Appendix 12-1: Riverine and Tidal Floodplain Vegetation of the Loxahatchee River and Its Major Tributaries

PRELIMINARY REPORT ON THE RIVERINE AND TIDAL FLOODPLAINS OF THE LOXAHATCHEE RIVER AND ITS MAJOR TRIBUTARIES

BY

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Coastal Ecosystem Division
Florida Department of Environmental Protection
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EXECUTIVE SUMMARY

As Florida's first National Wild and Scenic River, the Loxahatchee River and its major tributaries deserves the extensive attention received from the federal government, state and local agencies, local residents, and tourists. Its most impressive feature is the sub-tropical cypress swamp that encompasses most of the river's riparian floodplain. Between approximately River Mile (RM) 9 and 16, a bald cypress forest more than 300 years old endures as one of the last of its kind in Southeast Florida. Moreover, the Loxahatchee River is South Florida's last free-flowing river system. Its tidal floodplains and estuary also represent valuable ecological resources within the Loxahatchee River watershed. In fact, the Loxahatchee River supports the largest population of snook on the east coast of Florida.

In spite of the impressive list of enduring natural resources, problems still abound in "Paradise". The Loxahatchee watershed is now permanently altered by (1) stabilization of Jupiter Inlet, which further heightens the affect of sea level rise (i.e., tidal amplitude), saltwater intrusion, and the encroachment of salt tolerant mangrove communities; and (2) construction and operation of drainage canal systems, which alter the natural pattern of freshwater flow and inundation of the floodplain. The Restoration Plan for the Northwest Fork of the Loxahatchee River (2006) chronicles these problems and provides ecological target species, performance measures, and monitoring requirements needed to track the success of restoration goals and provide guidance to future adaptive management and operational practices.

The major concerns regarding floodplain communities in the riverine reach were: (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 canopy species into multiple forest type communities; and (4) insufficient inundation for aquatic organisms to utilize floodplain swamp communities. Since there are fewer reported deaths of canopy species in the tidal reaches and because we have a better understanding of the affects of tidal amplitude, our emphasis on restoration in the tidal reaches remained focused on reducing salinities to below 2 ppt at the mouth of Kitching Creek. Continued vegetation monitoring of the floodplains will be necessary to ensure that we are getting the water correct for these ecological communities.

In 2003, staff of the South Florida Water Management District (SFWMD or the District) and District 5 Florida Park Service (FPS) established 10 vegetative belt transects on the Northwest Fork and its major tributaries to further investigate floodplain community composition, structure and health. Seven of the 10 transects were previously investigated from 1967, 1983/1984, and 1993/1994. Three new transects were created to investigate additional tributaries. Guidelines were identified for the reaches (riverine, and upper and lower tidal) and the 16 forest community types that were encountered. The major vegetative types were identified as swamp, bottomland hardwood, hydric and mesic hammock, and uplands. Elevation was identified as one of the major factors in the determination of community composition. Other factors that contributed to the determination of plant community structure included logging and fire history, presence or absence of exotics, hummocks and the availability of nutrients and light..

Species richness, abundance, biomass (Relative Basal Area, RBA) and frequency of occurrence were examined within the 138 vegetative plots. Overall forest types were distributed as 58 percent swamp, 11 percent bottomland hardwood, 11 percent hammock, 10 percent mixed hardwood, 3 percent upland, and 1 percent freshwater marsh. Sites that had been previously disturbed exhibited higher species richness. Past lumbering activities were a factor in species richness as well as salinity and ground elevation. The canopy species included 26 trees and one woody vine while the shrub and groundcover layers yielded 49 and 118 species, respectively. The canopy consisted primarily of 5 species (white mangrove 22.5 percent, red mangrove, 14.2

percent, pond apple 13 percent, cabbage palm 12.4 percent, and bald cypress 9 percent). However, from the standpoint of biomass (RBA), approximately 63 percent of the canopy consisted of two species, bald cypress (40.6 percent), and cabbage palm (22.7 percent). Similar trends were observed with frequency of occurrence within the canopy. With regard to an overall importance ranking (abundance, basal area, frequency of occurrence) cabbage palm ranked the highest and was followed by bald cypress, white mangrove, pond apple, pop ash, red mangrove, red maple, wax myrtle, water hickory and Carolina willow.

During the 2004 hurricane season, Florida was hit by an unprecedented 5 hurricanes (Charley, Frances, Ivan, Jeanne, and Charley). The floodplain forest of the Loxahatchee River was impacted by both Hurricanes Frances and Jeanne. Hurricane Frances made landfall on September 5, 2004 near Sewall's Point, Florida with maximum sustained winds of 105 mph (91 kts, Category 2). Three weeks after Hurricane Frances, Hurricane Jeanne made landfall at Stuart, Florida on September 26, 2004 as a category 3 with winds of 120 mph (105 kts) and in almost the exact same location as Hurricane Frances.

Canopy trees were re-examined along the 10 belt transects in the summer and fall of 2005 to assess hurricane damage on the floodplains. Comparisons were made between the 2003 survey of the canopy trees and the remaining canopy. In the tidal floodplains, tall white mangrove (*Laguncularia racemosa*) on Transect 9 were heavily impacted in the form of tip-overs (windthrown, 47 percent) and broken branches (49 percent) while shorter red mangrove (*Rhizophora mangle)* were only marginally impacted by broken branches (72 percent) and defoliation. In the riverine floodplains, the heaviest damage occurred within bottomland hardwood communities. Large red maple (*Acer rubrum)* and water hickory *(Carya aquatic)* were easily tipped-overed with their shallow root systems (23.5 percent and 25 percent tip over rate, respectively). Few bald cypress (*Taxodium distichum*) were tipped over (0.008 percent); however, major branches were lost (86.3 percent), resulting in greater levels of light penetration on the floor of the floodplains. Most trees are recovering quickly by sending out new branches. Of the 1,694 canopy trees sampled, a 2.5 percent mortality rate occurred as a result of the storms. There is a concern that the storms may provide an opportunity for the expansion of exotics within the floodplains and future research is needed to measure long term impacts of the hurricanes.

In 2006, all ten transects were re-examined for species occurrence in the canopy, shrub and groundcover. For the 1993/1994 study and 2006 observations, species richness for Transects 1 through 6 showed very similar patterns. Again, 1993/1994 was an extremely wet period on the river while 2003 and 2006 had been dry. Species richness was slightly higher for the 1993/1994 study than the 2006 observation study with the exceptions of Transects 4 and 6. This is probably a direct result of a combination of hurricane impacts (increases in light availability as a result of the damaged canopy) and the extremely dry conditions of 2006. The 2003 study exhibited consistently lower values for species richness than the 1993/1994 and 2006 studies.

The proposed restoration target flows should enhance the native freshwater communities in the floodplain of the Loxahatchee River by discouraging the invasion of upland, transitional and exotic species while providing additional nutrients to the various floodplain plant communities. Due to the improved freshwater environment in the tidal floodplain, freshwater plant communities (primarily bald cypress, pop ash, and pond apple) would be expected to improve their domination of the canopy while saltwater species would be reduced to subcanopy except in the lower tidal reach. Pond apple may see some increases in the lower tidal because it appears to be more salt tolerant; however, the limiting factor in the lower tidal reach continues to be tidal amplitude. The restorative flows will provide SFWMD Operations Department with a scientifically based plan to regulate water deliveries from the C-18 Canal through the G-92 structure on a seasonal basis.

INTRODUCTION

The Loxahatchee River and Estuary are located along the lower East Coast of Florida (**Figures 1** and **2**). The watershed drains an area that was historically 240 square miles within northern Palm Beach and southern Martin Counties and connects to the Atlantic Ocean via the Jupiter Inlet, in Jupiter, Florida (**Figure 3**). Just west of the inlet, the river opens into a central embayment area, which formed at the confluence of three major branches, the Northwest Fork, the North Fork, and the Southwest Fork (**Figure 4**). The Northwest Fork is the largest branch with its two major tributaries (Cypress Creek and Kitching Creek). Wilson, Moonshine, and Ketter Creeks are three minor streams that can also be found along the tidal portion of the Northwest Fork of the Loxahatchee River. Other features include the Lainhart and Masten Dams, which were constructed in the 1930s at River miles (RM) 14.78 and 13.50, respectively.

During the past 100 years, the natural hydrologic regime of the Loxahatchee Watershed (**Figure 4**) has been altered by drainage activities associated with urban, agricultural development, and stabilization of the inlet. A year by year time line of the changes is shown in Appendix A. Most of the watershed was historically drained by the Northwest Fork. Headwaters of the river originated in the Loxahatchee and Hungryland Sloughs. Today much of the watershed has been impacted by the construction of canals and levees for drainage and flood protection. McPherson and Halley (1996) in their publication, *The South Florida Environment: A Region Under Stress*, documented the encroachment of mangroves, along with the overall reductions in freshwater flows, maintenance of lower groundwater levels, short duration high volume freshwater flows for flood protection, and changes in the quality of runoff. Environmental studies are continuing to be conducted today in order to document hydrological, chemical, and biological factors associated with the health of the floodplain area.

The floodplain of the Loxahatchee River consists of a tropical and temperate riparian forest. Species diversity in the understory has been high because of the overlapping of tropical and temperate vegetation communities. As a riparian forested wetland system, the vegetative communities within the floodplains vary from dry to occasionally flooded stages as the river and its tributaries react to local rainfall events. Plant communities in the floodplain include hammocks, bottomland hardwood, and swamps. Hydric hammocks are generally defined as "tree islands" that most often signify a heightened elevation within the floodplain topography and are often associated with transitional species. On the Loxahatchee River, hydric hammocks are dominated by cabbage palm (*Sabal palmetto)*. Bottomland hardwood communities contain diverse vegetation that varies along gradients of topography and flooding frequency. They are usually considered to be more productive than the adjacent uplands due to the periodic inflow of nutrients, especially when flooding is seasonal rather than continuous (Mitsch and Gosselink, 1993). Swamps are defined as woody wetlands that have standing water for most, if not all, of the growing season. On the floodplain of the Loxahatchee River, they consist primarily of bald cypress (*Taxodium distichum*), red and white mangrove (*Rhizophora mangle* and *Laguncularia racemosa*), pondapple (*Annona glabra*) and pop ash (*Fraxinus caroliniana*). The Loxahatchee River contains some of the last pristine subtropical cypress swamps in Southeast Florida. The more mature bald cypress trees range from 300-500 years old (Florida Department of Natural Resources (FDNR), 1984). In May 1985, 7.5 miles of the Northwest Fork of the Loxahatchee River was federally designated as Florida's first National Wild and Scenic River (outlined in red on Figure 2). Other unique resources of the river and estuary include designations of Aquatic Preserve, Outstanding Florida Waters and a State Park (**Figures 2 and 3**). The Loxahatchee River-Lake Worth Creek Aquatic Preserve consist of Lake Worth Creek, North Fork, Southwest Fork and Northwest Fork up to river mile 5.5, which is designated as an urban preserve while the remaining upper Northwest Fork is designated a wilderness preserve. All of the waters within Jonathan Dickinson State Park are designated as Outstanding Florida Waters.

Figure 1. South Florida – Martin and Palm Beach Counties, Jonathan Dickinson State Park, and Jupiter Inlet highlighted.

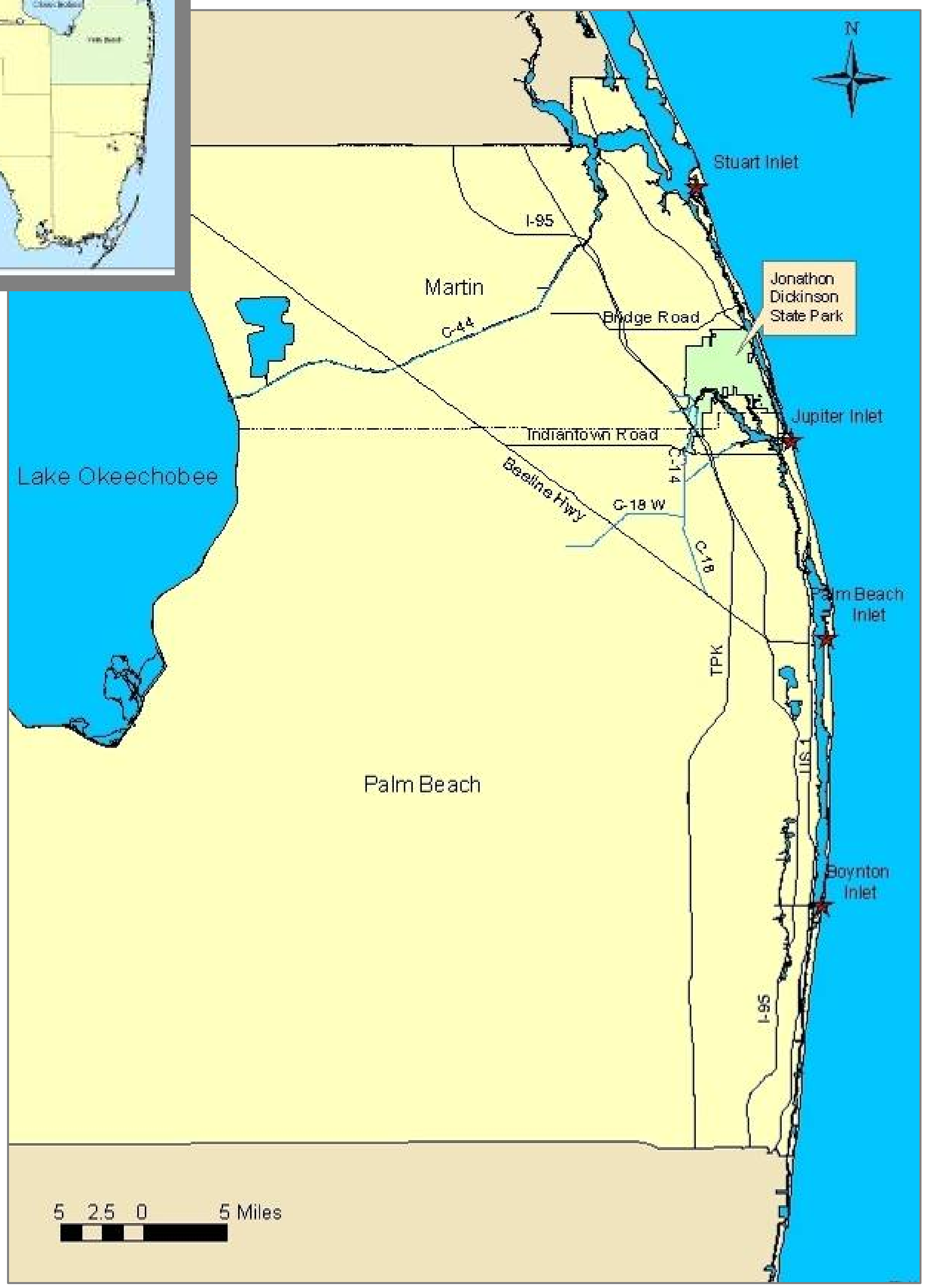


Figure 2. Detail – Martin and Palm Beach Counties, Jonathan Dickinson State Park, and Jupiter Inlet in South Florida.

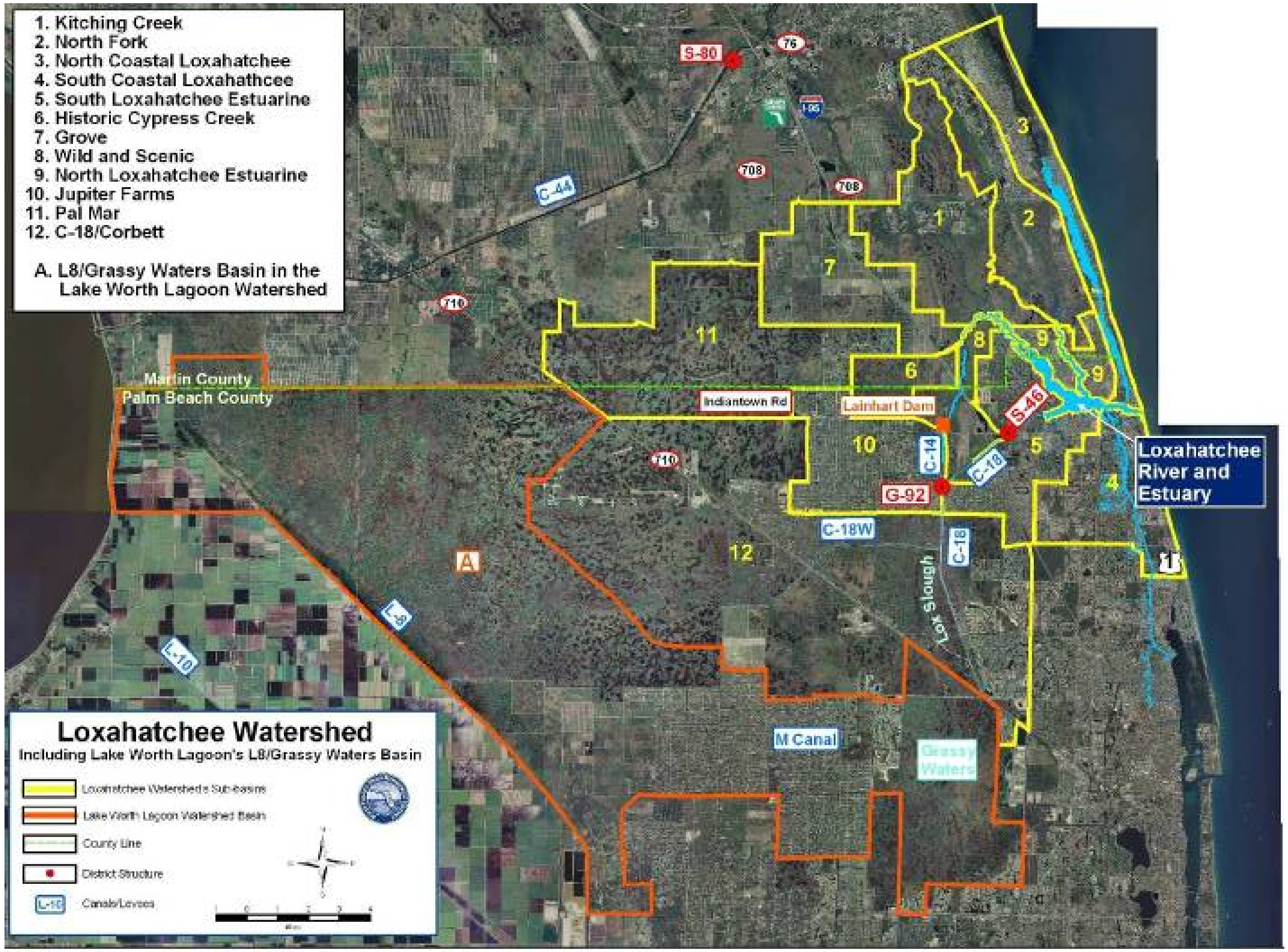


Figure 3. Map of the Loxahatchee River Watershed.

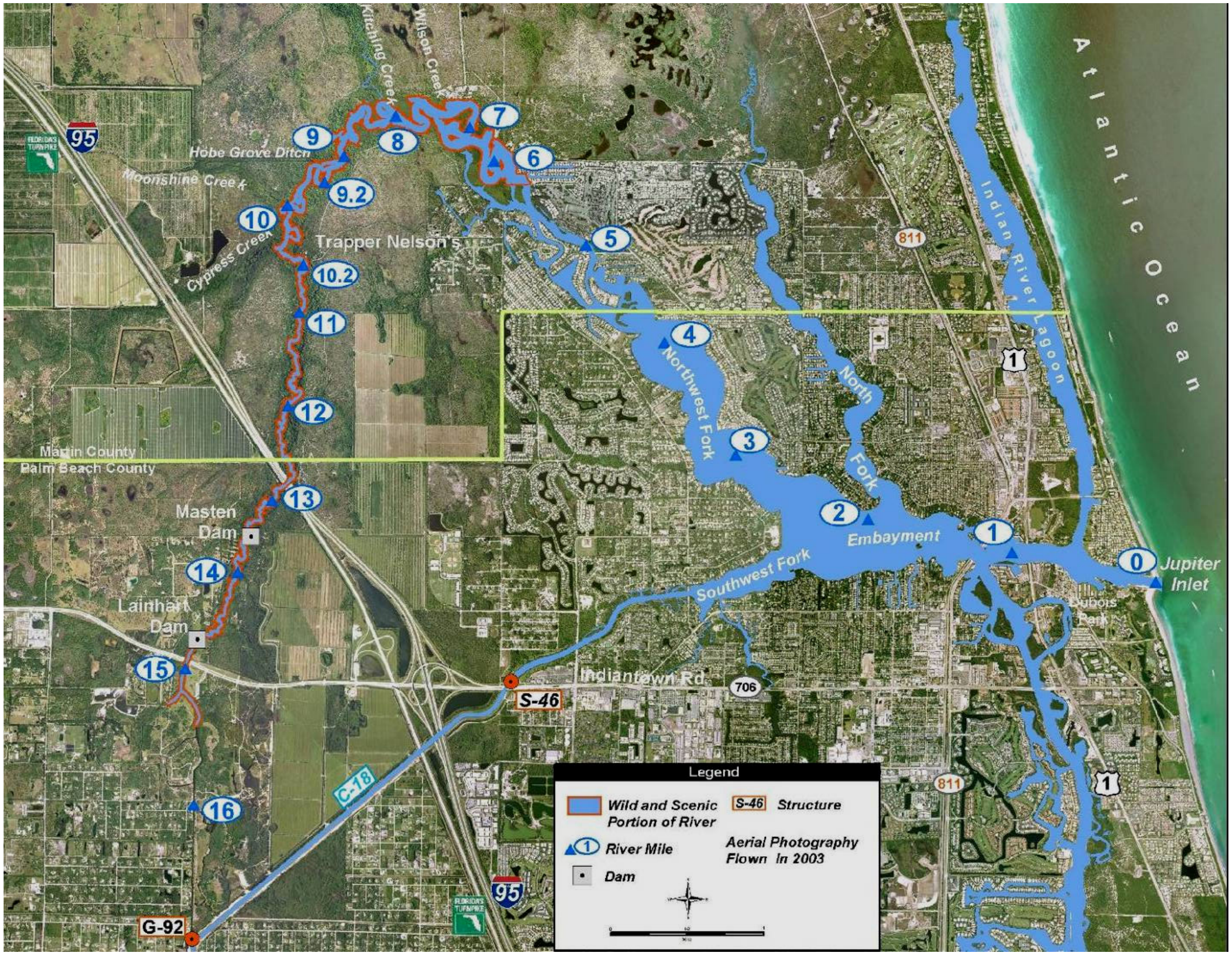


Figure 4. The Loxahatchee River and its major tributaries and water control structures.

PURPOSE AND SCOPE

With the development of an 2005 National Wild and Scenic River Management Plan, Minimum Flow and Level Rule, Restoration Plan, Water Reservations Rule, and specific segments of the Northern Palm Beach County CERP Project Implementation Report (CERP PIR) and Recovery Plan for the Loxahatchee River, it was imperative that a baseline floodplain vegetation monitoring program be established for canopy, shrubs, and ground cover communities. Therefore, the purpose of this study is to establish a long term monitoring program for plant community composition and structure in order to document baseline and future plant community health along the floodplains of the North and Northwest Forks of the Loxahatchee River as well as the major tributaries. The study consisted of the 2003 data collection period and will continue in the future with the monitoring of canopy communities every six years and groundcover/shrubs every three years. Six historical vegetation transects were utilized and four new transects were established in additional areas of concern**.** Groundwater within the transects was examined; however, this data will be detailed later in separate reports. This study was conducted jointly by staff from South Florida Water Management District (SFWMD) and Florida Department of Environmental Protection's Florida Park Service District 5 (FPS).

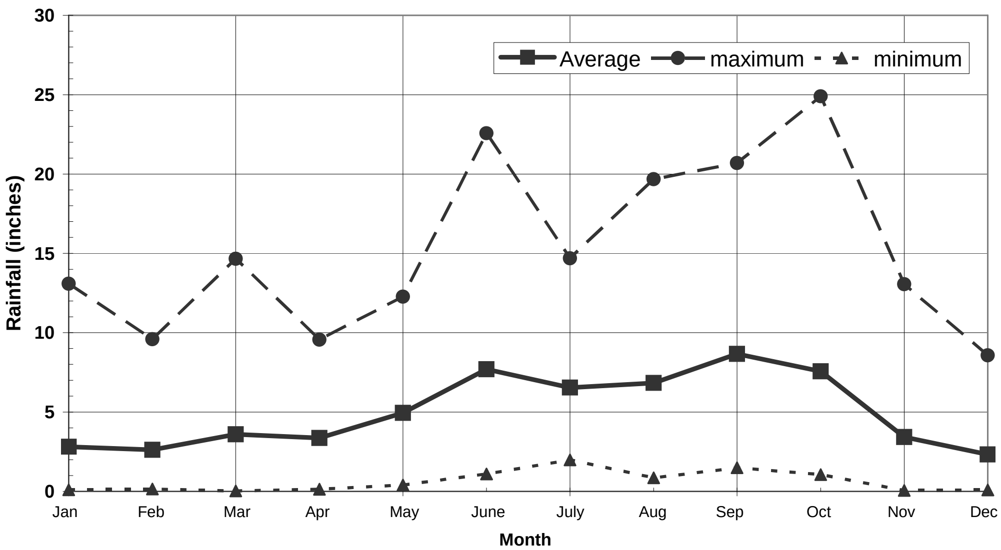
The CERP process is expected to provide additional freshwater flows to the river in the future. These hydrological modifications are expected to impact existing flora and fauna. Therefore the scope of this monitoring program are (1) to determine the composition and structure of floodplain plant communities and their associated hydrological characteristics; (2) to identify indicator forest type communities; (3) to identify key soil types that are indicative of the various forest types; (4) to examine the impact of exotic plants on this system; and (5) to verify the success or failure of established restoration performance measures for Valued Ecosystem Components (VECs).

CLIMATE AND RAINFALL

Climate in the vicinity of the Loxahatchee River is subtropical with daily temperatures ranging from an average of 82˚F in summer to an average of 66˚ in winter. Winters are mild with warm days and moderately cool nights. August is the warmest month, usually, usually having more than 29 days with temperatures above 90˚F. Even in the coldest winters, temperatures at or below freezing are rare. The average annual temperature is 75˚F (Breedlove, 1982).

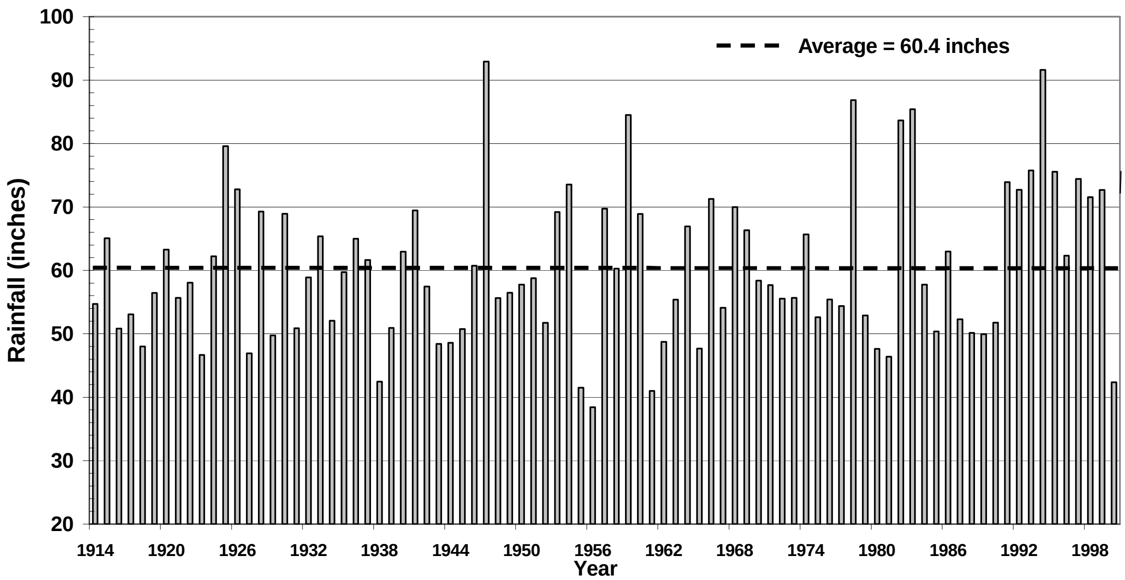
Rainfall within the Loxahatchee River Watershed averages about 61 inches annually (Breedlove, 1982; Dent 1997) with a median value of about 57 inches. Heaviest precipitation occurs during the wet season. Dent (1997) reports that since the early 1960s, about two-thirds of this precipitation (40.63 inches) occurs during the wet season (May through October), while the remaining one-third (20.42 inches) falls during the dry season (November–April). These data agree with rainfall data generated from the South Florida Water Management Model (SFWMM) (Ali et al., 1999) for a longer period of record (1914–2000) for northern Palm Beach and southern Martin Counties (**Figure 5**).

On average, the highest rainfall of 8.7 inches per month occurs during the month of September, while minimum average values range from 2.3–2.8 inches/month for the months of December, January and February (**Figure 6**). May and November are transitional months and sometimes represent key months for either prolonging or relieving a drought or flood condition (Dent, 1997). During the winter and early spring there are some years with long periods of little or no rainfall, resulting in a regional drought condition. In contrast, tropical storms or hurricanes over the area can produce as much as 6 to 10 inches of rainfall in one day. Total annual rainfall can be as much as 93 inches or as low as 38 inches.



Source: Model results from the South Florida Water Mangement Model (SFWMM)

Figure 5. Average, minimum, maximum rainfall values.



Source: South Florida Water Mangement Model

Data obtained from the following grid cells representing northern Palm Beach and southern Martin counities: Row 65 columns 32-38, Row 64 columns 30-38, Row 63 columns 30-38, Row 62 columns 30-38, Row 61 columns 30-37, Row 60 columns 31-37, Row 59 columns 32-37, Row 58 columns 33-37.

Figure 6. Long-term annual rainfall for northern Palm Beach and southern Martin Counties (1914–2000).

Figure 6 provides a summary of annual rainfall amounts received within northern Palm Beach and southern Martin Counties from 1914–2000 (data from South Florida Water Management Model, version 9.7). Mean annual rainfall for the full 86 year period of record was 60.4 inches with a median of 57.7 inches. The maximum amount of rainfall recorded was 92.9 (1947) and 91.6 inches (1994). Minimum rainfall values occurred in 1956 (38.4 inches) and 1961 (41 inches). Review of the distribution of annual rainfall data over time showed that a variance of about 10 percent of the mean (plus or minus 6 inches) occurs about once every three years on average. Extreme dry and wet periods can be defined as a variance of more than 20 percent of the mean (± 12 inches). Based on this definition, the long-term record shows that an extreme dry period occurs within the basin about once every 8.6 years, while extreme wet periods occur about once every 5.7 years.

BACKGROUND

Blackwater Floodplain Forests

Freshwater swamps occur throughout the Southeast and may be classified by their dominate vegetation, such as cypress/gum swamps or their hydrological features and primary water source, such as whitewater or blackwater swamps (Wunderlin and Hansen, 2003). The flowing portions of the upper and middle reaches of the Northwest Fork of the river and its tributaries are considered a blackwater river. The name characterizes the tea-colored waters of these streams, which are laden with tannins, particulates and other dissolved organics derived from the drainage through swamps, wet prairies and marshes (Roberts et al. 2006).This dark-colored water reduces light penetration and, thus, inhabits photosynthesis and the growth of submerged aquatic plants (FNAI and DNR 1990). Myers and Ewel (1990) presented several characteristics of blackwater river, swamp, bottomland hardwood, and hammock communities. These included:

- Underlying sandy soils contribute few nutrients to runoff that supplies the river
- Flooding is closely related to local rainfall events and water levels rise and fall rapidly
- Impermeable soil layers may be present that allow for horizontal movement of groundwater to the river and contribute to standing water in the floodplains
- Plant diversity is generally lower than white water or alluvial rivers
- Some forest type zones are narrow or absent
- One canopy species may dominate such as cypress because of historical hydroperiod and flow rates

Observations described in this report have shown that the Loxahatchee River fits most of Myers and Ewel’s characteristics of a blackwater river. Flow and stage level data since the 1970s showed that rises in stage level and inundation of the floodplain were correlated with local rainfall events and were generally of short duration; however, hydrological data was not available on flow and stage levels prior to human manipulation of the Loxahatchee River. The USGS study (2006) showed that groundwater does make a contribution to freshwater flow on the Loxahatchee River although the level of contribution appears to change by river mile and the location of major tributaries. Between September 2005 and July 2006, Loxahatchee River Environmental Control District (LRD) noted that color averaged 53 PCU/units with a range of 5 in the embayment area to 240 in upper Kitching Creek. This may partially explain the absence of freshwater submerged aquatic vegetation with the exception of small patches of the exotics *Limnophila* and *Hydrilla* in the freshwater segments of the river. The other major reason for the absence of SAV would be the low levels of light on the river channel due to the thickness of the canopy. Also, nutrient results of the USGS study indicated that primary production maybe nitrogen limited rather than the more usual phosphorus limitation. Canopy diversity is generally low consisting of primarily bald cypress in the riverine reach and mangroves in the tidal reaches. One would assume that it was historical flow rates and hydroperiods that created these bald cypress riparian communities along the river. Bald cypress trees on the Loxahatchee River have been estimated as 300 to 500 years old (Florida Department of Natural Resources, 1984). The dominant floodplain forest types on the Loxahatchee River appear to be swamp and hammock; however, the width of the hammock areas was variable or they can be absent or intermixed with swamp or bottomland hardwood communities.

Rainfall and Hydrology

Several studies were conducted on the vegetative transects during the course of our investigation. The 2003 vegetative transect data was collected between the period of July through November 2003. The canopy at all ten transects was reexamined between June and September 2005 to assess damages from Hurricanes Frances and Jeanne, which came through the area during September 2004 (Appendix E). Hurricane Wilma came through the area in October 2005. The transects were not re-assessed for damage after this event. Conditions were very dry during the winter and spring of 2006; therefore, additional observations were made on all ten transects in June 2006. Species presence was recorded for canopy, shrub and groundcover community levels.

Rainfall data (inches) for the study periods was obtained from the JDWX weather station located at the northern end of JDSP near Jenkins Ditch. Rainfall data was not available yet for 2006. Leading up to the 2003 Study that was conducted from July through November 2003, mean monthly rainfall values from January to March 2003 at the JDWX weather station were an inch or less (**Figure 7**). The rains came in spring with about 13 inches between April and June. July was again dry for wet season with only about 3 inches of rain. The late wet season began in August with all most 10 inches. The 2004 dry season began in December 2003 and was very dry up until May 2004, which received 4 inches of rain.

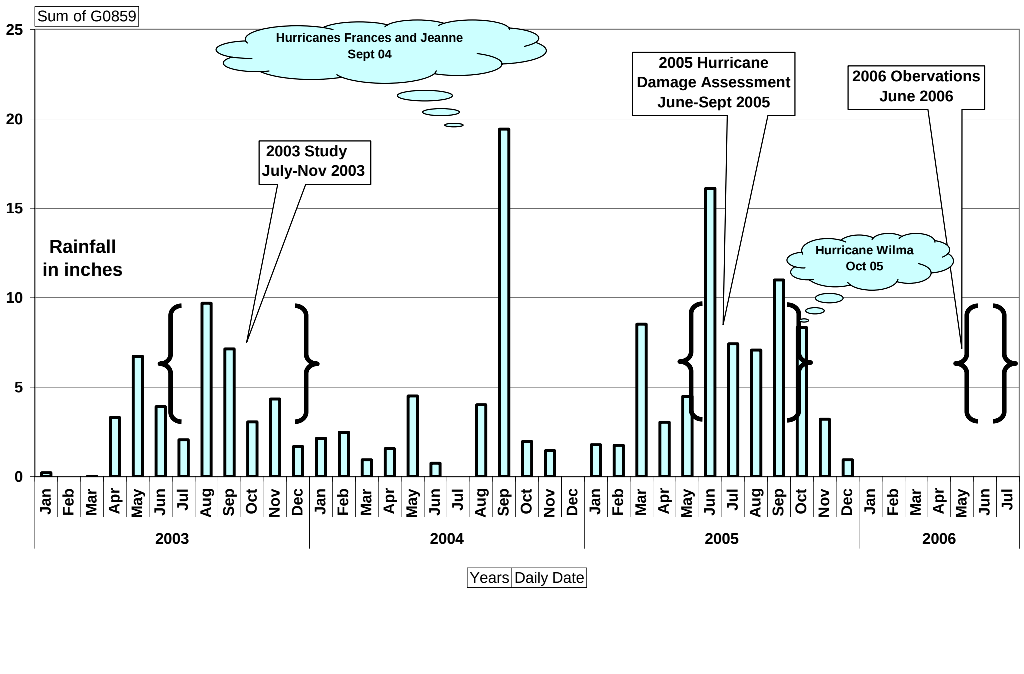


Figure 7. Rainfall amounts during the study periods January 2003 – December 2006.

This was followed by a very dry (less than 2 inches) June and July 2004 with rains picking up a little in August (4 inches). Total rainfall for September 2004 was 19 inches as a result of Hurricanes Frances and Jeanne, and the remnants of Hurricane Ivan. This was once again followed by a "very dry" dry season in 2005. Substantial rain was not seen again until March 2005, which received 8 inches of rain followed by a very wet June 2005 (over 15 inches). The period of July through October 2005 was wetter than the same period in 2004. Hurricane Wilma came along in early October 2005 and bought the October rainfall total to 8 inches. Although data is not available for the year 2006, it has been very dry.

In dry years, upland and transitional species generally increase their distribution within floodplain systems as a result of shortened hydroperiods. Canopy species may take hold in areas where they don't normally grow, while scrub and groundcover species may change seasonally with the change in hydrology. In the riverine reach, groundcover in the swamp communities died back dramatically after prolonged periods of inundation following the hurricanes of 2004 while during extended dry periods groundcover species flourished after the flooding from the hurricanes was gone. This was probably due to the increase in nutrients and increase in available light as a result of the damaged canopy. Total annual rainfall amounts for 2004 and 2005 were higher than 2003 primarily due to the hurricanes while the dry season of 2003 may have been dryer than the 2004 and 2005 dry seasons.

Dry and wet season patterns were also reflected in mean monthly flows in cubic feet per second (cfs) over Lainhart Dam (**Table 1**) for the same time frames. **Table 1** provides a baseline look at mean monthly flows (cfs) over Lainhart Dam for the period 1965 to 2003. No flow or stage data were available before this period at Lainhart Dam. Therefore, the flows do not reflect pre-development levels of freshwater input to the Loxahatchee River. However, it gives insight into rainfall patterns and surface and ground water input. In the table, mean monthly flows less than 35 cfs are shaded in red, flows from 35 cfs are shaded in yellow, and flows greater than 65 cfs are shaded in light green. With regard to stage/flow relationships, top of bank at Transect 1 is about 90 cfs while total inundation of the swamp community there is about 110 cfs. The 1983/84 SFWMD Study (Worth, unpublished) and the 1994/95 Ward and Roberts Study (unpublished) appear to have been conducted during much wetter years (i.e. higher flows) than our 2003 study. A comparison between species richness of the three studies is made in the Discussion and Conclusions section.

Vegetative communities in the floodplain are also affected by the length of inundation periods. **Table 2** provides a baseline of the number of days per month with 20-day rolling average greater than 110 cfs for the years 1965 to 2003. In **Table 2,** the green is greater than 20 days within a month while the yellow is less than 19 days within a month. For the period 1983/84, 13 months were greater than 20 days. Grand totals for 1983 and 1984 were 272 and 139 days, respectively. Both 1994 and 1995 were over 200 days (222 and 218 days) and were considered wet years. In 1995, Tropical Storm Irene dropped about 17 inches of rain on central Palm Beach County. In 2003, only 3 months averaged greater than 20 days and the grand total was 96 days.

Table 1. Baseline mean monthly flow at Lainhart Dam (cfs).

Dry Season	
<	35
<	65
>= 65 & <=90	
>	90

Wet Season	
<	35
<	65
>=	65

LNHRT-Base

	Date												
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1965	39	35	14	2	1	14	29	45	10	136	71	10	34
1966	90	76	34	22	53	211	220	127	88	203	63	37	102
1967	22	40	37	18	5	52	89	114	67	193	79	26	62
1968	14	13	7	2	19	302	173	136	197	274	147	62	112
1969	71	45	116	35	154	120	79	131	135	269	173	86	119
1970	113	104	208	237	97	155	112	64	56	71	29	18	105
1971	16	18	12	3	47	19	38	46	136	79	194	73	57
1972	44	39	21	41	191	204	85	50	33	33	68	28	70
1973	28	36	14	9	13	80	66	124	134	168	41	39	63
1974	150	39	45	14	8	131	151	156	54	134	57	63	84
1975	27	30	20	7	33	104	141	31	85	108	39	15	54
1976	9	20	27	5	106	114	30	67	182	72	72	28	61
1977	60	19	10	2	25	33	11	24	271	42	24	139	55
1978	72	30	32	6	14	145	140	145	88	168	263	190	108
1979	193	79	56	47	61	51	31	19	161	146	113	66	85
1980	47	58	39	20	33	29	86	34	32	80	26	17	42
1981	7	9	3	1	2	6	6	152	176	46	53	9	39
1982	12	26	150	200	166	241	124	93	110	145	302	182	146
1983	143	200	172	108	76	141	77	135	268	342	198	157	168
1984	123	86	127	84	102	124	65	48	179	120	196	150	117
1985	72	43	28	61	21	25	65	40	144	110	53	71	61
1986	125	42	102	82	14	93	112	72	76	80	92	99	83
1987	112	36	69	25	15	24	43	30	39	137	234	34	67
1988	57	47	42	14	29	91	116	184	75	18	14	7	58
1989	4	2	17	8	7	8	30	85	25	79	14	15	25
1990	11	6	7	10	7	15	17	77	93	151	22	16	36
1991	142	118	53	141	119	160	128	86	134	192	92	83	121
1992	49	117	66	56	20	122	125	188	217	164	198	95	118
1993	231	204	200	122	92	104	87	85	164	281	149	89	150
1994	96	142	84	82	70	143	114	223	273	209	278	285	166
1995	140	96	98	85	69	101	131	288	186	352	271	153	165
1996	82	73	156	116	137	140	176	96	128	163	123	78	123
1997	81	104	84	121	93	214	109	200	222	105	83	149	130
1998	148	204	161	88	106	53	84	66	208	133	289	102	136
1999	227	89	70	39	30	172	122	109	198	335	206	109	142
2000	81	74	62	91	34	19	40	18	52	174	29	23	58
2001	16	9	46	24	8	43	197	260	254	236	145	78	110
2002	69	125	60	44	15	116	185	57	40	51	43	36	70
2003	22	14	62	46	119	137	48	149	90	73	146	75	82
Average	78	65	67	54	57	104	94	104	130	151	120	77	92

SFWMD Dewey Worth 1983/84

Ward & Roberts Study 1993/94

2003 Study

Table 2. Baseline inundation analysis* during the study periods.

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grand Total
1965	0	0	0	0	0	0	0	0	0	12	16	0	28
1966	4	0	8	0	0	23	31	27	0	22	11	0	126
1967	0	0	0	0	0	0	18	15	0	24	18	0	75
1968	0	0	0	0	0	25	31	27	18	31	30	1	163
1969	0	0	18	0	22	21	11	16	17	31	30	5	171
1970	14	23	19	30	9	30	20	0	0	0	0	0	145
1971	0	0	0	0	0	0	0	0	18	2	29	1	50
1972	0	0	0	0	18	30	11	0	0	0	0	0	59
1973	0	0	0	0	0	2	0	26	28	29	5	0	90
1974	15	8	0	0	0	13	31	31	1	21	0	0	120
1975	0	0	0	0	0	11	24	9	1	19	0	0	64
1976	0	0	0	0	4	21	0	0	26	7	0	0	58
1977	0	0	0	0	0	0	0	0	26	13	0	16	55
1978	5	0	0	0	0	6	31	26	0	20	30	31	149
1979	31	13	0	0	0	0	0	0	14	31	22	3	114
1980	0	0	0	0	0	0	0	0	0	4	0	0	4
1981	0	0	0	0	0	0	0	11	30	14	0	0	55
1982	0	0	16	30	25	30	26	0	3	27	29	31	217
1983	31	28	31	28	1	21	1	9	30	31	30	31	272
1984	23	0	8	14	1	23	0	0	10	24	8	28	139
1985	0	0	0	0	0	0	0	0	10	19	0	0	29
1986	20	0	3	19	0	5	16	12	0	0	9	1	85
1987	23	0	0	0	0	0	0	0	0	17	30	7	77
1988	0	0	0	0	0	10	15	16	18	0	0	0	59
1989	0	0	0	0	0	0	0	5	0	2	0	0	7
1990	0	0	0	0	0	0	0	0	1	30	0	0	31
1991	13	23	0	15	15	30	31	5	21	31	5	6	195
1992	0	7	14	0	0	3	24	22	30	31	20	18	169
1993	27	28	31	25	0	0	0	0	25	31	30	16	213
1994	0	26	10	0	0	19	14	31	30	31	30	31	222
1995	31	5	0	0	0	3	26	31	30	31	30	31	218
1996	2	0	19	23	7	30	31	3	18	25	26	0	184
1997	0	5	7	14	6	29	28	29	30	21	0	17	186
1998	15	28	31	10	20	0	0	0	14	31	30	17	196
1999	29	13	0	0	0	14	22	7	30	31	30	22	198
2000	6	0	0	4	3	0	0	0	0	26	0	0	39
2001	0	0	0	0	0	0	21	31	30	31	28	0	141
2002	0	15	5	0	0	8	31	4	0	0	0	0	63
2003	0	0	0	0	4	30	0	21	18	0	23	0	96

* Number of days in a month with 20-Day Moving Average Flows Greater than 110 cfs.

Fire and Logging History on the Loxahatchee River

Historical factors contributing to forest composition and distribution on the Loxahatchee River are fire and logging. Fire occurrence on the river floodplain is generally low, primarily because the soils are saturated most of the year. Additionally, dry live and dead fuel in the floodplain is sparse, decomposition rate is rapid and frequent flood events tend to clear away combustible material. Bald cypress and mixed hardwood forests thrive in both fire-free habitats and occasionally in burned areas (see Gunderson 1984, Ewel 1990a). If a local seed source is available, bald cypress has been found to re-colonize after fire (Gunderson 1984).

Most of the bald cypress in southern Florida were harvested by the lumber industry by the 1940s leaving only isolated strands of cypress that were too difficult for loggers to reach. Bessie Wilson DuBois wrote in her book, “The History of the Loxahatchee River” (1981), that logging leases in two townships on the Loxahatchee were purchased by the Hunt brothers from Green Cove Springs in 1891. B. K. Hunt eventually built a sawmill on the river. Over the years, they cut pine from the uplands and cypress from the river’s edge. Later, a man by the name of Arbuthnot established another logging operation using a gas tramway to transport the pine and cypress logs across land to his sawmill. Before logging a portion of their property in the 1940s, local pioneers, John and Bessie DuBois, purposely saved 27 large cypress trees on Kitching Creek. This was the last recorded logging operation on the river. The cypress on the upper Northwest Fork near Indiantown Road remains largely intact from the pressures of lumbering. Many specimens along this reach of the river range from 300 to 500 years in age (FDEP 2000).

Logging was verified on most of the vegetative transects by the presence of tree stumps without the fallen trunk. This appeared to be more prevalent in the upper tidal portions of the river where logs could be removed to the uplands side or floated down the wider river channel. Occasionally, we observed logs that had obviously been cut but never been removed (**Figure 8**).

Figure 8. Logging evidence on Transect 6 where the tree was cut but the log was left.

Taylor Alexander's 1967 Bald Cypress and Mangrove Complex Study

During April 1967, Taylor Alexander established vegetation quadrants along a transect on the Northwest Fork of the Loxahatchee River near river mile 7.5 (unpublished) and documented the changes in plant species. Alexander considered it a rare opportunity to study temperate and tropical species in combination with salt tolerant and non-salt tolerant species in such a limited area. Furthermore, his transect contained dead, stressed but living, and healthy cypress trees. The transect was 137 m (450 feet) long with 36 total 5 m^2 random quadrats along each side. Species occurrence and density were examined for each quadrant. Water and soil samples were analyzed for pH, electrical conductivity, and chloride content. Alexander's raw transect data was examined as a part of this study, while his 1967 transect was included as Transect 9 of this study.

Alexander and Crook 1975 South Florida Ecological Studies

Alexander and Crook (1975) utilized aerial photographs and groundtruthing to examine plant communities along the Northwest Fork (**Figure 9**) of the Loxahatchee River and Kitching Creek. Plant species lists were compiled for Site 13 (RMs 7-8), Site 14 (RMs 7.0-7.5), and Site 15 (RMs 6.0-6.5) on the Northwest Fork and Site 10 on Kitching Creek. Upon identifying the signature of the most abundant community types, they were able to use photo-interpretation to identify major vegetative communities from a 1940 aerial photograph. Areas of dead and living cypress canopy within a mangrove understory were noted in 1970. They concluded that since 1940, wet prairie and swamp hardwoods had been converted to pineland and mangrove communities due to a lowering of the groundwater table and invasion of saltwater between RMs 6 and 8. They were able to identify areas of past logging in the aerial photographs, which could explain the loss of mature trees within portions of the watershed. Also, they mentioned the impact of fire, hurricanes and heavy frost on the major plant communities. At RM 6.5, they collected freshwater peat at a depth of 24 inches below the surface. Based on this information, they further concluded that there was no evidence that cypress forest had extended much further downstream than about RM 6. Finally, Alexander and Crook (1975) predicted that the mangrove invasion would accelerate, if anthropogenic activities in the upper floodplain of the river further reduced the freshwater head.

Figure 9. Dead bald cypress trees in the tidal floodplains of the Northwest Fork (ca. 1970s).

Dewey Worth 1983-1984 Loxahatchee Vegetation Transects

Dewey Worth established and examined six vegetation transects (10m wide) along the Northwest Fork of the Loxahatchee River as a part of South Florida Water Management District's Loxahatchee River Restoration Plan. His transects were surveyed and ground and surface water elevations were recorded along with heights and elevations of cypress knees. In addition, several shallow water groundwater monitoring wells were established during his study period. His six transects were re-examined as a part of this study and will be included in a later report.

Ward and Roberts 1994-1995 Vegetation Analysis of the Loxahatchee River Corridor

Between October 1993 and January 1994, Ward and Roberts (unpublished) re-examined Dewey Worth's six vegetative transects on the Northwest Fork of the Loxahatchee River between Indiantown Road (State Road (SR 706) and the mouth of Kitching Creek (RM 8.0). A more detailed summary of the results of this study will be presented in a later report. Each belt transect was 10m wide and partitioned into 10 m^2 plots. Within each 10 m^2 plot all trees greater than 10 cm (3.94 inches) diameter at breast height (dbh) were identified by species and dbh measured. Shrub vegetation with a height greater than 1 m with a dbh of less than 10 cm were counted by line intercept within each 10 m^2 Cover and stem counts, by species, of all herbaceous plants and woody plants under 1 m (3 feet) in height were measured in three 1x1 meter quadrats nested within each 10x10 plot. A total of 79 plots were surveyed during the study. Generally the density (stems/hectare) of bald cypress increased from downstream (Transect 6, RM 8.4) near Kitching Creek to upstream (Transect 1, upstream of RM 14.5 just north of State Road 706). A noticeable drop in cypress density occurred at Transect 3 (upstream of RM 12.1 and just north of Interstate 95), which was heavily populated with pop ash, red maple (*Acer rubrum*) and cabbage palm.

2002 Minimum Flows and Levels Technical Document

In an examination of historical aerial photography from 1940 to 1995, major vegetative communities were identified along the floodplains of the Northwest Fork of the Loxahatchee River (SFWMD, 2002). The results of the study indicated that floodplain vegetation had decreased due to Jupiter Inlet stabilization in 1947, bulkheading of the shoreline, filling for development, and changes in vegetation types (wetlands to transitional and upland species, marsh to mangrove, wet prairie to pine forest). 1940 aerial photography of the watershed revealed an abundance of swamps, wet prairies, inland ponds, and sloughs. Freshwater swamp hardwood and cypress communities were dominant within the floodplain portion of the Northwest Fork (RM 4.5 to 8.9), comprising about 73 percent of the vegetative coverage, while mangroves represented 22 percent. Mangroves were dominant from RM 4.5 to RM 6.0 and were present upstream to RM 7.8. By 1985, freshwater communities represented 61 percent of the coverage, while mangroves represented 25 percent of the coverage. Mangroves were dominant between RM 5.5 and 8.7 and extended up to RM 10.5. One would suspect that mangrove encroachment would appear much higher; however, there was a loss of approximately 80 acres of mangroves due to development between RMs 4.5 and 5.5. There were no major changes between cypress and mangrove floodplain coverages between 1985 and 1995. It was concluded that most of the mangrove encroachment occurred between 1947 and 1979. This timeframe corresponds to a period in which the Jupiter Inlet was stabilized and freshwater flows were redirected by C-18 Canal from the Northwest Fork to the Southwest Fork of the river for flood control.

Semi-quantitative and quantitative vegetation surveys (species composition and abundance) were conducted along the Northwest Fork of the Loxahatchee River as a part of the Minimum Flows and Level Technical Document (2002). Twenty-three semi-quantitative sites were sampled in November 2000 and December 2001. Eight sites were re-investigated from the series of semi-quantitative survey sites to produce a quantitative database in 2002. Using the results of the vegetation surveys and a salinity time series generated from the 2-D hydrodynamic/salinity model, correlation analysis was used to examine vegetation trends relative to salinity event duration along the river corridor. From this data a river/vegetation/salinity model (SAVELOX) was developed using an empirical approach to extrapolate vegetation parameter response given a set of long-term salinity conditions. Results from the 2000 semi-quantitative survey identified at least 35 species of vascular plants. Correlated with distance upstream from Jupiter Inlet, the results indicated that the number of species increased as a function of distance from the inlet, which is correlated to salinity. Bald cypress and cabbage palm appeared to tolerate a wider range of salinity conditions than a number of other common floodplain species while red maple, pop ash, dahoon holly (*Ilex cassine*), pond apple, red bay (*Persea borbonia*) and Virginia willow (*Salix caroliniana*) appeared to be impacted within a very short segment of the river.

Related Projects

Concurrent with this project, the SFWMD Coastal Ecosystem Division is in the process of planning and implementing other projects. These projects will provide information critical for understanding the impact of saltwater intrusion and fresh water flux within the river's floodplain and the feasibility of restoring freshwater vegetation among existing brackish water plant communities. Brief descriptions of these projects are given below:

LOXAHATCHEE WATERSHED HYDROLOGIC MODEL

The model domain covers the entire historic watershed, including the floodplain area that is represented with a fine grid system. This model was built on the new generation of hydrologic models in the District, and simulates 2-D overland flow, 3-D ground water flow, 1-D channel flow, and flow in and out of banks in an integrated manner. After calibration, this model will provide historic and current water level in the floodplain and estimates of fresh water discharge into the River.

INTEGRATED LOXAHATCHEE SALINITY MODEL

The model domain covers the entire Estuary, River and the floodplain area. The Estuary salinity model establishes a 3-D hydrodynamic framework. The salinity model in the floodplain is a salt transport model, and can be coupled or de-coupled with the estuary model. This integrated model predicts salt movement in the estuary, river and floodplain as influenced by tide and freshwater input from the watershed.

LOXAHATCHEE RIVER FLOODPLAIN DIGITAL ELEVATION MODEL

Existing LIDAR data was examined to determine if it could be utilized to produce a Digital Elevation Model (DEM). The DEM will provide details of micro-relief data that are critical for determining water inundation in the floodplain area. It was determined that the existing LIDAR data cannot support the detail needed for the DEM because of the difficulty in acquiring this type of data in the heavy tree canopy and dense ground cover. The District is investigating the potential of using a low flying helicopter to shoot the photography needed to acquire the data. Also, the hurricanes of 2004 and 2005 have greatly reduced the density of the canopy cover, which should improve conditions for collecting the needed photography.

LOXAHATCHEE FLOODPLAIN GROUNDWATER MONITORING NETWORK

This study is examining groundwater conductivity, temperature, and stage within the Loxahatchee floodplain. Twelve (12) groundwater wells were installed along Vegetation Transects 1, 3, 7, 8 and 9 (**Figure 10**). Transect 1 serves as the background freshwater site whereas the remaining stations are exposed to different levels of tidal fluctuations and saltwater intrusion. These wells are 2 in. in diameter and were installed to a depth of 5 to 15 ft below the existing ground surface. Each well contains a Troll 2900 Transducer along with a data logger.

Figure 10. Downloading groundwater data.

This project will provide critical information for model calibration and understanding the relationship between rainfall, groundwater input, inundation/stage levels in the floodplains, and the health and recovery of the floodplain. The data is currently being analyzed and monitoring will continue into the next several years.

GROUNDWATER FLUXES AND WATER QUALITY STUDY

In this U.S. Geological Survey contract, historical groundwater data were examined and groundwater discharge and recharge were estimated using the isotope technique with wet and dry season samplings during a two-year period on Transects 1, 3, 6, 7 and 9 (U.S. G. S. ,2006). The distribution of dissolved organic carbon (DOC), silica, select trace metals (Mn, Fe, Ba, Sr, Co, V) and a suite of naturally-occurring radionuclides in the U/Th decay series (^{222}RN, $^{223, 224, 226, 228}$Ra, ^{238}U) were studied during high and low discharge conditions in the Loxahatchee River Estuary. Estimates were obtained for submarine groundwater discharge and rates of NH_4^+ and PO_4^{-3} flux to the estuary. The results of surface and pore water sampling yielded a higher ionic strength with depth compared to surface water. The results suggested that high salinity water may only be impacting the viability of freshwater vegetation along Transect 9 and portions of Transect 6. The distribution of higher levels of sulfides in soil/sediment pore water were also noted. This project provided data that was critical for model calibration (surface/groundwater interaction) and interpretation of vegetation health in the floodplain.

FLOODPLAIN SOIL CHARACTERIZATION STUDY

Soil profiles were collected from each major forest type within each transect as part of this associated project with the University of Florida (UF), IFAS, Tropical Research and Education Center in Homestead, Florida (**Figure 11**). Soil samples were collected within each 10x10 plot and combined to create a composite sample to represent each major forest type within a transect. A soil auger was used to collect the top 20 cm of soil. Soil moisture (percent saturation), soil texture, conductivity, nitrogen, potassium, phosphorus, pH, cation exchange capacity, and percent organic matter was determined for each composite sample. Eight soil moisture and salinity stations were established on Transects 1 and 7. Three separate Hydra probes placed at deep, intermediate and shallow depths were installed in four different locations along the two transects.

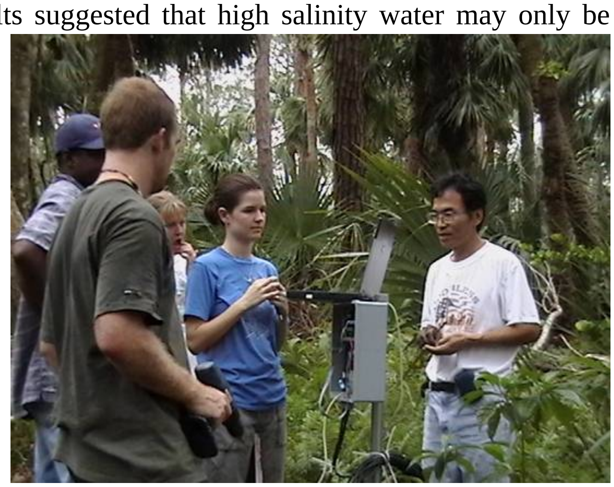


Figure 11. Downloading data from soil moisture probes.

SALINITY AND ALTERED HYDROLOGY ON THE SURVIVAL, GROWTH AND RESTORATION OF BALD CYPRESS

This study was designed to isolate the major factors that would prohibit reforestation of bald cypress. The study consisted of laboratory experiments (**Figure 12**) and field observations that would determine (1) the influence of salinity and altered hydroperiods on the growth and survival of bald cypress seedlings grown from seeds collected from the brackish segments of the Loxahatchee River and its tributaries; and (2) field observations of bald cypress seedling/sapling growth along the floodplain noting water levels, elevation, and the salinity. The laboratory study examined various treatment levels of saline water and flooding and a combination of the two impacts on seedlings grown from seed stock taken from cypress growing in tidally impacted zones of the Loxahatchee River and its tributaries. The field monitoring portion of the study consisted of observing natural populations of bald cypress seedlings and saplings, then planting representatives of the laboratory stock within the saltwater impacted and riverine floodplain zones. In the laboratory study bald cypress seedlings tolerated 100 percent flooding (i.e., plant roots submerged in water) without salinity for as long as 30 days. All seedlings survived the 50 percent flooding with exposure to 2, 4, 6 and 8 ppt. All seedling survived 50 percent and 100 percent flooding with 2 ppt while 25-75 percent the seedlings died under 100 percent flooding with 4 to 8 ppt. Field observations showed that seedling started growing in February or March and reached their maximum growth rate in May.

Figure 12. Bald cypress flooding and salinity experiment.

The impact of these related studies on the current study is diagramed in **Figure 13**. They present an integrated study approach to providing needed information to our adaptive management process for future restoration of the Loxahatchee River. Tidal stage and salinity have been monitored real time to support model development and other analyses and is needed to give water control operators at the West Palm Beach headquarters an overview of these parameters as they manage control structures. Groundwater and soils monitoring are essential for documenting hydroperiods and salinity movement within the floodplains and explaining changes in floodplain vegetation. More in depth relationships would be established between soil moisture, floodplain stage, and river flow. LIDAR and survey data and the Digital Elevation Model would provide a means of examining detailed levels of predictable inundation that could be used to predict the health of ecological communities and to evaluate floodplain vegetation performance measures for swamp and hammock areas as freshwater flow is restored to the system. Reassessment of floodplain vegetation abundance, basal area, and frequency of occurrence would be essential for identifying changes in vegetative community composition and plant species distribution, including yearly seed production, germination and successful seedling recruitment.

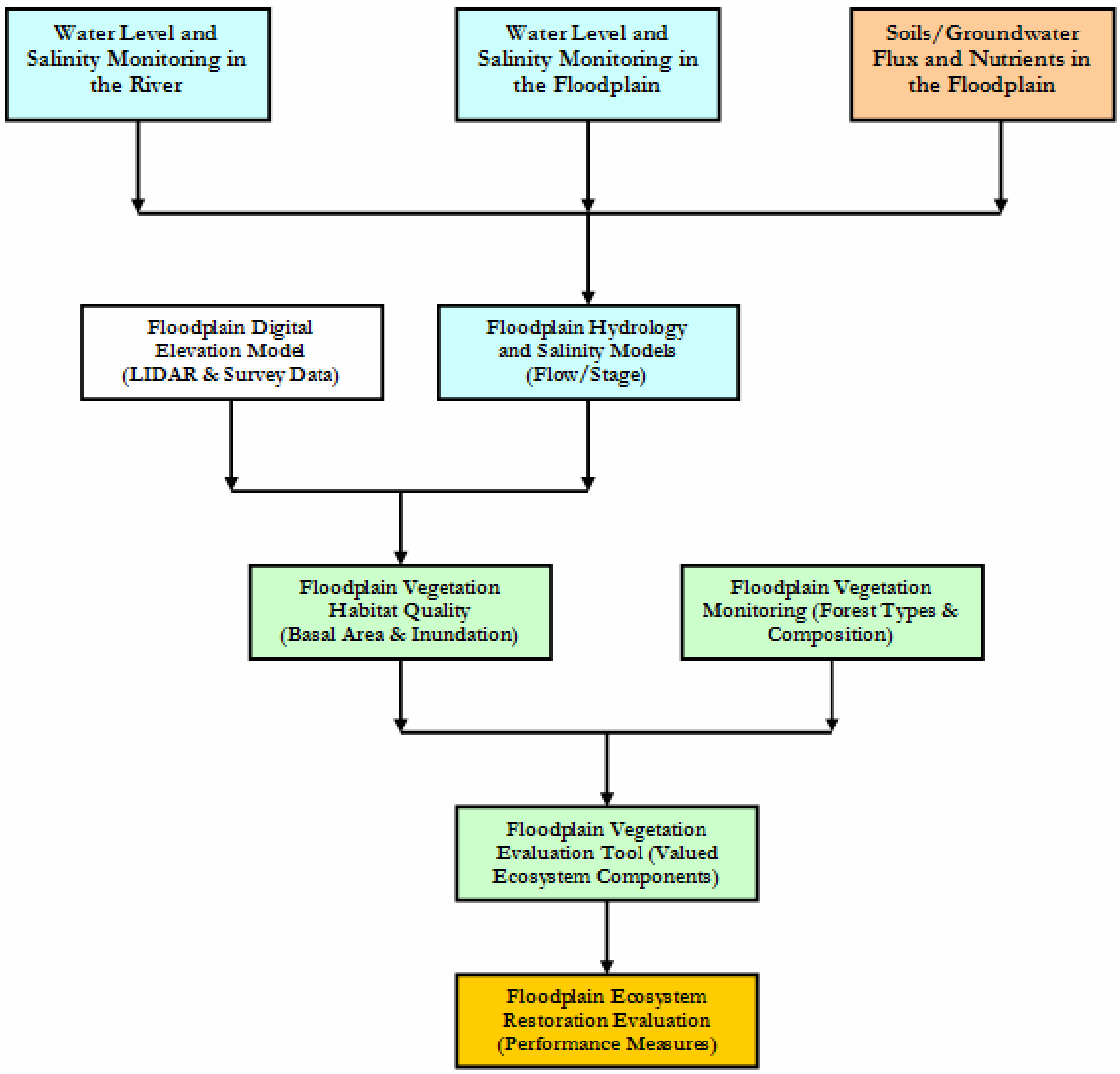


Figure 13. Interrelated projects provide information needed to evaluate floodplain plant communities.

METHODS

IDENTIFICATION OF FOREST TYPES

As previously mentioned in the Methods Section, guidelines for reach and forest type determinations were developed based on floodplain forest studies done by Melanie Darst and Helen Light on the Suwannee River (Darst et. al., 2003 and USGS 2002), and their assessment of the forest communities of the Loxahatchee River from the Ward and Roberts 1994/95. Relative Basal Area (RBA) of the canopy was the primary factor used for the determination. Adjustments were made to a few plots where the canopy clearly did not reflect the character of the shrub and groundcover vegetation. The rules that we created specifically for the Loxahatchee River floodplain forest is presented in **Table 3** and reflects river reach, forest types, canopy species, and community. **Table 4** presents a summary of the forest types, hydrological conditions, soil textures, and dominant species of the forest types.

Oak/pine upland forests are present at the edge of the floodplain on both the riverine and tidal reaches of the river and are inundated only for short periods of time during the highest floods (**Figure 14**). Most of the species found in this type of forest community can only survive brief periods of inundation. These upland systems are dominated by slash pine (*Pinus elliottii*), myrtle oak (*Quercus myrtifolia*) and saw palmetto (*Serenoa repens*).

Figure 14. Upland forest type.

Table 3. Reach and forest type determinations.

Category		Species
Swamp	Riverine	*Fraxinus caroliniana**, Pop ash *Taxodium distichum*, Bald cypress
Swamp	Tidal	*Annona glabra*, pond apple *Laguncularia racemosa*, W. mangrove *Rhizophora mangle*, Red mangrove
Bottomland Hardwood	Low	*Acer rubrum*, Red maple *Cephalanthus occidentalis*, Buttonbush *Persea palustris*, Swamp Bay *Salix caroliniana*, Carolina willow *Syzygium cumini*, Java plum
Bottomland Hardwood	High	*Carya aquatica*, Water Hickory *Chrysobalanus icaco*, Cocoplum Citrus spp. *Ilex cassine*, Dahoon holly *Psidium cattleianum*, Strawberry guava *Quercus laurifolia*, Laurel Oak *Roystonea regia*, Royal Palm
Hammock		*Ficus microcarpa*[a], Ficus Ficus aurea[a], Strangler ficus *Myrica cerifera*, Wax myrtle *Persea borbonia*, Red Bay *Quercus virginiana*[c], Live Oak Rapanea punctata, Myrsine *Sabal palmetto*[d], Cabbage palm
Upland		*Pinus elliottii*, Slash pine *Quercus myrtifolia*, Myrtle Oak *Schinus terebinthifolius*, Brazil. Pepper Serenoa repens, saw palmetto

Determination of Reach:

1. IF *Taxodium distichum* +*Fraxinus caroliniana* + *Acer rubrum* + *Carya aquatica* > 80% THEN reach is **riverine**.
2. IF *Taxodium distichum* + *Acer rubrum* + *Carya aquatica* < 20% and *Annona glabra* +*Fraxinus caroliniana* > 60% OR
3. IF *Rhizophora mangle* + *Laguncularia racemosa* + *Fraxinus caroliniana*> 60%, THEN reach is **upper tidal**.
4. IF *Rhizophora mangle*> 80% OR
5. IF *Rhizophora mangle* + *Laguncularia racemosa* > 75% and *Annona glabra* *<10%*, THEN reach is **lower tidal**.

Determination of Forest Types:

If Upland >= 75%, THEN forest type is **upland.**

1. IF upland <50% and hammock > 50%, THEN forest type is **hammock.**

Riverine reach forest types:

1. IF riverine swamp > 50% THEN
2. IF *Taxodium distichum* >= 80%, OR
3. IF *Taxodium distichum* + *Fraxinus caroliniana* >= *80%* and *Taxodium distichum >50%* THEN forest type is **Rsw1.**
4. IF *Fraxinus caroliniana* >=80%, OR
5. IF *Taxodium distichum* + *Fraxinus caroliniana* > 80% and *Fraxinus caroliniana* > 50%, THEN forest type is **Rsw2**.
6. If *Taxodium distichum* > 50% and hammock > 40% but < 60 % THEN forest type is **Rmix.**
7. IF riverine swamp < 50% THEN
8. IF low blh > 80%, OR
9. IF *Acer rubrum* > = 80%, THEN forest type is **Rblh1**.
10. IF high blh + low blh> 80% and high blh > 50%, THEN forest type is **Rblh2**.
11. IF high blh + uplands or hammock>= 70%, THEN forest type is **Rblh3.**
12. IF hammock >= 80%,OR
13. IF hammock + high blh is > 80% and hammock > 50%, Then forest type is **hammock.**

Upper tidal reach forest types:

1. IF mixed swamp[b] >= 70% and *Laguncularia racemosa* <30%, THEN forest type is **UTsw1**.
2. IF mixed swamp[b] < 70% and *Annona glabra* > 30%, THEN forest type is **UTsw2**.
3. IF *Lagunularia racemosa* > 50% THEN forest type is **UTsw3**.
4. IF mixed swamp[b] < 50% and hammock + upland > 60% OR
5. IF hammock + blh < 75%, THEN forest type is **UTmix.**
6. IF hammock > 75, THEN forest type is **hammock.**

Lower tidal reach forest types:

1. IF LT swamp > 50% OR,
2. IF *Rhizophora mangle* is >80%, THEN forest type **LTsw1**.
3. IF *Laguncularia racemosa*+ *Annona glabra* is >70%, THEN forest type is **LTsw2.**
4. IF LT swamp < 50% THEN,
5. IF *Sabel palmetto* >= 50% and *Laguncularia racemosa* + *Annona glabra* >40%, THEN forest type is **LTmix**
6. IF *Sabel palmetto*+ *Chrysobalnus icaco* >= 75%, THEN forest type is **hammock.**

[a] Present as epiphytes at Transects #7 and #9. Species in red font are exotics.
[b] Both riverine and tidal swamp species present.
[c] Dominant canopy species in Mesic Hammock.
[d] Dominant canopy species in Hydric Hammock.

Table 4. Summary of hydrological conditions, soil textures, and dominant canopy species of forest types in the floodplains of the Loxahatchee River and its major tributaries (modified from Light and others, 2002).

Forest Type	Typical Hydrological Conditions	Primary Soil Textures	Dominant Canopy Species
Oak/pine	Flooded average of every 10 years; soils dry quickly after floods recede	**Sand**	*Pinus elliottii* *Quercus myrtifolia*
Hydric Hammock	Flooded average 2 months (30-60 days)	Sand	*Sabal palmetto*
Mesic Hammock	Rarely inundated at higher elevation; soils dry quickly after floods recede		*Quercus virginiana*
Rblh3 **Rblh2**	Flooded average of every 3 years, for durations of 1-2 months or more; soils dry quickly after floods recede	sometimes Sand	*Quercus laurifolia* *Chrysobalanus icaco* *Ilex cassine* *Carya aquatica* *Persea borbonia*
Rblh1	Flooded average of one months every year remain saturated another month	Sand, loam, clay	*Acer rubrum* *Cephalanthus occidentalis* *Persea palustris* *Salix caroliniona*
Rsw2 **Rsw1**	Flooded average 4-7 months every year; soils remain saturated another 5 months	Clay, muck	*Taxodium distichum* *Fraxinus caroliniana*
Rmix	Flooded 2 to 3 months every year	Sand	*Taxodium distichum* *Sabel palmetto*
UTmix	Flooded 2 to 3 months every year; soils dry quickly in some areas and remain continuously saturated in others	Loam, muck, sand	*Laguncularia racemosa* *Annona glabra* *Acer rubrum* *Salix caroliniana* *Cephalanthus occidentalis* *Taxodium distichum*
UTsw3	Flooded monthly by high tides or high river flows	Muck	*Annona glabra* *Fraxinus caroliniana* *Rhizophora mangle* *Laguncularia racemosa*
UTsw2 and UTsw1	Flooded daily by high tides from 9-11 months of a year Most soils continuously saturated		
Hammock	Flooded every 1-2 years by either storm surge or high river flows, high water table, surface soils on higher elevations dry quickly and soils continuously saturated in lower areas	Muck	*Sabel palmetto* *Chrysobalnus icaco* *Quercus virginiana* *Myrica cerifera*
LTmix	Flooded daily or several times a month by high tides except in isolated areas; soils continuously saturated except for the interior of hammocks	Muck	*Lagunularia racemosa* *Sabel palmetto* *Rhizophora mangle* *Annona glabra*
LTsw2	Flooded daily for 9 months every year	Muck	*Laguncularia racemosa* *Rhizophora mangle* *Annona glabra*
LTsw1	Flooded daily every year	Muck	*Rhizophora mangle* *Laguncularia racemosa*

Hammocks support a vast diversity of tropical and temperate plants including hardwood trees, palms, orchids and other air plants (Mitch and Gosselink, 1993). Hydric hammock communities are dominated by cabbage palms (*Sabal palmetto*) whereas mesic hammocks are dominated by live oaks (*Quercus virginiana*) (**Figure 15**). Mesic hammocks are found at higher elevations than hydric hammocks. No mesic hammocks were found in the tidal reaches of the Loxahatchee River. Other fairly common species in the hammock areas are myrsine (*Rapenea punctata*), mulberry (*Morus rubra*), red bay (*Persea borbonia*), and ficus (*Ficus aurea*). Hammocks are generally found between the uplands, bottomland hardwood and swamp areas. Although with changes in elevation in the floodplain, they may also appear as isolated islands or may border the riverbed where elevations are higher. Hammocks are briefly inundated by storm surges but characteristically have a high water table due to their proximity to wetland areas. Hydric hammocks are flooded continuously for several weeks or longer every 1 to 3 years depending on reach. Mesic hammocks are rarely flooded because of their high elevations. Soils are mostly sandy in both types of hammock. Brazilian pepper (*Schinus terebinthifolius*) may occur as an exotic pest species in many of the forest community types as long as there is sufficient elevation for its growth.

Figure 15. Hammocks are found in both riverine and tidal reaches of the river.

In the riverine reach, high bottomland hardwoods are found on higher ridges while low bottomland hardwoods are found on swamp margins (**Figure 16**). Periods of inundation are generally 1 to 2 months every few years for high bottom land hardwood (Rblh2 and Rblh3) and about 2 months every year for low bottomland hardwood (Rblh1). Rblh1 are characterized by red maple (*Acer rubrum*), buttonbush (*Cephalanthus occidentalis*), swamp bay (*Persea palustris*) and Carolina willow (*Salix caroliniana*) while Rblh3 are dominated by water hickory (*Carya aquatic*), cocoplum (*Chrysobalanus icaco*), dahoon holly (*Ilex* cassine), and laurel oak (*Quercus laurifolia*). Found at lower elevations than Rblh2 and Rblh3, the forest type Rblh1 is characterized by a dominance of red maple. The forest type Rblh2 has approximately equal amounts of low and high bottom land species while Rblh3 has combinations of high bottomland mixed with hammock or even some upland representatives. Riverine Mixed (Rmix) is even more extreme with bald cypress and hammock almost equally mixed.

Figure 16. Bottomland hardwood forest type (Rblh2).

The exotic plant species, java plum (*Syzgium cumini*), and strawberry guava (*Psidium cattleianum*) are found in both areas of the riverine and tidal bottomland hardwoods. The occurrence of a few royal palms (*Roystonea regia*) is attributed to their spread from the adjacent Ornamental Garden property. Java plum and strawberry guava may have been introduced by Trapper Nelson.

Riverine swamps are characterized by the lowest elevation and wettest areas with either inundation or saturation most of the time (**Figure 17A**). Soils are sandy with some loam and clay. On the Northwest Fork of the Loxahatchee River, older riverine swamps are dominated primarily by bald cypress (*Taxodium distichum*) communities (Rsw1). Younger subcanopy swamp communities and impacted areas (logged) are more populated by pop ash (*Fraxinus caroliniana*, Rsw2) **(Table 3)**. Occasionally, bald cypress/cabbage palm (swamp/hammock) and bald cypress/red maple/cabbage palm (swamp/low bottomland hardwood/hammock) communities are present and are categorized as Riverine Mixed (Rmix). Pond apples are found in the riverine swamp but mostly only in association with the banks of the riverbed. The most problematic exotic pest plant species in this community is golden pathos (*Epipremnum pinnatum*), nephthytes (*Syngonium podophyllum*) and wild taro (*Colocasia esculenta*).

As with riverine swamps, upper tidal swamps are present at elevations below median monthly high stage (**Figure 17A**). Unlike riverine swamps, upper tidal surface soils consist of permanently saturated mucks. On the Northwest Fork of the river, upper tidal swamps are a mixture of brackish and freshwater vegetative communities. They primarily consist of pond apple, red and white mangrove (*Laguncularia racemosa*) with smaller numbers of bald cypress, pop ash, red maple and Carolina willow (**Table 3**). Areas of riverine swamp Rsw1 (i.e., mostly older bald cypress) are present and have probably survived at the back of the tidal floodplains due to surface and groundwater runoff from the adjacent uplands. UTsw1 is defined as a community of 70 percent mixed swamp with less than 30 percent white mangrove while UTsw2 is defined as less than 70 percent mixed swamp but with greater than 30 percent pond apple. White mangroves are more dominant in the UTsw3 forest type. White mangroves are most often found at higher elevations than red mangrove, bald cypress, and pop ash; therefore, they should represent less relative basal area in the deeper mixed swamp communities. When mixed swamp communities are less than 50 percent, and hammock, uplands and/or bottomland hardwood species are greater than 60 percent, then the forest type is identified as upper tidal mixed (UTmixed). However, if hammock represents greater than 75 percent, then the forest type is identified as hammock. No bottomland hardwood sites are found in the upper or lower tidal reaches.

A

B

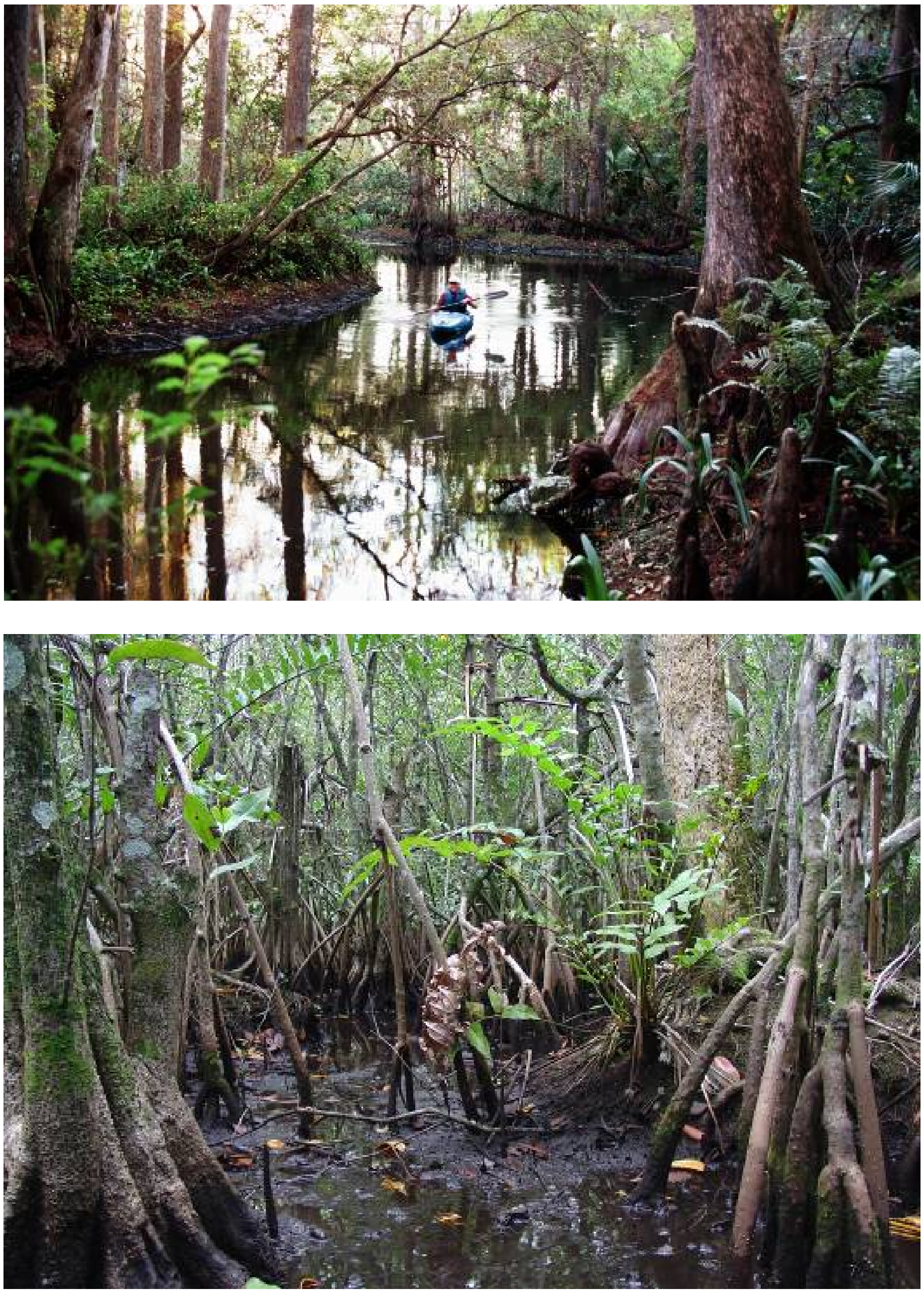


Figure 17. (A) Riverine swamp forest type and (B) Upper tidal swamp forest type (UTsw1).

Lower tidal forest types are primarily mangrove forests (i.e., swamps) with some areas of hammock, which is representative of areas with very little change in topography within the floodplains (**Figure 18**). Soils are mucky with some areas of sand. LTsw1 is representative of a swamp dominated by red mangroves, while LTsw2 is representative of a white mangrove swamp with infrequent pond apples and red mangroves. Other plots contain mixtures of white mangrove, pond apple, and cabbage palm. If cabbage palm is greater than or equal to 50 percent, and white mangrove and pond apple are greater than 30 percent, then the forest type is identified as lower tidal mixed (LTmixed). If cabbage palm and cocoplum (*Chrysobalnus icaco*) are greater than 75 percent, then the forest type is identified as hammock. Cabbage palm is found intermixed and in clumps with swamp species; however, those palms that were found at these low elevations and exposed to saltwater did not appear to be as healthy as those found at the higher elevations. Others were found growing on small mounds or hummocks. Today, cabbage palms are quite common along the shoreline of the tidal Northwest Fork of the river. In a comparison of the 1940 to the 1995 shoreline of the Northwest Fork, it was shown that the river channel has widened between the park boundary (RM 5.92) and the Trapper Nelson Interpretive Site (RM 10.50) (SFWMD, 2002). This widening suggests that erosion has occurred within these cabbage palm communities leaving them exposed to greater tidal fluctuations and saltwater exposure.

Figure 18. Lower tidal swamp forest type (LTsw1).

VEGETATION SAMPLING

The major components of this study were the river and floodplain vegetational sampling, forest type identification, topographic elevations, floodplain hydrology and soil characteristics. The methods were based on those largely defined by Melanie Darst and Helen Light on the Suwannee River (Darst et al. 2003 and USGS 2002). In the 2003 vegetation study, ten vegetation belt transects (**Figure 19** and **Table 5**) were established for plant community composition and structure in order to document baseline and future plant community health along the floodplains of the North and Northwest Forks of the Loxahatchee River and Cypress and Kitching Creeks. This study re-examined six historical vegetation transects and establishing four new transects in additional areas of concern. Transect locations were representative of riverine (predominantly non-impacted freshwater), upper (saltwater intruded with fresh and brackish water) and lower tidal (highly influenced by tides and salinity) communities. Seven transects were located at designated locations along the middle and upper segments of the Northwest Fork of the Loxahatchee River (T-1, T-2, T-3, T-4, T-6, T-7, T-9). Additional transects were established in the lower portions of Kitching (T-8) and Cypress Creeks (T-5) (tributaries of the Northwest Fork), and in the upper North Fork of the Loxahatchee River (T-10). Transects T-1, T-2, T-3, T-5, T-6 are the historical transects utilized by Dewey Worth in 1983-86 and again by Ward and Roberts in 1993-1994. Transect 9 was surveyed previously by Taylor Alexander in 1967 while Transect 10 is a completely new study area on the North Fork of the Loxahatchee River. In a later report, data from the historical transects of Alexander (1967, unpublished), Worth (1984, unpublished SFWMD), and Ward and Roberts (1993-1994, unpublished) will be compared with the 2003 baseline data to determine changes in the composition and structure of these forest communities over time.

Belt transects were positioned perpendicular to the river and the existing elevational gradient as with similar floodplain studies in Arkansas (Smith, 1996), northern Florida (USGS, 1993 and 2002), and previous Loxahatchee River studies (Alexander 1967, Worth 1986, Ward and Roberts 1996). Transects began inland at the upland edge of the wetland and continued to the river's edge. The upland edge was determined by visual cues and by examining soils. Transects were surveyed and permanently marked with PVC pipe and /or flagged.

Within each 10 m^2 vegetation plot, all trees with greater than 10 cm (3.94 inches) diameter at breast height (dbh), were identified by species and dbh measured for canopy analysis (**Figure 13**). Trees were randomly chosen for height measurement. Heights were measured using a Haglöf Vertex III Hypsometer and T3 Transponder. Shrub cover was measured by examining all woody plant species with a height greater than 1 m (3.28 feet) and dbh less than 10 cm within a 10 m line-intercept nested within each 10 m^2 plot. Cover and stem counts of all herbaceous plants and woody plant species (i.e., groundcover) under 1 m were measured within three, 1 m^2 subplots nested within each 10 m^2 plot. Additional information, collected within each vegetation plot, included presence of hummocks, presence of cypress stumps, as well as estimates of percent open ground, percent exposed roots, percent leaf litter, and percent fallen logs. Also within each transect and vegetation plot, corresponding elevation and soil type were determined to investigate environmental factors affecting plant distribution and abundance.

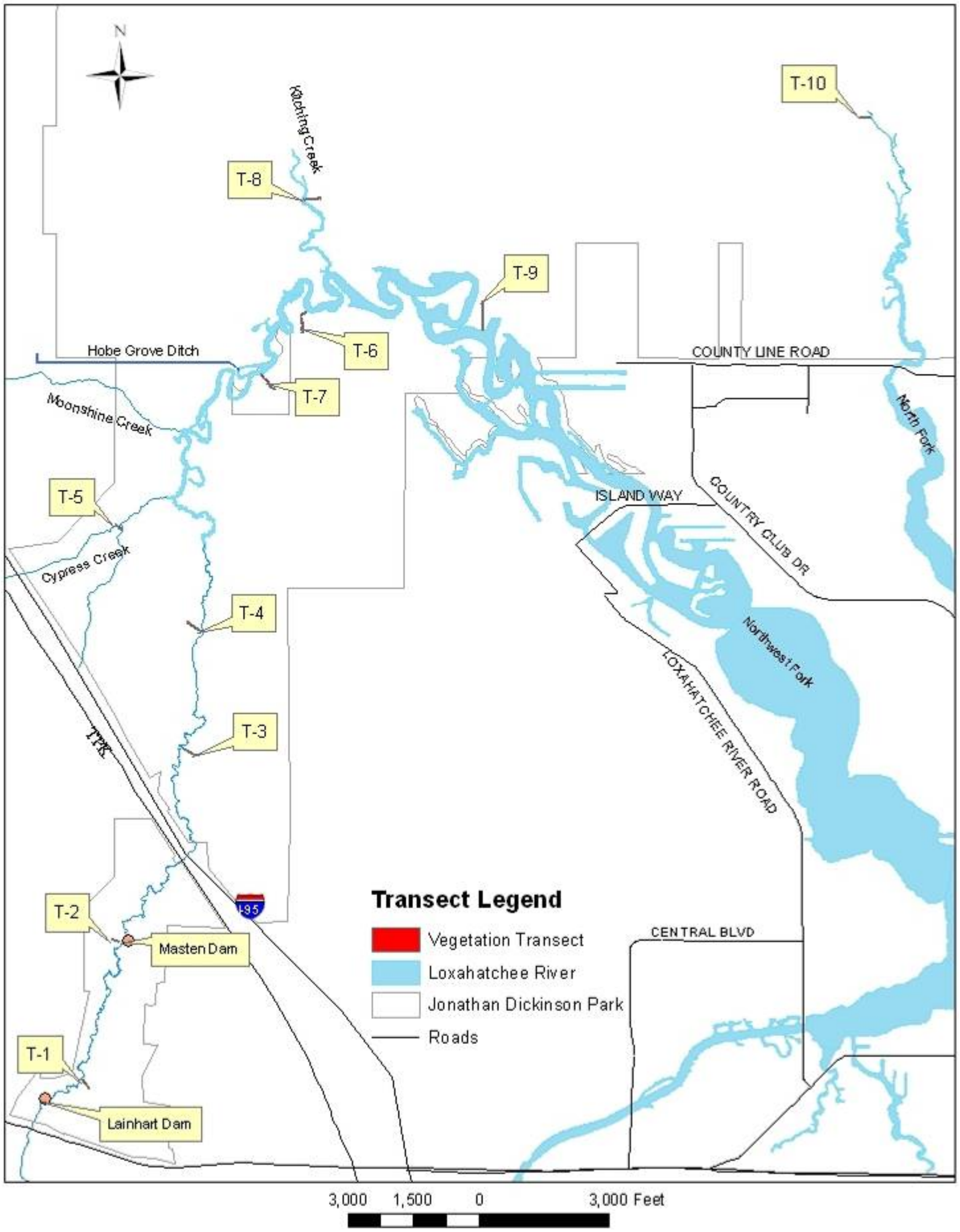


Figure 19. Ten vegetational belt transects in the Loxahatchee River Floodplain.

Table 5. Geographical information for the 2003 study vegetation transects.

Tran-sect	Twp./Rge./Sec.	Latitude	Longitude	Length	River-mile
Riverine					
T-1	T41S/R42E/S5	26°56'23.552"N	80°10'19.464"W	150m	14.5
T-2	T40S/R42E/S32	26°56'57.303"N	80°10'14.107"W	130m	13.57
T-3	T40S/R42E/S29	26°57'39.309"N	80°09'52.029"W	130m	13.43
T-4	T40S/R42E/S20	26°58'09.885"N	80°09'53.596"W	120m	11.18
T-5	T40S/R42E/S20	26°58'33.248"N	80°10'13.960"W	140m	10.33
T-6	T40S/R42E/S16	26°59'15.464"N	80°09'24.084"W	160m	8.43
T-7	T40S/R42E/S20	26°59'06.939"N	80°09'35.901"W	160m	9.10
T-8	T40S/R42E/S16	26°59'46.271"N	80°09'18.714"W	100m	8.13
T-9	T40S/R42E/S16	27°00'09.426"N	80°08'38.662"W	190m	6.46
T-10	T40S/R42E/S11	27°06'59.819"N	80°06'59.819"W	74m	2.44

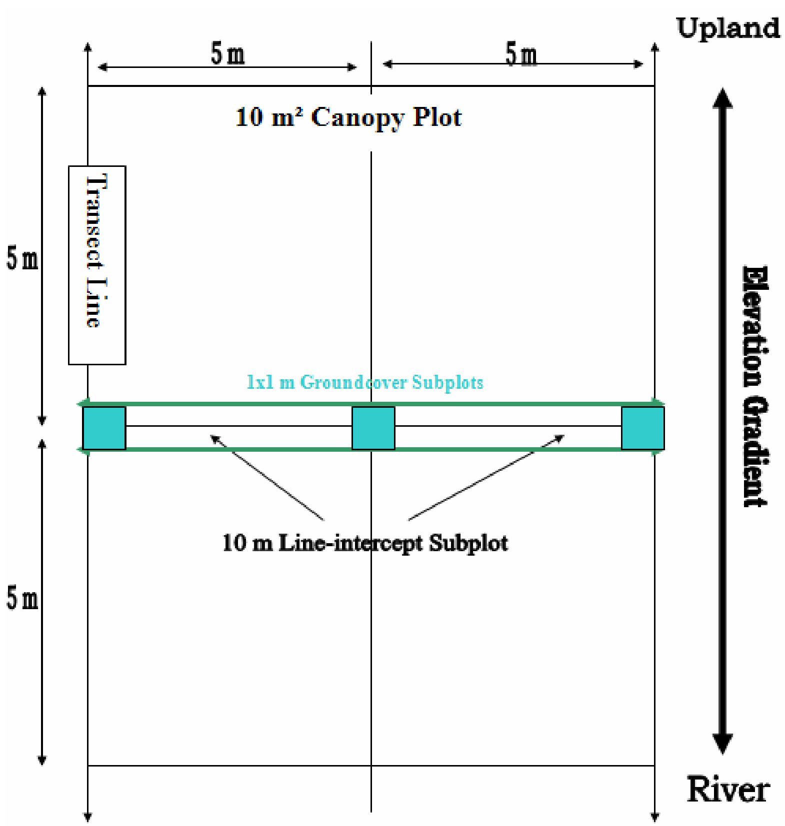


Figure 20. Schematic of transect monitoring.

PLANT AND FOREST TYPE IDENTIFICATION AND ENUMERATION

Plants were identified to the lowest possible taxonomic level. Plant identification and nomenclature followed that of Wunderlin and Hansen (2003). Species were verified according to those previously cited in "*Vascular Plants of Jonathan Dickinson State Park*" (Roberts et al, in press). A few plants that were not listed in this publication were pressed and sent to the herbarium at the University of South Florida for verification.

For the analysis of plant data from the 2003 Vegetation study, floodplain plant communities were divided into three distinct groups or reaches (**Figures 21** and **22**) riverine (R), upper tidal (UT) and lower tidal (LT)**.** These groups were distinguished based on hydrological conditions, vegetation, and soils (modified from USGS, 2002a). The boundaries were based on distribution of the different canopy tree species using the 1995 aerial photography and the corresponding GIS coverage. The Northwest Fork of the Loxahatchee River contains approximately 320 hectares of riverine, 24 hectares of upper tidal and 45 hectares of lower tidal floodplain.

The riverine reach is that part of the floodplain forest having primarily freshwater canopy forest that is generally unaffected by salinity. On the Northwest Fork of the Loxahatchee River, this area ranges from just north of the G-92 Structure (**Figure 3**) downstream to RM 9.5 (**Figures 21** and **22**). Vegetative communities in this reach are dominated by bald cypress (*Taxodium distichum*) with pop ash (*Fraxinus caroliniana*), red maple (*Acer rubrum*), pond apple (*Annona glabra*), water hickory (*Carya aquatica*) and other trees present with less frequency.

The upper tidal reach is that part of the floodplain forest having a mixed freshwater/brackish canopy forest that has experienced some salt water intrusion due to tidal influences and lack of freshwater flow in the dry season. On the Northwest Fork of the Loxahatchee River this area occurs between RM 9.5 and RM 8.13 (the mouth of Kitching Creek), as illustrated in **Figure 21**. Upper tidal reach communities are dominated by pond apple, red and white mangrove (*Rhizophora mangle* and *Laguncularia racemosa)* and cabbage palm (*Sabal palmetto)* with some communities of bald cypress present in the inner floodplain areas away from the river channels.

The lower tidal reach is that part of the Northwest Fork having primarily salt tolerant species and is highly influenced by tides and salinity in the water and soils (**Figure 21**). This area extends from approximately RM 8.13 to RM 5.5 although several smaller areas can be found around RM 4.5 and in the embayment area. The lower tidal reach is dominated by red and white mangrove.

The identification of floodplain forest community types was based on the canopy tree species that generally grow together in recognizable communities (modified from Darst et al., 2003). Tree canopy data from both the 1995 Ward and Roberts study (76 10 m^2 plots) and the 2003 transect study (130 10 m^2 plots) were utilized. Prior to the creation of the forest types specific for the Loxahatchee River, Twin Span (two way indicator analysis) was used to analyze the 1993/1994 Ward and Robert's canopy dataset for Transects 1 through 6. Based on the results of this analysis, indicator species were identified for the various forest types. The relative basal area (RBA) of each tree species within a plot was determined using diameter at breast height (dbh) measurements. RBA is 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. Multi-trunk trees were considered separate trees for this analysis. The most common multi-trunk trees observed were pond apple, red mangrove and bald cypress.

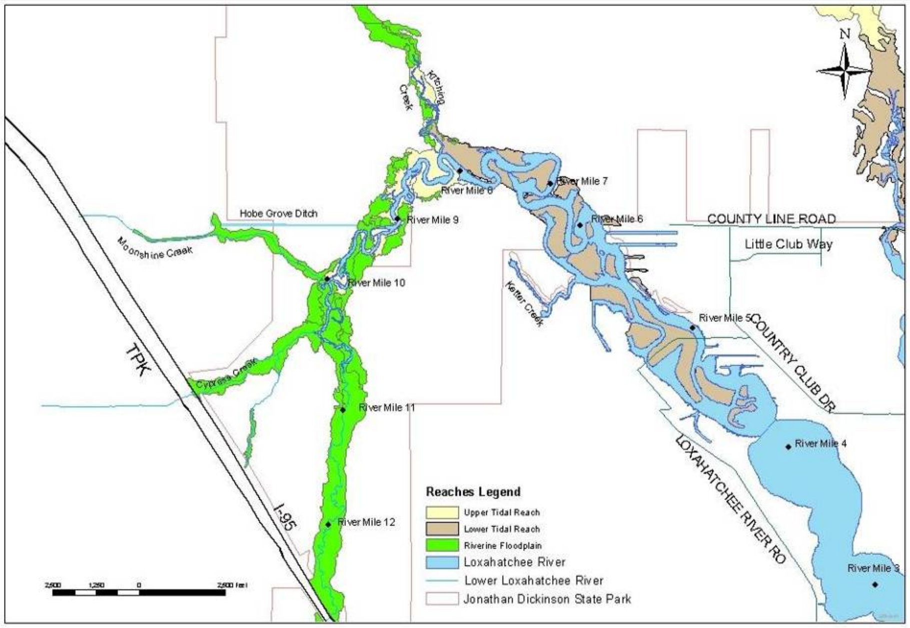


Figure 21. Designated reaches of the Northwest Fork of the Loxahatchee River – North.

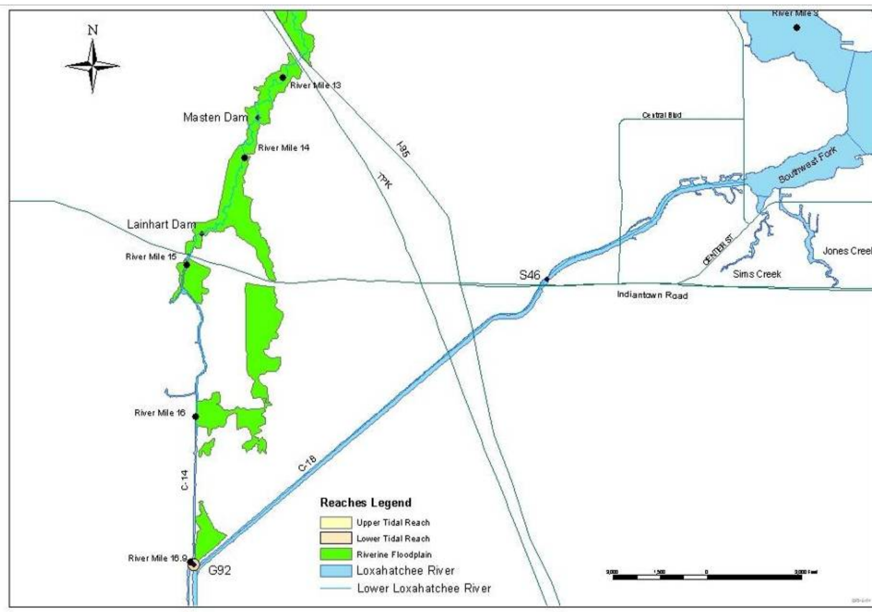


Figure 22. Designated reaches of the Northwest Fork of the Loxahatchee River – South.

Guidelines were developed to identify the 16 forest community types by reach. For each area, the major vegetative community category was identified as swamp (S), bottomland hardwood (low and high Blh), hydric or mesic hammock (H), or uplands (U) (**Table 6**). Then, the reach and type of the forest community was determined based on species composition. Using these guidelines, it was possible to consistently distinguish among forest community types (distinguish a riverine swamp community from an upper tidal swamp community).

Table 6. Major forest types used in the 2003 study.

Forest Type	Riverine (R)	Upper Tidal (UT)	Lower Tidal (LT)
Swamp	Rsw1 Rsw2 (FPsw1[a])	UTsw1 UTsw2 (FPsw1[a]) UTsw3 (LRsw3[b])	LTsw1 (RMsw1[c]) LTsw2
Low Bottomland Hardwood High Bottomland Hardwood	Rblh1 Rmix Rblh2 Rblh3	UTmix	LTmix
Hammock	H (Mesic and Hydric)	H (Hydric only)	H (Hydric only)
Upland	U	U	U

[a] Another name for *Fraxinus caroliniana* swamp.
[b] Another name for *Laguncularia racemosa* swamp.
[c] Another name for *Rhizophora mangle* swamp.

Note: Riverine reach information is generally presented in this report with a green background color. Upper tidal reach information is generally presented in this report with a yellow background color. The lower tidal reach information in this report is generally presented with a beige color background.

Split plots and mixed plots also occurred. Based on RBA, a split plot has two major forest types (split 50 percent) on either side of the plot such as Hammock/Rsw1. A mixed plot has several forest types intermixed together within the plot. These plots were classified as Rmix, UTmix, or LTmix. A total of 26 canopy species were identified during the 2003 belt transect survey and were categorized by their most common occurrence in the floodplains. Forest types clearly differ as a result of changes in hydrology, topography, vegetation, soils, and proximity to the coast (Darst et al., 2003). Other factors that influence forest type include logging and fire history, presence or absence of exotic species, and the availability of nutrients and light. Composition, structure and distribution was determined for woody vegetation along the 10 transects. For each transect and reach, canopy, shrub and groundcover data were analyzed for species richness (i.e., total number of species), frequency of occurrence, and distribution. Canopy data was further analyzed for abundance and relative basal area (RBA). Shrub and groundcover data were further examined for density of cover. Additional measurements of seedling/sapling counts were made and summarized.

In a later publication, the survey work will reflect the use of the PC ORD software to further examine the vegetation data along with several other environmental factors including elevation and soil type.

TOPOGRAPHIC CHARACTERISTICS

Each transect was surveyed by SFWMD surveyors. Additional survey measurements and GIS locations were taken by a Senior Geographer with SFWMD's Coastal Ecosystems Division. Based on the permanent benchmarks established by SFWMD surveyors, a laser level was used to determine elevation (feet MSL). Profiles were prepared for each transect and later over-laid with designated forest community types. This information will be used to calculate water inundation within the floodplain area at various locations along the Northwest Fork of the Loxahatchee River.

GIS vegetation coverages were completed for all transects using Digital Ortho Quads (DOQQs) from year 2003 and the Florida Land Use, Cover and Forms Classification System (FLUCCS). Extensive GIS coverages were prepared for Kitching Creek, Cypress Creek and the North Fork. Historical coverages from 1940, 1985 and 1995 are available for most of the NW Fork transects. Additional coverages (1953, 1964, and 1979) are available for the Taylor Alexander or Wilson Creek site, which were part of a 6-decade analysis in the 2002 MFL document (SFWMD, 2002).

FLOODPLAIN HYDROLOGY AND SALINITY

Real time water level (stage), water temperature, conductivity and salinity are being recorded at several stations (**Figure 13**). Mean forest elevation of forest types, daily high stage, and flows over Lainhart Dam were used to calculate flood depths and duration. Real time (every 15 minutes) bottom and surface salinities and water level in the river are being collected at several locations near the study transects for the 3-D Hydrodynamic/Salinity Model. A total of seven monitoring stations for the project area have been established and are operational. Hobe Grove Ditch and Cypress Creek Stations provide current velocity and water level for estimates of freshwater input to the Northwest Fork.

Ground water level data are being recorded at twelve shallow water wells with recorders placed along Transects 1, 3, 7, 8, and 9 for the Loxahatchee watershed groundwater monitoring network. Transects 1 and 3 serve as the background freshwater sites for study purposes. The remaining stations are exposed to different levels of tidal fluctuations and saltwater intrusion. Estimates of groundwater discharge and recharge, and other water quality constituents within several of the transects were examined during wet and dry periods. Data from the USGS groundwater study and the University of Florida soils study will be summarized in the conclusions of this report. Groundwater data from the twelve Loxahatchee watershed groundwater monitoring network will be summarized in an additional report in the future.

SOIL CHARACTERISTICS

Soil profiles were collected within each transect as part of the University of Florida's "Soils Analysis in the Floodplains of the Loxahatchee River Watershed." Soil samples were collected within each 10 m^2 plot and combined to create a composite sample to represent each major forest type within a transect. A soil auger was used to collect the top 20 cm of soil. Soil moisture (percent saturation), soil texture, drainage class, soil classification, thickness of horizons, conductivity, nitrogen, potassium, phosphorus, pH, cation exchange capacity, and percent organic matter was determined for each composite sample.

RESULTS

FOREST COMPOSITION AND DISTRIBUTION ON THE LOXAHATCHEE RIVER

Overall View of Plant and Forest Type Distribution

In the 2002 MFL document, the 1940 and 1995 aerial vegetative coverages of portions of the Loxahatchee River were presented. Florida Land Use, Cover and Forms Classification System (FLUCCS) codes were used to describe aerial views of the vegetative communities. For the floodplain area the categories were mangrove swamp, inland ponds and sloughs, stream and lake swamp, mixed wetland hardwood, wet pine flatwood, cypress, and freshwater marsh. Through the study of the 10 vegetative belt transects of the river and its major tributaries, we were given a closer view of the plant communities that occupied the FLUCCS codes listed above. **Table 7** presents a summary of the 138 plots by forest type. Plots were also broken down by split and mixed plots. Within the 138 plots, forest types were distributed as 58 percent swamp, 11 percent hammock, 11 percent bottomland hardwood, 10 percent mixed hardwoods, 3 percent upland, and 1 percent freshwater marsh. Almost one-half of the plots were located in the riverine reach while 37 percent and 14 percent were located in the upper tidal and lower tidal reaches, respectively. Again, 6 of the 10 transects were historical transects from the SFWMD 1983/84 study (Worth, unpublished) and Ward and Roberts 1994/95 study. The freshwater marsh was only found on Transect 10 on the North Fork of the river while communities of bottomland hardwood were only found in the riverine reach, although species generally associated with bottomland hardwoods were present in the upper tidal reach.

Table 7. Summary of the 138 vegetative plots by forest type with split and mixed plots included.

Forest Type	Riverine (R)	Upper Tidal (UT)	Lower Tidal (LT)
Swamp	Rsw1 (25) Rsw2 (8) Rsw1/Rblh2 (1)	UTsw1 (15) UTsw2 (6) UTsw3 (6) Rsw1 (3) Rmix (7) UTmix (6)	LTsw1 (4) LTsw2 (13) LTmix (1)
Low Bottomland Hardwood High Bottomland Hardwood	Rblh1 (3) Rblh2 (10) Rblh3 (3)		
Hammock	MH (8) HH (4) HH/U (1) HH/Rsw1 (2) HH/Rsw2 (1)	HH (3) HH/Marsh (1) MH/Rsw1 (1)	HH (1)
Upland	U/HH (1)	U (2)	U (1)
(Marsh)		M (1)	

Species richness (i.e., total number of species) is a simple method of illustrating diversity within live communities. Therefore, we examined species richness by transect and river mile in the 2003 Study. Riverine Transects 1 through 4 were located on the Northwest Fork of the river while Transect 5 was located on lower Cypress Creek. Transects 6, 7, 8 (Kitching Creek) and 10 (North Fork) were located in the upper tidal reaches while Transect 9 was located in the lower tidal reach. For all three plant layers (canopy, shrub, and groundcover) of the 2003 study transects, Transect 3 (RM 12.07) had the highest species richness with 58 species while T2-B (RM 13.43) had the lowest number with 24 species (**Figure 23)**. Transect 3 may have more species because this area has good topographical relief and has been disturbed more than other riverine transects. Transect 3, located upstream of the area known as Governor's Dock, has been impacted by selective lumbering, exotic plant management and contains multiple braided channels. Transect 3 also had the greatest number of pop ash of any site. This appears to be true also of areas in the upper tidal where bald cypress were selectively lumbered, while an area like Transect 1 with full bald cypress canopy had none. In this analysis, Transect 2 was divided into two sites (T2-A (RM 13.57) and T2-B) for later comparison with the 1993/94 Ward and Roberts study. T2-A represented the area just upstream of Masten Dam which is primarily swamp whereas T2-B represented the area downstream of the dam, which is primarily hydric hammock. Masten Dam also has the effect of somewhat impounding surface water and groundwater. Plant species, common names and electronic code names are listed in Appendix B by vegetative layer.

There were a total of 138 trees, shrubs, groundcover and woody vine species identified in the floodplain forest. The canopy species included 26 trees and 1 woody vine. In the shrub layer, 49 species of younger trees and shrubs were identified while 118 species of herbs and young shrub/tree seedlings were identified as groundcover.

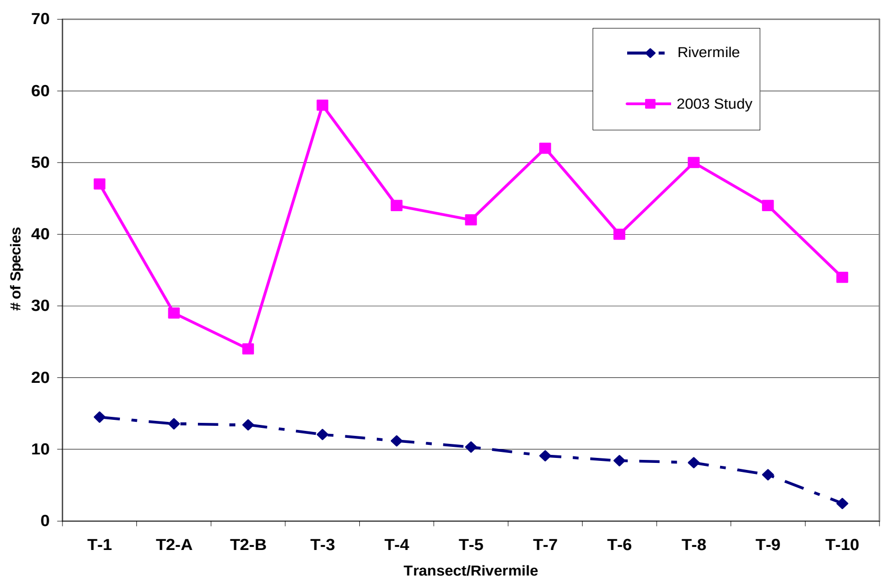


Figure 23. Species richness for canopy, shrub and groundcover layers in the 2003 study.

Species abundance is another method of enumeration that illustrates the composition of live communities. Without consideration of reach, the floodplain canopy of the Loxahatchee River and its major tributaries consisted primarily of 5 species, i.e., white mangrove (22.5 percent), red mangrove (14.2 percent) pond apple (13 percent), cabbage palm (12.4) and bald cypress (9 percent) (**Figure 24**). These percentages reflected that mangroves often grow as denser forest stands than the freshwater communities dominated by hardwoods. Quite frequently, they were found with multiple trunks. Abundance also changed by reach. The canopy of the riverine reach consisted primarily of five species, including cabbage palm (23.3 percent), pop ash (22.6 percent), bald cypress (21.4 percent), red maple (10.4 percent), and water hickory (8.1 percent) (**Figure 25**). Cabbage palm was the most abundant species within hammock areas while red maple and water hickory dominated bottomland hardwood communities. Bald cypress and pop ash dominated swamp communities. The most abundant canopy species of the upper tidal reach was pond apple (21.9 percent) followed by red mangrove (16 percent), white mangrove (15.7 percent), wax myrtle (12.5 percent), cabbage palm (9.6 percent) and bald cypress (7.6 percent) (**Figure 26**). These percentages reflected the impact of selective lumbering and the abundance of hummocks that occurred throughout the upper tidal reach. Hummocks were found throughout the swamp community allowing vegetative species that tolerate shorter hydroperiods, like cabbage palm and wax myrtle, to live among true swamp species. **Figure 27** illustrates the abundance of canopy species on the one lower tidal transect (Transect 9). White mangroves were the most abundant species (61.8 percent) in areas normally covered by water at high tide. Red mangroves were more abundant (23.4 percent) adjacent to the river channel that characteristically had lower elevations and more tidal action.

Because of the effect of multiple trunks on canopy species abundance, basal area more accurate reflected the actual aerial coverage and age of the forest communities as we know them today. **Figure 28** illustrates the overall break down of basal area within the 10 vegetative transects. Approximately 63 percent of the canopy consisted of two species, bald cypress (40.6 percent) and cabbage palm (22.7 percent). Mangroves were reduced to 8.4 percent (white) and 1.6 percent (red). Basal area was highest for bald cypress and cabbage palm within the riverine reach where the percentage of bald cypress rose to 49.1 percent and cabbage palm fell to 17.6 percent (**Figure 29**). The older water hickory trees were represented by 12.6 percent basal area in the riverine reach. In the upper tidal reach, basal area fell somewhat for bald cypress and cabbage palm (35.8 percent and 32.7 percent, respectively, **Figure 30**). Pond apple rose from less than 1 percent in the riverine to 9.8 percent in the upper tidal reach while white mangrove appeared as 7.1 percent and red mangrove appeared as 3.5 percent. In the lower tidal reach, white mangrove accounted for 58.5 percent of the canopy basal area while cabbage palm and red mangrove accounted for 31.5 percent and 6.2 percent respectively. (**Figure 31**).

Percent frequency of occurrence illustrated others factors related to forest community composition within the canopy of the floodplains. The most frequently occurring species was cabbage palm (53 percent) followed by bald cypress (43 percent) and pond apple (32 percent) (**Figure 32**). The high frequency of cabbage palm was reflected by its high presence in all three river reaches (**Figures 33, 34,** and **35**). Wax myrtle topped the frequency list in appearing within 72 percent of the plots in the upper tidal reach (**Figure 34**) while white mangrove appeared in over 90 percent of the lower tidal plots (**Figure 35**). With regards to the frequency of exotics, Brazilian pepper was present in approximately 30 percent of the upper tidal plots and 40 percent of the lower tidal plots.

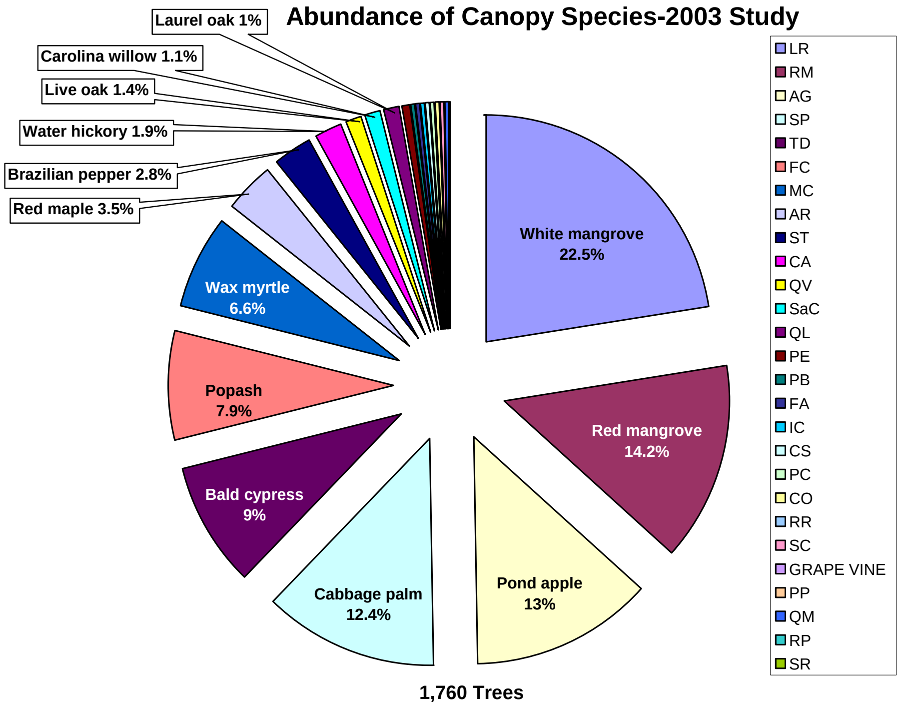


Figure 24. Overall abundance of canopy species in the 2003 study.

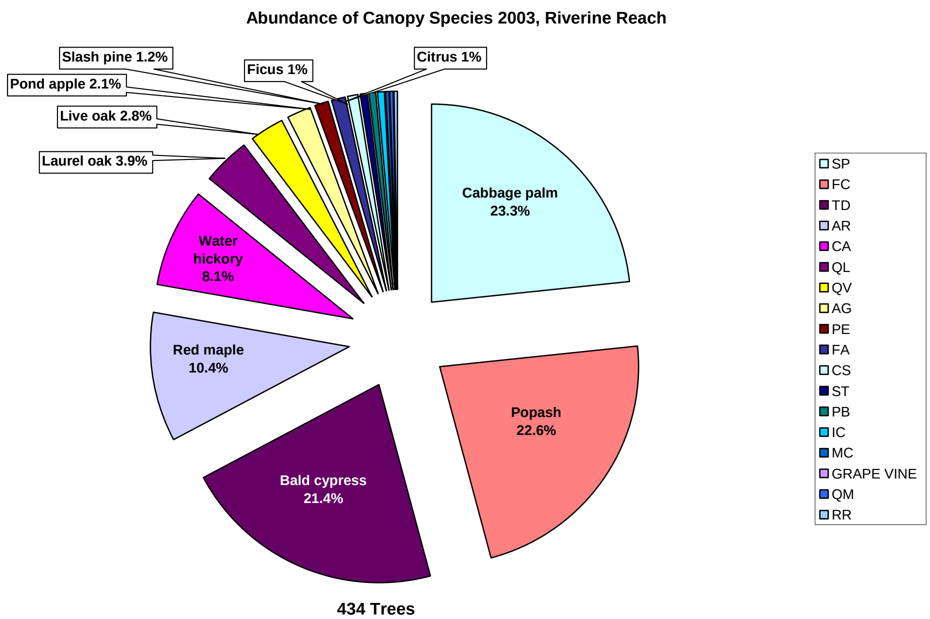


Figure 25. Canopy abundance in the riverine reach.

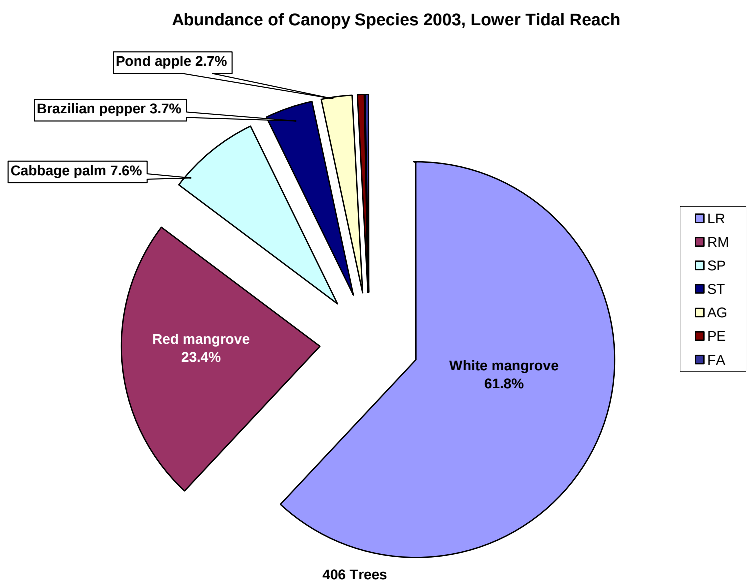


Figure 26. Canopy abundance in the upper tidal reach.

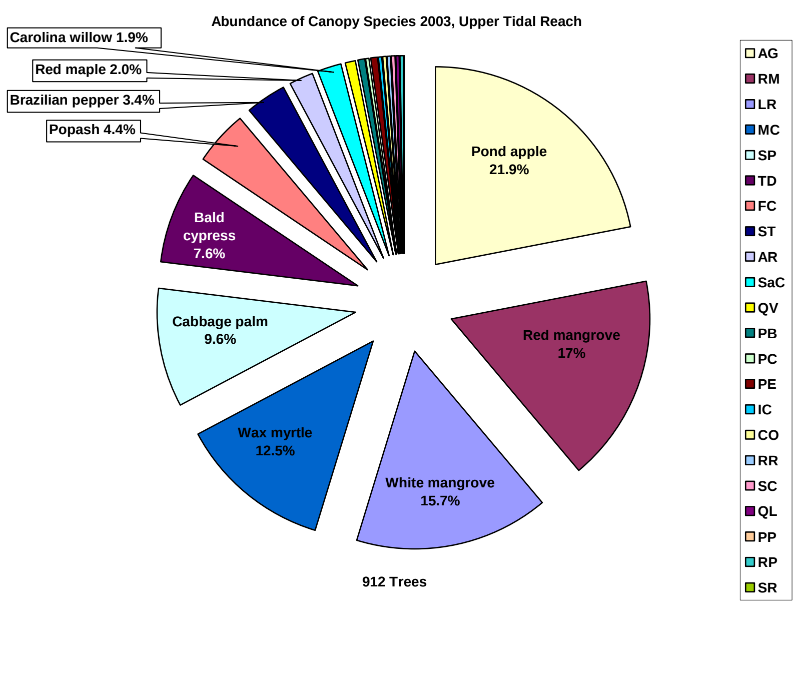


Figure 27. Canopy abundance in the lower tidal reach.

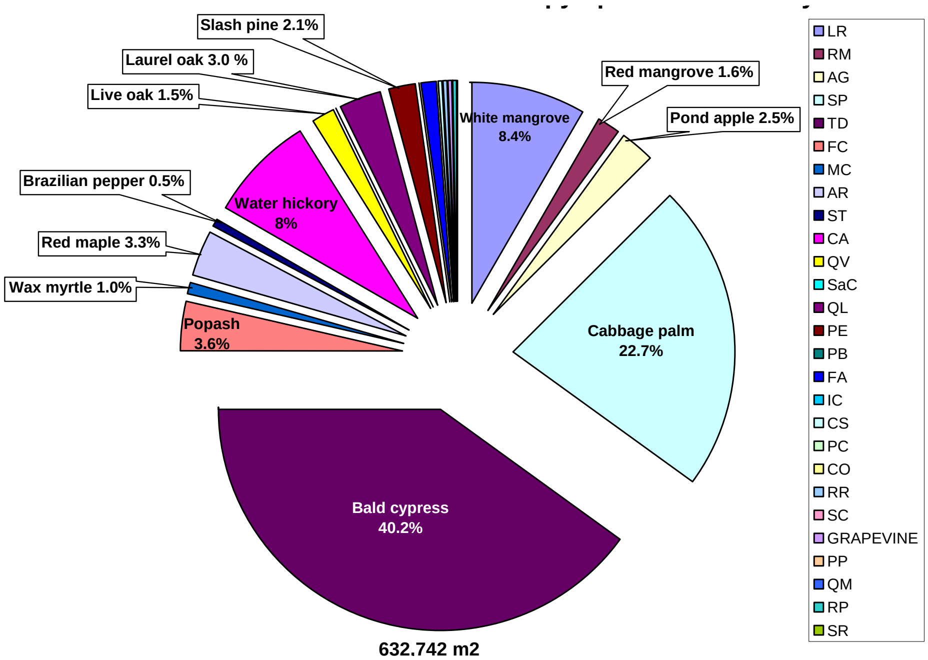


Figure 28. Overall total basal area for the 2003 study.

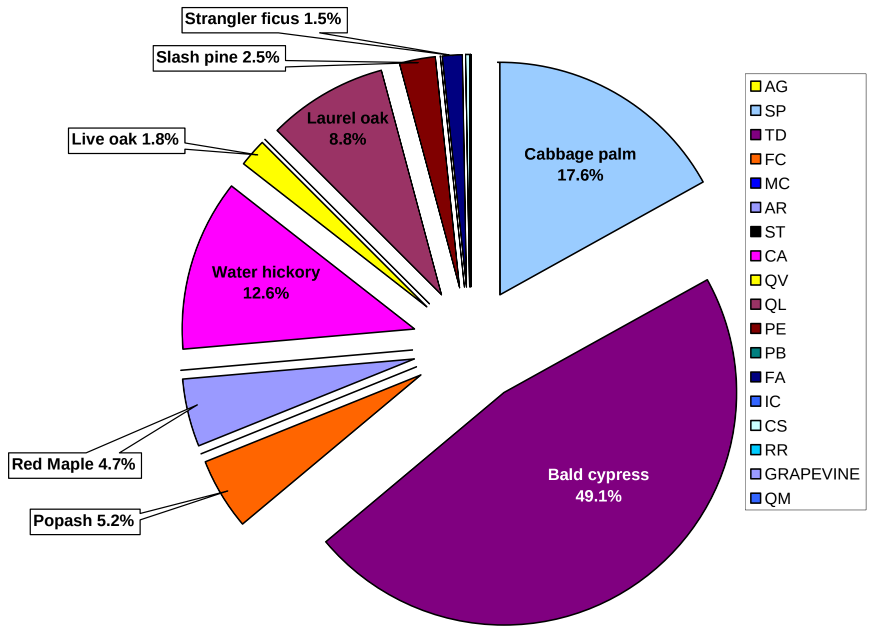


Figure 29. Basal area for the riverine reach.

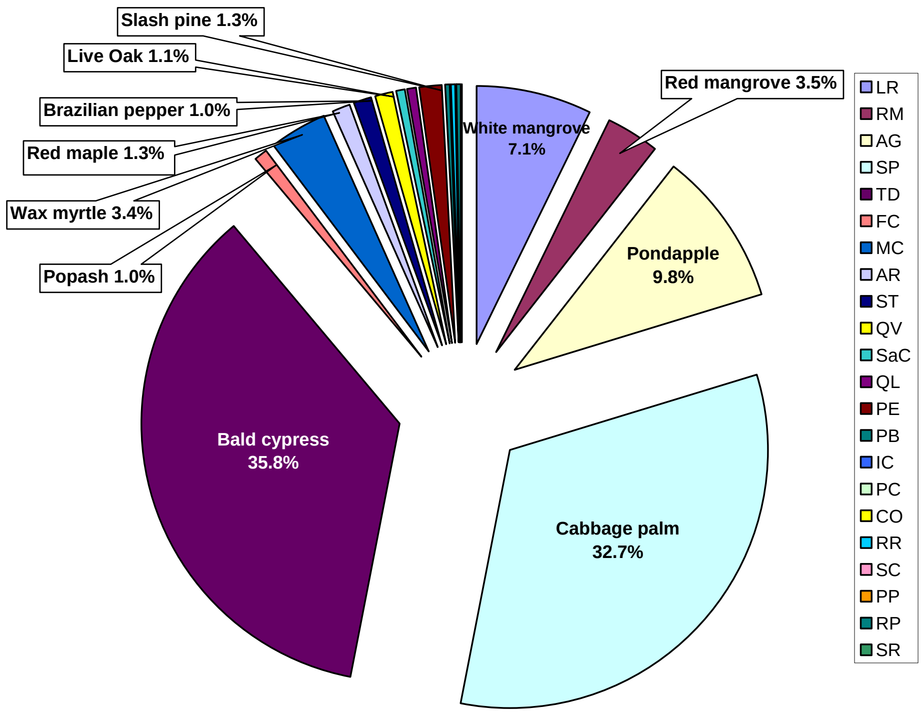


Figure 30. Basal area for the upper tidal reach.

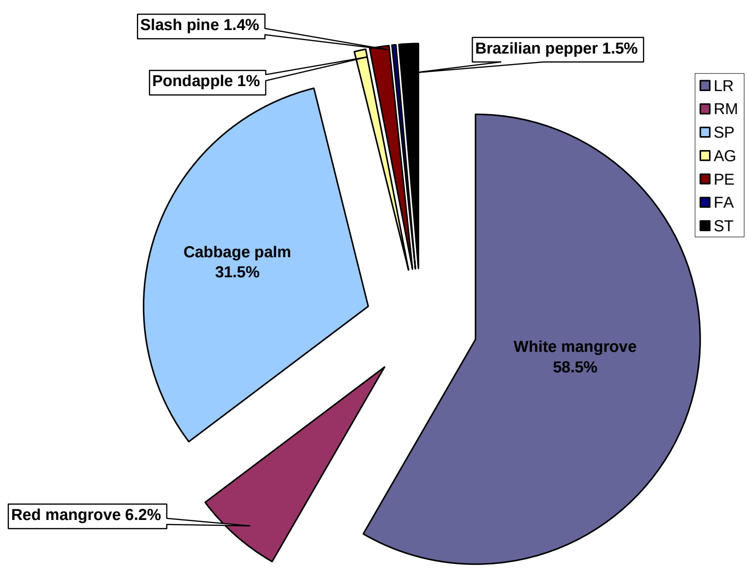


Figure 31. Basal area for the lower tidal reach.

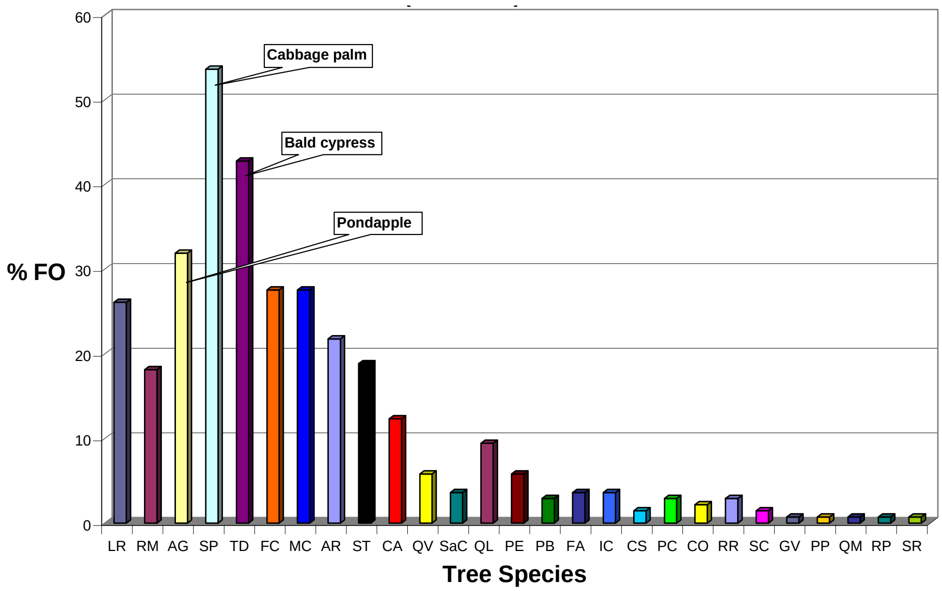


Figure 32. Frequency of occurrence for all canopy species in the 2003 study.

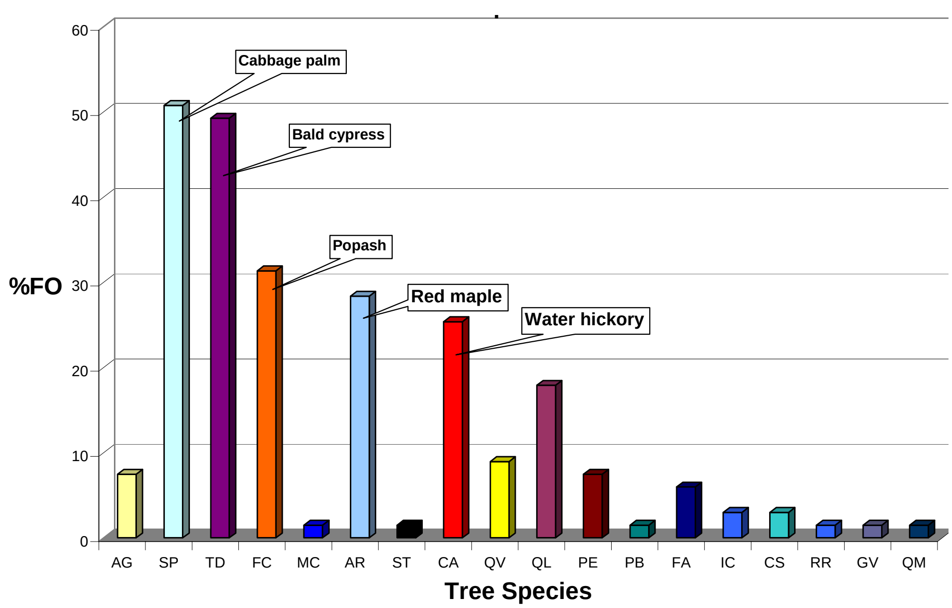


Figure 33. Frequency of occurrence of canopy species in the riverine reach.

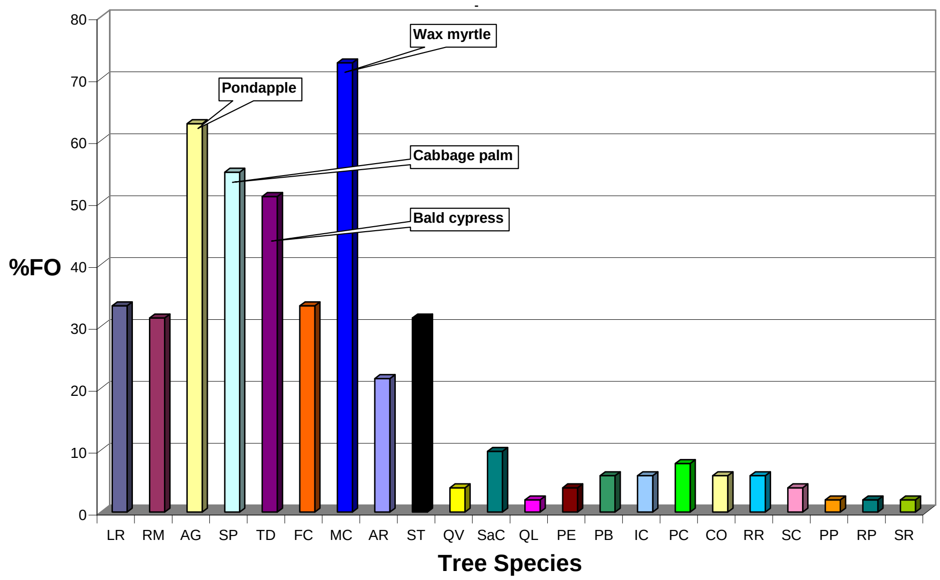


Figure 34. Frequency of occurrence of canopy species in the upper tidal reach.

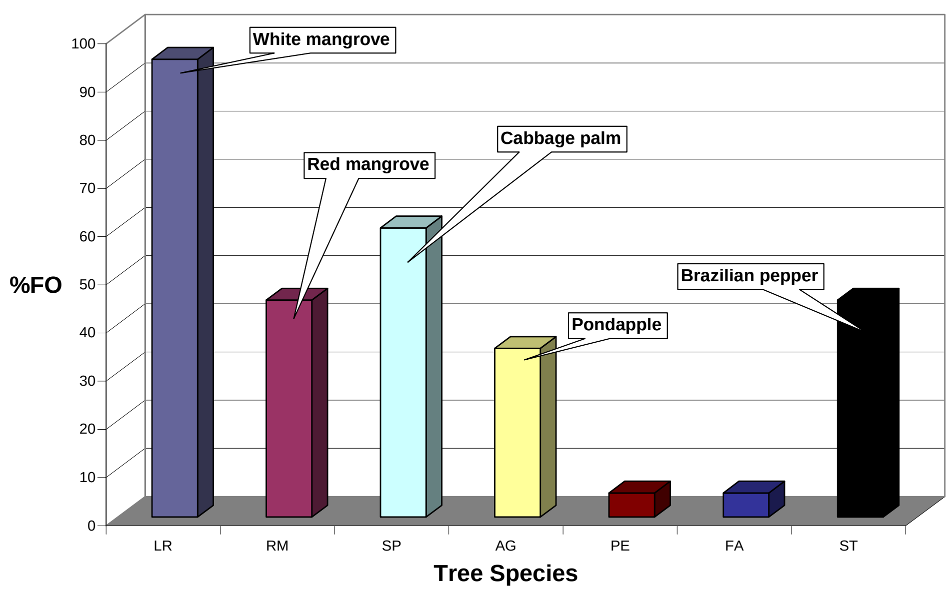


Figure 35. Frequency of occurrence of canopy species in the lower tidal reach.

The overall importance of the ten top canopy species is illustrated in **Table 8**. Species were ranked by abundance, basal area, and frequency of occurrence and then total rank was calculated. An importance factor was developed by then classifying the total ranks of each species. Cabbage palm ranked as the top most important species followed by bald cypress, white mangrove, pond apple, pop ash, red mangrove, red maple, wax myrtle, water hickory, and Carolina willow. Pond apple was the most important species of the upper tidal reach while white mangrove served as the most important species of the lower tidal reach.

Table 8. Summary of importance rankings of the 2003 canopy species.

	Rankings			
Species	**Abundance**	**Basal Area**	**Frequency**	**Total Rank & Importance**
Red maple	8	6	6	20 (7)
Pond apple	3	8	3	14 (4)
Water hickory	10	4	9	38.5 (9)
Pop ash	6	5	4.5	15.5 (5)
White mangrove	1	3	5	9(3)
Wax myrtle	7	11.5	4.5	23 (8)
Red mangrove	2	5	8	15 (6)
Cabbage palm	4	2	1	7(1)
Carolina willow	12	12	15	39(10)
Bald cypress	5	1	2	8 (2)

The overall importance of the ten top canopy species is illustrated in **Table 8** while **Tables 9, 10, and 11** present similar information for each reach of the river. Species were ranked by percent abundance, percent basal area, and percent frequency of occurrence. Then the ranks for each species were summed to obtain a "total rank". An importance factor was calculated by re-ranking the total ranks of each species. In **Table 8,** cabbage palm ranked as the most important species followed by bald cypress, white mangrove, pond apple, red mangrove, pop ash, red maple, wax myrtle, water hickory, and Carolina willow. In the riverine reach (**Table 9**), cabbage palm ranked again as the most important species followed by bald cypress, pop ash, water hickory, red maple, laurel oak, live oak, slash pine, pond apple, and strangler ficus. These values reflect the abundance of swamp, bottomland hardwood, and hammock communities present in the upper portions of the river whereas the tidal floodplain communities were more representative of a swamp community with additional representatives from bottomland hardwood and hammock communities. In the upper tidal reach (**Table 10**), pond apple ranked as the most important species followed by white mangrove, red mangrove, cabbage palm, bald cypress, wax myrtle, pop ash, red maple, Brazilian pepper, and Carolina willow. This is further evidence that pondapple appears to be somewhat more tolerant of brackish water than other freshwater species. Of the seven canopy species in the lower tidal reach (**Table 11**), white mangrove ranked as the most important species followed by cabbage palm, red mangrove, Brazilian pepper, pond apple, slash pine and strangler ficus. The high values for white and red mangrove reflect the significance of tidal amplitude, floodplain elevation, and salinity in the lower tidal reach. The abundance of the exotic, Brazilian pepper, is representative of floodplain areas impacted by saltwater intrusion, brackish water species, and past lumbering activities.

Table 9. Summary of the importance rankings of the ten top canopy species in the riverine reach.

Top 10 Rankings: Riverine Reach				
Species	**Abundance**	**Basal Area***	**Frequency**	**Total Rank & Importance**
Red maple	4	5	4	13 **(4.5)**
Strangler ficus	10	9	9	28 **(9)**
Pond apple	8	11	8.5	27.5 **(8)**
Water hickory	5	3	5	13 **(4.5)**
Pop ash	2	4	3	9 **(3)**
Slash pine	9	7	8.5	24.5 **(7)**
Cabbage palm	1	2	1	4 **(1)**
Laurel oak	6	6	6	18 **(5)**
Live oak	7	8	7	22 **(6)**
Bald cypress	3	1	2	6 **(2)**

*Citrus sp. was ranked 10th with regards to basal area but was higher than 10th in the other two categories.

Table 10. Summary of the importance rankings of the ten top canopy species in the upper tidal reach Summary of the importance rankings of the ten top canopy species in the riverine reach.

Top 10 Rankings: Upper Tidal Reach				
Species	**Abundance**	**Basal Area***	**Frequency**	**Total Rank & Importance**
Red maple	9	8	8	25 **(8)**
Pond apple	1	3	3	7 **(1)**
Pop ash	7	10	6	23 **(7)**
White mangrove	3	4	1	8 **(2)**
Red mangrove	2	5	2	9 **(3)**
Brazilian pepper	8	11	9	28 **(9)**
Cabbage palm	5	2	4	11 **(4)**
Carolina willow	10	12	10	32 **(10)**
Wax myrtle	4	6	7	17 **(6)**
Bald cypress	6	1	5	12 **(5)**

* Slash pine and live oak were ranked as 7th and 8th with regards to basal area but were higher than 10th in the other two categories.

Table 11. Summary of the importance rankings of the canopy species in the lower tidal reach Summary of the importance rankings of the ten top canopy species in the upper tidal reach Summary of the importance rankings of the ten top canopy species in the riverine reach.

Rankings :Lower Tidal Reach				
Species	**Abundance**	**Basal Area**	**Frequency**	**Total Rank & Importance**
Pond apple	5	6	4	15 **(5)**
Strangler ficus	7	7	5.5	19.5 **(7)**
White mangrove	1	1	1	3 **(1)**
Red mangrove	2	3	3.5	8.5 **(3)**
Slash pine	6	5	5.5	16.5 **(6)**
Cabbage palm	3	2	2	7 **(2)**
Brazilian pepper	4	4	3.5	11.5 **(4)**

Exotic Species

In his publication "Vascular Plants of Jonathan Dickinson State Park" (2006), Roberts et al. noted several exotic tree, shrub, and vine species in wetland plant communities. The most problematic species were Old World climbing fern (*Lygodium microphyllum*), cajeput tree (*Melaleuca quinquenervia*), Brazilian pepper (*Schinus terebinthifolius*), nephthytes (*Syngonium podophyllum*), strawberry guava (*Pisidium cattleianum*) and java plum (*Syzygium cumini*). Of the 173 non-native species found in Jonathan Dickinson State Park, Old World climbing fern has become the primary concern for continued management of existing biological communities since it first appeared in the early 1970s in the ecotone between the pinewoods and wetlands in the lower Kitching Creek basin. More recently, it has invaded the floodplains and strand swamps, cypress domes, wet prairies, wet flatwoods, hydric hammocks, depression marshes, ditches and even scrub habitats. The fern aggressively forms a thick mat over vegetation and eliminates understory native species.

In the 1993-1994 (Ward and Roberts, unpublished), 2003, and 2006 vegetation studies, 37 species of exotic trees, shrubs, and vines were identified in the floodplain of the Loxahatchee River (**Table 9**). All of the species listed above were noted with the exception of *Melaleuca*. The most prevalent species was Old World climbing fern, which was found in 1993-1994 Ward and Roberts' Study only on Transects T2-1, T-3, T-4, T-5 and T-6. In the 2003 study, the fern was found on all of transects except T-1, T-2, T-5, and T-7. In fact, it was not found on T-1 until the 2006 study. Other significant exotic understory plants found more frequent on the transects were Caesar weed (*Urena lobata*), day flower (*Commelina diffusa*), and downy shield fern (*Thelypteris dentata*), which were primarily found in the riverine reach. With regards to hardwoods observed per transect, Brazilian pepper, strawberry guava and java plum were the most common exotic canopy species in the floodplain. Brazilian pepper was found on all study sites except T-5 while strawberry guava was found on T-1 and T-2 in 1993-1994 study and on all tidal sites. Java plum was not as widely distributed and was only found on T-5, T-6, and T-7. In the riverine reach, Brazilian pepper was very low in abundance, basal area, and occurrence; however, in the tidal reaches it was high in occurrence (31 percent in the upper tidal and 45 percent in the lower tidal reach). Both strawberry guava and java plum were less than 1 percent in abundance and basal area and 7.8 and 3.9 percent, respectively, in occurrence. Disturbances are often associated with an increase in invasive species, but disturbances do not have to be large or a result of human activity to promote infestations of invasive plants (Marler, 2000). However Old World climbing fern, Brazilian pepper, nephthytes, strawberry guava, Java plum, wild taro (*Colocasia esculenta*), day flower (*Commelina diffusa*), Indian swamp weed (*Hygrophilia polysperma*) and Asian marsh weed (*Limnophila sessiliflora*) have invaded relatively undisturbed sites within and ecotones separating wetlands and uplands (Richard Roberts, pers. observ.).

Table 12. Summary of exotic species.

Exotic Species	Common Name						Transect #					
		T-1	T2-1	T2-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10
Abrus precatorius	**Rosary Pea**	**OY**									**OY**	
Alternanthera philoxeroides	**Alligator weed**	**XOY**		**X**								
Alternanthera sessilis	**Sessile joyweed**	**O**					**X**					
Ardisia elliptica	**Shoebutton**									**Y**		
Bischofia javanica	**Bishop wood**						**O**					
Citrus sp.		**OY**										
Colocasia esculenta	**Wild taro**	**OY**										
Commelina diffusa	**Dayflower**	**XOY**	**XO**	**XOY**	**XOY**	**X**	**XOY**					
Cyperus entrerianus	**Wood rush flat sedge**						**Y**					
Desmodium incanum	**Zarzabacoa**	**X**										
Desmodium triflorum	**Beggar weed**									**O**	**O**	
Eichhornia crassipes	**Water hyacinth**	**XY**										
Ficus microcarpa	**Indian laurel ficus**										**O**	
Gomphrena serrata	**Globe amaranth**										**OY**	
Hygrophila polysperma	**Indian swamp weed**	**Y**	**Y**	**Y**			**OY**					
Limnophila sessiliflora	**Asian marsh weed**	**X**			**XY**	**XOY**	**Y**					
Ludwigia peruviana	**Peruvian primrose willow**	**XY**								**Y**		

X=1993/1994 Ward and Roberts Study
O=2003 Study
Y=2006 Observations

Table 12. Continued.

Exotic Species	Common Name					Transect #					
		T-1	T2-1	T2-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10
Lygodium microphyllum	**Old World climbing fern**	**Y**	**XY**		**XOY**	**XOY**	**XY**	**XOY**	**Y**	**OY**	**O**	**OY**
Momordica charantia	**Wild balsum apple**						**X**					
Nephrolepis cordifolia	**Tuberous sword fern**				**Y**							
Nephrolepis multiflora	**Boston fern**			**XY**		**Y**						
Panicum maximum	**Guinea grass**						**Y**					
Pouzolzia zeylanica	**Pouzoulz's bush**	**Y**			**XY**	**Y**	**Y**					
Psidium cattleianum	**Strawberry guava**	**X**	**X**					**XOY**	**Y**	**OY**	**OY**	**OY**
Psidium guajava	**Guava**				**X**					**Y**		
Ptychosperma macarthurii	**MacArthur's palm**										**Y**	
Salvinia minima	**Water spangles**	**X**										
Schinus terebinthifolius	**Brazilian pepper**	**X**	**X**	**X**	**XOY**	**OY**		**XOY**	**OY**	**OY**	**OY**	**OY**
Senna pendula	**Climbing cassia**	**OY**	**O**									
Sphagneticola trilobata	**Creeping oxeye**	**OY**										
Synogium podophyllum	**Arrowhead vine, Nephthytis**	**XOY**		**X**								
Syzgium cumini	**Java plum**						**Y**	**Y**	**OY**			
Syzgium jambos	**Rose apple**	**X**										
Thelypteris dentata	**Downy shield fern**	**XOY**	**XO**	**Y**	**X**	**XO**	**OY**		**Y**			
Urena lobata	**Caesar-weed**	**XOY**	**XY**	**XOY**	**XOY**	**XOY**	**XOY**					
Urochloa mutica	**Paragrass**	**X**					**Y**					
Xanthosoma sagittifolium	**Elephant ear**	**OY**										

Top canopy (green) and shrub/groundcover (yellow) species.

X=1993/1994 Ward and Roberts Study
O=2003 Study
Y=2006 Observations

TRANSECT VEGETATION SUMMARIES

In this summary of the 2003 vegetation survey, Transects 1, 2, 3, and 4 on the Northwest Fork and Transect 5 on Cypress Creek were riverine floodplain forest. Transects 6, 7, and 8 were upper tidal and Transect 9 was lower tidal floodplain forest. Canopy species' abundance, basal area, and each frequency of occurrence were examined for within each transect. Forest type of each $10m^2$, plot along with its survey profile were given to illustrate the layout of each transect. Survey profiles of transect elevations were expressed as feet NGVD29. A more detailed discussion of shrub and groundcover layers is discussed in the next section.

Riverine Transects

Transect 1 (T1-1 and T1-2) is located just downstream of Lainhart Dam at RM 14.7. This site transverses the north and south sides of the Northwest Fork with 15 $10m^2$ plots. The thick canopy showed no evidence of past logging activities. It was primarily composed of native vegetation with the major exceptions being the exotic wild taro (*Colocasia esculenta)*, elephant ear (*Xanthosoma sagittifolium*) and arrowhead vine (*Syngonium podophyllum*) present as groundcover within the swamp community. T-1 was the only riverine transect without pop ash (*Fraxinus caroliniana*).

Soils in the hammock area of T1-1 were Riviera fine sand while they were Pineda fine sand on T1-2. Swamps communities were found in Aquents soils on T1-1 and T1-2. The bottomland hardwood plot adjacent to the river on T1-2 was also Aquents (Appendix C).

T1-1 on the south side (**Figure 36**) had several elevation changes from 14.04 ft at the top of the mesic hammock to about 9.34 ft in the deeper swamp areas and 5.44 ft in the river channel. The landward-side of T1-1 was dominated by several plots of upland and hammock areas before dropping down into the floodplains as a cypress swamp (Rsw1) that borders the riverbed. There is an old agricultural ditch that runs through the hammock area and into the swamp. Ground elevations on either side of the ditch may have been altered by the placement of fill from the original excavation of the ditch. Dewey Worth (unpublished) examined flows from this ditch for several months between February 1984 and December 1985. Other than some occasional low readings of 4 cfs, he showed a peak of about 17 cfs around September 15 and a peak of 31 cfs around December 15, 1984. **Figure 36** also depicts total inundation of the swamp community at about 10.4 ft corresponding to a flow of approximately 114 cfs over Lainhart Dam. Top of bank for the river channel was achieved around 90 cfs at Transect 1.

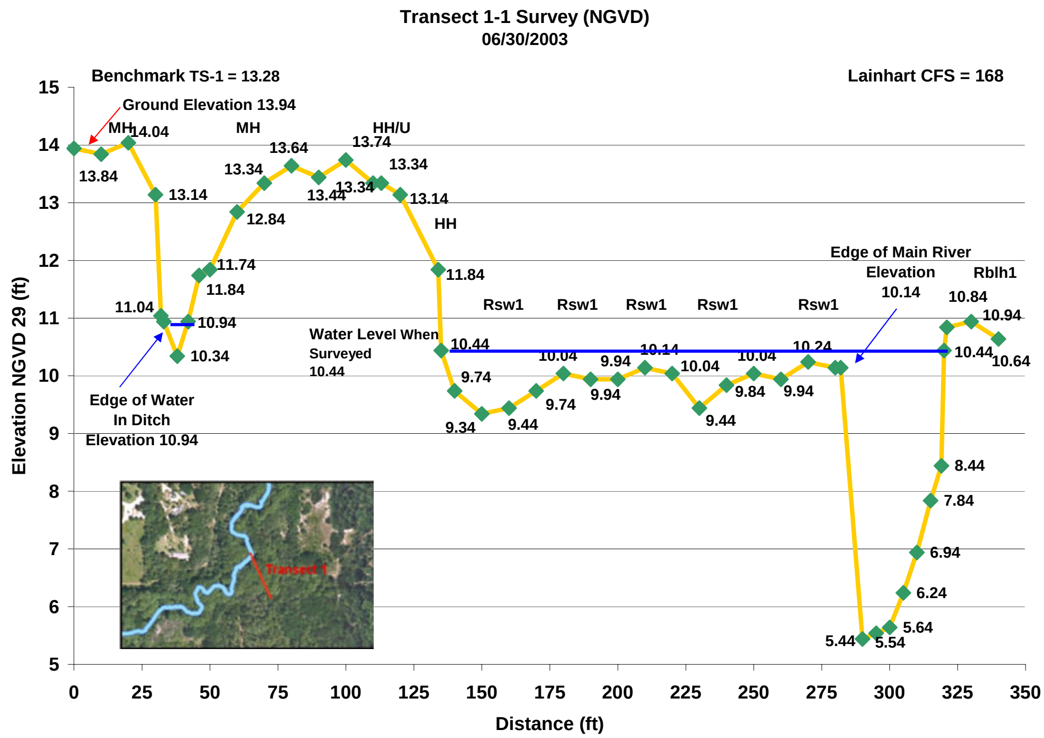


Figure 36. Profile of transect 1-1 with forest types.

T1-2 is located on the north side of the river and includes a side-channel or creek that dead-ends into a low swamp area containing numerous very large bald cypress. The channel itself had been observed dry in this area; however, the dead-end always appeared to have some standing water, which leads one to think that perhaps there is a confining layer of clay in this area. T1-2 on the north side of the river is not pictured; however, it had 6 plots that transitioned from bottomland hardwood (Rblh1) at the river, to 4 plots of swamp (Rsw1), and to 1 plot of hydric hammock adjacent to the mesic hammock and uplands. The higher area adjacent to the bank of the river on T1-2 was classified as Rblh1 because red maple occurred within the plot and water hickory just outside of the measured plot.

Cabbage palm, live oak (*Quercus virginiana*), and slash pine dominated the hammock and uplands plots while a stand of mostly very old bald cypress with an average dbh of 49 cm dominated the Rsw1 plots **(Figure 37)**. Pond apples (*Annona glabra*) were only found associated with the river channel banks. Canopy composition and tree size is illustrated in **Figure 38** showing the abundance of canopy species by dbh size frequencies. Bald cypress were found in five of the six dbh size classes although they primarily ranged between the size classes of 21 to 80 cm dbh. The smallest bald cypress had a dbh of 9.9 cm while the largest was 80.4 cm. The presence of five dbh size frequencies for bald cypress is an indication of multiple year classes in a canopy dominated by trees estimated between 300-500 years old. On the other hand, only two bald cypress trees were present in the 5-20 cm dbh size class, which is an indication of fewer successful recruits in recent years. Cabbage palms were predominately in the 21-40 cm range while red maples were all very young trees in the 5-20 cm range.

Tree heights of cabbage palm, bald cypress, red maple and laurel oak were randomly measured on both T-1 and T-2 sites. One cabbage palm was measured at 14.1 meters. Seventeen bald cypress on T1-1 averaged 20.8 m in height while 20 on T1-2 averaged 21.8 m. One young red maple on T1-1 was measured at 8.23 m while one laurel oak on T1-2 measured 18.8m.

Because the canopy is so well established on Transect 1 and because of periodic high flow velocities, there is very little indication of a subcanopy present at this transect (**Figure 38**). Shrubs and groundcover in the Rsw1 areas were dominated by swamp lily (*Crinum americanum*), tri-veined fern (*Thelypteris interrupta*) and downy shield fern (*Thelypteris dentata*). Groundcover densities were directly related to hydroperiod in the swamp communities. It was noted shortly after the 2004 Hurricanes Frances and Jeanne that the extended periods of flooding reduced ground cover to only a few species while the extended dry season of 2006 saw a tremendous expansion in groundcover density and species richness. Increased light availability due hurricane impacts (i.e., branch loss, broken trunks, etc.) also contributed to the expansion of ground cover.

Transect 2-1 is located at RM 13.6 just upstream of the western side of Masten Dam while, T2-2 is located downstream of Masten Dam on the same side of the river. On T2-1, there are several elevation changes between bottom land hardwood(7.85 ft), split plots of hammock (7.4 and 7.53 ft) and swamp (7.65 and 8.27 ft), a braided channel (6.32 ft), swamp area (7.53), and hammock areas adjacent to the river with elevations of 7.92 and 9.95 ft (**Figure 39**). Water flows continuously through the braided channel, which is connected to the river above and below Masten Dam. On T2-2, ground elevations in the hammock ranged from 11.4 to 10.2 ft while elevations in the swamp ranged from 6.4 to 6.6 ft (**Figure 40**).

Soils in the hammock and swamp areas of T2-1 were Chobee/Sapric muck while the bottomland hardwood area was Wabasso fine sand. The three plots of mesic hammock on T2-2 were Pineda fine sand while the swamp community was Gator/Sapric muck (Appendix C).

Figure 41 illustrates the combined distribution of canopy species on T2-1 and T2-2. Transect 2 had more hammock forest types (7 out of the 13 plots) than any other transect. Two and a half of the six plots on Transect 2-2 were mesic hammock that consisted of 100 percent cabbage palm. The Rsw1 and the Rmix plots were more diverse with younger pop ash, red maple and water hickory intermixed with the cypress.

Figure 42 illustrates the dbh size classes for the canopy species at Transect 2. Cabbage palms were primarily in the 21-40 cm range. Bald cypress were found in the four larger size classes (21-99+ cm) while none occurred in the 5-20 cm range. A few red maples were found in the three smaller size classes (5-60 cm). Tree heights of laurel oak and bald cypress were measured on T1-2 while in addition to these pond apple, water hickory and cabbage palm were measured on T2-2. One laurel oak on T2-1 measured 18.8 m in height while another on T2-2 measured 10.6m. Twenty-one cabbage palms on T2-1 averaged 9.93 m. Twenty bald cypress on T2-1 averaged 21.83m while 7 on T2-2 averaged 21.17m. Three water hickory on T2-2 averaged 23.63m.

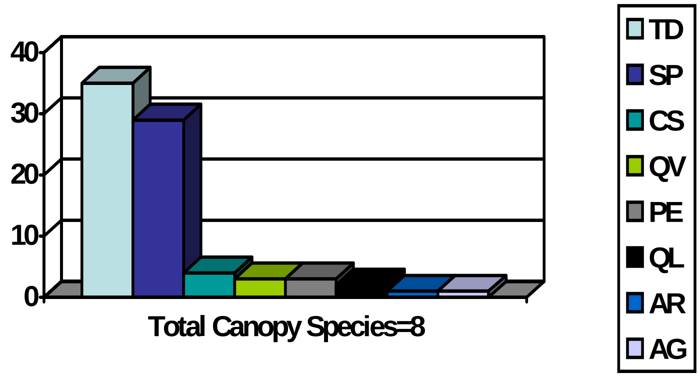


Figure 37. Canopy abundance at Transect 1.

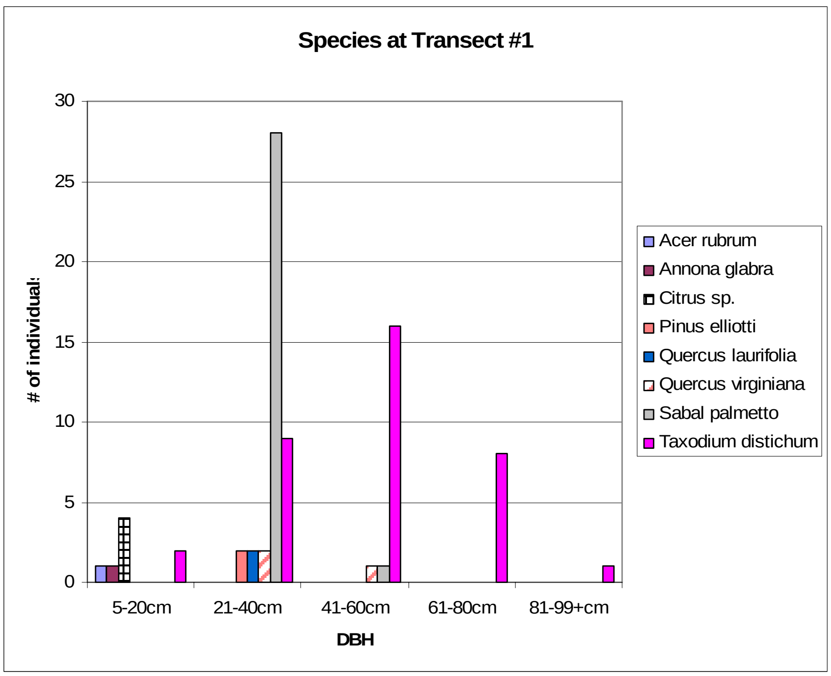


Figure 38. DBH size classes at Transect 1.

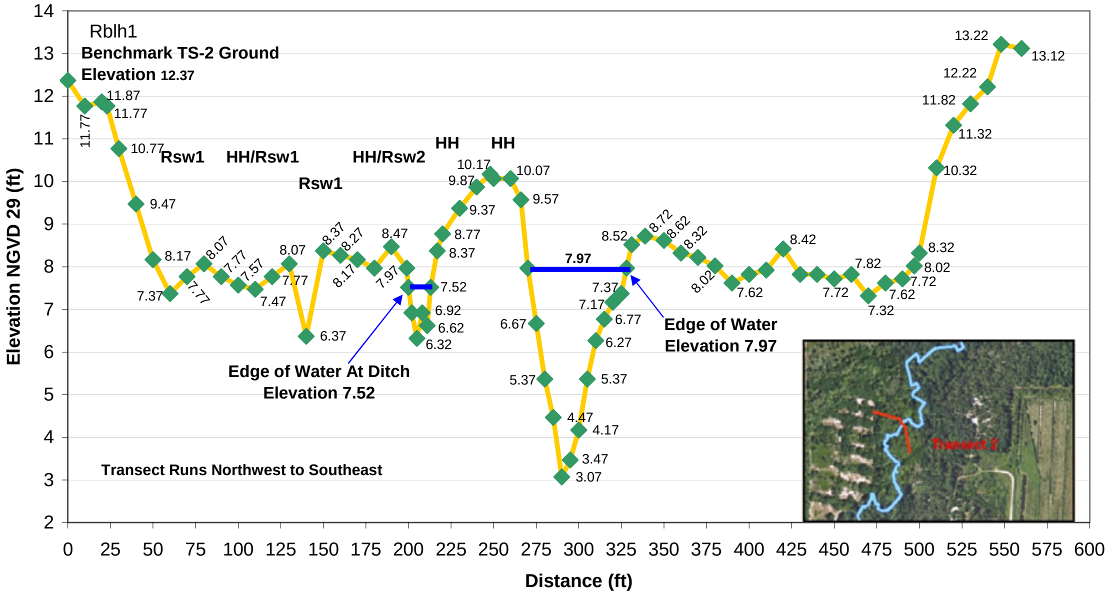


Figure 39. Profile of Transect 2-1 (surveyed in 1983).

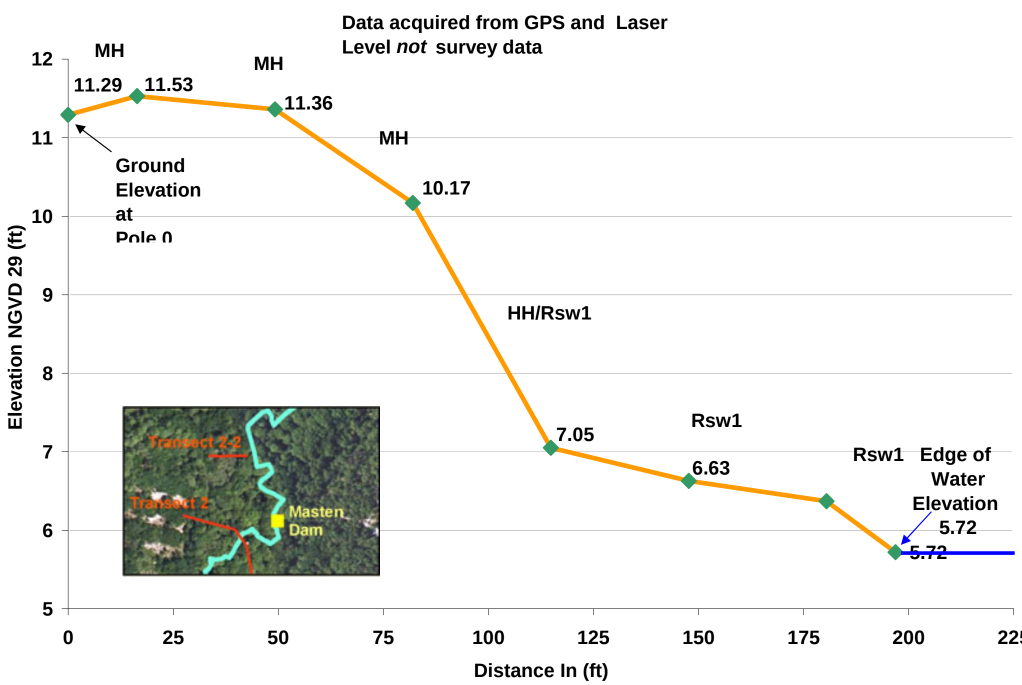


Figure 40. Profile of Transect 2-2.

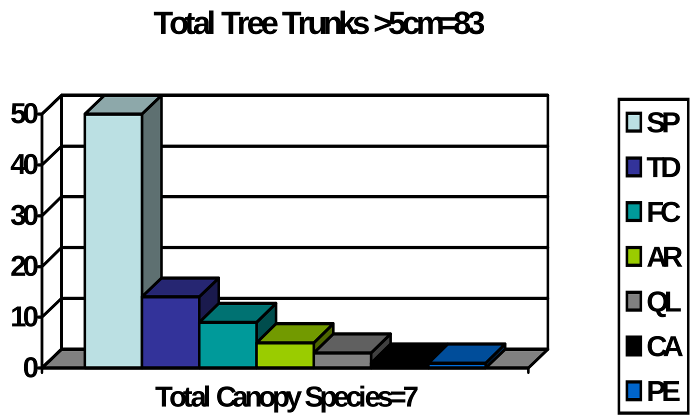


Figure 41. Canopy abundance at Transect 2.

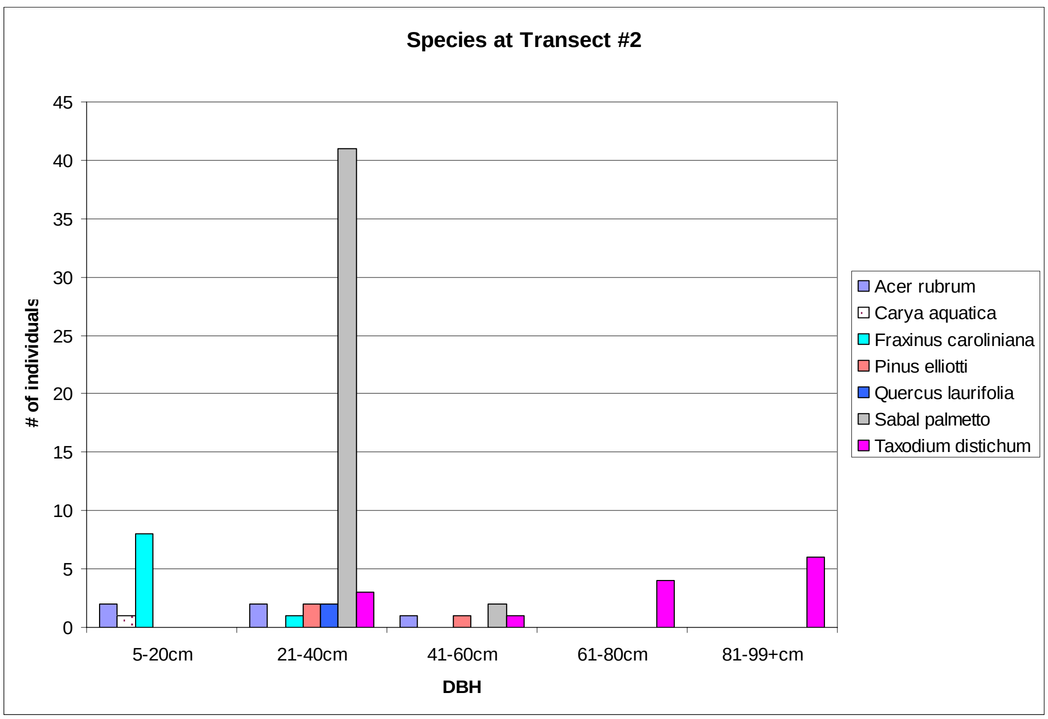


Figure 42. DBH size classes at Transect 2.

Shrubs and groundcover were primarily tri-veined fern, Meniscium fern (*Thelypteris serrata*), leather fern, swamp fern, Virginia willow (*Itea virginica)*, downy shield fern, royal fern (*Osmunda regalis*), lizard's tail (*Saururus cernus*), and swamp lily. Tri-veined fern, day flower (*Commelina diffusa)* and wild coffee (*Psychotria nervosa* a hammock or upland species) were prevalent in the Rblh1 plot.

Transect 3 is located at RM 12.1 downstream of I-95 and the Florida Turnpike on the east side of the river just south of Governor's Dock. In the past, this site has been impacted by selective logging and by the presence of Old World climbing fern (*Lygodium microphyllum*). There are multiple braided channels within the floodplains at this site. The first and second braided channels from the uplands receive freshwater flow directly from the river channel while the braided channel closest to the river receives flow from another braided channel to the north. The first braided channel flows north and ends adjacent to Governor's Dock. Elevations ranged from 5.54 ft at the benchmark to 2.03 ft at the bottom of the braided streams, and -9.87 ft in the river channel **(Figure 43)**. The majority of the floodplain had an elevation of approximately 4 ft in this area. Nine of the 13 plots were either Rsw1 or Rsw2. The profiles of the 2 plots of T3-2 are not shown; however, they were Upland/Hydric hammock and Rblh2 with average ground elevations of 5.35 and 4.53 ft.

Soil types in the hammock and bottomland hardwood areas were represented by Nettles sand while swamp areas were represented by Aquents (Appendix C).

Bottomland hardwood and hammock were present near the uplands and adjacent to the floodplain. Transect 3 had the highest concentration of pop ash of any of the ten transects (**Figure 44**). Their average dbh was 17 cm; however, the range was 5-41 cm. Only four bald cypress are within the transect canopy but they are very large with an average dbh of 91.5 cm. Pond apples and red maple are also present with average dbhs of 7.1 cm and 14.4 cm, respectively.

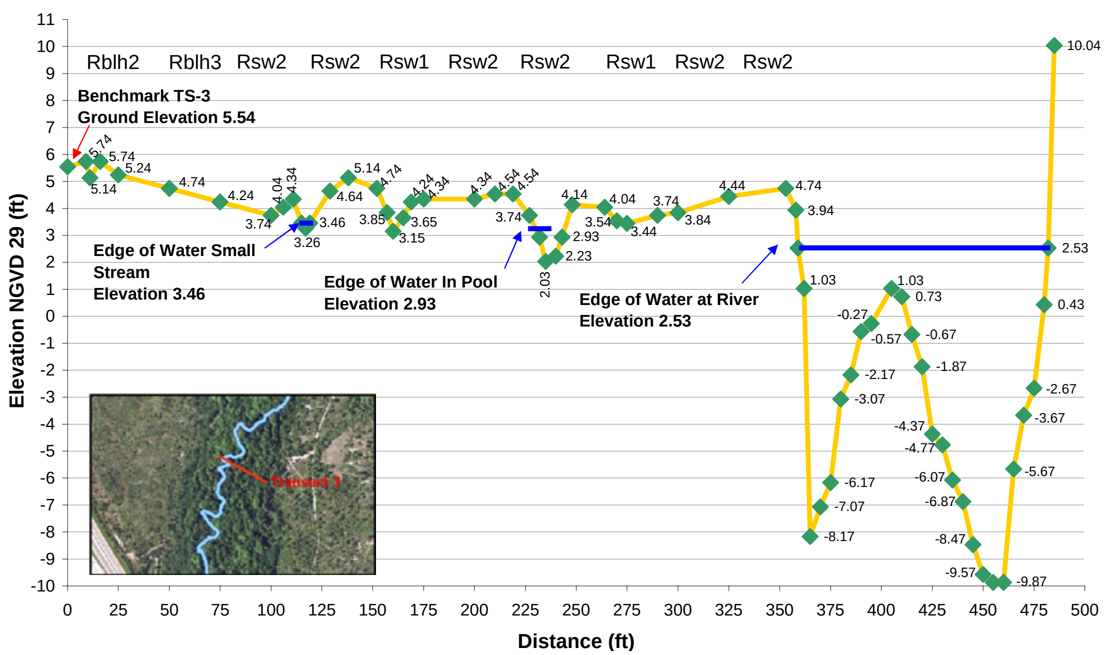


Figure 43. Profile of Transect 3.

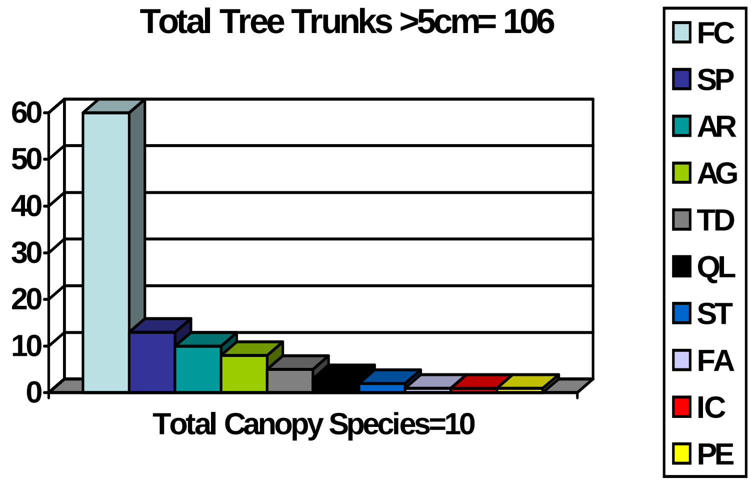


Figure 44. Canopy abundance at Transect 3.

Pop ash was present in the first three dbh size classes (5-60 cm); however, the majority of pop ash was from the 5-20 cm class (**Figure 45**). Bald cypress was present in three size classes (21-40 cm, 41-60 cm, and 81-99+ cm). There were none present in the 61-80 cm class. Again, we are probably observing the effects of selective lumbering and the opportunistic nature of pop ash. The largely upland exotic, Brazilian pepper (*Schinus terebinthifolius*), was present only in the 5-20 cm class, which reflects a newer species entry into the floodplain communities.

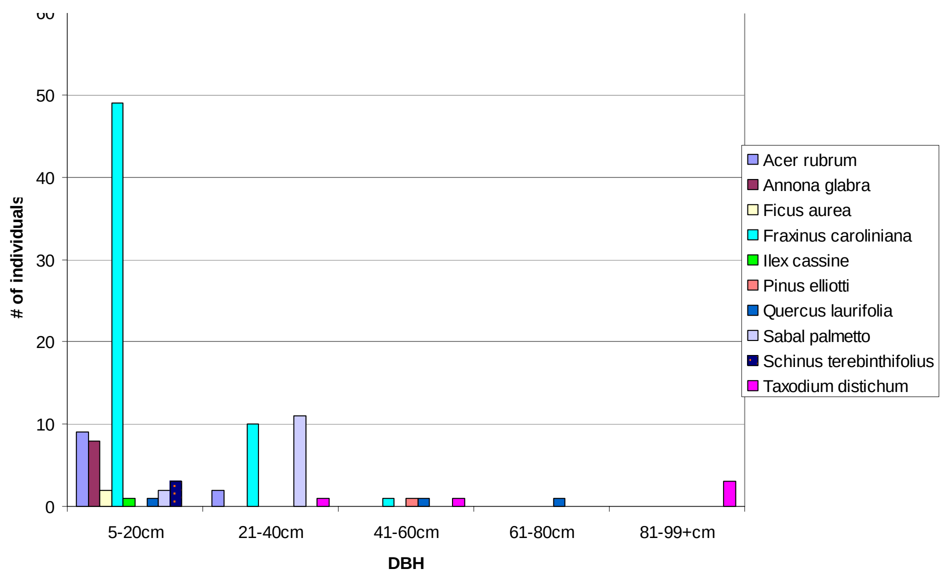


Figure 45. DBH size classes for species at Transect 3.

Tree heights were measured on 5 canopy species at Transect 3. Four pond apple averaged 8.53 m, 35 pop ash averaged 11.05 m and 5 bald cypress averaged 21.64m in the swamp community. Cabbage palm (5) and one oak were 9.45m and 38.05 m, respectively.

Shrubs and groundcover on Transect 3 were primarily leather fern, maiden fern (*Thelypteris kunthii*), meniscium fern, and lizard's tail in the swamp while tri-veined fern and swamp fern (*Blechnum serralatum*) were the most dominant in the bottomland hardwood plots.

Transect 4 is located at RM 11.18 on the west side of the river approximately 1 mile upstream of Trapper Nelson Interpretive Site and contains 12 vegetation plots. This transect is just downstream from an old logging road that crossed the floodplains and river. The site was probably selectively logged in the past and the road was used to remove the trees. There are several elevation changes between the upland edge of the floodplain and the channel on these 12 plots (**Figure 46**). The benchmark for this site is very near a large dead pine tree, which is on the slope at about 5.62 ft. From the hammock the transect drops down into several Rsw1 plots intermixed with plots of Rlbh2 and Rlbh3. Elevations of the Rlbh2 and Rlbh3 plots were approximately 2.51 to 3.91 ft. Bottom elevations of the swamp plots were approximately 2.17 ft while the bottom of the river channel was -2.45 ft.

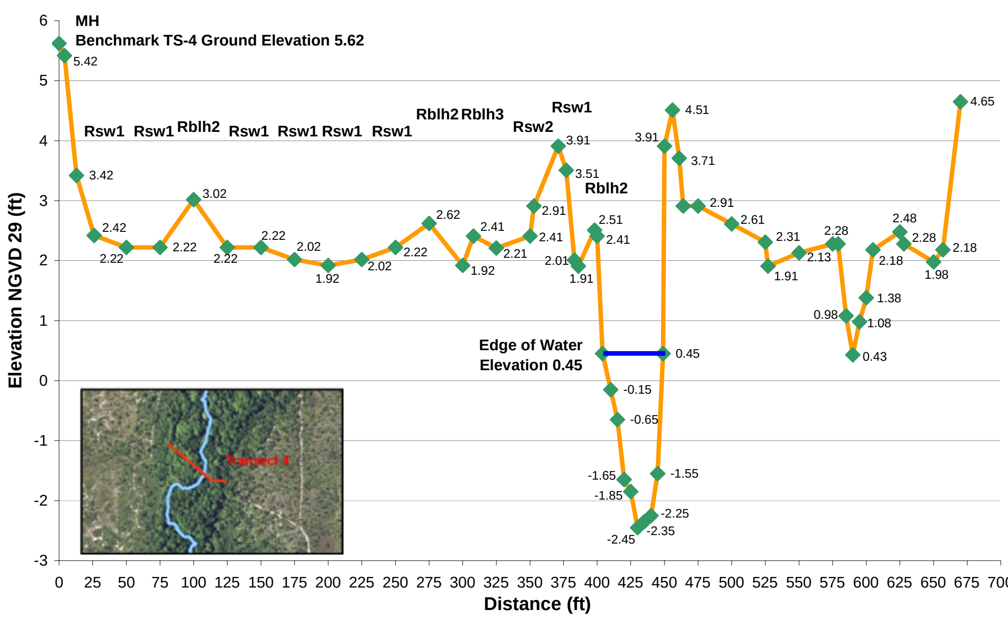


Figure 46. Profile of Transect 4.

Soil types for Transect 4 were identified as Symyrna fine sand in the mesic hammock and Histic Haplaquoll and Aquents in the swamp and bottomland hardwood communities (Appendix C).

The 12 plots were a mixture of mesic hammock (a very narrow band adjacent to the uplands), and bottomland hardwood and swamp communities in accordance with elevation (**Figures 46** and **34**). This transect had some of the largest water hickory observed in the watershed **(Figures 47** and **48)**. The average dbh of water hickory on the transect was 36.1 cm and with the largest at 88.6 cm. Some of these large hickory trees exhibit the allelopathic nature of this species as little groundcover or shrubs are present beneath their canopy. Bald cypress varied considerably in size and age across Transect 4 and were present in all five dbh size classes (**Figure 48**). The average dbh was 30.0 cm; but, they ranged in size from 5.7 to 83.6 cm dbh indicating that several generations were present. They were most abundant in the 5-20 cm class. Pop ash and red maples averaged 12.2 and 11.0 cm dbh, respectively. No tree heights were measured on this transect.

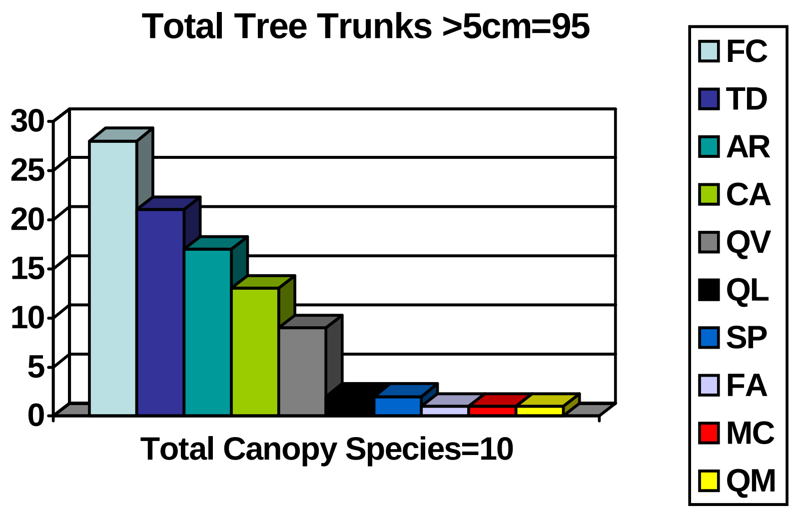


Figure 47. Canopy species abundance at Transect 4.

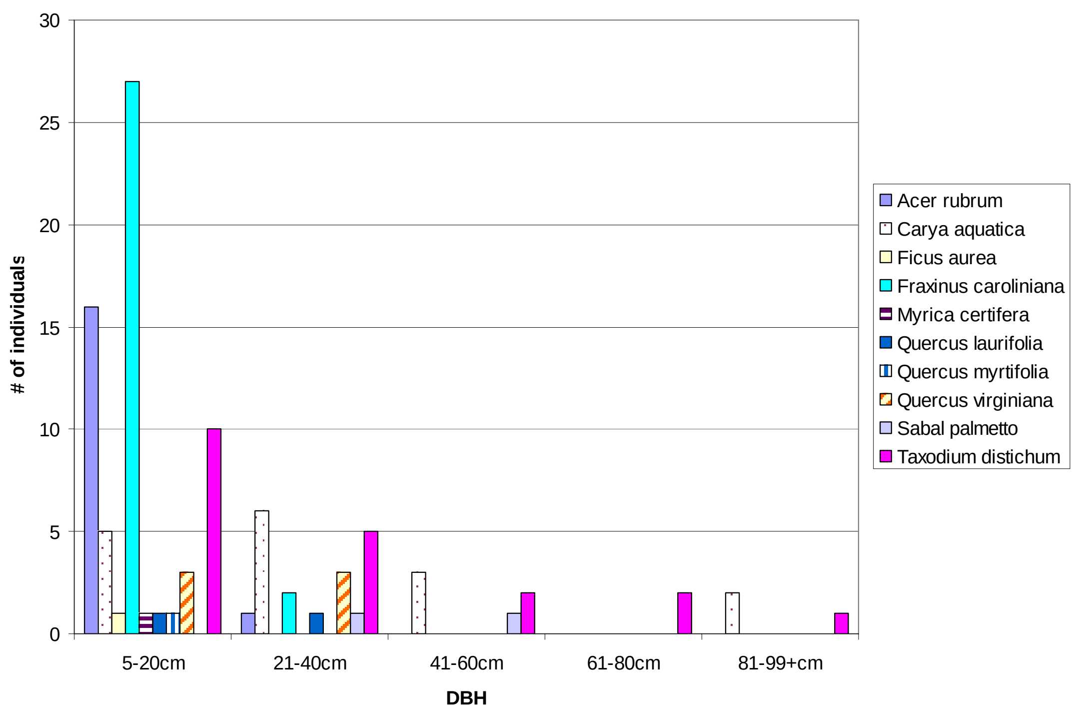


Figure 48. DBH size classes for species at Transect 4.

Shrubs and groundcover on Transect 4 were primarily leather fern, maiden fern, downy shield fern, Virginia willow, swamp fern, royal fern, lizard's tail, swamp lily, and pond apple.

Transect 5 is located on lower Cypress Creek (**Figure 49**) just east of Interstate 95 and the Florida Turnpike and contains 14 plots. **Figure 49** illustrates the remaining historic flowway (blue line) and the impacted flowway, which no longer exist (dashed green). This creek enters the Northwest Fork of the Loxahatchee River at RM 10.33 just downstream from the Trapper Nelson Interpretative Site in Jonathan Dickinson State Park. The majority of the land is owned by state and local governments. The Cypress Creek basin is located in Martin and Palm Beach Counties. This pine flatwood/wetland mosaic habitat supports many species of wildlife including wood stork, deer, sandhill crane, and snail kite. It is also potential habitat for red- cockaded woodpecker.

The basin is interspersed with hardwood hammock, pinelands, xeric oak shrub, marshes, cypress swamps, wet prairies and open water. Ranch Colony Canal runs west to east and drains into the northern branch of Cypress Creek (**Figures 49**). There is an old water structure located on the canal just east of a USGS Gage station and Gulfstream Road. The water control structure was further damaged by the hurricanes of 2004 (Appendix E). A manmade drainage ditch, designated Hell's Canal, was excavated to provide runoff for agricultural lands just west of I-95 and Florida Turnpike (**Figure 50**). It was directly connected to the Northwest Fork of the river, resulting in negative impacts to the natural hydrology, runoff retention and groundwater recharge. In 2006 to negate this impact, the canal was filled in and the water flows rerouted to the southern branch of Cypress Creek. The rerouting of the canal to Cypress Creek will help to restore the hydrology of a dewatered portion of this natural creek, reducing the intensity of water flows to the river and improve water quality.

Figure 50 illustrates the historic pathway of surface water flow for the northern and southern branches of Cypress Creek. Portions of the southern branch were filled in with the advent of agricultural row crops which has broken the connection to upstream wetland areas. The area south of Ranch Colony Canal and north of Indiantown Road and adjacent to Gulfstream Road is owned by Palm Beach County and is known as the Cypress Creek Natural Area. The Pine Glades Natural Area and the John C. and Marianna Jones/Hungryland Wildlife and Environmental Area are located between Beeline Highway and South Indian Trail Water Control District. Also, **Figure 50** provides a more detail view of the floodplain wetland systems (stream swamp, mixed hardwood, and cypress strands) associated the current surface water flow pattern on Cypress Creek. Other land covers include pine flatwood and wet prairies that with the marsh system forms a linkage between the Dupuis Preserve, Corbett Water Management Area and Jonathan Dickinson State Park.

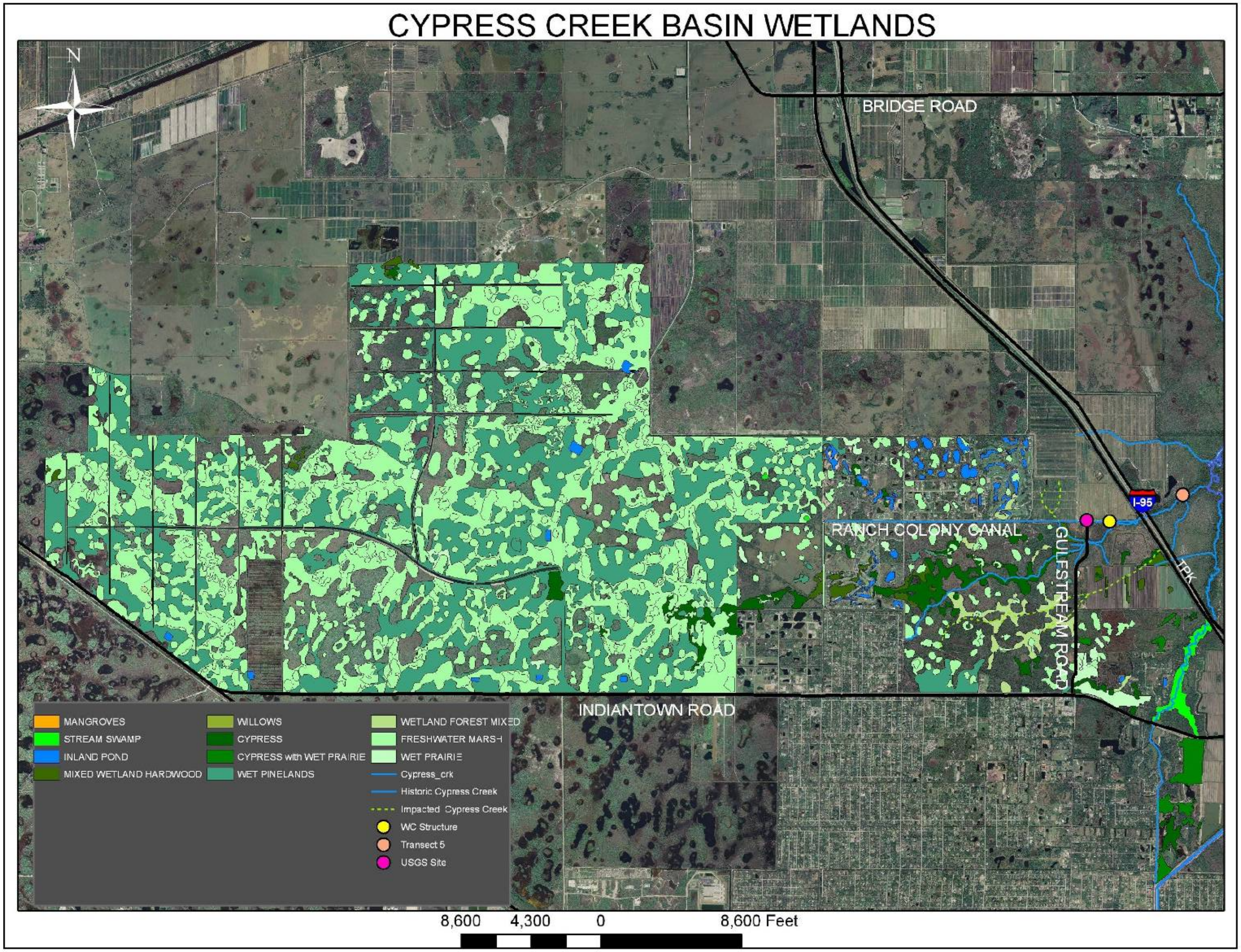


Figure 49. Cypress Creek wetland systems and neighboring drainage basins.

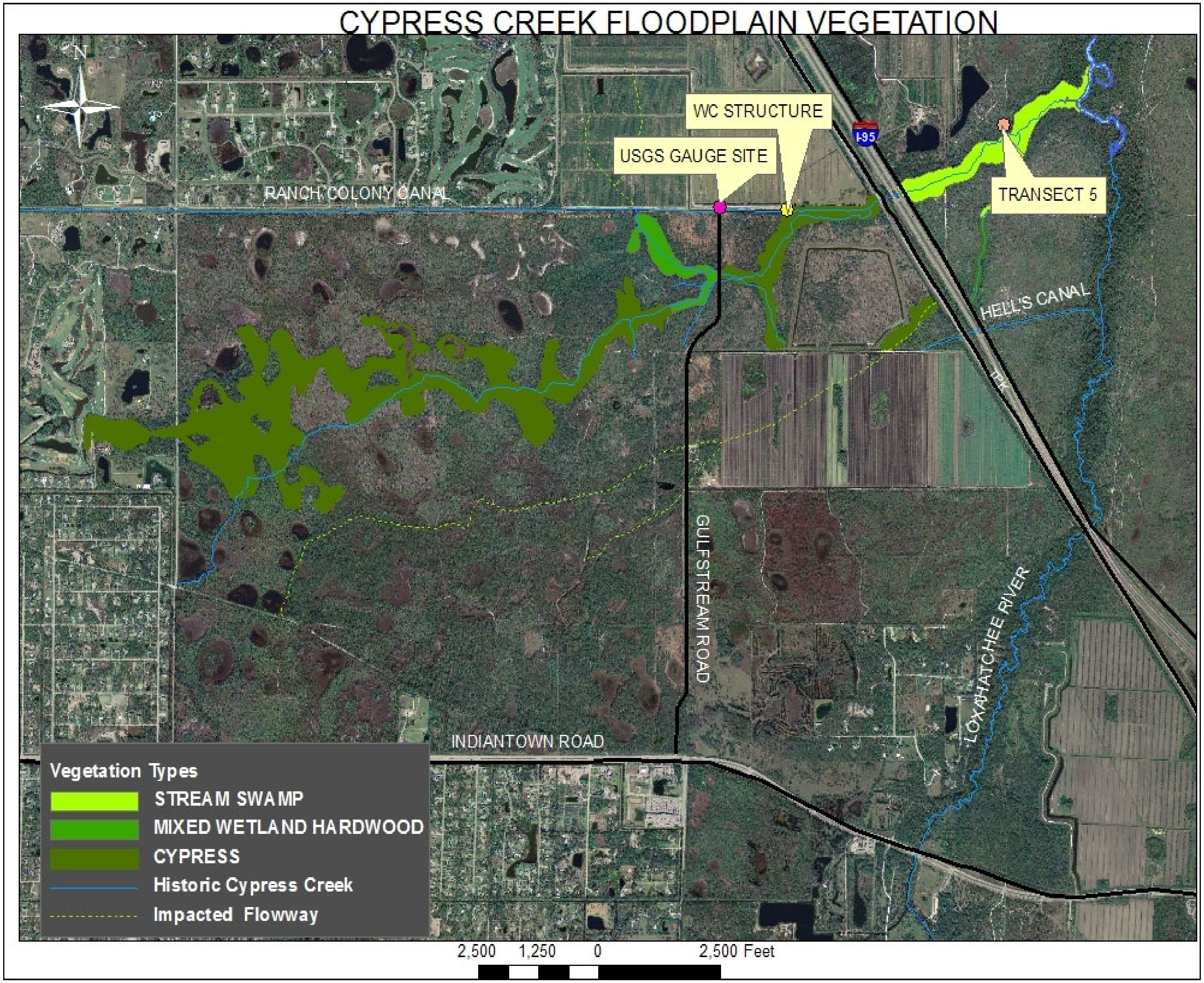


Figure 50. Map of historical surface water flow through Cypress Creek Basin.

As described in the Loxahatchee Greenways project (FDEP, 1997) will protect the headwaters of Cypress Creek and return it to a more natural water flow. Currently during periods of heavy rain, runoff from development causes canal bank scouring and carries suspended solids into the creek and the Northwest Fork of the Loxahatchee River resulting in siltation and shoaling downstream.

Cypress Creek is a significant source of surface water to the Northwest Fork of the Loxahatchee River. It is an outlet for an extensive network of agricultural canals and natural wetlands. There is an active USGS gage station that monitors stage and flow just east of the bridge on Gulfstream Road (**Figures 49** and **50**). Cypress Creek drains the development, Ranch Colony, Pal/Mar and a portion of the Groves Sub-basin into the Northwest Fork of the Loxahatchee River. It is estimated that an average daily flow contribution to the Northwest Fork from the historic Cypress Creek basin was as 3 percent while Pal/Mar Basin was 28 percent (SFWMD, 2006).

Approximately 7 of the 14 plots of Transect 5 (RM 10.3, T5-1, 5 plots and T5-2, 9 plots) were bottomland hardwood particularly the T5-2 segment (5 continuous plots of Rblh 2, not pictured) had the widest band of bottomland hardwood observed in the 2003 study. Plot 1 of T5-2 is a Rblh1 followed by 3 plots of Rsw1. T5-1 consisted of two plots of mesic hammock, an Rblh3, and Rswl, and a split plot of Rsw1/Rblh2. Elevations within the plots were measured; however, a transect profile has not been produced yet. Laser level measurements of the plots indicated an elevation of 6.43 ft in the mesic hammock adjacent to the uplands while mesic hammock within the floodplain was 3.04 ft on T5-1. Bottomland hardwood and swamp communities were 10.08 ft and 8.28 ft. On T5-2, bottomland hardwood ranged from 2.9 ft to 3.81 ft while swamp ranged from 3.03 ft (adjacent to the uplands) to 3.4 ft.

Soil types were represented by Pompano fine sand in the mesic hammock and Rblh3 plots of T5-1 while Aquents were present in the bottomland hardwood and swamp communities (Appendix C).

The canopy on Transect 5 was dominated in abundance by bald cypress, water hickory, and red maple (**Figure 51**). Many of the water hickory and red maple trees were overturned in this area during the 2004 and 2005 hurricane seasons (Appendix E). Water hickory was present at all five dbh size classes (5-99+ cm); but, they were most abundant in the 5-20 cm and 41-60 cm classes (**Figure 52**). Bald cypress were also present at all 5 dbh size classes; but they were most abundant at the 21-40 cm class. Red maple was present in the three smallest size classes (5-80 cm).

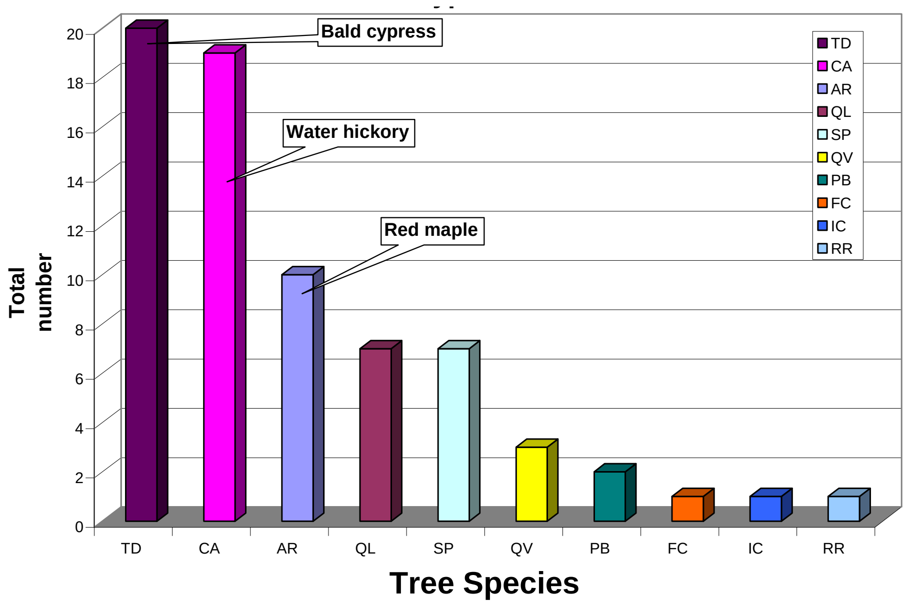


Figure 51. Canopy abundance at Transect 5 (Cypress Creek).

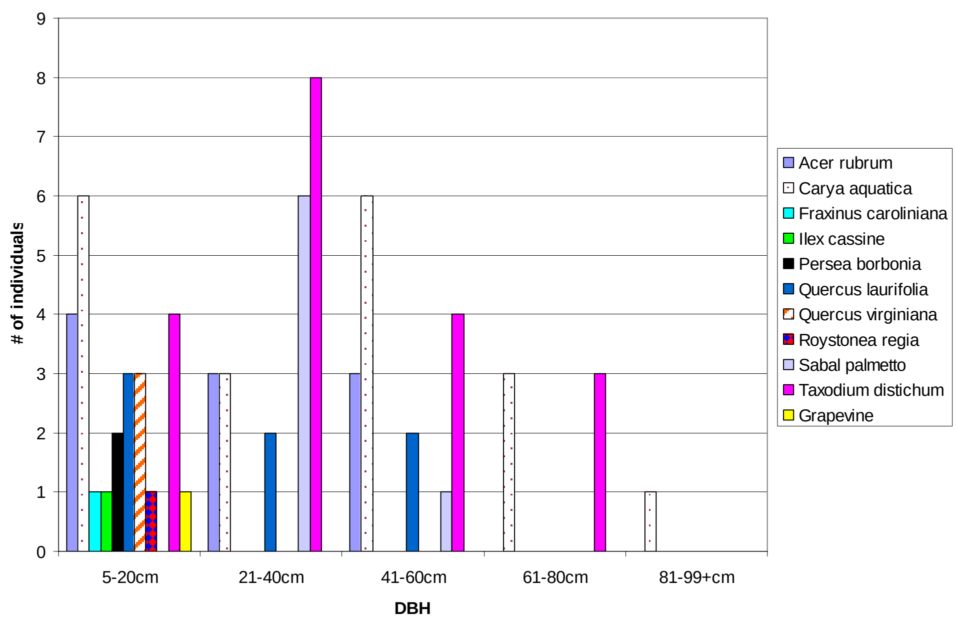


Figure 52. DBH size classes for species at Transect 5.

Tidal Transects

Of the five tidal transects, three are on the Northwest Fork of the Loxahatchee River; two upper tidal, Transects 7 (RM9.10) and 6 (RM 8.43), and one lower tidal, Transect 9 (RM 6.46), one lower Kitching Creek (Transect 8, RM 8.13) and one upper tidal North Fork (Transect 10). The elevations of these tidal transects are generally flatter and lower (fewer changes in topographical relief) and contain fewer braided streams that the floodplain areas of the riverine reach. There are no bottomland hardwood plots in the tidal reaches, although indicator species for these forest types were present. In the tidal reaches, canopy diversity is increased by the presence of hummocks (i.e., elevated mounds), cypress stumps, and fallen logs. Hummocks allow canopy species that would not normally be present in swamp communities to successfully occupy areas of lower elevation. Forest types in the tidal reaches are generally mixtures of swamp species (fresh and brackish water species) and mixtures of swamp, hammock, and upland. Historical records and aerial photography have shown us that the most abundant vegetative species in the truly tidal reaches of the Northwest Fork of the Loxahatchee River were bald cypress, cabbage palm, and pond apple. Saltwater intrusion, increasing sea level, lowered groundwater levels, and decreased freshwater flows have resulted in increases in the distribution of red and white mangrove throughout the tidal reaches. In addition, historical logging, fire, freezes, exotic plants (Old World climbing fern, Brazilian pepper, java plum, and strawberry guava), and erosion of the river channel have impacted sections of the tidal transects. A 1860s military drawing of the Northwest Fork of the Loxahatchee River showed only a floodplain with a small “canoeable” creek just upstream of the mouth of Kitching Creek. It was thought that in this time period, canoe travel along the Northwest Fork was extremely difficult (Pepe and Steele, 1997). In the Second Seminole Water, it was probably not coincidence that the U.S. Army utilized the Southwest Fork rather that the Northwest Fork to engage the Seminoles in the first skirmishes of the 1838 Battle of the Loxahatchee River. Today this part of the river is navigable by boat for an additional 2.2 miles.

Regarding the extent of tidal influence within the Loxahatchee River system, Gonzalez (2005) noted that there was no tidal influence at Transects 1 and 2, little at Transect 3, and a strong affect at Transect 4, which is still fresh in non-drought conditions.

Transect 6 (T6-1 and T6-2) is located at RM 8.43 on a peninsula just upstream of Kitching Creek and adjacent to Ornamental Garden (Figure 54). T6-1 consists of thirteen plots that begin in the uplands and transverse the floodplain due north for 125 meters towards the river channel while T6-2 continues from that point due east for an additional three plots. It is our understanding that the original Transect 6 proposed by Dewey Worth in 1983 was planned to continue on a straight line due north to the river channel; however, with very little change in topography and canopy species diversity, a shorter route was sought for reaching the river, which was closer due east. Ward and Roberts in 1994 also turned Transect 6 to the east to reach the river by a shorter route in their river corridor study.

The Transect 6 peninsula had been selectively logged in the past and contained remnants of many dead bald cypress from logging activities and saltwater intrusion. Today, there are still live bald cypress growing among the pond apple and mangrove and a band of bald cypress trees still exist adjacent to the uplands. At approximately 85 meters from the uplands on T6-1, there is a large bald cypress (live and healthy looking) totally surrounded by red mangroves. Again, greater distances from the river channel and groundwater runoff from the uplands probably provides additional features of saltwater intrusion protection primarily in this area of the upper tidal reach.

Of the sixteen plots on Transect 6, there were two upland, one Rsw1, six UTsw1, six UTsw3, and one UTmix plot. Elevations ranged from 6.82 ft in the uplands to an average elevation of 1.59 ft over the remaining transect (**Figure 53**). Red mangrove and pond apple were more prevalent in the plots beyond 100 meters from the uplands. Cabbage palm and wax myrtle were only found on hummocks. This is another illustration of the significance of floodplain topography in species distribution.

Soil types were represented by Pompano fine sand in the uplands and Terra Ceia Variant in the riverine and upper tidal swamp communities (Appendix C).

The most prevalent canopy species were red and white mangrove and pond apple (average dbh 8.3 cm.) (**Figures 54** and **55)**. Red and white mangroves were only found in the 5-20 cm dbh frequency. There were no canopy trees beyond the 41-60 cm size class with the exception of one bald cypress tree in the 61-80 cm frequency. Red maple (dbh 17.5 cm) and pop ash (average dbh. 5.7 cm.) were present in much smaller numbers. The average dbh of the living bald cypress was 29.8 cm. An exotic species, Brazilian pepper, was found in the 5-20 cm dbh size class and numbered less than twenty.

Shrubs and groundcover consisted primarily of very young red and white mangrove, leather fern, pond apple, buttonbush, maiden fern, swamp fern, and rubber vine (*Rhabdadenia biflora*).

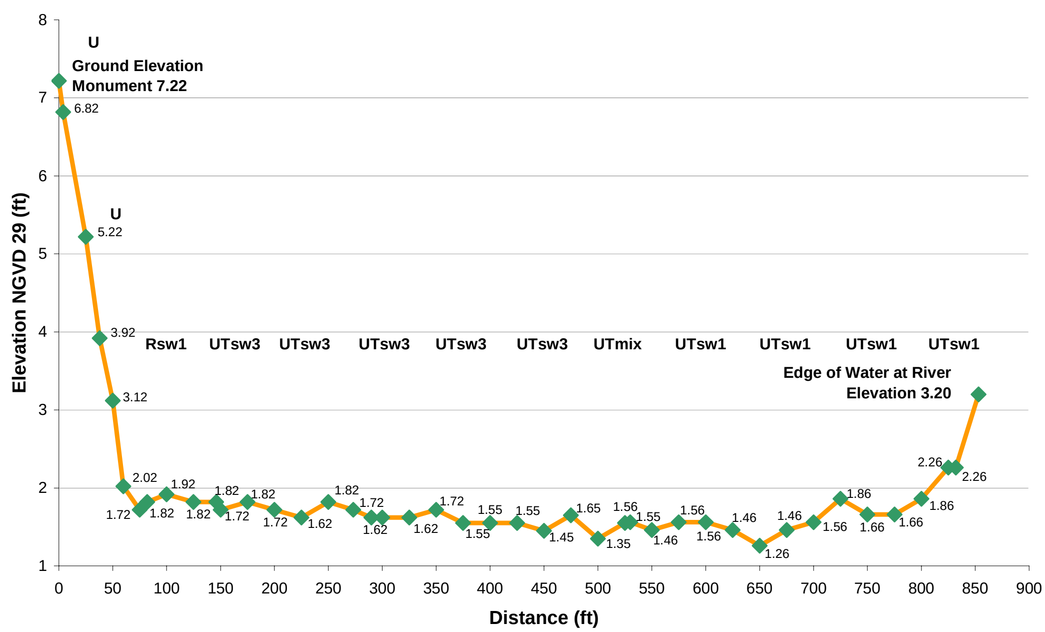


Figure 53. Profile of Transect 6-1.

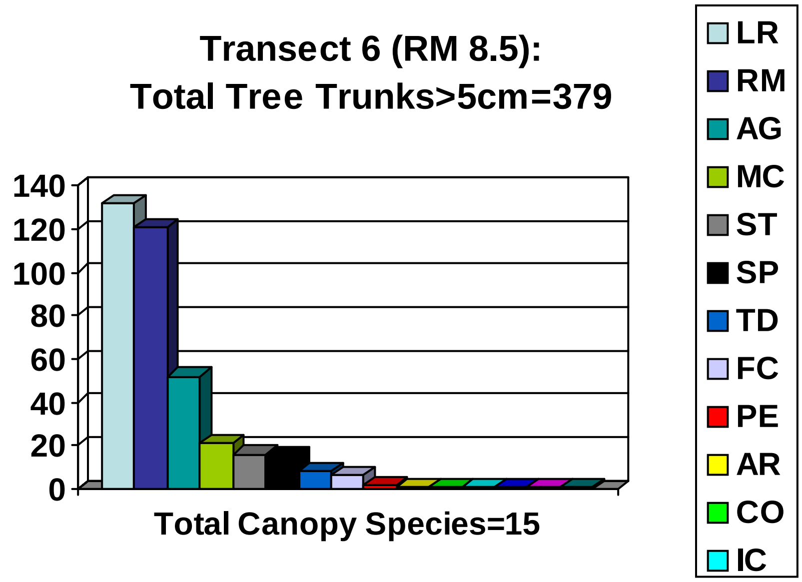


Figure 54. Canopy abundance on Transect 6.

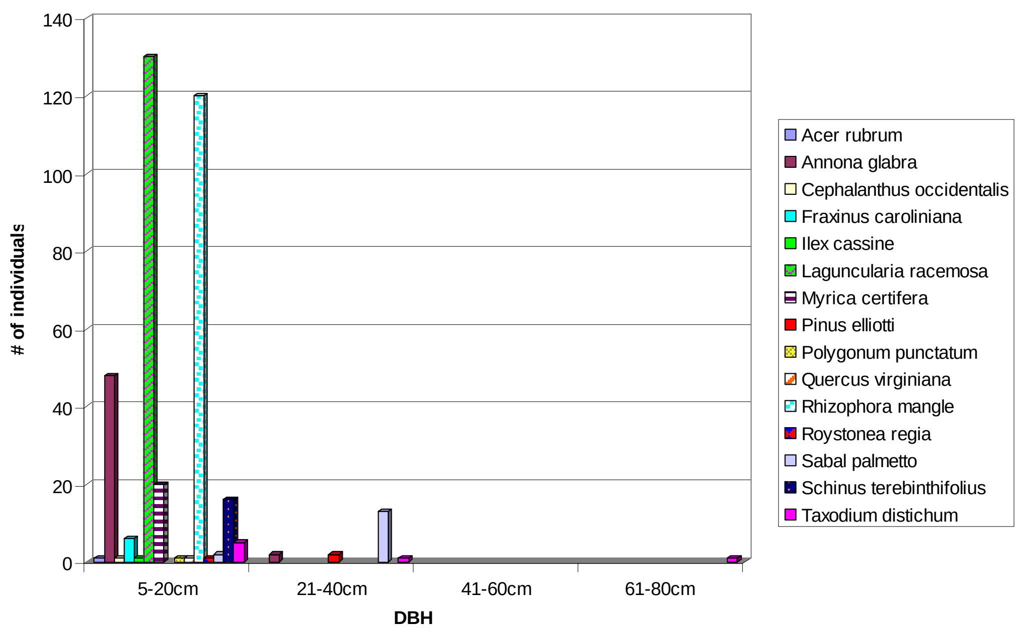


Figure 55. DBH size classes on Transect 6.

Transect 7 is located at RM 9.1 on the south side of the middle of the Northwest Fork across from the eastern end of Hobe Grove Ditch. This transect has been impacted by salt water intrusion, exotics (mostly Old World climbing fern, Brazilian pepper, and java plum) and logging activities. It is a very long transect with 15 plots that contain a mixture of eight riverine and seven upper tidal forest type plots **(Figures 56** and **57)**. Elevations changed from 10.06 ft at the benchmark in the uplands to 5.12 ft at the mesic hammock and finally to an average of 1.58 ft across most of the floodplain swamp (**Figure 56**).

The riverine section of the transect consists of a mixed plot (Hammock/Rsw1) with live oak, wax myrtle, and a large cypress (50.1 cm dbh) followed by two plots of Rsw1, and five plots of Rmix (primarily bald cypress, cabbage palm and wax myrtle, **Figure 58**). Cabbage palm and wax myrtle are coexisting with the swamp species by living on small hummocks, old logged cypress stumps, and other fallen logs. The Upper Tidal segment of Transect 7 has four plots of UTsw1, and three plots of UTsw2 (**Figure 56**). At a distance of 120m from the upland, red mangroves began to appear and became more abundant along with pond apple. White mangrove were present but too small to be considered canopy (>5 cm. dbh). Live bald cypress are present from the edge of the uplands out to 120m of the 150 meter transect (**Figure 56**).

All fifteen canopy species were represented in the 5-20 cm dbh size class group (**Figure 59**), which directly reflects the impacts of past logging activities and the increase in available sun light. Bald cypress trees in this plot had an average dbh of 28.3 cm and ranged in size from 7.2 cm to 50.1 cm and were present in three dbh size classes (5 cm to 60 cm).

Red maples were present primarily in the 21-40 cm dbh class. Exotic species, Brazilian pepper and java plum (*Syzygium cuminii*), were also present in the 5-20 cm dbh class while strawberry guava (*Psidium cattleianum*) were present as shrub but not large enough to meet the 5 cm dbh canopy criteria.

On Transect 7, tree heights were measured on pond apple, white and red mangrove and buttonbush. Fourteen pond apples on the transect averaged 6.2 m while three button bush averaged about the same, 6.3 m Similarly, eleven red mangroves averaged 6 m. Two white mangroves measured in a little taller at 8.87 m.

Soil types on Transect 7 changed between the hammock, riverine and upper tidal swamp communities. The mesic hammock half plot that begins Transect 7 consisted of Immokalee fine sand. The riverine swamp and mixed plots consisted of Terra Ceia Variant inclusion, which is generally considered to be a more inland muck while the upper tidal swamp plots consisted of Okeelanta Variant muck, which is considered to be a more coastal muck.

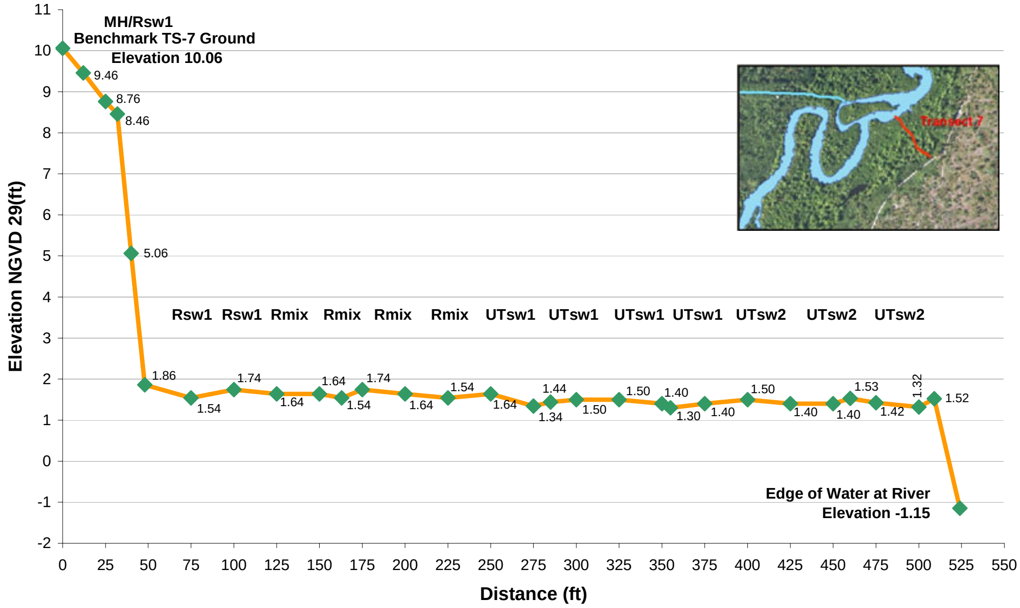


Figure 56. Profile of Transect 7.

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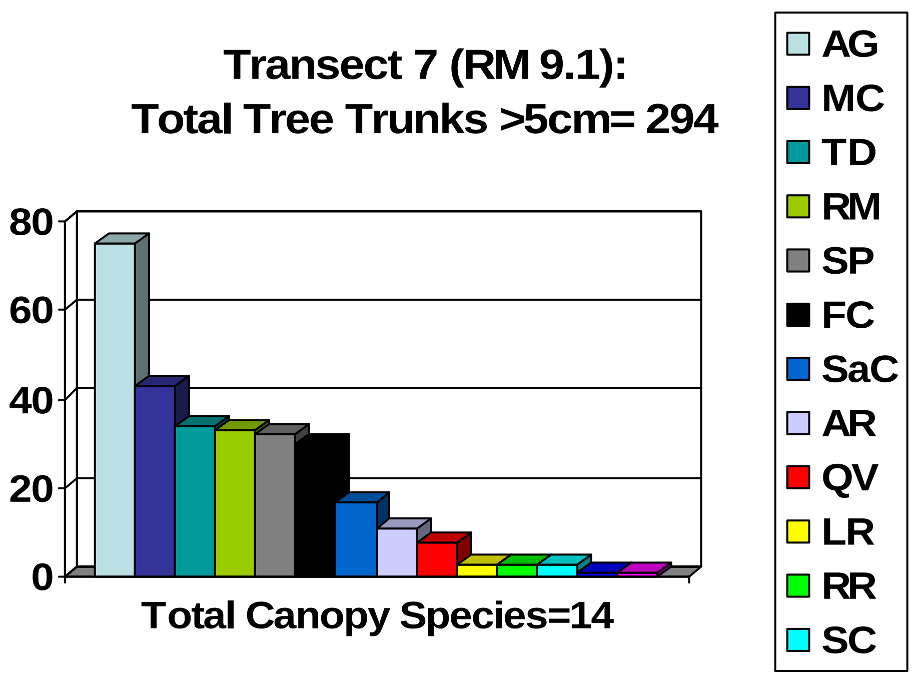


Figure 57. Canopy species abundance on Transect 7.

Figure 58. Forest type Rmix (pond apple, bald cypress, red maple, wax myrtle and cabbage palm) in a selectively logged area of Transect 7.

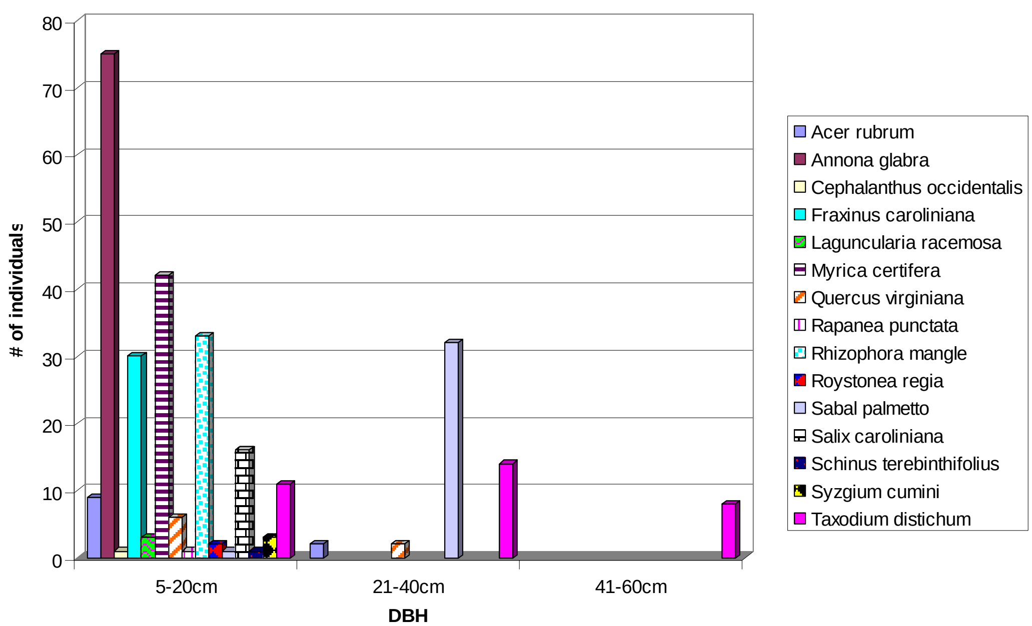


Figure 59. DBH size classes on Transect 7.

Shrubs and ground cover consisted primarily of leather fern, wax myrtle, button bush, salt bush, primrose willow, poison ivy, swamp fern, marsh fern, meniscium fern, royal fern, swamp lily, milk vine and young mangroves, pond apples and pop ash.

In the late fall of 2003, Transect 7 had an extremely large number of cypress seedlings ranging from 5 cm to 7.6 cm in height. Germination of new seedlings continued well into the late spring. The following dry season (December 2003 to May 2004) was very dry.

Tides did not reach the entire transect during this period and the rains did not come until mid-July 2004. This dry period may have been advantageous for germination and early bald cypress seedling growth. During a visit in 2003, USGS botanists, Helen Light and Melanie Darst, suggested that the stress of the salt may have made the trees more reproductively active. They also noted that the bald cypress trees on this site were probably younger than their counterparts in the riverine reaches of the river. Also in the riverine portion of the river, the cypress tree canopy was much taller and thicker. Therefore, less light maybe available for the development of an extensive subcanopy and groundcover in the riverine reach. Duever et al. (1983) suggested that a good recruitment season for bald cypress may take place every 30 to 40 years. During a visit to Transect 7 in August 2004, it was noted that many of the fall 2003 bald cypress seedlings were gone. Daily tides had returned to the interior of the Transect 7. Seedling deaths may have occurred because the seedlings were too short to survive the periods of tidal flooding (twice a day) or because of increased salinity.

Transect 8 is located on lower Kitching Creek, which enters the Northwest Fork at RM 8.13 and contains 12 plots (**Figure 4**). Kitching Creek is located within the Jonathan Dickinson/Hobe Sound Sub-basin of the Loxahatchee River Watershed. Kitching Creek is in that portion of the sub-basin known as the Eastern Flatlands. The headwaters of Kitching Creek are located north of Jonathan Dickinson State Park with the natural channel lying within the Park boundary (Loxahatchee River Planning Committee, 2002). The basin has been divided for some time by the construction of Bridge Road (SR 708) in the 1930s. Most of the water flowing to Kitching Creek enters the northwest corner through Jenkins Canal (**Figure 61**). Kitching Creek is credited with contributing approximately 8 percent of the total flow to the Northwest Fork of the Loxahatchee River. Average daily flow was estimated at 17.4 cfs in the Restoration Plan (SFWMD, 2006).

In the past, water originating from and entering the creek through Jenkins Canal was thought to be of poor quality, but it was never proven. Also, during periods of heavy rainfall, surface water has tendency to pile-up on the north side of Bridge Road due to the insufficient number of culverts to carry the water southward. Furthermore, Jenkins Canal diverts water that has historically drained into the upper portion of Kitching Creek, which has dewatered the area and contributed to a lowered groundwater table. Freshwater flow to Kitching Creek is now extremely rainfall driven. Martin County continues to lead an effort to recreate a natural flow way and improve water quality.

Natural communities within the Kitching Creek area include pinelands, freshwater marsh, wet prairie, strand swamp and open water (**Figure 60**).

The headwaters of the creek are included along with several other natural areas within the Loxahatchee River **Watershed** in the Loxahatchee Greenways Projects (1997). This project will protect these natural communities along historic hydrological corridors and allow for recreational, wildlife use and water movement. Two monitoring stations exist within Kitching Creek (**Figures 60** and **61**). The USGS has maintained a long term stage and flow monitoring station about one-quarter mile upstream of its confluence with the Northwest Fork of the river. The other USGS monitoring station is located at the mouth of the creek and has monitored stage, flow, conductivity and temperature since 2003.

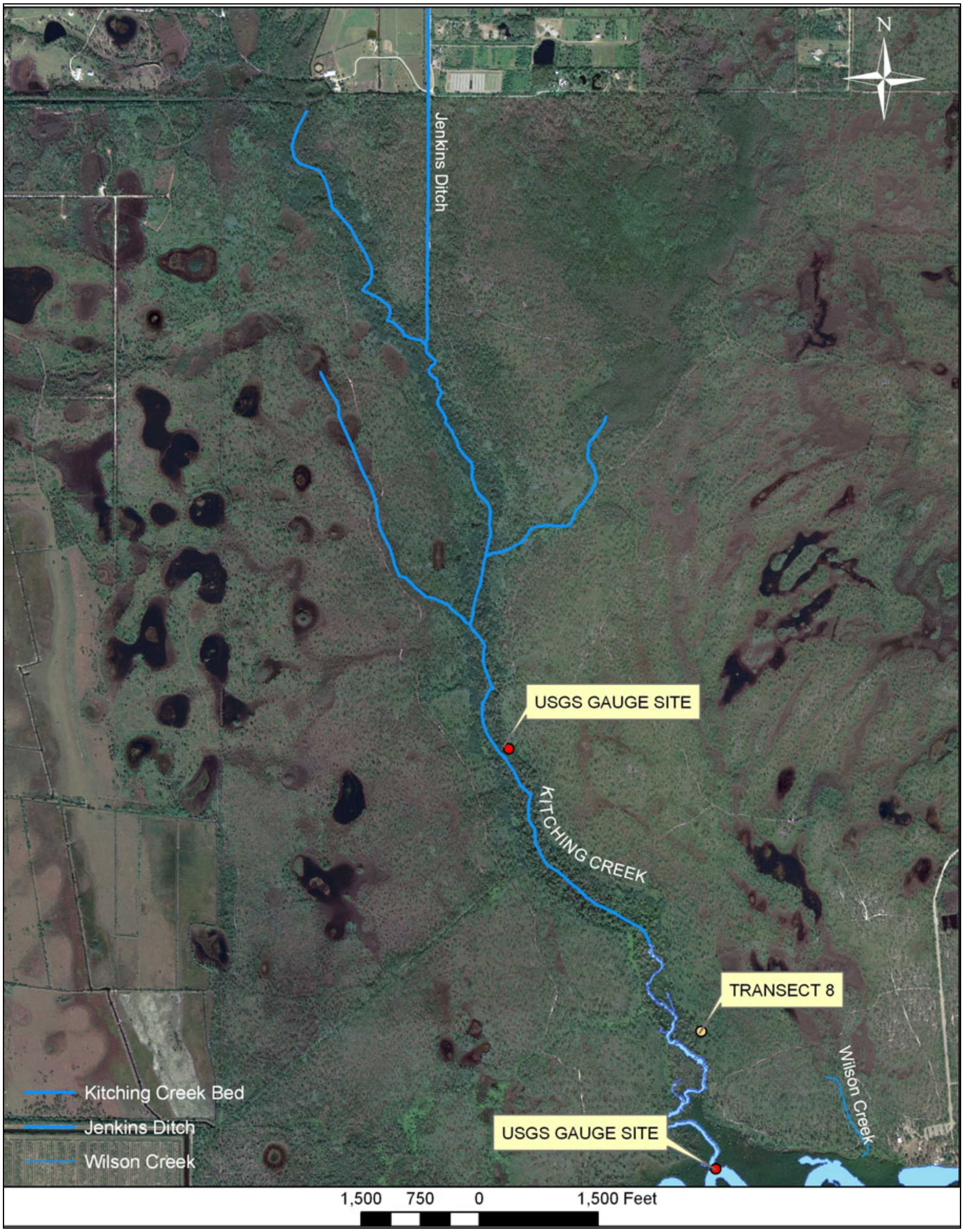


Figure 60. Kitching Creek Area and the natural pathway of its channel.

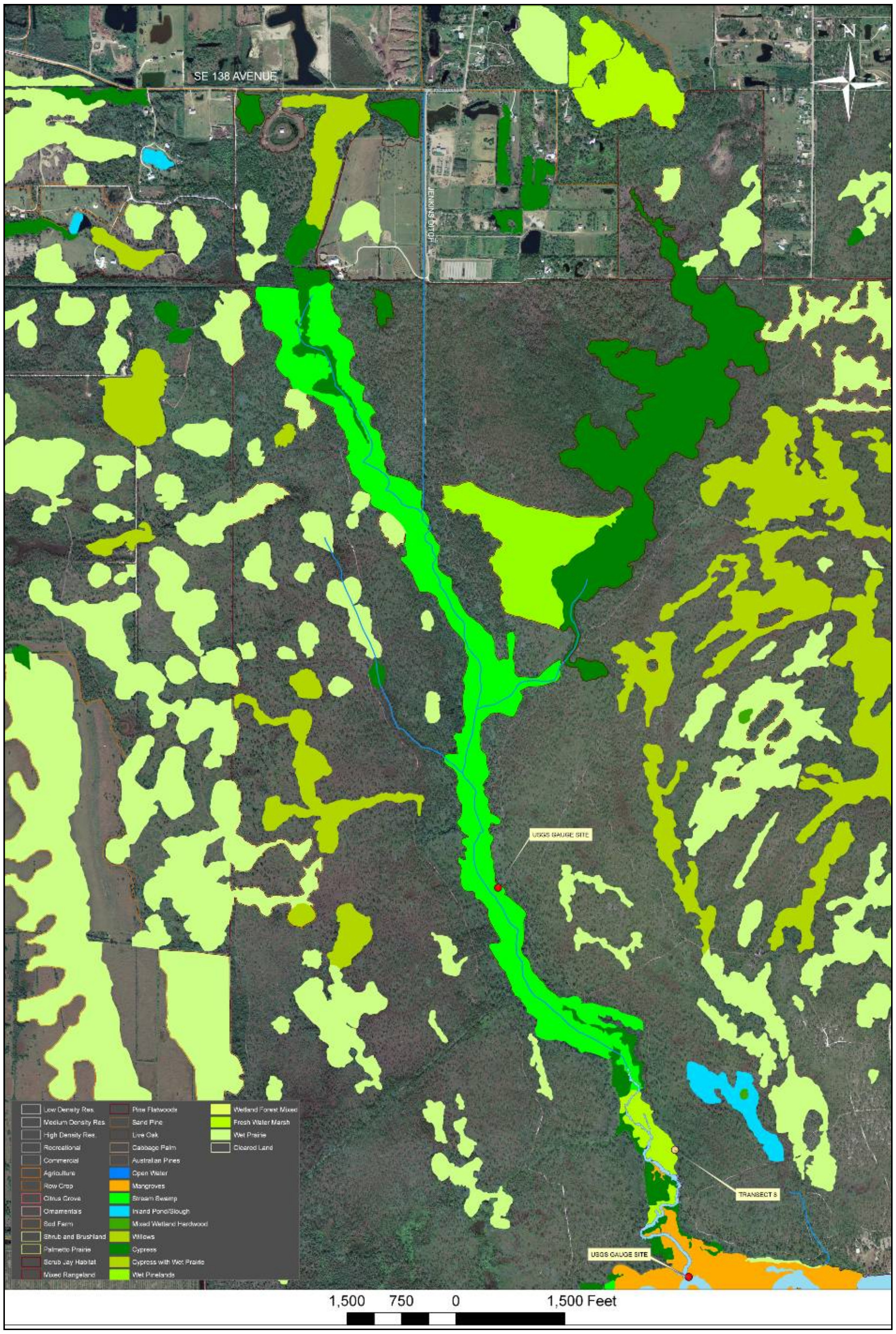


Figure 61. Kitching Creek and adjacent wetland systems.

The Kitching Creek Transect (8) is located on the east side of the floodplain approximately one tenth of a mile north of the mouth of the creek and just upstream of the Kitching Creek viewing platform in the Park. Transect 8 consists of twelve plots in the saltwater tidal portion of lower Kitching Creek **(Figure 62)**. The first three plots are Rmix, hydric hammock (HH) and Rmix with elevations of 8.36 ft, 6.56 ft. and 4.2 ft, respectively. The remaining nine plots are upper tidal swamp and mixed communities (UTsw1 and UTmix) and range in elevation from 2.06 to 1.27 c. There is one braided channel on this transect at approximately 95 meters from the upland and two plots away from the creek channel. The bottom of the braided channel is at about 0.4 ft in elevation. Red mangroves are present within the braided channel, which are primarily surrounded by pond apples. Therefore, it appears that the braided channel has contributed to the migration of brackish water species into the interior of the floodplain. In the transitional area, along with a quick change in topography, the upland communities change very quickly into hammock and then riverine swamp communities.

Soil types are represented by Nettles/Myakka sand in the most landward two plots of Rmix and HH followed by Okeelanta Variant muck in the second Rmix plot and Okeelanta Inclusion in Bessie muck in the upper tidal plots. In the soil survey performed by the University of Florida study (unpublished, 2006), it was noted that a mineral/sand layer was present below approximately 120 cm on all of the upper tidal plots.

With regard to vegetation and logging activities on Kitching Creek, Bessie Wilson DuBois in her book “The History of the Loxahatchee River” wrote:

> Wishing not to have the cypress cut around his Kitching Creek property, John DuBois marked the trees that should not be cut. He went with a bucket of white paint and marked 27 trees that stood around the camp and they were saved. Later, when he went to Tallahassee hoping to get the land back, which had been taken for Camp Murphy in 1942, he was told he could not possibly have it because of all of those nice trees which he had saved from the woodman’s axe years before!

Some of these trees are pictured below in the 2004 photograph of lower Kitching Creek (**Figure 63**). Along the shoreline, the canopy is primarily bald cypress and cabbage palms with a sub-canopy of mangroves. Taylor Alexander has photographs of this area from the 1970s and the mangrove sub-canopy is not as prominent as it is today.

Canopy species on Transect 8 were represented by fourteen species. Pond apples were the most abundant species followed by wax myrtle, and bald cypress **(Figure 64)**. Pond apples were found in all upper tidal plots and not within the Rmix plot. Red and white mangroves were not abundant; however, they were present as sub-canopy and seedlings. Red mangroves appeared to have been restricted primarily to the braided channel and the plot adjacent to the creek channel. Cabbage palms, wax myrtle, and Brazilian pepper were nearly always found on hummocks.

Although vegetation in the upper freshwater segments of Kitching Creek were not studied; aerial photograph and site visits indicated the presence of freshwater mixed hardwoods and bald cypress swamp and strands either on or associated with this strand swamp.

Thirteen of the fourteen canopy species were present in the 5-20 cm dbh size classes (**Figure 66**). Cabbage palm was the only species not present in the 5-20 cm dbh size class. They were only found in the 21-40 cm class. Pond apple was only present in the 5-20 cm and 21-40 cm classes. Bald cypress were found in all three classes (5-60 cm). Only a few pop ash were observed and they were all in the 5-20 cm dbh class. The exotics, Brazilian pepper and strawberry guava were only found in the 5-20 cm dbh class.

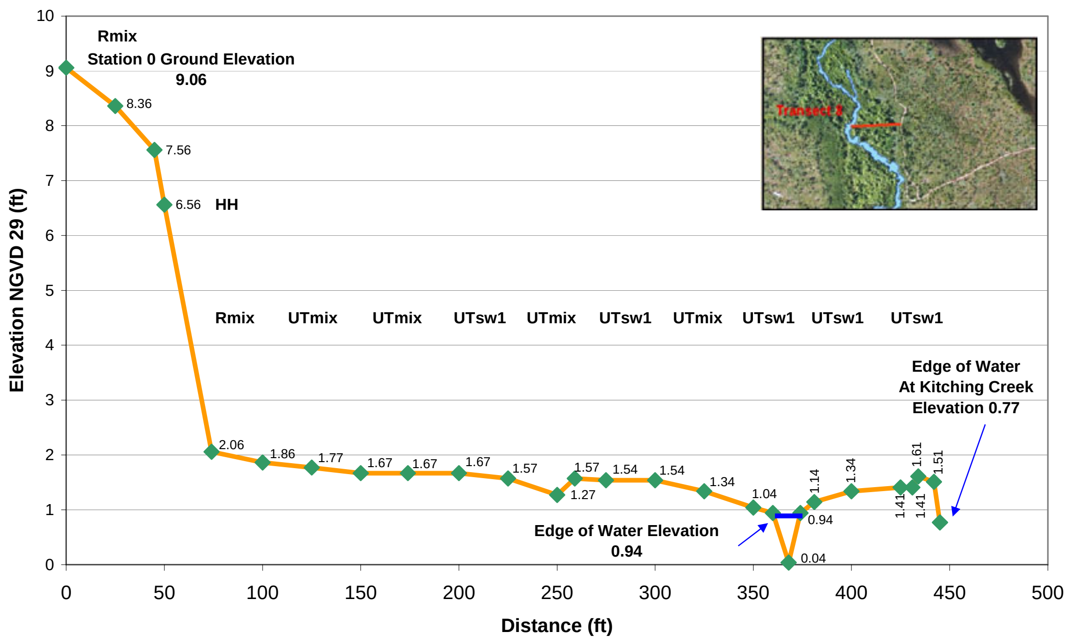


Figure 62. Profile of Transect 8 (Kitching Creek).

Figure 63. The 2004 shoreline of lower Kitching Creek where bald cypress were spared from lumbering activities.

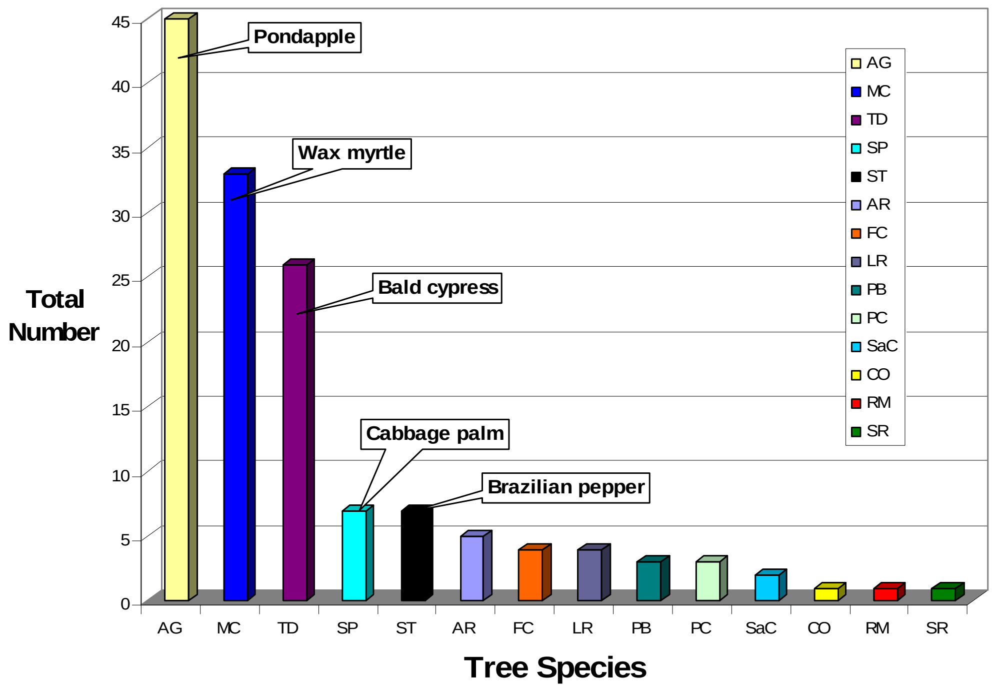


Figure 64. Abundance of canopy species on Transect 8 (Kitching Creek, RM 8.13).

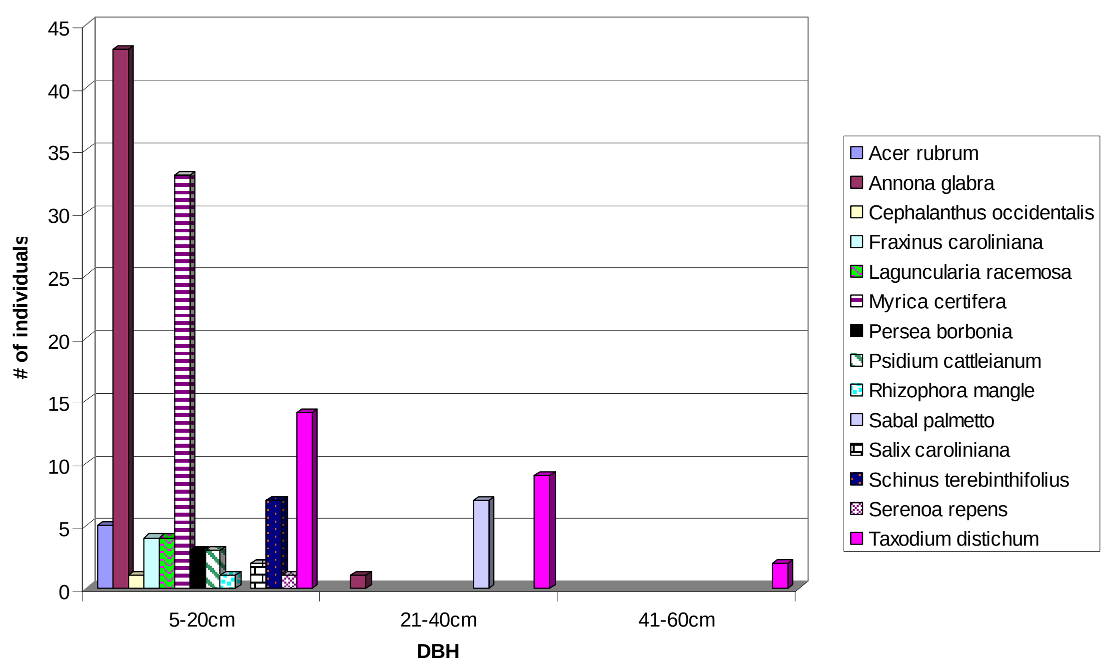


Figure 65. DBH size classes on Transect 8.

Transect 9 is located at RM 6.46 on a peninsula near the JDSP boat ramp (**Figure 66**). The hydrology of the floodplain in this area has been impacted by the placement of an elevated trail that divides a portion of the peninsula. During extreme high tides, the trail acts as a barrier and traps saltwater in the predominantly white mangrove community in the interior of the peninsula. Elevations across Transect 9 range from 9.48 ft at the benchmark to the shoreline (1.31 ft) adjacent to the river (**Figure 67**). Between 50 and 70 meters from the upland a quite pronounced LTmix area exists (i.e. hammock and swamp). Elevations in the hammock range from 1.95 ft to 2.05 ft and elevation along the trail is 2.01 ft; the remaining areas in the floodplain are approximately 1.63 ft.

There were three soil types present on Transect 9 (Appendix C). Pomello sand was present in the upland and hammock communities while Okeelanta Variant muck and Gator muck were present in the primarily mangrove swamp communities. The Gator muck was associated with a slight rise in ground elevation and change in forest type (i.e. LTsw2 (white mangrove) to LTmix (hammock and swamp).

Of the twenty plots on this transect, seventeen were lower tidal swamp (LTsw1 and LTsw2, **Figure 67**). **Figures 68** and **69** are photographs of LTsw1 and LTsw2 forest types at Transect 9. The other three were upland, hammock, and LTmixed. The most prevalent species in the canopy, shrub and groundcover layers were red and white mangroves in the swamp areas and cabbage palm in the hammock and mixed areas (**Figure 70**).

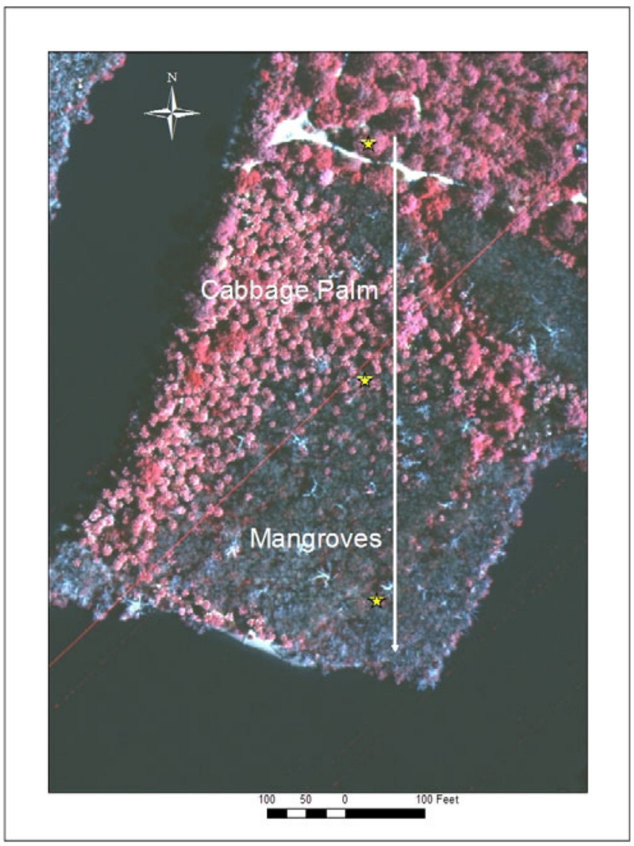


Figure 66. Location of Transect 9 (white line)and the three groundwater wells (yellow stars) from a 1985 infrared photograph, which also reflected damage to the mangroves as a result of a local freeze. The pink in the floodplains is cabbage palm.

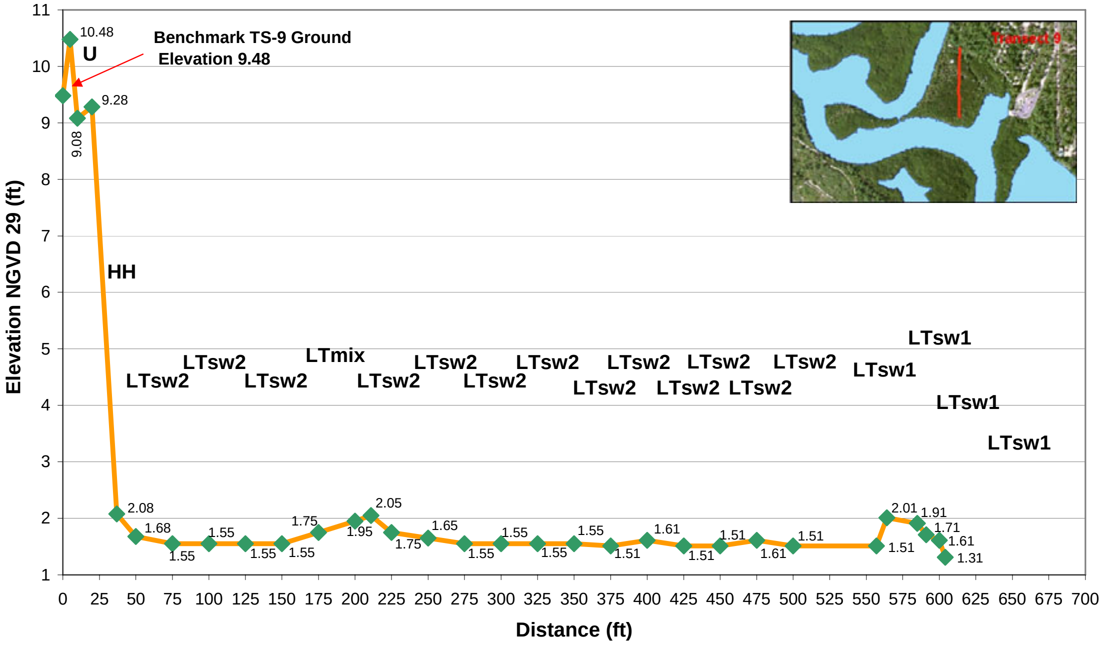


Figure 67. Profile of Transect 9.

Figure 68. LTsw2 forest type (white mangrove) with a dead bald cypress in the background on Transect 9.

Figure 69. LTsw1 forest type (red mangrove) on Transect 9.

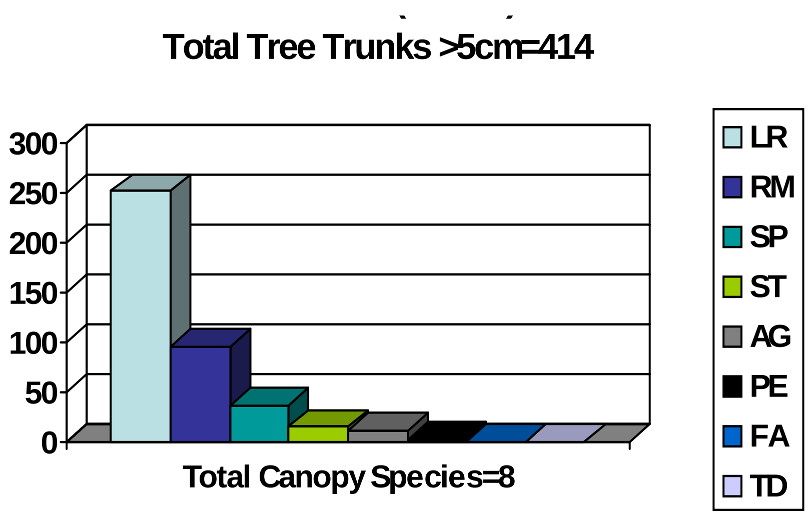


Figure 70. Canopy species abundance on Transect 9.

Pond apples in the canopy were rare. They were found predominately in the deeper swamp area at the back of the floodplains and had an average dbh of 7.2 cm. There is a noticeable difference between the distribution of red and white mangroves on Transect 9. White mangroves were dominant from the toe of the slope out to approximately 160 m. The remaining four plots (160 m to 200 m) were dominated by red mangrove. White mangroves were present in two size classes (5-20 cm and 21-40 cm) while red mangroves were present in 5-20 cm class (**Figure 71**).

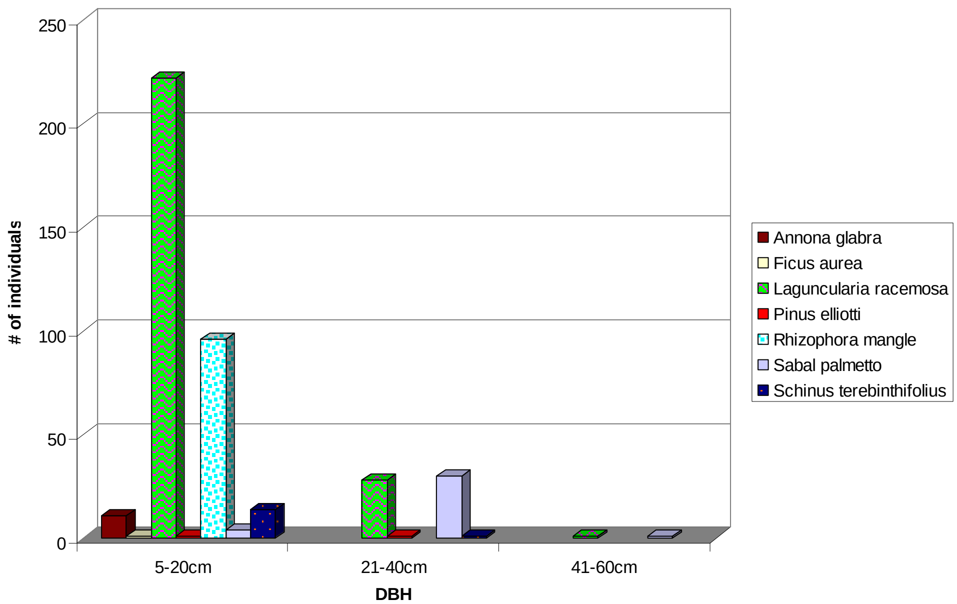


Figure 71. DBH size classes on Transect 9.

Tree heights were measured on 6 canopy species on Transect 9. The heights of eighty-seven white mangroves were measured and averaged 12.93 m. Ten red mangroves averaged 9.42 m. Four pond apples averaged 7.78 m while 7 cabbage palms averaged 8.19 m. In the upland plot, one live oak was measured at 5.8 m and two slash pines averaged 16.18 m.

Leather fern dominated the shrub layer while water hyssop, leather fern and rubber vine dominated the groundcover. During a visit in August 2004, it was noted that the majority of the cabbage palms that had been recorded as alive in 2003 were now dead. The only cabbage palms remaining alive were associated with the trail and the hammock areas.

Historically, the canopy on Transect 9 was dominated by bald cypress trees; however, most of these trees are now dead. In his 1967 plant survey of this transect, Taylor Alexander reported live bald cypress at a frequency of 22.2 and a density of 0.39 (14 live and 28 dead). Red and white mangroves were at a frequency and density of 52.8/1.31 and 36.1/2.64 (47 red and 95 white). Alexander also reported the presence of several other freshwater species in small numbers including sawgrass (*Cladium jamaicense*), swamp lily, red bay, pop ash, red maple, and button bush.

In a 1975 JDSP survey of one hundred bald cypress trees on the peninsula, seventy-one were dead, twenty-one were healthy and eight were stressed. In our 2003 survey, there were no live cypress within Transect 9 and red and white mangroves were at a frequency and density of 47/5.79 and 100/12.32. In an April 2004 re-survey of bald cypress trees on the peninsula, one hundred and fifty one were dead, seven were stressed and three were living. The three living bald cypress trees are directly adjacent to or on the elevated trail.

The North Fork tributary of the Loxahatchee River where Transect 10 (8 plots) is located meets the Central Embayment area of the Loxahatchee River at approximately RM 2.0 (**Figure 4**) while its headwaters reach far to the north to the Atlantic Coastal Ridge and coastal savannah systems of southern Martin County. The North Fork has been called the “Eastern Slough” of the Loxahatchee River because of its general north/south flowway character from above Bridge Road to the Loxahatchee River and because of its location east of Kitching Creek. In a 1952 black and white aerial of coastal Martin County (**Figure 72**), a bridge spans the floodplain area of the North Fork in the vicinity of Banner Lake. Just north of Bridge Road, the North Fork tributary appears as a savannah system running parallel to the back of the Atlantic Coastal Ridge. Bridge Road was constructed during the 1930s and appears to act as a barrier to sheet flow from the Atlantic Ridge area. South of Bridge Road the wetland system changes to a forested wetland system at first dominated by bald cypress but transitions for awhile into freshwater marsh. The freshwater marsh system branches off to the east and then southward while the bald cypress slough picks up again and continues southward as it enters JDSP. The two wetland systems at this point are separated by an area of higher elevation scrub habitat in the middle that is further surrounded on both sides by pine flatwood and wet prairie systems (**Figure 73**). This scrub is habitat for the threatened Florida scrub jay, *Aphelocoma coerulescens*. The bald cypress slough continues southward through JDSP and into the property currently leased by the Girl Scout Council of the Palm Beaches (Camp Welaka) while the freshwater marsh system continues southward to what is today Park Drive. Today, there are three small culverts that convey North Fork surface water flow beneath Park Drive. The area just east of Park Drive was impacted originally by agricultural activities (i.e. tomato farming) and later Camp Murphy, which was established in 1942 as a U.S. Signal Corps radar training base. The base grew to become 800 buildings including a hospital and served some 6,000 radar students from all service branches of the military (Snyder, 2003). The camp was decommissioned in the fall of 1944. In 1947, the Florida Board of Forestry and Parks officially obtained title of a 7,871 acre parcel that was to be named Jupiter State Park. The park was renamed in 1955 in honor of Jonathan Dickinson’s shipwreck on Jupiter Island. Additional parcels totally over 3,000 acres would be purchased over the years by the state and the South Florida Water Management District..

The tidal segment of the North Fork tributary begins in an area of mixed hardwoods (stream swamp), bald cypress slough, and cabbage palm hammock south of Park Drive (**Figure 75**). Both the bald cypress slough and mixed forested wetland systems meet up again as floodplain elevations fall and a recognizable channel appears and grows wider as the tributary approaches the main branch of the river. Mangroves appear in the section north of County Line Road in the 1952 black and white aerial photograph; however, there distribution has continued northward since that period.

Some of the problems associated with the North Fork include lowering of the groundwater table, decreasing freshwater flow, sediment deposition (muck) in the lower tributary, saltwater intrusion, and an invasion of mangroves into the freshwater floodplain community. Urban development to the north and installation of culverts under Bridge Road for the slough has contributed to the diminishing groundwater table and surface water flow. Currently there are 15 culverts (two on the North Fork) under Bridge Road, which affect the North Fork or Kitching Creek. These culverts do not appear to be adequate for transporting water to the south side of Bridge Road for the two tributaries. Lack of freshwater flow has resulted in a diminishing of the bald cypress sloughs, freshwater marsh, and wet prairie communities and the continuing spread of mangroves throughout the upper tidal North Fork floodplain.

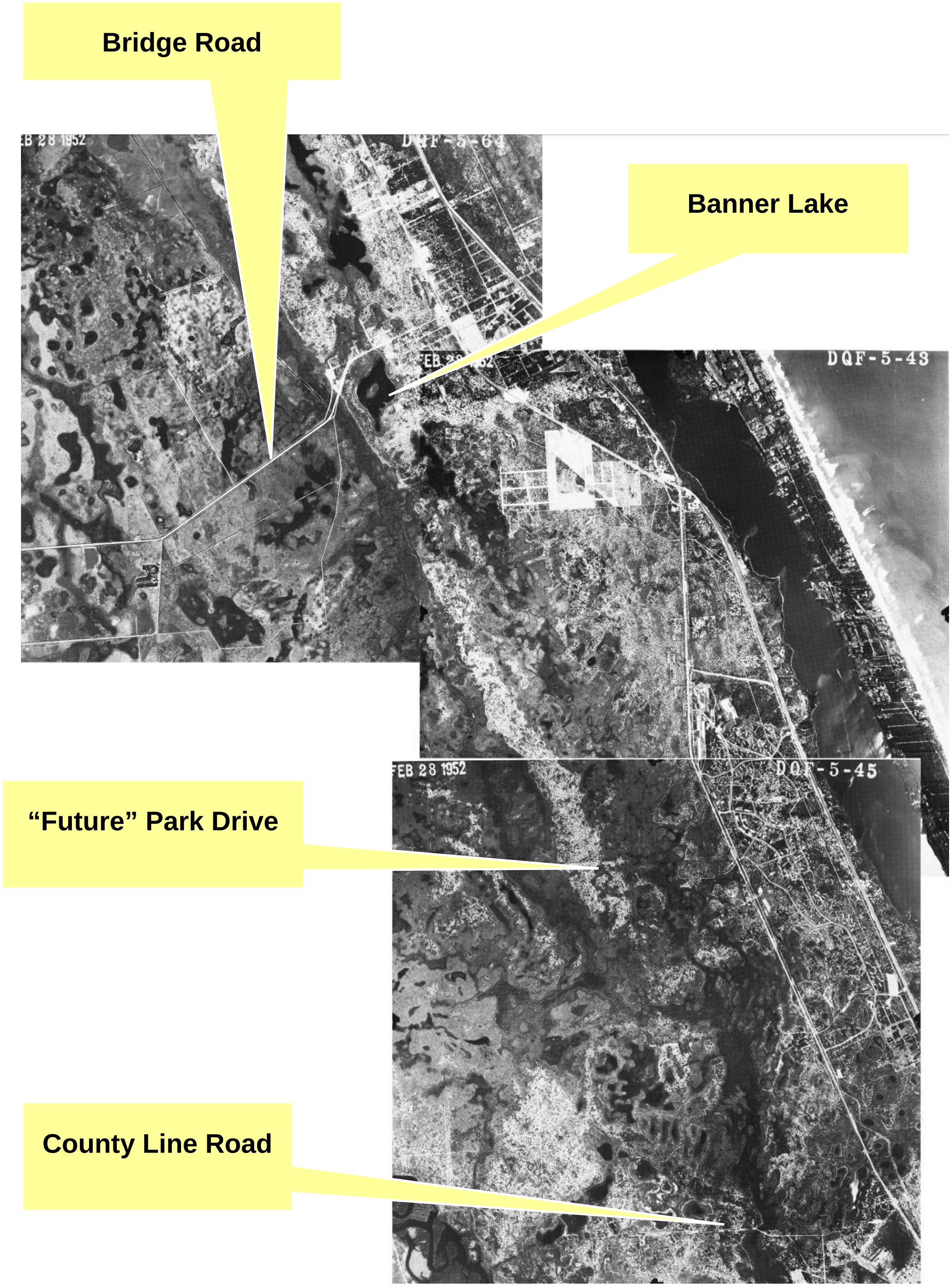


Figure 72. Black and white aerial photograph of the North Fork in 1952.

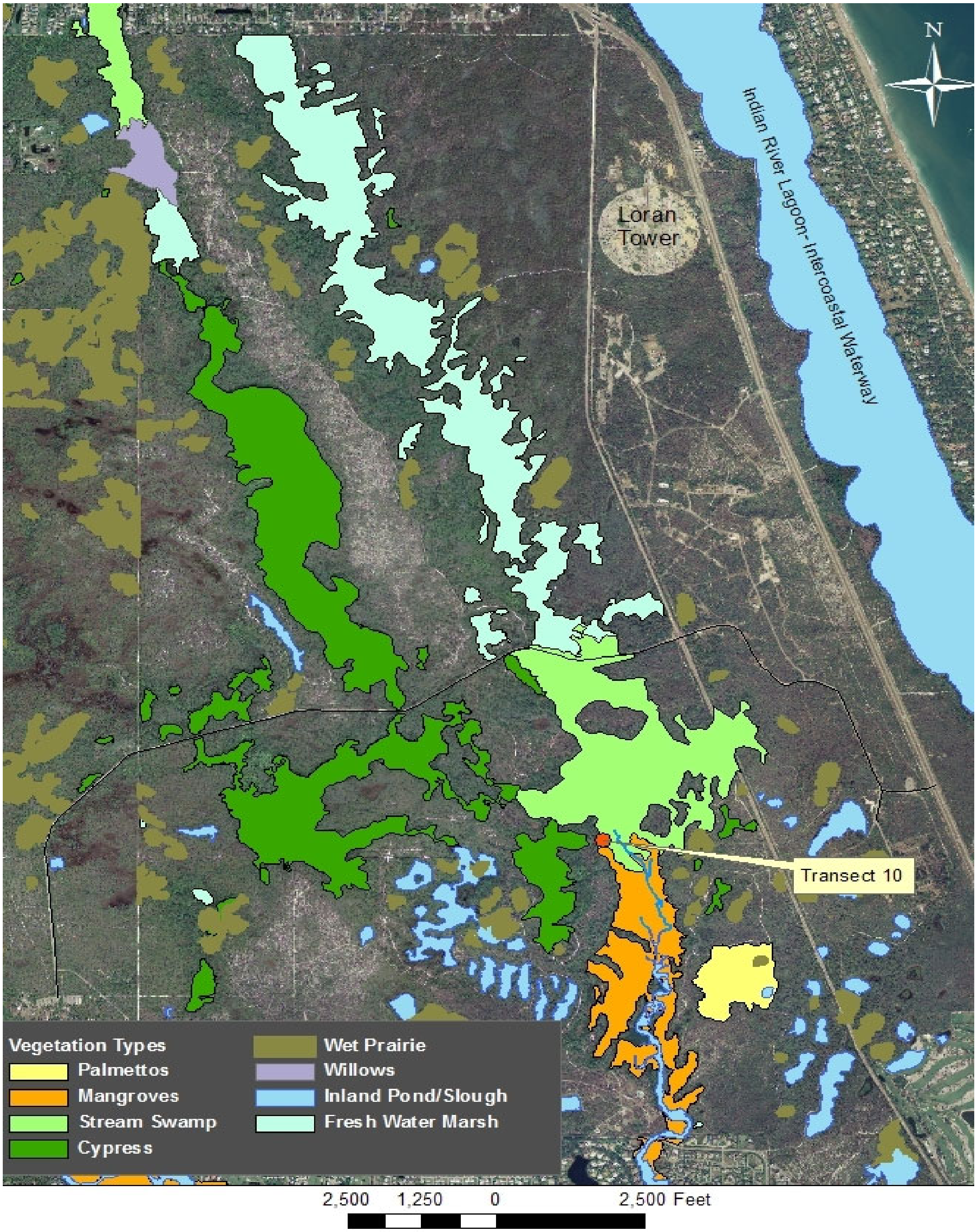


Figure 73. North Fork wetland systems.

During the original field trip in 2003 to establish a vegetative transect on the floodplain of the North Fork, staff from the FPS and SFWMD staff investigated three potential locations starting just north of Camp Welaka on the west side of the channel. The first two site investigations were met with an overwhelming dominance of primarily white mangrove. On the third attempt to establish a transect, there was a prevalence of freshwater species along with the appearance of a young sub-canopy of mangroves and pond apples. Although it was quite a distance from the fire road for access (**Figure 73**), the SFWMD survey team established a bench mark adjacent to the fire road and proceeded to measure elevations through the slash pine/ saw palmetto/oak upland system down to the floodplain of the North Fork.

Figure 74 shows a profile of only the floodplain segment of the survey. The survey was taken from the edge of the floodplain out to an open channel system with flowing water. From the fire road and benchmark, elevations within the upland community dropped towards the floodplain. About midway to Transect 10, the topography suddenly flattened and there was a noticeable change in groundcover vegetation. The dominant groundcover became cutthroat grass (*Panicum abscissum).* Whereas the upland community had been dry and hilly, this area, which was approximately 20 feet in width, was flat, frequently wet, and was dominated by the short grass species. It appears that this area is a hydric seepage slope wherein surface water runoff from the higher elevated upland communities is captured perhaps by a pervious layer of clay. Beyond the seepage slope the upland communities continues its descent to the floodplain.

The drop from uplands into the edge of the floodplain is quite dramatic on Transect 10 on the North Fork. Vegetation changes are immediate. A narrow band of hydric hammock (7.06 ft) drops down into a marsh system that averaged out to 7.03 ft. Elevations then rose to 7.83 and 7.23 ft for a plot of UTsw2 and a plot of UTmix (**Figures 75** and **76**). This was followed by two plots of hydric hammock at 7.18 and 7.03 ft. The last two plots adjacent to the tributary channel were 7.28 and 6.77 ft. No logging activities had been noted on the North Fork.

Soils in the upland and adjacent hammock community were represented by Waveland sand depressional. In the lower elevations of the transect UTsw2 and UTmix were Okeelanta muck while the two hydric hammock plots were Sanibel muck (Appendix C). The last two plots were Aquents.

Transect 10 is a short transect of approximately 75 meters in length with only eight plots. Pond apple, cabbage palm, and wax myrtle were the most abundant of the eleven canopy species present (**Figures 75** and **76**). Brazilian pepper and white mangrove were present in small numbers as canopy trees. The largest trees on Transect 10 were cabbage palm, which were found at three dbh size classes (5-60 cm, **Figure 77**). Pond apples were found in the 5-20 cm and 21-40 cm size classes. Most of which were in the smaller class. Ten of the eleven canopy species were present in the 5-20 cm dbh size class. Laurel oak was only found in the 21-40 cm class.

Shrub and groundcover layers consisted mainly of swamp fern, myrsine, saltbush, white mangrove, and pond apple. Bald cypress were recorded in the ground cover layer and were noted as very young trees adjacent to the transect plots. Saw grass was present in the marsh and UTsw2 habitats.

From the young size classes displayed by the canopy on Transect 10, it is concluded that this upper tidal area of the North Fork tributary represents a wetland system in transition. It appears that it is transitioning from a freshwater coastal marsh or savannah and hammock system to a young forested wetland dominated by pond apples and white mangroves.

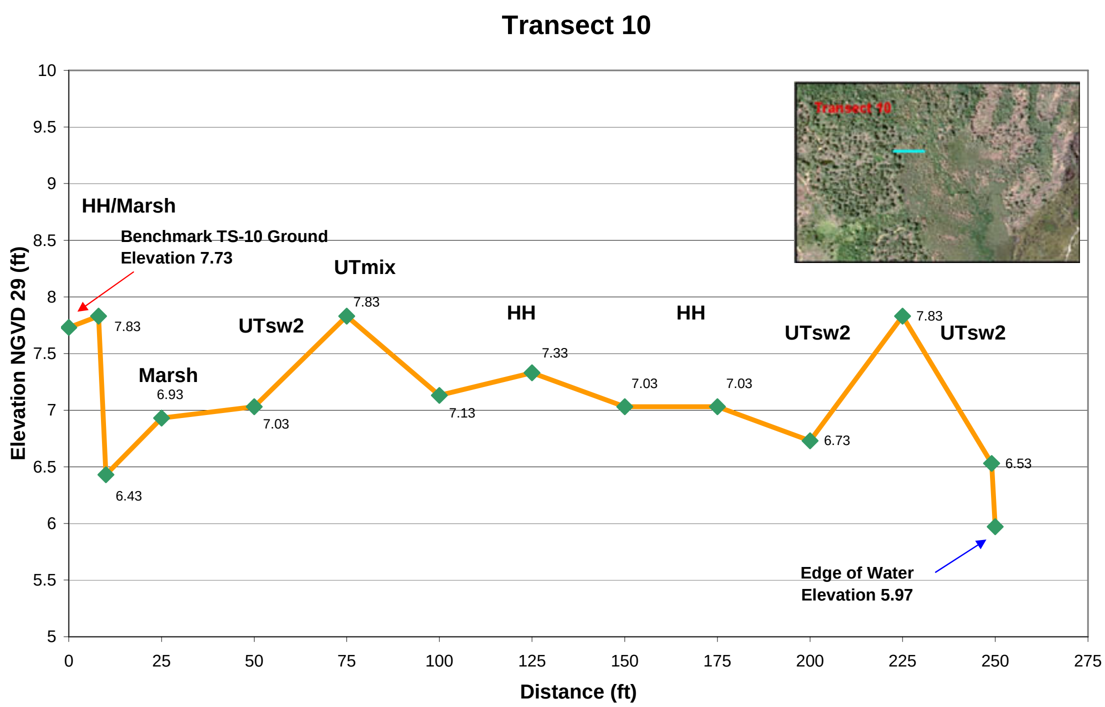


Figure 74. Profile of Transect 10.

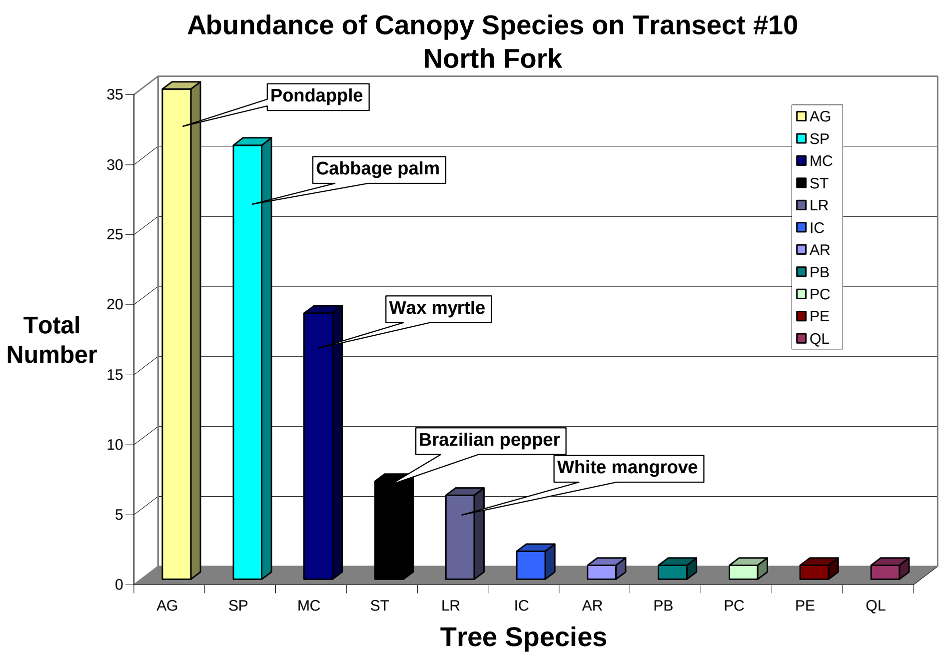


Figure 75. Canopy abundance on Transect 10 (North Fork).

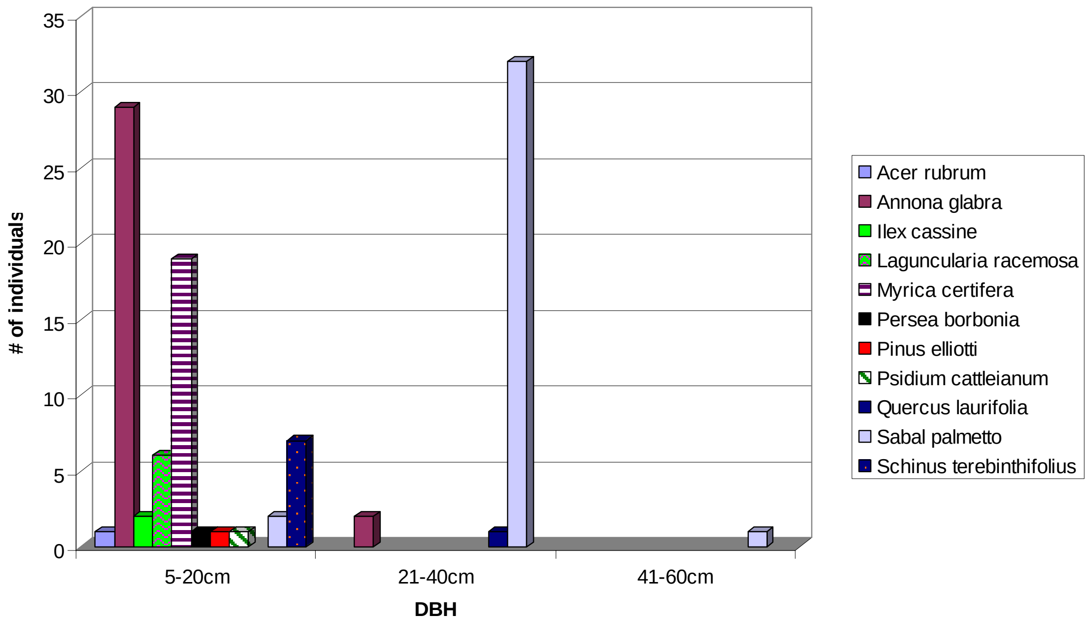


Figure 76. DBH size classes on Transect 10.

DISCUSSION AND CONCLUSIONS

COMPARISONS BETWEEN THE 1993-1994, 2003, AND 2006 STUDIES

Rainfall and hydrological data indicated that the 2003 and 2006 study periods were very dry, while the 1993-1994 study period of Ward and Roberts was wet. The 1993-1994 study of Ward and Roberts was conducted around a season impacted by the heavy rainfall of Tropical Storm Irene, in addition to the already wet year. Between the 2003 study period and the 2006 study period, three major hurricanes heavily impacted the floodplain communities on the Loxahatchee River and resulted in raising seasonal totals for rainfall and freshwater flow for extended periods of time. The extent of physical damage to the floodplain canopy within the study area is summarized for 2004 Hurricanes Frances and Jeanne in Appendix E. Severe damage and mortality was most apparent in areas of the tallest canopy tree species (bald cypress, red maple, and water hickory). Forty-eight percent of the canopy examined in the riverine reach was damaged, 39 percent of the upper tidal, and 54 percent of the lower tidal. An assessment of the impacts of Hurricane Wilma in 2005 has not been conducted; however, new breaks, tipovers, and deaths within canopy communities were observed during the 2006 observations.

Appendix D contains a summary table of the plant species observed in the 1993-1994 Ward and Roberts Study (X), the 2003 Study (0), and the 2006 Observations (Y) by transect. The plant list for this table includes all three layers of the floodplain community (canopy, shrub, and ground cover). The 1993-1994 Ward and Roberts Study did not include Transects 7, 8, 9 and 10. With regards to canopy species most were present in all three studies with a few exceptions. Red maple was present on T2-2 in 1993-1994 but was absent in 2003 and 2006. From our field observations, we believe that large red maple and water hickory are particularly susceptible to injury (mainly tipovers) when compared to bald cypress and cabbage palm. Water hickory may have succumbed to the hurricanes. They were present at T2 and T3 in 1993-1994, but were not present at T2-2 in 2003 and not present at either T2-1 or T2-2 in 2006. However, water hickory did appear in 2006 at Transect 6 in the tidal reach. Pop ash just appeared for the first time at Transect 1 in 2006. It was not present at Transect 6 in 93-1994, but showed up at Transects 6, 7, and 8 (tidal transects) in 2003 and 2006. Virginia willow (*Itea virginica*), a shrub, was present at Transect 1 in 93-1994 but absent in 2003 and 2006. On Transect 5, Virginia willow was present except in 2006. Carolina willow (*Salix caroliniana*), a canopy tree, was observed only at Transects 7 and 8 in 2003 and 2006. In the tidal reaches, bald cypress was present in all years at Transects 6 and 8 (Kitching Creek), and was missing from 2006 on Transects 9 and 10 (North Fork), although trees were on the trail of the peninsula of Transect 9 and were observed just off of the transect on T-10. With regards to exotics, Brazilian pepper was totally absent from Transect 5 in all years and was not found on Transect 4 in 1993-1994. It was also not found on Transects 1 and 2 in 2003 and 2006. Java plum was only found on Transects 5 (2006 only), 6 (2006 only), and 7 (2003 and 2006) while strawberry guava was found on Transects 1 and 2 in the riverine reach and on all of the tidal transects. Old World climbing fern was found on all transects; however only recently (2006) on Transect 1.

Figure 77 shows a comparison of species richness for all ten transects in 2003 and 2006 by transect and river mile. For both 2003 and 2006, T2-2 had the lowest species richness; however this was due to the fact that T2-2 is primarily a monoculture of cabbage palm hammock with the exception of two swamp plots. If species richness was combined for Transect 2 (T2-1 and T2-2), this transect would still possess the lowest species richness of the 10 transects. It has not been determined whether Masten Dam acts as a semi-impoundment, which may factor into the low species richness values at Transect 2. Transect 10 on the North Fork had the next lowest amount. Transect 8 (Kitching Creek), which has an understory of mangroves mixed with the freshwater canopy, had the highest species richness in 2006. From it's location on Kitching Creek, Transect 8 has also experienced probably lower salinity values over time than the other tidal transects located on the Northwest Fork. As with the other upper tidal transects on the Northwest Fork, past lumbering activities is a factor in increasing species richness, which was also a factor on Transect 8. Transect 3 also had displayed impacts of lumbering activities and other disturbances from agricultural activities. Overall, 2006 had greater species richness on all 10 transects. In our opinion, this is a direct result of a combination of hurricane impacts (i.e. increases in light availability as a result of the damaged canopy) and the extremely dry conditions of 2006. Again, if hydroperiods in the floodplain are not adequate in depth and duration then these conditions allow for intrusion of non-hydric species and displacement of different hydric species into floodplain forest community types.

Figure 78 illustrates the same concept except number of plots within a transect is added to the equation to obtain an average number of species per plot on a transect. The dominance of white and red mangroves was reflected in the low average for Transect 9 in the lower tidal reach in both 2003 and 2006. Under these conditions, Transects T2-2 (riverine) and 8 (tidal) displayed the highest values for species richness in 2006.

Figures 79 and **80** provide a comparison of species richness and species/number of plots by transect for each of the three studies (1993-1994, 2003, and 2006). Although the six historical transects were all used in four Loxahatchee River studies, the SFWMD Dewey Worth 1983/84 study was not used in the comparison because sampling methodologies were so different from the other 3 studies. Results from the SFWMD Dewey Worth 1983/84 study will be included in the appendix of our final report.

For the 1993-1994 Study and 2006 Observations, species richness for Transects 1 through 6 showed very similar patterns while the 2003 study consistently possessed lower species richness than the 1993-1994 and the 2006 (**Figure 79**). Transects 3 and 5 of 1993-1994 possessed the highest values for species richness. We really don't have a simple explanation for this association. The same senior botanist was present for all three field studies. We will examine further the times of year and more detailed hydrologic conditions in which each study was conducted. In **Figure 82**, species richness (#species/#plots) was slightly higher for the 1993-1994 Study than the 2006 Observation Study with the exceptions of Transects 4 and 6. Again, 1993-1994 was an extremely wet period on the river while 2006 has been a dry period. Also in **Figure 80**, Transects T2-2, T2-1 and T-3 displayed the highest values for species richness in 1993-1994 and 2006 while T-3 displayed the highest value for 2003.

Additional vegetative analysis is forthcoming in early 2007 in a separate final report, which will include a more detailed analysis of shrub and groundcover communities, multivariate analysis of the vegetation data and environmental factors, and more extensive summaries of previous floodplain studies. Future vegetation monitoring consists of examining canopy communities every 6 years and shrub and groundcover communities every 3 years. This schedule was presented in the Loxahatchee Restoration Plan as a means to best utilize staff and allow the sites to recover from impacts created during the sampling events. The dbhs of canopies species were re-measured in 2005 during the hurricane assessment investigation. So, the next sampling events will be 2007 for shrub and groundcover and 2009 for canopy.

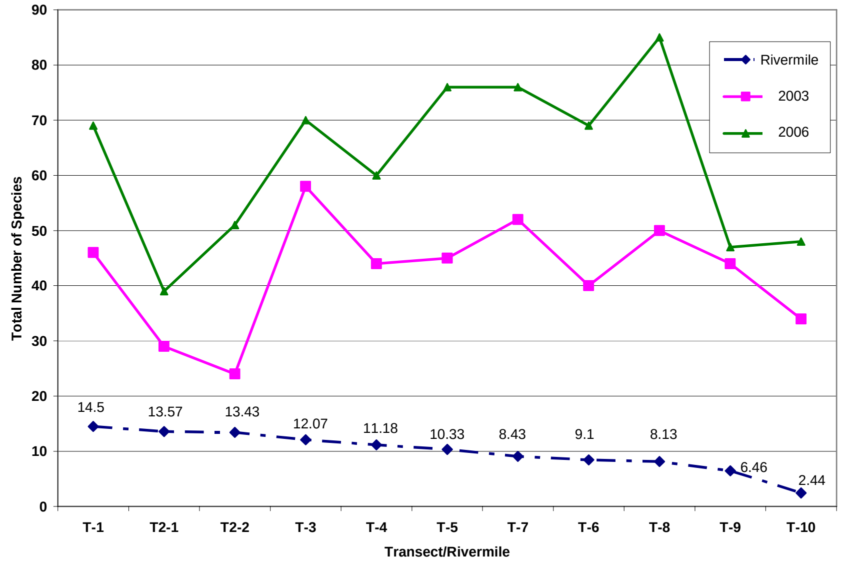


Figure 77. Comparison of species richness for the 10 transects of the 2003 and 2006 studies.

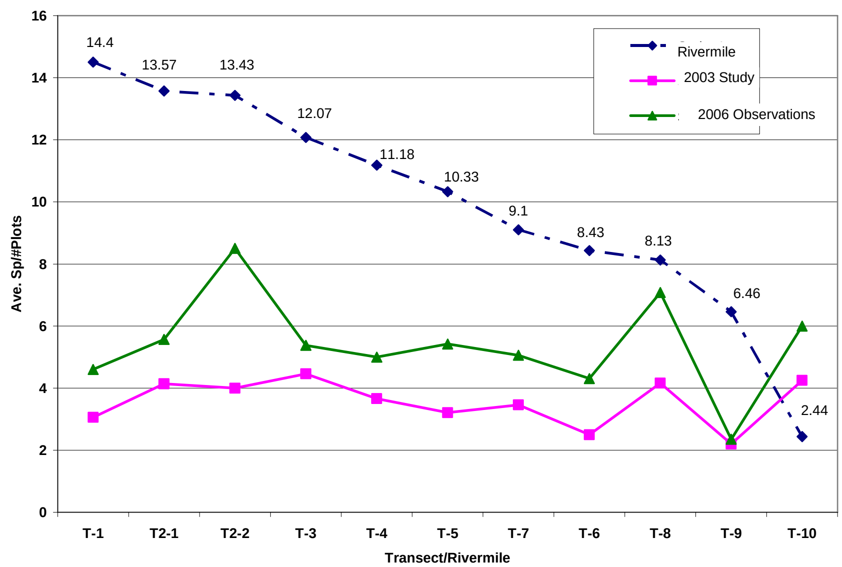


Figure 78. Comparison of the average number of species/plot for the 2003, and 2006 observation study.

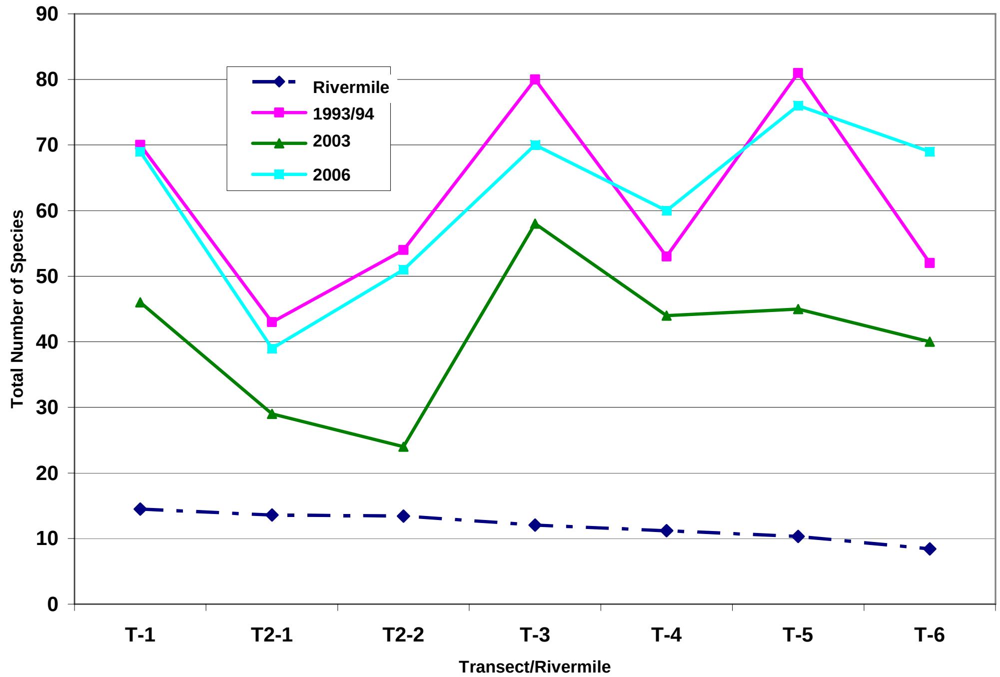


Figure 79. Comparison of species richness for the 1993-1994 and 2003 studies and the 2006 observation study.

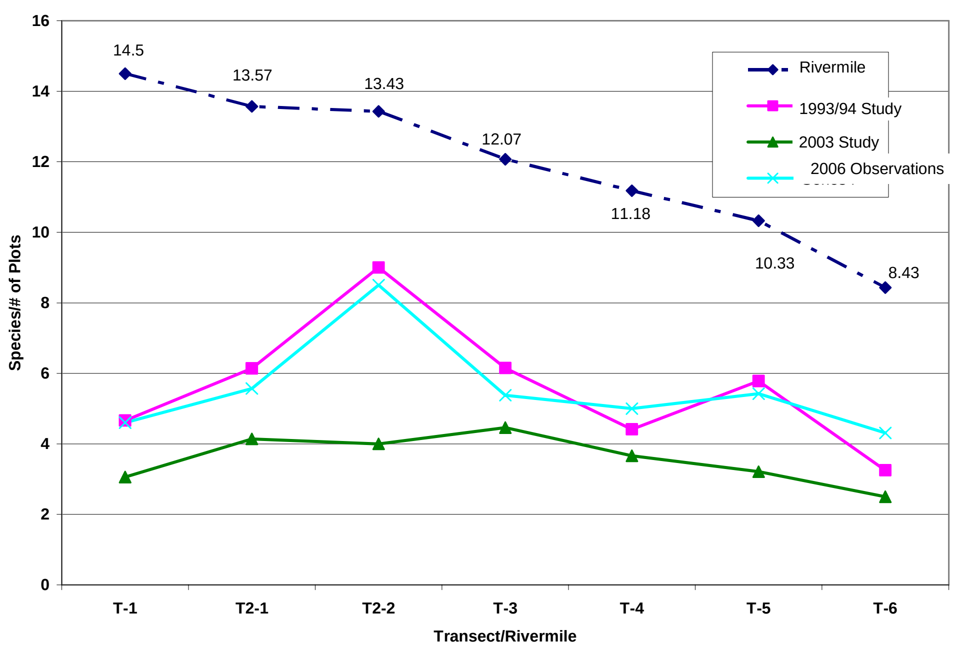


Figure 80. Comparison of the average number of species/plot for the 1993-1994, 2003, and 2006 observation study.

RESTORATION CONSIDERATIONS WITH REGARDS TO VEGETATION AND FISH AND WILDLIFE UTILIZATION

Several enhancement and restoration issues were identified in the riverine floodplain communities. The major concerns in the riverine reach of the Northwest Fork of the Loxahatchee River were: (1) minimal post development inundation of the floodplain swamp community; (2) insufficient inundation to discourage the intrusion of transitional, upland, and exotics plant species; (3) displacement of younger canopy species into multiple forest type communities; and, (4) insufficient inundation for aquatic organisms to utilize floodplain swamp communities.

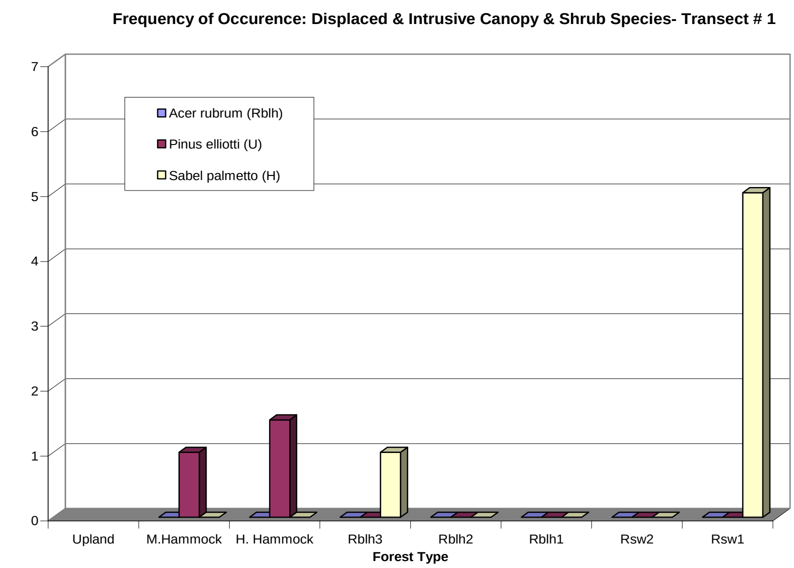
The 300+ year old community of bald cypress in the floodplain of the Northwest Fork is representative of the oldest vegetative community along the river and one of the last remaining communities of its type in southeast Florida (hence the designation as Florida's first National Wild and Scenic River). Pre-development flows down the Northwest Fork must have been sufficient to sustain this community for several centuries. Therefore, we concluded that this would be the primary species for restoration and enhancement in the riverine swamp, while red maple and water hickory would be the primary species for bottomland hardwoods communities and cabbage palm for hydric hammocks.

Since the 1930s the river has experience considerable hydrologic change. After the diversion of freshwater flow to the Southwest Fork (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 the very dry years. In the riverine reach, local residents reported that the river channel would dry up for long stretches during the 1960s and 1970s, which was also probably the most stressful period for bald cypress and other freshwater species in the tidal floodplain. Lainhart and Masten Dams may have provided some protection by impounding the freshwater 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 (1978). This is probably why we are not seeing significant canopy tree deaths today caused by saltwater intrusion. Of significance was the death of most of the remaining cabbage palms within the swamp and mixed plots of Transect 9 in the lower tidal reach. The USGS report (2006) identified high conductivity and high sulfides on portions of this transect and Transect 6 probably due to poor flushing conditions.

Post development stage and flow relationships were examined using a combination of field collected and modeled data. Approximately 110 cfs over Lainhart Dam is needed for 100% inundation of the floodplain swamp at Transect 1 (SFWMD, 2006). Average mean monthly flow for the 1965-2003 study period revealed that complete inundation of the floodplain swamp area occurred on average for only three months (September, October and November) per year while a monthly median flow averaged only one month (October) a year of inundation. Because the river is so rainfall driven now, water levels along the floodplain fall back within the banks of the river channel within a short period of time after most rainfall events. This can be true of both dry and wet season stage levels.

Recent river restoration studies have emphasized the importance of reestablishing natural flow regimes, rather than just minimum flows in regulated systems such as the Loxahatchee River (Poff et al. 1997, Toth et al., 1998, and Benke, 2001). Benke stated that maintaining the connectivity between the river channel and floodplain is vital for diverse and productive invertebrate assemblages and the higher trophic levels that depend on them. Thus, enhancement and restoration of the riverine floodplain forest communities is warranted to provide additional freshwater flow to improve seasonal hydroperiod and depth and subsequently ecological community health. Recommendations for hydric hammock and floodplain swamp communities' hydroperiod and depth are presented in Chapter 4 of the Restoration Plan (SFWMD, 2006). For hydric hammock, the performance measure was inundation of at least 30-60 days/year with 2-6 inches of water. For floodplain swamp, the performance measure was 4-8 months (100-300 days) with 18-30 inches of water. At this time, we have no estimates of pre-development flows for the Northwest Fork; however, estimates may be obtained in the future from the Natural Systems Model, which is expected to be completed this year.

Evidence of plant species intrusion and displacement (i.e. a shift in plant species over time with primarily drier species into swamp areas) can be found throughout all of the riverine transects. **Figures 81, 82** and **83** illustrate examples of displacement of plant species on Transects 1, 2 and 4. **Figure 15**, the photograph, depicts an old water hickory (representative of the older community) surrounded by cabbage palms, saw palmetto, and various ferns that would be more representative of hammock and upland communities. On Transects 1 and 2, slash pine, was intruding into hammock areas while cabbage palm was displaced into swamp areas. Young red maple was displaced from bottomland hardwood areas into swamp areas. Transect 3, also had cabbage palm displaced to bottomland hardwood and swamp areas along with wild coffee and myrtle oak. Brazilian pepper, normally an upland species, had invaded bottomland hardwood and swamp communities of Transects 3 and 4.



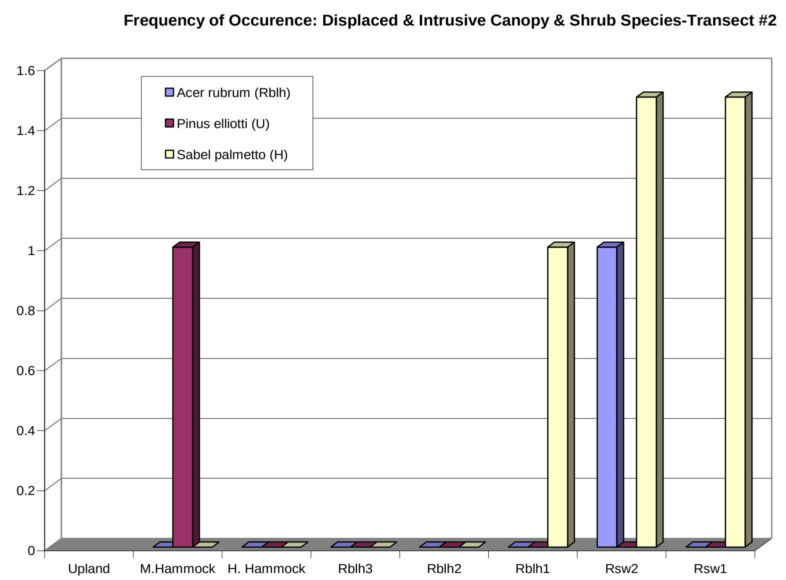


Figure 81-82. Examples of displaced and intrusive species on Transects 1 and 2.

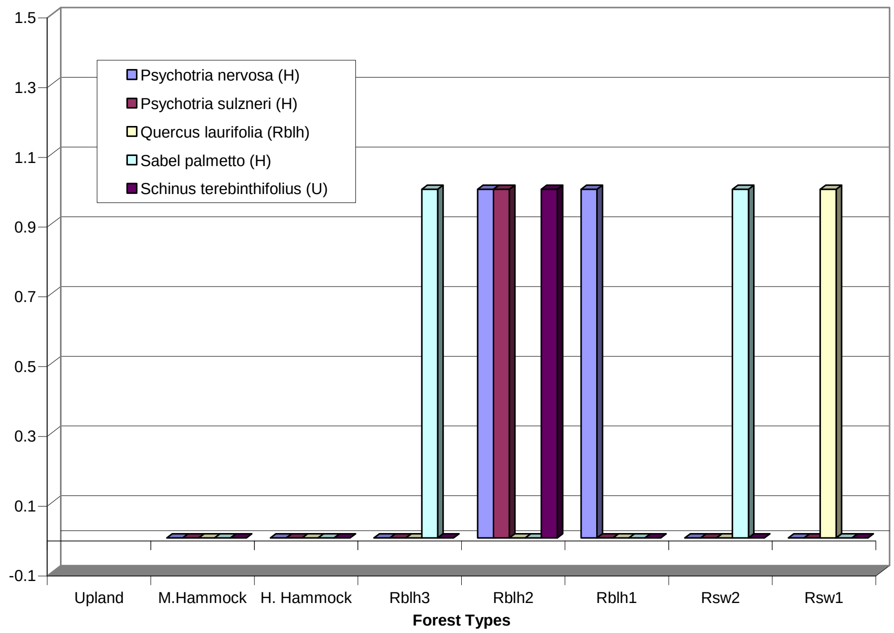


Figure 83. Examples of displaced and intrusive species in the riverine floodplain at Transect 4.

Although we have not conducted field surveys of riverine fish and wildlife, historical inundation analysis revealed that the riverine floodplain was unavailable for aquatic community utilization (i.e. lack of inundation and depth) about 75 percent of the time for most years. The need for baseline field monitoring and the plan for study are outlined in Chapter 10 of the Restoration Plan. A more natural hydroperiod in the riverine floodplain would potentially increase food resource availability (i.e. invertebrates, amphibians, fish and birds) and provide a multitude of aquatic habitats. Amphibians in particular are important indicators of ecological health, because they require out of channel aquatic habitat to breed successfully. South Florida amphibians need various lengths of continuous inundation for the metamorphosis from larvae to adult. Larval and juvenile riverine fishes utilize the out of channel experience to hide from larger predators. Depending upon water depth, fishes of all sizes migrate into the floodplain and use the vast plant and invertebrate food resources. Several recent publications have illustrated the significance of submerged snags as habitat to increase invertebrate populations, which in turns increase food resources for several other biological communities. Benke (2001) found that benthic invertebrate assemblages in the floodplains of the Ogeechee River (Georgia) were different from both snags and benthos of the main channel. Oligochaetes, isopods, and dipterans were the major groups in density and biomass on the floodplain. Oligochaete biomass was somewhat lower in the floodplain than in the main channel, while dipteran biomass was somewhat higher. Total biomass and density were much lower in the floodplain than observed on snags. Their floodplain inundation model illustrated that the biomass of invertebrates within the floodplain was extended over a period of time by retention of water by floodplain pools and inputs of rainfall and groundwater. High biomass and production of snag-dwelling insects is made possible by an abundant supply of microbially enriched amorphous detritus that primarily originates from floodplain forest. On the Ogeechee River, Benke found that the regular exchange of water, nutrients, and other organic matter between the river channel and floodplain was a critical connection. These factors point to the significant need to provide additional floodplain inundation on the riverine floodplain and within the river channel of the Loxahatchee River and its major tributaries.

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APPENDIX A:
LOXAHATCHEE RIVER: TIME LINES OF CHANGE

Colonization / Homestead Period	**3000-750 BC** - Late Archaic Period: Early Indian encampments along the river **750 BC-1750AD** - East Okeechobee Periods I-IV: Villages and middens constructed near the river **1696** - Jonathan Dickinson is shipwrecked on Jupiter Island **1800s** - Seminoles name the river "Lowchow" for turtle and "Hatchee" for River **1838**- Battle of Loxahatchee (January 24,1838), Second Seminole War **1850s** - Loxahatchee River known to locals as Jupiter River **1855-1860** - Jupiter Lighthouse constructed **1860s** - Early settlers arrive in Martin and Palm Beach County areas **1870s** - Ft Jupiter established on Jupiter Island/ developer Henry Flagler begins to fill in natural slough areas **1886** - The family of Walter Kitching purchases land for $1.25/acre and establishes trade boat business **Late 1800s - 1912** - Atlantic Intracoastal Waterway channelized between Jacksonville and Miami Construction of St. Lucie and Lake Worth Inlets further diverted flow away from Jupiter Inlet
Drainage Period	**Early 1900s** - Construction of the Florida East Coast Railroad (FECRR) trestle bridge with filling of surrounding submerged lands **1928** - Small agricultural ditch dredged to divert water from the Loxahatchee Marsh to the Southwest Fork of the Loxahatchee River **1930s** - The Lainhart and Masten Dams were privately constructed by local families on the Northwest Fork **Mid 1930s-1942** - U.S. Army Corps of Engineers dredged lower estuary **1940s** - Bridge Road constructed and sod farms established, reducing sheet flow to the northern portion of Kitching Creek **1940-41** - Cypress trees were cut for lumber along Kitching Creek **1947** - Jupiter Inlet permanently stabilized for navigation **1947** - US. Army Base Camp Murphy deactivated and state acquires the property to create Jonathan Dickinson State Park **1957-58** - Southwest Fork of the Loxahatchee River heavily altered, dredged and drained by the construction of the C-18 Canal to divert water from the Northwest Fork to the Southwest Fork **1968** - The state acquired land purchased by Trapper Nelson during the 1930s and established his home and grounds as an Interpretive Site **1970-71**- Severe drought throughout the watershed further reducing freshwater flows **1970** - Loxahatchee River-Lake Worth Creek Aquatic Preserve established **1974** - C-14 Canal allowed water to be re-diverted from C-18 to the Northwest Fork G-92 Structure constructed at the intersection of C-18 and the Northwest Fork allowing a flow of 50 cubic feet per second (cfs) and a maximum flow of 100 cfs to be redirected to the NW Fork **1975** - Alexander and Crook documented the historical migration of mangroves in formerly cypress areas **1976-77** - U.S. Army Corps of Engineers dredged the lower estuary, which increased saltwater intrusion **1977-78** - Oyster bars dredged at the FECRR Bridge to improve navigation and flushing in the embayment area **1978** - Loxahatchee River Environmental Control District began operation of a sewage treatment plant that discharged from 0 to 2.0 million gallons per hour (mg/h) to the Northwest Fork
Urbanization Period	**1980s** - Lainhart and Masten Dams are reconstructed to maintain higher water levels **1980** - Operation of S-46 Structure on C-18 Canal altered to provide more storage in the canal. Discharge occurred to the Southwest Fork when water levels were greater than 15 feet above mean sea level **1980** - Three channels were dredged in the embayment area to improve navigation **1981** - In August, Hurricane Dennis hit the area and caused prolonged heavy flows of freshwater **1984** - Florida Department of Natural Resources reported that the majority of the cypress trees downstream of Kitching Creek (River mile 7.8) were dead **1985** - Pristine portions of the Northwest Fork of the Loxahatchee River designated as a Federal and State Wild and Scenic River **1987** - G-92 is replaced by a gated control structure capable of passing up to 400 cfs via remote telemetry from the SFWMD Operations Control Room **2000** - Projects are underway to restore hydrology in the Loxahatchee Slough and enhance flow to the Northwest Fork

APPENDIX B:
SPECIES LISTS WITH CODES

Table B-1. Canopy species list and codes.

Scientific Name	Common Name	Code
Acer rubrum	Red maple	AR
Annona glabra	Pond apple	AG
Carya aquatica	Water hickory	CA
Cephalanthus occidentalis	Buttonbush	CO
Chrysobalanus icaco	Cocoplum	CI
Citrus sp.	Citrus	CS
Ficus aurea	Strangler ficus	FA
Fraxinus caroliniana	Pop ash	FC
Ilex cassine	Dahoon holly	IC
Laguncularia racemosa	White mangrove	LR
Myrica cerifera	Wax myrtle	MC
Persea borbonia	Red bay	PB
Persea palustris	Swamp bay	PP
Pinus elliottii	Slash pine	PE
Psidium cattleianum	Strawberry guava	PC
Quercus laurifolia	Laurel oak	QL
Quercus myrtifolia	Myrtle oak	QM
Quercus virginiana	Live oak	QV
Rapanea punctata	Myrsine	RP
Rhizophora mangle	Red mangrove	RM
Roystonea regia	Royal Palm	RR
Sabal palmetto	Cabbage palm	SP
Salix caroliniana	Carolina willow	SaC
Schinus terebinthifolius	Brazilian pepper	ST
Serenoa repens	Saw palmetto	SR
Syzygium cumini	Java plum	SC
Taxodium distichum	Bald cypress	TD

Table B-2. Shrub species list and codes.

Scientific Name	Common Name	Code
Abrus precatorius	Rosary pea	ABRPRE
Acer rubrum	Red maple	ACERUB
Acrostichum danaefolium	Leather fern	ACRDAN
Alternanthera philoxeroides	Alligator weed	ALTPHI
Alternanthera sessilia	Joyweed	ALTSES
Amorpha fruticosa	False indigo	AMOFRU
Annona glabra	Pond apple	ANNGLA
Ardisia escallonioides	Marlberry	ARDESC
Baccharis halimifolia	Salt bush	BACHAL
Blechnum serrulatum	Swamp fern	BLESER
Boehmeria cylindrica	False nettle	BOECYL
Callicarpa americana	Beautyberry	CALAME
Canna flaccida	Golden canna	CANFLA
Carex lupulina	Hop sedge	CARLUP
Carya aquatica	Water hickory	CARAQU
Cephalanthus occidentalis	Button bush	CEPOCC
Chrysobalanus icaco	Coco plum	CHRICA
Cladium jamaicense	Sawgrass	CLAJAM
Commelina diffusa	Dayflower	COMDIF
Crinum americanum	Swamp lily	CRIAME
Cyperus retrorsus	Flat sedge	CYPRET
Dichanthelium commutatum	Witchgrass	DICCOM
Dichanthemlium spp		DICSPP
Fern seedling		JUVFER
Ficus microcarpa	Indian laurel ficus	FICMIC
Fraxinus caroliniana	Pop ash	FRACAR
Hydrocotyle spp	Pennywort	HYDSPP
Hypericum spp	St. John's wort	HYPSPP
Ilex cassine	Dahoon holly	ILECAS
Ipomoea indica	Blue morning glory	IMPIND
Itea virginica	Virginia willow	ITEVIR
Laguncularia racemosa	White mangrove	LAGRAC
Ludwigia octivalvus	Primrose willow	LUDOCT
Ludwigia peruviana	Primrose willow	LUDPER
Ludwigia seedling		LUDSEE
Lygodium microphyllum	Old world climbing fern	LYGMIC
Lyonia fruiticosa	Staggerbush	LYOFRU
Mikania scandens	Hemp vine	MIKSCA
Morus rubra	Mulberry	MORRUB
Moss species		MOSSSP

Scientific Name	Common Name	Code
Myrica cerifera	Wax myrtle	MYRCER
Nephrolepis exaltata	Boston fern	NEPEXA
Osmunda cinnamomea	Cinnamon fern	OSMCIN
Osmunda regalis	Royal fern	OSMREG
Parthenocissus quinquefolia	Virginia creeper	PARQUI
Persea barbonia	Red bay	PERBAR
Pluchea odorata	Marsh fleabane	PLUODA
Psidium cattleianum	Strawberry guava	PSICAT
Psychotria nervosa	Wild coffee	PSYNER
Psychotria sulzneri	Wild coffee	PSYSUL
Quercus laurifolia	Laurel oak	QUELAU
Quercus seedling		QUESEE
Quercus virginiana	Live oak	QUEVIR
Rapenea punctata	Myrsine	RAPPUN
Rhabdadenia biflora	Rubber vine	RHABIF
Rhizophora mangle	Red mangrove	RHIMAN
Rhynchospora rariflora	Beak sedge	RHYRAR
Rubus trivialis	Blackberry	RUBTRI
Sabal palmetto	Cabbage palm	SABPAL
Sarcostemma clausum	White vine	SARCLA
Saururus cernuus	Lizard's tail	SAUCER
Schinus terebinthifolius	Brazilian pepper	SCHTER
Senna pendula	Climbing cassia	SENPEN
Serenoa repens	Saw palmetto	SERREP
Smilax bona-nox	Greenbrier	SMIBON
Syngonium podophyllum	Nephthytes	SYNPOD
Syzygium cumini	Java plum	SYZCUM
Taxodium distichum	Bald cypress	TAXDIS
Thelypteris dentata	Downy shield fern	THEDEN
Thelypteris interrupta	Willdenow's maiden fern	THEINT
Thelypteris palustris	Marsh fern	THEPAL
Thelypteris serrata	Meniscium fern	THESER
Tillandria fasciculata	Cardinal airplant	TILFAS
Toxicodendron radicans	Poison ivy	TOXRAD
Tripsacum dactyloides	Gamma grass	TRIDAC
Typha spp.	Cattail	TYPSPP
Unidentified Poaceae		UNIPOA
Unidentified seedling		UNISEE
Unidentified spp.		UNISPP
Urena lobata	Caesar weed	URELOB
Vitis rotundifolia	Grape vine	VITROT
Wedelia trilobata	Creeping oxeye	WEDTRI
Xanthosoma sagittifolium	Elephant ear	XANSAG

Table B-3. Groundcover species list and codes.

Scientific Name	Common Name	Code
Abrus precatorius	Rosary pea	ABRPRE
Acer rubrum	Red maple	ACERUB
Acrostichum danaefolium	Leather fern	ACRDAN
Alternanthera philoxeroides	Alligator weed	ALTPHI
Alternanthera sessilia	Joyweed	ALTSES
Amorpha fruticosa	False indigo	AMOFRU
Annona glabra	Pond apple	ANNGLA
Ardisia escallonioides	Marlberry	ARDESC
Baccharis halimifolia	Salt bush	BACHAL
Blechnum serrulatum	Swamp fern	BLESER
Boehmeria cylindrica	False nettle	BOECYL
Callicarpa americana	Beautyberry	CALAME
Canna flaccida	Golden canna	CANFLA
Carex lupulina	Hop sedge	CARLUP
Carya aquatica	Water hickory	CARAQU
Cephalanthus occidentalis	Button bush	CEPOCC
Chrysobalanus icaco	Coco plum	CHRICA
Cladium jamaicense	Sawgrass	CLAJAM
Commelina diffusa	Dayflower	COMDIF
Crinum americanum	Swamp lily	CRIAME
Cyperus retrorsus	Flatsedge	CYPRET
Dichanthelium commutatum	Witchgrass	DICCOM
Dichanthemlium spp		DICSPP
Fern seedling		JUVFER
Ficus microcarpa	Indian laurel ficus	FICMIC
Fraxinus caroliniana	Pop ash	FRACAR
Hydrocotyle spp	Pennywort	HYDSPP
Hypericum spp	St. John's wort	HYPSPP
Ilex cassine	Dahoon holly	ILECAS
Ipomoea indica	Blue morning glory	IMPIND
Itea virginica	Virginia willow	ITEVIR
Laguncularia racemosa	White mangrove	LAGRAC
Ludwigia octivalvus	Primrose willow	LUDOCT
Ludwigia peruviana	Primrose willow	LUDPER
Ludwigia seedling		LUDSEE
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Lyonia fruiticosa	Staggerbush	LYOFRU
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Scientific Name	Common Name	Code
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Osmunda cinnamomea	Cinnamon fern	OSMCIN
Osmunda regalis	Royal fern	OSMREG
Parthenocissus quinquefolia	Virginia creeper	PARQUI
Persea barbonia	Red bay	PERBAR
Pluchea odorata	Marsh fleabane	PLUODA
Psidium cattleianum	Strawberry guava	PSICAT
Psychotria nervosa	Wild coffee	PSYNER
Psychotria sulzneri	Wild coffee	PSYSUL
Quercus laurifolia	Laurel oak	QUELAU
Quercus seedling		QUESEE
Quercus virginiana	Live oak	QUEVIR
Rapenea punctata	Myrsine	RAPPUN
Rhabdadenia biflora	Rubber vine	RHABIF
Rhizophora mangle	Red mangrove	RHIMAN
Rhynchospora rariflora	Beak sedge	RHYRAR
Rubus trivialis	Blackberry	RUBTRI
Sabal palmetto	Cabbage palm	SABPAL
Sarcostemma clausum	White vine	SARCLA
Saururus cernuus	Lizard's tail	SAUCER
Schinus terebinthifolius	Brazilian pepper	SCHTER
Senna pendula	Climbing cassia	SENPEN
Serenoa repens	Saw palmetto	SERREP
Smilax bona-nox	Greenbrier	SMIBON
Syngonium podophyllum	Nephthytes	SYNPOD
Syzygium cumini	Java plum	SYZCUM
Taxodium distichum	Bald cypress	TAXDIS
Thelypteris dentata	Downy shield fern	THEDEN
Thelypteris interrupta	Willdenow's maiden fern	THEINT
Thelypteris palustris	Marsh fern	THEPAL
Thelypteris serrata	Meniscium fern	THESER
Tillandria fasciculata	Cardinal airplant	TILFAS
Toxicodendron radicans	Poison ivy	TOXRAD
Tripsacum dactyloides	Gamma grass	TRIDAC
Typha spp.	Cattail	TYPSPP
Unidentified Poaceae		UNIPOA
Unidentified seedling		UNISEE
Unidentified spp.		UNISPP
Urena lobata	Caesar weed	URELOB
Vitis rotundifolia	Grape vine	VITROT
Wedelia trilobata	Creeping oxeye	WEDTRI
Xanthosoma sagittifolium	Elephant ear	XANSAG

APPENDIX C:
UF SOIL SURVEY CONDUCTED MAY 2004

Appendix C: UF Soil Survey conducted May 2004 - Transect 1 — Page C-1

Sample ID	Depth (cm)	Length, transect (m)	Lat	Long	Map Unit name	On-site soil series	Soil descr. (cm)	Layer (cm)	Water (cm)	Veg. Desc. Marion	Notes
T1-1-20	0-20						0-15cm: 10YR3/1, fine sand with many uncoated sand grains; 15-20 see next entry	0-15: A horizon; 15-60: E1 horizon	>120	Cabbage Palm, slash pine, we are on the edge of the cypress.	
T1-1-40	20-40						15-60: 10YR5/1 fine sand	same	>120		
T1-1-60	40-60	25	N 26° 56.390'	W 80° 10.321'	Winder fine sand	Riviera Series	same	same	>120		
T1-1-80	60-80						60-90: 10YR7/1 fine sand	60-90: E2	>120		
T1-1-100	80-100						90-120: 10YR4/3 sandy clay loam	90-120 Bt layer	>120		
T1-1-120	100-120						same	" "	>120		
T1-2-20	0-20	65	N 26° 56.409'	W 80° 10.346'			0-30: 5Y2.5/1 clay w/ C2D 10Y5/6 mottles	A	>120	cypress, red maple, water hickory	
T1-2-40	20-40	65	N 26° 56.409'	W 80° 10.346'			same to 30; 30-50: 5Y3/1 Sandy Clay	C1	>120		
T1-2-60	40-60	65	N 26° 56.409'	W 80° 10.346'	Winder fine sand	Aquents	same to 50; 50-60: change to fine sand, 2.5Y5/2	C2	>120		
T1-2-80	60-80	65	N 26° 56.409'	W 80° 10.346'			10YR8/1 fine sand	C3	>120		
T1-2-100	80-100	65	N 26° 56.409'	W 80° 10.346'			10YR3/2 loamy sand	C4	>120		
T1-2-120	100-120	65	N 26° 56.409'	W 80° 10.346'			same	" "	>120		
T1-3-20	0-20	25 (?)	N 26° 56.428'	W 80° 10.365'			0-22: 5Y3/1 sandy clay loam	A	100	cypress, water hickory, red maple.	Waypoint 39
T1-3-40	20-40	25 (?)	N 26° 56.428'	W 80° 10.365'			22-45: white sand	C1	100		
T1-3-60	40-60	25 (?)	N 26° 56.428'	W 80° 10.365'	Winder fine sand		45-100+: change to grey loamy fine sand, 5Y3/1	C2	100		
T1-3-80	60-80	25 (?)	N 26° 56.428'	W 80° 10.365'			same	" "	100		
T1-3-100	80-100	25 (?)	N 26° 56.428'	W 80° 10.365'			same	" "	100		
T1-3-120	100-120	25 (?)	N 26° 56.428'	W 80° 10.365'		Aquents			100		
T1-4-20	0-20	55 (?)	N 26° 56.432'	W 80° 10.367'			10YR4/1 fine sand	A	110		
T1-4-40	20-40	55 (?)	N 26° 56.432'	W 80° 10.367'			20-50: 10YR5/3 fine sand	Bw	110		
T1-4-60	40-60	55 (?)	N 26° 56.432'	W 80° 10.367'			50: same getting loamier, sandy loam	Bt	110		
T1-4-80	60-80	55 (?)	N 26° 56.432'	W 80° 10.367'	Winder Series	Pineda	same	" "	110		
T1-4-100	80-100	55 (?)	N 26° 56.432'	W 80° 10.367'			90-120: loamy sand w/ common shell fragments, 5Y7/1	IIC	110		
T1-4-120	100-120	55 (?)	N 26° 56.432'	W 80° 10.367'			same		110		

Appendix C: UF Soil Survey conducted May 2004 -Transect 2

Sample ID	Depth (cm)	Length,	Lat	Long	Map Unit name	On-site soil series	Soil descr. (cm)	Layer (cm)	Water (	Veg. Desc. Marion Cabbage palm, red maple, cypress	Notes Waypoint 43
T2-1-20	0-20	0-5	N 26° 56.951'	W 80° 10.230'			0: 10YR3/1 fine sand with many uncoated sand grains; 10: 10YR2/2 fine sand	10:Bh (no E)	>120		
T2-1-21	20-40	0-5	N 26° 56.951'	W 80° 10.230'			same to 30. 30: 10YR5/4 color change	30: E1 horizon	>120		
T2-1-22	40-60	0-5	N 26° 56.951'	W 80° 10.230'			same.	E2 horizon	>120		
T2-1-23	60-80	0-5	N 26° 56.951'	W 80° 10.230'	Winder fine sand	Wabasso	10YR6/3 fine sand	E3 horizon	>120		
T2-1-24	80-100	0-5	N 26° 56.951'	W 80° 10.230'			80: 5Y5/1 sandy clay loam with few fine F1P 7.5YR5/8 mottles (red); 90:10YR5/2 loamy sand	Btg1	>120		
T2-1-25	100-120	0-5	N 26° 56.951'	W 80° 10.230'			same to 110. 110-120: 10YR5/2 sandy loam	Btg2	>120		
none	>120	0-5	N 26° 56.951'	W 80° 10.230'			10YR3/3 sand	IIC	>120		
T2-2-20	0-20	55-65	N 26° 56.940'	W 80° 10.184'			5Y2.5/1 Sapric Muck	0-30: Oa horizon	120		Masten Dam, impounded area
T2-2-40	20-40	55-65	N 26° 56.940'	W 80° 10.184'			same to 30. 30: 5Y4/1 sandy clay loam	Btg1	120		
T2-2-60	40-60	55-65	N 26° 56.940'	W 80° 10.184'	Winder fine sand	Chobee	sandy clay loam, lighter in texture	Btg2	120		
T2-2-80	60-80	55-65	N 26° 56.940'	W 80° 10.184'			5Y5/1 sandy loam, sandier.	IIC1	120		
T2-2-100	80-100	55-65	N 26° 56.940'	W 80° 10.184'			5Y5/1sand	IIC2	120		
T2-2-120	100-120	55-65	N 26° 56.940'	W 80° 10.184'			same	""	120		
none	>120	55-65	N 26° 56.940'	W 80° 10.184'			sandy to 204 cm.	" "	120		
T2.2-1-20	0-20	5	N 26° 56.996'	W 80° 10.209'			0: 10YR3/1 fine sand, many uncoated sand grains; 10: 10YR6/2 fine sand	AP horizon E1	>120	Pine tree, live oak, pop ash, cabbage palm, Cocoplum (Chrysobalanus icaco).	We are in a cabbage palm hammock. Waypoint 45
T2.2-1-40	20-40	5	N 26° 56.996'	W 80° 10.209'			same	" "	>120		
T2.2-1-60	40-60	5	N 26° 56.996'	W 80° 10.209'			10YR6/3 fine sand	Bw horizon	>120		
T2.2-1-80	60-80	5	N 26° 56.996'	W 80° 10.209'	Winder fine sand	Pineda	same	" " horizon	>120		
T2.2-1-100	80-100	5	N 26° 56.996'	W 80° 10.209'			same to 90; 90: 10YR6/3 sandy loam with M12D 10YR5/8 mottles and common C2D 10YR6/2 mottles	Bt	>120		
T2.2-1-120	100-120	5	N 26° 56.996'	W 80° 10.209'					>120		
none	>120	5	N 26° 56.996'	W 80° 10.209'			10YR5/3 sand to >120	IIC			
T2.2-2-20	0-20	35-45	N 26° 56.994'	W 80° 10.194'			5Y2.5/1 Sapric muck	Oa	100	cypress	Waypoint 46
T2.2-2-40	20-40	35-45	N 26° 56.994'	W 80° 10.194'			same		100		
T2.2-2-60	40-60	35-45	N 26° 56.994'	W 80° 10.194'			same		100		
T2.2-2-80	60-80	35-45	N 26° 56.994'	W 80° 10.194'	Winder fine sand	Gator muck	same		100		
T2.2-2-100	80-100	35-45	N 26° 56.994'	W 80° 10.194'			5Y2.5/1 Sandy loam	IIC1	100		
T2.2-2-120	100-120	35-45	N 26° 56.994'	W 80° 10.194'			same	" "	100		
none	160-160+	35-45	N 26° 56.994'	W 80° 10.194'			10YR6/2 sand	IIC2	100		

Appendix C: UF Soil Survey conducted May 2004 -Transect 2

Sample ID	Depth (cm)	Length,	Lat	Long	Map Unit name	On-Site soil series	Soil descr. (cm)	Layer (cm)	Water (cm)	Veg. Desc. Marion	Notes
T3-1-20	0-20	0	N 26° 57.665'	W 80° 09.856'			0:10YR2/1; 7.6: 10YR3/1 to 33cm	0: A1 Horizon, 7.6: A2 layer	none	Cabbage Palm,slash pine	This transect has one well
T3-1-40	20-40	0	N 26° 57.665'	W 80° 09.856'			same to 33. 33:10YR6/1	33:E Horizon	none		
T3-1-60	40-60	0	N 26° 57.665'	W 80° 09.856'	Pompano fine sand, occasionally flooded	Nettles	same to 55. 55: 10YR3/2	55: Bh1	none		
T3-1-80	60-80	0	N 26° 57.665'	W 80° 09.856'			same to 75. 75: 10YR2/1, weakly cemented	75: Bh2	none		
T3-1-100	80-100	0	N 26° 57.665'	W 80° 09.856'			same to 90. 90: change layer t	90:Bh3	none		
T3-1-120	100-120	0	N 26° 57.665'	W 80° 09.856'			100: 10YR5/3; 115: 5YR5/1 sandy loam	100:E' Layer; 115: Btg	none		
T3-2-20	0-20	55	N 26° 57.660'	W 80° 09.888'			10YR2/1 stratified sand/sandy clay loam, various texture	A	100	a lot of pop ash	
T3-2-40	20-40	55	N 26° 57.660'	W 80° 09.888'	Pompano fine sand, occasionally flooded	Aquents	10YR2/1 Sandy clay loam	C1	100		
T3-2-60	40-60	55	N 26° 57.660'	W 80° 09.888'			7.5YR2/0	C2	100		
T3-2-80	60-80	55	N 26° 57.660'	W 80° 09.888'			10YR4/2 Sandy texture	C3	100		
T3-2-100	80-100	55	N 26° 57.660'	W 80° 09.888'			10YR5/3 Sand	C4	100		
	151	55	N 26° 57.660'	W 80° 09.888'			5GY6/1 Sandy clay	C5	100		
T3-3-20	0-20	79	N 26° 57.667'	W 80° 09.911'			10YR2/1 Sandy clay	A	85	cypress, pop ash, Brazilian pepper, pond apple	Waypoint 36
T3-3-40	20-40	79	N 26° 57.667'	W 80° 09.911'			same to 35. 35: change in texture to 10YR3/1 sand	C1	85		
T3-3-60	40-60	79	N 26° 57.667'	W 80° 09.911'	Pompano fine sand, occasionally flooded	Aquents	10YR3/1 stratified sand and sandy clay	C2	85		
T3-3-80	60-80	79	N 26° 57.667'	W 80° 09.911'			same to 70. 70: 10YR4/1 sand	C3	85		
T3-3-100	80-100	79	N 26° 57.667'	W 80° 09.911'			sand 10YR7/1	C4	85		
T3-3-120	100-120	79	N 26° 57.667'	W 80° 09.911'			same	" "	85		
T3-4-20	0-20	105	N 26° 57.678'	W 80° 09.922'			10YR3/1	A Layer	70	pop ash more than any other site, cypress, red maple, water hickory	
T3-4-40	20-40	105	N 26° 57.678'	W 80° 09.922'			24: change to 10YR7/2 fine sand matrik with MPP 2.5YR44 iron red mottling	C1	70		
T3-4-60	40-60	105	N 26° 57.678'	W 80° 09.922'	Pompano fine sand, occasionally flooded	Aquents	same	" "	70		
T3-4-80	60-80	105	N 26° 57.678'	W 80° 09.922'			same to 70. 70:texture change to 10YR7/1 stratified sandy loam / 2.5YR5/0 sand	C2	70		
T3-4-100	80-100	105	N 26° 57.678'	W 80° 09.922'			10YR3/2, still stratification	C3	70		
T3-4-120	100-120	105	N 26° 57.678'	W 80° 09.922'			115: change to 10YR7/1 sand to 120+	C4	70		

Appendix C: UF Soil Survey conducted May 2004 -Transect 4

27-May-04

Sample ID	Depth (cm)	Length, transec	Lat	Long	Map Unit name	On-Site soil ser	Soil descr. (cm)	Horizon (cm)	Water (cm)	Veg. Desc. Marion	Notes
T4-1-20	0-20	5	N 26° 58.161'	W 80° 09.902'	Pompano fine sand, occasionally flooded	Smyrna soil	10YR3/1 fine sand with many uncoated sand grains	A	>120	live oak, w. hickory, cypress, saw palmetto in upland	
T4-1-21	20-40	5	N 26° 58.161'	W 80° 09.902'			10YR4/2 fine sand	E	>120		
T4-1-22	40-60	5	N 26° 58.161'	W 80° 09.902'			10YR3/2 fine sand	Bh	>120		
T4-1-23	60-80	5	N 26° 58.161'	W 80° 09.902'			same	Bh	>120		
T4-1-24	80-100	5	N 26° 58.161'	W 80° 09.902'			same to 90. 90: 10R4/3 fine sand	C1	>120		
T4-1-25	100-120	5	N 26° 58.161'	W 80° 09.902'			10YR5/3 fine sand; 110 10YR6/2	100: C2; 110: C3	>120		
T4-2-20	0-20	75-85	N 26° 58.136'	W 80° 09.868'	Pompano fine sand, occasionally flooded	Histic Haplaquoll, frequently flooded	10YR2/1 Sapric material	Oa	106	cypress, pop ash, water hickory, lots	Waypoint 42
T4-2-40	20-40	75-85	N 26° 58.136'	W 80° 09.868'			Same to 30. 30: fine sandy loam.	30: C1	106		Entire area run over by pigs.
T4-2-60	40-60	75-85	N 26° 58.136'	W 80° 09.868'			Sandy clay loam	C2	106		Near a well
T4-2-80	60-80	75-85	N 26° 58.136'	W 80° 09.868'			10YR4/1 fine sandy loam with stra. layers of 10YR6/2 sand	C3	106		
T4-2-100	80-100	75-85	N 26° 58.136'	W 80° 09.868'			same		106		
T4-2-120	100-120	75-85	N 26° 58.136'	W 80° 09.868'			same		106		
none	163-204+	75-85	N 26° 58.136'	W 80° 09.868'			10YR7/2 sand, entire column is stratified.	C4	106		
T4-3-20	0-20	115	N 26° 58.107'	W 80° 09.847'	Pompano fine sand, occasionally flooded	Aquents	many uncoated sand grains; 6: stratified	A ..6: C1		W. hickory, red maple, laurel oak, cypress.	
T4-3-40	20-40	115	N 26° 58.107'	W 80° 09.847'			same	""			
T4-3-60	40-60	115	N 26° 58.107'	W 80° 09.847'			same				
T4-3-80	60-80	115	N 26° 58.107'	W 80° 09.847'			same				
T4-3-100	80-100	115	N 26° 58.107'	W 80° 09.847'			same to 90. 90: sandy clay loam stra. with 5YR3/2 sand	C2			
T4-3-120	100-120	115	N 26° 58.107'	W 80° 09.847'			same				
none	120-204+	115	N 26° 58.107'	W 80° 09.847'			alternating layers of sand / sandy clay loam	C3			

Appendix C: UF Soil Survey conducted May 2004 -Transect 5

27-May-04

Sample ID	Depth (cm	Length, tra	Lat	Long	Map Unit name	On-Site soil series	Soil descr. (cm)	Horizon (c	Water (cm	Veg. Desc. Marion
T5.1-1-20	0-20	5	N 26° 58.529'	W 80° 10.184'	Pompano fine sand, occasionally flooded	Pompano fine sand, occasionally flooded	0: 10YR3/1 fine sand; 10: 10YR5/2 fine sand	0-10:A	>120	live oak, pop ash, saw palmetto
T5.1-1-40	20-40	5	N 26° 58.529'	W 80° 10.184'			same	C1	>120	
T5.1-1-60	40-60	5	N 26° 58.529'	W 80° 10.184'			same		>120	
T5.1-1-80	60-80	5	N 26° 58.529'	W 80° 10.184'			10YR6/2 fine sand	C2	>120	
T5.1-1-100	80-100	5	N 26° 58.529'	W 80° 10.184'			same		>120	
T5.1-1-120	100-120	5	N 26° 58.529'	W 80° 10.184'			same to 110. 110: 10YR4/3 fine sand	110: C3	>120	
T5.1-2-20	0-20	25-35	N 26° 58.517'	W 80° 10.177'	Pompano fine sand, occasionally flooded	Aquents	0: 10YR3/1 fine loamy sand; 10: sandy clay loam	0-10: A..C1	>120	cypress, water hickory, red maple, sable palm.
T5.1-2-40	20-40	25-35	N 26° 58.517'	W 80° 10.177'			10YR6/1 fine sand	C2	>120	
T5.1-2-60	40-60	25-35	N 26° 58.517'	W 80° 10.177'			same		>120	
T5.1-2-80	60-80	25-35	N 26° 58.517'	W 80° 10.177'			10YR4/2 loamy fine sand	C3	>120	
T5.1-2-100	80-100	25-35	N 26° 58.517'	W 80° 10.177'			10YR3/3 loamy fine sand	C4	>120	
T5.1-2-120	100-120	25-35	N 26° 58.517'	W 80° 10.177'			same		>120	
none	150+	25-35	N 26° 58.517'	W 80° 10.177'			same to 150+		>120	
T5.2-1-20	0-20	25	N 26° 58.554'	W 80° 10.171'	Pompano fine sand, occasionally flooded	Aquents	0: 10YR 6/3 sand; 5: 5Y 2.5/1 sandy clay loam with C1P10YR5/8 mottles	A…C1	120	red maple, water hickory, cypress
T5.2-1-40	20-40	25	N 26° 58.554'	W 80° 10.171'			same		120	
T5.2-1-60	40-60	25	N 26° 58.554'	W 80° 10.171'			10YR6/2 fine sand	C2	120	
T5.2-1-80	60-80	25	N 26° 58.554'	W 80° 10.171'			color change to 6YR7/2. 70: 2.5Y4/2 fine loamy sand	C3	120	
T5.2-1-100	80-100	25	N 26° 58.554'	W 80° 10.171'			same		120	
T5-3-120	100-120	25	N 26° 58.554'	W 80° 10.171'			same to 110. 110: 10YR6/7 matrix fine sand with10YR4/3 organic streaks	C4	120	
T5.2-2-20	0-20	80	N 26° 58.542'	W 80° 10.141'	Pompano fine sand, occasionally flooded	Aquents	10YR3/2 sandy clay loam with 7.5YR4/4 mottles	A	125	red maple, water hickory
T5.2-2-40	20-40	80	N 26° 58.542'	W 80° 10.141'			Sandy clay	C1	125	
T5.2-2-60	40-60	80	N 26° 58.542'	W 80° 10.141'			same to 50. 50: 10YR3/1 sandy loam	C2	125	
T5.2-2-80	60-80	80	N 26° 58.542'	W 80° 10.141'			same to 70: loamy sand, same color	C3	125	
T5.2-2-100	80-100	80	N 26° 58.542'	W 80° 10.141'			same		125	
T5.2-2-120	100-120	80	N 26° 58.542'	W 80° 10.141'			10YR7/2 sand with 10YR4/2 s	streaking	125	
none	120+	80	N 26° 58.542'	W 80° 10.141'			same	C4^	125	

Appendix C: UF Soil Survey conducted May 2004 -Transect 6

Sample ID	Depth (cm)	Length, tra	Lat	Long	Map Unit name	On-Site soil series	Soil descr.	Layer (cm)	Water (cm)	Veg. Desc. Marion	Notes		
T6-1-20	0-20	5	N 26° 59.260'	W 80° 09.405'	Nettles sand	Pompano sand	10YR 3/1sand, many uncoated sand grains, few accretions	A horizon: 0	not found	Slash pine, live oak, saw palmetto, gallberry	Nettles sand, poorly drained, transitional between Nettles and Waveland Depressional,		
T6-1-40	20-40	5	N 26° 59.260'	W 80° 09.405'			20-30: 10YR 4/2 fine sand; 30-40:10YR 5/2 fine sand, transition to…	C1	not found				
T6-1-60	40-60	5	N 26° 59.260'	W 80° 09.405'			10YR 5/2 sand	C2	not found				
T6-1-80	60-80	5	N 26° 59.260'	W 80° 09.405'			10YR 6/2	C3 horizon: 60	not found				
T6-1-100	80-100	5	N 26° 59.260'	W 80° 09.405'			same to 110		not found				
T6-1-120	100-120	5	N 26° 59.260'	W 80° 09.405'			110: 10YR4/3 sand	C4:110, not typical horizon, n	not found				
none	204	5	N 26° 59.260'	W 80° 09.405'			sandy to 204 cm+		not found				
T6-2-20	0-20	26	N 26° 59.272'	W 80° 09.409'	Terra Ceia Variant muck	Terra Ceia Variant muck	5YR 2.5/1 Muck	OA-1	4	Cypress, pond apple, red maple, white/red mangrove	highly organic, higly decomposed, original plants are unrecognizable (lots of roots found)		
T6-2-40	20-40	26	N 26° 59.272'	W 80° 09.409'			5YR 2.5/1 Muck	OA-1	4				
no sample	204	26	N 26° 59.272'	W 80° 09.409'			no sand layer found, not viewed	not viewed	4				
T6-3-20	0-20	115	N 26° 59.321'	W 80° 09.406'	Terra Ceia Variant muck	Terra Ceia Variant muck	5YR 2.5/1 Muck	OA-1	33	red/white mangroves, pond apples	Waypoint 30&31		
T6-3-40	20-40	115	N 26° 59.321'	W 80° 09.406'			5YR 2.5/1 Muck	OA-1	33				
T6-3-60	40-60	115	N 26° 59.321'	W 80° 09.406'			5YR 2.5/1 Muck	OA-1	33				
no sample	204	115	N 26° 59.321'	W 80° 09.406'			Muck 204+, no sand found		33				
T6-4-20	0-20	130	NA	NA	Terra Ceia Variant muck	Terra Ceia Variant muck	5YR 2.5/1 Muck	OA-1	15	pond apple, red mangrove, probably white mangrove, live cypress; thick mangrove			
T6-4-40	20-40	130	NA	NA					15				
T6-4-60	40-60	130	NA	NA					15				

Appendix C: UF Soil Survey conducted May 2004 -Transect 7 Page C-7

Sample ID	Depth (cm)	Length,	Lat	Long	Map Unit nam	On-Site soil serie	Soil descr. (cm)	Layer (cm)	Water (cm)	Veg. Desc. Marion	Notes		
T7-1-20	0-20	0	N 26° 59.045'	W 80° 09.510'	Terra Ceia Variant Muck	Immokalee series	fine grained sand, 10YR3/1, with many uncoated sand grains	0:A horizon	none	Live oak, saw palmatto(at high points)	Waypoint 32; Hobe: H20 at 60-80" during wet season, excessively drained; high point drops down quickly, transitional area. Section 20,Township 40S, Range 42E. Soil compact, hard to core.		
T7-1-40	20-40	0	N 26° 59.260'	W 80° 09.405'			same but 10YR6/1, to 70 cm	E	none				
T7-1-60	40-60	0	N 26° 59.260'	W 80° 09.405'					none				
T7-1-80	60-80	0	N 26° 59.260'	W 80° 09.405'			70: 10YR4/3	70:Bh	none				
T7-1-100	80-100	0	N 26° 59.260'	W 80° 09.405'			80:loamy fine sand, 10YR2/2; 90:Bh2	90:Bh2	none				
T7-1-120	100-120	0	N 26° 59.260'	W 80° 09.405'					none				
none	204	0	N 26° 59.260'	W 80° 09.405'			sandy to 204+ cm	Cg	none				
T7-2-20	0-20	15	N 26° 59.043'	W 80° 09.538'	Terra Ceia Variant Muck	Terra Ceia Variant	5YR2.5/1, muck no sand	Oa	10	Young cypress, poison ivy.	mapped as Okeelanta		
T7-2-40	20-40	15	N 26° 59.043'	W 80° 09.538'			5YR2.5/1, muck no sand	" "	10				
T7-3-20	0-20	165	N 26° 59.079'	W 80° 09.560'	Terra Ceia Variant Muck	Okeelanta Variant	5YR2.5/1, muck no sand	Oa	15	Pond Apples, pop ash, cypress	Waypoint 33; 4 wells at this transect.		
T7-3-40	20-40	165	N 26° 59.079'	W 80° 09.560'					15				
no sample	180	165	N 26° 59.079'	W 80° 09.560'			180:sand layer	Cg	15				
T7-4-20	0-20	145	N 26° 59.101'	W 80° 09.579'	Terra Ceia Variant Muck	Okeelanta Variant Muck	5YR2.5/1 muck	Oa	27	Red mangrove, cabbage palm, swamp fern, pond apple.	Waypoint 34		
T7-4-40	20-40	145	N 26° 59.101'	W 80° 09.579'					27				
T7-4-60	40-60	145	N 26° 59.101'	W 80° 09.579'					27				
no sample	130	145	N 26° 59.101'	W 80° 09.579'			130:sand layer	Cg					

May 18th, 2004

Appendix C: UF Soil Survey conducted May 2004 -Transect 8   Page C-8

Sample ID	Depth (cm)	Length, t	Lat	Long	Map Unit name	On-Site soil series	Soil descr.
T8-1-20	0-20	0-10	N 26° 59.764'	W 80° 09.325'	Nettles Sand	Myakka Sand	A .. sandy to 80 inches(or 204 cm)
T8-1-40	20-40	0-10	N 26° 59.764'	W 80° 09.325'			E
T8-1-60	40-60	0-10	N 26° 59.764'	W 80° 09.325'			
T8-1-80	60-80	0-10	N 26° 59.764'	W 80° 09.325'			Bh Layer 60 cm;Myakka Soil: an inclusion in the Nettles Unit
T8-1-100	80-100	0-10	N 26° 59.764'	W 80° 09.325'			Cg
T8-1-120	100-120	0-10	N 26° 59.764'	W 80° 09.325'			
T8-2-20	0-20	35	N 26° 59.769'	W 80° 09.347'	Bessie Muck	Okeelanta Variant Muck	Oa
T8-2-40	20-40	35	N 26° 59.769'	W 80° 09.347'			
T8-2-60	40-60	35	N 26° 59.769'	W 80° 09.347'			
T8-2-80	60-80	35	N 26° 59.769'	W 80° 09.347'			
T8-2-100	80-100	35	N 26° 59.769'	W 80° 09.347'			
T8-2-120	100-120	35	N 26° 59.769'	W 80° 09.347'			Cg
no sample	122	35	N 26° 59.769'	W 80° 09.347'			Mineral/sand at 122 cm
T8-3-20	0-20	65-75	N 26° 59.767'	W 80° 09.367'	Okeelanta, an inclusion in the Bessie Muck	Okeelanta, an inclusion in the Bessie Muck	Oa
T8-3-40	20-40	65-75	N 26° 59.767'	W 80° 09.367'			
T8-3-60	40-60	65-75	N 26° 59.767'	W 80° 09.367'			
T8-3-80	60-80	65-75	N 26° 59.767'	W 80° 09.367'			
T8-3-100	80-100	65-75	N 26° 59.767'	W 80° 09.367'			
T8-3-120	100-120	65-75	N 26° 59.767'	W 80° 09.367'			Cg
no sample	196	65-75	N 26° 59.767'	W 80° 09.367'			Mineral/sand layer at 196 cm
T8-4-20	0-20	115	N 26° 59.762'	W 80° 09.391'	Bessie Muck	Okeelanta Variant Muck	Oa
T8-4-40	20-40	115	N 26° 59.762'	W 80° 09.391'			
T8-4-60	40-60	115	N 26° 59.762'	W 80° 09.391'			Cg
140	NS	115	N 26° 59.762'	W 80° 09.391'			Mineral layer at 140 cm

Appendix C: UF Soil Survey conducted May 2004 -Transect 9 Page C-9

Sample ID	Depth (cm)	Length, transect (m)	Lat	Long	Map Unit name	On-Site soil series	soil description	Water Table (cm)	Veg. description Marion	Notes
T9-1-20	0-20	0-10	N 26° 59.373'	W 80° 08.646'	Pomello Sand, 0 to 5% slopes	Pomello Series		>140	Cabbage palms died only in this transect	
T9-1-40	20-40	0-10	N 26° 59.373'	W 80° 08.646'			A	>140		
T9-1-60	40-60	0-10	N 26° 59.373'	W 80° 08.646'				>140		
T9-1-80	60-80	0-10	N 26° 59.373'	W 80° 08.646'			E	>140		
T9-1-100	80-100	0-10	N 26° 59.373'	W 80° 08.646'				>140		
T9-1-120	100-120	0-10	N 26° 59.373'	W 80° 08.646'			Bh	>140		
T9-1-140	120-140	0-10	N 26° 59.373'	W 80° 08.646'			Spodic Horizon at 125 cm	>140		
T9-2-20	0-20	25-35	NA	NA	Okeelanta Variant Muck	Okeelanta Variant Muck	Oa	46	A very salty area.	
T9-2-40	20-40	25-35	NA	NA				46		
T9-2-60	40-60	25-35	NA	NA				46		
T9-2-80	60-80	25-35	NA	NA			Cg	46		
no sample	155						Mineral layer at 155 cm	46		
T9-3-20	0-20	55-65	N 26° 59.341'	W 80° 08.641'	Okeelanta Variant Muck	Gator Muck, flooded	Oa	40		
T9-3-40	20-40	55-65	N 26° 59.341'	W 80° 08.641'				40		
T9-3-60	40-60	55-65	N 26° 59.341'	W 80° 08.641'				40		
T9-3-80	60-80	55-65	N 26° 59.341'	W 80° 08.641'			Cg	40		
T9-3-100	80-100	55-65	N 26° 59.341'	W 80° 08.641'			Mineral layer at 90 cm	40		
T9-4-20	0-20	175-185	N 26° 59.281'	W 80° 08.634'	Okeelanta Variant Muck	Okeelanta Variant Muck	Oa	25		
T9-4-40	20-40	175-185	N 26° 59.281'	W 80° 08.634'			Cg	25	Can't sample due to effects of w. table.	
no sample	168	175-185	N 26° 59.281'	W 80° 08.634'			Mineral layer at 168 cm	25		

Appendix C: UF Soil Survey conducted May 2004 -Transect 10									Page C-10
Sample ID	**Depth (cm**	**Length, transect (**	**Lat**	**Long**	**Map Unit name**	**On-Site soil series**	**Water (cm)**	**Veg. Desc. Marion**	**Notes**
T10-1-20	0-20	0-5	N 27° 00.058'	W 80° 07.036'	Waveland Sand, Depressional	Waveland depressional, sandy all the way down	25	old freshwater marsh?	
T10-1-40	20-40	0-10	N 27° 00.058'	W 80° 07.036'		Waveland depressional	25		
T10-1-60	40-60	0-10	N 27° 00.058'	W 80° 07.036'		Waveland depressional	25		
T10-1-80	60-80	0-10	N 27° 00.058'	W 80° 07.036'		Waveland depressional	25		
T10-1-100	80-100	0-10	N 27° 00.058'	W 80° 07.036'		Waveland depressional, Bh begins at 80 cm	25		
T10-2-20	0-20	25-35 (30)	N 27° 00.054'	W 80° 07.022'	Salerno Sand	Okeelanta Muck Variant	32	Take waypoint 26, mapped as Waveland in Soil Survey	
T10-2-40	20-40	25-35 (30)	N 27° 00.054'	W 80° 07.022'		Okeelanta Muck Variant	32		
T10-2-60	40-60	25-35 (30)	N 27° 00.054'	W 80° 07.022'		Okeelanta Muck Variant	32		
no sample	96	25-35 (30)	N 27° 00.054'	W 80° 07.022'		Mineral/sand layer at 96 cm (96-150+)	32		
T10-3-20	0-20	55-65	N 27° 00.057'	W 80° 07.004'	Salerno Sand	Sanibel Muck	40		Take waypoint 27
T10-3-40	20-40	55-65	N 27° 00.057'	W 80° 07.004'		Sand at 30 cm	40		
T10-3-60	40-60	55-65	N 27° 00.057'	W 80° 07.004'		Sandy to 60+	40		
T10-4-20	0-20		N 27° 00.062'	W 80° 06.997'	Satellite Variant Sand	Aquents	50	Take waypoint 28,water is low	
T10-4-40	20-40		N 27° 00.062'	W 80° 06.997'		Loamy Mineral layer at 50 cm, sandy to 80+ cm	50		
T10-4-60	40-60		N 27° 00.062'	W 80° 06.997'			50		
T10-4-80	60-80		N 27° 00.062'	W 80° 06.997'			50		

APPENDIX D:
VEGETATION STUDY COMPARISONS

Table D-1. Vegetation study comparisons.
X=1993-1994 Ward and Roberts, 0=2003 Study and Y=2006 Observations.

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
†**Abrus precatorius*	**Rosary Pea**	OY									OY	
Acer rubrum	**Red Maple**	XOY	XOY	X	XOY	XOY	XOY	XOY	OY	OY		OY
Acrostichum danaeifolium	**Giant Leather Fern**	XOY	XOY	XOY	XOY	XOY	XY	XOY	OY	OY	OY	OY
**Alternanthera philoxeroides*	**Alligator Weed**	XOY		X								
**Alternanthera sessilis*	**Sessile Joyweed**	O					X					
†*Ambrosia artemisiifolia*	**Common Ragweed**				Y							
Ammannia latifolia	**Toothcup**	Y										
Amorpha fruticosa	**Bastard Indigo**							XOY	OY	Y	O	
Ampelopsis arborea	**Pepper Vine**				Y							
Annona glabra	**Pond Apple**	OY	OY	X	XOY	XOY		XOY	OY	OY	OY	OY
Apios americana	**Groundnut**		X		XOY							
Apteria aphylla	**Nodding Nixie**			X								
**Ardisia elliptica*	**Shoebutton**									Y		
†*Ardisia escallonioides*	**Marlberry**	XOY	XOY	XOY	X	XY	XOY	Y		O		
Avicennia geminanas	**Black Mangrove**										O	
Azolla caroliniana	**Mosquito Fern**	X										
Baccharis glomeruliflora	**Groundsel Tree**				X	X	O	XY	OY	OY		OY
Baccharis halimifolia	**Salt Bush**								O	O		
Bacopa monnieri	**Herb-of-Grace**							XOY	OY	OY	OY	OY
†*Bejaria racemosa*	**Tar Flower**							OY	Y			
†*Bidens alba*	**Beggar Ticks**	Y					O					
†**Bischofia javanica*	**Bishop Wood**						O					
Blechnum serrulatum	**Swamp Fern**	XOY	XOY	XOY	XOY	XOY	XOY	XOY	OY	OY	OY	OY

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
Boehmeria cylindrica	False Nettle	XOY	XY	XOY	XOY	XOY	XOY	Y	OY	OY		
†*Callicarpa americana*	American Beautyberry	XOY	XO	XOY	X	X	XY		Y		Y	
Campyloneurum phyllitidis	Strap Fern				XY	X						
Canna flaccida	Golden Canna				XO		XY					
Carex lupuliformis	Hop Sedge	O			Y	Y	OY			Y		
Carya aquatica	Water Hickory	Y	XO	X	XY	XOY	XOY	Y				
Cassytha filiformis	Love Vine									Y		
Cephalanthus occidentalis	Buttonbush	XOY	XOY		XOY	XOY	Y	XO	OY	OY		Y
†*Chamaecrista fasciculata*	Partridge Pea				XOY					Y		
†*Chromolaena odorata*	Jack-in-the-Bush	XY					Y					
Chrysobalanus icaco	Coco-plum	XY	Y	XOY						OY	OY	
†*Chrysophyllum oliviforme*	Satinleaf			X								
**Citrus* sp.		OY										
Cladium jamaicense	Saw Grass									Y		OY
**Commelina diffusa*	Dayflower	XOY	XO	XOY	XOY	X	XOY					
Crotalaria pallida	Mucronata										O	
Crinum americanum	Swamp Lily	XOY	XOY	XOY	XOY	XOY	XY	XOY	OY	OY	Y	OY
Cynoglossum virginianum	Wild Comfrey								Y	Y		
Cyperus distinctus	Swamp Flat Sedge									Y		
Cyperus haspan	Haspan Flat Sedge						X					O
Cyperus ligularis	Swamp Flat Sedge				X	Y	XY	Y		Y	OY	
Cyperus odoratus	Fragrant Flat Sedge	Y			?		Y			Y		Y
Cyperus retrorsus	Flat Sedge			O							Y	
Cyperus surinamensis	Tropical Flat Sedge						X					
Cyperus tetragonus	Four Angle Flat Sedge			X								
Dalbergia ecastaphyllum	Coin Vine							Y	Y	OY	OY	Y
†**Desmodium incanum*	Zarzabacoa	X										

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
	Comun											
†**Desmodium triflorum*	**Beggar Weed**									O	O	
†*Dicanthelium aciculare*	**Needle Leaf Witch Grass**	X						X				
Dicanthelium acuminatum	**Tapered Witch Grass**					Y						
Dicanthelium commutatum	**Variable Witch Grass**	XOY	X	XY	XY	X	XOY	X	Y	Y		
†*Dicanthelium laxiflorum*	**Open Flower Witch Grass**			X		Y		Y			Y	
+*Dicanthelium* spp.				O	O	O	O	O	O			
Dichromena colorata	**White-top Sedge**				Y							
Diodia virginiana	**Buttonweed**						XY	Y		Y		Y
Diospyros virginiana	**Persimmon**									Y		
Echinochloa muricata	**Barn Yard Grass**						X					Y
Echinochloa walteri	**Coast Cockspur**						XY					
Eclipta prostrata	**False Daisy**	XY	Y	Y	Y	Y	XY					
**Eichhornia crassipes*	**Water hyacinth**	XY										
Eleocharis baldwinii	**Road Grass**							O				
Encyclia tampensis	**Butterfly Orchid**						Y		Y			
†*Erechtites hieraciifolia*	**Fire Weed**	Y	Y	Y	OY	Y	Y	Y	Y	Y		
†*Erythrina herbacea*	**Coralbeans**		X				XY					
Eulophia alta	**Wild Coco**				X		Y					
Eupatorium capillifolium	**Dog Fennel**	Y		Y	Y	Y				Y	Y	Y
Eupatorium rotundifolium	**False Hoarhound**	X										
Fern seedling		O		O					O			
Ficus aurea	**Strangler Fig**	X	X	XY	XOY	XO		X			O	
+**Ficus microcarpa*	**Indian Laurel Ficus**										O	
Fraxinus caroliniana	**Pop Ash**	Y	XOY	XOY	XOY	XOY	XOY	OY	OY	OY		
†*Galactia* sp.		Y			XOY		Y					

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
Galium tinctorium	**Bedstraw**	Y										
**Gomphrena serrata*	**Globe Amaranth**										OY	
Grass seedling						O		Y	Y		Y	
Gratiola ramosa	**Creeping Hedge Hyssop**	X	X	X	X	X	X					
Hydrocotyle sp.	**Pennywort**	XOY	XOY	XOY	XOY	XOY	XOY	OY	OY	OY		OY
**Hygrophila polysperma*	**Indian Swamp Weed**	Y	Y	Y			OY					
Hypericum hyperiocoides	**St. Andrew's Cross**				Y	XY				Y		
Hypericum spp.	**St. John's Wort**				O	Y						
†*Hypoxis juncea*	**Yellow-star Grass**						X					
Hyptis alata	**Musky Mint**				XOY	X	X		OY	Y		
Ilex cassine	**Dahoon Holly**				XOY		XOY	XOY	Y	Y		OY
†*Ilex glabra*	**Inkberry, Gallberry**						X	XY	OY			
Ipomoea alba	**Moonflowers**	Y	XY	XY	X		Y					
Ipomoea cordatotriloba	**Tie Vine**									Y		
Ipomoea indica	**Morning-glory**	XO	O		OY	O	XOY	O		Y		
Itea virginica	**Virginia Willow**	X	XOY	XOY	XOY	XOY	XO		OY	OY		
Juncus marginatus	**Grass Leaf Rush**						Y					
Laguncularia racemosa	**White Mangrove**							XOY	OY	OY	OY	OY
Licania michauxii	**Gopher Apple**										O	
**Limnophila sessiliflora*	**Asian Marsh Weed**	X			XY	XOY	Y					
Ludwigia alata										Y		
Ludwigia erecta	**Yerba-De-Jicotea**	X										
Ludwigia lanceolata	**Lance Leaf Primrose Willow**							X				
Ludwigia octovalvis	**Mexican Primrose Willow**						XY	XY	Y	OY		
**Ludwigia peruviana*	**Peruvian Primrose Willow**	XY								Y		
Ludwigia repens	**Creeping Primrose Willow**	Y	Y	Y	XO	XOY	X	X	OY	OY		O

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
Ludwigia seedling		O			O		O		OY	OY		
**Lygodium microphyllum*	Old World Climbing Fern	Y	XY		XOY	XOY	XY	XOY	Y	OY	O	OY
†*Lyonia fruiticosa*	Stagger Bush							Y	OY		Y	
†*Lyonia lucida*	Fetterbush							OY	OY		OY	
Lythrum alatum	Winged Loose Strife						Y					
†*Melanthera nivea*	Square Stem											
Melothria pendula	Creeping Cucumber		Y	Y			XY					
Micranthemum glomeratum	Baby's Tears				O							
†*Mikania cordifolia*	Keys Hemp Vine			X	X	Y			Y	Y		
Mikania scandens	Climbing Hemp Vine		OY	Y	XOY	XY	XY	XY	OY	OY		OY
†*Mimosa quadrivalvis*	Sensitive Briar				XOY	Y		XY			OY	
Mitreola petiolata	Miterwort			X								
†**Momordica charantia*	Wild Balsam Apple						X					
Morus rubra	Red Mulberry	O		XY						O		
Moss spp.		O										
Myrica cerifera	Wax Myrtle				Y	OY	XO	XOY	OY	OY		OY
Nephrolepis biserrata	Boston Fern							X		Y		
Nephrolepis cordifolia					Y							
Nephrolepis exaltata	Boston Fern	X	XO		X	X		X	OY	OY	OY	
**Nephrolepis multiflora*	Boston Fern			XY		Y						
Oplisemus hirtellus	Woods Grass	XY		XY								
Osmunda cinnamomea	Cinnamon Fern				X	XY	X	XY	OY	OY		
Osmunda regalis	Royal Fern	O	XOY		XO	XY	X	XOY	OY	OY		
Panicum hians	Gaping Panicum						X					
**Panicum maximum*	Guinea Grass						Y					
Panicum rigidulum	Redtop Panicum	X		X	XOY	XOY	XY			OY		
Panicum virgatum	Switchgrass			X								OY

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
Parietaria floridana	**Pellitory**	Y		Y								
Parthenocissus quinquefolia	**Virginia Creeper**	XO	OY			XOY						
Paspalum conjugatum	**Sour Paspalum**						X					
Paspalum setaceum	**Thin Paspalum**				XY							
†*Passiflora incarnata*	**Purple Passion Flower**										Y	
Persea borbonia	**Red Bay**			Y			OY	Y	Y	OY		O
Persea palustris	**Swampbay**											
Phlebodium aureum	**Golden Polypody**	XY	X	XY	X	X	XY	XY		Y	O	Y
Phragmites australis	**Common Reed**						X					
†*Phyla nodiflora*	**Frog-fruit, Carpetweed**						X					
Phytolacca americana	**Pokeweed**			Y			Y					
†*Pinus elliottii*	**Slash Pine**	XOY		XO	XOY			XOY			OY	OY
Pistia stratiotes	**Water-lettuce**	X	Y	Y								
Pityopsis graminifolia	**Silk Grass**										OY	
Pleopeltis polypodioides	**Resurrection Fern**	Y	Y	XY	XY	XOY	XY	Y		Y		OY
Pluchea odorata	**Sweetscent**	X			XY	Y	XY	Y	Y	Y		Y
†*Polygonella polygama*											Y	
Polygonum hydropiperoides	**Mild Water-pepper**	X		X	Y	Y	Y	Y	Y	Y		OY
Polygonum punctatum	**Dotted Smartweed**	XY	X	Y	X	X	XY		O	O		
Pontederia cordata	**Pickerelweed**				XY	XY	XY	XY	Y	Y		
Portulaca oleracea	**Little Hogweed**										Y	
Pouzolzia zeylanica	**Pouzoulz's Bush**	Y			XY	Y	Y					
Psidium cattleianum	**Strawberry Guava**	X	X					XOY	Y	OY	OY	OY
Psidium guajava	**Guava**				X					Y		
Psilotum nudum	**Whisk fern**				X			XOY	Y			OY
+*Psychotria nervosa*	**Wild Coffee**	XOY	OY	XY	XOY	XOY	XOY		OY			
+*Psychotria sulzneri*	**Wild Coffee**	XOY	XOY	XY	XOY	OY	XOY					
†*Pteridium aquilinum*	**Bracken Fern**	X			Y	Y	XY	XY	Y		OY	

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
Ptilimnium capillaceum	**Mock Bishop Weed**	Y	Y	Y	Y	Y	Y	Y				
**Ptychosperma macarthurii*	**MacArthur's Palm**										Y	
Quercus geminata								Y			O	
Quercus laurifolia	**Laurel Oak**	XOY	XOY	XO	XOY	XO	XOY				OY	OY
†*Quercus myrtifolia*	**Myrtle Oak**					O		Y			OY	
+*Quercus* seedling		O			O		OY	O	O			
†*Quercus virginiana*	**Live Oak**	XOY			O	OY	XOY	XOY	OY			
†*Rapanea punctata*	**Myrsine**				XOY	Y	XOY	OY	OY	OY		OY
Rhabdadenia biflora	**Rubber Vine**							XOY	OY	Y	OY	OY
Rhizophora mangle	**Red Mangrove**							XOY	OY	OY	OY	OY#
†*Rhus copallinuum*	**Winged Sumac**							Y	Y	Y	OY	
Rhynchospora colorata	**White-top sedge**						Y					
Rhynchospora decurrens	**Swamp-forest Beakrush**									Y		
Rhynchospora fascicularis	**Fascicled Beakrush**				Y							
†*Rhynchospora grayi*	**Gray's beakrush**				Y							
Rhynchospora inundata	**Beak Sedge**				XO	X	X			OY		
Rhynchospora miliacea	**Beak Sedge**						X			Y		
Rhynchospora rariflora	**Beak Sedge**				O							
Rhynchospora sp.								Y				
Roystonea regia	**Royal Palm**						OY	OY	OY			
†*Rubus trivialis*	**Blackberry**				XOY							
Rumex verticillatus?	**Swamp Dock**						X					
Sabal palmetto	**Cabbage Palm**	XOY	XOY	XOY	XOY	XOY	XOY	XOY	OY	OY	OY	OY
Sabatia camparulata	**Rose Gentian**								Y	Y		Y
Saccharum giganteum	**Sugarcane Plumegrass**				X							
Sagittaria lancifolia	**Lance Leaf Arrowhead**				X		X	X				

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
Sagittaria latifolia	**Duck potato**				O	O				OY		
Salix caroliniana	**Carolina Willow**								OY	OY		
**Salvinia minima*	**Water Spangles**	X										
Samolus valerandi	**Pineland Pimpernel**		Y	Y	XY	XY	X	O	Y	OY		Y
Sarcostemma clausum	**White-vine**		X		XOY			XOY	OY	Y	OY	OY
Saururus cernuus	**Lizard's-tail**	XOY	XOY	XOY	XOY	XOY	XOY	X	OY	OY		
†**Schinus terebinthifolius*	**Brazilian Pepper**	X	X	X	XOY	OY		XOY	OY	OY	OY	OY
Scleria triglomerata	**Tall Nutgrass**				Y		X					
+Sedge seedling						O		Y				
†**Senna pendula*	**Climbing Cassia**	OY	O									
†*Serenoa repens*	**Saw Palmetto**	XY	XY	XOY	XY	XOY	XOY	XOY	OY	OY	OY	OY
†*Sida acuta*	**Wire Weed**						OY					
†*Smilax auriculata*	**Earleaf Greenbrier**	Y		Y	Y			Y	Y	Y	OY	
Smilax bona-nox	**Greenbrier**	XOY		Y	XOY	XOY	XO	XO	O			
+*Smilax* seedling						O						
†*Solanum americanum*	**Common Nightshade**	XY		Y			Y					
Solidago odora	**Goldenrod**				X	Y					OY	
Spermacoce assurgens	**False Button Weed**						X					
†**Sphagneticola trilobata*	**Creeping Oxeye**	OY										
Symphyotrichum carolinianum	**Climbing Aster**							XY	Y	Y		
Symphyotrichum dumosum	**Rice Button Aster**						X					
Symphyotrichum subulatum	**Salt Marsh Aster**	X										
**Syngonium podophyllum*	**Arrowhead Vine, Nephthytis**	XOY		X								
**Syzgium cumini*	**Java Plum**						Y	Y	OY			
†**Syzgium jambos*	**Rose Apple**	X										
Taxodium distichum	**Bald Cypress**	XOY	XOY	XOY	XOY	XOY	XOY	XOY	OY	OY	O	
Teucrium canadense	**Wood Sage**				X		X					
†**Thelypteris dentata*	**Downy Shield Fern**	XOY	XO	Y	X	XO	OY		Y			

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
Thelypteris interupta	**Tri-Veined Fern**	XOY	XOY	X	XOY	XOY	XOY	XOY	OY	OY		
Thelypteris kunthii	**Maiden Fern**	XY		X	X	XY						
Thelypteris palustris	**Marsh Fern**				XO			O	O			
Thelypteris serrata	**Meniscium Fern**	XOY	XOY	XOY	XOY	XOY				O		
Tillandsia balbisiana	**Reflexed Air Plant**	XY					X	XY	Y			
Tillandsia fasciculata	**Cardinal Air Plant**	XOY	XY	XY	XY	X	XOY	XY	Y	Y	Y	Y
+*Tillandsia recurvata*	**Ball Moss**	XY	X		X		X					Y
Tillandsia setacea	**Needle Leaf Air Plant**	Y		Y	XY	XY	XOY	XY	Y	Y	Y	Y
Tillandsia usneoides	**Spanish Moss**	XY	X	XY	X	XY	X	XY	Y	Y	Y	Y
Tillandsia utriculata	**Giant Air Plant**	XY	X	X	X			X				
Toxicodendron radicans	**Poison Ivy**	XOY	XY	X	XOY	XOY	XOY	XOY	OY	OY	OY	OY
Triglochin striata	**Arrow Grass**							Y		Y		Y
Tripsacum dactyloides	**Fakahatchee Grass**	Y			XOY	Y	XY				Y	
Typha angustifolia	**Narrow-Leafed Cattail**								Y			
Typha domingensis	**Southern Cattail**									Y		
Typha spp.	**Cattail**									O		
+Unidentified *Cyperaceae*					O		O					OY
+Unidentified *Poaceae*					O	O	OY		O	O	O	OY
+Unidentified seedling		O	O	O	O	O	O	O	O	O		Y
+Unidentified species		O			O		O		O	O		
+Unidentified *Xyris*						O						
+**Urena lobata*	**Caesar-weed**	XOY	XY	XOY	XOY	XOY	XOY					
**Urochloa mutica*	**Paragrass**	X					Y					
Vaccinium myrsinites	**Shiny Blueberry**							Y	Y			
Verbesina virginica	**Frostweed**	X										
†*Vigna luteola*	**Yellow Vigna**	Y					XY		Y	Y	Y	
Vitis aestivalis	**Summer Grape**	X	Y		Y		XY					
Vitis rotundifolia	**Muscadine Grape**	XOY	X	XOY	OY	XY	XY	XY	OY	Y	OY	

Species	Common Name	Transect #										
		1	T2-1	T2-2	3	4	5	6	7	8	9	10
Vittaria lineata	**Shoestring Fern**	XY	X	XY	X		X		Y		OY	Y
Woodwardia virginica	**Virginia Chain Fern**				XY							
**Xanthosoma sagittifolium*	**Elephant Ear**	OY										
Ximenia americana	**Tallow Wood**								Y		Y	
†*Zanthoxylum fagara*	**Wild Lime**				X							

X=observed in 1993-4 study
O=observed in 2003 study
Y=observed in 2006
* exotic
† found in upland communities
+ can be found in both wetland and upland communities
# only a few seedlings
Note: On Transect 10, the first plot was within a prescribed burn on January 13, 2006.
Possible *Rumex obovatus* Tropical Dock on Transect 5

APPENDIX E: IMPACTS FROM 2004 HURRICANES FRANCES AND JEANNE THE FLOODPLAIN FOREST COMMUNITIES OF THE LOXAHATCHEE RIVER

R. E. Roberts, M. Y. Hedgepeth, and Rachel R. Gross

INTRODUCTION

Hurricanes play an important ecological role in shaping the structure and dynamics of many natural communities. Spectacular as their physical destruction can be, these storms have been viewed historically as exogenous disturbances (DeAngelis, 1994) that can cause successional setbacks for these communities. They can also alter hydrology, disperse seed materials and change land contours (Alexander and Crook, 1975). Documentation of how these hurricanes interact with other natural processes to produce these varied landscapes is critical to our understanding of how existing ecosystems have come into being and are likely to re-colonized in the future (Duever and McCollom, 1993).

Our research has evaluated the effects of Hurricanes Frances and Jeanne on the floodplain forest of the Loxahatchee National Wild & Scenic River in southeastern Florida. The storms both occurred in September 2004. The primary focus is on the mortality and damage to canopy species within the various riverine and tidal floodplain plant communities. The effect of hurricanes on South Florida plant communities has been previously discussed by numerous scientists (Craighead and Gilbert, 1962; Craighead, 1964, Alexander, 1967, Craighead, 1971, Duever, 1986, and Loope et al., 1994). While long periods of records are not available for hurricanes, it is probable that these storms have significantly affected the ecology of this area at least since the stabilization of South Florida's shoreline (Gentry, 1974).

In recent times several severe hurricanes have been documented, showing the impressive impacts these events had on the region's vegetation. Both the "Labor Day" hurricane in 1935 and Hurricane Donna in 1960 completely altered the mangrove forest of Florida's southern tip (Craighead, 1971). The 1935 storm virtually demolished the mature mangrove forest (local residents called this the "black forest") along Florida Bay's mainland coast around Flamingo and Cape Sable (Craighead, 1971). The peak winds were estimated between 241 and 322 kilometers per hour on some of the Florida Keys (National Oceanic and Atmospheric Administration, 1977). The 1960 storm, Hurricane Donna, moved slower in a westerly direction over this same area for nearly 36 hours, with wind gusts up to 290 kilometers per hour recorded. Between Flamingo and West Lake, there were many sites where nearly all of the trees over 5 centimeters in diameter were sheared off 1.8 to 3 meters above the ground. Right after the storm, observers commented that the twisted trunks and limbs made a nearly impenetrable tangle (Craighead and Gilbert, 1962).

In 1965 Hurricane Betsy impacted the lower southeast Florida coast with winds of 193 kilometers per hour causing extensive flooding of saltwater forced in from the east coast. The damage in the form of total kill of sawgrass was noted in the area around Canal 111 (near the northeast boundary of Everglades National Park) and U.S. Highway 1. Post-storm vegetation and soil data collected supported the conclusion that death of the plants by this storm was due primarily to the sudden overland influx of salt water and its subsequent impoundment behind U.S. Highway 1.

Hurricane Andrew swept across south Florida in late August 1992. The eye wall winds were about 244 kilometers per hour. Over 28,329 ha of mangrove forest were destroyed, mostly due to wind stress on the taller trees (Wanless et al., 1994). Much like the aftermath of Hurricane Donna, many of these flattened mangrove forests have not yet re-colonize as mangrove swamps because of deeper water, i.e., intertidal to subtidal environments did not allow mangrove seedlings to become established.

The effects of Hurricane Andrew on freshwater riverine forests was less severe, with only 1 to 2% of cypress trees suffering major damage within the vicinity of the hurricane's eye (Loope et al., 1994). However, when Hurricane Hugo passed over the National Audubon Society's Francis Beidler Forest in South Carolina with mean hourly wind speed at 116 kilometers per hour, 43% of the cypress trees sustained major damage (Duever and McCollom, 1993). The authors attributed the more heavily damaged forest in South Carolina to the fact the large trees in this area were more vulnerable to storm damage than the smaller size cypress in south Florida. Confirmation of this observation is derived from damage caused by Hurricane Donna to an estimated 30% of the large cypress trees at Corkscrew Swamp Sanctuary in southwest Florida (Loope et al., 1994).

The Loxahatchee River area that we studied has a rather unique onsite hurricane log that was recorded from 1947 to 1964 by Trapper Nelson, a landowner who lived beside the river. After his death the land was eventually purchased, becoming part of Jonathan Dickinson State Park. The log kept by Trapper Nelson described how intense he felt a hurricane was with regard to his residence. The only hurricane given his highest rating of 3 stars was "The Great Hurricane of '49". The storm came ashore at Palm Beach in 1949 and moved westward to the Lake Okeechobee area. Wind gusts were recorded at 246 kilometers per hour in Jupiter, Florida before the anemometer failed (Gentry, 1974). Major hurricanes and tropical storms that were recorded in the vicinity of the Loxahatchee River were in: 1893, 1903, 1924, 1926, 1928, 1933, 1948, 1949, 1964 and 1979. The 1979 storm (Hurricane David) had wind gusts of 137 kilometers per hour (Barnes, 1988).

During the 2004 hurricane season, Florida was hit by an unprecedented four major hurricanes (Charley, Frances, Ivan and Jeanne). The Loxahatchee River's floodplain forest was impacted by both Hurricanes Frances and Jeanne. Hurricane Frances **(Figure 1)** made landfall on September 5 near Sewall's Point with maximum sustained winds recorded at 169 kilometers per hour, a Category 2 storm. Approximately 3 weeks later, on September 26, Hurricane Jeanne **(Figure 2)** came ashore near the southern end of Hutchinson Island as a Category 3 storm with sustained winds of 193 kilometers per hour (Tuckwood, 2004). Both the tidal and riverine floodplain plant communities experienced damage from these storms.

Hurricane Frances made landfall as a Category 2 storm near Stuart, Florida on September 5, 2004. It impacted the floodplain forest of the Loxahatchee River, which is south of Stuart with top sustained winds of 169 km/hr. Winds in Jupiter, Florida, which lies east and seaward of the Northwest Fork were recorded between 146-156 km/hr. The storm had been slow in coming ashore as it spent several days circling off the coast of Florida. In August, rainfall had averaged 6.9 mm and flow had averaged 1.96 m^3/s (69 cfs) **(Figure 3)**. Daily rainfall measured 11.4, 40.9, 147.3 and 32 mm between September 3 and 6, 2004, respectively. Flows measured 4.02, 4.18, 15.56, and 17.08 m^3/s (142, 148, 549 and 603 cfs) for the same time period. As rainfall returned to normal, flows remained above 6.8 m^3/s (240 cfs) until September 11, 2004. At an average flow of 3.1 m^3/s (110 cfs) the river was out of the channel and into the floodplain at Transect #1, which continued until October 4, 2004. Rainfall averaged 19.6, 2.8, 0.7 mm per day for the months of September, October and November while flows averaged 8.78, 4.04, and 2.01 m^3/s (310,143, and 71 cfs), respectively.

The remnants of Hurricane Ivan swept through the area on September 21, 2004 and dropped 32 mm of rain, which brought flows up to 11-12 m^3/s (406 cfs average) for a day or two. There were no noticeable high winds with this rainfall event.

Hurricane Jeanne also came ashore in the Stuart area on September 26, 2004 as a Category 3 storm with top sustained winds of 193 km/hr. It too impacted the floodplain forest of the Loxahatchee River. This was a much faster moving storm than Hurricane Frances. There was no rainfall reported on September 25, 2004; however on September 26, 2004, 209 mm of rainfall was reported (Figure1). Flows had been between 5 and 6 m^3/s (194 cfs average) but increased to 22 and 18 m^3/s (706 cfs average) on September 26 and 27, 2004. Flows remained above 3.1 m^3/s (109.5 cfs) for five more days.

STUDY LOCATION

Most of the Northwest Fork of the Loxahatchee River is located within Jonathan Dickinson State Park in southeastern Florida's Martin and Palm Beach Counties (27 degrees 00'N; 80 degrees 06' W). This fork of the river flows from its headwaters in the Loxahatchee and Hungryland Sloughs downstream to merge with the North and Southwest Forks and then exits into the Atlantic Ocean at Jupiter Inlet. Although some lumbering occurred at the turn of the century and lastly in 1940, the trees have been protected since the State of Florida acquired the property for a state park in 1947 (Roberts et al., in press). The Loxahatchee River was Florida's first National Wild and Scenic River, receiving this designation in 1985.

METHODS

For the analysis of canopy data from the 2003 Vegetation study, plant communities of the floodplains of the Northwest Fork of the Loxahatchee River were divided into three distinct groups or reaches [riverine (R), upper tidal (UT) and lower tidal (LT)]. These groups were distinguished based on hydrological conditions, vegetation, and soils (modified from USGS, 2002). The riverine reach is that part of the floodplain forest having primarily freshwater canopy forest that is generally unaffected by salinity. On the Northwest Fork of the Loxahatchee River, this area ranges from just south of Indiantown Road at 24.8 km (River mile, RM 15.4) downstream to 15.3 km (RM 9.5). Vegetative communities in this reach are dominated by a canopy of bald cypress (*Taxodium distichum*) and a subcanopy pop ash (*Fraxinus caroliniana*), red maple (*Acer rubrum*), pond apple (*Annona glabra*), and water hickory (*Carya aquatica*).

The upper tidal reach is that part of the floodplain having a mixed freshwater/brackish forest that has experienced some saltwater intrusion due to tidal influences and reduced freshwater flow during the dry season. On the Northwest Fork of the Loxahatchee River this area extends between 15.3 km (RM 9.5) to 13.1 km (RM 8.13, the mouth of Kitching Creek)**.** Upper tidal reach communities are dominated by pond apple, red and white mangrove (*Rhizophora mangle* and *Laguncularia racemosa)* and cabbage palm (*Sabel palmetto)* with some stands of bald cypress in the floodplain areas away from the river channel.

The lower tidal reach is that part of the Northwest Fork with primarily salt tolerant species. It is highly influenced by tides and salinity in the water and soils. This area extends from approximately 13.1 km (RM 8.13) to 8.8 km (RM 5.5) although several small mangrove islands can be found around 7.2 km (RM 4.5) and in the embayment area (3.2 km, RM 2). The lower tidal reach is dominated by red and white mangrove.

A total of 138 10 m^2 plots in ten vegetative belt transects were resurveyed for this study. Six transects were established in 1983 at designated locations along the upper and middle segments of the

Northwest Fork of the river and along Cypress Creek, a tributary to the Northwest Fork. The additional four transects were created in 2003 at two more downstream locations of Northwest Fork and two additional tributary locations (Kitching Creek and North Fork). Transects 1 through 6 were studied by Dewey Worth (1983-1986) and by Ward and Roberts (1993-1994), with transect 5 being on Cypress Creek (Worth, unpublished report and Ward and Roberts, unpublished report). Transect 7 was established within the upper tidal reach of the river. Transect 9 was a resurvey of the area previously studied by Taylor Alexander in 1967. Both Transects 8 and 10 were on tributaries, with the former on Kitching Creek and the latter on the North Fork.

All vegetative belt transects were positioned perpendicular to the river or its tributaries and to the topographical gradients. The transects began at the upland edge of the floodplain and continued to the river's or tributary's edge. Each one was 10 meters wide and was partitioned off into 10 m^2 plots. All trees greater than 5 cm diameter at breast height (dbh) were measured. The identification of floodplain forest community type was based on the canopy tree species that generally grow together in recognizable communities (modified from USGS, 2002) along the three reaches of the river system (Figure 1). Tree canopy data from both the 1995 Ward and Roberts study and the 2003 transect study (138 $10m^2$ plots) were collected; the Relative Basal Area (RBA) of each tree species within a plot was determined using diameter at breast height (dbh) measurements. RBA is calculated by dividing the total basal area of a species (in m^2) by the total basal area of all species within a $10m^2$ plot. Multi-trunk trees were considered separate trees for this analysis. The most common multi-trunk trees observed were pond apple, red mangrove, and bald cypress.

Guidelines were developed to identify the 16 forest community types and assess damage by reach. For each reach, the major vegetative community categories were identified as swamp (Riverine swamp, Rsw1; Upper Tidal swamp, UTsw1; and Lower Tidal swamp, LTsw1, etc.), bottomland hardwood (Riverine bottomland hardwood, Rblh), hydric or mesic hammock (HH and MH), or uplands (U) with the lower the associated number in a community the lower the reported elevation. For example, Rsw1 plots occurred at lower elevations than Rsw2.

Following a method developed by Duever and McCollom (1993), trees affected by a hurricane were classified into four damage types, listed from the most to the least severe: main trunk or bole broken, uprooted, major branch damage and bent trunk. Trees that sustained several types of damage were assigned to the most severe damage category. Non-hurricane related deaths (i.e. saltwater, lightening, etc.) since 2003 were also noted.

Rainfall and flow prior, during and after the storms were examined to further describe the magnitudes and impacts of the hurricane events. Rainfall data was examined from a weather station within the watershed while freshwater flow measurements were obtained from Lainhart Dam, a long term flow/stage monitoring station located at 24 km (RM 14.8) on the Northwest Fork of the Loxahatchee River.

RESULTS

The results of our hurricane damage assessment by reach and forest type is summarized in **Table E1**. Of the 427 trees sampled in the riverine reach, 206 (48.2%) were damaged by the storms. Most of the observed damage was loss of branches (64%) while 19.4 % and 13.6% were broken trunks and tip overs. Only 18 deaths were reported in the riverine reach during the year following the storms. These were predominantly broken trunks. Of the 33 Rsw1 and Rsw2 plots, which were dominated by either bald cypress or pop ash, 58.5% of the canopy trees were damaged. Sixty-four percent of the damaged trees in the swamp was loss of branches, followed by 22% trunk breaks and 12% tip overs. In the 16 bottomland hardwood plots (Rblh), 55% were damaged of which 58.5% was loss of branches, 20.8% was trunk breaks, and 19% was tip over. In the 12 mesic and hydric hammock plots, only 27.4 % of the canopy trees were damaged, and 73% of this damage was loss of branches. Only 3 tip overs and 2 broken trunks were reported in the hammock plots.

Of the five riverine transects, the largest amount of damage occurred on Transect 5 (Cypress Creek) where 75% of the 71 canopy trees were damaged. Thirty four (64%) were broken branches, 13 (24.5%) were trunk breaks, 3 (4.2%) had bent trunks and 8 were tip overs (15%). Eleven trees died. Cypress Creek is a tributary of the Northwest Fork that is partly channelized downstream of agriculture and urban land uses. On average Cypress Creek provides about 35% of the total freshwater flow to the Northwest Fork of the Loxahatchee River (FDEP, 2002). An agricultural water control structure on a canal leading to Cypress Creek was breached during the hurricanes and the banks of the creek were eroded as a result of the heavy flows. On September 6, 2004 flows on Cypress Creek peaked at 14 m^3/s (504 cfs.) while flows on September 26, 2004 peaked at 29 m^3/s (1,020 cfs). The winds and high flows produced many tip overs primarily water hickory and red maple **(Figure 4)**, and covered the floodplain with fine grain sand (**Figure 5)** and organic matter downstream of the breached structure.

Of the 797 canopy trees sampled in the upper tidal reach, 338 (42.4%) were damaged in both fresh and brackish water vegetation plots. Due to the large numbers of individuals, mangroves and pond apples in the UTsw1 and UTsw3 plots were sub-sampled. Of the 230 canopy trees damaged in the tidal swamps, 159 (69%) had broken branches, 30 (13%) had trunk breaks, 12 (5%) had bent trunks and 29 (13%) were tip overs. Only five trees died. At the back of the floodplains in the freshwater plots, 18 of 31 trees were damaged and the damage was primarily broken branches. Forty-eight percent of the canopy trees were damaged in the three hydric hammock plots. Of these damaged trees in the hammock plots, 45% had broken trunks. Seven deaths (primarily cabbage palms) occurred as a result of the storms. Mangroves in this reach experienced some degree of defoliation from the hurricanes. Subsequent visits to the transects revealed that recovery from defoliation was rapid after the storms.

Of the 438 canopy trees sampled in the lower tidal reach, 235 (53.7%) were damaged. Most of the damaged occurred within the 13 LTsw2 plots, which consisted primarily of white mangroves. Of the 311 trees sampled in this community, 211 (68%) were damaged. Within the LTsw2 plots, 40% of the damaged trees had broken branches, 14.2% had broken trunks, 3.8% had bent trunks, and 56.4% were tip overs. In the 4 LTsw1 plots, which consisted primarily of red mangroves, only 12% of the canopy trees were damaged and there was only one tip over. Seven trees died in the lower tidal reach (one in the hydric hammock and 6 in the LTsw2 plots).

Many of the white mangrove tip overs on Transect 9 may have been caused by dead bald cypress snags falling onto these trees. The majority of the large bald cypress died on this peninsula as a result of saltwater intrusion since the 1960s. Out of 161 bald cypress trees surveyed in April 2004, only 3 remained healthy, 7 were stressed and 151 were dead. Another possible explanation for the large degree of impacts seen on this transect may be the occurrence of a localized tornado or severe wind gusts during the hurricanes. A few other similarly impacted mangrove areas were noted during helicopter flights and in aerial photography taken after the storms. Similar to the upper tidal reach, the mangroves were defoliated after the hurricanes but recovered quickly.

The damage results by canopy species is summarized in **Table E2**. Major canopy species with the largest number of damaged individuals included white mangrove (72%), bald cypress (71%), red maple (68%), water hickory (57%), pond apple (42%), and red mangrove (40%). Secondary species with notable damage included slash pine (80%) and laurel oak (75%). Bald cypress had the most abundant canopy tree in the riverine reach of the Loxahatchee River and its tributaries. Although bald cypress had the species with the highest numbers of damaged trees, most of the damage (86%) was branch loss. Bald cypress had only 15 broken trunks, one tip over, and four mortalities out of the 164 individuals sampled.

Bald cypress along with red maple and water hickory are the tallest trees on the floodplain; therefore they would be more likely to be impacted by the high wind velocities of hurricanes. Similarly in the tidal floodplains, white mangroves grow tall and close together sending out very few branches as they compete for sunlight in the canopy. They had the highest number of tip overs (47%) and broken trunks (9%). Cabbage palm followed by wax myrtle (*Myrica cerifera*) had the highest mortality (11 and 9 respectively); however, only 7% of the 214 cabbage palm and 37 % of the 107 wax myrtle examined during the study were damaged. Ten additional cabbage palms died probably related to high salinity as opposed to being damaged by the storms. Of the 1, 694 canopy trees sampled in this study, the mortality was only 3% one year after the 2004 storms.

Of the 180 exotic plant species that are found within Jonathan Dickinson State Park (Roberts, et al., in press), those that are the most problematic to the floodplain of the Northwest Fork of the Loxahatchee River are Old World climbing fern (*Lygodium microphyllum*); nephthytes (*Syngonium podophyllum*); wild taro (*Colocasia esculenta*); Brazilian pepper (*Schinus terebinthifolius*); Java plum (*Syzgium cumini*); and strawberry guava (*Psidium cattleianum*). In our study of only trees, the Brazilian pepper was the most abundant exotic canopy tree in the floodplain. Sixty-six percent of the Brazilian pepper we sampled were damaged. Of the damaged pepper trees sampled, 16 were tip overs while 3 were breaks and another 7 were bent trunks. Only two of the four strawberry guava examined were damaged of which one was a tip over. Of the three Java plum examined none appeared to have been impacted by the storms.

DISCUSSION

Both Hurricanes Frances and Jeanne appeared to have had stronger winds than Hurricane David in 1979 but not perhaps the “The Great Hurricane of 49”. And, since our investigation, the floodplain forest of the Loxahatchee River was hit again in October 2005 by Hurricane Wilma (Category 2) with the highest recorded wind gust in Jupiter, Florida at 183 km/hr . In comparison with the winds and impacts of Hurricane Hugo in South Carolina, the winds of the 2004 storms were higher; however, damage was somewhat comparable between the two studies except the measured trees were larger in South Carolina (15 cm versus 5 cm). With Hurricane Hugo 60% of the 1,233 trees sampled were damaged (Duever and McCollom, 1993) while 45.3% of the 1,694 trees sampled in our study were impacted. While most of the damage in South Carolina was breaks, the majority of our damage was broken branches (58.3%). Only 17.1% were breaks and 23.8% were tip overs in our study. Both studies recorded broken branches as the major damage to bald cypress while bottomland hardwood species were commonly uprooted or experienced broken trunks (i.e. boles) in riverine areas. Damages in the South Carolina study may have been more severe because the “old growth” forested wetlands within the Francis Beidler Forest are taller and older than the communities along the Loxahatchee River and it tributaries.

The results of our damage analysis on the Loxahatchee River clearly indicated a non- random pattern in the effects of Hurricane Frances and Jeanne. Severe damage and mortality was most apparent in areas of the tallest canopy species (bald cypress, red maple, and water hickory) as compared to those species of lower stature (i.e. mangrove). Non-forested wetland and upland pine communities did not appear to be greatly affected by the hurricanes. The freshwater plant communities of the riverine reach and the mangrove communities of the tidal floodplain reaches exhibited the most severe effects. The riverine reach experienced a 48.2% damage rate versus a 39.1% rate in the upper tidal reach and a 53.6% rate in the lower tidal reach. The higher damage rate of the lower tidal reach is a factor of the abundance of white mangroves that were impacted at Transect 9. These trees grew at very high densities with primarily one major trunk and branches primarily at the canopy surface only. After the storms, tip overs immediately began sending out new branches all along the base of the trunk.

There were also differences in geographical distance and differences in tree species between the two studies. Only four species could be compared. Pop ash, laurel oak, red maple and bald cypress were studied in both geographical areas. In our south Florida study, pop ash was the least affected (34%) while laurel oak was one of the most affected species (75%). Red maple and bald cypress and red maple were affected about the same (68% and 71%, respectively). In the South Carolina study (Deuver and McCollum, 1993), pop ash, laurel oak, and red maple were affected similar to the south Florida study (33%, 66%, and 77%, respectively). Only 46% of the bald cypress were affected by Hurricane Hugo.

The high winds of both storms apparently affected seed production of the bald cypress community for the fall of 2004 and winter of 2005. Cones, which generally release their seeds by the end of the year were absent on the trees after the storms. Subsequently, the observed number of seedlings was small over the course of the remaining year.

On a short and long term basis both Hurricane Frances and Jeanne decreased canopy cover and increased light penetration within the floodplain forest of the Loxahatchee River. Defoliation was only a short term factor; however, loss of major branches will be a long term factor although remaining bald cypress began to immediately sprout new branches **(Figures 6 and 7)**. The winter of 2005 was mild in terms of South Florida temperatures and rainfall in 2005 had been above normal. Instead of going dormant for the winter season, the bald cypress began to sprout new branches and leaves in an effort to recover. Except in flooded areas shrub and ground cover species have reacted positively to the increase in light levels and nutrients.

In the past frequent hurricane disturbances have been a normal part of the South Florida environment. Many species probably depended upon these periodic perturbations. However, with the presence of many more exotic pest plants within the landscape, there are now more ecological consequences. Hurricanes have multiple disturbance factors, i.e., sunlight gaps, soil disturbance, flooding, shoaling, nutrients, sediments, etc. These can lead to an increased exotic plant invasion rate that can change plant community structure and environmental conditions.

Additional concerns of the storm impacts were the abundance of downed branches and leaves within the floodplains. Fifty-eight percent of the tree damage was branches while another 18% was broken trunks. This increased the organic loadings in the river and dramatically reduced dissolved oxygen levels. After Hurricane Frances, the dissolved oxygen levels dropped to zero for a week. This probably had a short term impact on the river's biological productivity, but this will require further assessment. Also, some of the tip overs were attributed to the flows from these storm events that undermined the bases of trees near the river and braided channels.

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Figure 1. NOAA Radar of Hurricane France taken September 4, 2004.

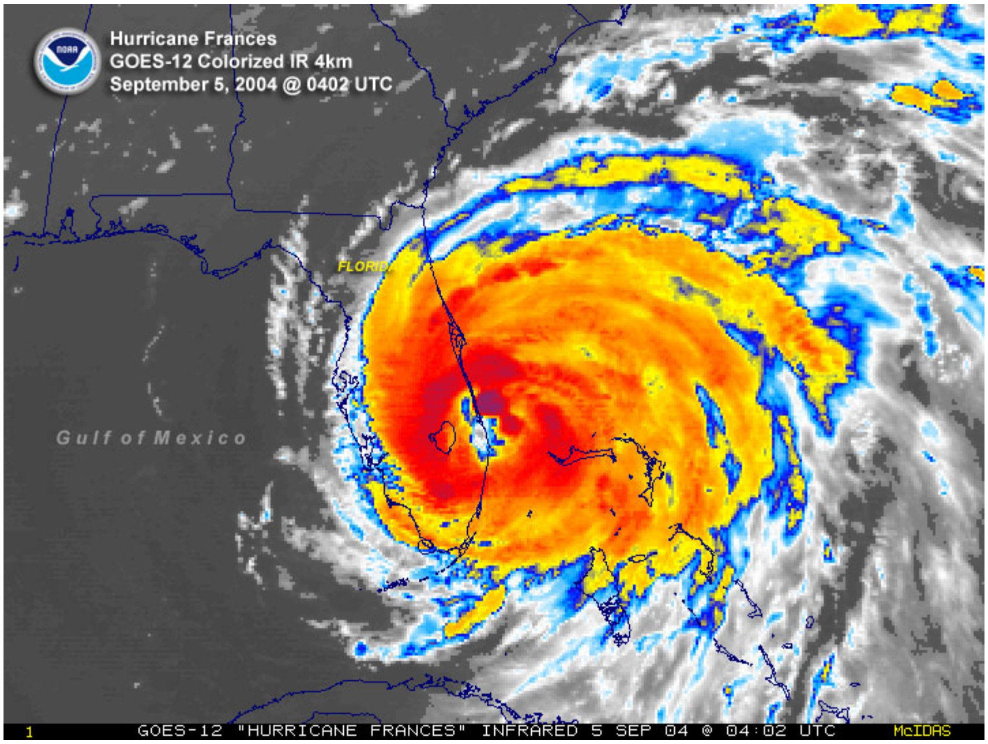

Figure 2. NOAA Radar of Hurricane Jeanne taken September 26, 2004

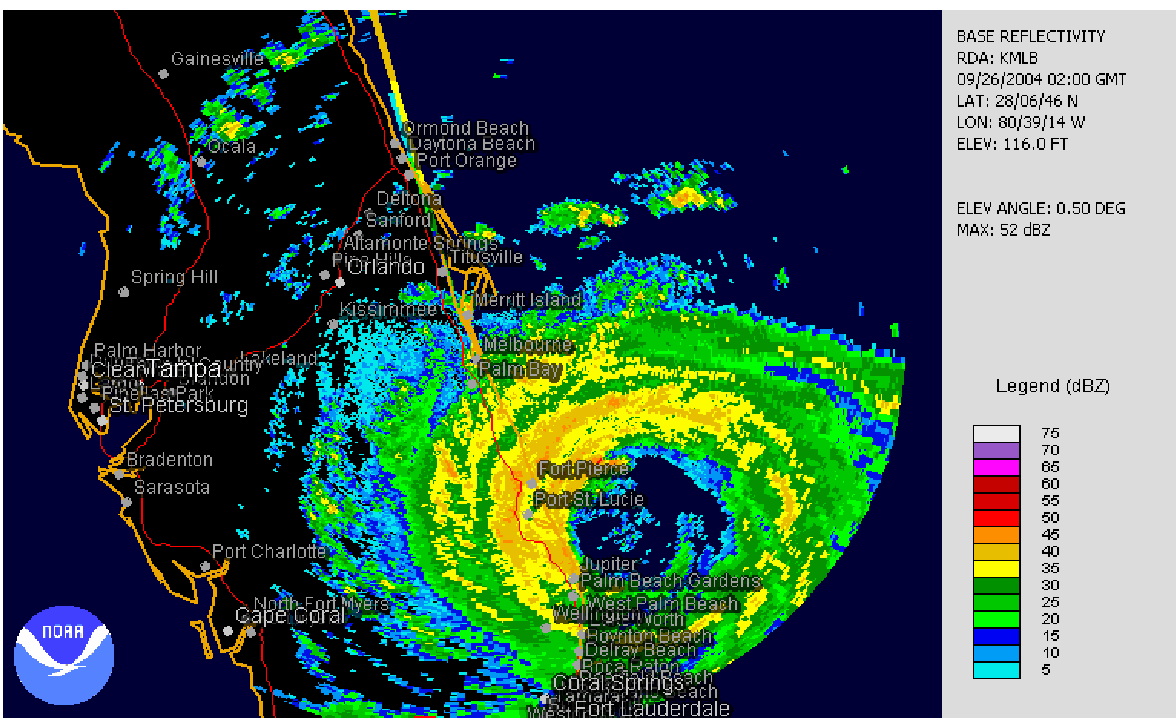

Figure. 3. Local Rainfall and Lainhart Dam Flow between August 1, 2004 and November 30, 2004.

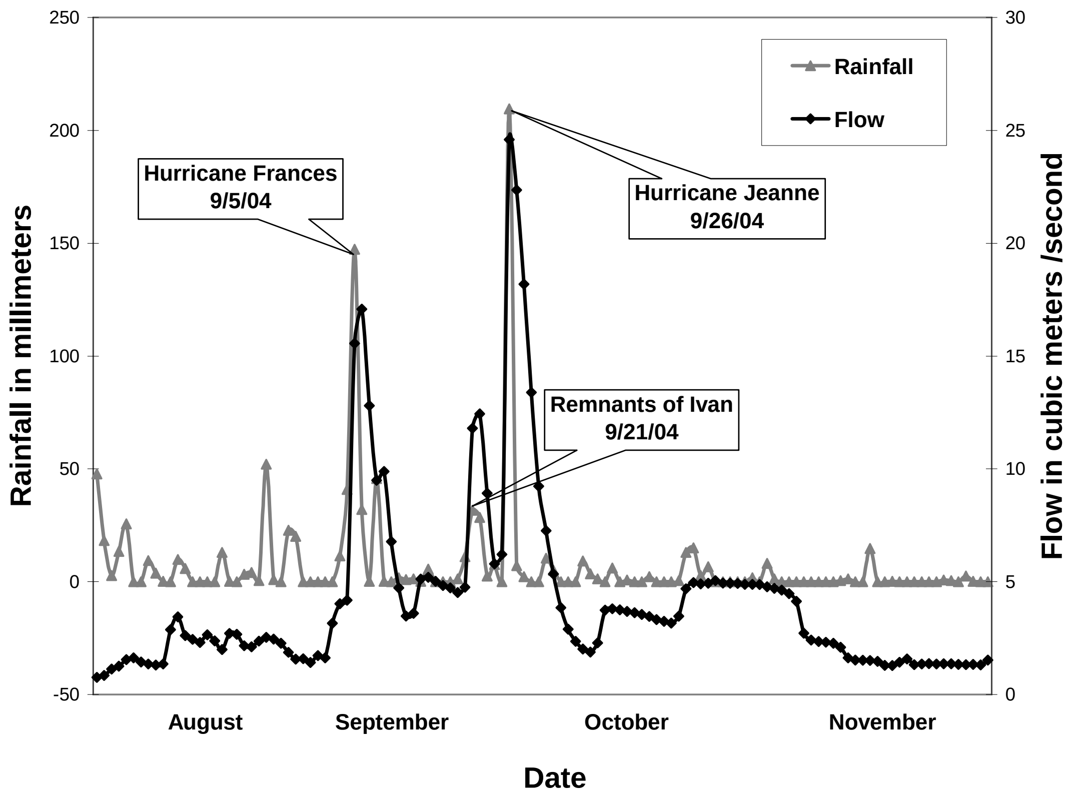

Figure 4. An example of windthrown water hickory on Transect #5 (Cypress Creek).

Figure 5. Sand displaced into the floodplains from upstream erosion at Transect #5.

Figure 6. Recovery: Loss of the upper tree followed by recovery with new branches.

Figure 7. Recovery: New branches from the main trunk.

Table E-1. Summary of hurricane damage by transect and forest type.

Reach	Forest Type	# Plots	Total Sampled	Total Damaged	Type of damage: Branches	Break	Bent	Tip over	Mortality (storm)	Mortality (non-storm)
Riverine	MH	8	54	20	15	1	1	2	2	
Transects	HH	4	41	6	4	1		1		
#1,2,3,4,	HH/U	2	9	4	3			1		
& 5	HH/Rsw1	2	9	1	1					
	HH/Rsw2	1	7							
	Rsw1	25	139	90	67	12		11	7	
	Rsw2	8	66	30	10	14	3	3	2	
	Rsw1/Rblh2	1	5	2	1	1			2	
	Rblh1	3	15	11	7	4				
	Rblh2	10	67	33	17	5	1	10	5	
	Rblh3	3	15	9	7	2				
Upper Tidal	Marsh	1	4	2		1		1		
Transects	HH/Marsh	1	2							
#	HH	3	46	22	6	10	2	4	7	
6,7,8, &	U	2	5	2	1		1			
10	MH/Rsw1	1	11	2	1			1		
	Rsw1	3	31	18	13	3		2	1	
	UTsw1	15	279*	126	93	16	5	12	2	1
	UTsw2	6	155	35	28	3		4	1	
	UTsw3	6	162*	69	38	11	7	13	2	
	UTmix	6	75	39	26	9	2	2	1	1
	Rmix	7	94	23	11	9		2	4	
Lower Tidal	U	1	2	2	2					
Transect	HH	1	10	3		1		2	1	
#9	LTsw2	13	311	211	84	30	8	119	6	5
	LTsw1	4	99	12	8	1	2	1		
	LTmix	1	16	7	5	1		1		3

*subsample

Table E-2. Summary of hurricane damage by selected species.

Species	Total sampled	Total damaged	Type of damage				Mortality (storm)	Mortality (non-storm)
			Branches	Break	Bent	Tip over		
***Acer rubrum*, Red maple**	50	34	17	10		8	4	
***Annona glabra*, Pond apple**	193	80	59	17	4	1	3	
***Carya aquatica*, Water hickory**	35	20	15	1		5	5	
***Cephalanthus occidentalis*, Button bush**	2	1	1					
***Citrus* sp.**	3	1				1		
***Ficus aurea*, Ficus**	5	1	1					
***Fraxinus caroliniana*, Pop ash**	125	43	17	18	3	5	3	
Grapevine	1							
***Illex cassine*, Dahoon holly**	5	3	1		2			
***Laguncularia racemosa*, White Mangrove**	408*	258	127	24	9	121	2	
***Myrica cerifera*, Wax myrtle**	107	40	7	22		11	9	
***Persea borbonia*, Red bay**	6	2		1		1		
***Pinus elliottii*, Slash pine**	10	8	8					
Psidium cattleianum*, Strawberry guava*	4	2	1			1		
***Quercus laurifolia*, Laurel oak**	16	12	10	2			1	
***Quercus myrtifolia*, Myrtle oak**	1							
***Quercus virginiana*, Live oak**	22	12	8	2	1			
***Rhizophora mangle*, Red mangrove**	251*	88	64	12	6	5	1	
***Roystonea regia*, Royal palm**	4	1	1					
***Sabal palmetto*, Cabbage palm**	214	15	2	4		11	11	10
***Salix caroliniana*, Carolina willow**	18	4		1		3		
Schinus terebinthifolius*, Brazilian pepper*	44	29	8	3	7	16		
***Serenoa repens*, Saw palmetto**	3							
Syzgium cumini*, Java plum*	3							
***Taxodium distichum*, Bald cypress**	164	117	101	15		1	4	

*Subsample of 221 RM, 358 LR
**Exotic