13 | 0.13 | |
| American pokeweed | | | | | | 0.15 | | | | | | | | | | | | | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-6-14. continued

| Common Name[1] | Frequency of Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | | T2 | | | T3 | | | T4 | | | T5 | | | T6 | | | T7 | | | T8 | | | T9 | | | T10 | | |
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Marsh fleabane | | | | | | | | | | | | | | | | | | | | | | 0.25 | 0.08 | 0.17 | | | | | | |
| Pouzolz's bush[2] | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | | |
| Strawberry guava[2] | | | | | | | | | | | | | | | | 0.07 | 0.19 | | | | | 0.25 | 0.25 | 0.42 | | 0.05 | 0.05 | 0.25 | 0.25 | 0.25 |
| Wild coffee | 0.07 | 0.7 | 0.06 | | | | 0.08 | 0.08 | 0.08 | 0.08 | 0.25 | 0.08 | 0.07 | | 0.07 | | | | | | | | | | | | | | | |
| Shortleaf wild coffee | | 0.13 | 0.06 | | | 0.23 | 0.08 | 0.08 | 0.08 | | | | 0.07 | 0.07 | 0.07 | | | | | | | | | | | | | | | |
| Giant brake fern[2] | | | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | |
| Laurel oak | | | | | | | | | 0.08 | | | | 0.07 | | | | | | | | | | | | 0.05 | 0.05 | | | | |
| Myrtle oak | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | 0.05 | | | |
| Live oak | | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | |
| Rubber vine | | | | | | | | | | | | | | | | | 0.38 | 0.25 | | 0.13 | 0.06 | | 0.33 | 0.08 | 0.05 | 0.15 | 0.35 | | 0.25 | 0.25 |
| Myrsine | | | | | | | 0.08 | 0.08 | 0.08 | | | | | | | 0.07 | 0.06 | 0.06 | 0.13 | 0.07 | 0.06 | | 0.08 | 0.08 | | | | 0.25 | 0.38 | 0.13 |
| Red mangrove | | | | | | | | | | | | | | | | 0.38 | 0.25 | 0.38 | 0.07 | 0.07 | 0.13 | 0.08 | | | 0.25 | 0.35 | 0.45 | | | |
| Swamp dock | | | | | | | | | | | | | | | 0.14 | | | | | | | | | | | | | | | |
| Cabbage palm | 0.20 | 0.13 | 0.27 | 0.08 | 0.15 | 0.15 | | 0.08 | 0.08 | | | | 0.14 | 0.07 | 0.21 | | | | 0.13 | 0.07 | 0.06 | 0.08 | 0.08 | 0.08 | 0.05 | 0.05 | 0.10 | 0.63 | 0.13 | 0.13 |
| Carolina willow | | | | | | | | | | | | | | | | | | | | 0.27 | 0.2 | | | | | | | | | |
| White vine | | | | | | | | | 0.08 | | | | | 0.07 | | | 0.13 | 0.06 | | 0.2 | 0.27 | | 0.08 | 0.08 | | | | | | |
| Lizard's tail | | 0.13 | | | | | | 0.08 | 0.08 | | | | | | | | | | | | | | 0.08 | 0.08 | | | | | | |
| Brazilian pepper[2] | | | | | | | | | | 0.08 | | | | | | 0.19 | 0.31 | | 0.07 | | 0.06 | 0.33 | 0.17 | 0.17 | 0.35 | 0.20 | 0.20 | 0.13 | 0.63 | 0.63 |
| Climbing cassia | | | 0.13 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Saw palmetto | | | | 0.08 | 0.08 | 0.08 | | | | 0.08 | 0.08 | 0.08 | 0.14 | 0.14 | 0.14 | 0.07 | 0.13 | 0.13 | 0.07 | 0.07 | 0.06 | 0.08 | 0.08 | | | 0.05 | 0.05 | | | 0.13 |
| Wire weed | | | | | | | | | | | | | | 0.07 | 0.14 | | | | | | | | | | | | | | | |
| Earleaf greenbrier | | | | | | | | | 0.15 | | | | | | | | | | | | | | | | | | | | | |
| Laurel greenbrier | | 0.70 | 0.13 | | | | | | | | | | | | | | 0.06 | | | 0.07 | 0.06 | | | | | 0.05 | | | | |
| Common sow thistle | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| Climbing aster | | | | | | | | | | | | | | | | | | | | 0.13 | | | | 0.08 | | | | | | |
| Nephthytis[2] | | | 0.06 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Java plum[2] | | | | | | | | | | | | | | | | | | | 0.33 | 0.4 | | | | | | | | | | |
| Bald cypress | | 0.13 | | | | | | | | | | | | | | | | | | | | | | 0.17 | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-6-14. continued

| | Frequency of Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | | T2 | | | T3 | | | T4 | | | T5 | | | T6 | | | T7 | | | T8 | | | T9 | | | T10 | | |
| **Common Name[1]** | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Downy shield fern[2] | | | 0.13 | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | |
| Tri-veined fern | 0.13 | 0.47 | 0.20 | 0.08 | 0.54 | 0.15 | 0.31 | 0.77 | 0.54 | 0.50 | 0.83 | 0.38 | 0.07 | 0.57 | | | 0.13 | | | 0.20 | | 0.17 | | | | | | | | |
| Marsh fern | | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | |
| Meniscium fern | | | | 0.15 | 0.08 | | 0.31 | 0.15 | 0.15 | 0.08 | | | | | | | | | | | | | | | | | | | | |
| Cardinal airplant | | | | | | | | | | | | | | | | | | | | | 0.13 | | | | | | | | | |
| Needleleaf airplant | | | | | | | | | | | | | | | | | | | | | 0.06 | | | | | | | | | |
| Spanish moss | | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | 0.05 | | | 0.13 | |
| Poison ivy | | | | | | | | | 0.08 | | 0.17 | | | | 0.07 | | 0.31 | 0.25 | | 0.47 | 0.67 | 0.08 | 0.25 | 0.25 | | | | | 0.25 | 0.25 |
| Fakahatchee grass | | | | | | | 0.08 | 0.15 | 0.23 | | | | | | | | | | | | | | | | | | | | | |
| Narrowleaf cattail | | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | | | | | |
| Broadleaf cattail | | | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | | | | 0.25 |
| Caesar weed[2] | | 0.27 | | 0.08 | 0.23 | 0.08 | 0.08 | 0.15 | | | 0.08 | | 0.07 | 0.14 | 0.29 | | | | | | | | | | | | | | | |
| Summer grape | | | | | | | | | | | | | | 0.21 | | | | | | | | | | | | | | | | |
| Hairy pod cowpea | | 0.27 | | | | | | | | | | | | | | | 0.06 | | | 0.27 | 0.20 | | | 0.08 | | | | | | |
| Muscadine grape | | 0.70 | 0.06 | | | 0.08 | 0.08 | | 0.08 | | 0.17 | 0.08 | | 0.07 | 0.14 | | 0.13 | | | 0.13 | 0.06 | | 0.17 | 0.08 | | 0.20 | 0.05 | | | |
| Unidentified fern | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

# APPENDIX 3-7
# SHRUB PERCENT COVER BY TRANSECT AND FOREST TYPE

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## FOREST TYPE DEFINITIONS

| | |
|---|---|
| HH | hydric hammock forest type |
| LTmix | lower tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| LTsw1 | lower tidal reach swamp forest type 1 |
| LTsw2 | lower tidal reach swamp forest type 2 |
| LTsw3 | lower tidal reach swamp forest type 3 |
| M | marsh forest type |
| MH | mesic hammock forest type |
| Rblh1 | bottomland hardwood forest type 1 |
| Rblh2 | bottomland hardwood forest type 2 |
| Rblh3 | bottomland hardwood forest type 3 |
| Rmix | riverine forest type with canopy dominance 50% bald cypress and 50% cabbage palm |
| Rsw1 | riverine reach swamp forest type 1 |
| Rsw2 | riverine reach swamp forest type 2 |
| Rsw3 | riverine reach swamp forest type 3 |
| U | uplands forest type |
| UTmix | upper tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| UTsw1 | upper tidal reach swamp forest type 1 |
| UTsw2 | upper tidal reach swamp forest type 2 |
| UTsw3 | upper tidal reach swamp forest type 3 |

Some plots contain more than one forest type. For example, HH/Rsw1 indicates the plot contains both hydric hammock and riverine reach swamp forest type 1.

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## Table 3-7-15. Shrub percent cover for Transect 1 by forest type

| Species[1] | MH | | | HH/U | | | HH | | | Rblh1 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Leather fern | | | | | | | | | | | | 0.18 | 3.17 | | 1.14 |
| Pond apple | | | | | | | | | | 0.12 | 0.04 | | 0.36 | | |
| Marlberry | | | | | | | 0.41 | | 0.18 | | | | | | |
| Swamp fern | 0.64 | 0.41 | 0.39 | | 0.40 | 0.01 | 0.89 | | 0.85 | | | | | | |
| False nettle | | | | | | | | | | | | | | 0.20 | |
| American beautyberry | 0.30 | | | | | | 0.34 | | 0.19 | | | | | | |
| Buttonbush | | | | | | | | | | 0.54 | 0.28 | 0.41 | | | |
| Coco plum | | 0.39 | 0.64 | | | | | | 0.20 | | | | | | |
| Wild taro[2] | | | | | | | | | | | | | | 0.68 | 1.78 |
| Common dayflower[2] | | | | | | | | | | | | | | 0.12 | |
| Swamp lily | | | | | | | | | | | | | | | |
| Pop ash | | | | | | | | | | | | | | | 0.09 |
| Moon vine | | | | | | | | | | | 0.31 | | | 0.23 | |
| Blue morning glory | | | | | | | 0.13 | | | | 0.15 | | | 0.33 | |
| Old World climbing fern[2] | | 0.46 | 0.08 | | | | | | | | | | | | 0.28 |
| Creeping cucumber | | | | | | | | | | | 0.09 | | | | |
| Hemp vine | | | | | | | | | | | | | | 0.15 | |
| Wild coffee | | | | | | | 0.23 | | 0.20 | | | | | | |
| Shortleaf wild coffee | | | 0.15 | | 0.18 | | | | | | | | | | |
| Cabbage palm | 1.06 | 0.40 | 0.64 | 1.00 | 0.16 | 0.81 | | | 0.34 | | | | | | |
| Lizard's tail | | | | | | | | | | | | | | 0.11 | |
| Climbing cassia[2] | | | | | | | | | | | | | | | 0.56 |
| Laurel greenbrier | | | | | 0.04 | 0.18 | | | 0.01 | | | | | | 0.06 |
| Bald cypress | | | | | | | | | | | | | | 0.48 | |
| Downy shield fern[2] | | | 0.10 | | | | | | | | | | | | 0.13 |
| Tri-veined fern | | | | | | | | | | 0.36 | 0.14 | | 0.47 | 4.51 | 0.63 |
| Caesar weed[2] | | 0.29 | | | 0.22 | | | | | | | | | | |
| Hairypod cowpea | | | | | | | | | | | | | | 0.06 | |
| Muscadine grape | | 0.03 | | | | | | | 0.03 | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-7-16. Shrub percent cover for Transect 2 by forest type

| Species[1] | MH | | | HH | | | HH/Rsw1 | | | Rblh1 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Red maple | | | | | | | | 0.06 | 0.54 | 0.51 | 0.25 | 0.68 | | | |
| Leather fern | | | | | | | 0.90 | 0.18 | 0.44 | | | | 1.00 | 0.46 | 1.01 |
| Marlberry | 0.37 | 0.55 | 0.05 | 2.00 | 0.31 | 1.49 | | | | | | | | | |
| Swamp fern | 0.15 | 0.19 | | | 0.06 | 0.03 | 0.16 | 0.09 | 0.19 | | 0.06 | | | 0.06 | |
| False nettle | | | | | | | | 0.02 | | | | | | | |
| American beautyberry | 0.98 | 1.12 | 0.05 | | | | | | | | | | | | |
| Buttonbush | | | | | | | | | | 0.48 | 0.06 | 0.12 | | | |
| Coco plum | 0.56 | 0.08 | 0.03 | | | | | | | | | | | | |
| Pop ash | | | | | | | | | | | 0.01 | 0.20 | | | 1.00 |
| Moon vine | | | | | | | | | | | | | | 0.21 | |
| Blue morning glory | | | | | | | | 0.53 | | | | | | 0.27 | |
| Virginia willow | | | | | | | 0.84 | 0.48 | 0.77 | | 0.04 | | 1.84 | 1.24 | 1.95 |
| Hemp vine | | | | | | | | | | | | | | 0.43 | |
| Wild Boston fern | | | 0.09 | | | | | | | | | | | | |
| Royal fern | | | | | | | | | | | | | | 0.27 | |
| American pokeweed | | | 0.02 | | | | | | | | | | | | |
| Shortleaf wild coffee | | | | | | 0.48 | | | 0.03 | | | | | | |
| Cabbage palm | 0.02 | 0.20 | 0.99 | | | | | | | | | | | | |
| Saw palmetto | 0.72 | 0.47 | 0.35 | | | | | | | | | | | | |
| Tri-veined fern | | | | | 1.63 | | | 0.45 | 0.02 | | 1.26 | | 0.02 | 1.06 | 0.03 |
| Meniscium fern | | | | | | | 0.10 | 0.15 | | | | | 0.14 | | |
| Caesar weed[2] | 0.41 | 0.39 | 0.04 | | | | | 0.17 | | | | | | | |
| Muscadine vine | | | 0.19 | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-7-17. Shrub percent cover for Transect 3 by forest type

| | U/HH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red maple | | 0.23 | | | | | | 0.10 | 0.78 | | | | | | |
| Leather fern | | | | | | | | 0.09 | | 3.37 | 1.49 | 2.47 | 0.38 | 0.06 | 0.37 |
| Pond apple | | | | | | | | | | | 0.02 | 0.43 | | | |
| Groundnut | | | | | | | | | 0.02 | | | | | | |
| Swamp fern | | | 0.08 | 0.05 | | | | | 0.10 | | 0.01 | | | | |
| False nettle | | | | | | | | | | | 0.02 | | | | |
| Buttonbush | | | | | | | | | | 0.15 | | 0.54 | | | |
| Pop ash | | | | | | | | | | | 2.03 | 2.07 | | 0.13 | 0.70 |
| Moon vine | | | | | | | | | | | 0.09 | | | | |
| Blue morning glory | | | | | | | | | | | 0.19 | | | 0.18 | |
| Old World climbing fern[2] | | | 0.07 | | | | | | | | | | | | |
| Square stem | | 0.04 | | | | | | 0.92 | | | | | | | |
| Wild coffee | | | | 0.39 | | | | 0.12 | 0.22 | | | | | | |
| Shortleaf wild coffee | | | | | 0.31 | | | | | | | | 0.38 | | 0.08 |
| Giant brake fern | | | | | | | | | | | | 0.08 | | | |
| Laurel oak | | | | | | | | | 0.13 | | | | | | |
| Myrsine | | | | | | | 0.56 | 0.42 | 0.38 | | | | | | |
| Cabbage palm | | | | | | | | 0.05 | 0.27 | | | | | | |
| White vine | | | | | | | | | | | | 0.01 | | | |
| Lizard's tail | | 0.01 | | | | | | | | | | 0.02 | | | |
| Earleaf greenbrier | | | 0.41 | | | | | | 0.02 | | | | | | |
| Downy shield fern[2] | | | | | | | | | | | | | | | 0.11 |
| Tri-veined fern | | 0.56 | | | 0.69 | | | 0.21 | | 0.17 | 2.91 | 1.23 | 0.10 | 0.68 | 0.36 |
| Meniscium fern | | 0.10 | | | | | | | | 0.30 | 0.24 | 0.15 | 1.00 | | |
| Poison ivy | | | | | | | | | | | | | | | 0.18 |
| Fakahatchee grass | 1.00 | 0.13 | 0.43 | | | 1.00 | | 0.02 | 0.09 | | | | | | |
| Caesar weed[2] | 1.00 | 0.03 | | | | | | 0.06 | | | | | | | |
| Muscadine grape | | | | | | | | | | | | | 0.14 | | 0.20 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-7-18. Shrub percent cover for Transect 4 by forest type**

| | MH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species[1] | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Red maple | | | | | | 1.00 | 0.07 | 0.34 | 0.82 | | | | 0.50 | 0.26 | |
| Leather fern | | | | | | | 0.93 | 0.75 | 0.95 | | | 0.15 | 1.27 | 0.37 | 0.68 |
| Pond apple | | | | | | | | | 0.01 | | | | 0.42 | 0.28 | |
| Swamp fern | | | | 0.68 | 0.27 | | 0.36 | 0.32 | | 0.64 | 0.09 | | 0.57 | | 0.07 |
| False nettle | | | | | | | | | | | | | | | 0.06 |
| Buttonbush | | | | | | | | | | | | | 0.28 | 0.26 | 0.95 |
| False sawgrass | | | | | | | | 0.12 | | | | | 0.39 | | |
| Pop ash | | | | | | | | | | | | | | 0.46 | 0.83 |
| Blue morning glory | | | | | | | | 0.02 | | | | | | | |
| Virginia willow | | | | | | | 0.38 | | 0.05 | 0.23 | 0.03 | 0.85 | 1.51 | 0.44 | 1.80 |
| Old World climbing fern[2] | | 0.15 | | | | | | | | | | | | 0.32 | |
| Hemp vine | | | | | | | | | | | 0.02 | | | 0.21 | |
| Royal fern | | | | | | | | | | | | | | 0.12 | |
| Wild coffee | | | | 0.07 | 0.18 | | 0.26 | 0.11 | 1.00 | | | | | | |
| Brazilian pepper[2] | | | | | | | | | | | | | | | |
| Saw palmetto | 1.00 | 0.83 | 0.99 | | | | | | | | | | | | |
| Tri-veined fern | | | | 0.25 | 0.52 | | 0.60 | 1.33 | 0.18 | 0.13 | 0.86 | | 1.07 | 3.26 | 1.05 |
| Meniscium fern | | | | | | | 0.19 | | | | | | | | |
| Poison ivy | | | | | | | | | | | | | | 0.04 | |
| Caesar weed[2] | | | | | 0.03 | | | 0.01 | | | | | | | |
| Muscadine grape | | 0.03 | 0.01 | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-7-19. Shrub percent cover for Transect 5 by forest type

| | MH | | | HH/Rblh3 | | | Rblh3 | | | Rblh2 | | | Rblh1 | | | Rsw1/Rblh2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species[1] | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Red maple | | | | | | | | | | | 0.1 | 0.04 | | | 0.75 | | | | | | |
| Marlberry | | | | 0.05 | | 0.13 | | | | 0.27 | 0.06 | 0.17 | | | | | 0.02 | | | | |
| Swamp fern | 0.24 | 0.04 | 0.01 | 0.06 | 0.38 | | 1.00 | 0.04 | 0.48 | 1.07 | | 0.08 | | | | 1.00 | 0.17 | | 2.00 | 0.61 | |
| False nettle | | | | | 0.16 | | | | | | 0.14 | | | | | | | | | 0.26 | |
| American beautyberry | | 0.36 | 0.45 | | | | | | | | | | | | | | | | | | |
| Water hickory | | | | | | 0.06 | | | 0.52 | | | | | | 0.25 | | | | | 0.06 | 0.79 |
| Buttonbush | | | | | | | | | | | | | | | | | 0.19 | | | | 0.23 |
| Jack-in-the-bush | | 0.16 | | | | | | | | | | 0.03 | | | | | | | | | 0.06 |
| Common dayflower[2] | | | | | | | | | | | 0.50 | | | | | | 0.04 | | | 0.06 | |
| Green flat sedge | | | | | | | | | | | | | | | | | | | | | 0.68 |
| Florida butterfly orchid | | | | | | | | | | | 0.10 | | | | | | | | | | |
| Indian laurel ficus[2] | | | | | | | | | | | 0.24 | | | | | | | | | | |
| Pop ash | | | | | | | | | | | | 0.37 | | | | | | | | | |
| Musky mint | | | | | | | | | | | 0.01 | | | | | | | | | | |
| Dahoon holly | | | | | | | | | | | | | | | | | | | | 0.05 | 0.26 |
| Moon vine | | | | | | | | | | | 0.97 | | | | | | | | | 0.27 | |
| Blue morning glory | | | | | | 0.02 | | | | | | | | | | | | | | 0.02 | |
| Primrose willow species | | | | | | | | | | | | | | | | | 0.29 | | | | |
| Hemp vine | | | | | | | | | | | 0.04 | | | | | | | | | | |
| Cinnamon fern | | | | | | | | | | | 0.07 | | | | | | | | | | |
| Guinea grass[2] | | | | | | | | | | | | | | | | | | | | | 0.75 |
| Elephant grass[2] | | | | | | | | | | | | | | | | | 0.29 | | | | 0.28 |
| Pouzolz's bush[2] | | | | | 0.04 | | | | | | | | | | | | | | | | |
| Wild coffee | | | | 0.41 | | 0.10 | | | | | | | | | | | | | | | |
| Shortleaf wild coffee | | | | 0.05 | 0.17 | 0.06 | | | | | | | | | | | | | | | |
| Laurel oak | | | | | | | | | | 0.21 | | | | | | | | | | | |
| Swamp dock | | | | | | | | | | | | 0.18 | | | | | | | | | 0.25 |
| Cabbage palm | | | | | | | | | | | 0.56 | 1.68 | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-7-19. continued**

| Species[1] | MH | | | HH/Rblh3 | | | Rblh3 | | | Rblh2 | | | Rblh1 | | | Rsw1/Rblh2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| White vine | | | 0.04 | | | | | | | | | | | | | | | | | 0.02 | |
| Saw palmetto | 0.76 | 0.18 | 0.23 | 0.42 | 0.26 | 0.42 | | | | 1.45 | | | | | | | | | | | |
| Wire weed | | | | | | | | | | | | 0.23 | | | | | | | | 0.37 | 0.08 |
| Chapman's goldenrod | | | | | | | | | | | | 1.00 | | | | | | | | | |
| Tri-veined fern | | | | | | | | 0.96 | | | 0.70 | | 1.00 | 1.00 | | | 0.30 | | | 1.90 | |
| Poison ivy | | | | | | | | | | | | | | | | | | | | | 0.23 |
| Caesar weed[2] | | | 0.09 | | | | | | | 1.00 | 0.38 | | | | | | | | | | 0.40 |
| Para grass[2] | | | | | | | | | | | | 0.001 | | | | | | | | | |
| Summer grape | | 0.27 | | | | | | | | | | | | | | | | | | | |
| Muscadine grape | | | 0.18 | | | 0.05 | | | | | 0.15 | | | | | | | | | 0.39 | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-7-20. Shrub percent cover for Transect 6 by forest type**

| Species[1] | U | | | Rsw1 | | | UTmix | | | UTsw3 | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Leather fern | | | | 0.46 | | 0.50 | 0.12 | 0.62 | | 1.63 | 2.12 | 1.00 | 2.55 | 4.16 | 2.84 |
| False indigo | | | | 0.28 | | 0.25 | | | | | | | | 0.14 | |
| Pond apple | | | | | | | | | | 0.73 | 0.35 | 131.80 | 0.70 | 0.02 | 0.18 |
| Swamp fern | 0.23 | | | 0.03 | | | | | | | | | | 0.08 | |
| Buttonbush | | | | 0.23 | | 0.21 | | | | 0.50 | 0.59 | 0.85 | 0.05 | 0.11 | 0.43 |
| Coin vine | | | | | | | | | | | | | | | 0.03 |
| Pop ash | | | | | | | | | | 0.27 | 0.10 | 0.12 | 0.12 | | 0.28 |
| White mangrove | | | | | | | | | | 0.90 | 0.54 | 0.72 | | | 0.15 |
| Primrose willow species | | | | | | | | | | | | | | 0.16 | |
| Old World climbing fern[2] | | 0.12 | | | | | | | | | 0.07 | | | | |
| Hemp vine | | | | | | | | | | | 0.11 | 0.08 | | 0.27 | |
| Wax myrtle | | 0.09 | | | | | | | | 0.35 | 0.49 | 0.66 | 0.34 | | 0.41 |
| Royal fern | | | | | | | | | | 0.13 | 0.02 | 0.07 | | | |
| Strawberry guava[2] | 0.75 | 0.13 | | | | | | | | | 0.04 | | | | |
| Live oak | 0.05 | | | | | | | | | | | | | | |
| Rubber vine | | | | | | 0.02 | | | | | 0.51 | 0.07 | | 0.23 | 0.14 |
| Myrsine | | | | | | | | | | | | | 0.14 | 0.11 | 0.11 |
| Red mangrove | | | | | | | 0.84 | 0.29 | 1.00 | 1.01 | 0.89 | 0.99 | 2.11 | 0.31 | 0.43 |
| White vine | | | | | 0.04 | 0.01 | | | | | | | | 0.01 | |
| Brazilian pepper[2] | | | | | 0.35 | | 0.05 | 0.09 | | 0.44 | 0.03 | | | 0.05 | |
| Saw palmetto | 0.95 | 1.00 | 2.00 | | | | | | | | | | | | |
| Laurel greenbrier | | 0.08 | | | | | | | | | | | | | |
| Tri-veined fern | | | | | | | | | | | 0.03 | | | 0.07 | |
| Marsh fern | 0.02 | | | | | | | | | | | | | | |
| Poison ivy | | | | | | | | | | | 0.11 | 0.09 | | 0.55 | 0.96 |
| Hairypod cowpea | | | | | | | | | | | | | | 0.02 | |
| Muscadine grape | | 0.59 | | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-7-21. Shrub percent cover for Transect 7 by forest type

| Species[1] | MH/Rsw1 | | | Rsw1 | | | Rmix | | | UTsw1 | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Red maple | | | | 1.87 | 0.06 | 0.11 | 1.46 | | 0.22 | | | | 2.88 | | |
| Leather fern | | | | | 0.37 | 0.09 | | 1.04 | 0.98 | | 1.52 | 1.33 | | 1.75 | 1.35 |
| False indigo | | | | 0.04 | | 0.17 | 0.09 | | 0.28 | | 0.08 | | | | |
| Pond apple | | | | | | | 0.80 | 0.03 | 0.57 | 2.37 | 1.28 | 1.69 | | 0.11 | 0.10 |
| Marlberry | | | | | | | | 0.03 | | | | | | | |
| Salt bush (groundsel tree) | | | | | | | | 0.05 | | | | | | | |
| Baccharis species | | | | 0.02 | | | 0.37 | 0.05 | 0.15 | | | | | | 0.14 |
| Swamp fern | 0.04 | 0.04 | 0.02 | | | | 0.37 | 0.11 | 0.04 | | 0.02 | | | | |
| False nettle | | | | | | 0.03 | | 0.01 | 0.01 | | | 0.01 | | | |
| Buttonbush | | | | 0.60 | 0.36 | 0.73 | 0.63 | 0.32 | 0.38 | 0.09 | 0.06 | 0.13 | | | |
| Coin vine | | | | | | | | | 0.32 | | 0.01 | 0.20 | | 0.32 | 0.03 |
| Pop ash | | | | 0.09 | | | 0.18 | 0.13 | 0.13 | 0.08 | | 0.13 | | 0.08 | 0.26 |
| Dahoon holly | | | | | | | | 0.08 | 0.06 | | | | | | |
| Virginia willow | | | | | | | | 0.17 | 0.01 | | | | | 0.01 | |
| White mangrove | | | | | | | | | | | | | | | 0.17 |
| Peruvian primrose willow[2] | | | | | | | | 0.03 | | | 0.07 | | | 0.03 | 0.20 |
| Primrose willow species | | | | | | | | | | | | 0.01 | | | |
| Stagger bush | 0.03 | 0.02 | | | | | | | | | | | | | |
| Hemp vine | | | | | 0.03 | | | 0.13 | 0.03 | | 0.18 | 0.17 | | 0.11 | 0.15 |
| Sensitive brier | | | 0.04 | | | | | | | | | | | | |
| Wax myrtle | | | | 0.36 | 0.15 | 0.27 | 0.32 | 0.39 | 0.86 | | 0.15 | 0.18 | | | |
| Wild Boston fern | | | | | | | 0.27 | 0.01 | | | | | | | |
| Cinnamon fern | 0.20 | 0.18 | 0.25 | | 0.25 | 0.11 | | | | | | | | | |
| Royal fern | | | | | 0.07 | 0.06 | | 0.30 | 0.29 | | | | | | |
| Red bay | | | | | | 0.03 | | | | | | | | | |
| Rubber vine | | | | | | | | | | | | | | 0.03 | 0.08 |
| Myrsine | | | | | | | 0.21 | 0.26 | 0.11 | | | | | | |
| Red mangrove | | | | | | | | | | | | | 0.12 | 0.37 | 0.24 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-7-21. continued**

| Species[1] | MH/Rsw1 | | | Rsw1 | | | Rmix | | | UTsw1 | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Cabbage palm | | | | 0.02 | | 0.27 | 0.08 | 0.03 | | | | | | | |
| Carolina willow | | | | | | | | | 0.04 | | 0.33 | 0.01 | | 0.13 | 0.18 |
| White vine | | | | | 0.01 | | | | 0.02 | | | 0.01 | | 0.07 | 0.04 |
| Lizard's tail | | | | | | | | 0.01 | | | 0.01 | | | | |
| Brazilian pepper[2] | | | | | | | 0.02 | | 0.06 | | | | | | |
| Saw palmetto | 0.74 | 0.72 | 0.61 | | | | | | | | | | | | |
| Laurel greenbrier | | 0.02 | 0.01 | | | | | | | | | | | | |
| Climbing aster | | | | | | | | 0.01 | | | | | | 0.01 | |
| Java plum[2] | | | | 0.02 | 0.16 | | 0.56 | 0.89 | | | | | | | |
| Downy shield fern[2] | | | | | | | | 0.01 | | | | | | | |
| Tri-veined fern | | | | | 0.30 | | | 0.01 | | | | | | | |
| Cardinal airplant | | | | | | | | | 0.04 | | | 0.03 | | | |
| Needleleaf airplant | | | | | | | | | 0.04 | | | | | | |
| Poison ivy | | | | | 0.11 | 0.12 | | 0.69 | 0.38 | | 0.11 | 0.27 | | | 0.06 |
| Hairypod cowpea | | | | | | | | 0.06 | 0.08 | | 0.16 | 0.01 | | | |
| Muscadine grape | | 0.03 | 0.07 | | 0.02 | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-7-22. Shrub percent cover for Transect 8 by forest type**

| Species[1] | HH | | | Rmix | | | UTmix | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Red maple | | | | | | | | 0.14 | | 0.09 | | |
| Leather fern | 0.40 | | 0.07 | 0.10 | 0.23 | 0.05 | 0.71 | 0.70 | 0.36 | 2.22 | 1.22 | 1.01 |
| False indigo | | | | | 0.28 | 0.14 | | 0.04 | | 0.05 | 0.15 | 0.24 |
| Pond apple | | | | | 0.12 | | 1.02 | 0.33 | 0.63 | 1.32 | 1.43 | 1.91 |
| Salt bush (groundsel tree) | | | | | | | | | | | 0.12 | |
| Marlberry | | | | 0.07 | | | | | | | | |
| Baccharis species | | | | | | | 0.46 | | 0.03 | 0.12 | 0.24 | |
| Swamp fern | 0.05 | | | 0.05 | | | 0.21 | 0.01 | 0.01 | 0.05 | | 0.02 |
| False nettle | | | | | | | 0.03 | | 0.05 | 0.02 | | |
| Buttonbush | 0.36 | | 0.65 | 0.42 | 0.81 | 0.92 | 0.10 | 0.74 | 0.76 | | 0.08 | 0.27 |
| Coco plum | | | | | | | 0.04 | 0.06 | | | | |
| Coin vine | | | | | | | | 0.05 | | | 0.01 | 0.08 |
| Persimmon | | | | | 0.03 | | | | | | | |
| Fire weed | | | | | 0.02 | | | | | | | |
| Virginia willow | | | | | | | 0.02 | | | | | |
| White mangrove | | | | | | | | 0.15 | 0.23 | 0.28 | 0.35 | 0.22 |
| Mexican primrose willow | | 0.44 | | | 0.01 | | | | | | | |
| Peruvian primrose willow[2] | | | | | | | | | | | 0.23 | |
| Old World climbing fern[2] | | | 0.08 | 0.94 | 0.15 | 0.67 | | 0.11 | 0.15 | | 0.02 | 0.04 |
| Hemp vine | | | | | 0.01 | 0.03 | | 0.11 | 0.06 | | | |
| Wax myrtle | 0.14 | | | 0.17 | 0.19 | 0.04 | 0.79 | 0.53 | 0.80 | 0.15 | 0.42 | 0.36 |
| Myrsine | | | | | | | | | | | 0.08 | 0.13 |
| Royal fern | | | | | | | 0.04 | | | | | |
| Redtop panicum | | 0.22 | | | | | | | | | | |
| Red bay | | | | | | | | 0.05 | | | | |
| Marsh fleabane | | | | 0.03 | | 0.02 | 0.05 | 0.01 | 0.07 | 0.07 | | |
| Strawberry guava[2] | 0.05 | | 0.07 | 0.10 | | 0.06 | 0.04 | 0.11 | 0.09 | 0.30 | 0.18 | 0.11 |
| Rubber vine | | | | | | | | 0.04 | | | 0.07 | 0.01 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-7-22. continued**

| Species[1] | HH | | | Rmix | | | UTmix | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Red mangrove | | | | | | | | | | 0.25 | | |
| Cabbage palm | | | | | | | 0.21 | 0.22 | 0.26 | | | |
| White vine | | | | | | | | 0.02 | 0.04 | | | |
| Lizard's tail | | | | | | | | 0.01 | 0.06 | | | |
| Brazilian pepper[2] | | | | 0.06 | | | 0.07 | 0.36 | 0.22 | 0.08 | 0.02 | 0.43 |
| Saw palmetto | | | | | 0.01 | | | | | | | |
| Climbing aster | | | | | | 0.01 | | | | | | |
| Bald cypress | | | 0.10 | | | | | | | | | 0.15 |
| Tri-veined fern | | | | | | | | | | | | |
| Spanish moss | | | | | | | | | | | 0.27 | |
| Poison ivy | | | | | 0.01 | 0.06 | | | 0.03 | 0.02 | 0.10 | 0.01 |
| Narrowleaf cattail | | | | | | | | 0.18 | | | | |
| Broadleaf cattail | | | 0.01 | | | | | | | | | |
| Hairypod cowpea | | | | | | | | | 0.07 | | | |
| Muscadine grape | | | | | 0.12 | | | 0.05 | 0.08 | | | |
| Unidentified fern | | | | | | | 0.02 | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-7-23. Shrub percent cover for Transect 9 by forest type

| Species[1] | U | | | HH | | | HH/LTsw2 | | | LTmix | | | LTsw2 | | | LTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Rosary pea | | | 0.51 | | | | | | | | | | | | | | | |
| Leather fern | | | | | 0.08 | 0.13 | | | 1.00 | 1.00 | 1.00 | 1.00 | 8.17 | 6.07 | 6.39 | 0.49 | 0.71 | 1.13 |
| False indigo | | 0.04 | | | | | | | | | | | | | | | | |
| Pond apple | | | | | | 0.10 | 0.89 | | 1.00 | | | | 0.05 | | 0.23 | | | |
| Swamp fern | | | | 0.43 | | 0.01 | | | | | | | | | | | | |
| Black mangrove | | | | | | | | | | | | | | 0.05 | | | | |
| Coco plum | 0.67 | 0.60 | 0.39 | 0.55 | 0.71 | 0.49 | | | | | | | 0.25 | 0.05 | | | | |
| Coin vine | | | | | | | | 1.00 | 0.80 | | | | | 0.30 | 0.26 | | | |
| Indian laurel ficus[2] | | | | | | | | | | | | | 0.25 | 0.35 | 0.20 | | | |
| White mangrove | | | | | | | | | | | | | 0.79 | 2.74 | 1.89 | | | |
| Strawberry guava[2] | | | | | 0.02 | 0.01 | | | | | | | | | | | | |
| Laurel oak | 0.33 | 0.19 | | | | | | | | | | | | | | | | |
| Myrtle oak | | 0.08 | 0.10 | | | | | | | | | | | | | | | |
| Rubber vine | | | | | | | | | | | | | 0.13 | 0.15 | 0.59 | | | |
| Red mangrove | | | | | | | | | | | | | 0.23 | 0.56 | 1.67 | 3.27 | 3.29 | 2.87 |
| Cabbage palm | | | | | | | | | | | | | 0.24 | 0.09 | 0.08 | | | |
| Brazilian pepper[2] | | | | | | | 0.11 | | | | | | 1.91 | 0.64 | 0.58 | 0.25 | | |
| Saw palmetto | | | | | 0.16 | | | | | | | | | | | | | |
| Laurel greenbrier | | | | | 0.02 | | | | | | | | | | | | | |
| Spanish moss | | | | | 0.01 | | | | | | | | | | | | | |
| Muscadine grape | | 0.09 | | | | | | | | | | | | 0.02 | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-7-24. Shrub percent cover for Transect 10 by forest type

| | HH | | | HH/M | | | M | | | UTmix | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Leather fern | | | | 0.06 | | | 0.02 | 0.15 | | 0.22 | 0.19 | 0.05 | | | |
| Pond apple | | | | | | | 0.06 | 0.20 | 0.16 | 1.33 | 1.32 | 1.31 | 0.08 | 0.15 | 0.13 |
| Baccharis species | | | | | | 0.03 | | | | | | 0.02 | | | |
| Swamp fern | 0.10 | | | | | | 0.12 | | | 0.18 | | 0.04 | | | 0.01 |
| Buttonbush | | 0.22 | 0.06 | | | | 0.01 | 0.01 | | 0.21 | 0.28 | 0.11 | 0.14 | 0.09 | 0.17 |
| Sawgrass | 0.17 | 0.10 | 0.08 | 0.60 | 0.94 | 0.29 | 0.21 | 0.14 | | 0.08 | 0.10 | 0.05 | 0.10 | 0.13 | 0.06 |
| Coin vine | | | | | | | | | | | 0.13 | 0.04 | | | |
| Dahoon holly | 0.09 | | | | | | | | | | | | | 0.02 | |
| White mangrove | | 0.07 | 0.01 | | | | | | 0.11 | 0.16 | 0.62 | 1.25 | | | 0.24 |
| Old World climbing fern[2] | | | | | 0.06 | 0.12 | | | 0.37 | | 0.13 | 0.03 | | 0.29 | 6.17 |
| Wax myrtle | 0.28 | 0.45 | 0.35 | 0.33 | | 0.48 | 0.17 | 0.23 | | 1.14 | 0.17 | 0.46 | 0.48 | 0.03 | 0.03 |
| Panic grass species | | | | | | | | | | | | 0.12 | | | |
| Red bay | | | | | | | | | | | | | 0.11 | 0.05 | |
| Strawberry guava[2] | 0.15 | 0.11 | 0.09 | | | | | | | 0.26 | 0.06 | 0.04 | | | |
| Myrsine | 0.22 | | 0.06 | | | | | 0.04 | | 0.06 | 0.07 | 0.10 | | | |
| Rubber vine | | | | | | | | | | | 0.02 | | | 0.02 | 0.02 |
| Cabbage palm | | | | | | | | | | 0.03 | 0.07 | 0.11 | | | |
| Brazilian pepper[2] | | | | 0.01 | | | 0.42 | 0.18 | 0.19 | 0.31 | 0.52 | 0.23 | 0.10 | 0.20 | 0.09 |
| Saw palmetto | | | | | | | | | 0.07 | | | | | | |
| Spanish moss | | | | | | | | | | | | | | 0.02 | |
| Poison ivy | | 0.03 | 0.34 | | | | | 0.04 | 0.07 | | | | | | |
| Broadleaf cattail | | | | | | 0.08 | | | 0.02 | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

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# APPENDIX 3-8

# 2003, 2007 AND 2010 GROUND COVER STEMS BY TRANSECT AND RIVER REACH

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**Table 3-8-25. 2003, 2007 and 2010 Ground Cover Stems by Transect and River Reach**

| | Riverine Total | | | Upper Tidal Total | | | Lower Tidal Total | | | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Rosary pea[2] | 1 | 0 | 0 | | | | 39 | 53 | 8 | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | 39 | 53 | 8 | | | | 40 | 53 | 8 |
| Red maple | 35 | 15 | 49 | 0 | 10 | 15 | | | | 2 | 1 | 0 | | | | 22 | 9 | 5 | 5 | 5 | 7 | 6 | 0 | 37 | 0 | 1 | 2 | 0 | 1 | 5 | 0 | 8 | 8 | | | | | | | 35 | 25 | 64 |
| Leather fern | 7 | 5 | 12 | 46 | 135 | 173 | 42 | 46 | 25 | 4 | 2 | 0 | 3 | 3 | 12 | | | | | | | | | | 31 | 57 | 56 | 12 | 53 | 93 | 3 | 22 | 23 | 42 | 46 | 25 | 0 | 3 | 1 | 95 | 186 | 210 |
| Blue mink[2] | 0 | 27 | 36 | | | | | | | | | | | | | | | | | | | 0 | 27 | 36 | | | | | | | | | | | | | | | | 0 | 27 | 36 |
| Alligator weed[2] | 6 | 61 | 50 | | | | | | | 6 | 28 | 4 | 0 | 33 | 45 | | | | | | | 0 | 0 | 1 | | | | | | | | | | | | | | | | 6 | 61 | 50 |
| Joyweed[2] | 11 | 5 | 0 | | | | | | | 11 | 0 | 0 | | | | | | | | | | 0 | 5 | 0 | | | | | | | | | | | | | | | | 11 | 5 | 0 |
| Sessile joyweed[2] | 0 | 1 | 0 | 0 | 0 | 1 | | | | | | | | | | | | | | | | 0 | 1 | 0 | 0 | 0 | 1 | | | | | | | | | | | | | 0 | 1 | 1 |
| Tooth cup #1 | | | | 0 | 0 | 6 | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 6 | | | | | | | | | | 0 | 0 | 6 |
| False indigo | | | | 3 | 32 | 5 | | | | | | | | | | | | | | | | | | | | | | 3 | 17 | 1 | 0 | 15 | 4 | | | | | | | 3 | 32 | 5 |
| Pond apple | 8 | 71 | 7 | 95 | 132 | 279 | 97 | 1 | 329 | 6 | 1 | 1 | 0 | 3 | 1 | 2 | 59 | 3 | 0 | 8 | 1 | 0 | 0 | 1 | 29 | 38 | 21 | 3 | 50 | 86 | 32 | 28 | 99 | 97 | 1 | 329 | 31 | 16 | 73 | 200 | 204 | 615 |
| Groundnut | 2 | 2 | 11 | 0 | 0 | 1 | | | | | | | | | | 2 | 2 | 11 | | | | | | | | | | | | | 0 | 0 | 1 | | | | | | | 2 | 2 | 12 |
| Marlberry | 36 | 10 | 13 | 0 | 11 | 2 | | | | 2 | 0 | 0 | 33 | 8 | 6 | | | | | | | 1 | 2 | 7 | | | | 0 | 11 | 2 | | | | | | | | | | 36 | 21 | 15 |
| Salt bush (silverling) | 2 | 0 | 1 | 9 | 9 | 0 | | | | | | | | | | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | | | | 4 | 0 | 0 | 0 | 6 | 0 | | | | 5 | 3 | 0 | 11 | 10 | 0 |
| Salt bush (groundsel tree) | | | | 0 | 7 | 30 | | | | | | | | | | | | | | | | | | | | | | 0 | 7 | 18 | 0 | 0 | 8 | | | | 0 | 0 | 4 | 0 | 7 | 30 |
| Baccharis species | | | | 0 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 1 | 0 | | | | | | | | | |
| Water hyssop | | | | 327 | 2498 | 1242 | 100 | 8 | 350 | | | | | | | | | | | | | | | | 83 | 174 | 72 | 2 | 373 | 195 | 191 | 1101 | 818 | 100 | 8 | 350 | 51 | 850 | 157 | 427 | 2506 | 1592 |
| Tar flower | | | | 2 | 2 | 0 | | | | | | | | | | | | | | | | | | | 2 | 2 | 0 | | | | | | | | | | | | | 2 | 2 | 0 |
| Beggar ticks | 2 | 0 | 0 | | | | | | | | | | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | | | | 2 | 0 | 0 |
| Bishop wood[2] | 6 | 0 | 0 | | | | | | | | | | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | | | | 6 | 0 | 0 |
| Swamp fern | 663 | 611 | 469 | 227 | 115 | 80 | 1 | 5 | 7 | 121 | 243 | 155 | 185 | 115 | 167 | 51 | 117 | 26 | 54 | 36 | 30 | 252 | 100 | 91 | 70 | 37 | 9 | 43 | 41 | 35 | 46 | 8 | 13 | 1 | 5 | 7 | 68 | 29 | 23 | 891 | 731 | 556 |
| False nettle | 59 | 375 | 117 | 8 | 31 | 75 | | | | 4 | 107 | 34 | 0 | 126 | 7 | 4 | 72 | 16 | 3 | 18 | 20 | 48 | 52 | 40 | 0 | 0 | 1 | 3 | 14 | 46 | 5 | 17 | 28 | | | | | | | 67 | 406 | 192 |
| American beautyberry | 8 | 6 | 22 | 0 | 0 | 8 | | | | 2 | 0 | 2 | 6 | 2 | 6 | | | | 0 | 0 | 3 | 0 | 4 | 11 | | | | | | | 0 | 0 | 8 | | | | | | | 8 | 6 | 30 |
| Golden canna | 1 | 0 | 0 | | | | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | 1 | 0 | 0 |
| Bitter cress | 0 | 144 | 18 | | | | | | | | | | 0 | 144 | 10 | | | | | | | 0 | 0 | 8 | | | | | | | | | | | | | | | | 0 | 144 | 18 |
| False hop sedge | 8 | 38 | 152 | | | | | | | 3 | 22 | 0 | 0 | 6 | 0 | | | | 0 | 0 | 74 | 5 | 10 | 78 | | | | | | | | | | | | | | | | 8 | 38 | 152 |
| Hop sedge species | 0 | 0 | 5 | 0 | 0 | 1 | | | | | | | 0 | 0 | 5 | | | | | | | | | | | | | | | | 0 | 0 | 1 | | | | | | | 0 | 0 | 6 |
| Water hickory | 44 | 43 | 63 | | | | | | | | | | 11 | 0 | 4 | 0 | 0 | 1 | 3 | 20 | 11 | 30 | 23 | 47 | | | | | | | | | | | | | | | | 44 | 43 | 63 |
| Buttonbush | 0 | 0 | 2 | 7 | 14 | 17 | | | | | | | | | | 0 | 0 | 2 | | | | | | | 2 | 5 | 6 | 4 | 6 | 7 | 1 | 2 | 2 | | | | 0 | 1 | 2 | 7 | 14 | 19 |
| Partridge pea | 3 | 1 | 0 | | | | 0 | 0 | 1 | | | | | | | 3 | 0 | 0 | 0 | 1 | 0 | | | | | | | | | | | | | 0 | 0 | 1 | | | | 3 | 1 | 1 |
| Jack-in-the-bush | 1 | 4 | 6 | 0 | 1 | 0 | | | | | | | | | | | | | | | | 1 | 4 | 6 | 0 | 1 | 0 | | | | | | | | | | | | | 1 | 5 | 6 |
| Coco plum | 0 | 6 | 6 | | | | 42 | 87 | 15 | 0 | 0 | 2 | 0 | 6 | 4 | | | | | | | | | | | | | | | | | | | 42 | 87 | 15 | | | | 42 | 93 | 21 |
| Sawgrass | | | | 2 | 9 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 9 | 2 | 2 | 9 | 2 |
| Wild taro[2] | 3 | 1 | 198 | | | | | | | 3 | 1 | 198 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | 1 | 198 |
| Common dayflower[2] | 299 | 489 | 389 | | | | | | | 81 | 38 | 8 | 59 | 4 | 23 | 6 | 10 | 0 | 30 | 13 | 12 | 123 | 424 | 346 | | | | | | | | | | | | | | | | 299 | 489 | 389 |
| Swamp lily | 91 | 66 | 49 | 89 | 172 | 70 | 0 | 0 | 2 | 52 | 27 | 15 | 21 | 15 | 27 | 18 | 23 | 7 | | | | 0 | 1 | 0 | 23 | 12 | 14 | 17 | 21 | 15 | 37 | 133 | 32 | 0 | 0 | 2 | 12 | 6 | 9 | 180 | 238 | 121 |
| Mucronate rattlebox | | | | | | | 0 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 2 | 0 | | | | 0 | 2 | 0 |
| Flat sedge | | | | 2 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 0 | 0 | 2 | 0 | 0 |
| False sawgrass | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 0 | 0 | | | | 1 | 0 | 0 |
| Pine barren flat sedge | 5 | 0 | 0 | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 5 | 0 | 0 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-8-25. continued**

| | Riverine Total | | | Upper Tidal Total | | | Lower Tidal Total | | | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Sedge seedling | 1 | 0 | 0 | | | | | | | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | 1 | 0 | 0 |
| Green flat sedge | 0 | 0 | 805 | 0 | 0 | 2 | | | | | | | | | | | | | | | | 0 | 0 | 805 | 0 | 0 | 2 | | | | | | | | | | | | | 0 | 0 | 807 |
| Coin vine | | | | 0 | 4 | 3 | 1 | 6 | 2 | | | | | | | | | | | | | | | | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 6 | 2 | 0 | 1 | 1 | 1 | 10 | 5 |
| Florida beggar weed | | | | | | | 0 | 0 | 12 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 12 | | | | 0 | 0 | 12 |
| Three-flower beggar weed[2] | | | | | | | 3 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 3 | 0 | 0 | | | | 3 | 0 | 0 |
| Variable witch grass | 338 | 377 | 437 | 5 | 31 | 9 | | | | 7 | 16 | 21 | 17 | 97 | 56 | 0 | 62 | 75 | 0 | 151 | 160 | 314 | 51 | 125 | 0 | 31 | 0 | 5 | 0 | 3 | 0 | 0 | 3 | | | | 0 | 0 | 3 | 343 | 408 | 446 |
| Dwarf cypress witch grass | 0 | 299 | 149 | 0 | 0 | 5 | | | | | | | 0 | 0 | 2 | 0 | 0 | 20 | | | | 0 | 299 | 127 | 0 | 0 | 5 | | | | | | | | | | | | | 0 | 299 | 154 |
| Open flower witch grass | 0 | 3 | 7 | 0 | 3 | 0 | | | | | | | | | | 0 | 0 | 2 | 0 | 3 | 5 | | | | | | | | | | 0 | 3 | 0 | | | | | | | 0 | 6 | 7 |
| Witch grass spp. | 81 | 29 | 3 | 2 | 5 | 2 | 0 | 15 | 20 | | | | | | | 24 | 0 | 0 | 11 | 3 | 0 | 46 | 26 | 3 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | 1 | 0 | 15 | 20 | | | | 83 | 49 | 25 |
| False daisy | 0 | 0 | 18 | 0 | 0 | 1 | | | | | | | | | | | | | | | | 0 | 0 | 18 | 0 | 0 | 1 | | | | | | | | | | | | | 0 | 0 | 19 |
| Road grass | 0 | 1 | 0 | 5 | 0 | 0 | | | | | | | 0 | 1 | 0 | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | | | | 5 | 1 | 0 |
| Fire weed | 3 | 5 | 2 | 0 | 30 | 0 | | | | 0 | 2 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | | | | 0 | 0 | 2 | | | | | | | 0 | 30 | 0 | | | | | | | 3 | 35 | 2 |
| Dog fennel | 0 | 4 | 13 | 0 | 1 | 0 | | | | | | | | | | | | | | | | 0 | 4 | 13 | | | | | | | | | | | | | 0 | 1 | 0 | 0 | 5 | 13 |
| Yankee weed | 0 | 0 | 18 | | | | | | | | | | | | | | | | | | | 0 | 0 | 18 | | | | | | | | | | | | | | | | 0 | 0 | 18 |
| Pop ash | 17 | 116 | 8 | 0 | 0 | 1 | | | | | | | | | | 16 | 56 | 2 | 0 | 60 | 6 | 1 | 0 | 0 | | | | 0 | 0 | 1 | | | | | | | | | | 17 | 116 | 9 |
| Milk pea | 0 | 4 | 6 | 0 | 2 | 4 | 0 | 0 | 3 | | | | | | | 0 | 4 | 6 | | | | | | | 0 | 2 | 4 | | | | | | | 0 | 0 | 2 | | | | 0 | 6 | 13 |
| Bed straw | 0 | 37 | 24 | | | | | | | 0 | 26 | 19 | 0 | 11 | 0 | | | | | | | 0 | 0 | 5 | | | | | | | | | | | | | | | | 0 | 37 | 24 |
| Caribbean purple everlasting | 0 | 0 | 1 | | | | | | | | | | | | | | | | | | | 0 | 0 | 1 | | | | | | | | | | | | | | | | 0 | 0 | 1 |
| cud weed | 0 | 0 | 15 | | | | | | | | | | | | | | | | | | | 0 | 0 | 15 | | | | | | | | | | | | | | | | 0 | 0 | 15 |
| Pennywort species | 227 | 666 | 294 | 135 | 487 | 175 | 0 | 0 | 2 | 44 | 33 | 23 | 173 | 429 | 252 | 6 | 185 | 11 | | | | 4 | 19 | 8 | 2 | 11 | 42 | 11 | 237 | 40 | 105 | 222 | 92 | 0 | 0 | 2 | 17 | 17 | 1 | 362 | 1153 | 471 |
| Many flower marsh pennywort | | | | 0 | 0 | 36 | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 35 | 0 | 0 | 1 | | | | | | | 0 | 0 | 36 |
| Whorled marsh pennywort | | | | 0 | 0 | 8 | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 4 | 0 | 0 | 4 | | | | | | | 0 | 0 | 8 |
| Indian swamp weed[2] | 3 | 129 | 437 | | | | | | | 0 | 5 | 0 | | | | 0 | 0 | 4 | 0 | 124 | 353 | 3 | 0 | 80 | | | | | | | | | | | | | | | | 3 | 129 | 437 |
| Alligator lily | | | | 0 | 0 | 76 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 76 | | | | | | | 0 | 0 | 76 |
| Roundpods St. John's wort | 0 | 9 | 0 | | | | | | | | | | | | | 0 | 9 | 0 | | | | | | | | | | | | | | | | | | | | | | 0 | 9 | 0 |
| St. John's wort species | 0 | 12 | 0 | | | | | | | | | | | | | | | | 0 | 12 | 0 | | | | | | | | | | | | | | | | | | | 0 | 12 | 0 |
| Four petal St. John's wort | 0 | 0 | 88 | | | | | | | | | | | | | | | | | | | 0 | 0 | 88 | | | | | | | | | | | | | | | | 0 | 0 | 88 |
| Musky mint | 3 | 15 | 11 | 1 | 6 | 0 | | | | | | | | | | 3 | 15 | 9 | 0 | 0 | 2 | | | | | | | 1 | 0 | 0 | 0 | 6 | 0 | | | | | | | 4 | 21 | 11 |
| Dahoon holly | | | | 0 | 0 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 1 | 0 | 0 | 1 |
| Gallberry | 5 | 0 | 0 | 8 | 8 | 2 | | | | | | | | | | 5 | 0 | 0 | | | | | | | | | | 8 | 2 | 2 | | | | | | | | | | 13 | 2 | 2 |
| Moon vine | 0 | 58 | 0 | | | | | | | | | | 0 | 15 | 0 | | | | | | | 0 | 43 | 0 | | | | | | | | | | | | | | | | 0 | 58 | 0 |
| Blue morning glory | 34 | 37 | 8 | 3 | 0 | 0 | | | | | | | 1 | 11 | 0 | 27 | 10 | 0 | 1 | 0 | 0 | 5 | 16 | 8 | 3 | 0 | 0 | | | | | | | | | | | | | 37 | 37 | 8 |
| Virginia willow | 44 | 13 | 55 | 2 | 2 | 5 | | | | | | | 13 | 5 | 17 | 6 | 2 | 1 | 11 | 6 | 37 | 14 | 0 | 0 | 0 | 1 | 2 | 2 | 1 | 3 | | | | | | | | | | 46 | 15 | 60 |
| White mangrove | | | | 130 | 2486 | 257 | 121 | 490 | 79 | | | | | | | | | | | | | | | | 22 | 1618 | 123 | 4 | 268 | 68 | 64 | 406 | 46 | 121 | 490 | 79 | 40 | 194 | 20 | 251 | 2976 | 336 |
| Asian marsh weed[2] | 5 | 682 | 169 | | | | | | | | | | | | | 0 | 276 | 4 | 5 | 366 | 148 | 0 | 40 | 17 | | | | | | | | | | | | | | | | 5 | 682 | 169 |
| Winged water primrose | | | | 0 | 0 | 33 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 33 | | | | | | | 0 | 0 | 33 |
| Mexican primrose willow | 0 | 1 | 0 | | | | | | | | | | | | | | | | | | | 0 | 1 | 0 | | | | | | | | | | | | | | | | 0 | 1 | 0 |
| Peruvian primrose willow[2] | 0 | 2 | 0 | 0 | 7 | 0 | | | | | | | | | | | | | | | | 0 | 2 | 0 | | | | 0 | 7 | 0 | | | | | | | | | | 0 | 9 | 0 |
| Creeping primrose willow | 4 | 140 | 333 | 383 | 537 | 1477 | | | | 0 | 52 | 4 | 0 | 50 | 37 | 1 | 19 | 5 | 3 | 19 | 146 | 0 | 0 | 141 | 0 | 125 | 170 | 24 | 46 | 484 | 359 | 366 | 823 | | | | | | | 387 | 677 | 1810 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-8-25. continued**

| | Riverine Total | | | Upper Tidal Total | | | Lower Tidal Total | | | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Primrose willow seedling | 6 | 12 | 8 | 31 | 84 | 23 | | | | 1 | 5 | 2 | 0 | 1 | 0 | 4 | 0 | 0 | | | | 1 | 6 | 6 | 0 | 1 | 1 | 2 | 61 | 12 | 29 | 22 | 10 | | | | | | | 37 | 96 | 31 |
| Old World climbing fern[2] | 59 | 59 | 39 | 47 | 245 | 84 | | | | 0 | 0 | 4 | 0 | 1 | 25 | 1 | 0 | 5 | 58 | 58 | 0 | 0 | 0 | 5 | 9 | 22 | 0 | 0 | 9 | 1 | 36 | 95 | 17 | | | | 2 | 119 | 66 | 106 | 304 | 123 |
| Stagger bush | | | | 0 | 10 | 3 | | | | | | | | | | | | | | | | | | | 0 | 2 | 3 | 0 | 8 | 0 | | | | | | | | | | 0 | 10 | 3 |
| Fetterbush; shiny lyonia | | | | 23 | 1 | 2 | | | | | | | | | | | | | | | | | | | 10 | 0 | 2 | 13 | 1 | 0 | | | | | | | | | | 23 | 1 | 2 |
| Square stem | 0 | 6 | 4 | | | | | | | | | | | | | 0 | 6 | 4 | | | | | | | | | | | | | | | | | | | | | | 0 | 6 | 4 |
| Baby tears | 35 | 0 | 0 | | | | | | | | | | | | | 35 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | 35 | 0 | 0 |
| Hemp vine | 6 | 40 | 42 | 18 | 68 | 188 | | | | 0 | 2 | 1 | 5 | 9 | 1 | 1 | 8 | 10 | 0 | 20 | 18 | 0 | 1 | 12 | 0 | 3 | 3 | 4 | 42 | 135 | 11 | 21 | 50 | | | | 3 | 2 | 0 | 24 | 108 | 230 |
| Sensitive brier | 1 | 1 | 1 | | | | 2 | 1 | 1 | | | | | | | 1 | 0 | 0 | 0 | 1 | 0 | | | | | | | | | | | | | 2 | 1 | 1 | | | | 3 | 2 | 1 |
| Horn pod | 0 | 0 | 4 | 4 | 3 | 1 | | | | | | | | | | | | | 0 | 0 | 4 | | | | | | | 4 | 1 | 0 | 0 | 2 | 1 | | | | | | | 4 | 3 | 5 |
| Mulberry | 0 | 3 | 0 | | | | | | | 0 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 3 | 0 |
| Wax myrtle | 1 | 0 | 0 | 5 | 0 | 2 | | | | | | | | | | | | | | | | 1 | 0 | 0 | 3 | 0 | 0 | | | | 1 | 0 | 1 | | | | 1 | 0 | 1 | 6 | 0 | 2 |
| Tuberous sword fern | 0 | 0 | 34 | 0 | 0 | 0 | | | | 0 | 0 | 34 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 34 |
| Wild Boston fern | 5 | 12 | 28 | 1 | 0 | 7 | | | | | | | 5 | 12 | 28 | | | | | | | | | | | | | | | | 1 | 0 | 7 | | | | | | | 6 | 12 | 35 |
| Woods grass | 0 | 59 | 23 | 0 | 0 | 0 | 0 | 103 | 30 | 0 | 59 | 23 | | | | | | | | | | | | | | | | | | | | | | 0 | 103 | 30 | | | | 0 | 162 | 53 |
| Cinnamon fern | | | | 16 | 0 | 39 | | | | | | | | | | | | | | | | | | | 0 | 0 | 28 | 16 | 0 | 8 | 0 | 0 | 3 | | | | | | | 16 | 0 | 39 |
| Royal fern | 14 | 0 | 10 | 61 | 85 | 115 | | | | 6 | 0 | 0 | 8 | 0 | 5 | 0 | 0 | 5 | | | | | | | 1 | 10 | 3 | 38 | 55 | 91 | 22 | 20 | 21 | | | | | | | 75 | 85 | 125 |
| Guinea grass[2] | 0 | 26 | 115 | 0 | 0 | 0 | | | | | | | | | | | | | | | | 0 | 26 | 115 | | | | | | | | | | | | | | | | 0 | 26 | 115 |
| Redtop panicum | 2 | 175 | 78 | 3 | 90 | 15 | | | | 0 | 0 | 38 | 0 | 3 | 0 | 1 | 0 | 0 | 1 | 162 | 40 | 0 | 10 | 0 | | | | | | | 3 | 90 | 15 | | | | | | | 5 | 265 | 93 |
| Switch grass | | | | 3 | 0 | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | 0 | 9 | 3 | 0 | 9 |
| Pellitory | 0 | 758 | 1720 | | | | | | | 0 | 421 | 470 | 0 | 286 | 0 | 0 | 14 | 0 | | | | 0 | 37 | 1250 | | | | | | | | | | | | | | | | 0 | 758 | 1720 |
| Virginia creeper | 10 | 10 | 21 | | | | | | | 7 | 4 | 0 | 1 | 4 | 12 | | | | 2 | 2 | 9 | | | | | | | | | | | | | | | | | | | 10 | 10 | 21 |
| Elephant grass[2] | 0 | 0 | 7 | | | | | | | | | | | | | | | | | | | 0 | 0 | 7 | | | | | | | | | | | | | | | | 0 | 0 | 7 |
| Red bay | 0 | 1 | 0 | 1 | 0 | 1 | | | | 0 | 1 | 0 | | | | | | | | | | | | | | | | 0 | 0 | 1 | 1 | 0 | 0 | | | | | | | 1 | 1 | 1 |
| Golden polypody | 0 | 2 | 0 | | | | | | | | | | 0 | 2 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 2 | 0 |
| American pokeweed | 0 | 12 | 26 | | | | | | | | | | 0 | 12 | 26 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 12 | 26 |
| Slash pine | 0 | 0 | 1 | 0 | 0 | 3 | | | | | | | | | | 0 | 0 | 1 | | | | | | | 0 | 0 | 2 | | | | 0 | 0 | 1 | | | | | | | 0 | 0 | 4 |
| Water lettuce | 0 | 0 | 2 | | | | | | | 0 | 0 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 2 |
| Silk grass | 0 | 0 | 0 | | | | 0 | 16 | 39 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 16 | 39 | | | | 0 | 16 | 39 |
| Resurrection fern | 0 | 0 | 40 | 1 | 0 | 0 | | | | | | | | | | | | | 0 | 0 | 40 | | | | | | | | | | | | | | | | 1 | 0 | 0 | 1 | 0 | 40 |
| Marsh fleabane | 0 | 0 | 7 | 0 | 1 | 14 | | | | | | | | | | | | | | | | 0 | 0 | 7 | | | | | | | 0 | 1 | 12 | | | | 0 | 0 | 2 | 0 | 1 | 21 |
| Fleabane species | 0 | 0 | 3 | | | | | | | | | | | | | | | | | | | 0 | 0 | 3 | | | | | | | | | | | | | | | | 0 | 0 | 3 |
| Swamp smartweed | 0 | 142 | 12 | 21 | 21 | 54 | | | | 0 | 0 | 4 | 0 | 9 | 0 | 0 | 101 | 0 | 0 | 15 | 0 | 0 | 17 | 8 | | | | | | | 0 | 21 | 45 | | | | 21 | 0 | 9 | 21 | 163 | 66 |
| Dotted smartweed | 0 | 0 | 2 | 6 | 10 | 0 | | | | | | | | | | | | | | | | 0 | 0 | 2 | | | | 3 | 10 | 0 | 3 | 0 | 0 | | | | | | | 6 | 10 | 2 |
| Smartweed | 0 | 0 | 56 | | | | | | | | | | | | | 0 | 0 | 21 | 0 | 0 | 30 | 0 | 0 | 5 | | | | | | | | | | | | | | | | 0 | 0 | 56 |
| Pickerelweed | 0 | 20 | 0 | 0 | 20 | 11 | | | | | | | | | | 0 | 20 | 0 | | | | | | | 0 | 4 | 0 | | | | 0 | 16 | 11 | | | | | | | 0 | 40 | 11 |
| Pouzolz's bush[2] | 0 | 23 | 141 | | | | | | | | | | 0 | 3 | 0 | | | | 0 | 0 | 2 | 0 | 20 | 139 | | | | | | | | | | | | | | | | 0 | 23 | 141 |
| Combleaf mermaid weed | 0 | 0 | 1 | | | | | | | | | | | | | | | | | | | 0 | 0 | 1 | | | | | | | | | | | | | | | | 0 | 0 | 1 |
| Strawberry guava[2] | | | | 1 | 8 | 1 | | | | | | | | | | | | | | | | | | | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 4 | 1 | | | | 1 | 0 | 0 | 1 | 8 | 1 |
| Whisk-fern | | | | 10 | 16 | 15 | | | | | | | | | | | | | | | | | | | 9 | 0 | 0 | 0 | 0 | 15 | | | | | | | 1 | 16 | 0 | 10 | 16 | 15 |
| Wild coffee | 90 | 44 | 82 | 2 | 3 | 0 | | | | 62 | 4 | 4 | 9 | 8 | 33 | 7 | 11 | 7 | 1 | 1 | 0 | 11 | 20 | 38 | | | | 2 | 3 | 0 | | | | | | | | | | 92 | 47 | 82 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-8-25. continued**

| | Riverine Total | | | Upper Tidal Total | | | Lower Tidal Total | | | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Shortleaf wild coffee | 96 | 27 | 46 | | | | | | | 3 | 6 | 8 | 4 | 8 | 18 | 48 | 8 | 15 | 9 | 3 | 5 | 32 | 2 | 0 | | | | | | | | | | | | | | | | 96 | 27 | 46 |
| Bracken fern | 0 | 1 | 2 | 0 | 12 | 7 | | | | | | | | | | | | | | | | 0 | 1 | 2 | 0 | 8 | 4 | 0 | 4 | 3 | | | | | | | | | | 0 | 13 | 9 |
| Mock bishops weed | 0 | 45 | 176 | 0 | 0 | 1 | | | | 0 | 25 | 0 | 0 | 20 | 1 | 0 | 0 | 3 | 0 | 0 | 8 | 0 | 0 | 164 | | | | | | | 0 | 0 | 1 | | | | | | | 0 | 45 | 177 |
| Laurel oak | 0 | 10 | 17 | | | | 0 | 0 | 2 | 0 | 6 | 5 | 0 | 1 | 4 | 0 | 3 | 0 | | | | 0 | 0 | 8 | | | | | | | | | | 0 | 0 | 2 | | | | 0 | 10 | 19 |
| Sand live oak | | | | 0 | 0 | 1 | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 1 | | | | | | | | | | 0 | 0 | 1 |
| Myrtle oak | | | | 0 | 0 | 11 | 4 | 48 | 4 | | | | | | | | | | | | | | | | 0 | 0 | 5 | 0 | 0 | 6 | | | | 4 | 48 | 4 | | | | 4 | 48 | 15 |
| Oak seedling | | | | 0 | 31 | 0 | | | | | | | | | | | | | | | | | | | 0 | 10 | 0 | 0 | 21 | 0 | | | | | | | | | | 0 | 31 | 0 |
| Live oak | 3 | 1 | 3 | 19 | 4 | 20 | | | | 1 | 0 | 3 | | | | 1 | 0 | 0 | 1 | 1 | 0 | | | | 19 | 4 | 1 | 0 | 0 | 19 | | | | | | | | | | 22 | 5 | 23 |
| Myrsine | 1 | 0 | 4 | 3 | 2 | 5 | | | | | | | 0 | 0 | 1 | 0 | 0 | 3 | | | | 1 | 0 | 0 | 1 | 1 | 3 | 1 | 0 | 0 | 1 | 1 | 2 | | | | | | | 4 | 2 | 9 |
| Rubber vine | | | | 30 | 29 | 30 | 19 | 23 | 35 | | | | | | | | | | | | | | | | 22 | 18 | 19 | 3 | 2 | 0 | 0 | 4 | 5 | 19 | 23 | 35 | 5 | 5 | 6 | 49 | 52 | 65 |
| Red mangrove | | | | 594 | 86 | 32 | 41 | 33 | 26 | | | | | | | | | | | | | | | | 589 | 67 | 27 | 4 | 19 | 3 | 1 | 0 | 0 | 41 | 33 | 26 | 0 | 0 | 2 | 635 | 119 | 58 |
| Winged sumac | | | | 0 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 1 | 0 | | | | | | | 0 | 1 | 0 |
| Horned beak sedge | 6 | 0 | 0 | 17 | 0 | 0 | | | | | | | | | | 6 | 0 | 0 | | | | | | | | | | | | | 17 | 0 | 0 | | | | | | | 23 | 0 | 0 |
| Few flower weak sedge | 1 | 0 | 0 | | | | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | 1 | 0 | 0 |
| Beak sedge species | 0 | 0 | 4 | | | | | | | | | | | | | | | | | | | 0 | 0 | 4 | | | | | | | | | | | | | | | | 0 | 0 | 4 |
| Rouge plant | 0 | 5 | 0 | | | | | | | 0 | 5 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 5 | 0 |
| Tooth cup #2 | | | | 0 | 3 | 1 | | | | | | | | | | | | | | | | | | | | | | 0 | 2 | 0 | | | | | | | 0 | 1 | 1 | 0 | 3 | 1 |
| Blackberry | 3 | 21 | 3 | | | | | | | | | | | | | 3 | 21 | 3 | | | | | | | | | | | | | | | | | | | | | | 3 | 21 | 3 |
| Swamp dock | 0 | 5 | 27 | | | | | | | | | | | | | | | | | | | 0 | 5 | 27 | | | | | | | | | | | | | | | | 0 | 5 | 27 |
| Cabbage palm | 19 | 5 | 11 | 2 | 8 | 4 | 24 | 4 | 9 | 12 | 4 | 5 | 4 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 2 | 0 | 4 | 1 | 1 | 0 | 2 | 0 | 1 | 1 | 24 | 4 | 9 | 1 | 3 | 0 | 45 | 17 | 24 |
| Coastal rose gentian | | | | 0 | 14 | 76 | | | | | | | | | | | | | | | | | | | | | | 0 | 11 | 67 | 0 | 3 | 9 | | | | | | | 0 | 14 | 76 |
| Carolina willow | | | | 7 | 16 | 6 | | | | | | | | | | | | | | | | | | | 0 | 9 | 0 | 7 | 7 | 6 | | | | | | | | | | 7 | 16 | 6 |
| Water spangles | 0 | 0 | 5 | | | | | | | 0 | 0 | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 5 |
| Pineland pimpernel | 0 | 41 | 143 | 7 | 187 | 142 | | | | | | | 0 | 9 | 1 | 0 | 25 | 4 | 0 | 7 | 135 | 0 | 0 | 3 | 1 | 63 | 8 | 0 | 62 | 75 | 6 | 62 | 56 | | | | 0 | 0 | 3 | 7 | 228 | 285 |
| White vine | 0 | 0 | 4 | 41 | 8 | 12 | | | | | | | | | | 0 | 0 | 4 | | | | | | | 8 | 1 | 3 | 28 | 7 | 8 | | | | | | | 5 | 0 | 1 | 41 | 8 | 16 |
| Lizard's tail | 308 | 495 | 397 | 214 | 254 | 250 | | | | 46 | 139 | 111 | 109 | 110 | 133 | 105 | 64 | 108 | 44 | 178 | 43 | 4 | 4 | 2 | 0 | 2 | 1 | 74 | 112 | 74 | 140 | 140 | 175 | | | | | | | 522 | 749 | 647 |
| Brazilian pepper[2] | 3 | 25 | 1 | 23 | 6 | 15 | 0 | 0 | 1 | 0 | 9 | 1 | 0 | 1 | 0 | 3 | 5 | 0 | 0 | 7 | 0 | 0 | 3 | 0 | 5 | 3 | 5 | 0 | 1 | 0 | 0 | 1 | 9 | 0 | 0 | 1 | 18 | 1 | 1 | 26 | 31 | 17 |
| Climbing cassia[2] | 3 | 9 | 0 | | | | | | | 3 | 9 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 | 9 | 0 |
| Saw palmetto | 5 | 2 | 0 | 3 | 1 | 1 | 2 | 0 | 0 | | | | | | | | | | 1 | 1 | 0 | 4 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | | | | 2 | 0 | 0 | 1 | 0 | 0 | 10 | 3 | 1 |
| Seapurslane | | | | | | | 0 | 10 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 10 | 0 | | | | 0 | 10 | 0 |
| Wire weed | 1 | 2 | 94 | | | | 0 | 0 | 1 | | | | | | | | | | | | | 1 | 2 | 94 | | | | | | | | | | 0 | 0 | 1 | | | | 1 | 2 | 95 |
| Earleaf greenbrier | 0 | 13 | 26 | | | | | | | | | | 0 | 1 | 0 | 0 | 12 | 26 | | | | | | | | | | | | | | | | | | | | | | 0 | 13 | 26 |
| Saw greenbrier | 0 | 13 | 18 | | | | | | | 0 | 5 | 0 | | | | 0 | 1 | 8 | 0 | 6 | 9 | 0 | 1 | 1 | | | | | | | | | | | | | | | | 0 | 13 | 18 |
| Laurel greenbrier | 0 | 2 | 8 | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 2 | 4 | | | | | | | | | | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 2 | 0 | | | | 0 | 1 | 0 | | | | 0 | 5 | 9 |
| Greenbrier species | 26 | 0 | 5 | 7 | 5 | 1 | | | | 1 | 0 | 0 | 0 | 0 | 1 | 8 | 0 | 0 | 4 | 0 | 4 | 13 | 0 | 0 | 1 | 4 | 0 | 6 | 1 | 1 | | | | | | | | | | 33 | 5 | 6 |
| Greenbrier seedling | 2 | 0 | 0 | | | | | | | | | | | | | | | | 2 | 0 | 0 | | | | | | | | | | | | | | | | | | | 2 | 0 | 0 |
| Common nightshade | 0 | 7 | 27 | | | | | | | | | | 0 | 2 | 0 | | | | | | | 0 | 5 | 27 | | | | | | | | | | | | | | | | 0 | 7 | 27 |
| Goldenrod species | | | | 0 | 0 | 1 | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 1 | | | | | | | | | | 0 | 0 | 1 |
| Common sow thistle | 0 | 0 | 1 | | | | | | | | | | | | | | | | | | | 0 | 0 | 1 | | | | | | | | | | | | | | | | 0 | 0 | 1 |
| False buttonweed[2] | | | | | | | 0 | 5 | 10 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 5 | 10 | | | | 0 | 5 | 10 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-8-25. continued**

| Species[1] | Riverine Total | | | Upper Tidal Total | | | Lower Tidal Total | | | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Creeping oxeye; wedelia | 1 | 0 | 0 | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 0 | 0 |
| Smut grass[2] | | | | | | | 0 | 180 | 24 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 180 | 24 | | | | 0 | 180 | 24 |
| St. Augustine grass | | | | 0 | 3 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 3 | 0 | | | | | | | 0 | 3 | 0 |
| Climbing aster | | | | 0 | 0 | 19 | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 6 | 0 | 0 | 13 | | | | | | | 0 | 0 | 19 |
| Nephthytis[2] | 2 | 3 | 4 | | | | | | | 2 | 3 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 3 | 4 |
| Java plum[2] | | | | 10 | 55 | 88 | | | | | | | | | | | | | | | | | | | | | | 10 | 55 | 88 | | | | | | | | | | 10 | 55 | 88 |
| Bald cypress | 1 | 2 | 27 | 1 | 16 | 267 | 0 | 0 | 1 | | | | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 26 | 0 | 0 | 5 | 0 | 12 | 97 | 1 | 4 | 165 | 0 | 0 | 1 | | | | 2 | 18 | 295 |
| Downy shield fern[2] | 68 | 109 | 189 | 0 | 2 | 9 | | | | 34 | 93 | 157 | 3 | 0 | 8 | 0 | 16 | 24 | 27 | 0 | 0 | 4 | 0 | 0 | | | | 0 | 2 | 9 | | | | | | | | | | 68 | 111 | 198 |
| Tri-veined fern | 978 | 1633 | 1955 | 60 | 161 | 219 | | | | 177 | 544 | 740 | 200 | 102 | 203 | 243 | 342 | 485 | 199 | 271 | 267 | 159 | 374 | 260 | 48 | 105 | 113 | 5 | 35 | 50 | 7 | 21 | 56 | | | | | | | 1038 | 1794 | 2174 |
| Maiden fern | | | | 0 | 1 | 0 | | | | | | | | | | | | | | | | | | | 0 | 1 | 0 | | | | | | | | | | | | | 0 | 1 | 0 |
| Marsh fern | 9 | 4 | 8 | 16 | 0 | 0 | | | | | | | 0 | 1 | 0 | 8 | 3 | 8 | 1 | 0 | 0 | | | | 8 | 0 | 0 | 8 | 0 | 0 | | | | | | | | | | 25 | 4 | 8 |
| Meniscium fern | 235 | 63 | 35 | | | | | | | 2 | 0 | 0 | 83 | 51 | 17 | 137 | 12 | 18 | 13 | 0 | 0 | | | | | | | | | | | | | | | | | | | 235 | 63 | 35 |
| Cardinal airplant | 1 | 0 | 0 | 0 | 1 | 3 | | | | | | | | | | | | | | | | 1 | 0 | 0 | 0 | 1 | 3 | | | | | | | | | | | | | 1 | 1 | 3 |
| Needleleaf airplant | 1 | 2 | 0 | 0 | 0 | 1 | | | | | | | | | | 0 | 2 | 0 | | | | 1 | 0 | 0 | 0 | 0 | 1 | | | | | | | | | | | | | 1 | 2 | 1 |
| Spanish moss | | | | | | | 0 | 1 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 1 | 0 | | | | 0 | 1 | 0 |
| Poison ivy | 23 | 23 | 38 | 78 | 115 | 156 | | | | 3 | 3 | 6 | 0 | 3 | 3 | 2 | 3 | 8 | 9 | 10 | 16 | 9 | 4 | 5 | 6 | 30 | 59 | 43 | 73 | 64 | 25 | 11 | 29 | | | | 5 | 1 | 4 | 102 | 138 | 194 |
| Arrow grass | | | | 0 | 638 | 178 | | | | | | | | | | | | | | | | | | | 0 | 1 | 0 | | | | 0 | 614 | 154 | | | | 0 | 23 | 24 | 0 | 638 | 178 |
| Fakahatchee grass | 0 | 23 | 0 | | | | | | | | | | | | | 0 | 23 | 0 | | | | | | | | | | | | | | | | | | | | | | 0 | 23 | 0 |
| Narrowleaf cattail | | | | 0 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 1 | 0 | 1 | 0 | | | | | | | 0 | 1 | 1 |
| Caesar weed[2] | 162 | 247 | 385 | | | | | | | 6 | 170 | 55 | 14 | 39 | 94 | 116 | 14 | 43 | 14 | 6 | 39 | 12 | 18 | 154 | | | | | | | | | | | | | | | | 162 | 247 | 385 |
| Para grass | 0 | 0 | 37 | 0 | 0 | 0 | | | | | | | | | | | | | | | | 0 | 0 | 37 | | | | | | | | | | | | | | | | 0 | 0 | 37 |
| Hairypod cowpea | 0 | 2 | 6 | 0 | 5 | 30 | 0 | 0 | 4 | 0 | 2 | 0 | 0 | 0 | 6 | | | | | | | | | | | | | 0 | 5 | 16 | 0 | 0 | 14 | 0 | 0 | 4 | | | | 0 | 7 | 40 |
| Summer grape | 0 | 4 | 1 | | | | | | | | | | | | | | | | 0 | 2 | 0 | 0 | 2 | 1 | | | | | | | | | | | | | | | | 0 | 4 | 1 |
| Muscadine grape | 4 | 32 | 28 | 3 | 6 | 4 | 6 | 1 | 1 | 3 | 7 | 9 | 1 | 1 | 7 | 0 | 8 | 10 | 0 | 1 | 0 | 0 | 15 | 2 | 0 | 4 | 3 | 3 | 2 | 1 | | | | 6 | 1 | 1 | | | | 13 | 39 | 33 |
| Shoestring fern | | | | 0 | 0 | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 2 | 0 | 0 | 2 |
| Tallow wood | | | | 0 | 2 | 0 | 0 | 0 | 5 | | | | | | | | | | | | | | | | | | | 0 | 2 | 0 | | | | 0 | 0 | 5 | | | | 0 | 2 | 5 |
| Yelloweyed grass species | 1 | 0 | 0 | | | | | | | | | | | | | | | | 1 | 0 | 0 | | | | | | | | | | | | | | | | | | | 1 | 0 | 0 |
| Unidentified sedges (Cyperaceae) | 0 | 1 | 220 | 0 | 5 | 0 | | | | | | | | | | 0 | 1 | 220 | | | | | | | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | | | | | | | 0 | 6 | 220 |
| Unidentified grass (Poaceae) | 87 | 78 | 49 | 21 | 20 | 23 | 21 | 36 | 7 | 0 | 1 | 1 | 0 | 8 | 2 | 27 | 29 | 4 | 2 | 35 | 3 | 58 | 5 | 39 | | | | 2 | 3 | 0 | 17 | 1 | 16 | 21 | 36 | 7 | 2 | 16 | 7 | 129 | 134 | 79 |
| Unidentified fern | 0 | 2 | 22 | 0 | 0 | 1 | | | | | | | | | | 0 | 2 | 22 | | | | | | | | | | 0 | 0 | 1 | | | | | | | | | | 0 | 2 | 23 |
| Unidentified juvenile fern | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 2 | 0 | 0 | | | | | | | | | | | | | 1 | 0 | 0 | | | | 0 | 0 | 1 | | | | 5 | 0 | 1 |
| Unidentified seedling | 466 | 190 | 242 | 19 | 66 | 707 | 0 | 0 | 16 | 319 | 0 | 11 | 54 | 17 | 3 | 52 | 24 | 10 | 14 | 144 | 52 | 27 | 5 | 166 | 9 | 7 | 141 | 8 | 52 | 466 | 2 | 1 | 100 | 0 | 0 | 16 | 0 | 6 | 0 | 485 | 256 | 965 |
| Unidentified species | 35 | 2 | 72 | 4 | 2 | 0 | | | | 29 | 0 | 1 | 0 | 1 | 41 | 0 | 0 | 29 | 0 | 0 | 1 | 6 | 1 | 1 | | | | 1 | 2 | 0 | 3 | 0 | 0 | | | | | | | 39 | 4 | 73 |
| **Number of Species** | 71 | 88 | 102 | 58 | 68 | 83 | 18 | 22 | 28 | 33 | 40 | 37 | 25 | 46 | 38 | 37 | 37 | 42 | 26 | 33 | 32 | 37 | 42 | 60 | 27 | 42 | 41 | 36 | 48 | 50 | 26 | 38 | 48 | 18 | 22 | 28 | 22 | 20 | 26 | 100 | 135 | 147 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

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# APPENDIX 3-9

# THREE-YEAR SUMMARY OF GROUND COVER PERCENT COVER

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**Table 3-9-26. Ground cover percent cover by transect for 2003, 2007 and 2010**

| | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Rosary pea[2] | 2.5 | | | | | | | | | | | | | | | | | | | | | | | | 50.0 | 10.0 | 15.0 | | | |
| Red maple | 5.0 | 2.5 | | | | | 50.0 | 12.5 | 10.0 | 12.5 | 7.5 | 3.0 | 27.5 | | 55.0 | | 2.5 | 5.0 | | 2.5 | 12.5 | | 10.0 | 10.0 | | | | | | |
| Leather fern | 22.5 | 2.5 | | 15.0 | 5.0 | 15.0 | | | | | | | | | | 115.0 | 32.5 | 121.5 | 57.5 | 17.5 | 204.0 | 17.5 | 10.0 | 84.5 | 112.0 | 32.5 | 84.5 | | 5.0 | 2.5 |
| Blue mink[2] | | | | | | | | | | | | | | 15.0 | 75.0 | | | | | | | | | | | | | | | |
| Alligator weed[2] | 2.5 | 15.0 | 7.5 | | 17.5 | 52.0 | | | | | | | | | 2.5 | | | | | | | | | | | | | | | |
| Sessile joyweed[2] | 15.0 | | | | | | | | | | | | | 2.5 | | | | 2.5 | | | | | | | | | | | | |
| Joy weed[2] | | | | | | | | | | | | | | 2.5 | | | | | | | | | | | | | | | | |
| Tooth cup #1 | | | | | | | | | | | | | | | | | | | | | 5.0 | | | | | | | | | |
| False indigo | | | | | | | | | | | | | | | | | | | 5.0 | 17.5 | 2.5 | | 7.5 | 32.5 | | | | | | |
| Pond apple | 7.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 5.0 | 40.0 | 7.5 | | 17.5 | 2.5 | | | 2.5 | 45.0 | 37.5 | 26.0 | 17.5 | 42.5 | 115.0 | 105.0 | 20.0 | 182.5 | 75.0 | 2.5 | 346.0 | 80.0 | 20.0 | 70.0 |
| Groundnut | | | | | | | 5.0 | 2.5 | 22.5 | | | | | | | | | | | | | | | 15.0 | | | | | | |
| Marlberry | 2.5 | | | 35.0 | 7.5 | 7.5 | | | | | | | 2.5 | 2.5 | 17.5 | | | | | 5.0 | 15.0 | | | | | | | | | |
| Salt bush (groundsel tree) | | | | | | | | | | | | | 2.5 | | | | | | 17.5 | | | 84.5 | 12.5 | | | | | 2.5 | 7.5 | |
| Baccharis species | | | | | | | 2.5 | | | | | 4.0 | | | | | | | | | 39.5 | | 2.5 | 22.5 | | | | | | 7.5 |
| Water hyssop | | | | | | | | | | | | | | | | 40.0 | 25.0 | 77.5 | 5.0 | 42.5 | 132.0 | 194.5 | 155.0 | 404.0 | 134.0 | 2.5 | 203.0 | 109.5 | 204.0 | 146.5 |
| Tar flower | | | | | | | | | | | | | | | | 2.5 | | | | | | | | | | | | | | |
| Beggar ticks | | | | | | | | | | | | | 15.0 | | | | | | | | | | | | | | | | | |
| Bishop wood[2] | | | | | | | | | | | | | 2.5 | | | | | | | | | | | | | | | | | |
| Green shrimp plant | | | | | | | | | | | | | | 2.5 | | | | | | | | | | | | | | | | |
| Swamp fern | 319.5 | 245.5 | 156.9 | 255.5 | 50.0 | 486.0 | 97.0 | 45.0 | 57.0 | 226.5 | 20.0 | 129.5 | 303.5 | 52.5 | 132.0 | 332.0 | | 27.5 | 179.5 | 30.0 | 125.0 | 181.5 | 2.5 | 45.0 | 15.0 | 2.5 | 30.0 | 182.5 | 15.0 | 74.5 |
| False nettle | 7.5 | 136.5 | 52.5 | | 72.5 | 44.5 | 30.0 | 27.5 | 30.0 | 17.5 | 17.5 | 30.0 | 65.0 | 40.0 | 87.5 | | | | 7.5 | 17.5 | 87.5 | 22.5 | 10.0 | 55.0 | | | | | | |
| American beautyberry | 2.5 | | 5.0 | 25.0 | 5.0 | 5.0 | | | | | | 5.0 | | 5.0 | 40.0 | | | | 22.5 | | | 2.5 | | 2.5 | | | | | | |
| Golden canna | | | | | | | 15.0 | | | | | | | | | | | | | | | | | | | | | | | |
| Bitter cress | | | | | 54.5 | 15.0 | | | | | | | | | 15.0 | | | | | | | | | | | | | | | |
| False hop sedge | 10.0 | 7.5 | | | 2.5 | | | | | | | 79.5 | 5.0 | 7.5 | 156.5 | | | | | | | | | | | | | | | |
| Hop sedge species | | | | | | 5.0 | | | | | | | 2.5 | | | | | | | | | | | 15.0 | | | | | | |
| Water hickory | | | | 7.5 | | 10.0 | | | 2.5 | 5.0 | 25.0 | 15.0 | 42.5 | 27.5 | 87.5 | | | | | | | | | | | | | | | |
| Buttonbush | | | | | | | | | | | 2.5 | | | | | 15.0 | 5.0 | 32.5 | | 10.0 | 35.0 | | 2.5 | 17.5 | | | | | 2.5 | 2.5 |
| Partridge pea | | | | | | | 17.5 | | | | | | | | | | | | | | | | | | | | 2.5 | | | |
| Jack-in-the-bush | | | | | | | | | | | | | 15.0 | 2.5 | 17.5 | | 2.5 | | | | | | | | | | | | | |
| Coco plum | | | 15.0 | | 5.0 | 5.0 | | | | | | | | | | | | | | | | | | | 50.0 | 20.0 | 17.5 | | | |
| Sawgrass | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15.0 | 5.0 | 17.5 |
| Wild taro[2] | 2.5 | 2.5 | 426.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Common dayflower[2] | 72.0 | 146.5 | 12.5 | 57.5 | 5.0 | 35.0 | 17.5 | 5.0 | | | | | 137.5 | 159.5 | 365.0 | | | | | | | | | | | | | | | |
| Swamp lily | 137.5 | 37.5 | 84.5 | 77.5 | 20.0 | 136.5 | 92.5 | 27.5 | 52.0 | 129.5 | 10.0 | 69.5 | | 2.5 | | 75.0 | 12.5 | 60.0 | 80.0 | 32.5 | 82.5 | 150.0 | 40.0 | 137.5 | | | 15.0 | 60.0 | 10.0 | 67.0 |
| Mucronate rattlebox | | | | | | | | | | | | | | | | | | | | | | | | | | 2.5 | | | | |
| Flat sedge | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5.0 | | |
| False sawgrass | | | | | | | | | | | | | | | | | | | | | | | | | 15.0 | | | | | |
| Pine barren flat sedge | | | | 15.0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Green flat sedge | | | | | | | | | | | | | | | 501.5 | | | 2.5 | | | | | | | | | | | | |
| Coin vine | | | | | | | | | | | | | | | | | 2.5 | | | 5.0 | 2.5 | | | 2.5 | 5.0 | 7.5 | 17.5 | | 2.5 | 2.5 |
| Florida beggar weed | | | | | | | | | | | | | | | | | | | | | | | | | | | 37.0 | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-9-26. continued**

| | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Three-flower beggar weed[2] | | | | | | | | | | | | | | | | | | | | | | | | | 2.5 | | | | | |
| Variable witch grass | 2.5 | 7.5 | 20.0 | 40.0 | 37.5 | 55.0 | 201.0 | 95.0 | 52.0 | 120.0 | 30.0 | 85.0 | 246.5 | 15.0 | 100.0 | 2.5 | 2.5 | | 5.0 | | 5.0 | | 2.5 | 2.5 | | 5.0 | 7.5 | | | 2.5 |
| Cypress witch grass | | | | | | | | | 17.5 | | | | | 102.0 | | | | | | | | | | | | | | | | |
| Dwarf cypress witch grass | | | | | | 2.5 | | | | | | | | | 85.0 | | | 17.5 | | | | | | | | | | | | |
| Open flower witch grass | | | | | | | | | 2.5 | | 2.5 | 2.5 | | | | | | | | | | | 5.0 | | | | | | | |
| Witch grass species | | | | | | | | | | | 2.5 | | 186.5 | 2.5 | 2.5 | | | | | | 2.5 | | | 2.5 | | | | | | |
| False daisy | | | | | | | | | | | | | | | 60.0 | | | 2.5 | | | | | | | | | | | | |
| Road grass | | | | | 2.5 | | | | | | | | | | | 2.5 | | | | | | | | | | | | | | |
| Fire weed | | 2.5 | | | 5.0 | | 2.5 | | | | | | | | 5.0 | | | | | | | | 12.5 | | | | | | | |
| Dog fennel | | | | | | | | | | | | | | 7.5 | 12.5 | | | | | | | | | | | | | | 2.5 | |
| Yankee weed | | | | | | | | | | | | | | | 35.0 | | | | | | | | | | | | | | | |
| Pop ash | | | | | | | 45.0 | 22.5 | 15.0 | | 45.0 | 10.0 | 15.0 | | | | | | | | 2.5 | | | | | | | | | |
| Milk pea | | | | | | | | 5.0 | 15.0 | | | | | | | | 2.5 | 7.5 | | | | | | | | | 15.0 | | | |
| Bed straw | | 10.0 | 15.0 | | 2.5 | | | | | | | | | | 15.0 | | | | | | | | | | | | | | | |
| Cud weed | | | | | | | | | | | | | | | 15.0 | | | | | | | | | | | | | | | |
| Pennywort species | | 17.5 | 32.5 | | 96.5 | 388.0 | 17.5 | 30.0 | 50.0 | | 2.5 | | 2.5 | 5.0 | 22.5 | 2.5 | 10.0 | 32.5 | 5.0 | 17.5 | | | 25.0 | 135.0 | | | 2.5 | | 2.5 | 2.5 |
| Many flower marsh pennywort | | | | | | | | | | | | | | | | | | | | | 39.5 | | | 2.5 | | | | | | |
| Whorled marsh pennywort | | | | | | | | | | | | | | | | | | | | | 15.0 | | | 5.0 | | | | | | |
| Indian swamp weed[2] | | 2.5 | | | | | | | 5.0 | | 17.5 | 211.0 | 2.5 | | 37.0 | | | | | | | | | | | | | | | |
| Alligator lily | | | | | | | | | | | | | | | | | | | | | | | | 99.0 | | | | | | |
| Roundpods St. John's wort | | | | | | | | 2.5 | | | | | | | | | | | | | | | | | | | | | | |
| St. John's wort species | 20.0 | | | 42.5 | | | 17.5 | | | 5.0 | | | | | | | | | | | 55.0 | 100.0 | | | | | | 15.0 | | |
| Four petal St. John's wort | | | | | | | | | | | | | | | 107.0 | | | | | | | | | | | | | | | |
| Musky mint | | | | | | | 15.0 | 7.5 | 20.0 | | | 2.5 | | | | | | | 2.5 | | | | 5.0 | | | | | | | |
| Dahoon holly | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15.0 |
| Gallberry | | | | | | | | | | | | | | | | | | | 15.0 | 2.5 | 15.0 | | | | | | | | | |
| Moon vine | | | | | 7.5 | | | | | | | | | 35.0 | | | | | | | | | | | | | | | | |
| Blue morning glory | | | | 2.5 | 12.5 | | 62.5 | 15.0 | | 2.5 | | | 17.5 | 20.0 | 37.5 | 2.5 | | | | | | | | | | | | | | |
| Virginia willow | | | | 25.0 | 5.0 | 54.5 | 30.0 | 2.5 | 15.0 | 52.5 | 5.0 | 82.0 | 25.0 | | | | 2.5 | 2.5 | 5.0 | 5.0 | 17.5 | | | | | | | | | |
| White mangrove | | | | | | | | | | | | | | | | 32.5 | 172.5 | 127.5 | 22.5 | 67.5 | 120.0 | 152.0 | 60.0 | 82.5 | 137.5 | 130.0 | 127.5 | 72.5 | 37.5 | 62.5 |
| Asian marsh weed[2] | | | | | | | | 92.0 | 15.0 | 2.5 | 92.0 | 96.5 | | 2.5 | 15.0 | | | | | | | | | | | | | | | |
| Winged water primrose | | | | | | | | | | | | | | | | | | | | | | | | 77.0 | | | | | | |
| Mexican primrose willow[2] | | | | | | | | | | | | | | 2.5 | | | | | | | | 15.0 | | | | | | | | |
| Peruvian primrose willow[2] | | | | | | | | | | | | | | 2.5 | | | | | | | | | | | | | | | | |
| Creeping primrose willow | | 25.0 | 2.5 | | 62.0 | 20.0 | 2.5 | 7.5 | 22.5 | 7.5 | 7.5 | 151.0 | | | 129.0 | | 17.5 | 164.0 | 27.5 | 22.5 | 481.5 | 159.0 | 64.5 | 456.5 | | | | 15.0 | | |
| Primrose species | | | 2.5 | | | | | | | | | | | 2.5 | | | | | | | 35.0 | | | | | | | | | |
| Primrose willow seedling | 2.5 | 7.5 | 2.5 | | 2.5 | | 7.5 | | | | | | 2.5 | 5.0 | 7.5 | | 2.5 | 2.5 | 15.0 | 10.0 | | 84.5 | 15.0 | 5.0 | | | | | | |
| Old World climbing fern[2] | | | 37.0 | | 2.5 | 15.0 | 2.5 | | 2.5 | 45.0 | 30.0 | | | | 15.0 | 17.5 | 5.0 | | | 2.5 | 2.5 | 127.0 | 27.5 | 35.0 | | | | 2.5 | 47.0 | 223.0 |
| Stagger bush | | | | | | | | | | | | | | | | | 2.5 | 15.0 | | 2.5 | | | | | | | | | | |
| Fetterbush; shiny lyonia | | | | | | | | | | | | | | | | 30.0 | | 5.0 | 17.5 | 2.5 | | | | | | | | | | |
| Square stem | | | | | | | | 15.0 | 2.5 | | | | | | | | | | | | | | | | | | | | | |
| Baby tears | | | | | | | 2.5 | | | | | | | | | | | | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-9-26. continued**

| | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Hemp vine | | 7.5 | 2.5 | 5.0 | 12.5 | 2.5 | 2.5 | 12.5 | 32.5 | | 20.0 | 17.5 | | 2.5 | 30.0 | | 5.0 | 15.0 | 5.0 | 42.5 | 194.0 | 55.0 | 22.5 | 147.5 | | | | 17.5 | 2.5 | |
| Sensitive brier | | | | | | | 2.5 | | | | 2.5 | | | | | | | | | | | | | | 2.5 | 2.5 | 2.5 | | | |
| Horn pod | | | | | | | | | | | | 2.5 | | | | | | | 2.5 | 2.5 | | | 2.5 | 2.5 | | | | | | |
| Mulberry | | 2.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wax myrtle | | | | | | | | | | | | | 2.5 | | | 2.5 | | | | | | 15.0 | | 2.5 | | | | 2.5 | | 2.5 |
| Wild Boston fern | | | 37.0 | 2.5 | 37.0 | 37.0 | | | | | | | | | | | | | | | | 2.5 | | 15.0 | | | | | | |
| Woods grass | | 37.0 | 15.0 | | | | | | | | | | | | | | | | | | | | | | | 2.5 | 15.0 | | | |
| Cinnamon fern | | | | | | | | | | | | | | | | | | 79.5 | 67.0 | | 37.0 | | | 15.0 | | | | | | |
| Royal fern | 15.0 | | | 15.0 | | 2.5 | | | 15.0 | 37.0 | | | | | | 15.0 | 7.5 | 15.0 | 117.0 | 17.5 | 141.0 | 102.0 | 5.0 | 74.0 | | | | | | |
| Guinea grass[2] | | | | | | | | | | | | | | 116.5 | 84.5 | | | | | | | | | | | | | | | |
| Redtop panicum | | | 81.5 | | 2.5 | | 2.5 | | | 15.0 | 17.5 | 47.5 | | 5.0 | | | | | | | | 2.5 | 20.0 | 30.0 | | | | | | 15.0 |
| Switch grass | | | | | | | | | | | | | | | | | | | | | | | | | | | | 30.0 | 2.5 | |
| Pellitory | | 171.5 | 149.5 | | 122.0 | | | 10.0 | | | | | | 17.5 | 615.5 | | | | | | | | | | | | | | | |
| Virginia creeper | 7.5 | 12.5 | | 2.5 | 5.0 | 17.5 | | | | 5.0 | 2.5 | 20.0 | | | | | | | | | | | | | | | | | | |
| Elephant grass[2] | | | | | | | | | | | | | | | 15.0 | | | | | | | | | | | | | | | |
| Red bay | | 2.5 | | | | | | | | | | | | | | | | | | | 2.5 | 2.5 | | | | | | | | |
| Golden polypody | | | | | 2.5 | | | | | | | | | | | | | | | | | | | | | | | | | |
| American pokeweed | | | | | 7.5 | 52.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Slash pine | | | | | | | | | 2.5 | | | | | | | | | 2.5 | | | | | | 15.0 | | | | | | |
| Water lettuce | | | 2.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Silkgrass | | | | | | | | | | | | | | | | | | | | | | | | | | 5.0 | 37.0 | | | |
| Resurrection fern | | | | | | | | | | | | 15.0 | | | | | | | | | | | | | | | | 2.5 | | |
| Marsh fleabane | | | | | | | | | | | | | | | 22.5 | | | | | | | | 2.5 | 62.5 | | | | | | 5.0 |
| Fleabane species | | | | | | | | | | | | | | | 15.0 | | | | | | | | | | | | | | | |
| Swamp smartweed | | | 15.0 | | 2.5 | | | 52.0 | | | 7.5 | | | 5.0 | 37.5 | | | | | 10.0 | | | 15.0 | 20.0 | | | | 52.5 | | 17.5 |
| Dotted smartweed | | | | | | | | | | | | | | | 17.5 | | | | 2.5 | | | 20.0 | | | | | | | | |
| Smartweed species | | | | | | | | | 45.0 | | | 47.5 | | | 15.0 | | | | | | | | | | | | | | | |
| Pickerelweed | | | | | | | | 62.5 | | | | | | | | | 2.5 | | | | | | 7.5 | 15.0 | | | | | | |
| Pouzolz's bush[2] | | | | | 2.5 | | | | | | | 2.5 | | 12.5 | 134.5 | | | | | | | | | | | | | | | |
| Combleaf mermaid weed | | | | | | | | | | | | | | | 2.5 | | | | | | | | | | | | | | | |
| Strawberry guava[2] | | | | | | | | | | | | | | | | | 2.5 | | | 2.5 | | | 2.5 | 15.0 | | | | 15.0 | | 15.0 |
| Whisk-fern | | | | | | | | | | | | | | | | 17.5 | | | | | 22.5 | | | | | | | 2.5 | | |
| Wild coffee | 92.0 | 5.0 | 2.5 | 12.0 | 2.5 | 84.5 | 15.0 | 7.5 | 7.5 | 2.5 | 5.0 | | 7.5 | 10.0 | 72.0 | | | | 5.0 | 5.0 | | | | | | | | | | |
| Shortleaf wild coffee | 15.0 | 5.0 | 32.5 | 15.0 | 5.0 | 35.0 | 85.0 | 7.5 | 54.5 | 30.0 | 5.0 | 5.0 | 77.5 | 5.0 | | | | | | | | | | | | | | | | |
| Bracken fern | | | | | | | | | | | | | | 2.5 | 37.0 | | 2.5 | 15.0 | | 5.0 | | | | | | | | | | |
| Mock bishops weed | | 7.5 | | | 10.0 | 2.5 | | | 2.5 | | | 5.0 | | | 171.5 | | | | | | | | | 2.5 | | | | | | |
| Laurel oak | | 2.5 | 7.5 | | 2.5 | 12.0 | | 7.5 | | | | | | | 12.5 | | | | | | | | | | | | 2.5 | | | |
| Sand live oak | | | | | | | | | | | | | | | | | | | | | 2.5 | | | | | | | | | |
| Myrtle oak | | | | | | | | | | | | | | | | | | 37.0 | | | 15.0 | | | | 5.0 | 20.0 | 17.5 | | | |
| Oak seedling | 7.5 | | | | | | 2.5 | | | | | | 7.5 | | | 2.5 | 5.0 | | 17.5 | 5.0 | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-9-26. continued**

| | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Live oak | 2.5 | | 15.0 | | | | 2.5 | | | 1.0 | 2.5 | | | | | 15.0 | 5.0 | 2.5 | | | 15.0 | | | | | | | | | |
| Myrsine | | | | | | 2.5 | | | 2.5 | | | | 2.5 | | | 15.0 | 2.5 | 15.0 | 2.5 | | | 2.5 | 2.5 | 15.0 | | | | | | |
| Rubber vine | | | | | | | | | | | | | | | | 27.5 | 25.0 | 89.5 | 7.5 | 5.0 | | | 7.5 | 60.0 | 57.5 | 35.0 | 177.0 | 5.0 | 7.5 | 35.0 |
| Red mangrove | | | | | | | | | | | | | | | | 82.5 | 60.0 | 47.5 | 20.0 | 12.5 | 5.0 | 2.5 | | | 125.0 | 30.0 | 85.0 | | | 5.0 |
| Winged sumac | | | | | | | | | | | | | | | | | | | | | | | 2.5 | | | | | | | |
| Horned beak sedge | | | | | | | 30.0 | | | | | | | | | | | | | | | 89.0 | | | | | | | | |
| Few flower beak sedge | | | | | | | 2.5 | | | | | | | | | | | | | | | | | | | | | | | |
| Beak sedge species | | | | | | | | | | | | | | | 17.5 | | | | | | | | | | | | | | | |
| Rouge plant | | 7.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tooth cup #2 | | | | | | | | | | | | | | | | | | | | 2.5 | | | | | | | | | 2.5 | 2.5 |
| Blueberry | | | | | | | 17.5 | 42.5 | 15.0 | | | | | | | | | | | | | | | | | | | | | |
| Swamp dock | | | | | | | | | | | | | | 5.0 | 134.5 | | | | | | | | | | | | | | | |
| Cabbage palm | 32.5 | 10.0 | 12.5 | 75.0 | | 5.0 | 2.5 | 2.5 | 2.5 | 15.0 | | 2.5 | 2.5 | | 5.0 | | 5.0 | 2.5 | 15.0 | | | | 2.5 | 2.5 | 30.0 | 10.0 | 32.5 | 2.5 | 2.5 | |
| Coastal rose gentian | | | | | | | | | | | | | | | | | | | | 5.0 | 65.0 | | 2.5 | 17.5 | | | | | | |
| Broadleaf arrowhead | | | | | | | 15.0 | | | | | | | | | | | | | | | 2.5 | | | | | | | | |
| Carolina willow | | | | | | | | | | | | | | | | | 5.0 | | 2.5 | 7.5 | | | | | | | | | | |
| Water spangles | | | 2.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pineland pimpernel | | | | | 5.0 | 2.5 | | 15.0 | 17.5 | | 2.5 | 76.5 | | | 5.0 | 2.5 | 2.5 | 35.0 | | 40.0 | 124.5 | 17.5 | 30.0 | 97.5 | | | | | | 2.5 |
| White vine | | | | | | | 2.5 | | 20.0 | | | | | 5.0 | | 15.0 | 2.5 | 17.5 | 37.5 | 12.5 | 47.5 | | | | | | | 12.5 | | 2.5 |
| Lizard's tail | 45.0 | 57.5 | 186.0 | 110.0 | 30.0 | 255.5 | 199.5 | 52.5 | 229.0 | 110.0 | 42.5 | 107.5 | 5.0 | 5.0 | 15.0 | | 2.5 | 2.5 | 90.0 | 35.0 | 127.5 | 202.0 | 57.5 | 363.5 | | | | | | |
| Brazilian pepper[2] | | 7.5 | 2.5 | | 2.5 | | 7.5 | 5.0 | | | 10.0 | | | 715.5 | | 7.5 | 7.5 | 17.5 | | 2.5 | | | 2.5 | 15.0 | | | 2.5 | 12.5 | 2.5 | 2.5 |
| Climbing cassia[2] | 2.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Saw palmetto | | | | | | | | | | 1.0 | 2.5 | | 2.5 | 2.5 | | 5.0 | 2.5 | | | | 15.0 | | | | 15.0 | | | 2.5 | | |
| Sea purslane | | | | | | | | | | | | | | | | | | | | | | | | | | 7.5 | | | | |
| Wire weed | | | | | | | | | | | | | 2.5 | 2.5 | 102.0 | | | | | | | | | | | | 2.5 | | | |
| Earleaf greenbrier | | | | | | | | 20.0 | 82.0 | | | | | | | | | | | | | | | | | | | | | |
| Saw greenbrier | 2.5 | 5.0 | | | | | 47.5 | 2.5 | 20.0 | 15.0 | 2.5 | 15.0 | 20.0 | 2.5 | 2.5 | 5.0 | | | 2.5 | | | | | | | | | | | |
| Laurel greenbrier | | 2.5 | 17.5 | | | | | | | | | | | | 10.0 | | | 2.5 | | 2.5 | | | | | | 2.5 | | | | |
| Greenbrier species | | | | | | 2.5 | | | | | | 2.5 | | | | | 5.0 | | | 2.5 | 2.5 | | | | | | | | | |
| Greenbrier seedling | | | | | | | | | | 3.5 | | | | | | | | | | | | | | | | | | | | |
| Common nightshade | | | | | 2.5 | | | | | | | | | 7.5 | 62.5 | | | | | | | | | | | | | | | |
| Chapman's goldenrod | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Goldenrod species | | | | | | | | | | | | | | | | | | | | | 15.0 | | | | | | | | | |
| Common sow thistle | | | | | | | | | | | | | | | 15.0 | | | | | | | | | | | | | | | |
| False buttonweed[2] | | | | | | | | | | | | | | | | | | | | | | | | | | 5.0 | 15.0 | | | |
| Creeping oxyeye; wedelia | 2.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Smut grass[2] | | | | | | | | | | | | | | | | | | | | | | | | | | 37.0 | 15.0 | | | |
| St. Augustine grass | | | | | | | | | | | | | | | | | | | | | | | 2.5 | | | | | | | |
| Climbing aster | | | | | | | | | | | | | | | | | | | | | 15.0 | | | 30.0 | | | | | | |
| Nephthytis[2] | 5.0 | 5.0 | 45.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Java plum[2] | | | | | | | | | | | | | | | | | | | 20.0 | 25.0 | 124.5 | | | | | | | | | |
| Bald cypress | | | | 2.5 | | | | 2.5 | | | | 2.5 | | | 37.5 | | | 11.0 | | 12.5 | 82.5 | 2.5 | 7.5 | 202.0 | | | 2.5 | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-9-26. continued**

| | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Downy shield fern[2] | 5.0 | 42.0 | 136.0 | 15.0 | | 20.0 | | 2.5 | 37.0 | 15.0 | | | 2.5 | | | | | | | | 15.0 | | | | | | | | | |
| Tri-veined fern | 281.0 | 778.0 | 949.5 | 370.5 | 67.5 | 595.5 | 451.0 | 177.0 | 806.5 | 636.5 | 136.5 | 528.5 | 135.0 | 72.5 | 208.5 | 110.0 | 30.0 | 102.0 | 5.0 | 12.5 | 90.0 | 30.0 | 12.5 | 72.0 | | | | | | |
| Maiden fern | | | | | | | | | | | | | | | | | 2.5 | | | | | | | | | | | | | |
| Marsh fern | | | | 183.5 | 2.5 | | 15.0 | 2.5 | 30.0 | | | | | | | 37.0 | | | 2.5 | | | | | | | | | | | |
| Meniscium fern | | | | | 42.0 | 91.5 | 151.5 | 5.0 | 37.0 | 37.0 | | | | | | | | | | | | | | | | | | | | |
| Cardinal airplant | | | | | | | | | | | | | 2.5 | | | | 2.5 | 62.0 | | | | | | | | | | | | |
| Needleleaf airplant | | | | | | | | 5.0 | | | | | | | | | | 2.5 | | | | | | | | | | | | |
| Spanish moss | | | | | | | | | | | | | | | | | | | | | | | | | | 2.5 | | | | |
| Poison ivy | 5.0 | 2.5 | 5.0 | | 2.5 | 5.0 | 17.5 | 5.0 | 22.5 | 17.5 | 7.5 | 25.0 | 7.5 | 7.5 | 30.0 | 22.5 | 27.5 | 117.0 | 70.0 | 52.5 | 185.0 | 60.0 | 5.0 | 55.0 | | | | 17.5 | 2.5 | 15.0 |
| Arrow grass | | | | | | | | | | | | | | | | | 2.5 | | | | | | 40.0 | 92.0 | | | | | 2.5 | 2.5 |
| Fakahatchee grass | | | | | | | | 62.5 | | | | | | | | | | | | | | | | | | | | | | |
| Narrowleaf cattail | | | | | | | | | | | | | | | | | | | | | 2.5 | | 2.5 | | | | | | | |
| Caesar weed[2] | 10.5 | 25.0 | 92.5 | 32.5 | 17.5 | 119.5 | 104.5 | 10.0 | 4.5 | 32.5 | 7.5 | 32.5 | 72.0 | 15.0 | 179.5 | | | | | | | | | | | | | | | |
| Para grass[2] | | | | | | | | | | | | | | | 15.0 | | | | | | | | | | | | | | | |
| Hairypod cowpea | | 5.0 | | | | 15.0 | | | | | | | | | | | | | | 10.0 | 35.0 | | | 55.0 | | | 10.0 | | | |
| Summer grape | | | | | | | | | | | 2.5 | | | 5.0 | 2.5 | | | | | | | | | | | | | | | |
| Muscadine grape | 7.5 | 10.0 | 32.5 | 2.5 | 2.5 | 22.5 | 25.0 | 15.0 | 20.0 | | 2.5 | 22.5 | | 7.5 | 15.0 | | 5.0 | 37.0 | 5.0 | 5.0 | 2.5 | | | | 15.0 | 2.5 | 2.5 | | | |
| Shoestring fern | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15.0 |
| Tallow wood | 2.5 | | | | | | | | | | | | | | | | | | | 2.5 | | | | | | | 37 | | | |
| Unidentified sedges (Cyperaceae) | | | | | | | 5.0 | 2.5 | 39.5 | 2.5 | | | 50.0 | | | | 2.5 | | | 2.5 | | | 2.5 | | | | | 2.5 | | |
| Unidentified grass (Poaceae) | | 2.5 | 2.5 | | 10.0 | 5.0 | 39.5 | 62.5 | 10.0 | 4.5 | 12.5 | 2.5 | 368.0 | 2.5 | 27.5 | | | | 15.0 | 5.0 | | 32.5 | 2.5 | 37.5 | 25.0 | 5.0 | 2.5 | 5.0 | 5.0 | 17.5 |
| Unidentified fern | | | | | | | | 2.5 | 5.0 | | | | | | | | | | 2.5 | | 2.5 | | | 2.5 | | | 2.5 | | | |
| Unidentified seedling | 60.0 | | 15.0 | 27.5 | 15.0 | 5.0 | 22.5 | 10.0 | 30.0 | 16.0 | 27.5 | 55.0 | 22.5 | 5.0 | 62.5 | 15.0 | 10.0 | 62.5 | 17.5 | 24.5 | 140.0 | 2.5 | 2.5 | 40.0 | | | 5.0 | | 5.0 | 5.0 |
| Unidentified species | 17.5 | | 2.5 | | 2.5 | 39.5 | | | 35.0 | | | 2.5 | 35.0 | 2.5 | 2.5 | | | | 2.5 | 2.5 | | 15.0 | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

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# APPENDIX 3-10

# GROUND COVER PERCENT COVER BY FOREST TYPE FOR EACH TRANSECT

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## FOREST TYPE DEFINITIONS

| | |
|---|---|
| HH | hydric hammock forest type |
| LTmix | lower tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| LTsw1 | lower tidal reach swamp forest type 1 |
| LTsw2 | lower tidal reach swamp forest type 2 |
| LTsw3 | lower tidal reach swamp forest type 3 |
| M | marsh forest type |
| MH | mesic hammock forest type |
| Rblh1 | bottomland hardwood forest type 1 |
| Rblh2 | bottomland hardwood forest type 2 |
| Rblh3 | bottomland hardwood forest type 3 |
| Rmix | riverine forest type with canopy dominance 50% bald cypress and 50% cabbage palm |
| Rsw1 | riverine reach swamp forest type 1 |
| Rsw2 | riverine reach swamp forest type 2 |
| Rsw3 | riverine reach swamp forest type 3 |
| U | uplands forest type |
| UTmix | upper tidal reach forest type containing some areas that are dry and others that are continuously saturated |
| UTsw1 | upper tidal reach swamp forest type 1 |
| UTsw2 | upper tidal reach swamp forest type 2 |
| UTsw3 | upper tidal reach swamp forest type 3 |

Some plots contain more than one forest type. For example, HH/Rsw1 indicates the plot contains both hydric hammock and riverine reach swamp forest type 1.

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**Table 3-10-27. Ground cover percent cover for Transect 1 by forest type**

| | MH | | | HH/U | | | HH | | | Rblh1 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Rosary pea[2] | 2.5 | | | | | | | | | | | | | | |
| Red maple | 2.5 | | | | | | | 2.5 | | 2.5 | | | | | |
| Leather fern | | | | | | | | | | | 2.5 | | 22.5 | 2.5 | |
| Alligator weed[2] | | | | | | | | 2.5 | | | | | 2.5 | 10.0 | 7.5 |
| Sessile joyweed[2] | | | | | | | | | | | | | 15.0 | | |
| Pond apple | | | | | | | | | | | | | 7.5 | 2.5 | 2.5 |
| Marlberry | | | | | | | 2.5 | | | | | | | | |
| Swamp fern | 99.0 | 62.5 | 57.4 | 101.5 | 76.5 | 67.0 | 119.0 | 106.5 | 193.5 | | | | | | |
| False nettle | | | | | | | | 7.5 | 2.5 | | | | 7.5 | 129.0 | 50.0 |
| American beautyberry | | | | 2.5 | | 2.5 | | | 2.5 | | | | | | |
| False hop sedge | | | | | | | | | | | | | 10.0 | 7.5 | |
| Coco plum | | | | | | | | | 15.0 | | | | | | |
| Wild taro[2] | | | | | | | | | 5.0 | | | | 2.5 | 2.5 | 424.0 |
| Common dayflower[2] | | | 2.5 | | | 15.0 | | | 5.0 | 37.0 | 2.5 | | 35.0 | 144.0 | 10.0 |
| Swamp lily | | | | | | | 2.5 | | 2.5 | 20.0 | 20.0 | | 115.0 | 17.5 | 82.0 |
| Variable witch grass | | | | | 2.5 | | 2.5 | | | | | | | | |
| Fire weed | | | | | | | | | | | 2.5 | | | | |
| Bed straw | | | | | | | | 2.5 | | | | | | 7.5 | 15.0 |
| Pennywort species | | | | | | | | | 5.0 | | | | 20.0 | 17.5 | |
| Indian swamp weed[2] | | | | | | | | | | | | | | 2.5 | |
| Creeping primrose willow | 2.5 | 2.5 | | | | | | 2.5 | | | | | | 7.5 | |
| Primrose willow species | | | | | | | | | | | | | | | 27.5 |
| Primrose willow seedling | | | | | | | | 2.5 | 2.5 | | | | 2.5 | 5.0 | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-27. continued**

| | MH | | | HH/U | | | HH | | | Rblh1 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Old World climbing fern[2] | | | | | | | | | | | | | | | 37.0 |
| Hemp vine | | | | | | | | | | | | 2.5 | | 5.0 | |
| Mulberry | | | | | | | | 2.5 | | | | | | | |
| Wild Boston fern | | | | | | | | | 37.0 | | | | | | |
| Woods grass | | 37.0 | | | | 15.0 | | | | | | | | | |
| Royal fern | 15.0 | | | | | | | | | | | | | | |
| Redtop panicum | | | | | | | | | | | | | | | 81.5 |
| Pellitory | | | | | | | | 89.5 | | | | | | 82.0 | 149.5 |
| Virginia creeper | 2.5 | 2.5 | | 2.5 | 2.5 | | | | | | | | 2.5 | 7.5 | |
| Red bay | | | | | | | | 2.5 | | | | | | | |
| Water lettuce | | | | | | | | | 2.5 | | | | | | |
| Swamp smartweed | | | | | | | | | | | | | | | 15.0 |
| Wild coffee | | 2.5 | | 2.5 | | | 2.5 | 2.5 | 2.5 | 84.5 | | | 2.5 | | |
| Shortleaf wild coffee | | 2.5 | 15.0 | | | | 15.0 | 2.5 | 17.5 | | | | | | |
| Mock bishops weed | | | | | | | | | | | | | | 7.5 | |
| Laurel oak | | 2.5 | 2.5 | | | 2.5 | | | 2.5 | | | | | | |
| Oak seedling | 5.0 | | | | | | 2.5 | | | | | | | | |
| Live oak | 2.5 | | 15.0 | | | | | | | | | | | | |
| Rouge plant | | | | | | | | 5.0 | | | | | | 2.5 | |
| Cabbage palm | 7.5 | 7.5 | 7.5 | 17.5 | 2.5 | 2.5 | 7.5 | | | | | | 2.5 | | 2.5 |
| Lizard's tail | | | | | | | | | | 5.0 | 2.5 | 2.5 | 40.0 | 55.0 | 183.5 |
| Brazilian pepper[2] | | 2.5 | | | | 2.5 | | 2.5 | | | | | | 2.5 | |
| Climbing cassia[2] | | | | | | | | | | 2.5 | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-27. continued**

| | MH | | | HH/U | | | HH | | | Rblh1 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Saw greenbrier | | | | | | | 2.5 | 5.0 | | | | | | | |
| Laurel greenbrier | | | | | 2.5 | 15.0 | | | 2.5 | | | | | | |
| Creeping oxeye; wedelia[2] | | | | | | | | | | | | | 2.5 | | |
| Nephthytis[2] | | | | | | | | | 15.0 | | | | 7.5 | 5.0 | 30.0 |
| Downy shield fern[2] | 2.5 | 37.0 | 62.0 | | | | | 5.0 | 37.0 | | | | 2.5 | | 37.0 |
| Tri-veined fern[2] | 15.0 | | | | | | | | | 64.5 | 243.5 | 99.5 | 201.5 | 534.5 | 850.0 |
| Meniscium fern | | | | | | | | | | | | | 2.5 | | |
| Poison ivy | 2.5 | 2.5 | 2.5 | | | | 2.5 | | 2.5 | | | | | | |
| Caesar weed[2] | 7.5 | 12.5 | 45.0 | 2.5 | 5.0 | 30.0 | 2.5 | 2.5 | 17.5 | | | | | 5.0 | |
| Hairypod cowpea | | | | | | | | | | | | | | 5.0 | |
| Muscadine grape | 7.5 | | 2.5 | 2.5 | 2.5 | 30.0 | | | | | | | | | |
| Unidentified grass (Poaceae) | | | 2.5 | | | | | | | | | | | 2.5 | |
| Juvenile fern | | | | | | | 2.5 | | | | | | 2.5 | | |
| Unidentified seedling | 7.5 | | 5.0 | 5.0 | | 2.5 | | | 5.0 | | | 2.5 | 50.0 | | |
| Unidentified species | 15.0 | | | | | | | | | | | | 2.5 | | 2.5 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-10-28. Ground cover percent cover for Transect 2 by forest type

| | MH | | | HH | | | HH/Rsw1 | | | Rblh1 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Leather fern | | | | | | | | | | | | | 15.0 | 5.0 | 15.0 |
| Alligator weed[2] | | | | | | | | 15.0 | | | | | | 2.5 | 52.0 |
| Pond apple | | | | | | | 2.5 | | | | | | | 2.5 | 2.5 |
| Marlberry | 32.5 | 5.0 | 5.0 | 2.5 | 2.5 | 2.5 | | | | | | | | | |
| Swamp fern | 45.0 | 12.5 | 109.0 | 104.0 | 7.5 | 129.0 | 15.0 | 5.0 | 119.0 | 74.0 | 7.5 | 52.0 | 17.5 | 15.0 | 77.0 |
| False nettle | | 7.5 | | | 2.5 | | 2.5 | 15.0 | | | | | 42.0 | 47.5 | |
| American beautyberry | 25.0 | 5.0 | | | | | | | | | | | | | |
| Bitter cress | | 54.5 | | | | | | | | | | | | | 15.0 |
| False hop sedge | | 2.5 | | | | | | | | | | | | | |
| Water hickory | | | | 2.5 | | 10.0 | 2.5 | | | 2.5 | | | | | |
| Coco plum | | 5.0 | 5.0 | | | | | | | | | | | | |
| Common dayflower[2] | | | | | 2.5 | | 20.0 | | 17.5 | | | | 37.5 | 12.5 | 17.5 |
| Swamp lily | 5.0 | 2.5 | | | 5.0 | | 30.0 | | | | | | | | 106.5 |
| Flat sedge | 15.0 | | | | | | | | | | | | | | |
| Variable witch grass | 37.5 | 35.0 | 40.0 | | | | 2.5 | | | | | | | 2.5 | 15.0 |
| Dwarf cypress witch grass | | | 2.5 | | | | | | | | | | | | |
| Road grass | | 2.5 | | | | | | | | | | | | | |
| Fire weed | | 2.5 | | | | | | | | | | | | 2.5 | |
| Bed straw | | | | | | | | | | | | | | 2.5 | |
| Pennywort species | | | | | 15.0 | | 7.5 | | 17.5 | | | | 35.0 | 81.5 | 370.5 |
| Moon vine | | | | | 2.5 | | | | | | | | | 5.0 | |
| Blue morning glory | | 5.0 | | | | | | 2.5 | | | | | 2.5 | 5.0 | |
| Virginia willow | | | | | | | | 2.5 | | 2.5 | | 37.0 | 22.5 | 2.5 | 17.5 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-28. continued**

| | MH | | | HH | | | HH/Rsw1 | | | Rblh1 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Creeping primrose willow | | | | | | | | | | | | | | 62.0 | 20.0 |
| Primrose willow seedling | | | | | | | | | | | | | | 2.5 | |
| Old World climbing fern[2] | | | | | | | | 2.5 | 15.0 | | | | | | |
| Hemp vine | | 5.0 | | | 2.5 | | 2.5 | | | | | | 2.5 | 5.0 | 2.5 |
| Wild Boston fern | | 37.0 | 37.0 | | | | | | | 2.5 | | | | | 2.5 |
| Woods grass | | | | | | | | | | | | | | | |
| Royal fern | | | | | | | | | | | | | 15.0 | | |
| Redtop panicum | | 2.5 | | | | | | | | | | | | | |
| Pellitory | | 5.0 | | | 20.0 | | | | | | | | | 97.0 | |
| Virginia creeper | | 5.0 | 5.0 | | | 10.0 | | | | 2.5 | | 2.5 | | | |
| Golden polypody | | 2.5 | | | | | | | | | | | | | |
| American pokeweed | | 7.5 | 52.0 | | | | | | | | | | | | |
| Swamp smartweed | | | | | | | | | | | | | | 2.5 | |
| Pouzolz's bush[2] | | | | | | | | | | | | | | 2.5 | |
| Wild coffee | | | 5.0 | 2.5 | 2.5 | 15.0 | 5.0 | | 62.0 | | | | 2.5 | | 2.5 |
| Shortleaf wild coffee | | | | | | 15.0 | 15.0 | 2.5 | 15.0 | | 2.5 | 2.5 | | | 2.5 |
| Mock bishops weed | | 7.5 | 2.5 | | 2.5 | | | | | | | | | | |
| Laurel oak | | | 7.5 | | 2.5 | 2.5 | | | | | | | | | |
| Myrsine | | | 2.5 | | | | | | | | | | | | |
| Cabbage palm | 5.0 | | 5.0 | | | | 2.5 | | | | | | | | |
| Pineland pimpernel | | | | | 2.5 | | | | | | | | | 2.5 | 2.5 |
| Lizard's tail | | 5.0 | | | 5.0 | | 50.0 | 5.0 | 97.0 | 2.5 | 2.5 | 15.0 | 57.5 | 12.5 | 143.5 |
| Brazilian pepper[2] | | | | | | | | | | | | | | 2.5 | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-28. continued**

| | MH | | | HH | | | HH/Rsw1 | | | Rblh1 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Earleaf greenbrier | | 2.5 | | | | | | | | | | | | | |
| Laurel greenbrier | | | | | | | | | | | | | | | |
| Greenbrier | | | 2.5 | | | | | | | | | | | | |
| Common nightshade | | | | | | | | | | | | | | 2.5 | |
| Bald cypress | | | | | | | | | | 2.5 | | | | | |
| Downy shield fern[2] | | | | | | 5.0 | 15.0 | | | | | | | | 15.0 |
| Tri-veined fern | | | | 228.0 | 27.5 | 345.0 | 50.0 | 7.5 | 91.5 | 45.0 | 5.0 | 67.0 | 47.5 | 27.5 | 92.0 |
| Marsh fern | | 2.5 | | | | | | | | | | | | | |
| Meniscium fern | | | | | | | 106.5 | 5.0 | 39.5 | | | | 77.0 | 37.0 | 52.0 |
| Poison ivy | | 2.5 | 2.5 | | | | | | | | | 2.5 | | | |
| Caesar weed[2] | 32.5 | 17.5 | 104.5 | | | | | | 15.0 | | | | | | |
| Hairypod cowpea | | | | | | | | | | | | 15.0 | | | |
| Muscadine grape | 2.5 | 2.5 | 22.5 | | | | | | | | | | | | |
| Unidentified sedge (Cyperceae) | | | | | | | | | 5.0 | | | | | | |
| Unidentified grass (Poaceae) | | 2.5 | 5.0 | | 2.5 | | | | | | | | | 5.0 | |
| Unidentified juvenile fern | | | | | | | 2.5 | | | | | | | | |
| Unidentified seedling | 7.5 | 7.5 | 5.0 | 5.0 | | | 7.5 | | | | | | 7.5 | 7.5 | |
| Unidentified species | | 2.5 | | | | | | | 2.5 | | | | | | 37.0 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-10-29. Ground cover percent cover for Transect 3 by forest type

| | U/HH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red maple | 5.0 | 2.5 | 7.5 | | | | 45.0 | | 2.5 | | 7.5 | | | 2.5 | |
| Pond apple | | | | | 2.5 | 2.5 | | 2.5 | | 2.5 | 25.0 | 2.5 | 2.5 | 10.0 | 2.5 |
| Groundnut | 5.0 | 2.5 | 17.5 | | | | | | 5.0 | | | | | | |
| Baccharis species | | | | | | | 2.5 | | | | | | | | |
| Swamp fern | | | | 37.0 | 17.5 | 37.0 | 30.0 | 7.5 | 5.0 | 30.0 | 20.0 | 15.0 | | | |
| False nettle | | | 2.5 | | | | 15.0 | 5.0 | 5.0 | 15.0 | 17.5 | 17.5 | | 5.0 | 5.0 |
| Golden canna | | | | | | | 15.0 | | | | | | | | |
| Water hickory | | | | | | | | | | | | 2.5 | | | |
| Partridge pea | 17.5 | | | | | | | | | | | | | | |
| Common day flower | | | | | | | 15.0 | | | 2.5 | 5.0 | | | | |
| Swamp lily | | | | | | | | | | 77.5 | 10.0 | 15.0 | 15.0 | 17.5 | 37.0 |
| Cypress witch grass | | | | | | 17.5 | | | | | | | | | |
| Open flower witch grass | | | 2.5 | | | | | | | | | | | | |
| Variable witch grass | 15.0 | 10.0 | 42.0 | 20.0 | 7.5 | | 2.5 | 72.5 | 10.0 | | 5.0 | | | | |
| Fire weed | 2.5 | | | | | | | | | | | | | | |
| Pop ash | | | | | 5.0 | | | 2.5 | 15.0 | 45.0 | 12.5 | | | 2.5 | |
| Milk pea | | 5.0 | 15.0 | | | | | | | | | | | | |
| Pennywort species | | | | | | | | | | 17.5 | 25.0 | 50.0 | | 5.0 | |
| Indian swamp weed[2] | | | | | | | | | | | | 5.0 | | | |
| Rounpods St. John's wort | | | | | 2.5 | | | | | | | | | | |
| St. John's wort species | 2.5 | | | 2.5 | | | | | | | | | | | |
| Musky mint | 15.0 | 5.0 | 20.0 | | | | | 2.5 | | | | | | | |
| Blue morning glory | | | | | | | | 2.5 | | 30.0 | 7.5 | | 32.5 | 5.0 | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-29. continued**

| | U/HH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Virginia willow | | | | | | | | | | 30.0 | 2.5 | 15.0 | | | |
| Asian marsh weed[2] | | | | | | | | | | | 92.0 | 15.0 | | | |
| Creeping primrose willow | | | | | | | | | | 2.5 | 5.0 | 9.0 | | 2.5 | |
| Primrose willow seedling | | | | | | | 2.5 | | | 5.0 | | | | | |
| Old World climbing fern[2] | 2.5 | | 2.5 | | | | | | | | | | | | |
| Square stem | | 15.0 | 2.5 | | | | | | | | | | | | |
| Baby tears | | | | | | | 2.5 | | | | | | | | |
| Hemp vine | | | | | | | 2.5 | | | | 10.0 | 30.0 | | 2.5 | 2.5 |
| Sensitive brier | 2.5 | | | | | | | | | | | | | | |
| Royal fern | | | | | | 15.0 | | | | | | | | | |
| Redtop panicum | | | | | | | | | | | | | 2.5 | | |
| Pellitory | | | | | | | | | | | 7.5 | | | 2.5 | |
| Slash pine | | | 2.5 | | | | | | | | | | | | |
| Swamp smartweed | | | | | | | | 2.5 | | | 47.0 | | | 2.5 | |
| Smartweed | | | | | | | | | 2.5 | | | 35.0 | | | 7.5 |
| Pickerelweed | | | | | | | | 62.5 | | | | | | | |
| Wild coffee | | | | | | | 15.0 | 2.5 | 5.0 | | | | | 5.0 | 2.5 |
| Shortleaf wild coffee | | | 15.0 | 30.0 | 2.5 | 2.5 | 20.0 | 5.0 | | 5.0 | | | 30.0 | | 37.0 |
| Mock bishops weed | | | | | | | | | | | | 2.5 | | | |
| Laurel oak | | 2.5 | | | | | | 2.5 | | | 2.5 | | | | |
| Live oak | | | | | | | 2.5 | | | | | | | | |
| Oak seedling | | | | | | | 2.5 | | | | | | | | |
| Myrsine | | | | | | | | | 2.5 | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-29. continued**

| | U/HH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Horned beak sedge | | | | | | | 30.0 | | | | | | | | |
| Few flower beak sedge | | | | | | | 2.5 | | | | | | | | |
| Blueberry | 17.5 | 42.5 | 15.0 | | | | | | | | | | | | |
| Cabbage palm | | 2.5 | 2.5 | | | | 2.5 | | | | | | | | |
| Broadleaf arrowhead | | | | | | | 15.0 | | | | | | | | |
| Pineland pimpernel | | | | | | | | | | | 7.5 | 15.0 | | 7.5 | 2.5 |
| White vine | | | | | | | | | | 2.5 | | 17.5 | | | 2.5 |
| Lizard's tail | | | | 20.0 | 7.5 | 30.0 | 30.0 | 30.0 | 47.5 | 119.5 | 15.0 | 84.5 | 30.0 | 2.5 | 67.0 |
| Brazilian pepper[2] | | | | 2.5 | | | 2.5 | | | | 2.5 | | 2.5 | 2.5 | |
| Earleaf greenbrier | | 15.0 | 67.0 | | 2.5 | | | 2.5 | 15.0 | | | | | | |
| Saw greenbrier | 30.0 | | 17.5 | 2.5 | | 2.5 | 15.0 | | | | 25.0 | | | | |
| Bald cypress | | | | | 2.5 | | | | | | | | | | |
| Downy shield fern[2] | | | | | | | | | | | | | | 2.5 | 37.0 |
| Tri-veined fern | | | | 79.5 | 54.5 | 99.5 | 32.5 | 40.0 | 57.0 | 257.0 | 70.0 | 543.0 | 82.0 | 12.5 | 107.0 |
| Marsh fern | 15.0 | 2.5 | 30.0 | | | | | | | | | | | | |
| Meniscium fern | | | | | | | | | | 149.0 | 5.0 | 39.5 | 2.5 | | |
| Needleleaf airplant | | | | | 5.0 | | | | | | | | | | |
| Poison ivy | 15.0 | | 5.0 | | | | 2.5 | | | | 2.5 | 15.0 | | 2.5 | 2.5 |
| Fakahatchee grass | | | | | | | | 62.5 | | | | | | | |
| Ceasar weed | 67.0 | 5.0 | | 5.0 | 2.5 | | 32.5 | 5.0 | 2.5 | | | | | | |
| Muscadine grape | 17.5 | 12.5 | 17.5 | | | | | | | | | | 2.5 | 2.5 | 2.5 |
| Unidentified fern | | | | | | | | | 2.5 | | 2.5 | | | | 2.5 |
| Unidentified sedge (Cyperceae) | 2.5 | | 39.5 | | | | | 2.5 | | | | | 2.5 | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-29. continued**

| | | U/HH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Unidentified grass (Poaceae) | 39.5 | 47.5 | | | | | | 77.5 | 2.5 | | 7.5 | 5.0 | | 5.0 | 2.5 |
| Unidentified seedling | 5.0 | | | 2.5 | | | 5.0 | | 7.5 | 10.0 | 10.0 | 20.0 | | | 2.5 |
| Unidentified species | | | 5.0 | | | | | | | | | 30.0 | | | |

[1] Scientific names are provided in Appendix 3-2.

**Table 3-10-30. Ground cover percent cover for Transect 4 by forest type**

| | | MH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red maple | | | | | | 2.5 | 2.5 | | 5.0 | | | | 7.5 | 7.5 | |
| Pond apple | | | | | | | | 5.0 | | | 5.0 | 2.5 | | 12.5 | |
| Baccharis species | | | | | | | | | | | | | | | 4.0 |
| Swamp fern | | | | 67.0 | 5.0 | 45.0 | 15.0 | 5.0 | 52.0 | 54.5 | 7.5 | 15.0 | 90.0 | 2.5 | 17.5 |
| False nettle | | | | | 2.5 | 5.0 | 15.0 | 7.5 | 7.5 | | 2.5 | 5.0 | 7.5 | 5.0 | 12.5 |
| American beautyberry | | | | | | | | | | | | | | | 5.0 |
| False hop sedge | | | | | | 15.0 | | | | | | 2.5 | | | 62.0 |
| Water hickory | | | | | 2.5 | 5.0 | | 5.0 | 2.5 | | 2.5 | | 5.0 | 15.0 | 7.5 |
| Buttonbush | | | | | | | | | | | 2.5 | | | | |
| Swamp lily | | | | 15.0 | | | | | | 2.5 | | | 112.0 | 10.0 | 69.5 |
| Variable witch grass | | | | 2.5 | 7.5 | 20.0 | 62.5 | 10.0 | 30.0 | 2.5 | 2.5 | 17.5 | 52.5 | 10.0 | |
| Open flower witch grass | | | | | | | | | | | | | | 2.5 | 2.5 |
| Witch grass species | | | | | | | | 2.5 | | | | | | | |
| Pop ash | | | | | 7.5 | 2.5 | | 10.0 | 5.0 | | 5.0 | 2.5 | | 22.5 | |
| Pennywort species | | | | | 2.5 | | | | | | | | 5.0 | | |
| Indian swamp weed[2] | | | | | | | | | 2.5 | | | | | 17.5 | 166.0 |
| Musky mint | | | | | | | | | | | | 2.5 | | | |
| Blue morning glory | | | | | | | | | | | | | 2.5 | | |
| Virginia willow | | | | | | | | | 2.5 | | | 20.0 | 52.5 | 5.0 | 59.5 |
| Asian marsh weed[2] | | | | | | | | 2.5 | 5.0 | | | | 2.5 | 89.5 | 91.5 |
| Creeping primrose willow | | | | | | 2.5 | | | 67.0 | | | | 7.5 | 7.5 | 81.5 |
| Old world climbing fern[2] | 15.0 | | | | | | | | | | | | | 30.0 | |
| Hemp vine | | | | | | | | 5.0 | 17.5 | | 2.5 | | | 10.0 | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-30. Continued**

| | | MH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Sensitive brier | | | | | | | | | | | | | | 2.5 | |
| Horn pod | | | | | | | | | | | | 2.5 | | | |
| Royal fern | | | | | | | | | | | | | 37.0 | | |
| Redtop panicum | | | | | | 30.0 | 15.0 | 17.5 | 17.5 | | | | | | |
| Virginia creeper | | | | | | | 2.5 | 2.5 | 5.0 | | | | 2.5 | | 15.0 |
| Resurrection fern | | | | | | | | | | | | | | | 15.0 |
| Swamp smartweed | | | | | | | | 2.5 | | | | | | 5.0 | |
| Smartweed | | | | | | 5.0 | | | 5.0 | | | 2.5 | | | 35.0 |
| Pouzolz's bush[2] | | | | | | | | | | | | | | | 2.5 |
| Wild coffee | | | | 2.5 | 2.5 | | | 2.5 | | | | | | | |
| Shortleaf wild coffee | | | | | | | 15.0 | 2.5 | 2.5 | | 2.5 | 2.5 | 15.0 | | |
| Mock bishops wood | | | | | | 2,5 | | | 2.5 | | | | | | |
| Live oak | 1.0 | 2.5 | | | | | | | | | | | | | |
| Cabbage palm | | | | | | 2.5 | | | | | | | 15.0 | | |
| Pineland pimpernel | | | | | | 37.0 | | | 37.0 | | | | | 2.5 | 2.5 |
| Lizard's tail | | | | | | 2.5 | 17.5 | 10.0 | 20.0 | 5.0 | 2.5 | 5.0 | 87.5 | 30.0 | 80.0 |
| Brazilian pepper[2] | | | | | 5.0 | | | 2.5 | | | 2.5 | | | | |
| Saw palmetto | 1.0 | 2.5 | | | | | | | | | | | | | |
| Saw greenbrier | | | | | | | 15.0 | 2.5 | 15.0 | | | | | | |
| Greenbrier | | | 2.5 | | | | | | | | | | | | |
| Greenbrier species seedling | 1.0 | | | | | | | | | | | | 2.5 | | |
| Bald cypress | | | | | | | | | | | | | | | 2.5 |
| Bald cypress seedlings | | | | | | | | | | | | | 2.5 | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-30. continued**

| | | MH | | | Rblh3 | | | Rblh2 | | | Rsw2 | | | Rsw1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Downy shield fern[2] | | | | | | | | | | | | | 15.0 | | |
| Tri-veined fern | | | | 52.0 | 5.0 | 52.0 | 214.0 | 20.0 | 173.5 | | 42.0 | 30.0 | 278.5 | 69.5 | 273.0 |
| Meniscium fern | | | | | | | | | | | | | 37.0 | | |
| Poison ivy | | | | | | | 2.5 | 2.5 | 5.0 | | | | 15.0 | 5.0 | 20.0 |
| Ceasar weed | | | | 15.0 | 2.5 | 2.5 | | 2.5 | 15.0 | | | | 17.5 | 2.5 | 15.0 |
| Summer grape | | | | | | | | 2.5 | | | | | | | |
| Muscadine grape | | 2.5 | | | | | | | | | | | | | |
| Yelloweyed grass species | | | | | | | | | | | | | 2.5 | | |
| Unidentified grass (Poaceae) | 3.0 | | | | 2.5 | | | 2.5 | 2.5 | | | | 2.5 | 7.5 | |
| Unidentified seedling | 1.0 | | 2.5 | | | 7.5 | 5.0 | 15.0 | 10.0 | 5.0 | | 7.5 | 5.0 | 12.5 | 27.5 |
| Unidentified species | | | | | | | | | | | | | | | 2.5 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-10-31. Ground cover percent cover for Transect 5 by forest type

| | MH | | | HH/Rblh3 | | | Rblh3 | | | Rblh2 | | | Rblh1 | | | Rsw1/Rblh2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red maple | | | | | | | | | 2.5 | 20.0 | | 15.0 | | | 7.5 | 2.5 | | 7.5 | 5.0 | | 15.0 |
| Blue mink[2] | | | | | | | | | | | 15.0 | 2.5 | | | 20.0 | | | 17.5 | | | 35.0 |
| Alligator weed[2] | | | | | | | | | | | | | | | | | | | | | 2.5 |
| Sessile joyweed[2] | | | | | | | | | | | 2.5 | | | | | | | | | | |
| Joy weed[2] | | | | | | | | | | | | | | | | | | | | 2.5 | |
| Pond apple | | | | | | 2.5 | | | | | | | | | | | | | | | |
| Marlberry | | | | 2.5 | 2.5 | 15.0 | | | | 2.5 | | | | | | | | | | | |
| Salt bush (groundsel tree) | | | | | | | | | | | | | | | | | | | 2.5 | | |
| Beggar ticks | | | | | | | | | | 15.0 | | | | | | | | | | | |
| Bishop wood[2] | | | | | | | | | | | | | | | | | | | 2.5 | | |
| Green shrimp plant[2] | | | | | | | | | | | 2.5 | | | | | | | | | | |
| Swamp fern | 5.0 | 7.5 | 15.0 | 17.5 | 7.5 | 30.0 | 15.0 | 5.0 | 30.0 | 22.5 | 15.0 | 39.5 | 2.5 | | | 77.0 | 7.5 | | 52.5 | 10.0 | 17.5 |
| False nettle | | | | | 5.0 | | | 2.5 | | 47.5 | 10.0 | 7.5 | | 5.0 | 20.0 | | 5.0 | 2.5 | 17.5 | 12.5 | 57.5 |
| American beautyberry | | 2.5 | 17.5 | | 2.5 | 20.0 | | | 2.5 | | | | | | | | | | | | |
| False hop sedge | | | | | | 2.5 | 2.5 | 2.5 | | | | | | | 2.5 | | | 2.5 | 2.5 | 5.0 | 149.0 |
| Sedge species | | | | | | | | | | | | | | | | | | | 2.5 | | |
| Water hickory | | 2.5 | | | 5.0 | 20.0 | | 5.0 | 2.5 | 30.0 | 2.5 | 37.5 | 2.5 | | | 5.0 | 5.0 | 7.5 | 5.0 | 7.5 | 20.0 |
| Bitter cress | | | | | | | | | | | | | | | | | | 15.0 | | | |
| Jack-in-the-bush | | | | | | 15.0 | | | | | 2.5 | | | | | | | | | | 2.5 |
| Common day flower[2] | | | | | 2.5 | 76.5 | | 7.5 | 92.0 | 85.0 | 22.5 | 22.5 | | 5.0 | 17.5 | 2.5 | 7.5 | 15.0 | 50.0 | 114.5 | 141.5 |
| Swamp lily | | | | | | | | | | | 2.5 | | | | | | | | | | |
| Green flat sedge | | | | | | | | | | | | 127.0 | | | 20.0 | | | 52.0 | | | 302.5 |
| Variable witch grass | | 7.5 | 32.5 | 5.0 | 2.5 | 17.5 | 45.0 | 2.5 | 2.5 | 114.0 | | | 2.5 | | 30.0 | 32.5 | 2.5 | 17.5 | 47.5 | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-10-31. continued

| | MH | | | HH/Rblh3 | | | Rblh3 | | | Rblh2 | | | Rblh1 | | | Rsw1/Rblh2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Cypress witch grass | | | | | 17.5 | | | 64.5 | 2.5 | | | 2.5 | | 7.5 | 17.5 | | | | | 12.5 | 62.5 |
| Witch grass species | | | | | | | | | | 47.5 | | | | | | | | | 139.0 | 2.5 | 2.5 |
| False daisy | | | | | | 2.5 | | | | | | 2.5 | | | | | | | | | 25.0 |
| Fire weed | | | | | | 2.5 | | | | | | | | | 2.5 | | | | | | |
| Dog fennel | | 2.5 | | | | | | | | | | | | 2.5 | | | 2.5 | 5.0 | | | 7.5 |
| Yankee weed | | | | | | | | | | | | 32.5 | | | 2.5 | | | | | | |
| Thoroughwort species | | | | | | | | | | | | 30.0 | | | | | | | | | |
| Pop ash | | | | | | | | | | 15.0 | | | | | | | | | | | |
| Bed straw | | | | | | | | | | | | | | | | | | | | | 15.0 |
| Cud weed | | | | | | | | | | | | 5.0 | | | 7.5 | | | | | | 2.5 |
| Pennywort species | | | | | | | | | 2.5 | | | | 2.5 | | 5.0 | | | | | 2.5 | 15.0 |
| Indian swamp weed[2] | | | | | | | | | | | | | | | | | | | 2.5 | | 37.0 |
| Four petal St. John's wort | | | | | | | | | | | | 20.0 | | | 54.5 | | | | | | 32.5 |
| Moon vine | | | | | | | | | | | 30.0 | | | | | | | | | 5.0 | |
| Blue morning glory | | | | | | | | | 2.5 | 15.0 | 10.0 | 15.0 | 2.5 | | 2.5 | | 2.5 | | | 7.5 | 17.5 |
| Virginia willow | | | | 2.5 | | | 2.5 | | | | | | | | | | | | 20.0 | | |
| Asian marsh weed[2] | | | | | | | | | | | | | | | | | | | | 2.5 | 15.0 |
| Mexican primrose willow | | | | | | | | | | | | | | | | | | | | 2.5 | |
| Peruvian primrose willow | | | | | | | | | | | | | | | | | | | | 2.5 | |
| Creeping primrose willow | | | | | | | | | | | 2.5 | | | | 124.0 | | | 5.0 | | | |
| Primrose willow species seedling | | | | | | | | | | 2.5 | | 2.5 | | | | | 2.5 | 5.0 | | 2.5 | |
| Old World climbing fern[2] | | | | | | | | | 15.0 | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-31. continued**

| | MH | | | HH/Rblh3 | | | Rblh3 | | | Rblh2 | | | Rblh1 | | | Rsw1/Rblh2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species**[1] | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Hemp vine | | | | | | 15.0 | | | | | 2.5 | 5.0 | | | | | | 5.0 | | | 5.0 |
| Wax myrtle | | | | | | | | | | 2.5 | | | | | | | | | | | |
| Guinea grass[2] | | | | | | | | | | | 101.5 | | | | | | | | | 15.0 | 84.5 |
| Redtop panicum | | | | | 2.5 | | | 2.5 | | | | | | | | | | | | 2.5 | |
| Pellitory | | | | | | | | | | | 7.5 | 365.5 | | | 2.5 | | 5.0 | | | 5.0 | 247.5 |
| Elephant grass[2] | | | | | | | | | | | | | | | | | | | | | 15.0 |
| Marsh fleabane | | | | | | | | | | | | 15.0 | | | | | | | | | 7.5 |
| Fleabane species | | | | | | | | | | | | | | | | | | 15.0 | | | |
| Swamp smartweed | | | | | | | | | | | | | | | | | 2.5 | | | 2.5 | 37.5 |
| Dotted smartweed | | | | | | | | | | | | | | | 15.0 | | | | | | 2.5 |
| Smartweed species | | | | | | | | | | | | | | | | | | | | | 15.0 |
| Pouzolz's bush[2] | | | | | | 99.5 | | | 2.5 | | 10.0 | 5.0 | | | 2.5 | | | 7.5 | | | 17.5 |
| Combleaf mermaid weed | | | | | | | | | | | | | | | | | | 2.5 | | | |
| Wild coffee | | 2.5 | 20.0 | 2.5 | | 52.0 | | | | | 2.5 | | | | | | | | 5.0 | | |
| Shortleaf wild coffee | | | | 5.0 | | | 7.5 | | | 47.5 | | | | | | | | | 17.5 | | |
| Bracken fern | | 2.5 | 37.0 | | | | | | | | | | | | | | | | | | |
| Mock bishop weed | | | | | | | | | | | | 30.0 | | | 89.0 | | | | | | 52.5 |
| Laurel oak | | | 5.0 | | | 2.5 | | | | | | 5.0 | | | | | | | | | |
| Oak species seedling | 2.5 | | | | | | | | | 2.5 | | | | | | | | | 2.5 | | |
| Myrsine | | | | 2.5 | | | | | | | | | | | | | | | | | |
| Beak sedge species | | | | | | | | | | | | | | | 15.0 | | | | | | 2.5 |
| Swamp dock | | | | | | | | | | | | 35.0 | | | | | | 15.0 | | 5.0 | 84.5 |
| Cabbage palm | | | 2.5 | | | | | | | 2.5 | | 2.5 | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-10-31. continued

| | MH | | | HH/Rblh3 | | | Rblh3 | | | Rblh2 | | | Rblh1 | | | Rsw1/Rblh2 | | | Rsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Pineland pimpernel | | | | | | | | | | | | | | | | | | 2.5 | | | 2.5 |
| White vine | | | | | | | | | | | | | | | | | | | | 5.0 | |
| Lizard's tail | | | | | | | | | | 2.5 | | | | | | | | | 2.5 | 5.0 | 15.0 |
| Brazilian pepper[2] | | | | | | | | | | | | | | | | | 5.0 | | | | |
| Saw palmetto | 2.5 | 2.5 | | | | | | | | | | | | | | | | | | | |
| Wire weed | | | | | | | | | | 2.5 | 2.5 | 59.5 | | | | | | 7.5 | | | 35.0 |
| Saw greenbrier | | 2.5 | 2.5 | 2.5 | | | | | | 17.5 | | | | | | | | | | | |
| Laurel greenbrier | | | 2.5 | | | 5.0 | | | | | | | | | | | | | | | |
| Common nightshade | | | | | | | | | | | 2.5 | 40.0 | | 2.5 | | | 2.5 | 2.5 | | | 20.0 |
| Common sow thistle | | | | | | | | | | | | | | | | | 2.5 | | | | 15.0 |
| Bald cypress | | | | | | | | | 2.5 | | | | | | 2.5 | | | 2.5 | | | 30.0 |
| Downy shield fern[2] | | | | | | | | | | | | | | | | | | | 2.5 | | |
| Tri-veined fern | | | | 2.5 | 20.0 | | 45.0 | 20.0 | 183.5 | 35.0 | 15.0 | 15.0 | 17.5 | 5.0 | | 15.0 | 2.5 | | 22.5 | 30.0 | 10.0 |
| Cardinal airplant | 2.5 | | | | | | | | | | | | | | | | | | | | |
| Needleleaf airplant | 2.5 | | | | | | | | | | | | | | | | | | | | |
| Poison ivy | | | | 2.5 | 5.0 | 15.0 | 2.5 | 5.0 | | | | 15.0 | | | | | | | 2.5 | | |
| Caesar weed[2] | | 2.5 | 17.5 | | | 37.0 | | | | 72.0 | 10.0 | 82.5 | | | 15.0 | | 2.5 | 2,5 | | | 42.5 |
| Para grass[2] | | | | | | | | | | | | 47.5 | | | | | | | | | |
| Summer grape | | | | | | | | | | | 5.0 | 2.5 | | | | | | | | | |
| Muscadine grape | | 5.0 | | | | 15.0 | | | | | | | | 2.5 | | | | | | | |
| Unidentified sedge (Cyperceae) | | | | | | | | | | 50.0 | | | | | | | | | | | |
| Unidentified grass (Poaceae) | | 2.5 | | | | | | | | 45.0 | | 7.5 | 20.0 | | | | | 2.5 | 303.0 | | 17.5 |
| Unidentified seedling | 2.5 | | 5.0 | 5.0 | | 2.5 | | | | 12.5 | 5.0 | 20.0 | | | | | | 5.0 | 5.0 | | 30.0 |
| Unidentified species | | | | | | | | | | 35.0 | 2.5 | | | | | | | 2.5 | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-32. Ground cover percent cover for Transect 6 by forest type**

| | U | | | Rsw1 | | | UTsw3 | | | UTmix | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red maple | | | 2.5 | | | | | 2.5 | | | | | | | 2.5 |
| Leather fern | | | | | | | 62.5 | 12.5 | 30.0 | | | 2.5 | 52.5 | 20.0 | 89.0 |
| Sessile joyweed[2] | | | | | | 2.5 | | | | | | | | | |
| Pond apple | | | | | 2.5 | 5.0 | 27.5 | 17.5 | 15.0 | | | | 17.5 | 17.5 | 6.0 |
| Water hyssop | | | | | | | 40.0 | 20.0 | 55.0 | | 2.5 | 5.0 | | 2.5 | 17.5 |
| Tar flower | 2.5 | 2.5 | | | | | | | | | | | | | |
| Swamp fern | 54.5 | 7.5 | | 32.5 | | | 182.5 | 12.5 | 25.0 | 30.0 | | | 32.5 | 5.0 | 2.5 |
| Buttonbush | | | | | 2.5 | 15.0 | | | 15.0 | | | | 15.0 | 2.5 | 2.5 |
| Jack-in-the-bush | | 2.5 | | | | | | | | | | | | | |
| Swamp lily | | | | | | | 45.0 | 7.5 | 30.0 | | | | 30.0 | 5.0 | 30.0 |
| Green flat sedge | | | | | | 2.5 | | | | | | | | | |
| Coin vine | | | | | | | | 2.5 | | | | | | | |
| Dwarf cypress witch grass | | | 17.5 | | | | | | | | | | | | |
| Witch grass species | 2.5 | 2.5 | | | | | | | | | | | | | |
| False daisy | | | 2.5 | | | | | | | | | | | | |
| Road grass | | | | | | | 2.5 | | | | | | | | |
| Milk pea | | 2.5 | 7.5 | | | | | | | | | | | | 2.5 |
| Pennywort species | | | | | 5.0 | 15.0 | | | 15.0 | | | | 2.5 | 5.0 | 2.5 |
| Blue morning glory | 2.5 | | | | | | | | | | | | | | |
| Virginia willow | | | | | | | | 2.5 | 2.5 | | | | | | |
| White mangrove | | | | | 5.0 | 2.5 | 7.5 | 105.0 | 47.5 | 2.5 | 7.5 | 2.5 | 22.5 | 55.0 | 75.0 |
| Creeping primrose willow | | | | | 17.5 | 161.5 | | | 2.5 | | | | | | |
| Primrose willow seedling | | | | | 2.5 | 2.5 | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-32. continued**

| | U | | | Rsw1 | | | UTsw3 | | | UTmix | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Old world climbing fern[2] | 15.0 | | | | | | 2.5 | 2.5 | | | | | | | |
| Stagger bush | | 2.5 | 15.0 | | | | | | | | | | | | |
| Fetterbush | 30.0 | | 5.0 | | | | | | | | | | | | |
| Hemp vine | | | | | 2.5 | | | | 15.0 | | 2.5 | | | | |
| Wax myrtle | | | | | | | | | | | | | 2.5 | | |
| Cinnamon fern | | | 79.5 | | | | | | | | | | | | |
| Royal fern | | 2.5 | | 15.0 | 2.5 | 15.0 | | 2.5 | | | | | | | |
| Slash pine | | | 2.5 | | | | | | | | | | | | |
| Pickerel weed | | | | | 2.5 | | | | | | | | | | |
| Strawberry guava | | 2.5 | | | | | | | | | | | | | |
| Whisk-fern | | | | | | | | | | 2.5 | | | 15.0 | | |
| Bracken fern | | 2.5 | 15.0 | | | | | | | | | | | | |
| Myrtle oak | | | 37.0 | | | | | | | | | | | | |
| Live oak | 15.0 | 2.5 | 2.5 | | | | | | | | | | | | |
| Oak species seedling | 2.5 | 5.0 | | | | | | | | | | | | | |
| Myrsine | | | | | | | | | | | | | 2.5 | 2.5 | 15.0 |
| Rubber vine | | | | | | 2.5 | 12.5 | 15.0 | 59.5 | | | | 15.0 | 12.5 | 27.5 |
| Red mangrove | | | | | | 2.5 | 22.5 | 22.5 | 10.0 | 15.0 | 7.5 | | 45.0 | 30.0 | 35.0 |
| Cabbage palm | | 5.0 | 2.5 | | | | | | | | | | | | |
| Carolina willow | | | | | | | | | | | | | | 5.0 | |
| Pineland pimpernel | | | | | | 15.0 | | | | | | | 2.5 | 2.5 | 20.0 |
| White vine | | | | | | | 2.5 | 2.5 | 17.5 | 2.5 | | | 10.0 | | |
| Lizard's tail | | | | | | | | 2.5 | 2.5 | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-32. continued**

| | U | | | Rsw1 | | | UTsw3 | | | UTmix | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Brazilian pepper[2] | | | | | 2.5 | | 5.0 | | 5.0 | | | | 2.5 | 5.0 | 15.0 |
| Saw palmetto | 5.0 | 2.5 | | | | | | | | | | | | | |
| Saw greenbrier | 5.0 | | | | | | | | | | | | | | |
| Laurel greenbrier | | | 2.5 | | | | | | | | | | | | |
| Greenbrier | | 5.0 | | | 7.5 | | | | | | | | | | |
| Bald cypress | | | | | | 2.5 | | | 5.0 | | | | | | 2.5 |
| Tri-veined fern | | | | 2.5 | | | 107.5 | 22.5 | | | | | | | |
| Maiden fern | | | | | | | | 25.0 | | | | | | | |
| Marsh fern | 37.0 | | | | | | | | | | | | | | |
| Cardinal airplant | | 2.5 | 59.5 | | | | | | 2.5 | | | | | | |
| Needleleaf airplant | | | 2.5 | | | | | | | | | | | | |
| Poison ivy | | | | | 2.5 | 15.0 | 17.5 | 12.5 | 50.0 | | | | 5.0 | 12.5 | 52.0 |
| Muscadine grape | | 5.0 | 37.0 | | | | | | | | | | | | |
| Elephant ear[2] | | | | | | | | 15.0 | | | | | | | |
| Unidentified sedge (Cyperaceae) | | | | | 7.5 | | | | | | | | | | |
| Unidentified seedling | | | | | | 2.5 | 15.0 | 5.0 | 17.5 | | | | | | 42.5 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-10-33. Ground cover percent cover for Transect 7 by forest type

| | MH/Rsw1 | | | Rsw1 | | | Rmix | | | UTsw1 | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red maple | | | | | | 2.5 | | 2.5 | 11.0 | | | | | | |
| Leather fern | | | | 2.5 | 2.5 | 32.5 | 30.0 | 5.0 | 20.0 | 5.0 | 5.0 | 47.5 | 20.0 | 5.0 | 104.0 |
| Tooth cup #1 | | | 2.5 | | | 2.5 | | | | | | | | | |
| False indigo | 2.5 | 2.5 | | | 10.0 | 2.5 | | 5.0 | | 2.5 | | | | | |
| Pond apple | | | | | 7.5 | 10.0 | 15.0 | 17.5 | 50.0 | | 12.5 | 27.5 | 2.5 | 2.5 | 25.0 |
| Marlberry | | | | | 2.5 | | | 2.5 | 15.0 | | | | | | |
| Baccharis species | | | | | | | 17.5 | | 39.5 | | | | | | |
| Water hyssop | | | | 2.5 | 10.0 | 67.0 | 2.5 | 17.5 | 2.5 | | 12.5 | 47.5 | | 2.5 | 15.0 |
| Swamp fern | 15.0 | 2.5 | | 97.0 | 10.0 | 30.0 | 65.0 | 12.5 | 80.0 | 2.5 | 2.5 | 15.0 | | 2.5 | |
| False nettle | 2.5 | 2.5 | 2.5 | 2.5 | 5.0 | 20.0 | 2.5 | 10.0 | 27.5 | | | 2.5 | | | 35.0 |
| Buttonbush | | | | 17.5 | 2.5 | 17.5 | 5.0 | 5.0 | 17.5 | | | | | 2.5 | |
| Swamp lily | | | | | | | 45.0 | 20.0 | 47.5 | 30.0 | 10.0 | 32.5 | 5.0 | 2.5 | 2.5 |
| Ceylon hound's tongue | | | | | | | 2.5 | | | | | | | | |
| Coin vine | | | | | | | | 2.5 | | | | | | 2.5 | 2.6 |
| Variable witch grass | | | | | | 2.5 | | | 2.5 | | | | | | |
| Witch grass species | 2.5 | | 2.5 | 2.5 | | | | | | | | | | | |
| Pop ash | | | | | | | | | | | | 2.5 | | | |
| Many flower marsh pennywort | | | | | | 39.5 | | | | | | | | | |
| Whorled marsh pennywort | | | | | | | | | | | | 15.0 | | | |
| Pennywort species | | | | 2.5 | 7.5 | | 2.5 | 5.0 | | | | | | 5.0 | |
| St. John's wort | | | | | | 15.0 | | | 22.5 | | | | | | 17.5 |
| Musky mint | | | | | | | 2.5 | | | | | | | | |
| Gallberry | 15.0 | 2.5 | 15.0 | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.

## Table 3-10-33. continued

| | MH/Rsw1 | | | Rsw1 | | | Rmix | | | UTsw1 | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species**[1] | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Virginia willow | | | | | | | 2.5 | 5.0 | 5.0 | | | | 2.5 | | 2.5 |
| White mangrove | | | | | | | 2.5 | 12.5 | 22.5 | | 17.5 | 65.0 | | 17.5 | 32.5 |
| Creeping primrose willow | | | 15.0 | | | 89.0 | 7.5 | | 15.0 | 5.0 | 7.5 | 290.5 | 15.0 | 2.5 | 87.0 |
| Primrose willow species | | | 15.0 | | | 17.5 | | | | | | | | | |
| Primrose willow species seedling | | 2.5 | | | | | 15.0 | 7.5 | | | | | | | |
| Old world climbing fern[2] | | | | | | | | 2.5 | 2.5 | | | | | | |
| Stagger bush | | | | | | | | 2.5 | | | | | | | |
| Fetterbush | 17.5 | | | | | | | | | | | | | | |
| Hemp vine | | | | | 2.5 | 10.0 | 5.0 | 10.0 | 79.5 | | 17.5 | 32.5 | | 12.5 | 77.0 |
| Horn pod | | | | | | | | 2.5 | | | | | | | |
| Cinnamon fern | 52.0 | | 37.0 | 15.0 | | | | | | | | | | | |
| Royal fern | | | | 60.0 | 7.5 | 52.0 | 57.0 | 10.0 | 52.0 | | | | | | 37.0 |
| Red bay | | | | | | 5.0 | | | | | | | | | |
| Swamp smartweed | | | | | 2.5 | | | 5.0 | | | 2.5 | | | | |
| Dotted smartweed | | | | | | | | | | 2.5 | | | | | |
| Strawberry guava[2] | | | | | 2.5 | | | | | | | | | | |
| Whisk-fern | | | | | | 2.5 | | | | | | 2.5 | | | 17.5 |
| Wild coffee | | | | 2.5 | 2.5 | | 2.5 | 2.5 | | | | | | | |
| Bracken fern | | 5.0 | | | | | | | | | | | | | |
| Sand live oak | | | 2.5 | | | | | | | | | | | | |
| Myrtle oak | | | 15.0 | | | | | | | | | | | | |
| Oak species seedling | 17.5 | 5.0 | | | | | | | | | | | | | |
| Live oak | | | 15.0 | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-33. continued**

| | MH/Rsw1 | | | Rsw1 | | | Rmix | | | UTsw1 | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species**[1] | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Myrsine | | | | 2.5 | | | | | | | | | | | |
| Rubber vine | | | | | | | | | | | | | 7.5 | 5.0 | |
| Red mangrove | | | | | | | | | | | 7.5 | | 20.0 | 12.5 | 5.0 |
| Tooth cup #2 | | | | | | | | 2.5 | | | | | | | |
| Cabbage palm | 15.0 | | | | | | | 2.5 | | | | | | | |
| Coastal rose gentian | | | | | 2.5 | 45.0 | | | 20.0 | | | | | | |
| Carolina willow | | | | | | | | | | 2.5 | | | | | |
| Pineland pimpernel | | 2.5 | 15.0 | | 7.5 | 39.5 | | 7.5 | 32.5 | | | 20.0 | | 10.0 | 2.5 |
| White vine | | | | 5.0 | | | 5.0 | 2.5 | | 12.5 | | 17.5 | 15.0 | 5.0 | 30.0 |
| Lizard's tail | 15.0 | 2.5 | | 25.0 | 12.5 | 60.0 | 50.0 | 20.0 | 67.5 | | | | | | |
| Brazilian pepper[2] | | | | | | | | 2.5 | | | | | | | |
| Saw palmetto | | | 15.0 | | | | | | | | | | | | |
| Saw greenbrier | 2.5 | | | | | | | | | | | | | | |
| Laurel greenbrier | | 2.5 | | | | | | | | | | | | | |
| Greenbrier species | | 2.5 | 2.5 | | | | | | | | | | | | |
| Goldenrod species | | | 15.0 | | | | | | | | | | | | |
| Climbing aster | | | | | | 2.5 | | | 2.5 | | | 5.0 | | | 5.0 |
| Java plum | 2.5 | | | 2.5 | 20.0 | 54.5 | 15.0 | 5.0 | 50.0 | | | 2.5 | | | |
| Bald cypress | | 2.5 | 2.5 | | 2.5 | 12.5 | | 5.0 | 42.5 | | | 27.5 | | | 7.5 |
| Downy shield fern[2] | | | | | | | | | 15.0 | | | | | | |
| Tri-veined fern | | | | 2.5 | 5.0 | 30.0 | 2.5 | 7.5 | 60.0 | | | | | | |
| Marsh fern | | | | 2.5 | | | | | | | | | | | |
| Poison ivy | 15.0 | 2.5 | 2.5 | 17.5 | 10.0 | 52.5 | 25.0 | 17.5 | 67.5 | 11.5 | | 47.5 | 2.5 | 5.0 | 15.0 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-33. continued**

| | MH/Rsw1 | | | Rsw1 | | | Rmix | | | UTsw1 | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Narrowleaf cattail | | | | | | | | | 2.5 | | | | | | |
| Hairy pod cowpea | | 5.0 | | | 2.5 | 17.5 | | 5.0 | | | | 5.0 | | | 2.5 |
| Muscadine grape | 5.0 | 5.0 | 2.5 | | | | | | | | | | | | |
| Tallow wood | | | | | | | | 2.5 | | | | | | | |
| Unidentified sedge (Cyperaceae) | | | | | | | | 2.5 | | | | | | | |
| Unidentified grass (Poaceae) | | | | | | | 15.0 | 5.0 | | | | | | | |
| Unidentified fern | | | | | | | 2.5 | | 2.5 | | | | | | |
| Unidentified seedling | 5.0 | 2.5 | 2.5 | 2.5 | 5.0 | 12.5 | 5.0 | 15.0 | 85.0 | 2.5 | | 30.0 | 2.5 | | 10.0 |
| Unidentified species | | | | | | | 2.5 | 2.5 | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.

## Table 3-10-34. Ground cover percent cover for Transect 8 by forest type

| | HH | | | Rmix | | | UTmix | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species**[1] | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red maple | | 2.5 | 5.0 | | 5.0 | 5.0 | | 2.5 | | | | |
| Leather fern | | | | 2.5 | 7.5 | | 15.0 | 5.0 | 67.0 | | | 17.5 |
| False indigo | | | 15.0 | | 7.5 | 32.5 | | | | | | |
| Pond apple | | 2.5 | 5.0 | | | 5.0 | 67.5 | 10.0 | 85.0 | 37.5 | 7.5 | 87.5 |
| Groundnut | | | | | | | | | 15.0 | | | |
| Salt bush (groundsel tree) | | 2.5 | | | 2.5 | | | 7.5 | | | | |
| Baccharis species | | 2.5 | 2.5 | | | | 32.5 | | 20.0 | 52.0 | | |
| Water hyssop | | 32.5 | | | | 2.5 | 62.5 | 67.5 | 206.0 | 132.0 | 55.0 | 195.5 |
| Swamp fern | 67.0 | 2.5 | 15.0 | 15.0 | | | 84.5 | | 30.0 | 15.0 | | |
| False nettle | | 2.5 | 17.5 | 2.5 | 7.5 | 5.0 | 2.5 | | 30.0 | 17.5 | | 2.5 |
| American beautyberry | | | | | | | | | | | | 2.5 |
| Sedge species | | | | | | | | | 15.0 | | | |
| Buttonbush | | | | 2.5 | | 15.0 | | | 2.5 | | 2.5 | |
| Swamp lily | | 2.5 | | | | | 75.0 | 12.5 | 75.0 | 75.0 | 25.0 | 62.5 |
| Coin vine | | | | | | | | | 2.5 | | | |
| Variable witch grass | | | | | | 2.5 | | | | | | |
| Open flower witch grass | | | | | 5.0 | | | | | | | |
| Witch grass species | | | | | | 2.5 | | 2.5 | | | | |
| Fire weed | | 5.0 | | | 7.5 | | | | | | | |
| Pennywort species | | | | | | 15.0 | 25.0 | 12.5 | 70.0 | 65.0 | 12.5 | 52.5 |
| Many flower marsh pennywort | | | | | | | | | | | | 2.5 |
| Whorled marsh pennywort | | | | | | | | | 2.5 | | | 2.5 |
| Alligator lily | | | | | | | | | 37.0 | | | 62.0 |
| Musky mint | | 2.5 | | | 2.5 | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.

**Table 3-10-34. continued**

| | HH | | | Rmix | | | UTmix | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species**[1] | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| White mangrove | | 2.5 | | | 2.5 | | 60.0 | 25.0 | 25.0 | 92.0 | 30.0 | 57.5 |
| Winged water primrose | | | | | | | | | 69.5 | | | 7.5 |
| Creeping primrose willow | 2.5 | 5.0 | 15.0 | | | 37.0 | 149.0 | 57.0 | 406.5 | 7.5 | 2.5 | 35.0 |
| Mexican primrose willow | | | | | | | | | | 15.0 | | |
| Primrose willow species seedling | 2.5 | 2.5 | | | | | 84.5 | 7.5 | | | 5.0 | |
| Old world climbing fern[2] | 30.0 | 5.0 | 15.0 | 97.0 | 20.0 | 5.0 | | | 15.0 | | 2.5 | |
| Hemp vine | | 5.0 | 45.0 | 2.5 | 7.5 | 5.0 | 37.5 | 5.0 | 80.0 | 15.0 | 5.0 | 17.5 |
| Horn pod | | | 2.5 | | 2.5 | | | | | | | |
| Wax myrtle | | | 2.5 | | | | 15.0 | | | | | |
| Wild Boston fern | | | | 2.5 | | | | | | | | 15.0 |
| Cinnamon fern | | | | | | 15.0 | | | | | | |
| Royal fern | 39.5 | | | 30.0 | 2.5 | 37.0 | 32.5 | 2.5 | 37.0 | | | |
| Redtop panicum | | 2.5 | 30.0 | | 17.5 | | | | | 2.5 | | |
| Red bay | | | | | | | 2.5 | | | | | |
| Slash pine | | | 15.0 | | | | | | | | | |
| Marsh fleabane | | | | | | 15.0 | | 2.5 | 47.5 | | | |
| Swamp smartweed | | 5.0 | 30.0 | | 2.5 | 20.0 | | 2.5 | 50.0 | | 5.0 | 20.0 |
| Dotted smartweed | | | | | | | 2.5 | | | | | |
| Pickerelweed | | 2.5 | | | | 2.5 | | 5.0 | 15.0 | | | 2.5 |
| Strawberry guava[2] | | | | | 2.5 | | | | 15.0 | | | |
| Mock bishops wood | | | | | | | | | | | | 2.5 |
| Myrsine | | | | | 2.5 | 15.0 | 2.5 | | | | | |
| Rubber vine | | | | | | | | | 15.0 | | 7.5 | 45.0 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-34. continued**

| | HH | | | Rmix | | | UTmix | | | UTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species**[1] | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red mangrove | | | | | | | | | | 2.5 | | |
| Winged sumac | | | | | 2.5 | | | | | | | |
| Horned beak sedge | | | | | | | 52.0 | | | 37.0 | | |
| Cabbage palm | | 2.5 | | | | | | | 2.5 | | | |
| Coastal rose gentian | | | | | | | | | 2.5 | | 2.5 | 15.0 |
| Broadleaf arrowhead | | | | | | | | | | 2.5 | | |
| Pineland pimpernel | | 7.5 | 15.0 | | 2.5 | 15.0 | | 7.5 | 5.0 | 17.5 | 20.0 | 62.5 |
| Lizard's tail | 5.0 | 10.0 | 45.0 | 5.0 | 10.0 | 32.5 | 105.0 | 17.5 | 191.0 | 87.0 | 20.0 | 95.0 |
| Brazilian pepper[2] | | 2.5 | 5.0 | | | 5.0 | | | 2.5 | | | 2.5 |
| St. Augustine grass | | | | | 2.5 | | | | | | | |
| Climbing aster | | | 20.0 | | | 5.0 | | | 5.0 | | | |
| Bald cypress | | 5.0 | 45.0 | | 2.5 | 7.5 | | | 57.5 | 2.5 | | 92.0 |
| Tri-veined fern | | | | | | | 15.0 | 2.5 | 17.5 | 15.0 | 2.5 | 54.5 |
| Poison ivy | 2.5 | | | 17.5 | 5.0 | | 22.5 | 2.5 | 24.5 | 17.5 | 5.0 | 30.0 |
| Arrow grass | | | | | | | | 7.5 | | | 32.5 | 92.0 |
| Narrowleaf cattail | | | | | | | | 2.5 | | | | |
| Hairy pod cowpea | | | 30.0 | | | 15.0 | | | 7.5 | | | 2.5 |
| Unidentified sedges (Cyperaceae) | | | | | 2.5 | | | | | | | |
| Unidentified grass (Poaceae) | | | | | | 17.5 | 15.0 | 2.5 | 2.5 | 17.5 | | 17.5 |
| Unidentified juvenile fern | | | | | | | | | 2.5 | | | |
| Unidentified seedling | | | 2.5 | | | 7.5 | | 2.5 | 12.5 | 2.5 | | 17.5 |
| Unidentified species | | | | | | | | | | 15.0 | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-10-35. Ground cover percent cover for Transect 9 by forest type

| | U | | | HH | | | HH/LTsw2 | | | LTmix | | | LTsw2 | | | LTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Rosary pea[2] | 45.0 | 7.5 | 15.0 | 5.0 | 2.5 | | | | | | | | | | | | | |
| Leather fern | | | | 62.0 | | 37.0 | | | | | | | 50.0 | 32.5 | 47.5 | | | |
| Pond apple | | | | | | 52.0 | 7.5 | 2.5 | 32.5 | 7.5 | | 5.0 | 60.0 | | 246.5 | | | 10.0 |
| Water hyssop | | | | | | | 67.0 | | 52.0 | 2.5 | | 62.0 | 62.0 | | 74.0 | 2.5 | 2.5 | 15.0 |
| Swamp fern | | | 15.0 | 15.0 | 2.5 | | | | | | | | | | 15.0 | | | |
| Partridge pea | | | 2.5 | | | | | | | | | | | | | | | |
| Coco plum | 30.0 | 17.5 | 2.5 | 17.5 | 2.5 | 15.0 | 2.5 | | | | | | | | | | | |
| Swamp lily | | | | | | | | | | | | | | | 15.0 | | | |
| Mucronate rattlebox | | 2.5 | | | | | | | | | | | | | | | | |
| False sawgrass | | | | | | | | | | | | | | | | 15.0 | | |
| Coin vine | | | | | | | | 2.5 | 15.0 | | | 2.5 | 5.0 | 5.0 | | | | |
| Florida beggar weed[2] | | | 37.0 | | | | | | | | | | | | | | | |
| Three-flower beggar weed[2] | 2.5 | | | | | | | | | | | | | | | | | |
| Witch grass species | | 5.0 | 5.0 | | | 2.5 | | | | | | | | | | | | |
| Milk pea | | | 15.0 | | | | | | | | | | | | | | | |
| Pennywort species | | | | | | | | | | | | | | | 2.5 | | | |
| White mangrove | | | | | 5.0 | 5.0 | | 7.5 | 32.5 | 5.0 | 7.5 | 17.5 | 72.5 | 72.5 | 57.5 | 60.0 | 37.5 | 15.0 |
| Sensitive brier | 2.5 | 2.5 | 2.5 | | | | | | | | | | | | | | | |
| Woods grass | | 2.5 | 15.0 | | | | | | | | | | | | | | | |
| Silk grass | | 5.0 | 37.0 | | | | | | | | | | | | | | | |
| Laurel oak | | | 2.5 | | | | | | | | | | | | | | | |
| Myrtle oak | | 20.0 | 2.5 | | | | | | | | | | | | | | | |
| Rubber vine | | | | | | | 7.5 | | 5.0 | 2.5 | 2.5 | 5.0 | 27.5 | 30.0 | 167.0 | 15.0 | 2.5 | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-35. continued**

| | U | | | HH | | | HH/LTsw2 | | | LTmix | | | LTsw2 | | | LTsw1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Red mangrove | | | | | | | | | 2.5 | | | | 10.0 | 15.0 | 2.5 | 115.0 | 15.0 | 80.0 |
| Cabbage palm | 5.0 | 5.0 | 2.5 | | 2.5 | 15.0 | 7.5 | | | | | | 17.5 | 2.5 | 15.0 | | | |
| Brazilian pepper[2] | | | 2.5 | | | | | | | | | | | | | | | |
| Saw palmetto | | | | 15.0 | | | | | | | | | | | | | | |
| Slender sea purslane | | | | | | | | | | | 2.5 | | | 5.0 | | | | |
| Wire weed | | | | | | | | | | | | | | | 2.5 | | | |
| Laurel greenbrier | | 2.5 | | | | | | | | | | | | | | | | |
| False buttonweed[2] | | 5.0 | 15.0 | | | | | | | | | | | | | | | |
| Smut grass[2] | | 37.0 | 15.0 | | | | | | | | | | | | | | | |
| Bald cypress | | | | | | | | | | | | | | | 2.5 | | | |
| Spanish moss | | 2.5 | | | | | | | | | | | | | | | | |
| Hairypod cowpea | | | | | | 2.5 | | | | | | | | | 7.5 | | | |
| Muscadine grape | 15.0 | 2.5 | | | | | | 2.5 | | | | | | | | | | |
| Unidentified grass (Poaceae) | 17.5 | 5.0 | | 7.5 | | | | | | | | | | | | | | 2.5 |
| Unidentified juvenile fern | | | 37.0 | | | | | | | | | | | | 2.5 | | | |
| Unidentified seedling | | | | | | | | | 2.5 | | | | | | 2.5 | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

## Table 3-10-36. Ground cover percent cover for Transect 10 by forest type

| | HH/M | | | M | | | UTmix | | | HH | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species[1] | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Leather fern | | | | | | | | 5.0 | 2.5 | | | | | | |
| Pond apple | | | 5.0 | 2.5 | 2.5 | 17.5 | 45.0 | 15.0 | 40.0 | 15.0 | 2.5 | 2.5 | 17.5 | | 5.0 |
| Salt bush (groundsel tree) | | 2.5 | | | | | | 5.0 | | | | | | | |
| Baccharis species | | | | | | | 2.5 | | 2.5 | | | | | | |
| Water hyssop | | 134.0 | 5.0 | | 5.0 | | 109.5 | 60.0 | 124.0 | | 2.5 | 2.5 | | 2.5 | 15.0 |
| Swamp fern | 15.0 | | | 15.0 | | 2.5 | 122.5 | 12.5 | 54.5 | 15.0 | 2.5 | 15.0 | 15.0 | | 2.5 |
| Buttonbush | | | | | | | | | 2.5 | | | | | 2.5 | |
| Sawgrass | | 2.5 | | | | | 15.0 | 2.5 | 2.5 | | | | | | 15.0 |
| Swamp lily | | | | | | | 30.0 | 10.0 | 30.0 | | | | 30.0 | 2.5 | 37.0 |
| Flat sedge | | | | | | | 2.5 | | | | | | 2.5 | | |
| Coin vine | | | | | | | | 2.5 | 2.5 | | | | | | |
| Witch grass species | | | | | | | | | 2.5 | | | | | | |
| Dog fennel | | 2.5 | | | | | | | | | | | | | |
| Pennywort species | | 2.5 | 2.5 | | | | | | | | | | 15.0 | | |
| Dahoon holly | | | | | | | | | 15.0 | | | | | | |
| White mangrove | | 2.5 | 17.5 | | 5.0 | 15.0 | 40.0 | 22.5 | 10.0 | 15.0 | 2.5 | 2.5 | 17.5 | 5.0 | 17.5 |
| Creeping primrose willow | | | | | | | 15.0 | | | | | | | | |
| Old World climbing fern[2] | | 37.0 | 104.0 | | 2.5 | 99.0 | | 5.0 | 17.5 | | | | 2.5 | 2.5 | 2.5 |
| Hemp vine | | 2.5 | | | | | 2.5 | | | | | | 15.0 | | |
| Wax myrtle | | | | | | | | | 2.5 | | | | 2.5 | | |
| Red top panicum | | | | | | | 30.0 | | 15.0 | | | | | | |
| Switch grass | | | | | | | | 2.5 | | | | | | | |
| Resurrection fern | | | | 2.5 | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-10-36. continued**

| | HH/M | | | M | | | UTmix | | | HH | | | UTsw2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Marsh fleabane | | | | | | | | | 2.5 | | | | | | 2.5 |
| Swamp smartweed | 2.5 | | | | | | 35.0 | | 2.5 | | | | 15.0 | | 17.5 |
| Strawberry guava[2] | | | | | | | 15.0 | | | | | 15.0 | | | |
| Whisk-fern | | | | 2.5 | | | | | | | | | | | |
| Rubber vine | | | | 2.5 | | | | 7.5 | 20.0 | | | | 2.5 | | 15.0 |
| Red mangrove | | | | | | | | | 5.0 | | | | | | |
| Lowland tooth cup | | | | | 2.5 | | | | | | | | | | 2.5 |
| Cabbage palm | | | | | | | 2.5 | 2.5 | | | | | | | |
| Pineland pimpernel | | | | | | | | | 2.5 | | | | | | |
| White vine | | | | | | | 12.5 | | 2.5 | | | | | | |
| Brazilian pepper[2] | | | 2.5 | | | | 10.0 | | | | | | 2.5 | | |
| Saw palmetto | | | | 2.5 | | | | | | | | | | | |
| Poison ivy | | | | | 2.5 | | 2.5 | | | | | 15.0 | 15.0 | | |
| Arrow grass | | | 2.5 | | | | | 2.5 | | | | | | | |
| Shoestring fern | | | | | | | | | 15.0 | | | | | | |
| Unidentified sedge (Cyperaceae) | | | | | | | 2.5 | | | | | | | | |
| Unidentified grass (Poaceae) | | | | | | 2.5 | 5.0 | 2.5 | | | 2.5 | 15.0 | | | |
| Unidentified seedling | | | 2.5 | | | | | 5.0 | 2.5 | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

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# APPENDIX 3-11

# THREE-YEAR SUMMARY OF GROUND COVER FREQUENCY OF OCCURRENCE

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**Table 3-11-37. Ground cover percent frequency of occurrence for each transect and each survey year**

| | Percent Frequency Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | |
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Rosary pea[2] | 0.07 | | | | | | | | | | | | | | | | | 0.13 | | | | | | | 0.10 | 0.10 | 0.05 | | | |
| Red maple | 0.20 | 0.06 | | | | | 0.15 | 0.31 | 0.15 | 0.33 | 0.25 | 0.17 | 0.36 | | 0.86 | | 0.63 | | | 0.07 | 0.30 | | 0.33 | 0.25 | | | | | | |
| Leather fern | 0.27 | 0.65 | | 0.08 | 0.15 | 0.08 | | | | | | | | | | 0.56 | 0.63 | 0.31 | 0.38 | 0.47 | 0.80 | 0.18 | 0.25 | 0.42 | 0.25 | 0.45 | 0.20 | | 0.25 | 0.13 |
| Blue mink[2] | | | | | | | | | | | | | | 0.07 | 0.36 | | | | | | | | | | | | 0.85 | | | |
| Alligator weed[2] | 0.07 | 0.24 | 0.07 | | | 0.15 | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| Sessile joyweed[2] | 0.27 | | | | | | | | | | | | | 0.07 | | | | 0.06 | | | | | | | | | | | | |
| Joy weed[2] | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | | |
| Tooth cup #1 | | | | | | | | | | | | | | | | | | | | | 0.13 | | | | | | | | | |
| False indigo | | | | | | | | | | | | | | | | | | | 0.13 | 0.27 | 0.07 | | 0.17 | 0.25 | | | | | | |
| Pond apple | 0.20 | 0.06 | 0.07 | 0.08 | 0.08 | 0.08 | 0.15 | 0.69 | 0.23 | | 0.50 | 0.08 | | | 0.07 | 0.69 | 0.63 | 0.31 | 0.13 | 0.80 | 0.80 | 0.55 | 0.42 | 1.00 | 0.65 | 0.05 | 0.85 | 0.88 | 0.75 | 1.00 |
| Groundnut | | | | | | | 0.08 | 0.08 | 0.15 | | | | | | | | | | | | | | | 0.08 | | | | | | |
| Marlberry | 0.07 | | | 0.23 | 0.23 | 0.23 | | | | | | | 0.07 | 0.07 | 0.14 | | | | | 0.13 | 0.07 | | | | | | | | | |
| Salt bush (silverling) | | | | | | | | | | | | | 0.07 | | | | | | 0.06 | | | 0.27 | | | | | | 0.13 | | |
| Salt bush (groundsel tree) | | | | | | | | | | | | | | | | | | | | 0.07 | | | 0.33 | 0.25 | | | | | 0.25 | 0.25 |
| Baccharis species | | | | | | | 0.08 | | | | | 0.08 | | | | | | | | | | | 0.08 | | | | | | | |
| Water hyssop species | | | | | | | | | | | | | | | | 0.25 | 0.44 | 0.44 | 0.13 | 0.47 | 0.47 | 0.27 | 0.75 | 0.75 | 0.20 | 0.05 | 0.20 | 0.50 | 1.00 | 0.88 |
| Tar flower | | | | | | | | | | | | | | | | 0.06 | 0.06 | | | | | | | | | | | | | |
| Beggar ticks | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | | | |
| Bishop wood[2] | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | | | |
| Swamp fern | 0.33 | 0.29 | 0.30 | 0.62 | 0.69 | 0.85 | 0.31 | 0.31 | 0.23 | 0.50 | 0.33 | 0.42 | 0.93 | 0.71 | 0.43 | 0.69 | 0.44 | 0.31 | 0.50 | 0.60 | 0.47 | 0.55 | 0.08 | 0.25 | 0.05 | 0.05 | 0.10 | 1.00 | 0.50 | 0.63 |
| False nettle | 0.20 | 0.53 | | 0.08 | 0.54 | 0.31 | 0.23 | 0.62 | 0.46 | 0.17 | 0.50 | 0.58 | 0.43 | 0.71 | 0.57 | | | 0.06 | 0.19 | 0.47 | 0.60 | 0.36 | 0.25 | 0.50 | | | | | | |
| American beautyberry | 0.07 | | 0.13 | 0.23 | 0.15 | 0.08 | | | | | | 0.17 | | 0.14 | 0.21 | | | | | | | | | 0.08 | | | | | | |
| Golden canna | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | | | |
| Bitter cress | 0.20 | | | | 0.08 | 0.08 | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| False hop sedge | | 0.18 | | | 0.08 | | | | | | | 0.25 | 0.21 | 0.21 | 0.43 | | | | | | | | | | | | | | | |
| Hop sedge species | | | | | | 0.08 | | | | | | | | | | | | | | | | | | 0.08 | | | | | | |
| Water hickory | | | | 0.23 | | 0.15 | | | 0.08 | 0.17 | 0.58 | 0.42 | 0.43 | 0.5 | 0.5 | | | | | | | | | | | | | | | |
| Buttonbush | | | | | | | | | 0.08 | | 0.08 | | | | | 0.06 | 0.13 | 0.19 | 0.25 | 0.27 | 0.20 | 0.09 | 0.08 | 0.17 | | | | | 0.13 | 0.13 |
| Partridge pea | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | 0.05 | | | |
| Jack-in-the-bush | | | | | | | | | | | | | | 0.07 | 0.14 | | 0.06 | | | | | | | | | | | | | |
| Coco plum | | | 0.07 | | 0.15 | | | | | | | | | | | | | | | | | | | | 0.15 | 0.10 | 0.10 | | | |
| Sawgrass | | | | | | 0.15 | | | | | | | | | | | | | | | | | | | | | | 0.13 | 0.25 | 0.25 |
| Wild taro[2] | 0.07 | 0.06 | 0.57 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Common dayflower[2] | 0.27 | 0.24 | 0.3 | 0.38 | 0.15 | 0.31 | 0.15 | 0.15 | | | | 0.79 | 0.57 | 0.93 | | | | | | | | | | | | | | | | |
| Swamp lily | 0.47 | 0.41 | 0.27 | 0.38 | 0.38 | 0.31 | 0.38 | 0.46 | | 0.42 | 0.25 | 0.25 | | 0.07 | | 0.25 | 0.25 | 0.25 | 0.44 | 0.33 | 0.40 | 0.45 | 0.50 | 0.50 | | | 0.05 | 0.25 | 0.38 | 0.25 |
| Mucronate rattlebox | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | | |
| Ceylon hound's tongue | | | | | | | | | | | | | | | | | | | 0.06 | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-11-37. continued**

| | Percent Frequency Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | | Transect 5 | | | Transect 6 | | | Transect 7 | | | Transect 8 | | | Transect 9 | | | Transect 10 | | |
| Species[1] | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Flat sedge | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.25 | | |
| False sawgrass | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | | | |
| Pine barren flat sedge | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Green flat sedge | | | | | | | | | | | | | | | 0.50 | | | 0.06 | | | | | | | | | | | | |
| Sedge seedling | | | | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | |
| Coin vine | | | | | | | | | | | | | | | | | 0.06 | | | 0.13 | 0.07 | | | 0.08 | 0.05 | 0.10 | 0.10 | | 0.13 | 0.13 |
| Florida beggar weed[2] | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | |
| Three-flower beggar weed[2] | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | | | |
| Variable witchgrass | 0.07 | | | | | | | | | | | | | | | | 0.06 | | | | | | | | | | | | | |
| Witch grass species | | 0.12 | 0.13 | 0.31 | 0.38 | 0.31 | 0.38 | 0.46 | 0.31 | 0.83 | 0.66 | 0.50 | 0.72 | 0.36 | 0.43 | 0.06 | | | 0.06 | | 0.20 | | 0.08 | 0.16 | | 0.05 | 0.10 | | | 0.13 |
| Cypress witch grass | | | | | | | | | 0.08 | | | | | | 0.43 | | | | | | | | | | | | | | | |
| Dwarf cypress witch grass | | | | | | 0.08 | | | | | | | | | | | | 0.13 | | | | | | | | | | | | |
| Open flower witch grass | | | | | | | | | 0.08 | | 0.08 | 0.08 | | | | | | | | | | | 0.08 | | | | | | | |
| False daisy | | | | | | | | | | | | | | | 0.36 | | | 0.06 | | | | | | | | | | | | |
| Road grass | | | | | 0.08 | | | | | | | | | | | 0.06 | | | | | | | | | | | | | | |
| Fire weed | | 0.06 | | | 0.15 | | 0.08 | | | | | | | | 0.14 | | | | | | | | 0.25 | | | | | | | |
| Dog fennel | | | | | | | | | | | | | | 0.21 | 0.21 | | | | | | | | | | | | | | 0.13 | |
| Yankee weed | | | | | | | | | | | | | | | 0.29 | | | | | | | | | | | | | | | |
| Indian laurel ficus[2] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pop ash | | | | | | | 0.23 | 0.54 | | | 0.75 | 0.25 | 0.07 | | | | | | | | 0.07 | | | | | | | | | |
| Milk pea | | | | | | | 0.08 | 0.08 | 0.38 | | | | | | | | 0.06 | 0.19 | | | | | | | | | 0.05 | | | |
| Bed straw | | 0.24 | 0.07 | | 0.08 | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| Cud weed | | | | | | | | | | | | | | | 0.29 | | | | | | | | | | | | | | | |
| Pennywort species | 0.33 | 0.29 | 0.3 | 0.31 | 0.23 | 0.31 | 0.15 | 0.38 | 0.08 | 0.83 | 0.08 | | 0.07 | 0.14 | | 0.06 | 0.13 | 0.19 | 0.13 | 0.47 | | 0.45 | 0.42 | 0.67 | | | 0.05 | 0.13 | 0.13 | 0.13 |
| Many flower marsh pennywort | | | | | | | | | | | | | | | | | | | | | 0.07 | | | 0.08 | | | | | | |
| Whorled marsh pennywort | | | | | | | | | | | | | | | | | | | | | 0.07 | | | 0.17 | | | | | | |
| Indian swamp weed[2] | | 0.06 | | | | | | | | | 0.17 | 0.33 | 0.07 | | 0.07 | | | | | | | | | | | | | | | |
| Aligator lily | | | | | | | | | | | | | | | | | | | | | | | | 0.17 | | | | | | |
| Roundpods St. John’s wort | | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | | |
| St. John’s wort species | | | | | | | | | | | | | | | 0.21 | | | | | | | | | | | | | | | |
| Four petal St. John's wort | | | | | | | | | | | | | | | 0.36 | | | | | | | | | | | | | | | |
| Musky mint | | | | | | | | 0.15 | 0.08 | | | 0.08 | | | | | | | 0.06 | | | | 0.17 | | | | | | | |
| Dahoon holly | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.13 |
| Gallberry | | | | | | | | | | | | | | | | | | | 0.06 | 0.07 | 0.07 | | | | | | | | | |
| Moon vine | | | | | 0.15 | | | | | | | | | 0.43 | | | | | | | | | | | | | | | | |
| Blue morning glory | | | | 0.08 | 0.23 | | 0.38 | 0.46 | | 0.08 | | | 0.14 | 0.36 | 0.29 | 0.06 | | | | | | | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-11-37. continued**

| | Percent Frequency Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Transect 1** | | | **Transect 1** | | | **Transect 1** | | | **Transect 1** | | | **Transect 1** | | | **Transect 1** | | | **Transect 1** | | | **Transect 1** | | | **Transect 1** | | | **Transect 1** | | |
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Virginia willow | | | | 0.15 | 0.15 | 0.23 | 0.15 | 0.08 | 0.08 | 0.42 | 0.08 | 0.50 | 0.21 | | | | 0.06 | 0.06 | 0.13 | 0.07 | 0.20 | | | | | | | | | |
| White mangrove | | | | | | | | | | | | | | | | 0.38 | 0.88 | 0.81 | 0.25 | 0.60 | 0.60 | 0.64 | 0.67 | 0.67 | 0.80 | 0.85 | 0.75 | 0.75 | 1.00 | 0.88 |
| Asian marsh weed[2] | | | | | | | | 0.15 | 0.08 | 0.08 | 0.33 | 0.33 | | 0.07 | 0.07 | | | | | | | | | | | | | | | |
| Winged water primrose | | | | | | | | | | | | | | | | | | | | | | | | 0.33 | | | | | | |
| Mexican primrose willow | | | | | | | | | | | | | | 0.07 | | | | | | | | 0.09 | | | | | | | | |
| Peruvian primerose willow[2] | | | | | | | | | | | | | | 0.07 | | | | | | 0.27 | | | | | | | | | | |
| Creeping primrose willow | | 0.24 | 0.07 | | 0.08 | 0.23 | 0.08 | 0.23 | | 0.17 | 0.25 | 0.67 | | | 0.14 | | 0.13 | 0.13 | 0.31 | 0.33 | 0.87 | 0.45 | 0.42 | 0.75 | | | | 0.13 | | |
| Primrose willow species | | | | | | | | | | | | | | 0.07 | | | | | | | 0.30 | | | | | | | | | |
| Primrose willow seedling | 0.07 | 0.18 | | | 0.08 | | 0.23 | | | | | | 0.07 | 0.14 | 0.14 | | 0.06 | 0.06 | 0.06 | 0.33 | | 0.27 | 0.33 | 0.17 | | | | | | |
| Old World climbing fern[2] | | | 0.07 | | 0.08 | 0.08 | 0.08 | | 0.08 | 0.17 | 0.17 | | | | 0.07 | 0.13 | 0.13 | | | 0.13 | 0.07 | 0.18 | 0.25 | 0.25 | | | | 0.13 | 0.63 | 0.63 |
| Stagger bush | | | | | | | | | | | | | | | | 0.13 | 0.06 | 0.06 | | 0.07 | | | | | | | | | | |
| Fetterbush; shiny lyonia | | | | | | | | | | | | | | | | | | 0.13 | 0.06 | 0.07 | | | | | | | | | | |
| Square stem | | | | | | | 0.08 | 0.08 | 0.08 | | | | | | | | | | | | | | | | | | | | | |
| Baby tears | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | | | |
| Hemp vine[2] | | 0.12 | 0.07 | 0.15 | 0.31 | 0.08 | 0.08 | 0.31 | 0.2 | | 0.42 | 0.08 | | 0.07 | 0.43 | | 0.13 | 0.06 | 0.13 | 0.80 | 0.87 | 0.45 | 0.50 | 0.58 | | | | 0.25 | 0.13 | |
| Sensitive brier | | | | | | | 0.08 | | | | 0.08 | | | | | | | | | | | | | | 0.05 | 0.05 | 0.05 | | | |
| Horn pod | | | | | | | | | | | | 0.08 | | | | | | | | | | | | 0.08 | | | | | | |
| Wax myrtle | | | | | | | | | | | | | 0.07 | | | 0.06 | | | | | | 0.09 | | 0.08 | | | | 0.13 | | 0.13 |
| Wild Boston fern | | | 0.07 | | 0.08 | 0.08 | | | | | | | | | | | | | | | | 0.09 | | 0.08 | | | | | | |
| Cinnamon fern | | | | | | | | | | | | | | | | | | 0.13 | 0.13 | | 0.07 | | | 0.08 | | | | | | |
| Woods grass | | 0.06 | 0.07 | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | |
| Royal fern | 0.07 | | | | | 0.08 | 0.15 | | 0.08 | 0.08 | | | | | | 0.06 | 0.19 | 0.06 | 0.31 | 0.27 | 0.27 | 0.45 | 0.17 | 0.17 | | 0.05 | | | | |
| Guineagrass[2] | | | | | | | | | | | | | | 0.07 | 0.07 | | | | | | | | | | | | | | | |
| Redtop panicum | | | 0.20 | | | | 0.08 | | | 0.08 | 0.17 | 0.17 | | 0.14 | | | | | | | | 0.09 | 0.17 | 0.08 | | | | | | |
| Switch grass | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.13 | | 0.13 |
| Pellitory | | 0.47 | 0.40 | | 0.31 | | | 0.31 | | | | | | 0.43 | 0.57 | | | | | | | | | | | | | | | |
| Virginia creeper | 0.20 | 0.24 | | | 0.15 | 0.38 | | | | 0.17 | 0.08 | 0.17 | | | | | | | | | | | | | | | | | | |
| Elephant grass[2] | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| Red bay | | 0.06 | | | | | | | | | | | | | | | | | | | 0.07 | 0.09 | | | | | | | | |
| Golden polypody | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | | | | | |
| American pokeweed | | | | | 0.15 | 0.08 | | | | | | | | | | | | | | | | | | | | | | | | |
| Slash pine | | | | | | | | | 0.08 | | | | | | | | | 0.06 | | | | | | 0.08 | | | | | | |
| Water lettuce | | | 0.07 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Silkgrass | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | | |
| Resurrection fern | | | | | | | | | | 0.08 | | 0.08 | | | | | | | | | | | | | | | 0.05 | 0.13 | | |
| Marsh fleabane | | | | | | | | | | | | | | | 0.29 | | | | | | | | 0.08 | 0.25 | | | | | | 0.25 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-11-37. continued**

| Species[1] | Percent Frequency Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | |
| | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 | 2003 | 2007 | 2010 |
| Fleabane species | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| Swamp smartweed | | | 0.07 | | 0.08 | | | 0.38 | | | 0.25 | | | 0.14 | 0.21 | | | | | 0.27 | | | 0.50 | 0.58 | | | | 0.50 | | 0.25 |
| Dotted smartweed | | | | | | | | | | | | | | | 0.14 | | | | 0.06 | | | 0.27 | | | | | | | | |
| Smartweed species | | | | | | | | | 0.38 | | | 0.58 | | | 0.07 | | | | | | | | | | | | | | | |
| Pickerelweed | | | | | | | | 0.08 | | | | | | | | | 0.06 | | | | | | 0.25 | 0.25 | | | | | | |
| Pouzolz's bush[2] | | | | | 0.08 | | | | | | | | | 0.21 | 0.57 | | | | | | | | | | | | | | | |
| Combleaf mermaid weed | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| Strawberry guava[2] | | | | | | | | | | | | | | | | | 0.06 | | | 0.07 | | | 0.08 | 0.08 | | | | 0.13 | | 0.13 |
| Whisk-fern | | | | | | | | | | | | | | | | 0.13 | | | | | 0.27 | | | | | | | 0.13 | 0.13 | |
| Wild coffee | 0.20 | 0.06 | 0.07 | 0.31 | 0.08 | 0.38 | 0.08 | 0.15 | 0.23 | 0.08 | 0.08 | | 0.21 | 0.21 | 0.14 | | | | 0.13 | 0.13 | | | | | | | | | | |
| Shortleaf wild coffee | 0.13 | 0.06 | 0.13 | 0.08 | 0.15 | 0.31 | 0.54 | 0.15 | 0.23 | 0.17 | 0.17 | 0.17 | 0.36 | 0.07 | | | | | | | | | | | | | | | | |
| Bracken fern | | | | | | | | | | | | | | 0.07 | 0.07 | | 0.06 | 0.06 | | 0.07 | 0.07 | | | | | | | | | |
| Mock bishops weed | | 0.12 | | | 0.15 | 0.08 | | | 0.08 | | | 0.17 | | | 0.50 | | | | | | | | | 0.08 | | | | | | |
| Laurel oak | | 0.06 | 0.20 | | 0.08 | 0.31 | | 0.23 | | | | | | | 0.21 | | | | | | | | | | | | 0.05 | | | |
| Sand live oak | | | | | | | | | | | | | | | | | | | | | 0.07 | | | | | | | | | |
| Myrtle oak | | | | | | | | | | | | | | | | | | 0.06 | | | 0.07 | | | | 0.05 | 0.05 | 0.05 | | | |
| Oak seedling | 0.13 | | | | | | 0.08 | | | | | | 0.21 | | | 0.06 | 0.06 | | 0.06 | 0.07 | | | | | | | | | | |
| Live oak | 0.07 | | 0.07 | | | | 0.08 | | | 0.08 | 0.08 | | | | | 0.06 | 0.06 | 0.06 | | | 0.07 | | | | | | | | | |
| Myrsine | | | | | | 0.08 | 0.08 | | 0.08 | | | | 0.07 | | | 0.06 | 0.06 | 0.06 | 0.06 | | | 0.09 | 0.08 | 0.08 | | | | | | |
| Rubber vine | | | | | | | | | | | | | | | | 0.38 | 0.44 | 0.50 | 0.13 | 0.07 | | | 0.25 | 0.33 | 0.45 | 0.55 | 0.60 | 0.25 | 0.38 | 0.38 |
| Red mangrove | | | | | | | | | | | | | | | | 0.69 | 0.69 | 0.63 | 0.19 | 0.20 | 0.13 | 0.09 | | | 0.35 | 0.35 | 0.25 | | | 0.13 |
| Horned beak sedge | | | | | | | 0.08 | | | | | | | | | | | | | | | 0.18 | | | | | | | | |
| Few flower beak sedge | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | | | |
| Beak sedge species | | | | | | | | | | | | | | | 0.14 | | | | | | | | | | | | | | | |
| Rouge Plant | | 0.12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tooth cup #2 | | | | | | | | | | | | | | | | | | | | 0.07 | | | | | | | | | 0.03 | 0.13 |
| Blueberry | | | | | | | 0.15 | 0.08 | 0.08 | | | | | | | | | | | | | | | | | | | | | |
| Swamp dock | | | | | | | | | | | | | | 0.14 | 0.50 | | | | | | | | | | | | | | | |
| Cabbage palm | 0.33 | 0.12 | 0.27 | 0.23 | | 0.15 | 0.08 | 0.08 | 0.08 | 0.08 | | 0.08 | 0.07 | | 0.14 | | 0.06 | 0.06 | 0.06 | | 0.07 | | 0.17 | 0.08 | 0.40 | 0.15 | 0.15 | 0.13 | 0.13 | |
| Coastal rose gentian | | | | | | | | | | | | | | | | | | | | 0.07 | 0.30 | | 0.08 | 0.17 | | | | | | |
| Broadleaf arrow head | | | | | | | 0.08 | | | 0.08 | | | | | | | | | | | | 0.09 | | | | | | | | |
| Carolina willow | | | | | | | | | | | | | | | | | 0.06 | | 0.06 | | 0.13 | | | | | | | | | |
| Water spangles[2] | | | 0.07 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pineland pimpernel | | | | | 0.08 | 0.08 | | 0.23 | 0.15 | | 0.08 | 0.25 | | | 0.14 | 0.06 | 0.13 | 0.25 | | 0.8 | 0.6 | 0.09 | 0.58 | 0.58 | | | | | | 0.13 |
| White vine | | | | | | | 0.08 | | 0.15 | | | | | 0.07 | | 0.31 | 0.06 | 0.13 | 0.63 | 0.33 | 0.27 | | | | | | | 0.50 | | 0.13 |
| Lizard’s tail | 0.47 | 0.41 | 0.60 | 0.54 | 0.54 | 0.54 | 0.77 | 0.69 | 0.54 | 0.67 | 0.67 | 0.75 | 0.14 | 0.14 | 0.07 | | 0.06 | 0.06 | 0.50 | 0.53 | 0.47 | 0.91 | 0.92 | 0.83 | | | | | | |
| Brazilian pepper[2] | | 0.18 | 0.07 | | 0.08 | | 0.23 | 0.15 | | | 0.25 | | | 0.07 | | 0.19 | 0.13 | 0.19 | | 0.07 | | | 0.08 | 0.33 | | | 0.05 | 0.50 | 0.13 | 0.13 |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-11-37. continued**

| | Percent Frequency Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | |
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Climbing cassia[2] | 0.07 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Saw palmetto | | | | 0.08 | | | | | | 0.08 | 0.08 | | 0.07 | 0.07 | | 0.13 | 0.06 | | | | 0.07 | | | | 0.05 | | | 0.13 | | |
| Sea purslane | | | | | | | | | | | | | | | | | | | | | | | | | | 0.10 | | | | |
| Wire weed | | | | | | | | | | | | | 0.07 | 0.07 | 0.5 | | | | | | | | | | | | 0.05 | | | |
| Earleaf freenbrier | | | | | 0.08 | | | 0.23 | 0.15 | | | | | | | | | | | | | | | | | | | | | |
| Saw greenbrier | 0.13 | 0.06 | | | | | 0.23 | 0.08 | 0.15 | 0.08 | 0.08 | 0.08 | 0.21 | 0.07 | 0.07 | 0.13 | | | 0.06 | | | | | | | | | | | |
| Laurel greenbrier | | 0.06 | 0.13 | | | | | | | | | | | | 0.21 | | | 0.06 | | 0.07 | | | | | | 0.05 | | | | |
| Greenbrier species | 0.80 | | 0.30 | 0.62 | 0.31 | 0.08 | 0.54 | 0.31 | 0.54 | 0.50 | 0.33 | 1.00 | 0.64 | 0.14 | 0.43 | 0.25 | 0.26 | 0.69 | 0.44 | 0.54 | 0.94 | 0.09 | 0.08 | 0.75 | | | 0.10 | | 0.25 | 0.13 |
| Greenbrier seedling | | | | | | | | | | 0.17 | | | | | | | | | | | | | | | | | | | | |
| Common nightshade | | | | | 0.08 | | | | | | | | | 0.21 | 0.43 | | | | | | | | | | | | | | | |
| Chapman's goldenrod | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Goldenrod species | | | | | | | | | | | | | | | | | | | | | 0.07 | | | | | | | | | |
| Common sow thistle | | | | | | | | | | | | | | | 0.07 | | | | | | | | | | | | | | | |
| False buttonweed[2] | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | |
| Creeping oxeye; wedelia[2] | 0.07 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Smut grass[2] | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | 0.05 | | | |
| St. Augustine grass | | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | | | | | |
| Climbing aster | | | | | | | | | | | | | | | | | | | | | 0.40 | | | 0.42 | | | | | | |
| Nephthytis[2] | 0.13 | 0.06 | 0.20 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Java plum[2] | | | | | | | | | | | | | | | | | | | 0.19 | 0.13 | 0.53 | | | | | | | | | |
| Bald cypress | | | | | | | | 0.08 | | | | 0.08 | | | 0.43 | | | 0.31 | | 0.40 | 0.87 | 0.09 | 0.25 | 0.92 | | | 0.05 | | | |
| Downy shield fern[2] | 0.13 | 0.12 | 0.27 | 0.08 | | 0.15 | | 0.08 | 0.08 | 0.08 | | | 0.07 | | | | | | | 0.07 | 0.07 | | | | | | | | | |
| Tri-veined fern | 0.53 | 0.53 | 0.53 | 0.54 | 0.54 | 0.54 | 0.85 | 1.00 | 0.92 | 1.00 | 0.83 | 0.92 | 0.71 | 0.79 | 0.36 | 0.31 | 0.31 | 0.25 | 0.13 | 0.33 | 0.40 | 0.18 | 0.17 | 0.33 | | | | | | |
| Maiden fern | | | | | | | | | | | | | | | | | 0.06 | | | | | | | | | | | | | |
| Marsh fern | | | | | 0.08 | | 0.08 | 0.08 | 0.08 | | | | | | | 0.06 | | | 0.06 | | | | | | | | | | | |
| Meniscium fern | 0.07 | | | 0.38 | 0.15 | 0.15 | 0.46 | 0.23 | 0.15 | 0.08 | | | | | | | | | | | | | | | | | | | | |
| Cardinal airplant | 0.07 | | | | | | | | | | | | 0.07 | | | | 0.06 | 0.13 | | | | | | | | | | | | |
| Needleleaf airplant | | | | | | | | 0.08 | | | | | 0.07 | | | | | 0.06 | | | | | | | | | | | | |
| Spanish moss | | | | | | | | | | | | | | | | | | | | | | | | | | 0.05 | | | | |
| Poison ivy | 0.13 | 0.06 | 0.13 | | 0.08 | | 0.15 | 0.15 | 0.23 | 0.17 | 0.17 | 0.42 | 0.23 | 0.14 | 0.14 | 0.25 | 0.56 | 0.44 | 0.81 | 0.87 | 0.80 | 0.55 | 0.42 | 0.42 | | | | 0.25 | 0.13 | 0.13 |
| Arrow grass | | | | | | | | | | | | | | | | | 0.06 | | | | | | 0.25 | 0.17 | | | | | 0.13 | 0.13 |
| Fakahatchee Grass | | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | | | |
| Narowleaf cattail | | | | | | | | | | | | | | | | | | | | | 0.07 | | 0.08 | | | | | | | |
| Caesar weed[2] | 0.27 | 0.35 | 0.27 | 0.15 | 0.23 | 0.31 | 0.15 | 0.23 | 0.15 | 0.17 | 0.25 | 0.25 | 0.21 | 0.36 | 0.93 | | | | | | | | | | | | | | | |
| Para grass[2] | | | | | | | | | | | | | | | 0.21 | | | | | | | | | | | | | | | |
| Hairypod cowpea | | 0.12 | | | | 0.08 | | | | | | | | | | | | | | 0.20 | 0.47 | | | 0.33 | | | 0.15 | | | |

[1] Scientific names are provided in **Appendix 3-2**.
[2] Nonnative species.

**Table 3-11-37. continued**

| | Percent Frequency Occurrence | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | | Transect 1 | | |
| **Species[1]** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** | **2003** | **2007** | **2010** |
| Summer grape | | | | | | | | | | | | | | 0.14 | 0.07 | | | | | | | | | | | | | | | |
| Muscadine grape | 0.20 | 0.18 | 0.13 | 0.08 | 0.08 | 0.23 | 0.23 | 0.15 | 0.15 | | 0.17 | | | 0.14 | 0.07 | | 0.13 | 0.06 | 0.06 | 0.07 | 0.07 | | | | 0.05 | 0.05 | 0.05 | | | |
| Shoestring fern | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 0.13 |
| Tallow wood | | | | | | | | | | | | | | | | | | | | 0.07 | | | | | | | 0.05 | | | |
| Yelloweyed grass species | | | | | | | | | | 0.08 | | | | | | | | | | | | | | | | | | | | |
| Unidentified s edges (Cyperceae) | | | | | | | 0.15 | 0.08 | 0.08 | 0.08 | | | 0.07 | | | | 0.06 | | | | | | 0.08 | | | | | 0.13 | | 0.13 |
| Unidentified grass (Poacaea) | | | 0.07 | | | 0.15 | 0.15 | 0.08 | 0.31 | 0.17 | | 0.08 | 0.43 | | 0.43 | | | | 0.06 | | | 0.27 | | 0.33 | 0.20 | | 0.05 | 0.25 | | 0.25 |
| Unidentified fern | 0.13 | 0.06 | | | 0.31 | | | 0.38 | 0.15 | | 0.33 | | | 0.36 | | | | | 0.06 | 0.13 | 0.07 | | 0.08 | | | 0.05 | | | 0.25 | |
| Unidentified juvenile fern | | | | | | | | | | | | | | | | | | | | | | | | 0.08 | | | 0.05 | | | |
| Unidentified seedling | 0.80 | | 0.30 | 0.62 | 0.31 | 0.08 | 0.54 | 0.31 | 0.54 | 0.50 | 0.33 | 0.92 | 0.64 | 0.14 | 0.43 | 0.25 | 0.13 | 0.69 | 0.44 | 0.47 | 0.87 | 0.09 | 0.08 | 0.75 | | | 0.10 | | 0.25 | 0.13 |
| Unidentified species | 0.20 | | 0.07 | | 0.08 | 0.15 | | | 0.23 | | | 0.08 | 0.14 | 0.07 | 0.07 | | | | | 0.07 | | 0.09 | | | | | | | | |

[1] Scientific names are provided in **Appendix 3-2**.

# APPENDIX 3-12

# ADDITIONAL PERCENT COVER AND STEM COUNT FIGURES FOR GROUND COVER SPECIES

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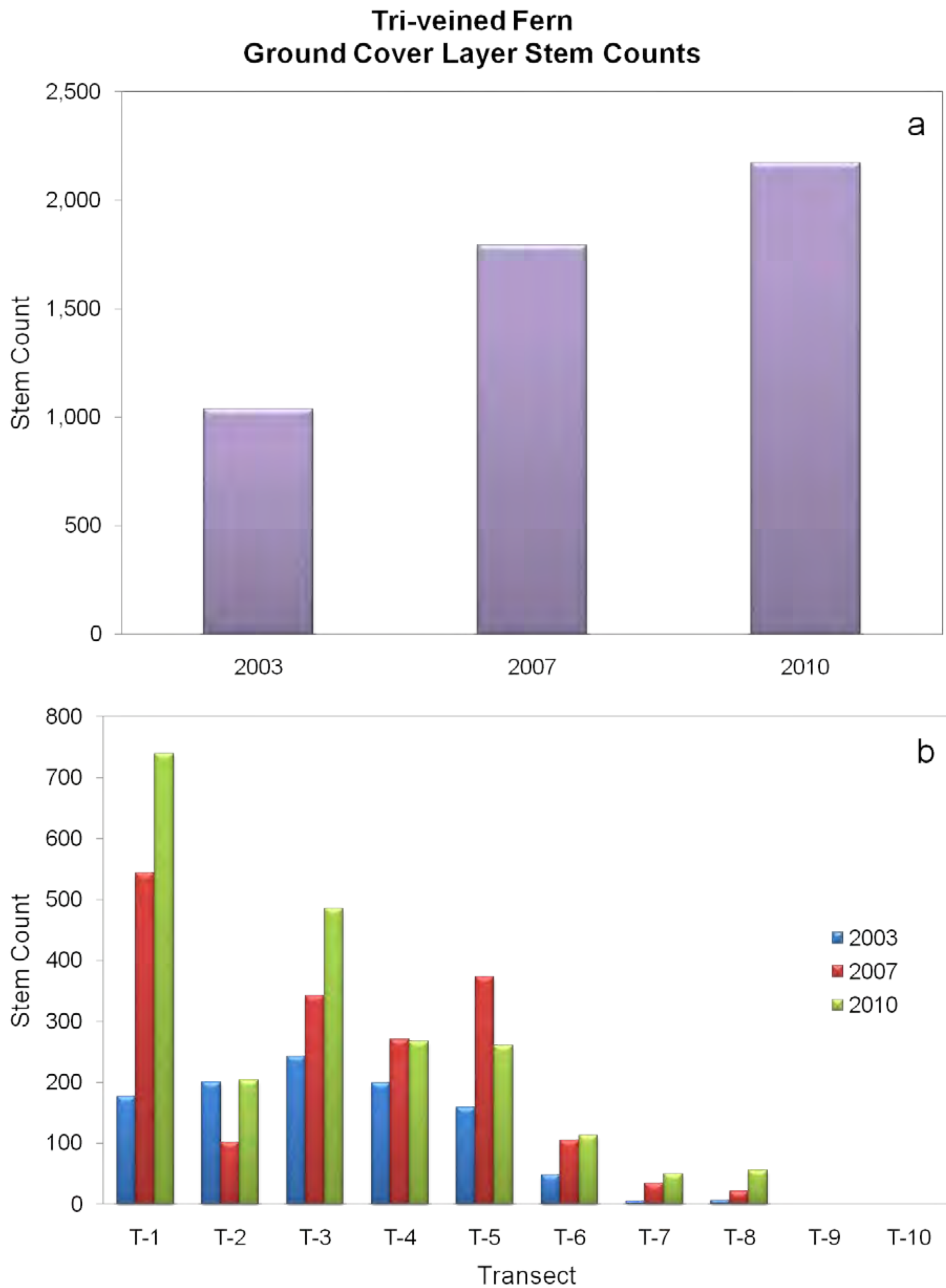


**Figure 3-12-8. Tri-veined fern (*Thelypteris interrupta*) ground cover layer stem counts for the three survey years for (a) all transect combined and (b) by transect**

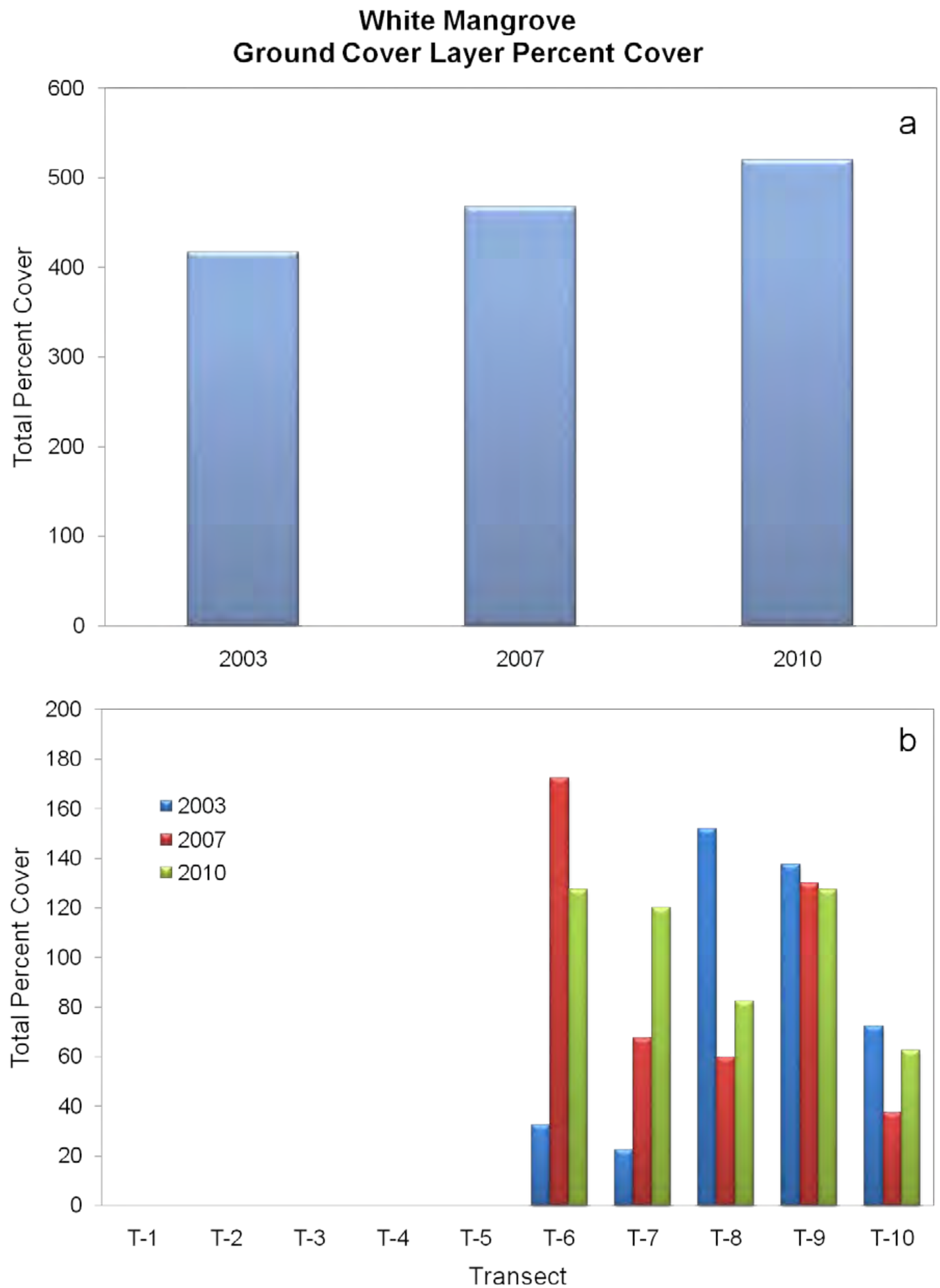


**Figure 3-12-9. White mangrove (*Laguncularia racemosa*) ground cover layer percent cover for the three survey years for (a) all transect combined and (b) by transect**

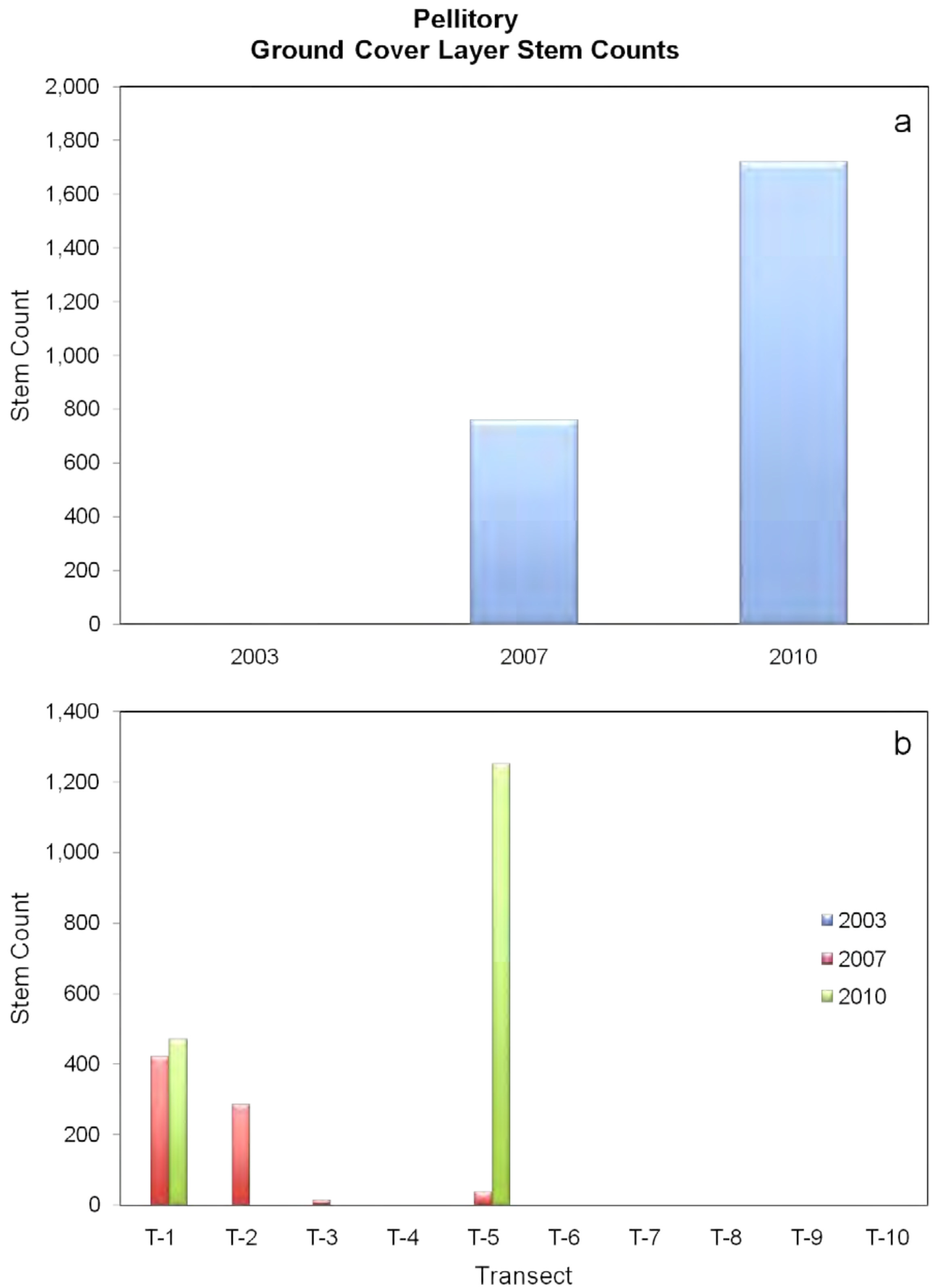


**Figure 3-12-10. Pellitory (*Parietaria floridana*) ground cover layer percent cover for the three survey years for (a) all transect combined and (b) by transect**

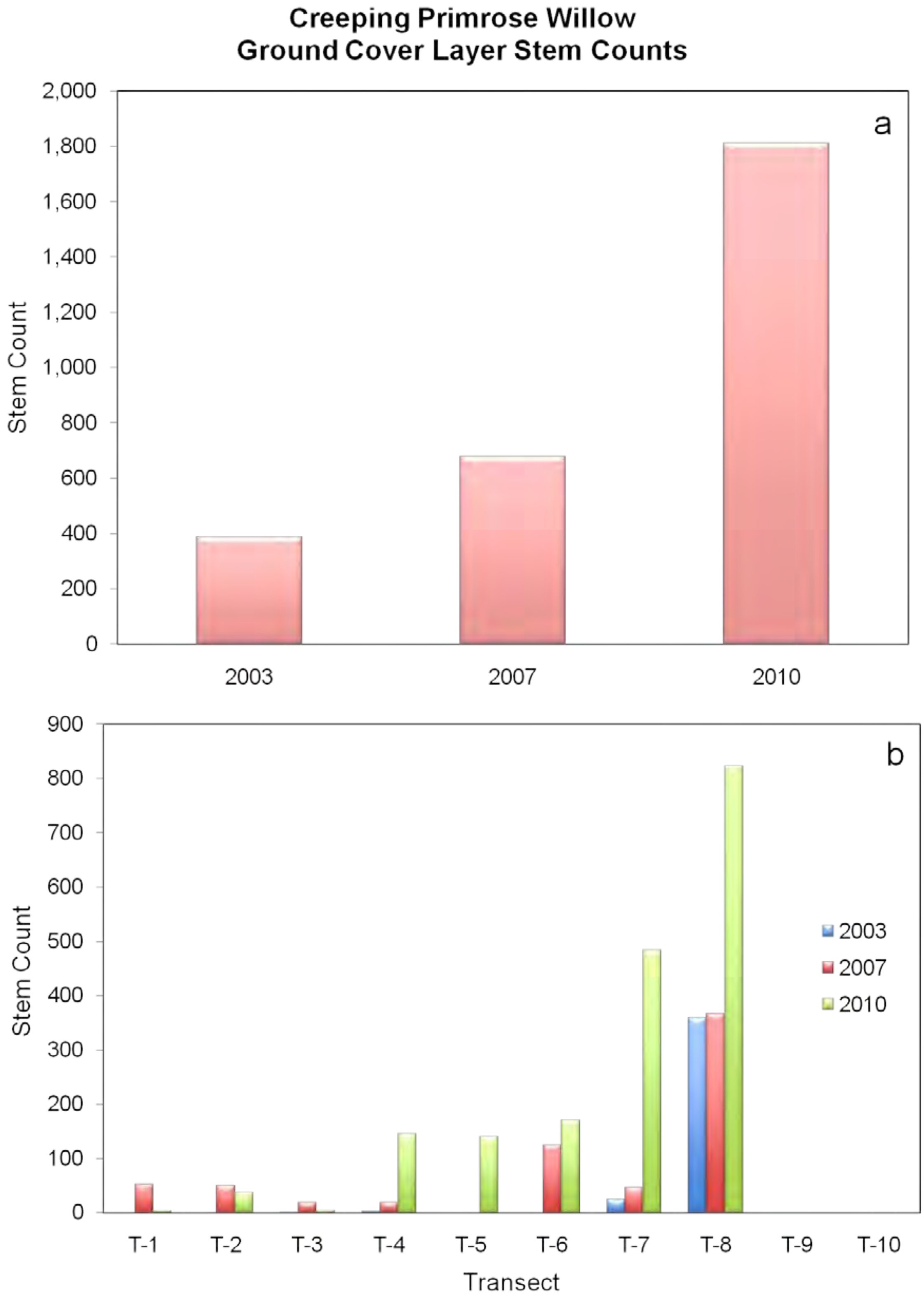


**Figure 3-12-11. Creeping primrose willow (*Ludwigia repens*) ground cover layer percent cover for the three survey years for (a) all transect combined and (b) by transect**

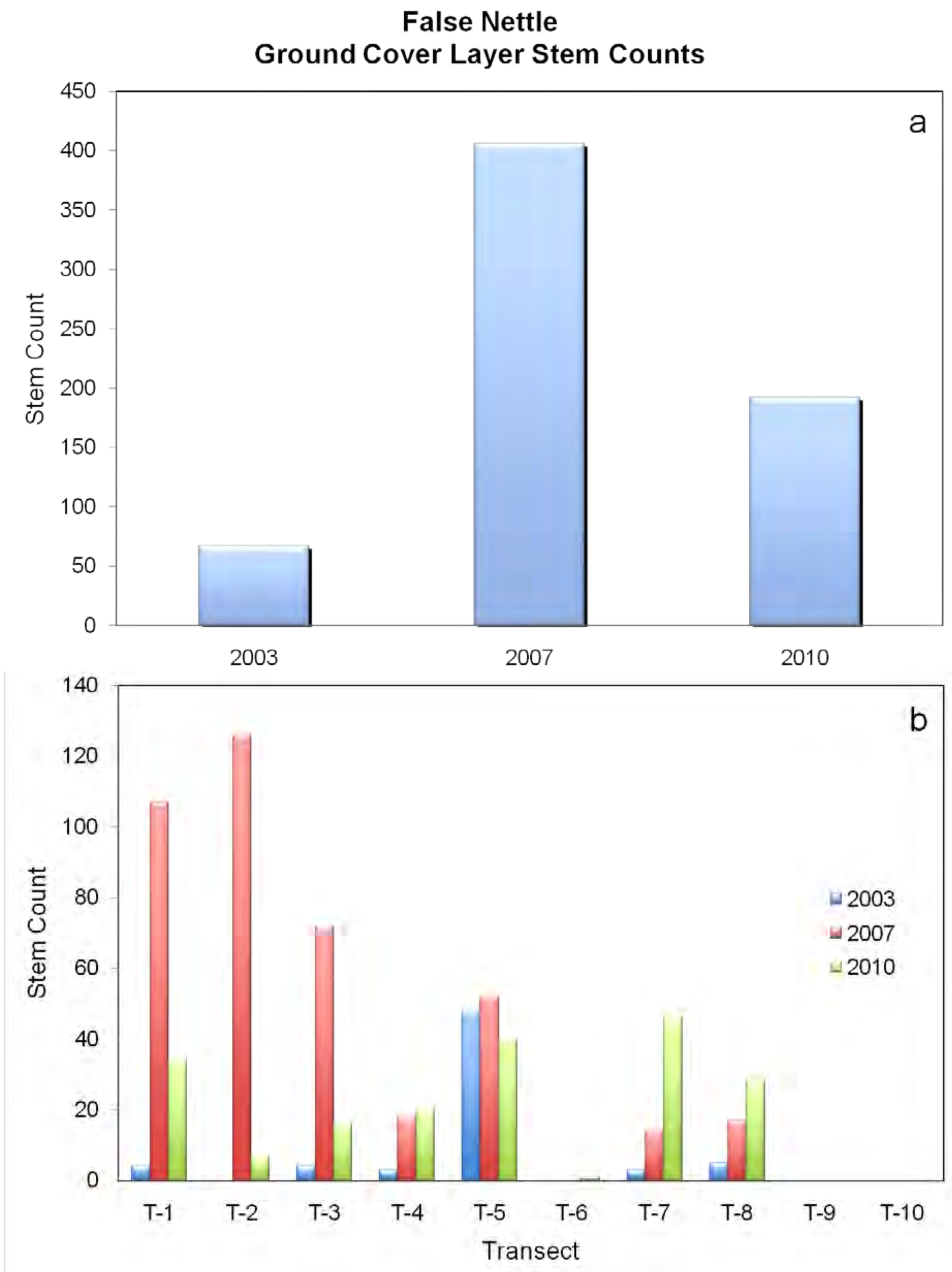


**Figure 3-12-12. False nettle (*Boehmeria cylindrical*) ground cover layer percent cover for the three survey years for (a) all transect combined and (b) by transect**

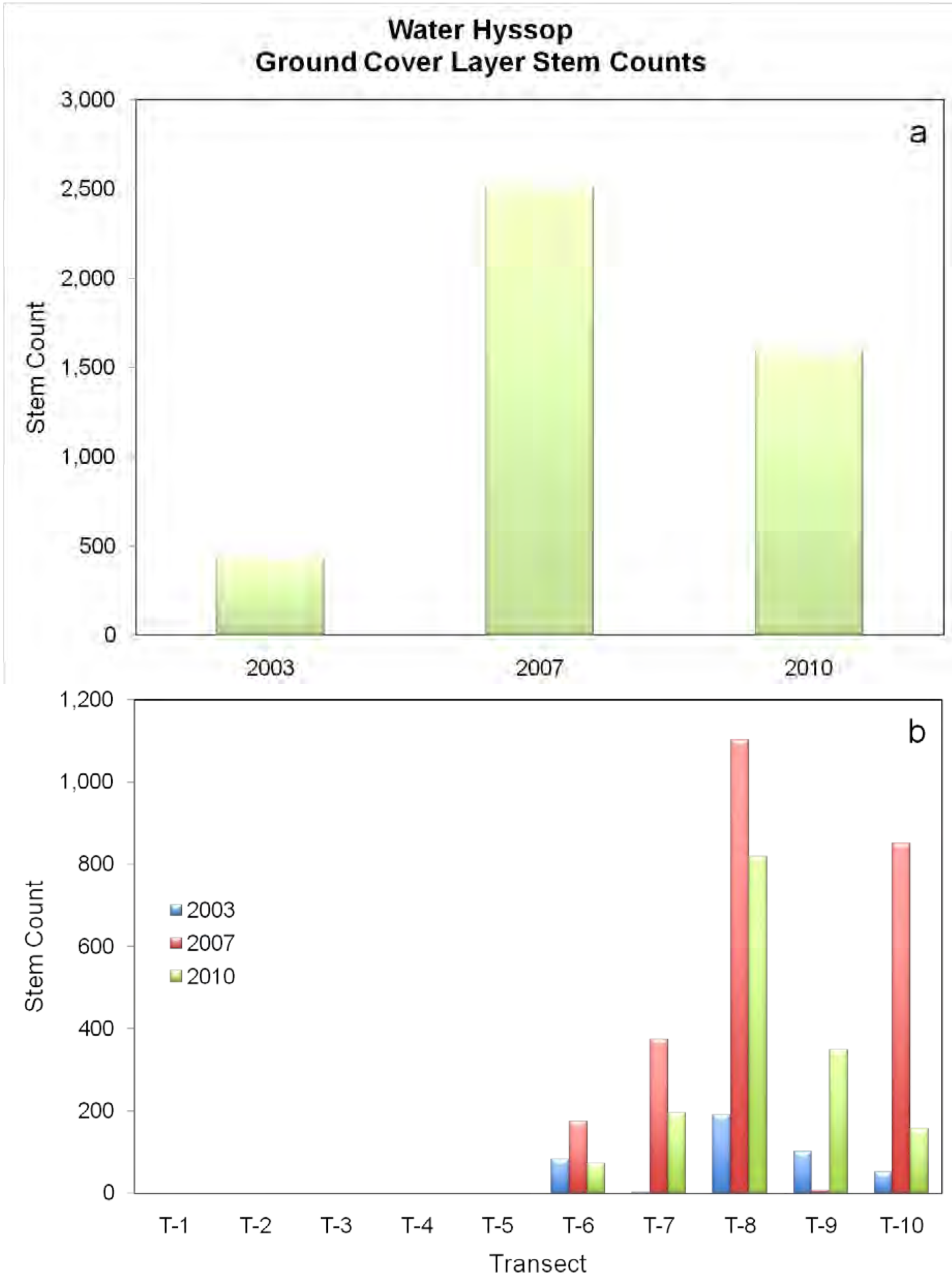


**Figure 3-12-13. Water hyssop (*Bacopa monnieri*) ground cover layer stem counts for the three survey years for (a) all transect combined and (b) by transect**

# APPENDIX 3-13

# FIELD PLANT LIST FOR THE LOXAHATCHEE RIVER VEGETATIONAL DEMONSTRATION RESEARCH PROJECT

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## Mitigation Site at Jonathan Dickinson State Park (Ornamental Gardens)
## by Richard Roberts, Florida Park Service (retired) and Jeff Gillett, May 2009

| Scientific Name | Common Name | Index Category | April/2004 | May/2009 |
|---|---|---|---|---|
| *Acrostichum danaeifolium* | leather fern | obligate | √ | √ |
| *Andropogon virginicus* | broom sedge | facultative | | √ |
| *Annona glabra* | pond apple | obligate | √ | √ |
| *Baccharis halimifolia* | groundsel | facultative | | √ |
| *Bambusa vulgaris*[1] | bamboo | facultative upland | √ | √ |
| *Bidens alba* | beggar ticks | facultative wet | | √ |
| *Blechnum serrulatum* | swamp fern | facultative wet | √ | √ |
| *Boehmeria cylindrica* | false nettle | obligate | √ | |
| *Carex lupuliformis* | hop sedge | obligate | √ | √ |
| *Cephalanthus occidentalis* | buttonbush | obligate | √ | √ |
| *Cladium jamaicense* | saw grass | obligate | | √ |
| *Crinum americanum* | swamp lily | obligate | √ | |
| *Cyperus haspan* | haspan flatsedge | obligate | | √ |
| *Cyperus virens* | green flatsedge | facultative wet | | √ |
| *Dalbergia ecastaphyllum* | coin vine | facultative wet | √ | √ |
| *Dichanthelium acuminatum* | tapered witch grass | facultative | √ | |
| *Dichanthelium commutatum* | variable witch grass | facultative | √ | |
| *Dichanthelium laxiflorum* | rough witch grass | facultative | √ | |
| *Dichanthelium* spp. | witch grass | ___ | | √ |
| *Echinochloa muricata*[1] | barn yard grass | facultative | | √ |
| *Erechtites hieraciifolius* | fire weed | facultative | √ | |
| *Eupatorium capillifolium* | dog fennel | facultative wet | √ | |
| *Galactia volubilis* | downy milk pea | facultative upland | √ | |
| *Hydrocotyle* spp. | pennywort | facultative wet | √ | √ |
| *Hypericum tetrapetalum* | St. John's wort | facultative wet | | √ |
| *Hyptis alata* | musky mint | facultative wet | | √ |
| *Itea virginica* | Virginia willow | obligate | | √ |

[1] Nonnative species

| Scientific Name | Common Name | Index Category | April/2004 | May/2009 |
|---|---|---|---|---|
| *Laguncularia racemosa* | white mangrove | obligate | √ | √ |
| *Ludwigia peruviana*[1] | primrose willow | obligate | √ | |
| *Ludwigia repens* | creeping primrose | obligate | √ | √ |
| *Ludwigia* spp. | primrose willow group | ___ | √ | √ |
| *Lygodium microphyllum*[1] | Old World climbing fern | ___ | √ | √ |
| *Mikania scandens*[2] | climbing hemp weed | facultative wet | √ | √ |
| *Myrica cerifera* | wax myrtle | facultative | √ | |
| *Pinus elliottii* | slash pine | upland | | √ |
| *Pluchea odorata* | marsh fleabane | facultative wet | √ | √ |
| *Polygonum punctatum* | dotted smartweed | obligate | √ | √ |
| *Polygonum* spp. | smartweed group | ___ | | √ |
| *Pontederia cordata* | pickerelweed | obligate | √ | √ |
| *Psidium cattleianum*[1] | strawberry guava | facultative | √ | |
| *Psychotria nervosa* | wild coffee | facultative | | √ |
| *Ptilimnium capillaceum* | mock bishop's weed | facultative wet | √ | √ |
| *Quercus* spp. | oak seedling | ___ | √ | |
| *Rhabdadenia biflora* | rubber vine | facultative wet | √ | √ |
| *Rhizophora mangle* | red mangrove | obligate | √ | √ |
| *Rhynchospora inundata* | narrowfruit horned beak sedge | obligate | √ | √ |
| *Sabal palmetto* | cabbage palm | facultative | √ | √ |
| *Sagittaria lancifolia* | lance leaf arrowhead | obligate | | √ |
| *Samolus valerandi* | pineland pimpernel | obligate | √ | √ |
| *Sarcostemma clausum* | white vine | facultative wet | √ | √ |
| *Saururus cernuus* | lizard's tail | obligate | √ | √ |
| *Schinus terebinthifolia*[1] | Brazilian pepper | facultative | √ | √ |
| *Serenoa repens* | saw palmetto | facultative upland | | √ |
| *Smilax bona-nox* | catbrier | facultative | √ | √ |
| *Symphyotrichum carolinianum*[2] | climbing aster | obligate | √ | √ |
| *Syzygium cumini*[1] | Java plum | facultative | √ | √ |
| *Taxodium distichum* | bald cypress | obligate | √ | √ |

[1] Nonnative species
[2] Nonnative nuisance plant or native plant negatively impacting the on-site research

| **Scientific Name** | **Common Name** | **Index Category** | **April/2004** | **May/2009** |
|---|---|---|---|---|
| *Thelypteris dentata*[1] | downy wood fern | facultative wet | √ | |
| *Toxicodendron radicans* | poison ivy | facultative | √ | √ |
| *Triglochin striata* | arrow grass | obligate | | √ |
| *Typha domingensis*[2] | southern cattail | obligate | | √ |
| *Vigna luteola* | wild cow pea | facultative wet | | √ |
| *Vitis rotundifolia*[2] | muscadine grape | facultative | √ | √ |
| Unidentified grass | | | | √ |
| Unidentified grass seedling | | | √ | √ |
| Unidentified seedling | | | √ | √ |

[1] Nonnative species
[2] Nonnative nuisance plant or native plant negatively impacting the on-site research

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# APPENDIX 4-1
# FISH LIST

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**Table 4-1-38. Fish species observed in the Northwest and Southwest Forks of the Loxahatchee River 2006–2009**

| Scientific Name | Common Name |
|---|---|
| *Agonostomus monticola* | Mountain mullet |
| *Ameiurus nebulosus* | Brown bullhead |
| *Amia calva* | Bowfin |
| *Anguilla rostrata* | American eel |
| *Archosargus probatocephalus* | Sheepshead |
| *Astronotus ocellatus*[1] | Oscar |
| *Awaous banana* | River goby |
| *Caranx hippos* | Crevalle jack / jack crevalle |
| *Carcharhinus leucas* | Bull shark |
| *Centropomus ensiferus* | Swordspine snook |
| *Centropomus parallelus* | Smallscale fat snook / fat snook |
| *Centropomus pectinatus* | Tarpon snook |
| *Centropomus undecimalis* | Common snook / snook |
| *Chaetodipterus faber* | Spadefish |
| *Cichlasoma bimaculatum*[1] | Black acara |
| *Cichlasoma urophthalma*[1] | Mayan cichlid |
| *Clarias batrachus*[1] | Walking catfish |
| *Dasyatis sabina* | Atlantic stingray |
| *Diapterus auratus* | Irish pompano |
| *Dormitator maculatus* | Fat sleeper |
| *Elassoma evergladei* | Everglades pygmy sunfish |
| *Eleotris amblyopsis* | Largescale spinycheek sleeper |
| *Elops saurus* | Ladyfish |
| *Erimyzon oblongus* | Lake chubsucker / creek chubsucker |
| *Eucinostomus argenteus* | Spotfin mojarra |
| *Eucinostomus harengulus* | Tidewater mojarra |
| *Eugerres plumieri* | Striped mojarra / stripped mojarra |
| *Fundulus chrysotus* | Golden topminnow |
| *Fundulus cingulatus* | Banded topminnow |
| *Gambusia holbrooki* | Eastern mosquitofish |
| *Gerres cinereus* | Yellowfin mojarra |
| *Giobiomorus dormitor* | Bigmouth sleeper |
| *Heterandria formosa* | Least killifish |
| *Hoplosternum littorale*[1] | Brown hoplo |
| *Jordanella floridae* | Flagfish |

[1] Nonnative species

**Table 4-1-38. continued**

| Scientific Name | Common Name |
|---|---|
| *Labidesthes sicculus* | Brook silverside |
| *Lepisosteus platyrhincus* | Florida gar |
| *Lepomis gulosus* | Warmouth |
| *Lepomis macrochirus* | Bluegill |
| *Lepomis marginatus* | Dollar sunfish |
| *Lepomis microlophus* | Redear sunfish |
| *Lepomis punctatus* | Spotted sunfish |
| *Lutjanus griseus* | Snapper / mangrove snapper |
| *Megalops atlanticus* | Tarpon |
| *Micropogonias undulatus* | Atlantic croaker / croaker |
| *Micropterus salmoides* | Largemouth bass |
| *Mugil cephalus* | Striped mullet |
| *Mugil curema* | White mullet |
| *Opisthonema oglinum* | Atlantic thread herring \ thread herring |
| *Oreochromis aureus*[1] | Blue tilapia |
| *Poecilia latipinna* | Sailfin molly |
| *Pomadasys crocro* | Burro grunt |
| *Pomatomus saltatrix* | Bluefish |
| *Pomoxis nigromaculatus* | Black crappie |
| *Pterygoplichthys disjunctivus* | Vermiculated sailfin catfish |
| *Pterygoplichthys multiradiatus*[1] | Sailfin catfish / armored catfish |
| *Selene vomer* | Lookdown |
| *Tilapia mariae*[1] | Spotted tilapia |
| *Trachinotus carolinus* | Florida pompano / pompano |
| *Trinectes maculatus* | Hogchoker |

[1] Nonnative species

# APPENDIX 4-2
# FISH SPECIES BY LOCATION

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**Table 4-2-39. Occurrence of fish species by location along the Northwest Fork of the Loxahatchee River**

| Scientific Name | Common Name | Occurrence of Fish Species by Location | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bridge Road Ditch | Flora Avenue Canal | Flora Avenue Stormwater Treatment | Hobe Grove Ditch | Hobe Grove Ditch Structure | Jenkins Ditch | Kitching Creek | North Fork Culverts | North Fork Loxahatchee River | Riverbend Park | Square Pond | Wilson Creek | Cypress Creek | SIRWCD[2] Canal |
| *Centropomus ensiferus* | Swordspine snook | | | | | X | | | | | | | | | |
| *Centropomus undecimalis* | Common snook | | | | X | | | | | | | | | | |
| *Cichlasoma bimaculatum*[1] | Black acara | | | X | | | | | | | | X | | X | |
| *Cichlasoma urophthalma*[1] | Mayan cichlid | | | | X | X | | | | | | X | | | |
| *Clarias batrachus*[1] | Walking catfish | | | | | | | | X | | | X | | | |
| *Elassoma evergladei* | Everglades pygmy sunfish | | | | | | | | | | | | X | | |
| *Erimyzon oblongus* | Creek / lake chubsucker | | | | | X | | | | | | | | | |
| *Eucinostomus argentus* | Spotfin mojarra | | | | X | X | | | | | | | | | |
| *Eugerres plumieri* | Striped /stripped mojarra | | | | | X | | | | | | | | | |
| *Fundulus cingulatus* | Banded topminnow | | | | | | | | | | | X | | | |
| *Fundulus chrysotus* | Golden topminnow | | | | | | | | | | | X | | | X |
| *Gambusia holbrooki* | Eastern mosquitofish | | X | X | X | | X | X | X | | X | X | X | X | X |
| *Heterandria formosa* | Least killifish | | | | | | | | | | | | | | X |
| *Hoplosternum littorale*[1] | Brown hoplo | | | X | | | | | | | | X | | | |
| *Jordanella floridae* | Flagfish | | | X | | | | | | | X | | | | |
| *Labidesthes sicculus* | Brook silverside | | | | | | | | | | X | | | | |
| *Lepisosteus platyrhincus* | Florida gar | X | | | | | | | | | | | | | |
| *Lepomis macrochirus* | Bluegill | X | | X | X | X | | | | | X | X | | | |
| *Lepomis microlophus* | Redear sunfish | | | | | X | | | | | X | | | | |
| *Micropterus salmoides* | Largemouth bass | | | | | | | | | | X | X | | | |
| *Mugil cephalus* | Striped mullet | | | | | X | | | | | | | | | |
| *Poecilia latipinna* | Sailfin molly | | | | X | | | | | | X | | | | |
| *Pomoxis nigromaculatus* | Black crappie | X | | | | X | | | | | | | | | |
| *Pterygoplichthys multiradiatus*[1] | Sailfin catfish | | | | | X | | | | | | | | | |
| *Tilapia mariae*[1] | Spotted tilapia | X | | | X | | | X | | | X | | | | |
| *Trinectes maculatus* | Hogchoker | | | | X | | | | | | | | | | |

[1]Exotic; note that a red X indicates an exotic within the table; [2]SIRWCD - South Indian River Water Control District

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# APPENDIX 4-3

# SEASONAL VARIATION IN TOTAL NUMBER OF BIRD OBSERVATIONS

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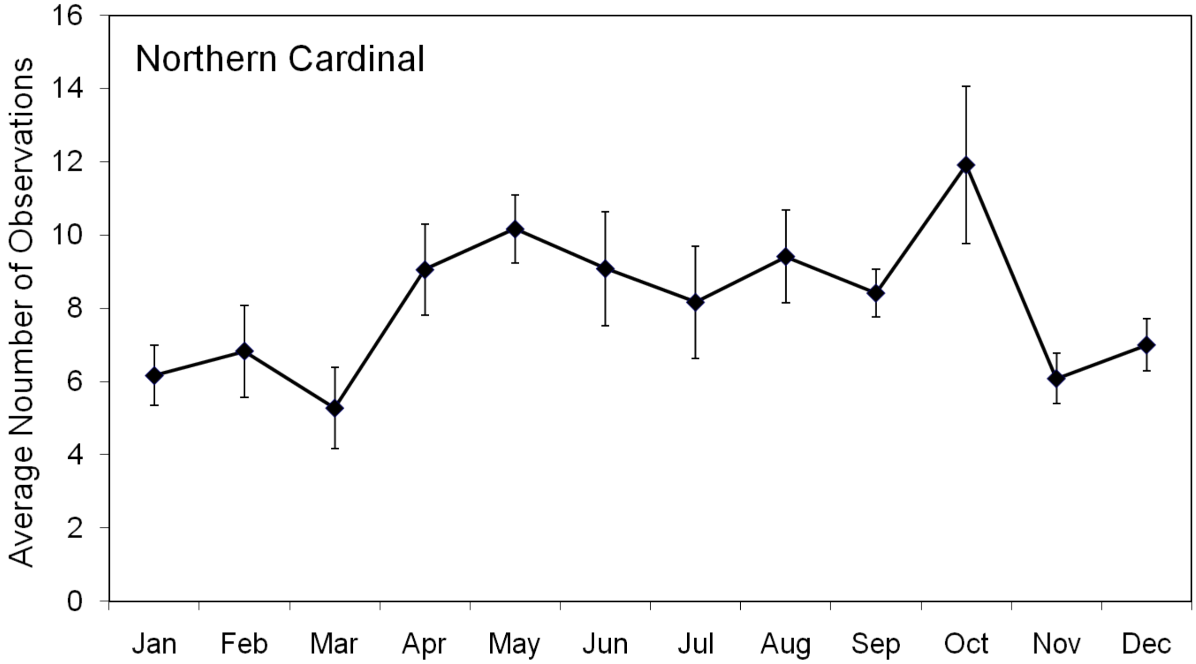


**Figure 4-3-14. Average number of observations by month of northern cardinals during the 2008–2009 survey period**

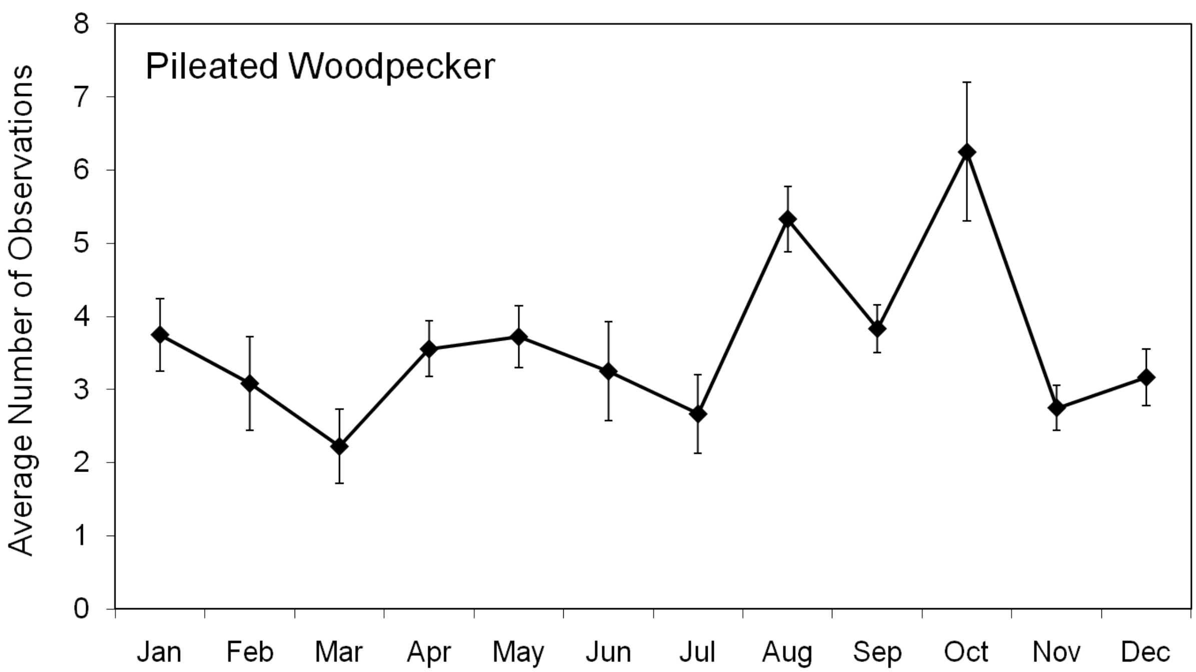


**Figure 4-3-15. Average number of observations by month of pileated woodpecker during the 2008–2009 survey period**

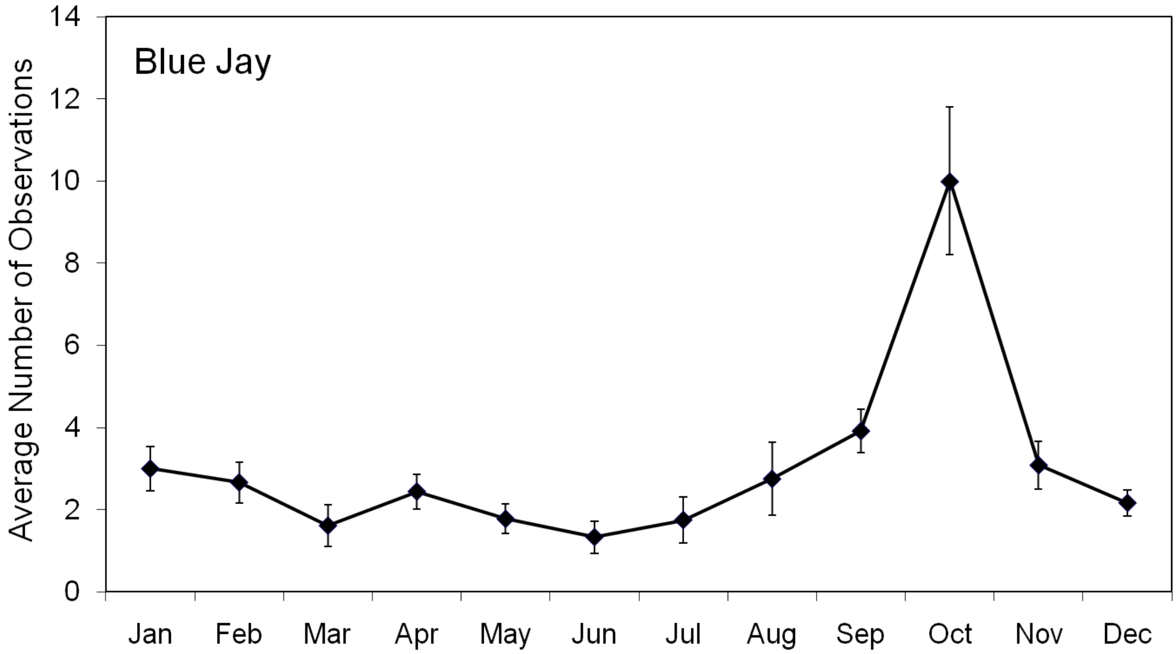


**Figure 4-3-16. Average number of observations by month of blue jay during the 2008–2009 survey period**

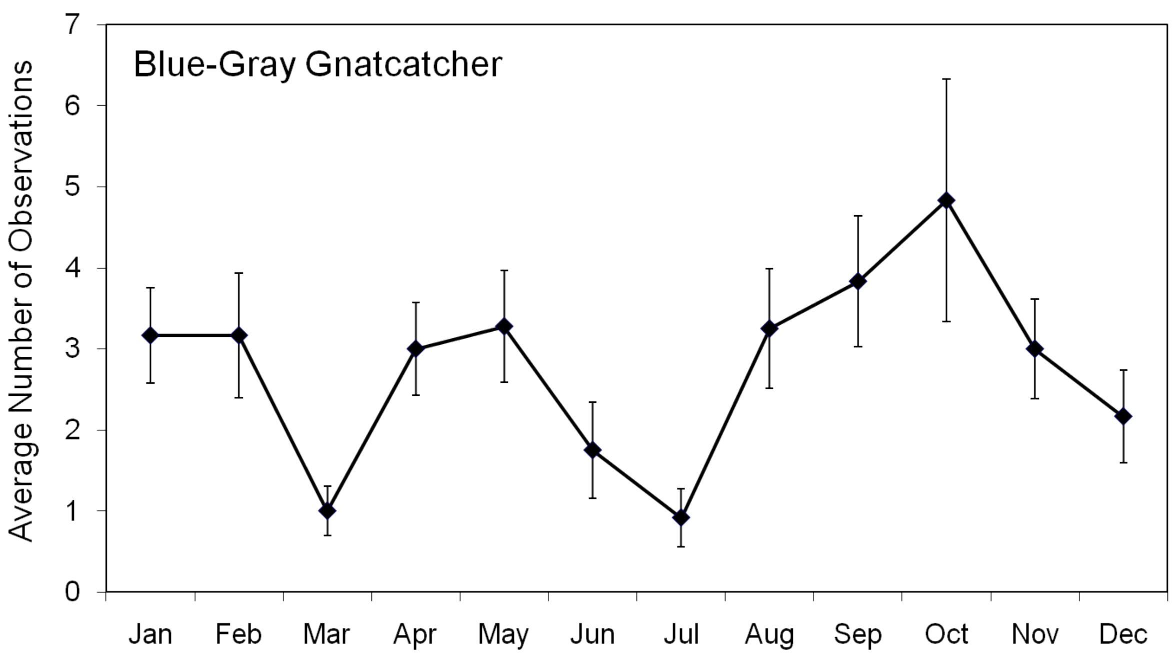


**Figure 4-3-17. Average number of observations by month of blue-gray gnatcatcher during the 2008–2009 survey period**

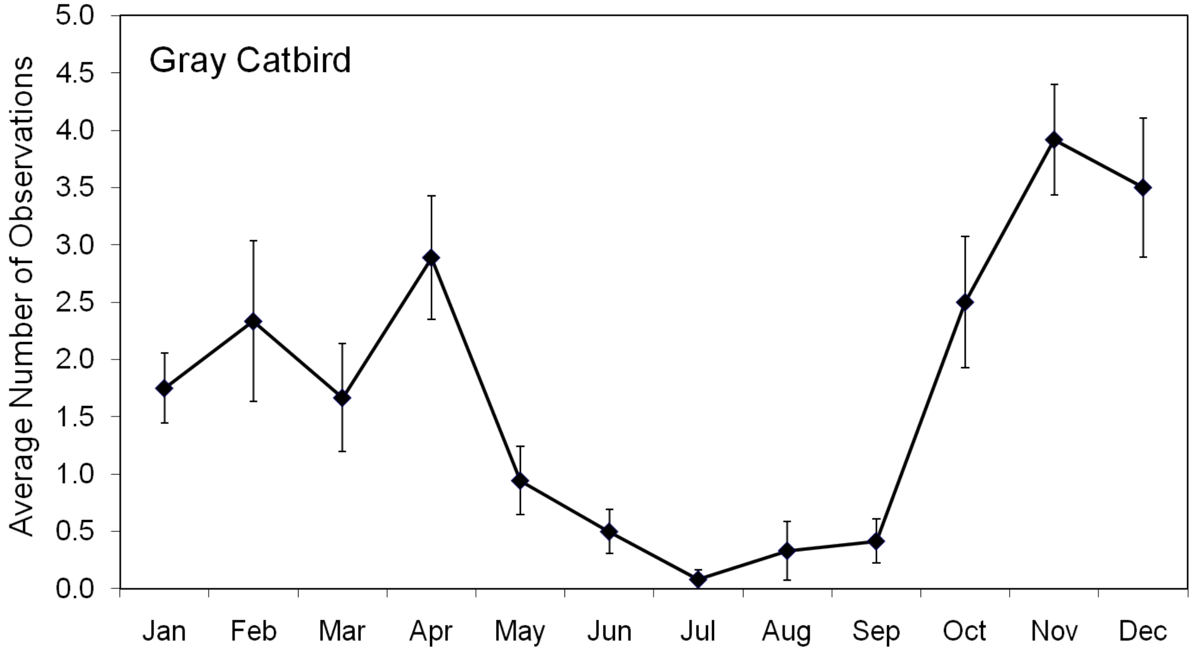


**Figure 4-3-18. Average number of observations by month of gray catbird during the 2008–2009 survey period**

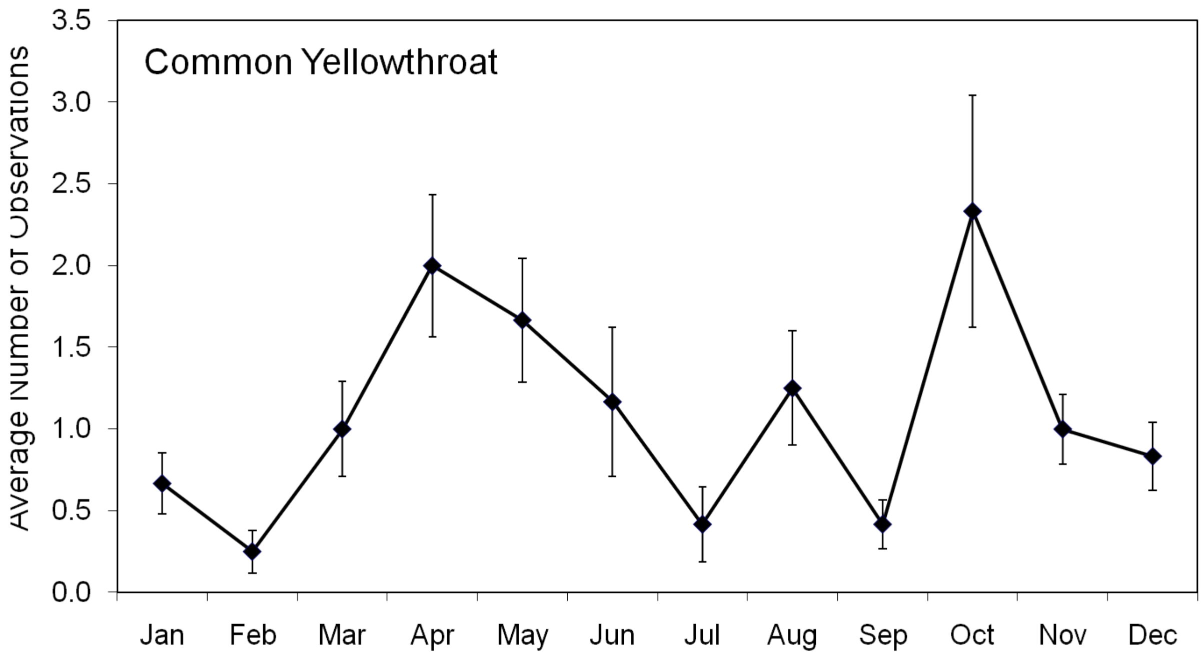


**Figure 4-3-19. Average number of observations by month of common yellowthroat during the 2008–2009 survey period**

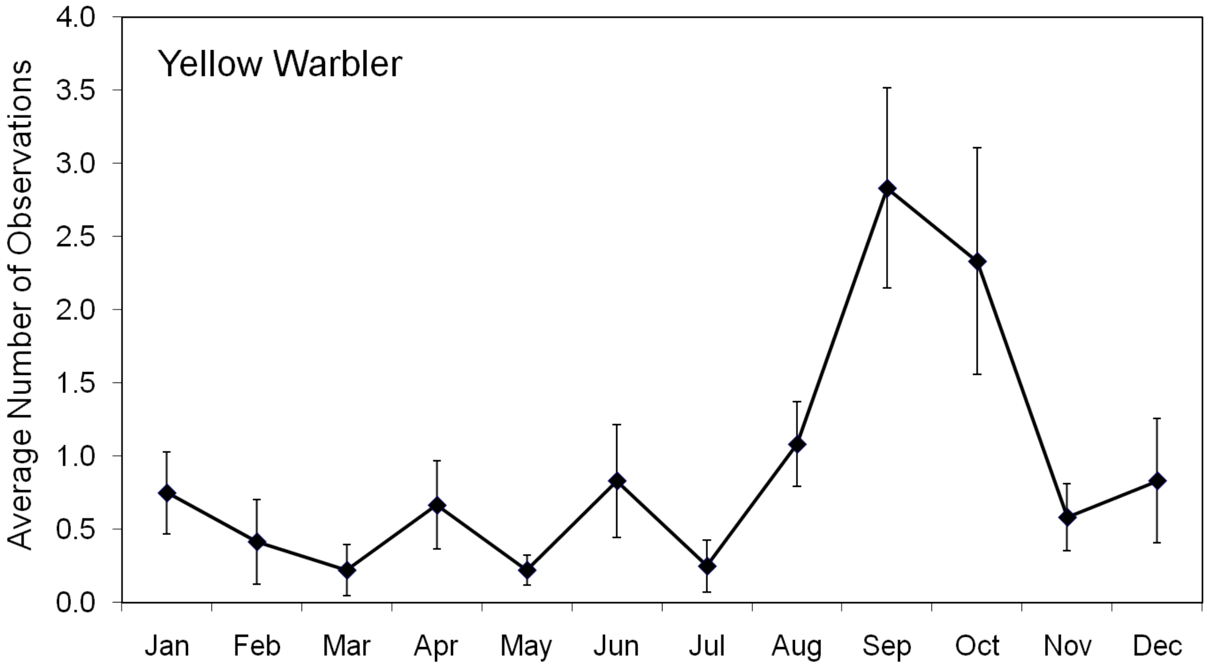


**Figure 4-3-20. Average number of observations by month of yellow warbler during the 2008–2009 survey period**

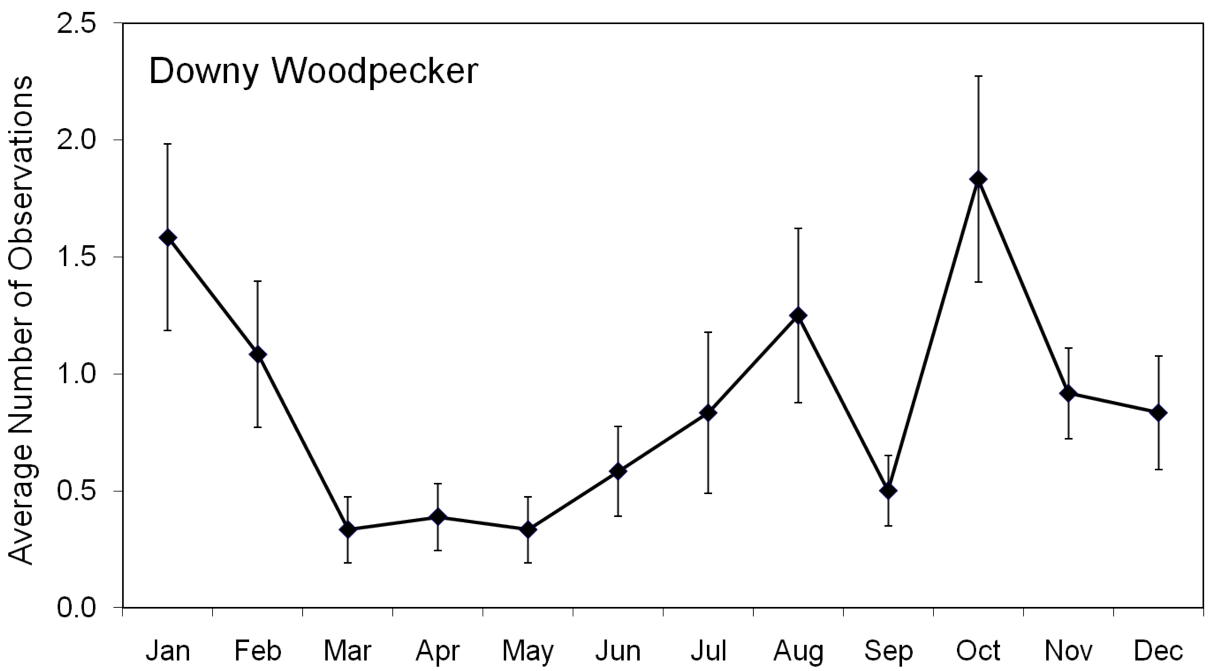


**Figure 4-3-21. Average number of observations by month of downy woodpecker during the 2008–2009 survey period**

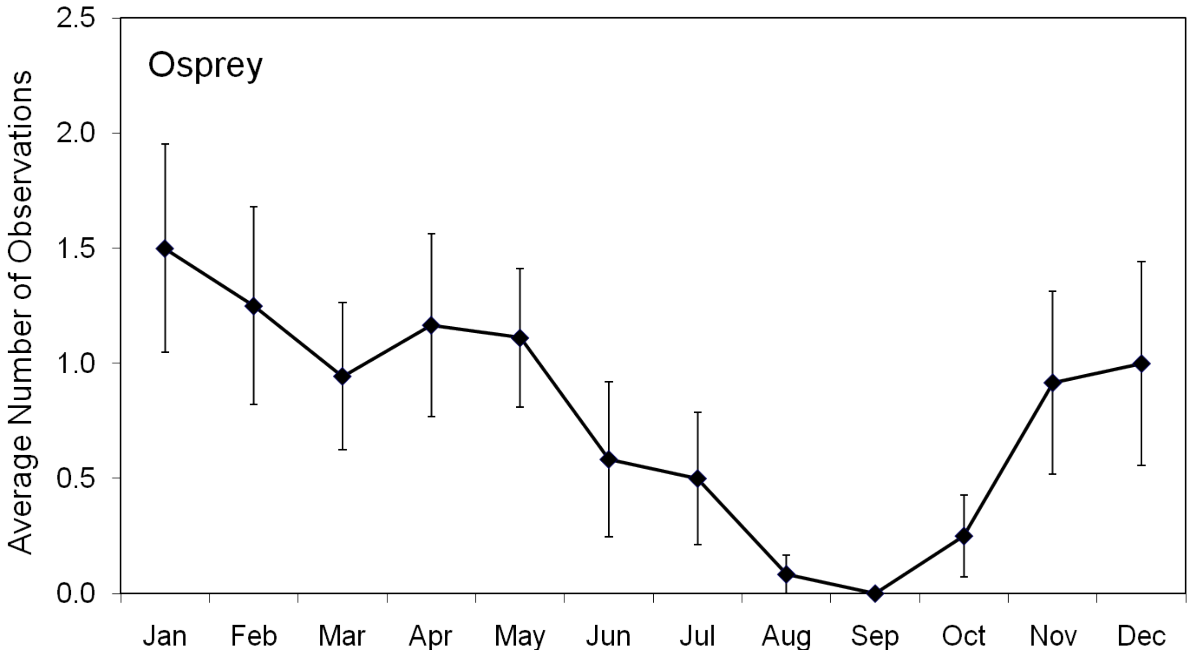


**Figure 4-3-22. Average number of observations by month of osprey during the 2008–2009 survey period**

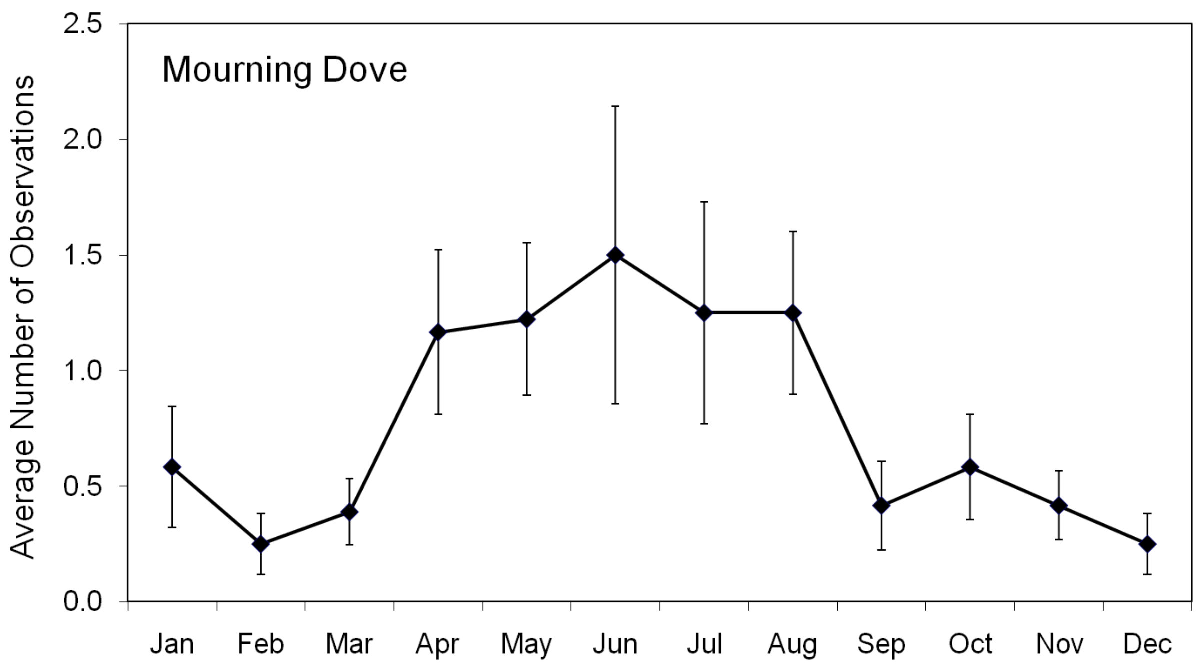


**Figure 4-3-23. Average number of observations by month of mourning dove during the 2008–2009 survey period**

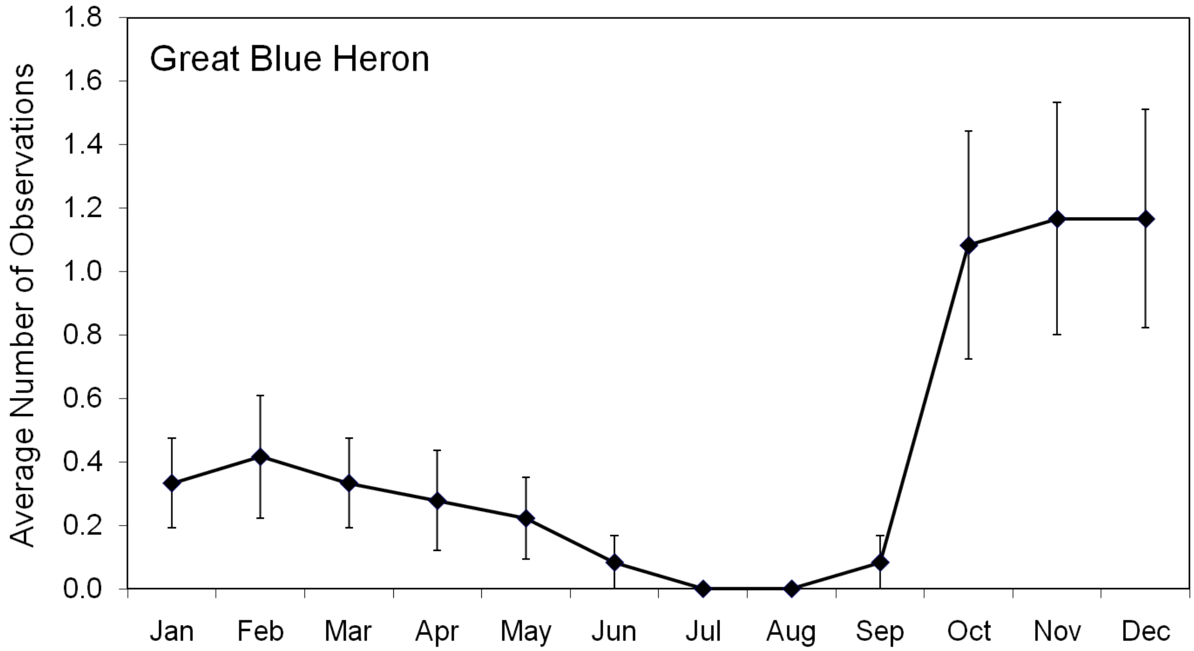


**Figure 4-3-24. Average number of observations by month of great blue heron during the 2008–2009 survey period**

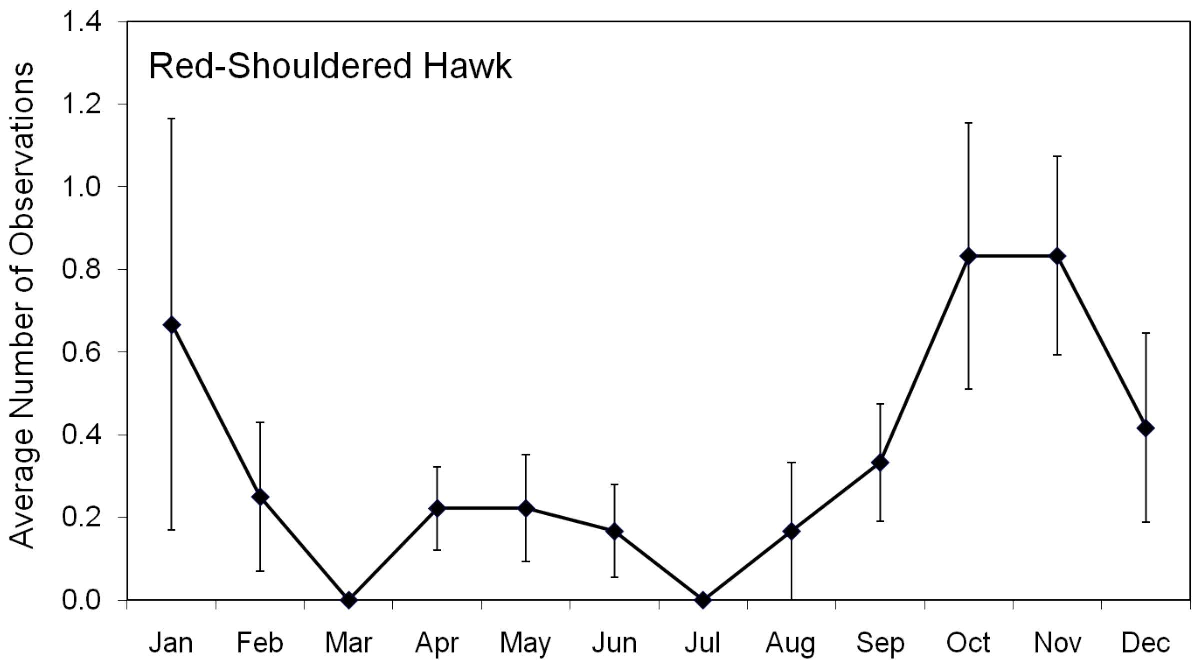


**Figure 4-3-25. Average number of observations by month of red-shouldered hawk during the 2008–2009 survey period**

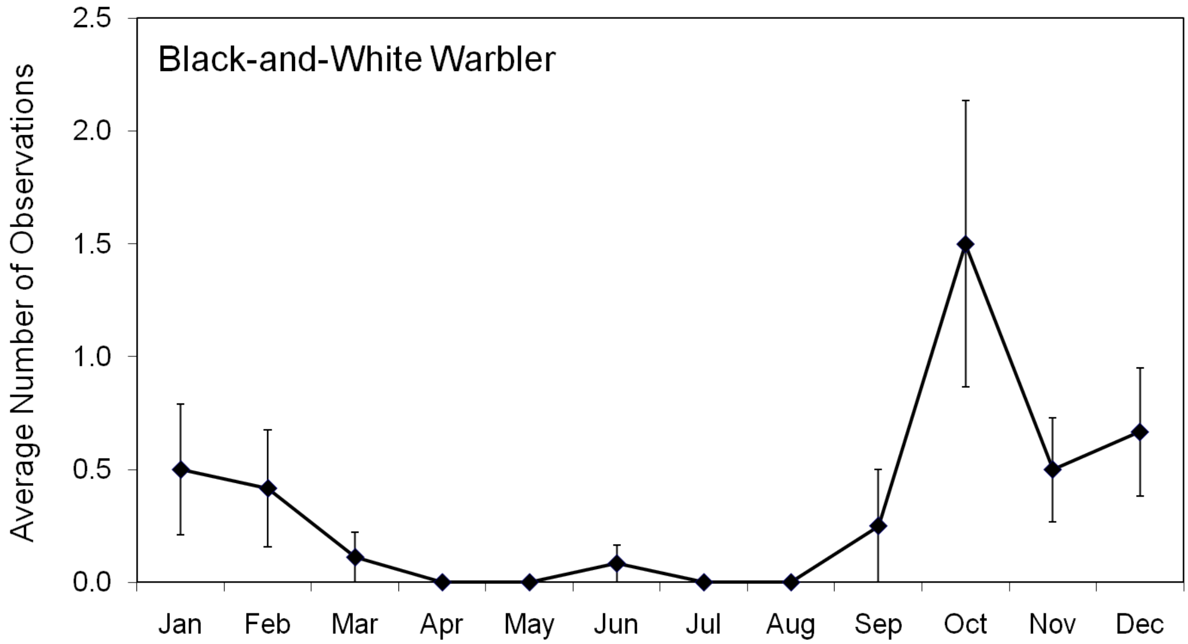


**Figure 4-3-26. Average number of observations by month of black-and-white warbler during the 2008–2009 survey period**

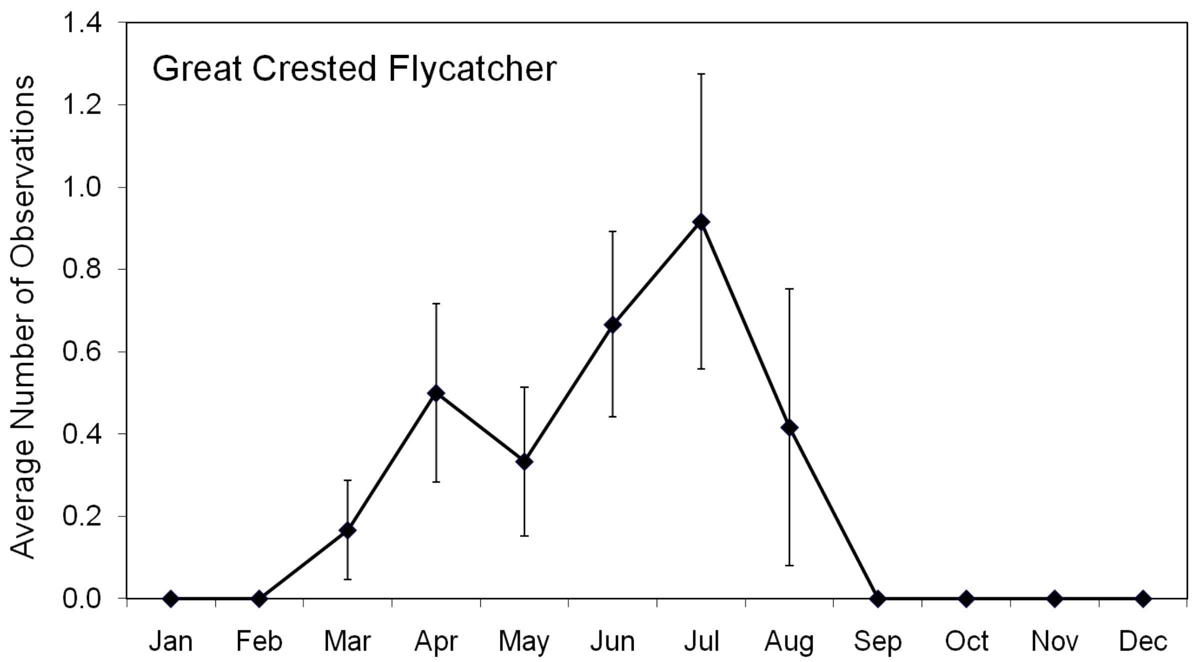


**Figure 4-3-27. Average number of observations by month of great crested flycatcher during the 2008–2009 survey period**

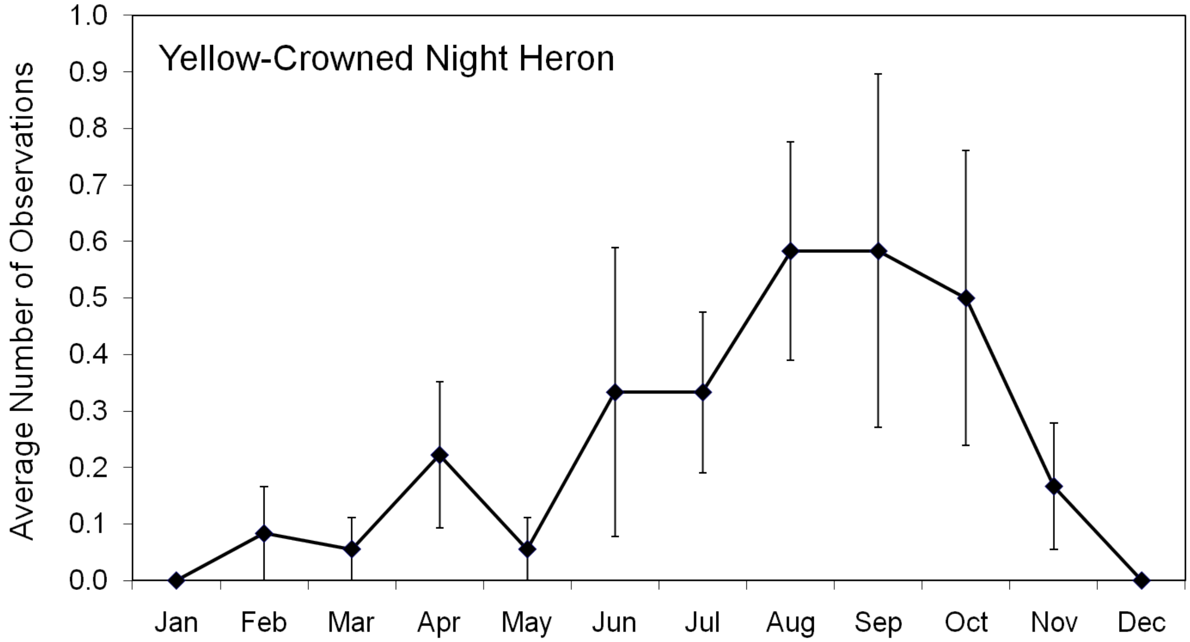


**Figure 4-3-28. Average number of observations by month of yellow-crowned night heron during the 2008–2009 survey period**

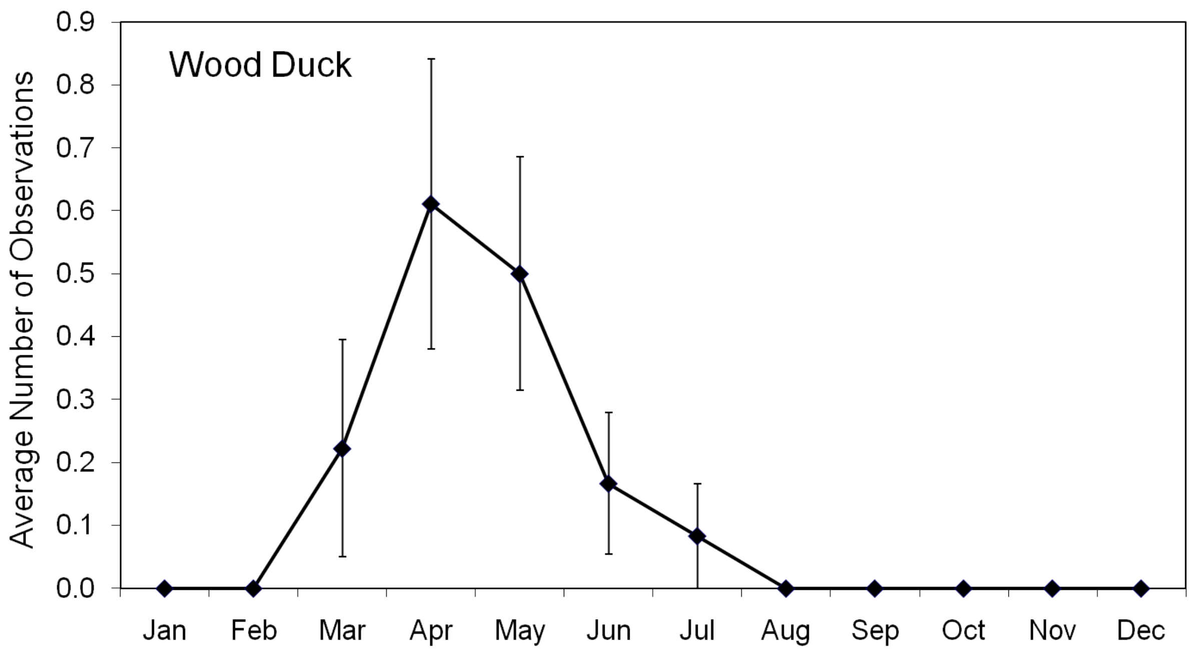


**Figure 4-3-29. Average number of observations by month of wood duck during the 2008–2009 survey period**

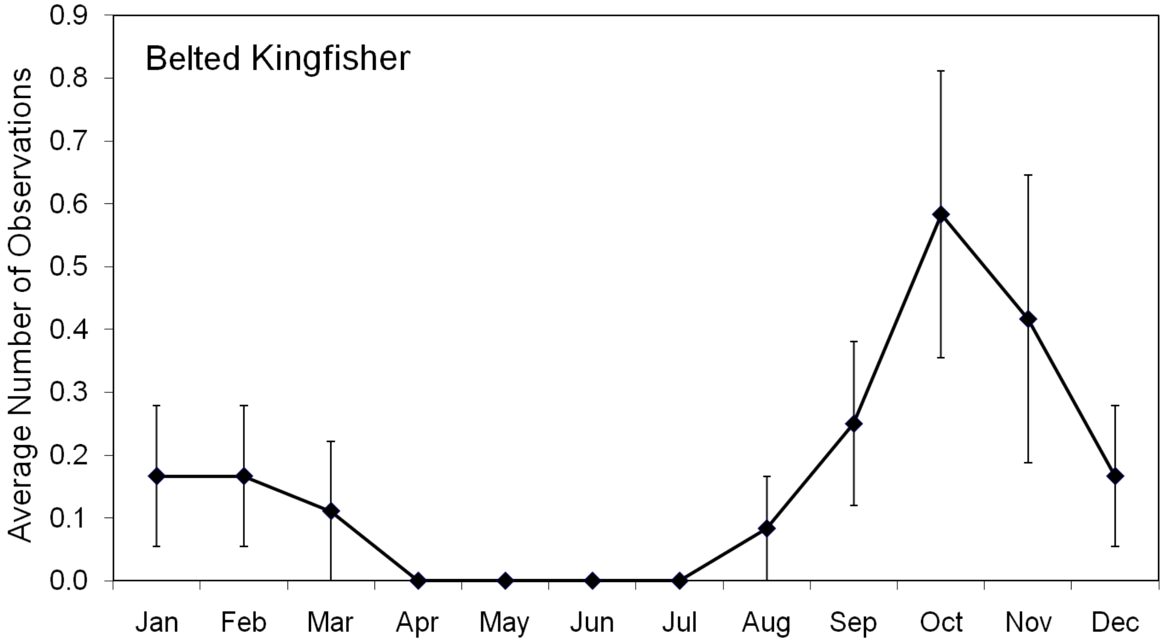


**Figure 4-3-30. Average number of observations by month of belted kingfisher during the 2008–2009 survey period**

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# APPENDIX 4-4
# FROG LIST

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**Table 4-4-40. Frogs observed in the Northwest Fork of the Loxahatchee River**

| Scientific Name | Common Name |
|---|---|
| *Acris gryllus dorsalis* | Cricket frog |
| *Anaxyrus quercicus*<br>(formerly *Bufo quercicus*) | Oak toad |
| *Anaxyrus terrestris*<br>(formerly *Bufo terrestris)* | Southern Toad |
| *Eleutherodactylus planirostris planirostris* | Greenhouse frog |
| *Gastrophryne carolinensis* | Narrowmouth toad |
| *Hyla cinerea* | Green treefrog |
| *Hyla femoralis* | Pinewoods treefrog |
| *Hyla gratiosa* | Barking treefrog |
| *Hyla squirella* | Squirrel treefrog |
| *Lithobates grylio*<br>(formerly *Rana grylio*) | Pig frog |
| *Lithobates sphenocephalus utricularius*<br>(formerly *Rana sphenocephala utricularia*) | Southern leopard frog |
| *Osteopilus septentrionalis* | Cuban treefrog |
| *Pseudacris ocularis* | Little grass frog |

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# APPENDIX 6-1
# WATER QUALITY STOPLIGHT DECISION RULES AND DATA

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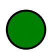
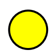
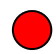
This appendix describes the decision rules and data used in the water quality stoplight assessment discussed in **Section 6**. We assumed the observed conditions during the target period (1998–2002) represent nondegradation conditions and we scored conditions equal to or better than those conditions as green (good). Conditions marginally worse than the target conditions (i.e., between the 75$^{th}$ and 90$^{th}$ percentile) were scored yellow (caution). Observed conditions significantly worse than the target conditions (i.e., falling above of the 90$^{th}$ percentile) were scored as red (poor and remedies should be sought) (**Table 6-1-41**). The scoring criteria is generally based on the numeric nutrient criteria for marine waters proposed by the Florida Department of Environmental Protection. Assessment is based on the annual geometric mean value, which is utilized by both the United States Environmental Protection Agency and Florida Department of Environmental Protection, for the parameter and period being assessed. Total nitrogen values prior to 2005 have smaller sample sizes due to data removal because of interference in analysis method, which is discussed in detail in **Section 6**.

**Table 6-1-41. Stoplight assessment conditions**

| < 75$^{th}$ Percentile Target Value | $\geq$ 75$^{th}$ Percentile and < 90$^{th}$ Percentile Target Value | $\geq$90$^{th}$ Percentile Target Value |
|---|---|---|
|  |  |  |

The tables on the following pages present the sample size, geometric mean, and 75$^{th}$ and 90$^{th}$ percentiles for the target period (1998–2002) and for each October 1–September 30 period from 2003 through 2010 for three water quality parameters. **Table 6-1-42** presents total nitrogen data. **Table 6-1-43** presents total phosphorus data. **Table 6-1-44** presents chlorophyll a data.

**Table 6-1-42. Data used in the total nitrogen stoplight assessment**

| Analysis Group | | 1998–2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Marine | N | 1 | 5 | 0 | 30 | 30 | 44 | 48 | 48 | 48 |
| | GM | 1.44 | 0.80 | | 0.66 | 0.41 | 0.16 | 0.17 | 0.13 | 0.15 |
| | 75th | N/A | | | | | | | | |
| | 90th | N/A | | | | | | | | |
| Polyhaline | N | 8 | 3 | 3 | 20 | 22 | 32 | 36 | 36 | 36 |
| | GM | 1.40 | 1.70 | 1.43 | 0.98 | 0.65 | 0.40 | 0.47 | 0.35 | 0.30 |
| | 75th | 1.95 | | | | | | | | |
| | 90th | 2.32 | | | | | | | | |
| Meso/ Oligohaline | N | 84 | 20 | 18 | 23 | 24 | 32 | 35 | 36 | 36 |
| | GM | 1.26 | 1.87 | 1.15 | 1.92 | 1.42 | 0.70 | 0.96 | 0.76 | 0.83 |
| | 75th | 1.54 | | | | | | | | |
| | 90th | 1.91 | | | | | | | | |
| Wild and Scenic | N | 120 | 24 | 24 | 24 | 24 | 32 | 36 | 36 | 36 |
| | GM | 0.96 | 1.10 | 0.99 | 1.32 | 1.38 | 1.15 | 0.96 | 1.03 | 0.87 |
| | 75th | 1.26 | | | | | | | | |
| | 90th | 1.56 | | | | | | | | |
| Freshwater Tributaries | N | 87 | 17 | 18 | 18 | 23 | 28 | 43 | 44 | 47 |
| | GM | 1.04 | 1.17 | 0.96 | 1.42 | 1.57 | 1.18 | 0.89 | 1.11 | 0.99 |
| | 75th | 1.29 | | | | | | | | |
| | 90th | 1.69 | | | | | | | | |
| Brackish Tributaries | N | 28 | 11 | 9 | 26 | 29 | 31 | 36 | 36 | 37 |
| | GM | 1.22 | 1.66 | 1.26 | 1.16 | 0.75 | 0.48 | 0.55 | 0.43 | 0.49 |
| | 75th | 1.46 | | | | | | | | |
| | 90th | 1.79 | | | | | | | | |
| Freshwater Canals | N | 179 | 48 | 44 | 47 | 46 | 45 | 50 | 49 | 57 |
| | GM | 1.11 | 1.18 | 1.15 | 1.61 | 1.66 | 1.47 | 1.03 | 1.31 | 1.14 |
| | 75th | 1.37 | | | | | | | | |
| | 90th | 1.77 | | | | | | | | |

N - sample size
GM - geometric mean
$75^{th}$ - $75^{th}$ percentile
$90^{th}$ - $90^{th}$ percentile
N/A - not applicable

**Table 6-1-43. Data used in the total phosphorus stoplight assessment**

| | | 1998–2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Marine | N | 149 | 30 | 30 | 35 | 36 | 44 | 48 | 48 | 48 |
| | GM | 0.019 | 0.014 | 0.014 | 0.031 | 0.020 | 0.010 | 0.016 | 0.015 | 0.015 |
| | 75th | 0.033 | | | | | | | | |
| | 90th | 0.043 | | | | | | | | |
| Polyhaline | N | 90 | 18 | 21 | 24 | 24 | 32 | 36 | 36 | 36 |
| | GM | 0.035 | 0.027 | 0.033 | 0.034 | 0.032 | 0.030 | 0.032 | 0.027 | 0.032 |
| | 75th | 0.044 | | | | | | | | |
| | 90th | 0.070 | | | | | | | | |
| Meso/ Oligohaline | N | 119 | 24 | 24 | 24 | 24 | 32 | 36 | 36 | 36 |
| | GM | 0.053 | 0.056 | 0.064 | 0.055 | 0.060 | 0.063 | 0.061 | 0.056 | 0.061 |
| | 75th | 0.066 | | | | | | | | |
| | 90th | 0.081 | | | | | | | | |
| Wild and Scenic | N | 120 | 24 | 24 | 24 | 24 | 32 | 36 | 36 | 36 |
| | GM | 0.042 | 0.044 | 0.043 | 0.042 | 0.045 | 0.069 | 0.050 | 0.049 | 0.044 |
| | 75th | 0.056 | | | | | | | | |
| | 90th | 0.089 | | | | | | | | |
| Freshwater Tributaries | N | 89 | 18 | 18 | 18 | 23 | 28 | 43 | 44 | 47 |
| | GM | 0.048 | 0.055 | 0.039 | 0.044 | 0.060 | 0.063 | 0.053 | 0.055 | 0.060 |
| | 75th | 0.079 | | | | | | | | |
| | 90th | 0.101 | | | | | | | | |
| Brackish Tributaries | N | 148 | 30 | 30 | 30 | 30 | 31 | 36 | 36 | 37 |
| | GM | 0.059 | 0.052 | 0.065 | 0.051 | 0.049 | 0.042 | 0.054 | 0.048 | 0.053 |
| | 75th | 0.080 | | | | | | | | |
| | 90th | 0.150 | | | | | | | | |
| Freshwater Canals | N | 179 | 48 | 45 | 47 | 46 | 45 | 50 | 49 | 57 |
| | GM | 0.053 | 0.048 | 0.051 | 0.047 | 0.067 | 0.069 | 0.057 | 0.076 | 0.058 |
| | 75th | 0.085 | | | | | | | | |
| | 90th | 0.134 | | | | | | | | |

N - sample size
GM - geometric mean
$75^{th}$ - $75^{th}$ percentile
$90^{th}$ - $90^{th}$ percentile

**Table 6-1-44. Data used in the chlorophyll a stoplight assessment**

| | | 1998–2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Marine | N | 146 | 29 | 30 | 35 | 36 | 38 | 48 | 48 | 48 |
| | GM | 2.5 | 3.3 | 3.3 | 4.2 | 2.0 | 1.8 | 4.0 | 2.4 | 2.7 |
| | 75th | 4.2 | | | | | | | | |
| | 90th | 6.9 | | | | | | | | |
| Polyhaline | N | 89 | 17 | 21 | 22 | 24 | 28 | 35 | 36 | 36 |
| | GM | 5.4 | 8.5 | 7.5 | 9.9 | 4.3 | 6.7 | 8.5 | 7.7 | 8.8 |
| | 75th | 9.3 | | | | | | | | |
| | 90th | 14.5 | | | | | | | | |
| Meso/ Oligohaline | N | 120 | 24 | 24 | 24 | 24 | 28 | 32 | 36 | 36 |
| | GM | 4.0 | 8.3 | 4.7 | 6.9 | 4.6 | 4.8 | 7.5 | 8.5 | 7.2 |
| | 75th | 5.8 | | | | | | | | |
| | 90th | 8.3 | | | | | | | | |
| Wild and Scenic | N | 120 | 24 | 24 | 24 | 24 | 28 | 34 | 36 | 36 |
| | GM | 2.4 | 2.2 | 1.9 | 4.2 | 2.0 | 4.1 | 4.2 | 5.3 | 3.9 |
| | 75th | 4.4 | | | | | | | | |
| | 90th | 8.3 | | | | | | | | |
| Freshwater Tributaries | N | 88 | 18 | 18 | 18 | 23 | 24 | 40 | 44 | 47 |
| | GM | 3.9 | 6.0 | 4.4 | 4.6 | 3.0 | 4.9 | 7.4 | 6.6 | 6.6 |
| | 75th | 8.0 | | | | | | | | |
| | 90th | 12.8 | | | | | | | | |
| Brackish Tributaries | N | 148 | 30 | 30 | 27 | 29 | 25 | 36 | 36 | 37 |
| | GM | 5.4 | 7.7 | 7.3 | 13.8 | 5.4 | 8.2 | 9.2 | 8.5 | 11.0 |
| | 75th | 8.9 | | | | | | | | |
| | 90th | 13.7 | | | | | | | | |
| Freshwater Canals | N | 176 | 47 | 45 | 47 | 46 | 36 | 46 | 49 | 57 |
| | GM | 5.8 | 11.3 | 5.5 | 8.1 | 5.3 | 5.9 | 7.9 | 10.2 | 9.3 |
| | 75th | 11.0 | | | | | | | | |
| | 90th | 26.5 | | | | | | | | |

N - sample size
GM - geometric mean
$75^{th}$ - $75^{th}$ percentile
$90^{th}$ - percentile

# APPENDIX 6-2
# WATER QUALITY BOX-AND-WHISKER PLOTS

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This appendix provides box-and-whisker plots of Loxahatchee River District's RiverKeeper data from October 1997 through September 2010. Site locations are provided in **Figure 6-2** in **Section 6** of the main document. In the boxes, the center horizontal line marks the median of the sample. The length of each box shows the range within which the central 50 percent of the values fall, with the box edges at the first and third quartiles. The whiskers show the range of observed values that fall within inner fences (1.5 times interquartile range). Because the whiskers extend to observed values and the fences need not correspond to observed values, the whiskers do not necessarily extend all the way to the inner fences. Values between the inner and outer fences (three times interquartile range) are plotted with asterisks. Values beyond the outer fences, called far outside values, are plotted with empty circles (SYSTAT 2009).

Box-and-whisker plots are provided for alkalinity (**Figure 6-2-31**), chlorophyll a (**Figure 6-2-32**), color (**Figure 6-2-33**), conductivity (**Figure 6-2-34**), salinity (**Figure 6-2-35**), dissolved oxygen (**Figure 6-2-36**), fecal coliform (**Figure 6-2-37**), percent light (**Figure 6-2-38**), nitrate + nitrite (**Figure 6-2-39**), total kjeldahl nitrogen (**Figure 6-2-40**), total nitrogen (**Figure 6-2-41**), ammonia (**Figure 6-2-42**), pH (**Figure 6-2-43**), temperature (**Figure 6-2-44**), orthophosphorus (**Figure** 6-2-45), total phosphorus (**Figure 6-2-46**), total suspended solids (**Figure 6-2-47**) and turbidity (**Figure 6-2-48**).

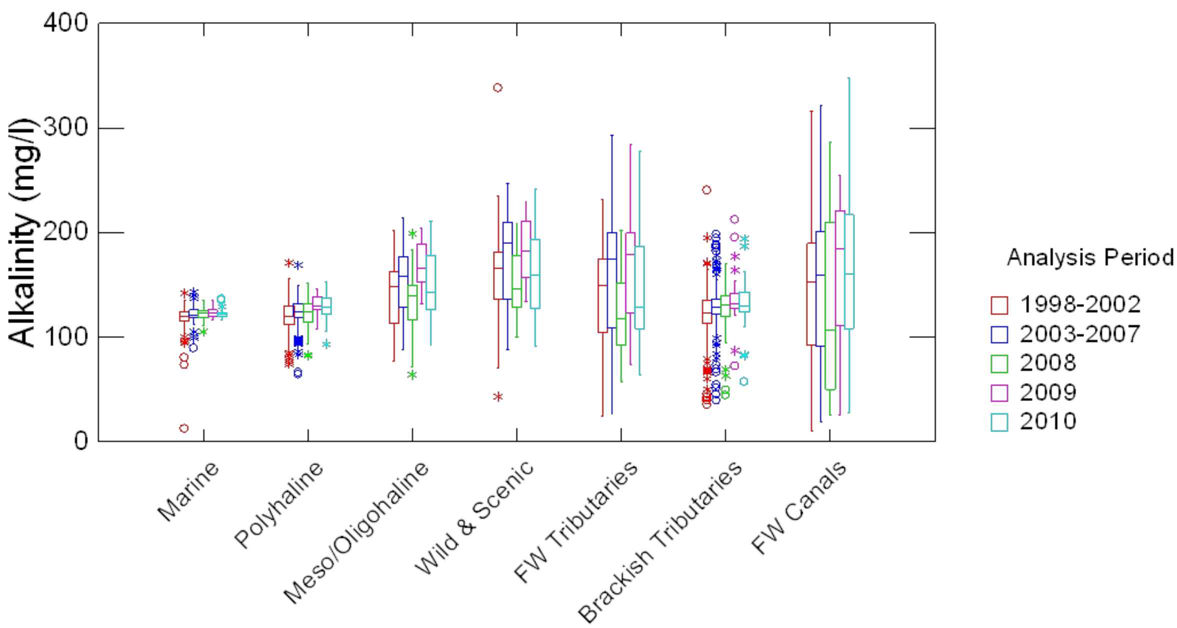


**Figure 6-2-31. Box-and-whisker plot for alkalinity**

mg/L - milligrams per liter

FW - freshwater

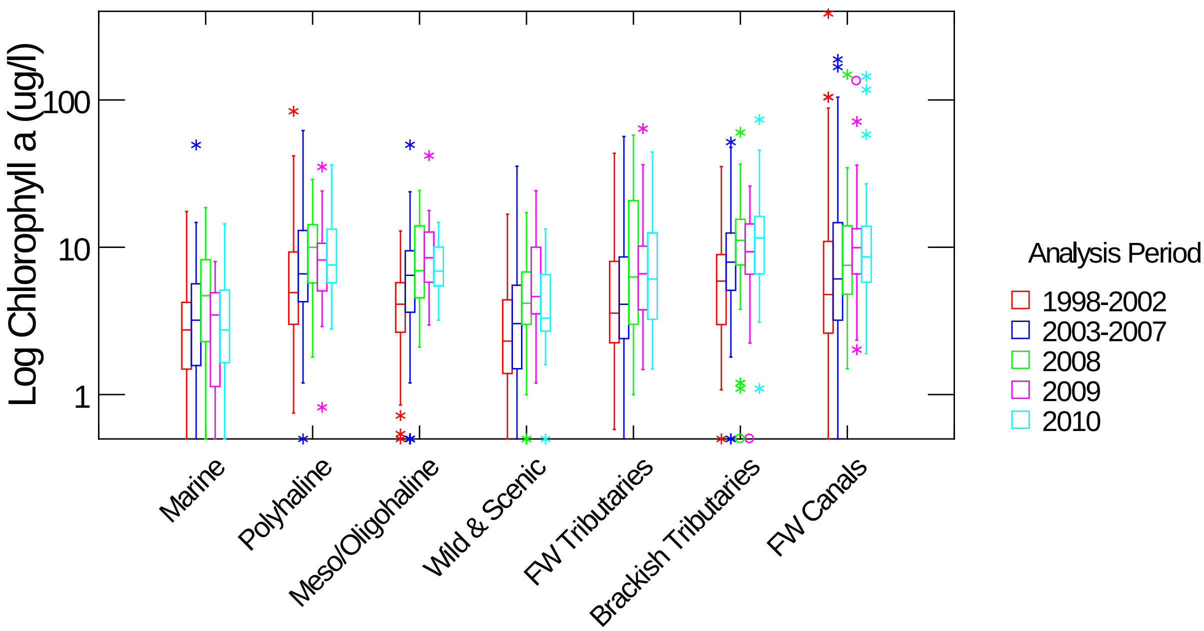


**Figure 6-2-32. Box-and-whisker plot for chlorophyll a**

µg/l - micrograms per liter

FW - freshwater

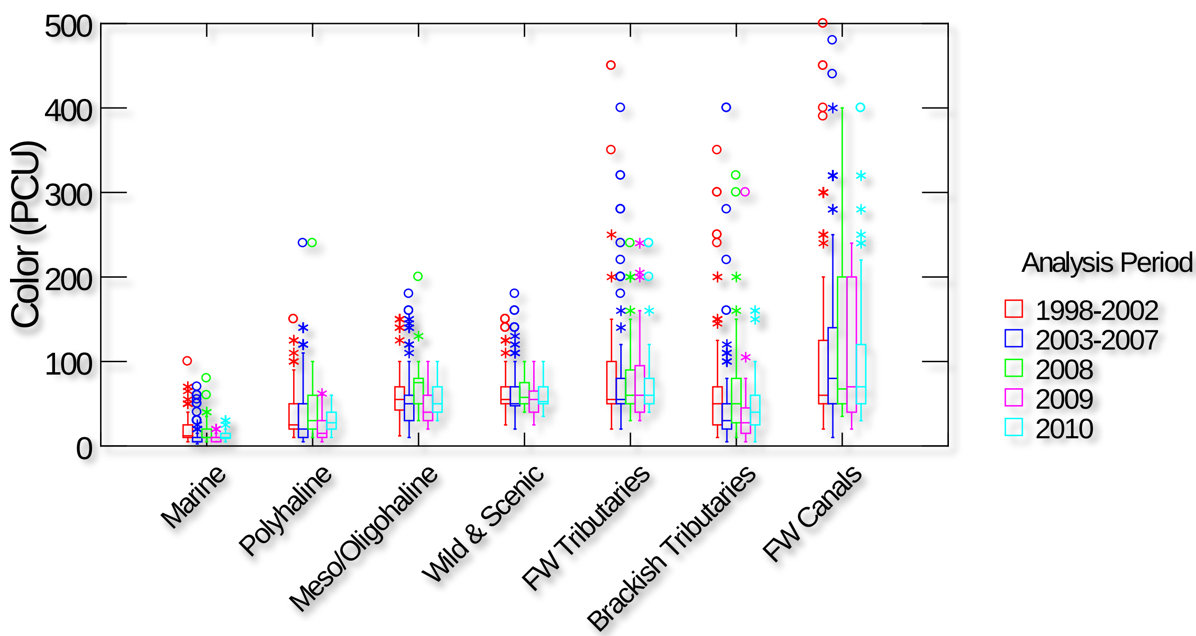


**Figure 6-2-33. Box-and-whisker plot for color**

PCU - platinum-cobalt units

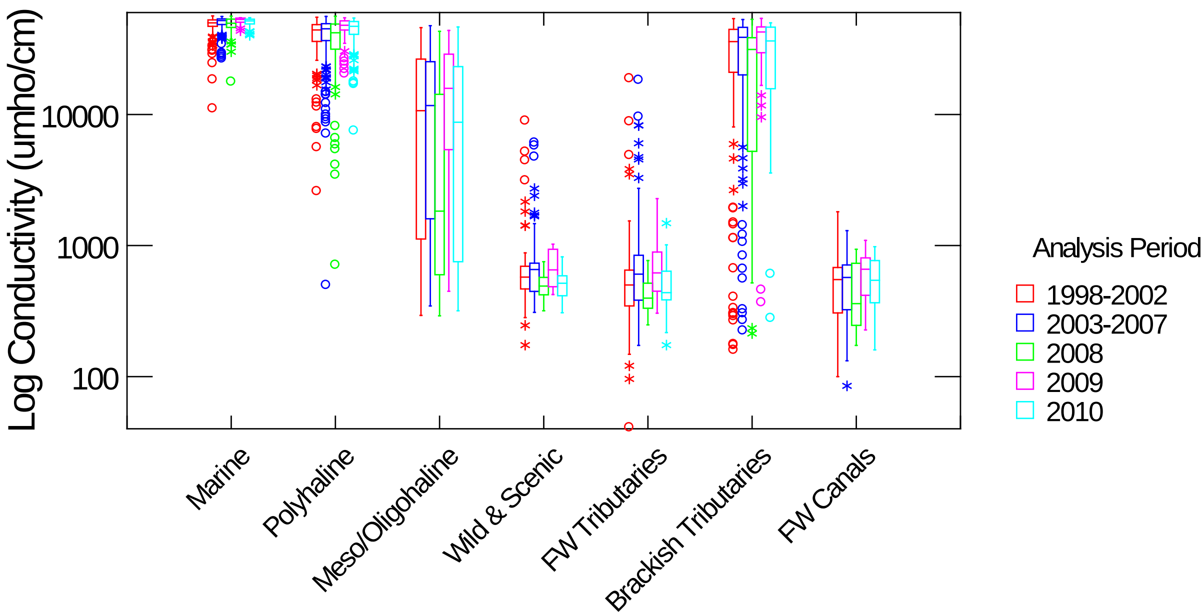


**Figure 6-2-34. Box-and-whisker plot for conductivity**

µmho/cm - micro Siemens per centimeter

FW - freshwater

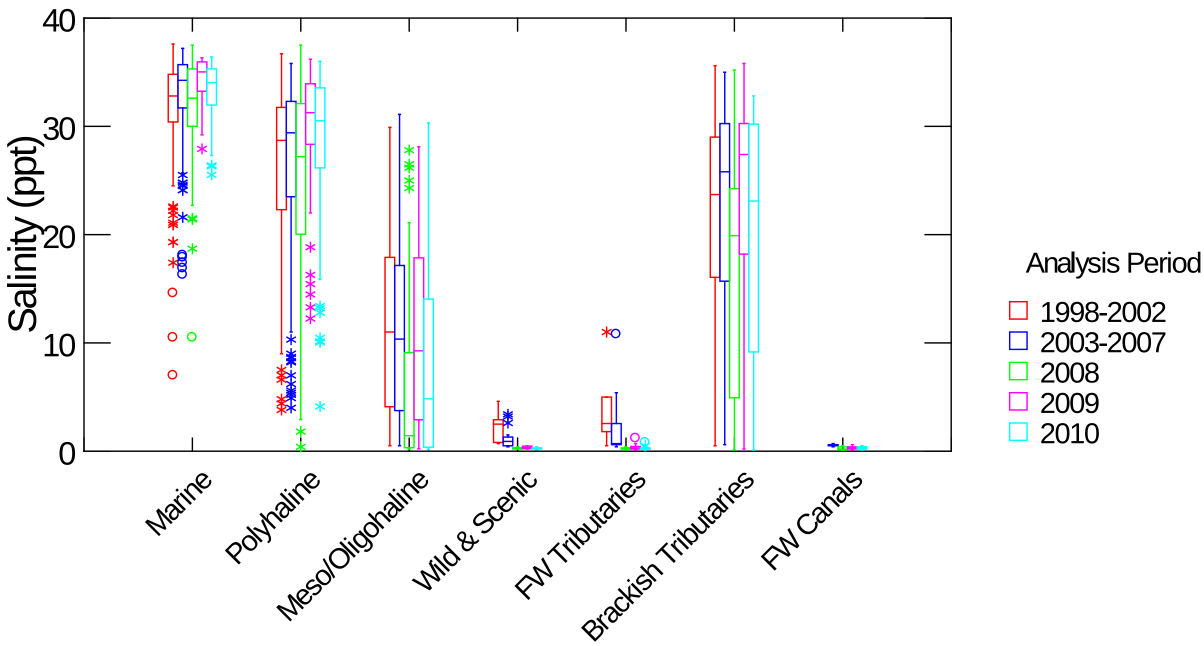


**Figure 6-2-35. Box-and-whisker plot for salinity**

ppt - parts per thousand, which is equivalent to practical salinity units (psu)

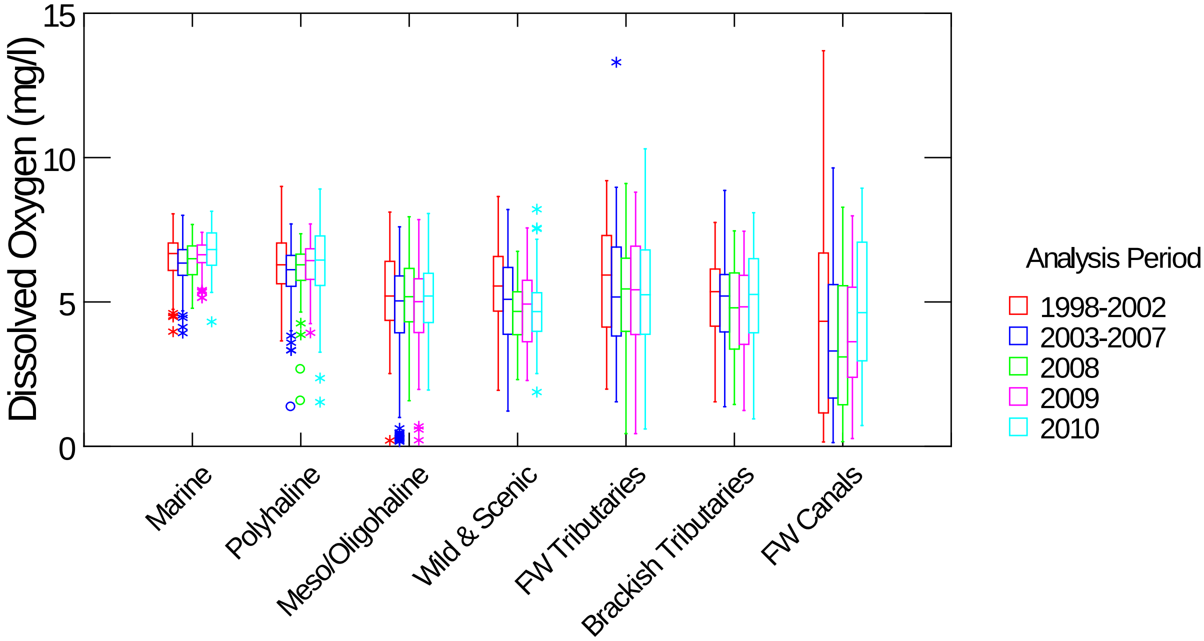


**Figure 6-2-36. Box-and-whisker plot of dissolved oxygen**

mg/L - milligrams per liter

FW- freshwater

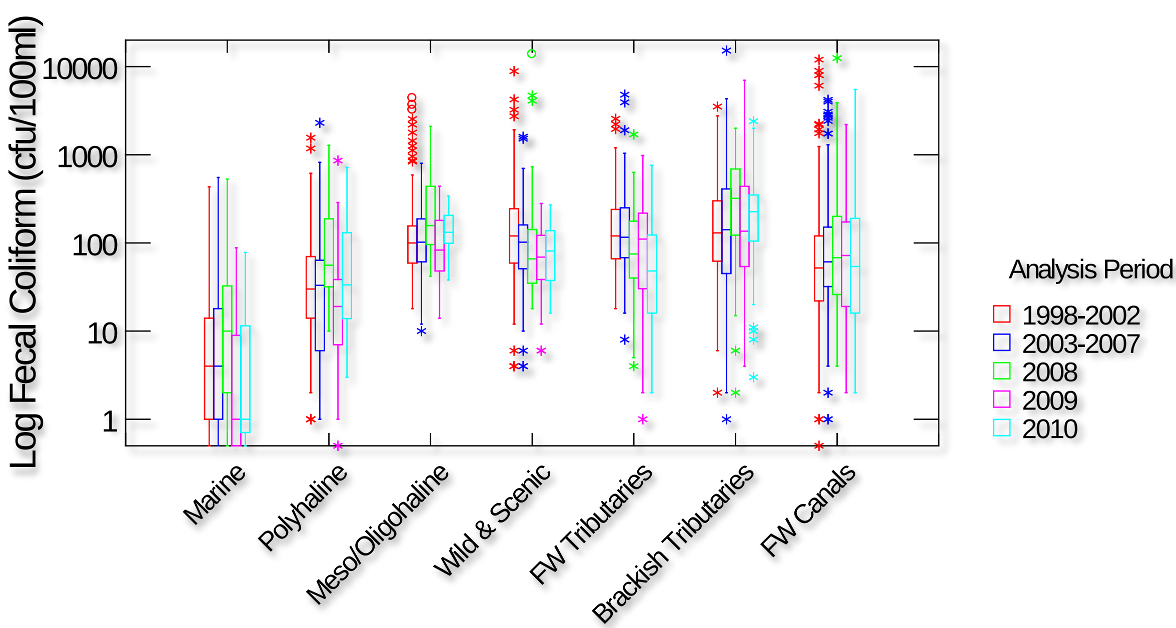


**Figure 6-2-37. Box-and-whisker plot of fecal coliform**

cfu/100ml - colony forming units per 100 milliliters

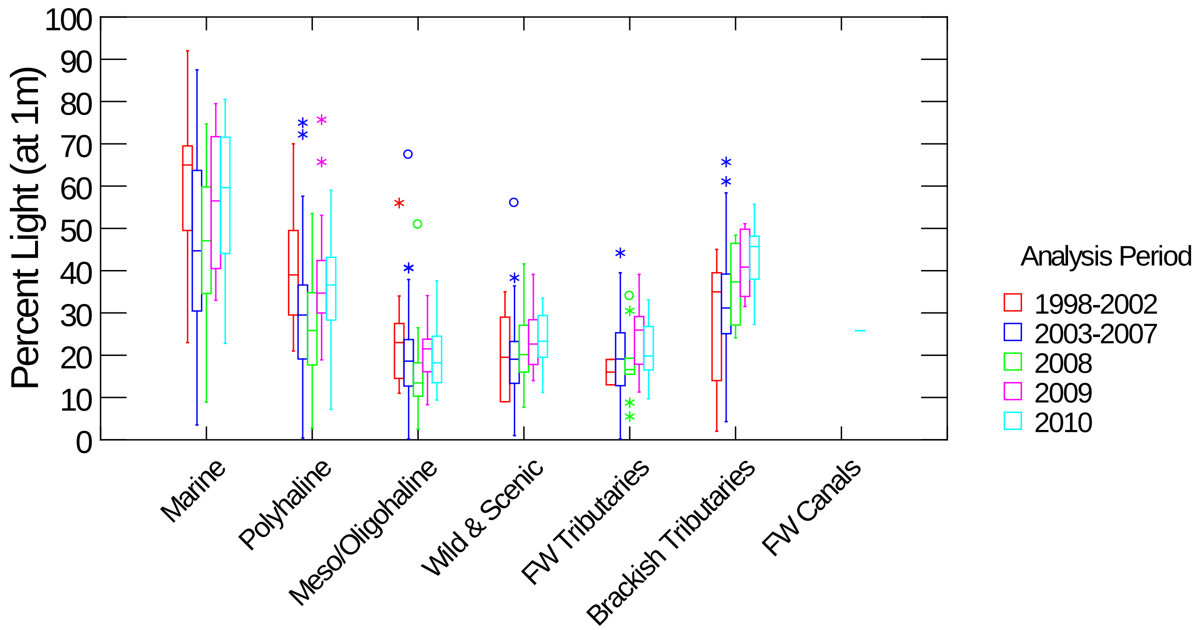


**Figure 6-2-38. Box-and-whisker plot of percent light transmission at one meter**

m - meter

FW- freshwater

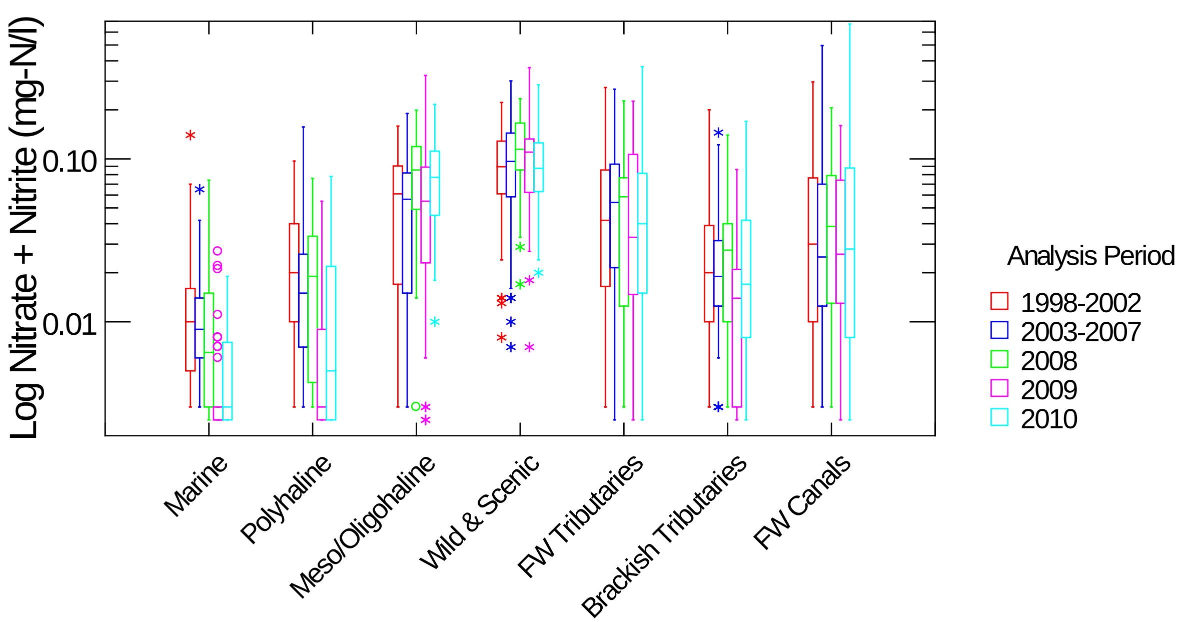


**Figure 6-2-39. Box-and-whisker plot of nitrate + nitrite**

mg-N/l - milligrams nitrogen per liter

FW- freshwater

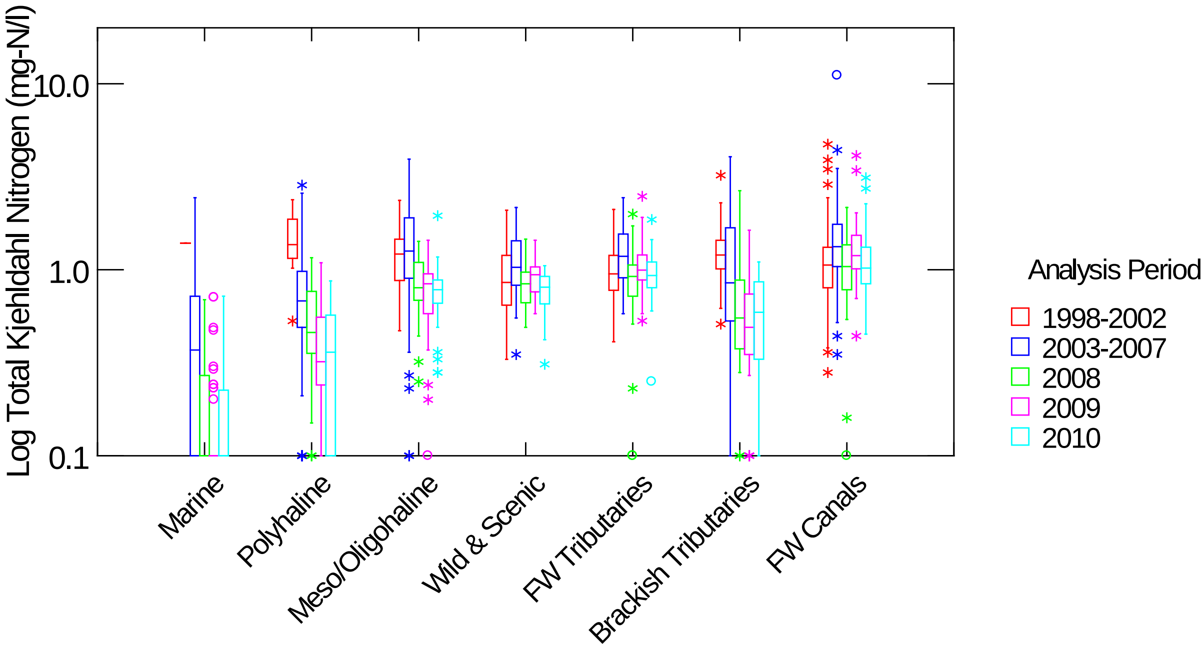


**Figure 6-2-40. Box-and-whisker plot of total kjeldahl nitrogen**

mg-N/l - milligrams nitrogen per liter

FW- freshwater

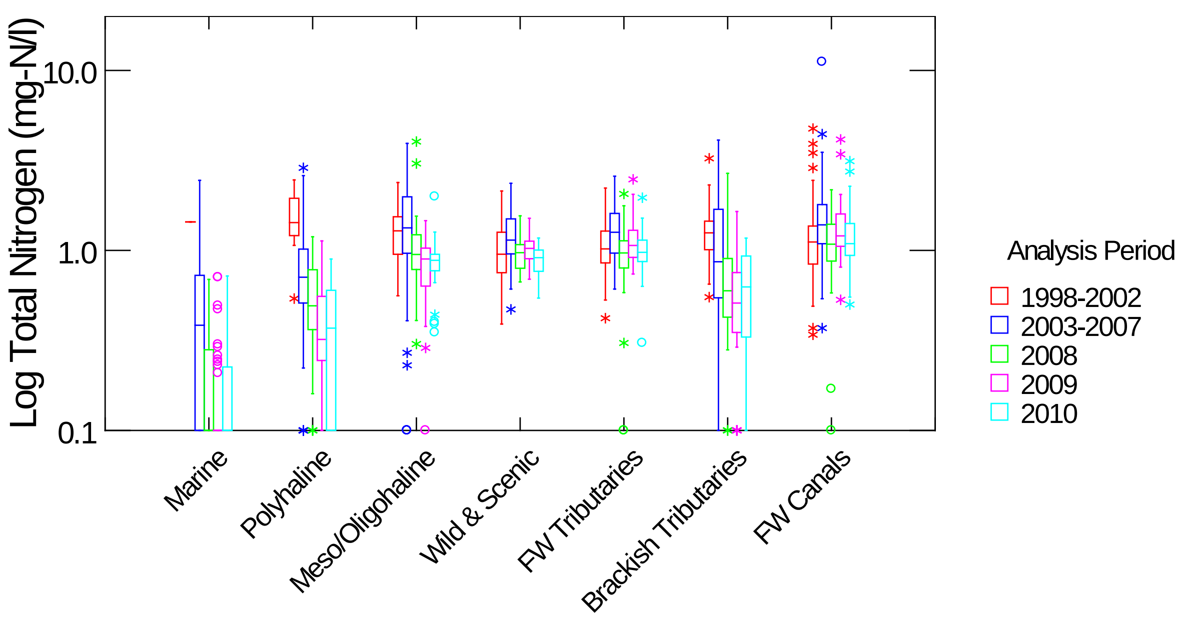


**Figure 6-2-41. Box-and-whisker plot of total nitrogen**

mg-N/l - milligrams nitrogen per liter

FW- freshwater

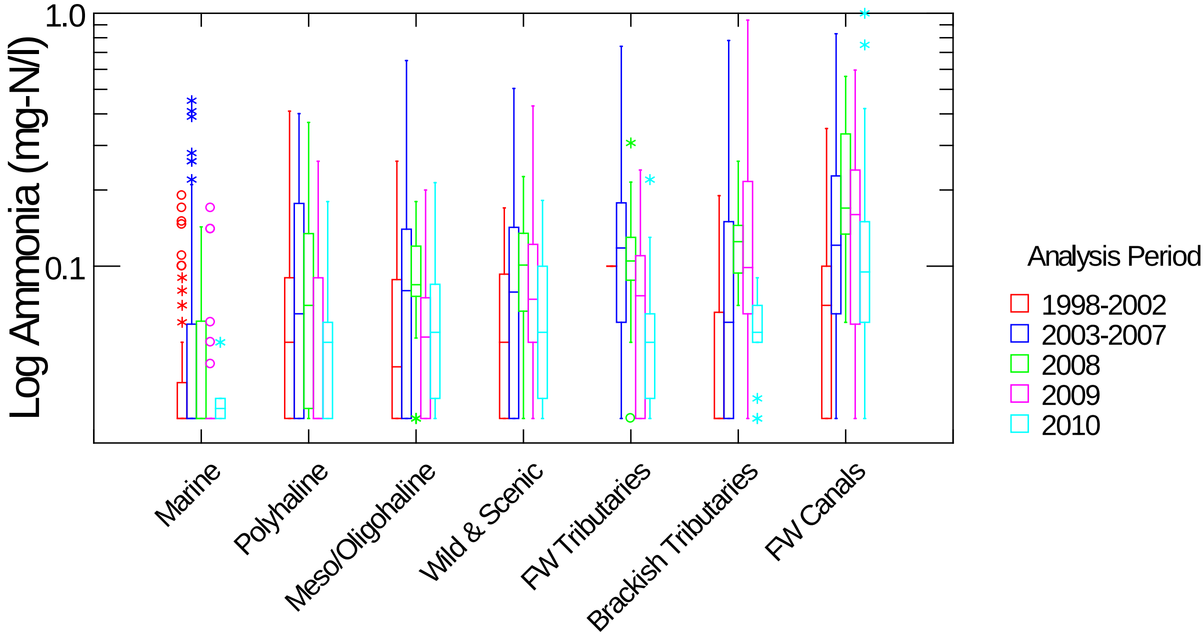


**Figure 6-2-42. Box-and-whisker plot of ammonia**

mg-N/l - milligrams nitrogen per liter

FW- freshwater

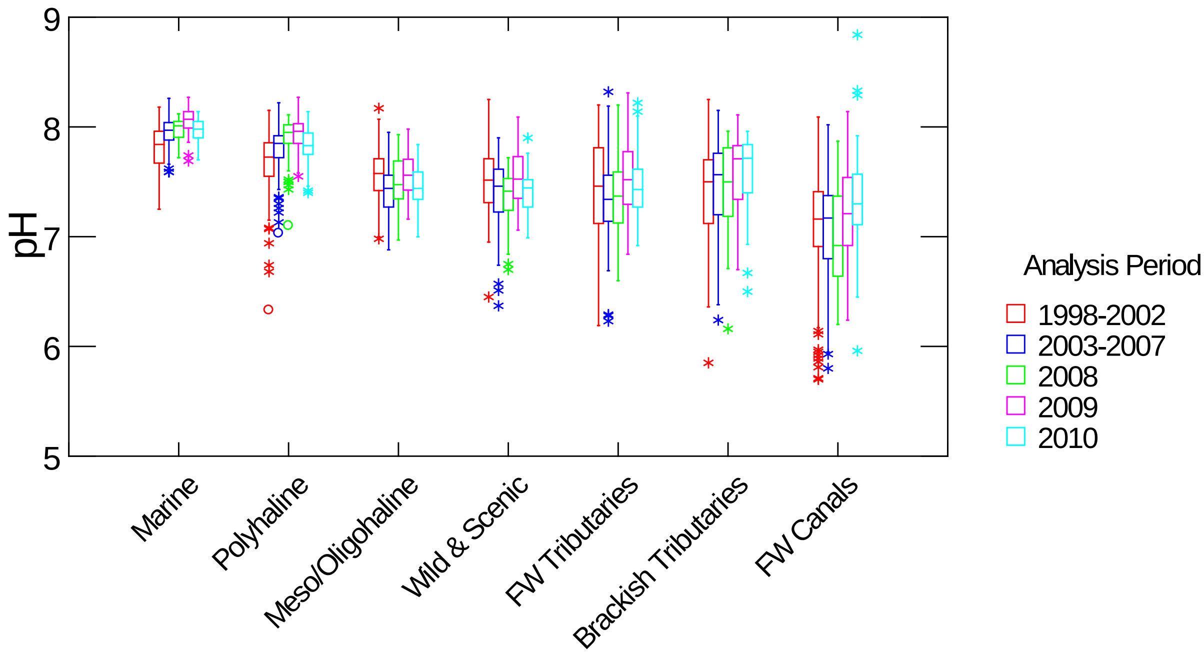


**Figure 6-2-43. Box-and-whisker plot of pH**

FW- freshwater

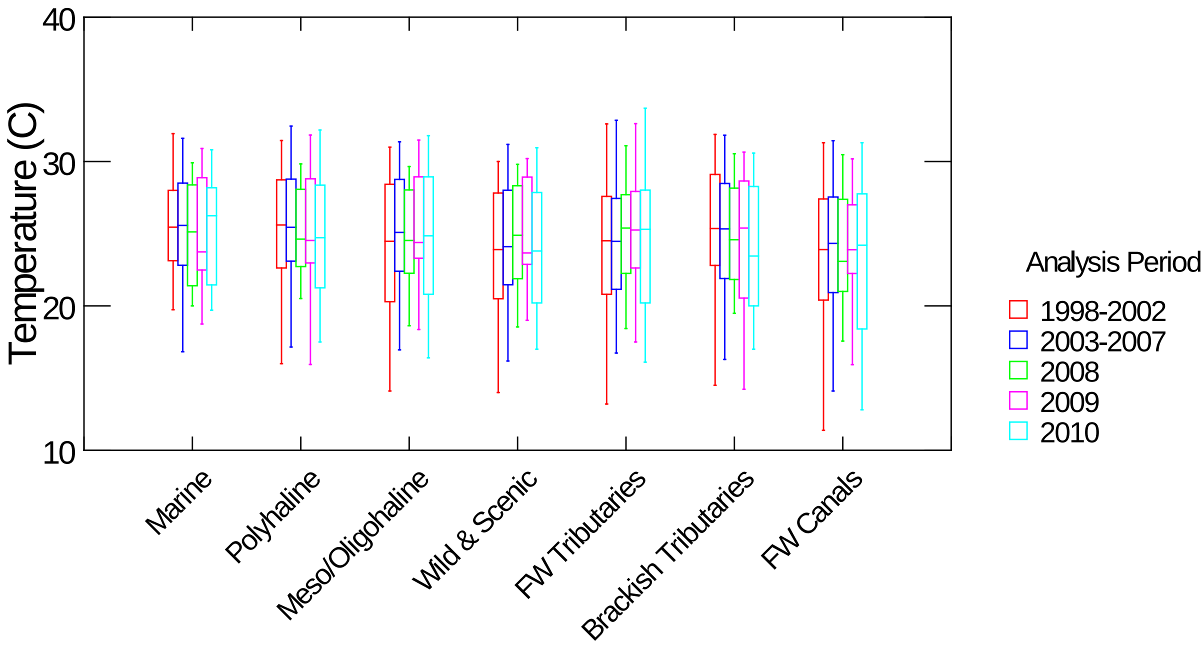


**Figure 6-2-44. Box-and-whisker plot of temperature**

C - degrees Celsius

FW- freshwater

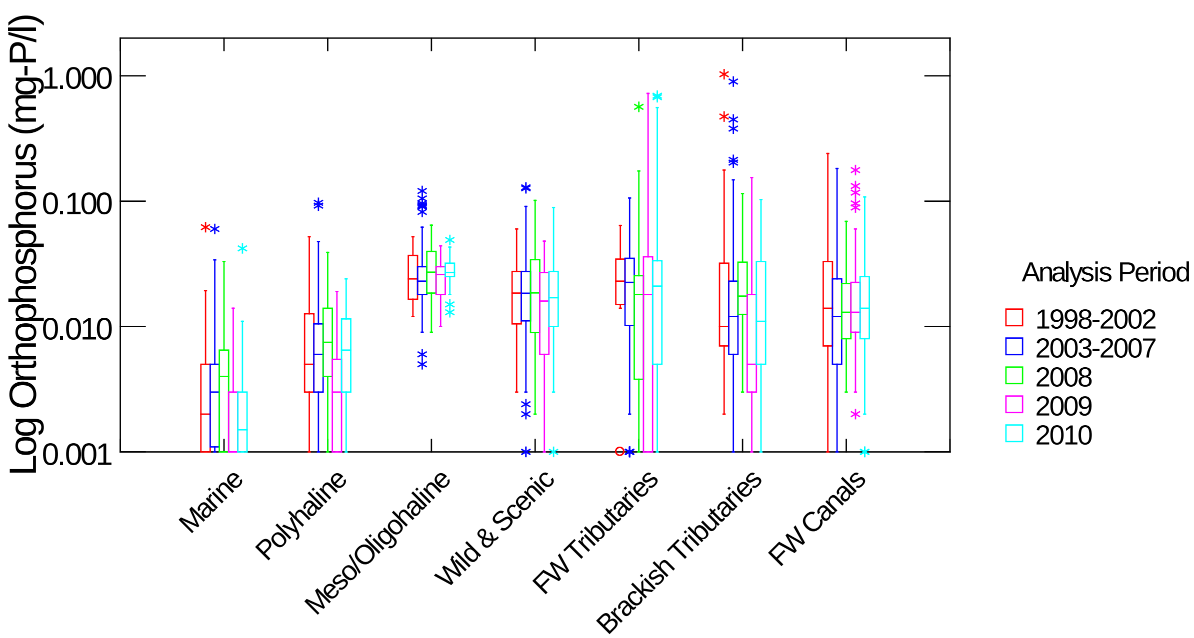


**Figure 6-2-45. Box-and-whisker plot of orthophosphorus**

mg-P/l - milligrams phosphorus per liter

FW- freshwater

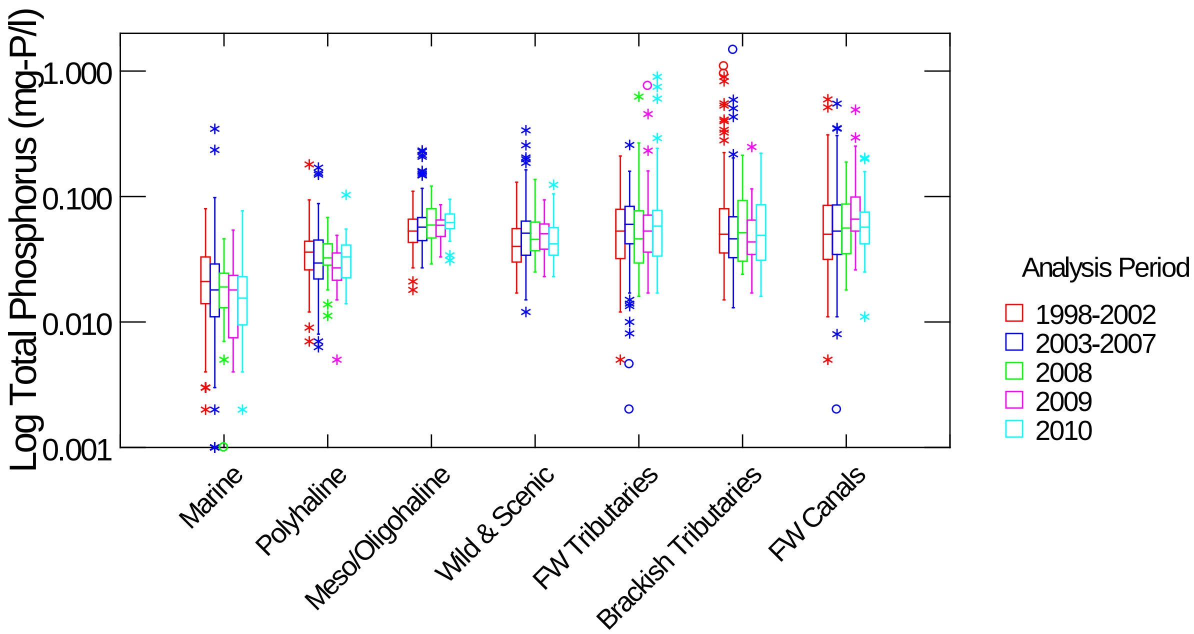


**Figure 6-2-46. Box-and-whisker plot of total phosphorus**

mg-P/l - milligrams phosphorus per liter

FW- freshwater

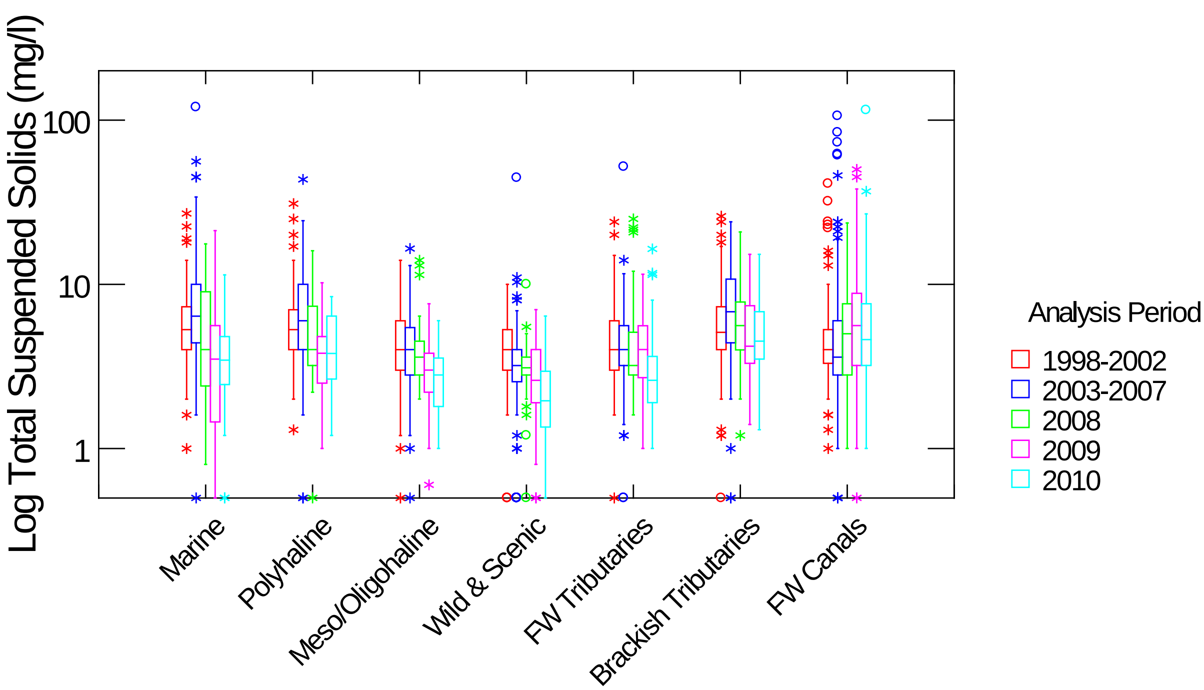


**Figure 6-2-47. Box-and-whisker plot of total suspended solids**

mg/L - milligrams per liter

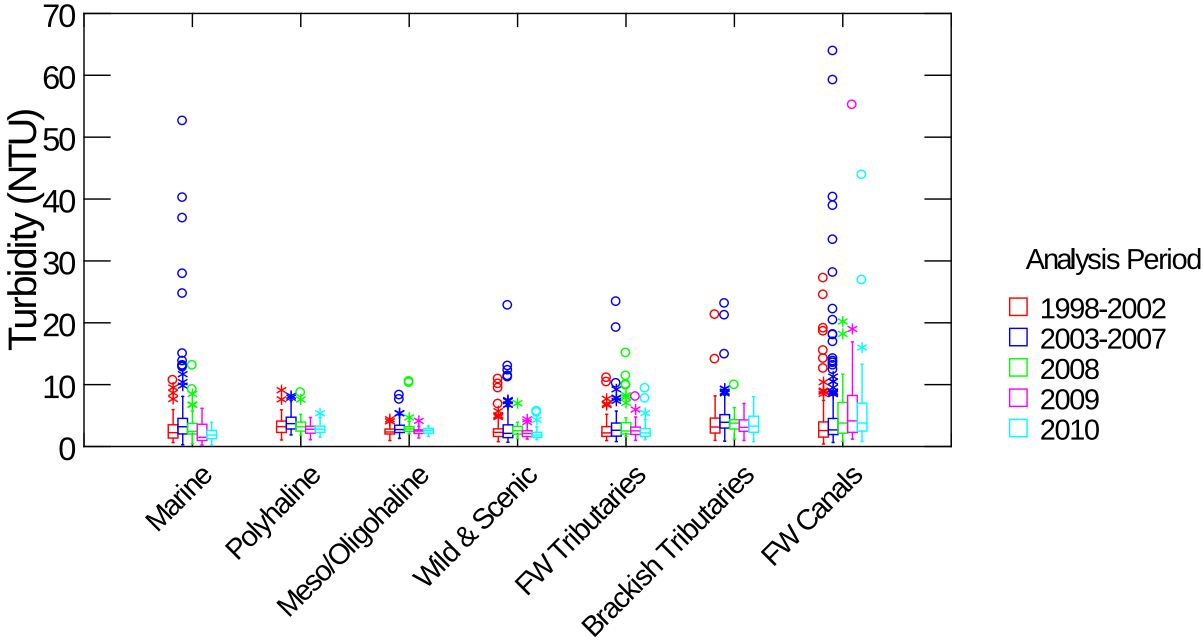


**Figure 6-2-48. Box-and-whisker plot of turbidity**

NTU - nephelometric turbidity unit

FW- freshwater

# APPENDIX 6-3
# WATER QUALITY SPATIAL PLOTS

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This appendix provides spatial plots of RiverKeeper data for five water quality parameters collected by the Loxahatchee River District from October 2009 through September 2010. The five parameters are total nitrogen (**Figure 6-3-49**), total phosphorus (**Figure 6-3-50**), chlorophyll a (**Figure 6-3-51**), dissolved oxygen (**Figure 6-3-52**) and fecal coliform bacteria (**Figure 6-3-53**).

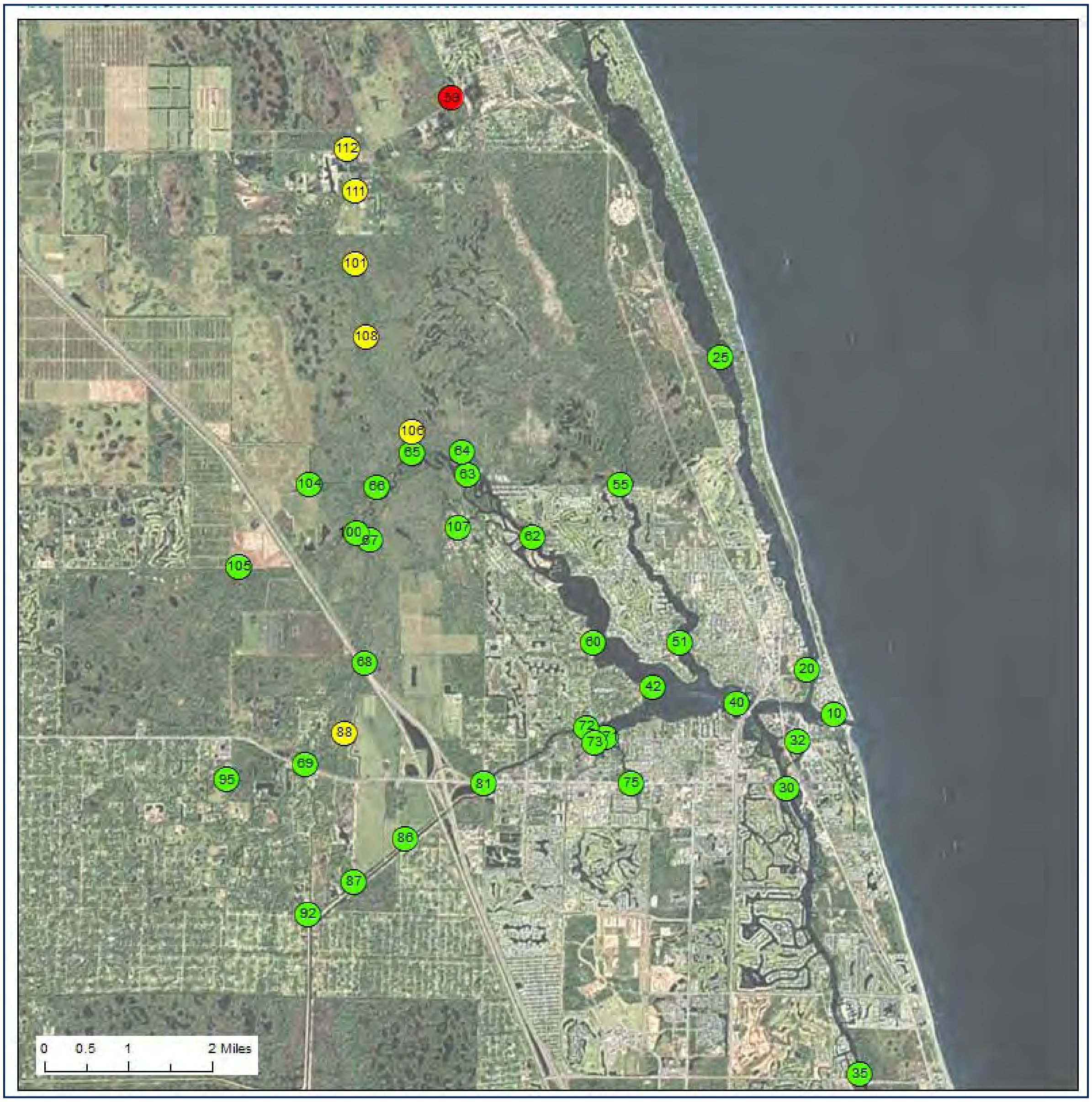


**Figure 6-3-49. Water quality stoplight scoring by sampling site for total nitrogen October 2009–September 2010**

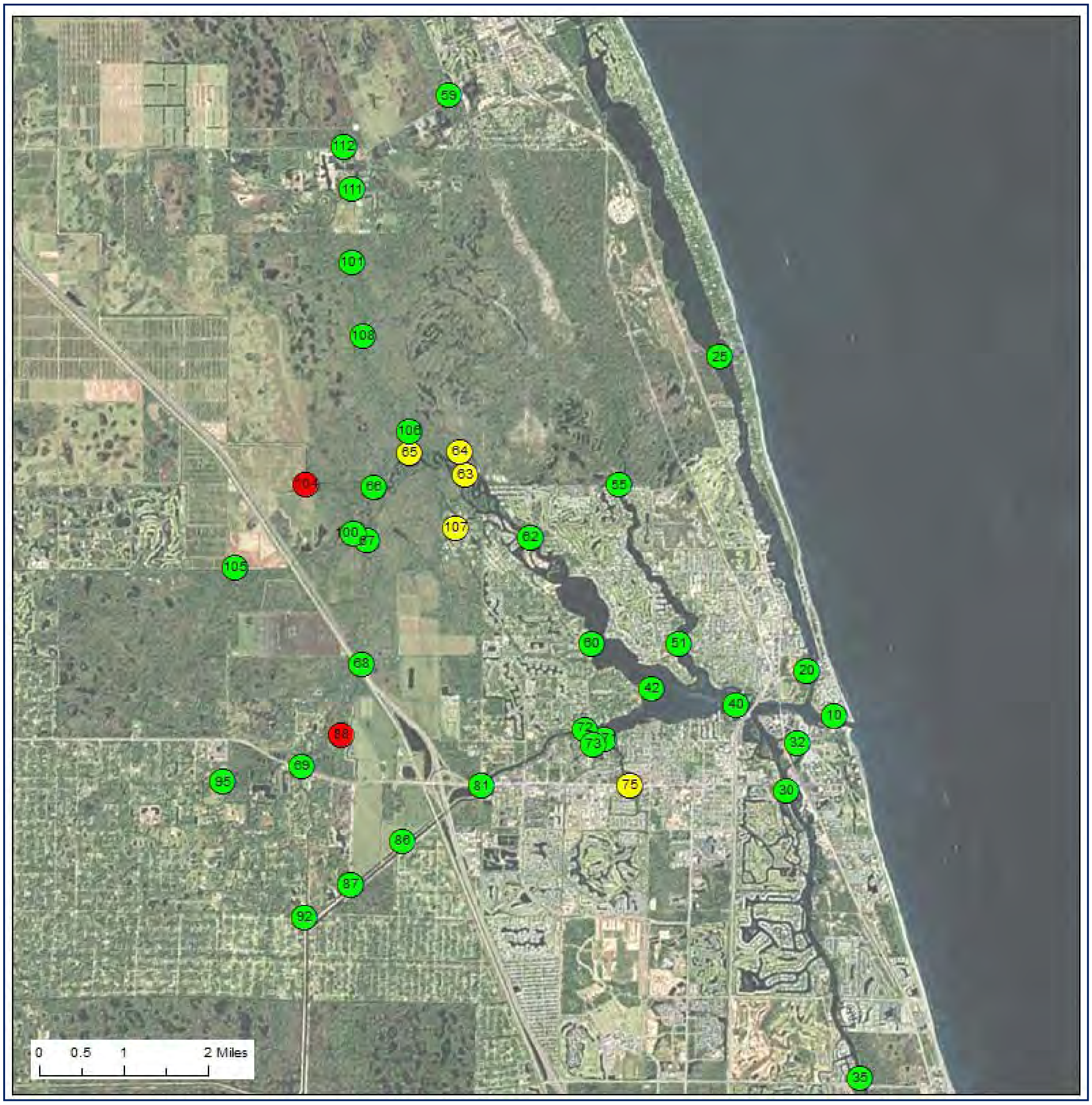


**Figure 6-3-50. Water quality stoplight scoring by sampling site for total phosphorus October 2009–September 2010**

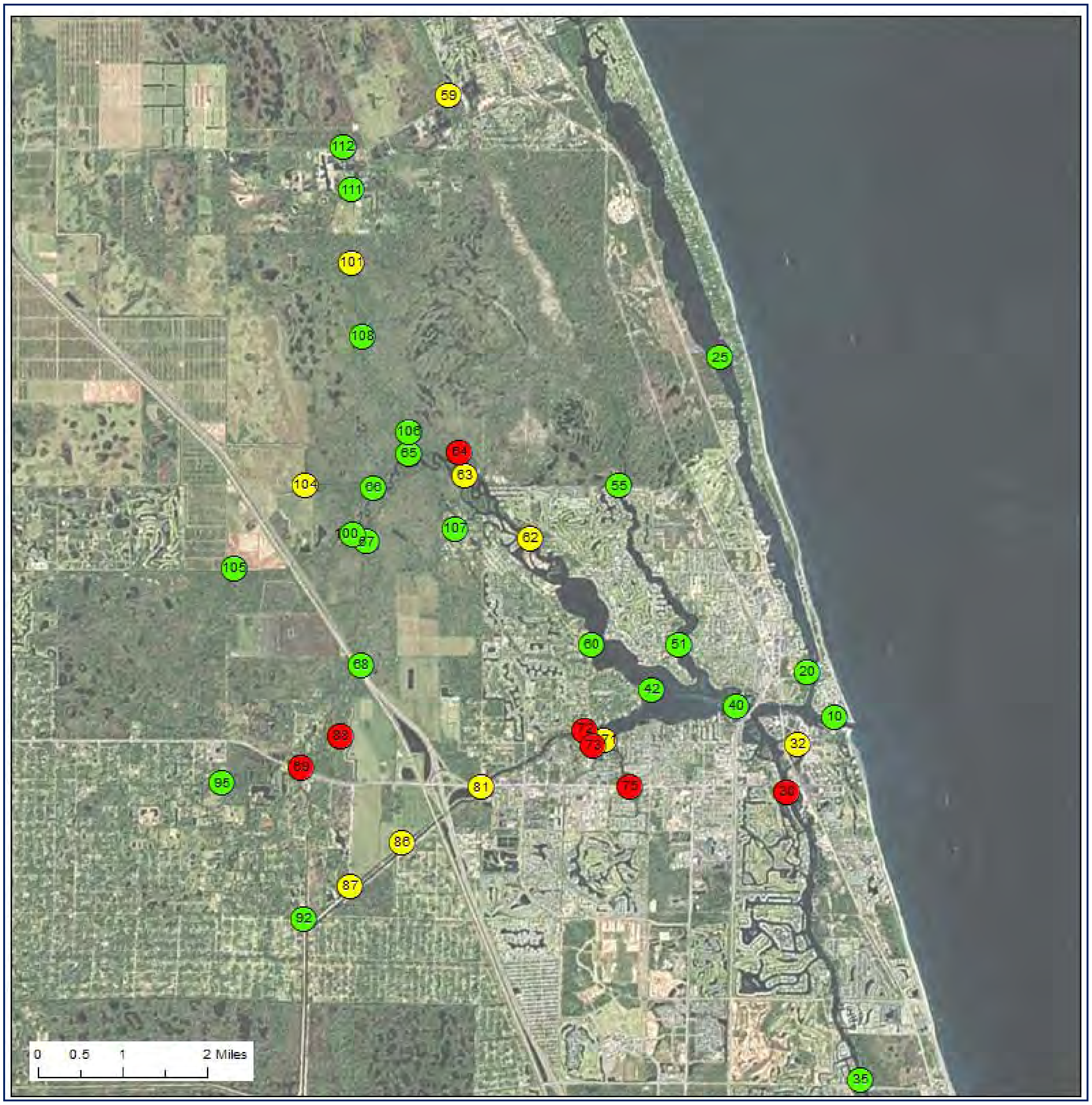


**Figure 6-3-51. Water quality stoplight scoring by sampling site for chlorophyll a October 2009–September 2010**

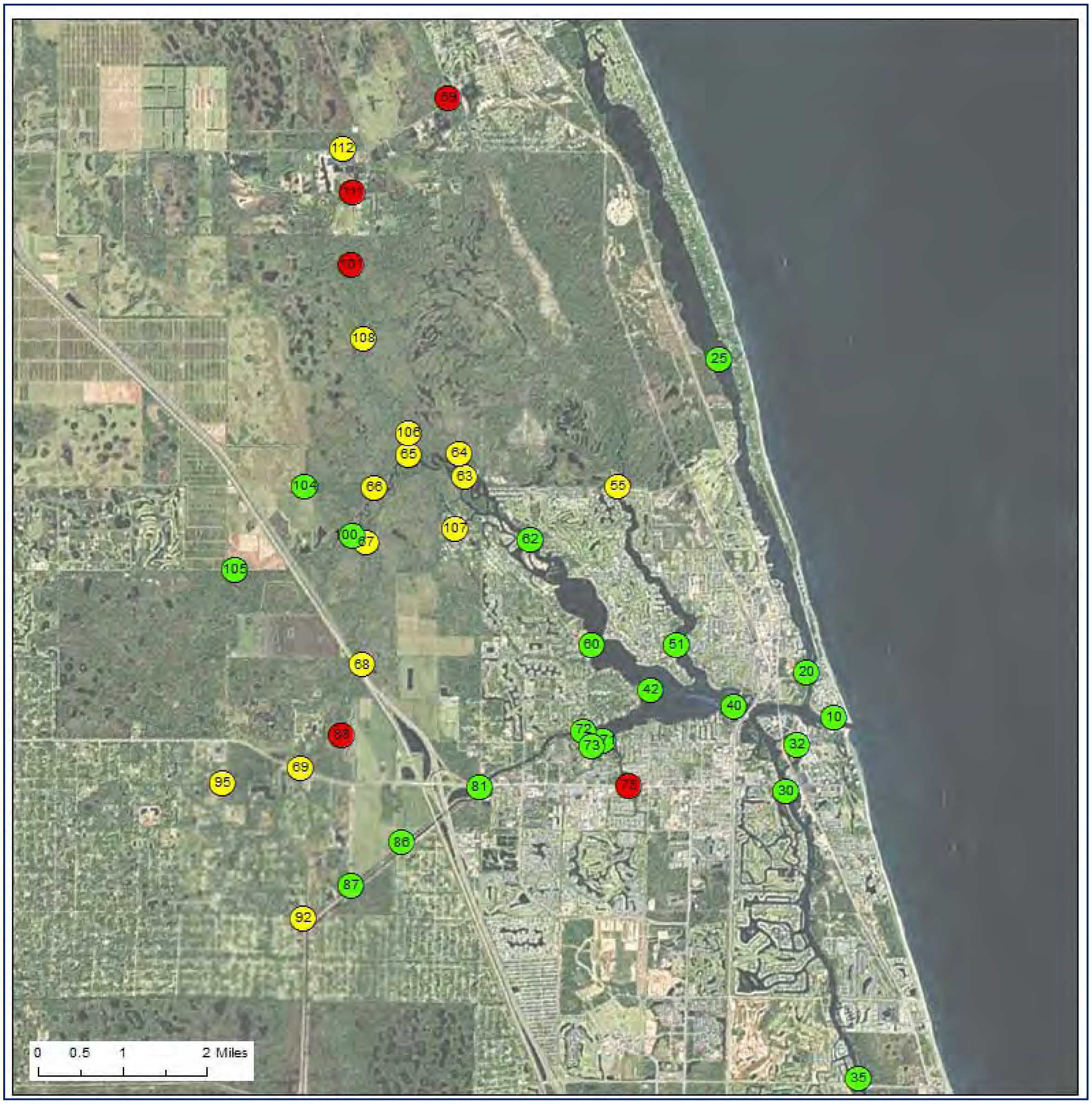


**Figure 6-3-52. Water quality stoplight scoring by sampling site for dissolved oxygen October 2009–September 2010**

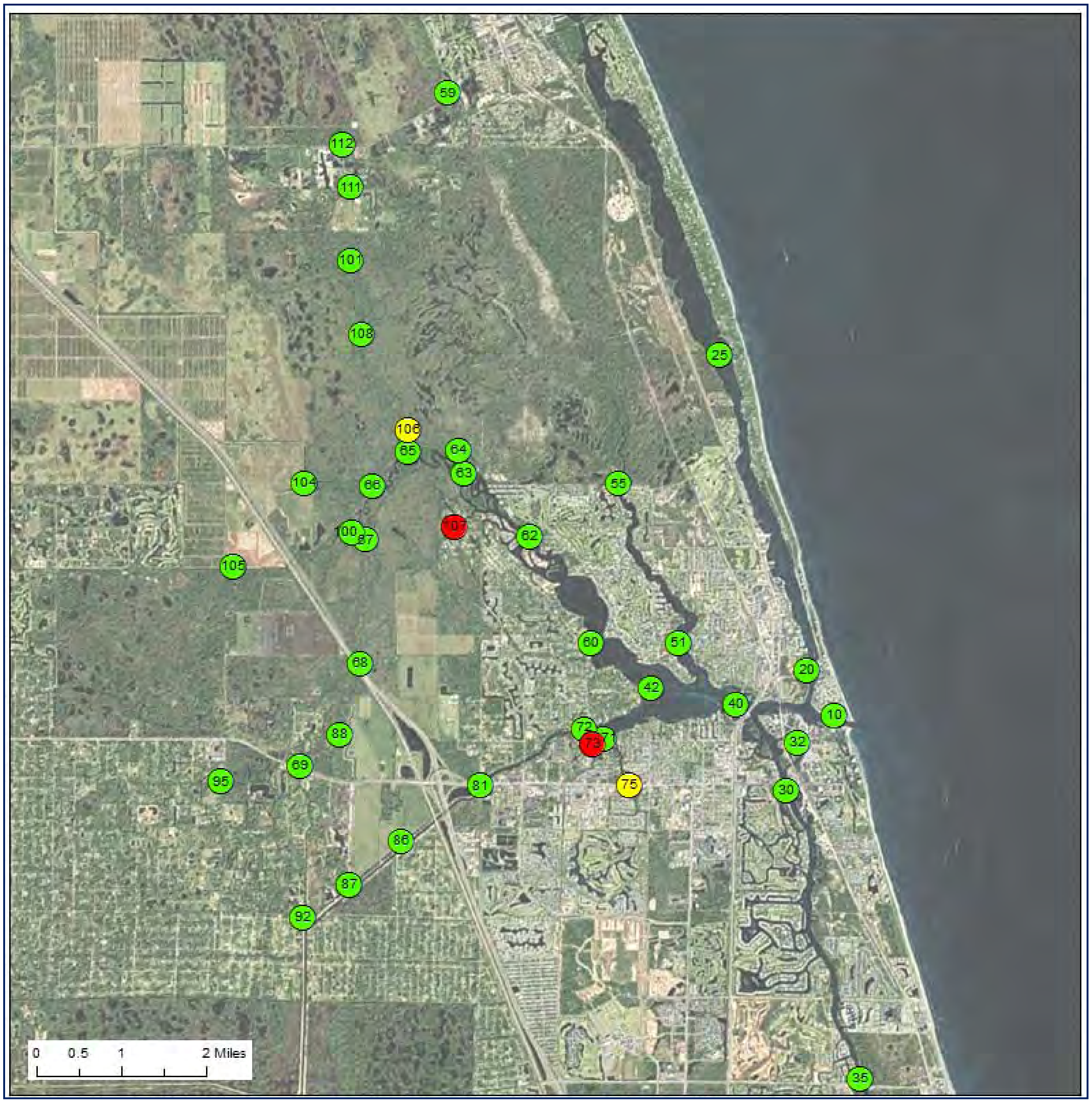


**Figure 6-3-53. Water quality stoplight scoring by sampling site for fecal coliform bacteria October 2009–September 2010**

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