Chapter 6: Ecology of the Everglades Protection Area

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SUMMARY

The studies and findings discussed in this chapter of the *2006 South Florida Environmental Report – Volume I* are presented within four main fields: (1) wildlife ecology, (2) plant ecology, (3) ecosystem ecology, and (4) landscape ecology. Programs of study were based on the short-term and long-term needs of the South Florida Water Management District (District or SFWMD) including operations, regulations, permitting, environmental monitoring, Everglades Forever Act mandates, and the Comprehensive Everglades Restoration Plan.

Wildlife: Monitoring of wading bird nesting success is a coordinated effort between the District, Everglades National Park, the Florida Fish and Wildlife Conservation Commission, University of Florida, the National Audubon Society, and the U.S. Fish and Wildlife Service. Each year, this coordination results in the production of the Annual Wading Bird Report. The estimated number of wading bird nests in South Florida in 2005 was 31,869. This is a 41 percent reduction in nest numbers from last year's relatively successful season and a 54 percent decrease from the banner year of 2002, which was the best nesting year on record in South Florida since the 1940s. While the 2005 estimate is relatively high compared to the average of recent decades, it represents a sharp divergence from the general rising trend in annual numbers of wading bird nests recorded since 1999, and this decline in nest numbers was observed among all wading bird species. Reduced prey availability, as a result of anthropogenic changes in hydrology, is considered the primary factor responsible for the decline in Everglades wading bird populations.

This year, two new programs to evaluate how aquatic organisms interact with hydrology were initiated. A crayfish study conducted at the Loxahatchee Impoundment Landscape Assessment (LILA) research facility at the Arthur R. Marshall Loxahatchee Wildlife Refuge found that crayfish respond to the seasonal drawdown by remaining on the ridges and safe from wading bird foraging until water levels become extremely low. As water levels continue to decline, they move into the sloughs where they subsequently become more available to foraging wading birds. The second new program, a spatially intensive survey of exotic fishes in the vicinity of the L-67 canal, suggests that at least two species – and possibly a third – are using marsh habitat for refuge or feeding, and that future studies will be needed to focus on the ecological factors determining the distribution of nonindigenous fish species and to reevaluate species-specific physiological tolerances to seasonal minimum temperature.

Plants: Previous Everglades Consolidated Reports (ECRs) discussed how plants allocate biomass, hydrologic tolerances, competition for nutrients, and physiological mechanisms under various soil and water conditions. The District is beginning to use this information at its weekly operational meetings where issues of water supply, flood control, and environmental restoration are discussed. Consequently, plant studies continue. During this year, the District evaluated an experiment conducted at the LILA facility to assess the drought and flood tolerances of small seedlings of eight dominant tree island species. The survival rate was 39 percent and 37 percent for the three-month drought and the six-month flood, respectively, suggesting that recruitment of seedlings is slightly more sensitive to drought than to flooding. The District also completed a vegetation analysis of half of all the tree islands in the critical – and hydrologically significant – region of Water Conservation Area 3B (WCA-3B).

Ecosystem: Previous ECRs have indicated that downstream impacts of Stormwater Treatment Areas 2 and 5 have led to an increase in hydroperiods and water depths, and to more desirable plant species. This trend has continued, in which there has been a doubling of the mean water depth from 0.4 to 0.8 feet due to inflow restoration and better management of the G-402 outflow structure. However, analysis of surface water quality shows that phosphorus concentrations are elevated near the inflow, and continued monitoring of the system is recommended. The ecology of tree islands is also still under investigation. Previous tree island studies found a significant decline in the abundance and aerial extent of these biodiversity "hot spots." To understand the mechanisms underpinning this decline, the District's tree island research continues to focus on (1) characterizing the existing vegetation, (2) creating a baseline dataset, (3) relating patterns of distribution and abundance to hydrology, and (4) evaluating performance measures and alternatives for preservation and restoration. This year, the results from belowground root analysis on tree islands located on WCA-3 were completed. These data indicate that contrary to what was anticipated, and despite the stress of low oxygen, the moderate and long hydroperiod islands had significantly greater amounts of live roots than the short hydroperiod islands. These roots appear to be an adaptive phenotypic response to the stress of flooding.

Landscape*:* The District is continuing to observe the total hydro-biogeochemical system of the Everglades Protection Area. Previous studies of soil nutrients have been significantly updated this year with the completion of a comprehensive spatial analysis of the upper 30 centimeters of soil across the entire Everglades. This chapter also presents some of the first completed grid-based vegetation mapping projects for WCA-2A and the Rotenberger Wildlife Management Area, utilizing 1:24,000 scale color infrared aerial photographs and using a single comprehensive classification system. Also, the District has initiated a new program to evaluate and monitor tree island hydrology by completing the construction of 31 new Class B benchmarks in the interior of WCA-3. To continue our analysis of the pre-drainage system and develop a better understanding of the ecological processes that drive the Everglades, the District has completed a dramatically new elevation contour that, when peer-reviewed, will be used with the Natural System Model to help set restoration performance goals.

INTRODUCTION

Drainage of the Everglades changed South Florida from a subtropical wetland to a human-dominated landscape with a strong retirement, tourism, and agricultural economy. As a result, the Everglades is half its original size, water tables have dropped, hydroperiods have been altered, flows have been diverted, wetlands have been impounded, wildlife has been reduced, water quality has been degraded, and habitats have been invaded by nonindigenous plants. All of these impacts are caused directly or indirectly by an altered hydrology. Previous reviews of the ecological impacts of altered hydrology in the Everglades (Davis, 1943; Loveless, 1959; Craighead, 1971; McPherson, et al., 1976; Gleason, 1984; Tropical BioIndustries, 1990; Davis and Ogden, 1994; Sklar and Browder, 1998; Sklar and van der Valk, 2002) have greatly increased public and scientific awareness of problems associated with altered hydrologic regimes and drainage. This chapter will update this natural history by highlighting some of the recent research findings and experimental programs sponsored by the South Florida Water Management District (District or SFWMD).

HYDROLOGIC PATTERNS FOR 2005

Direct cause and effect relationships between altered drainage and ecosystem disturbance are not always easily shown. It is difficult because a long period of record is needed to filter out changes due to climatic variability, and because many factors are associated with an altered hydrologic regime. It is globally recognized by wetland ecologists that source, timing, duration, and depth of water will influence biogeochemical processes in soils and water, physiological processes of plant growth and decomposition, and reproduction and migration of fauna (Sharitz and Gibbons, 1989; Patten, 1990; Mitsch and Gosselink, 2000). In turn, soils, plants, and animals affect the hydrology. These ecological feedbacks allow for self-organization and succession (Odum, 1983). It is clear that the decreased extent of the Everglades and surrounding uplands, changes in the soil and topography, presence of exotic species, and the current system of canals and levees all constitute constraints on restoration to pre-drainage (pre-1880) conditions. The challenge facing science and society is to determine how to manage the hydrology and land-use runoff so that key ecological driving forces will be restored. For this reason, and to help document the bio-complexity of the water-ecosystem interactions, this new *Hydrologic Pattern* section was added to Chapter 6.

The rainfall and associated stage readings for Water Year 2005 (WY2005) (May 1, 2004 through April 30, 2005) are shown in **Table 6-1**. Despite the substantially lower-than-average rainfall in each of the Everglades sub-basins, the 2005 hydrologic conditions were higher than the average throughout most of the Everglades Protection Area (EPA). Only Water Conservation Area 2 (WCA-2) stage was somewhat lower than average. This disconnection between lower-than-average rainfall and higher-than-average stage appears to be due to two significant hydrologic events. The first is an extended dry season that ended in mid-July instead of the more typical mid-May; the lack of rain in June – a month that normally contributes 10–12 inches of precipitation to the annual total – accounts for these low totals for WY2005. The second event was a series of hurricanes that quickly filled all the basins within the SFWMD, which in turn could not be drained for an extended period due to a lack of conveyance.

Table 6-1. Average, minimum, and maximum stage (feet National Geodetic Vertical Datum, or ft NVGD) and total annual rainfall (inches) for Water Year 2005 (WY2005), in comparison to historic stage and rainfall.[1] (Subtract elevation from stage to calculate average depths.)

Area	2005 Rainfall	Historic Rainfall	2005 Stage Mean (min; max)	Historic Stage Mean (min; max)	Elevation
WCA-1	43.72	51.96	15.85 (13.63;17.11)	15.59 (10.0;18.38)	15.1
WCA-2	43.72	51.96	12.21 (10.73;14.6)	12.56 (9.33;15.64)	11.2
WCA-3	40.27	51.37	9.94 (8.51;11.74)	9.51 (4.78;12.79)	8.2
ENP	40.15	55.00	6.26 (5.51;7.16)	5.96 (2.01;8.08)	5.1

[1] See Chapter 5 of this volume for a more detailed description of rain, stage, inflows, outflows, and historic databases.

The following figures and text highlight the average stage changes in each of the Water Conservation Areas (WCAs) for the last 1.5 years in relation to the regulation schedule, flooding tolerances for tree islands, drought tolerances for wetland peat, and recession rates and depths that support both nesting initiation and foraging success by wading birds. These indices are used by the District to facilitate weekly operational discussions and decisions. Tree island flooding tolerances are considered exceeded when depths on the islands exceed one foot for more than 120 days (Wu and Sklar, 2002). Drought tolerances are considered exceeded when water levels are more than 1 foot below ground for more than 30 days (the criteria for Minimum Flows and Levels in the Everglades; SFWMD 2003). The four figures that follow (**Figures 6-1** through **6-4**) show ground elevations in the WCAs as the threshold for peat conservation. The wading bird nesting period is divided into three simple categories (red, yellow, and green) based upon foraging observations in the Everglades (Gawlik, 2002). A red label means poor conditions due to recession rates that are too fast (greater than 0.6 ft per week) or too slow (less than 0.04 ft for more than two weeks). A red label is also given when the average depth change for the week is positive rather than negative. A yellow label indicates fair conditions. This is due to a slow recession rate of only 0.04 ft for a week or a rapid recession between 0.17 ft and 0.6 ft per week. A green/good label is given when water depth decreased between 0.05 ft and 0.16 ft per week. Although these labels are not indicative of an appropriate depth for foraging, they have been useful during high-water conditions to highlight recession rates that can lead to good foraging depths toward the end of the dry season (i.e., April and May).

WATER CONSERVATION AREA 1

This area experienced a significant extension of the dry season, and for two months, some areas within Water Conservation Area 1 (WCA-1) were belowground elevations (the Lower Tolerances shown on **Figure 6-1**). As such, parts of WCA-1 were susceptible to peat fires and accelerated processes of soil oxidation (Period A). Water levels were already on a rapid increase when hurricanes Frances and Jeanne put this basin within three inches of Zone A flood control. Water depths decreased at a moderate pace after the hurricanes, going from 2 feet in October 2004 to 1 foot in February 2005. Then, during the critical wading bird foraging and nesting period of March–May, reversals occurred and rainfall increased depths back up to 1.5 ft. This dry-season rain, plus a rapid return of the wet season (Period B), created a very poor nesting season for wading birds.

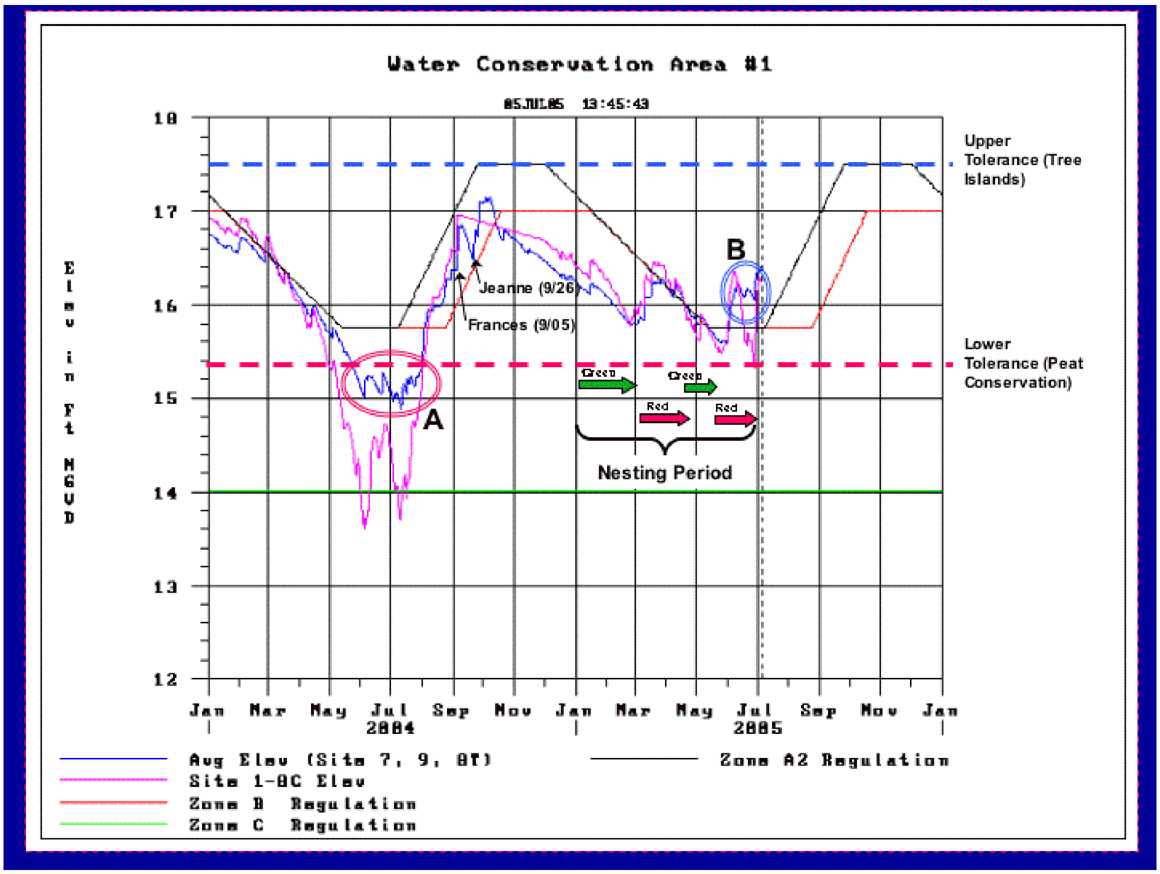


Figure 6-1. Hydrology in Water Conservation Area 1 (WCA-1) in relation to the regulation schedule and indices for tree islands, peat conservation, and wading bird foraging.

WATER CONSERVATION AREA 2A

The central marsh area of Water Conservation Area 2A did not experience a significant extension of the 2004 dry season (Period A), even though the surrounding borrow canals (Site 99) were almost dry (a testament to the ability of peat soils to retain water) (**Figure 6-2**). Wet season response to the hurricanes put WCA-2A about 2 ft over the Zone B regulation schedule by October 2004 (Period B). Marsh water levels decreased rapidly in WCA-2A during the dry season, decreasing from 14 feet National Geodetic Vertical Datum (ft NGVD) in November 2004 to 11.3 ft NGVD by March 2005. Then, just as in WCA-1, reversals occurred and rainfall increased depths, creating poor foraging habitat for wading birds during the critical nesting period. The return of the wet season in June 2005 was more rapid in WCA-2A (Period B) than it was in WCA-1, and by July 2005 caused this region to exceed the upper flood tolerance for tree islands.

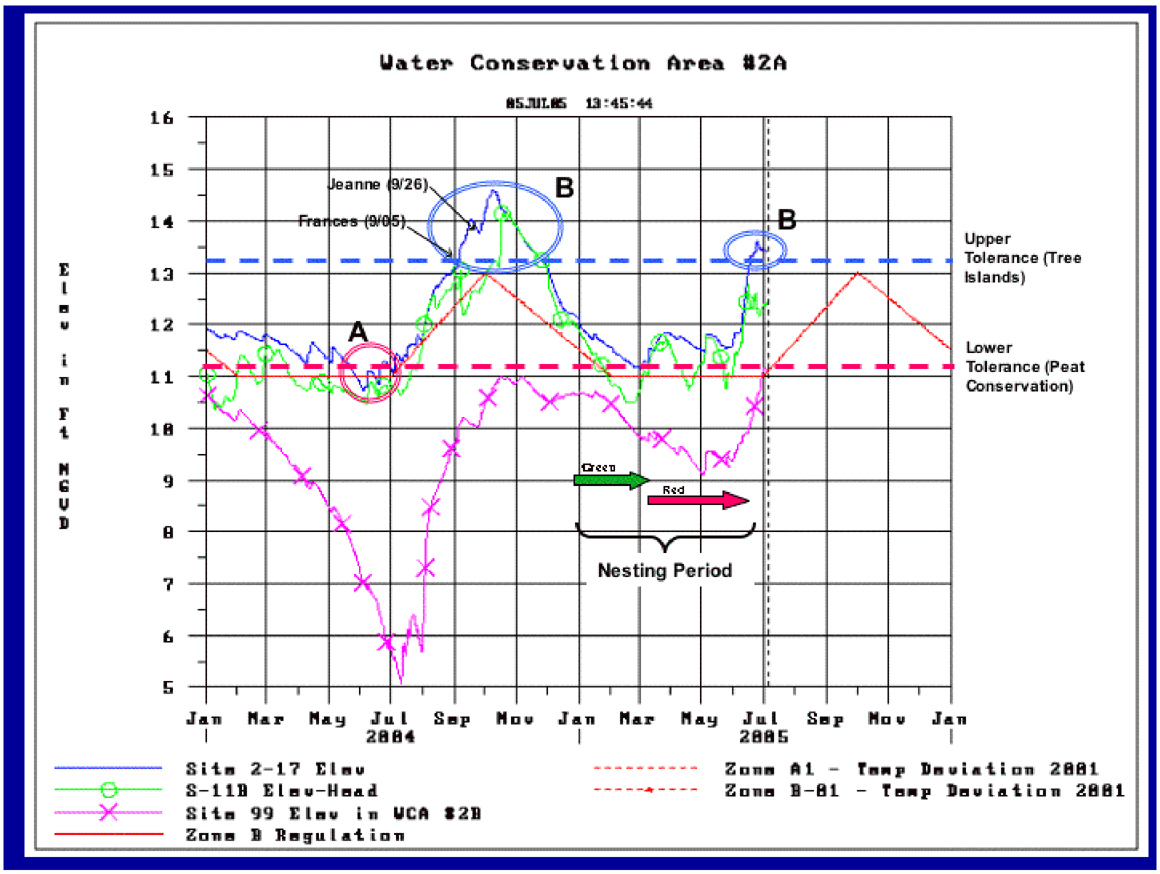


Figure 6-2. Hydrology in WCA-2A in relation to the regulation schedule and indices for tree islands, peat conservation, and wading bird foraging.

WATER CONSERVATION AREA 3A

Most of Water Conservation Area 3A did not experience an extension of the dry season during WY2005 (**Figure 6-3**). Unlike WCA-1, this region was not susceptible to peat fires and accelerated processes of soil oxidation (Period A). This is not obvious from the data shown below (Period A), because the average of three very different locations (Sites 63, 64, and 65) used for regulatory purposes for this vast region tends to mask significant spatial differences. The rapid rise in water levels starting in July 2004 (8.5 ft) and ending in October 2004 (11.7 ft) was due to a combination of local rainfall and conveyance of hurricane floodwaters from the north. Recession rates during the dry season were moderate. This region reached optimum depths and recession rates in March 2005. However, March 2005 was unseasonably wet, which caused numerous reversals and did not allow water depths to drop below one foot, especially in southern WCA-3A. This dry-season rain, plus a rapid return of the wet season (Period B), created very poor foraging habitat for wading birds.

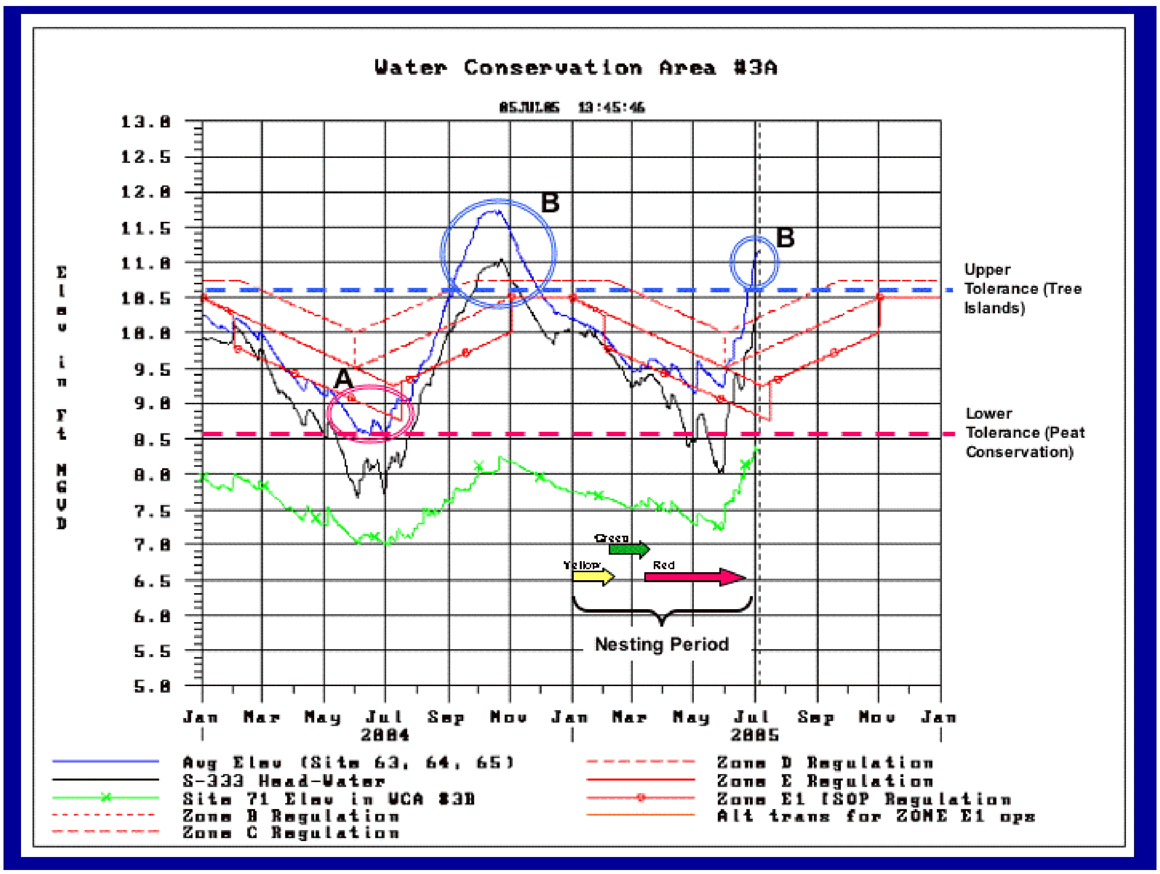


Figure 6-3. Hydrology in WCA-3A (the average of three stations) in relation to the regulation schedule and indices for tree islands, peat conservation, and wading bird foraging.

WATER CONSERVATION AREA 3B

In this region, although Site 71 is not representative of the region, it is generally indicative of the marsh hydrology, indicating that Water Conservation Area 3B did not experience either the extension of the dry season or the rapid flooding due to hurricanes during the wet season that affected the rest of the Everglades Protection Area (EPA) (**Figure 6-4**). However, some tree islands within WCA-3B may have experienced short-term flooding stress (Period B), as indicated by Site 69 hydrology. Unlike other regions of the Everglades, this region did not exceed its flood control regulation schedule during WY2005.

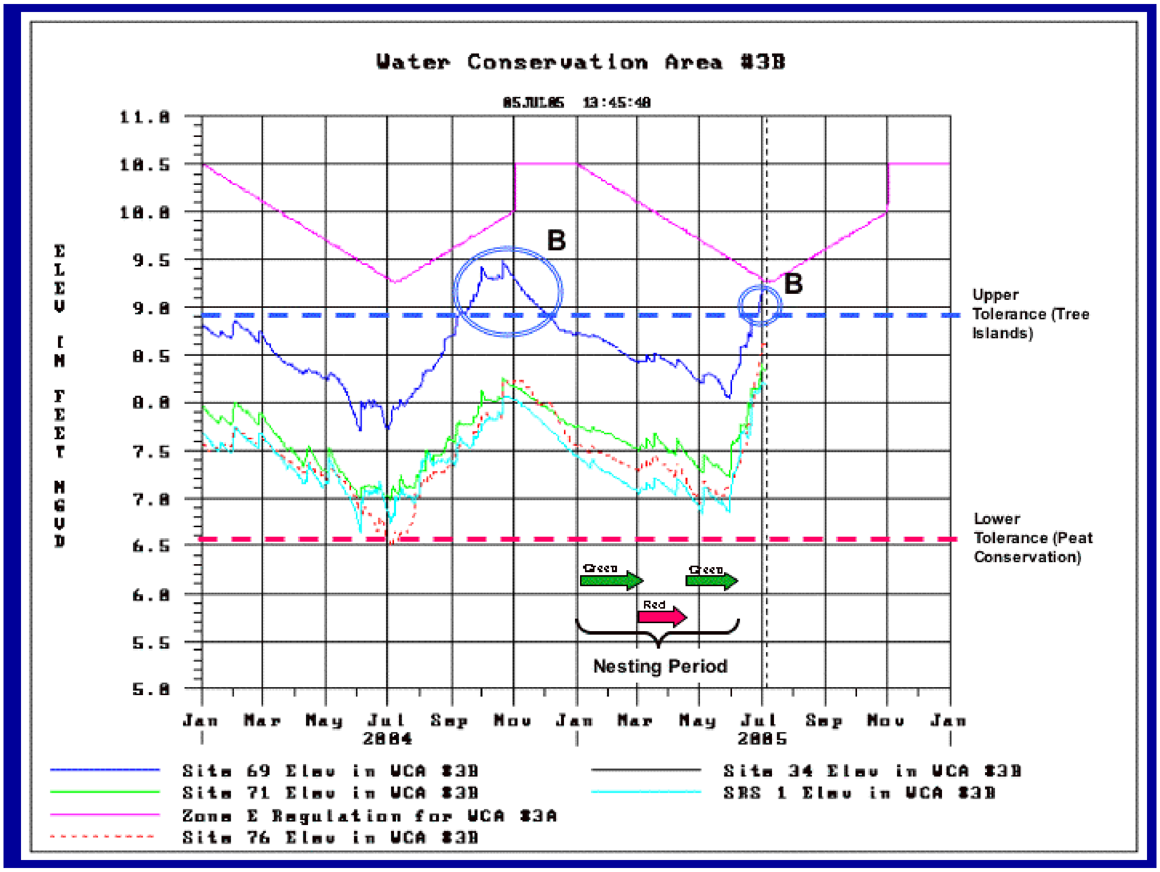


Figure 6-4. Hydrology in WCA-3B in relation to the regulation schedule and indices for tree islands, peat conservation, and wading bird foraging.

WILDLIFE ECOLOGY

Previous research has shown that the distribution of wildlife in the Everglades is a function of water quality, hydrology, climate, and habitat conditions. Wildlife within this context has included invertebrates, fish, amphibians, and birds. Most wildlife studies in the Everglades have been conducted by staff at the U.S. Fish and Wildlife Service (USFWS), Everglades National Park (ENP or Park), Florida Fish and Wildlife Conservation Commission (FWC), and universities throughout Florida. The District focuses on wading birds, their prey and the effects of nonindigenous species.

Last year's *Wildlife Ecology* section of this chapter focused solely on wading birds as indicators of the overall health of the system. This year we will continue to report wading bird nesting effort but will also include studies on wading bird prey and nonindigenous fish. Wading birds exhibit a suite of characteristics that render them particularly suitable for monitoring wetland ecosystem function. They are conspicuous, easy to count, and respond rapidly to hydrologic and other ecological conditions of the ecosystem. As the numerically dominant group of top predators, they have significant affects on food webs through predation and nutrient transport, and can reflect the health of lower trophic levels through their population dynamics. They also range widely over the landscape and have been monitored for over 100 years, allowing comparisons of ecological conditions across large areas of space and time. By examining long-term, system wide trends and the range of variability in nesting effort by wading birds, ecologists can gain greater understanding of how hydrologic conditions and other ecological processes affect Everglades function. In an effort to link wading bird population responses to the ecology of their prey, we also report on a study that examines how populations of a key trophic species, the slough crayfish (*Procambarus fallax*) respond to changing hydrologic conditions, and discuss the implications of this response for wading birds. We also provide the results of a preliminary survey of nonindigenous fish in the WCAs. Little is known of the distribution and abundance of these invaders yet their potential effects on native aquatic communities and hence on wading bird populations may be significant.

WADING BIRD MONITORING

Because wading birds are excellent indicators of wetland ecosystem health, they play a central role in the Comprehensive Everglades Restoration Plan (CERP). The timing of breeding, number of nests, and location of nesting colonies within the Everglades are used as CERP targets to evaluate the progress of the Everglades restoration effort. In addition to CERP, wading birds are of special interest to the public and play a prominent role in adaptive protocols, Minimum Flows and Levels (MFLs), and day-to-day operations of the District. The information reported in this chapter represents a compilation of data collected by a variety of institutions that monitor wading bird breeding parameters in South Florida, and the counts include all wading bird species (except cattle egret, *Bubulcus ibis*) nesting throughout the region (Cook and Call, 2005). However, nesting figures for CERP performance measures are restricted to five species – great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), tricolor heron (*E. tricolor*), white ibis (*Eudocimus albus*), and wood stork (*Mycteria americana*) – from nesting colonies in the greater Everglades region, i.e., the Water Conservation Areas and Everglades National Park. The period covered by this report is the nesting season February–June 2005.

The estimated number of wading bird nests in South Florida in 2005 was 31,869. This is a 41 percent reduction in nest numbers from last year's relatively successful season and a

54 percent decrease from the banner year of 2002, which was the best nesting year on record in South Florida since the 1940s. While the 2005 estimate is relatively high compared to the average of recent decades, it represents a sharp divergence from the general rising trend in annual numbers of wading bird nests recorded since 1999. A major decline in nest numbers was observed among all wading bird species examined.

As usual for recent years, nesting effort in the Everglades was not uniformly distributed among regions. WCA-3 supported the largest number of nests (73 percent), WCA-1 supported 19 percent of nests, whereas the ENP supported the lowest number of nests (8 percent). This pattern is similar to last year and the record year of 2002. The ENP continues to show relatively low numbers of wading bird nests, a pattern that must be reversed as part of restoration efforts. However, it is encouraging to note that this is the second successive season in which nesting has occurred at the traditional "rookeries" in the southern, mainland estuaries downstream from Shark Slough. Also noteworthy is the trend over recent years for a large proportion of nests in South Florida to be concentrated in a single colony (Alley North) located in northeast WCA-3A. This colony contained 52 percent of all wading bird nests and 69 percent of white ibis nests in South Florida.

Significant hurricane activity in 2004 resulted in above-average water levels across much of South Florida at the start of the dry season, but rapid recession rates produced good foraging condition by February and early March, particularly in WCA-2A. This likely induced the large numbers of white ibis and snowy egret nest initiations at Alley North colony at this time. Multiple heavy rain events through March and April resulted in a succession of reversals that left protracted high water levels and thus poor foraging condition over much of the system thereafter.

These rain events likely limited further nest initiations and were responsible for generally very poor nest success throughout the system. At Alley North alone, thousands of white ibis nests were abandoned due to nest flooding or poor foraging conditions. Note that the 2005 wading bird nest total may be an overestimate of nesting activity if the large numbers of white ibis that abandoned at Alley North subsequently re-nested elsewhere and were recounted, as circumstantial evidence suggests. Because this source of variation has yet to be quantified, the data in the SFER is better suited to identify long-term general patterns, and as an index of nesting effort rather than as an absolute population measure. Wood storks were particularly sensitive to the spring rains and experienced significant abandonment at most colonies. At Corkscrew Swamp Sanctuary, the largest wood stork colony in the region, all 240 nests failed shortly after the first rain event. Stork nests that survived at other colonies generally produced low numbers of fledglings compared to previous years. Storks did not re-nest after abandonment as they did last year, probably because of continued poor foraging conditions. This continues a disturbing downward spiral of both nesting effort and breeding success in recent years for this federally endangered species. Roseate spoonbills (*Ajaia ajaia*) in Florida Bay did not experience rain induced reversals, but continue to fare badly as a result of unsuitable hydrologic conditions in most areas of the bay.

The relationship between rain-driven reversal events and Everglades wading bird breeding populations was not described in this report because it has been examined in great detail elsewhere within the context of prey availability. Reduced prey availability as a result of anthropogenic changes in hydrology is considered the primary factor responsible for the decline in Everglades wading bird populations (e.g., Kahl, 1964; Kushlan, 1986; Kushlan and Frohring, 1986; Ogden, 1984; Gawlik, 2002). As water levels decline during the seasonal drydown, aquatic prey are increasingly concentrated in isolated pools and become available to wading birds. A subsequent reversal in water level re-disperses prey, reduces their availability and limits the ability of wading birds to forage effectively. Local rain-induced reversals probably negatively affected breeding birds in historical times, but birds probably also had the option of moving to alternative foraging areas which today are no longer available.

The poor nesting season in 2005 does not necessarily imply a decline in the suitability of the system to wading bird nesting. Relatively large numbers of wading birds present in the system prior to the water level reversals suggest that the Everglades retains the capacity to attract and support large numbers of birds. Indeed, compared to recent years, numbers of nests were relatively high by February and March and it is conceivable that breeding in 2005 would have been relatively successful for some species if extensive water-level reversals had not occurred. Even in pre-drainage years, wading bird populations often fluctuated considerably between years. This leads us to expect to see the return of relatively successful breeding years in the future when hydrologic conditions are more favorable. Nonetheless, it is evident that conditions in the Everglades remain unfavorable for breeding for a number of wading bird species irrespective of reversal events, and that reduced prey availability as a result of anthropogenic changes in hydrology may be the primary factor responsible for the decline in Everglades wading bird populations. Determining causation will require the continuation of long-term system-wide monitoring and shorter-term experiments and modeling.

Only two species-groups met the numeric nesting targets proposed by the South Florida Ecosystem Restoration Task Force (**Table 6-2**). Two other targets for the Everglades restoration are an increase in the number of nesting wading birds in the coastal Everglades and a shift in the timing of wood stork nesting to earlier in the breeding season (Ogden, 1997). The 2005 nesting year showed no improvement in the shift of colony locations or the timing of wood stork nesting.

Table 6-2. Numbers of wading bird nests in the Water Conservation Areas (WCAs) and Everglades National Park (ENP) compared to Comprehensive Everglades Restoration Plan (CERP) targets.

Species	1995 – 1997	1996 – 1998	1997 – 1999	1998 – 2000	1999 – 2001	2000 -2002	2001 – 2003	2002 – 2005	Target
Great Egret	4,302	4,017	5,084	5,544	5,996	7,276	8,535	7,829	4,000
Snowy Egret/ Tricolor Heron	1,488	1,334	1,862	2,788	4,269	8,614	8,089	4,085	10,000–20,000
White Ibis	2,850	2,270	5,100	11,270	16,555	23,983	20,725	20,993	10,000–25,000
Wood Stork	283	228	279	863	1,538	1,868	1,554	1,191	1,500–2,500

THE DISPERSAL RESPONSE OF CRAYFISH TO WATER RECESSION: IMPLICATIONS FOR WADING BIRD PREY AVAILABILITY

Prey availability has long been considered an important causal factor in structuring animal communities, and has significant implications for the conservation and management of threatened predator populations (Hutchinson, 1959; Hairston et al., 1960). It is considered the single most important factor limiting the distribution and nesting success of wading birds, and may be particularly relevant in the oligotrophic Everglades system (Hoffman et al., 1994). However, the mechanisms governing prey availability have received only modest empirical scrutiny and are poorly understood for most wading bird species.

Availability of prey depends not only on the total number of prey present in a habitat, but also on the localized distribution of prey and its vulnerability to predation (Gawlik, 2001). Prey distribution and vulnerability, in turn, are a function of dynamic relationships between prey, environment, and predator. A first step in elucidating the linkages between ecosystem processes and predator populations is to quantify the environmental mechanisms that affect prey distribution and to determine how that distribution subsequently influences prey vulnerability to a predator.

In the hydrologically fluctuating Everglades, a key environmental process driving prey availability is the interaction between the seasonal decline in water level and small-scale variability in vegetation structure and density across the ridge and slough landscape. As water levels recede, aquatic prey move from densely vegetated ridges to less vegetated, lower elevation sloughs, where they become increasingly concentrated in drying, shallow depressions. Wading bird foraging is constrained by an upper threshold water depth (approximately 20 cm) and becomes increasingly efficient as water depth and vegetation density decline. Thus, as water levels fall in the slough, prey density and vulnerability increase, and prey become progressively more available to wading birds. Changes to historic hydrologic patterns are believed to have reduced the frequency, magnitude, and distribution of these concentration events.

Research on wading bird prey availability in the Everglades has focused exclusively on fish as a prey source, yet another essential prey component are the crayfish. Crayfish are ubiquitous in the system, can reach high densities, and are an important food source for a number of wading bird species, particularly the white ibis. Because crayfish can breathe air, disperse within a terrestrial environment, and burrow or hide in damp vegetation in response to drought, the process by which they respond to declining water levels and how they become available to wading birds may be markedly different from that of fish prey. Understanding crayfish responses may be essential for the successful restoration of Everglades wading bird populations. Here we present results of an experiment designed to examine how crayfish become available to wading birds by measuring their dispersal within the ridge and slough landscape in response to declining water levels.

Methods: The experiment was conducted at the Loxahatchee Impoundment Landscape Assessment (LILA) research facility at the Arthur R. Marshall Loxahatchee Wildlife Refuge (Refuge). LILA consists of four identical 400 x 200 m macrocosms containing key landscape features of the Everglades (ridges, sloughs, tree islands, and alligator holes) and a naturalized population of the slough crayfish population. Dispersal of this crayfish was examined in response to three successively declining water levels (depth 1: water 50 cm above the ridge; depth 2: water 5 cm above the ridge; and depth 3: no standing water on the ridge and 5 cm above the slough) in two randomly selected macrocosms. A group of baited minnow traps were placed on the narrow ridge, on the wide ridge, and in the slough or alligator hole, and repeated this setup for a total of 10 transects spaced approximately 30 m apart within each macrocosm (**Figure 6-5**). Water levels were lowered over a period of several days to reach each target water depth, and each depth was attained at least one day prior to setting traps. Traps were checked after 24 hours. Crayfish dispersal response was in terms of the relative change in density within a habitat and the recapture of marked individuals between habitats. This setup was repeated in the two remaining macrocosms, but water levels were kept constant at 50 cm above the ridge to control for potential crayfish movements unrelated to water depth. The null hypothesis was that crayfish in each habitat remain in situ in response to declining water levels.

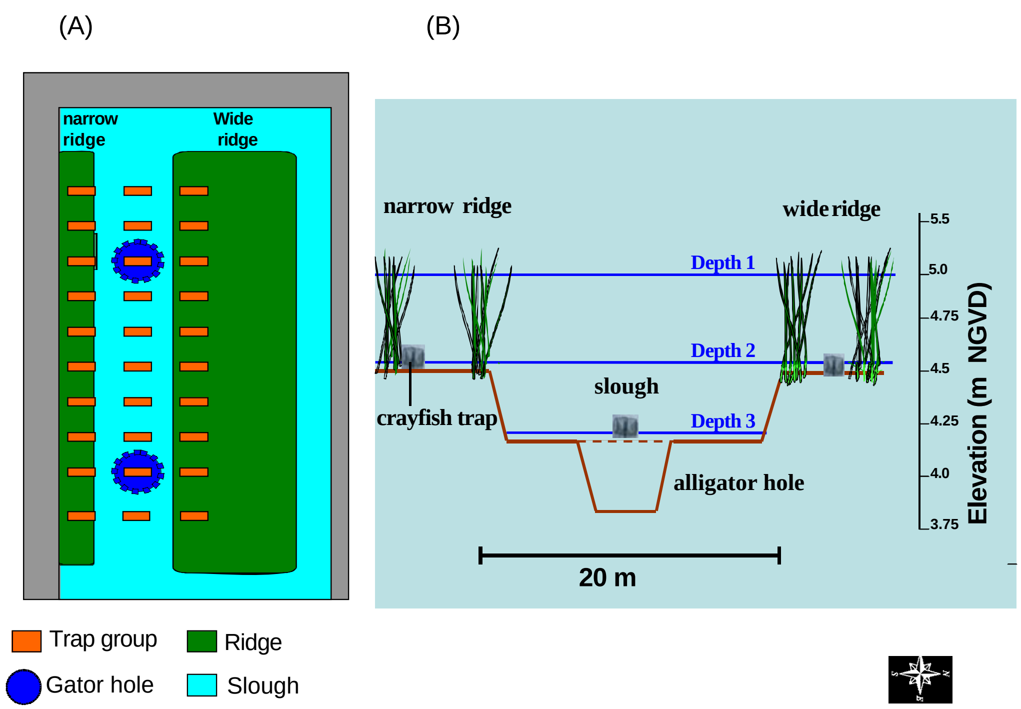


Figure 6-5. Diagram of the experimental setup at LILA. Panel A: Section of a macrocosm showing trap transects across ridges, sloughs, and gator holes (not to scale). Panel B: Cross-section of a ridge and slough transect showing the relative depth of each depth treatment 1–3.

Results: Crayfish density on the two ridges tended to increase as water levels declined (depth 2), then significantly decreased once the ridge became dry (depth 3, **Figure 6-6**; **Table 6-3**). In the sloughs and gator holes, initial crayfish densities were low and changed little whilst water remained on the ridge (depths 1 and 2) but significantly increased once the ridge dried (depth 3). A similar increase was evident (depth 2 to depth 3, $p < 0.07$) in the alligator holes once water levels declined in the slough. Thus, a decrease on the ridge was reflected by an increase in the slough, suggesting that crayfish followed the water as it moved off the ridges. Moreover, crayfish continued to follow the water from sloughs to alligator holes once water levels become shallow in the sloughs. By contrast, no change in density was evident within habitats in control macrocosms where water levels remained constant at 50 cm above the ridge. Mark-recapture data reveals a similar dispersal pattern: no movement between habitats was evident when water was 5 cm above the ridge, but when the ridge dried, 83 percent of recaptured crayfish had moved from ridge to slough and alligator holes, only 8 percent had moved in the opposite direction, and the remaining recaptures had remained in situ. These preliminary analyses suggest crayfish respond to the seasonal drawdown by remaining on the ridges and safe from wading bird foraging until water levels become extremely low. As water levels continue to decline, they move into the sloughs where they subsequently become more available to foraging wading birds. Analyses are currently ongoing for this study.

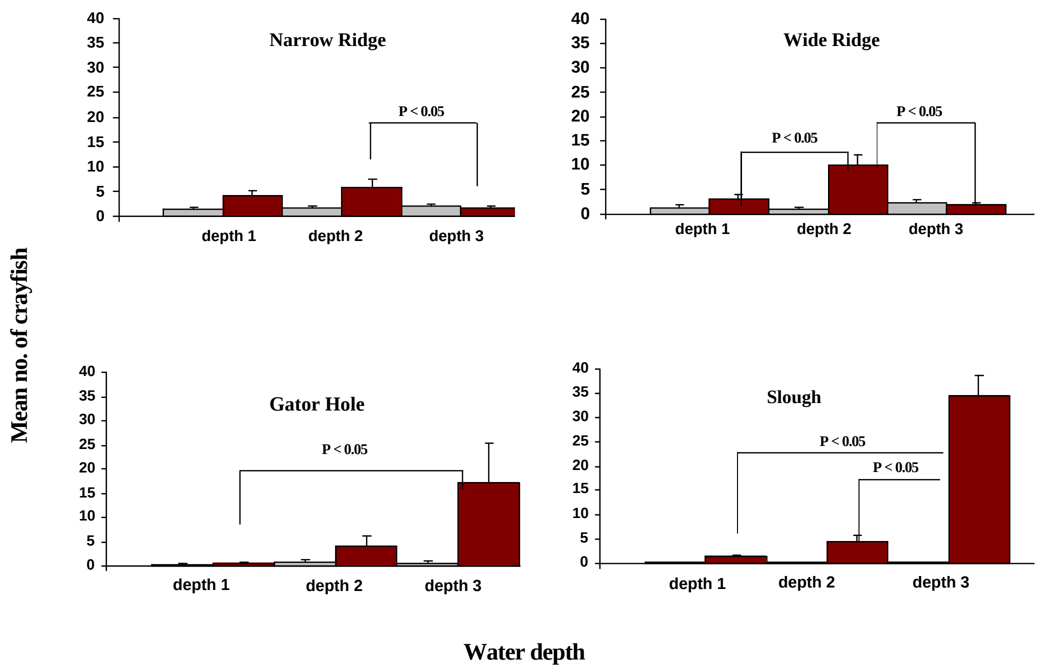


Figure 6-6. Mean (± S.E.) number of crayfish in each habitat within the control (gray bars) and experimental (red bars) macrocosms for each habitat: narrow ridge (n = 20), wide ridge (n = 20), alligator hole (n = 4), slough (n = 16). Significant differences between experimental treatments are displayed (Tukey post-hoc test).

Table 6-3. ANOVA table summarizing the effects of water depth (depths 1–3) and treatment (experiment and control) on the mean number of crayfish caught in each habitat.

Habitat	Source	d.f.	MS	F	P-value
Gator hole	water depth	2	76.38	5.83	0.011
	treatment	1	104.17	7.95	0.011
	water depth*treatment	2	75.76	5.78	0.012
	error	18	13.1		
Slough	water depth	2	165.75	48.84	<0.001
	treatment	1	259.78	76.55	<0.001
	water depth*treatment	2	166.88	49.17	<0.001
	error	90	3.39		
Narrow Ridge	water depth	2	2.33	2.35	0.100
	treatment	1	8.54	8.61	0.004
	water depth*treatment	2	3.33	3.36	0.038
	error	113	0.99		
Wide Ridge	water depth	2	8.44	7.41	0.001
	treatment	1	19.78	17.36	<0.001
	water depth*treatment	2	12.94	11.36	<0.001
	error	114	1.14		

MACRO-INVERTEBRATES FROM HARDWATER AND SOFTWATER MARSHES

In Chapter 6 of the *2005 South Florida Environmental Report– Volume I* (SFER), the ionic water quality contours for the Refuge were used to highlight how hardwater constituents from canals and STAs might be influencing the ecological dynamics of the Refuge. In this year's chapter, this possibility is further explored by comparing the invertebrate communities found in two chemically distinct ecosystems: the softwater Refuge ecosystem, with alkalinities ranging from 41–221 milligrams per liter (mg/L) (mean = 120 ± 56.4) and the hardwater WCA-2A, with alkalinities ranging from 186–278 mg/L (mean = 250 ± 23.5).

Invertebrate communities are believed to be an important trophic link and part of the dynamics of nutrient cycling. They are sensitive to local, small-scale environmental changes associated with management practices, and respond to altered nutrient loads in the Everglades (McCormick et al., 2004; Rader and Richardson, 1994). However, invertebrate community differences due to conductivity differences are lacking.

Insects, gastropods, crustaceans, and annelids sampled using a standardized sweep-net protocol (see previous Everglades Consolidated Reports, or ECRs), dominate the Everglades invertebrate assemblage. In general, this assemblage is consistent throughout the entire Everglades ecosystem. Despite the similarities in the types of organism, species diversity and richness were much higher in the low-conductivity marsh while greater overall densities were recorded in the high-conductivity marsh (**Figure 6-7**). However, some significant taxonomic differences were observed. Greater numbers of Ephemeroptera, Amphipoda, and tubificid oligochaetes were found in the Refuge, while greater numbers of Gastropods and Ceratopogonids were found in WCA-2A. Grass shrimp (Decapoda), beetles (Coleoptera), and water mites (Hydracarina) also had greater relative densities in WCA-2A. Using Principle Component Analysis (PCA), some taxa were found to be strongly associated with conductivity, including Chironomidae: *Beardius truncatus*, *Cladotanytarsus* sp., *Parakiefferiella* sp. F epler, *Parakiefferiella* sp. C epler, *Chironomus* sp., Tanytarsus sp. R epler, Ceratopogonidae: *Dasyhelea* sp., Gastropod: Hydrobiidae, *Littoridinops monroensis*, Oligochaeta: *Dero vaga.* Ninety-three taxa with a frequency of occurrence of at least 5 percent were used in this PCA. PCA axis 1 accounted for 16 percent of the variance and no measured environmental variable was associated with this axis. PCA axis 2 accounted for 14 percent of the variance and measures of conductivity were positively associated with the axis (meaning that some species are associated more with hard or soft waters). PCA axis 3 accounted for 9 percent of the variance and was correlated with temperature (temperature was used as a surrogate for seasonality). The confounding effects of nutrient status were minimized by restricting the analysis to sites with similar TP. Only sites in WCA-2A and the Refuge with TP < 10 ppb were selected. Thus, data are not indicative of eutrophication in the Everglades.

Of the 10 functional groups that were identified in both hardwater and softwater regions of the northern Everglades, there were significantly more predators and grazing collectors in the Refuge, and significantly more grazers in WCA-2A (**Figure 6-8**). Functional groups thought to have an impact on decomposition (i.e., shredders and herbivores) had similar densities and were numerically the least important groups. Although these invertebrate population data show some clear differences between the Refuge and WCA-2A, they do not prove cause and effect. Differences can be due to genetic isolation, hydrology, or vegetation types. The findings of this study do, however, support the hypothesis that the invertebrates of the Everglades are not uniformly distributed across gradients of conductivity. They suggest that the invertebrates may be sensitive to water quality in ways that need to be further explored, especially if the SFWMD is going to “get the water right” for restoration.

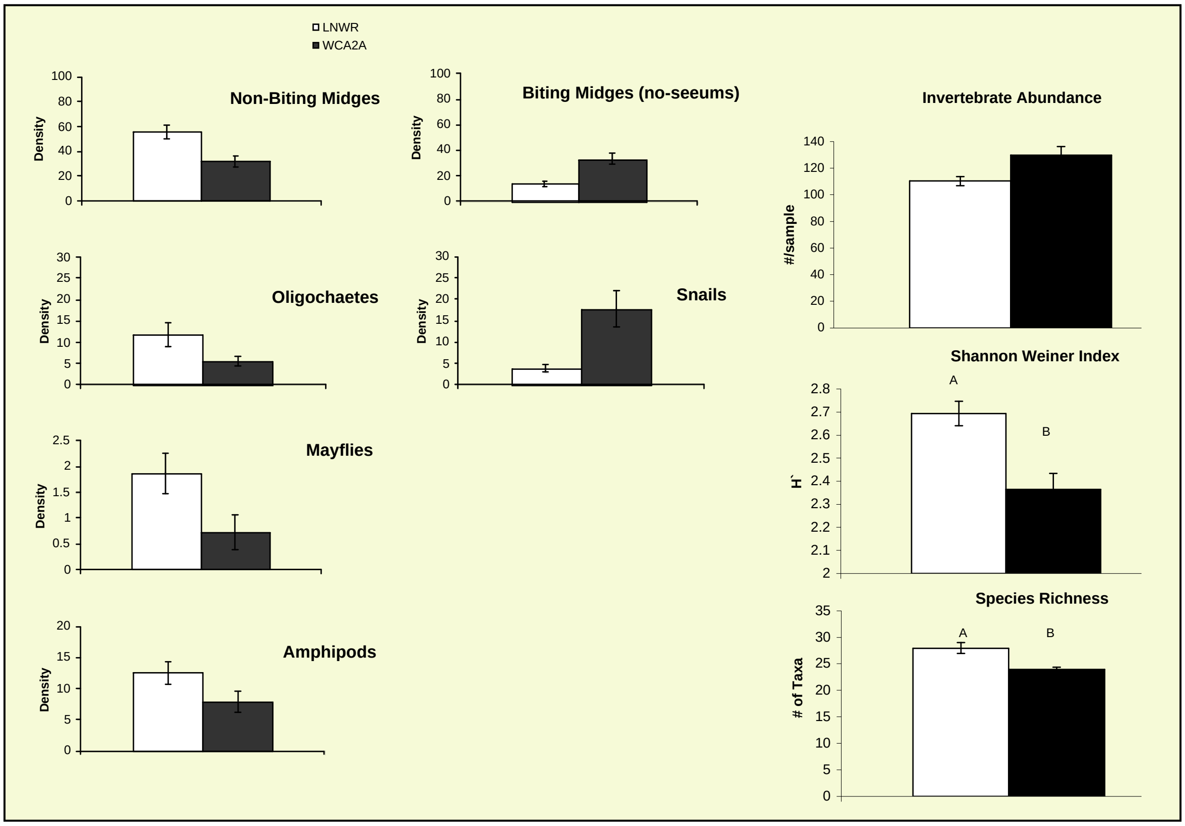


Figure 6-7. Densities (number per sweep) of influential taxa in the Refuge and WCA-2A and average total abundance, species diversity, and species richness of the Refuge and WCA-2A. Bars are ± one standard error. Different letters signify statistically significant differences.

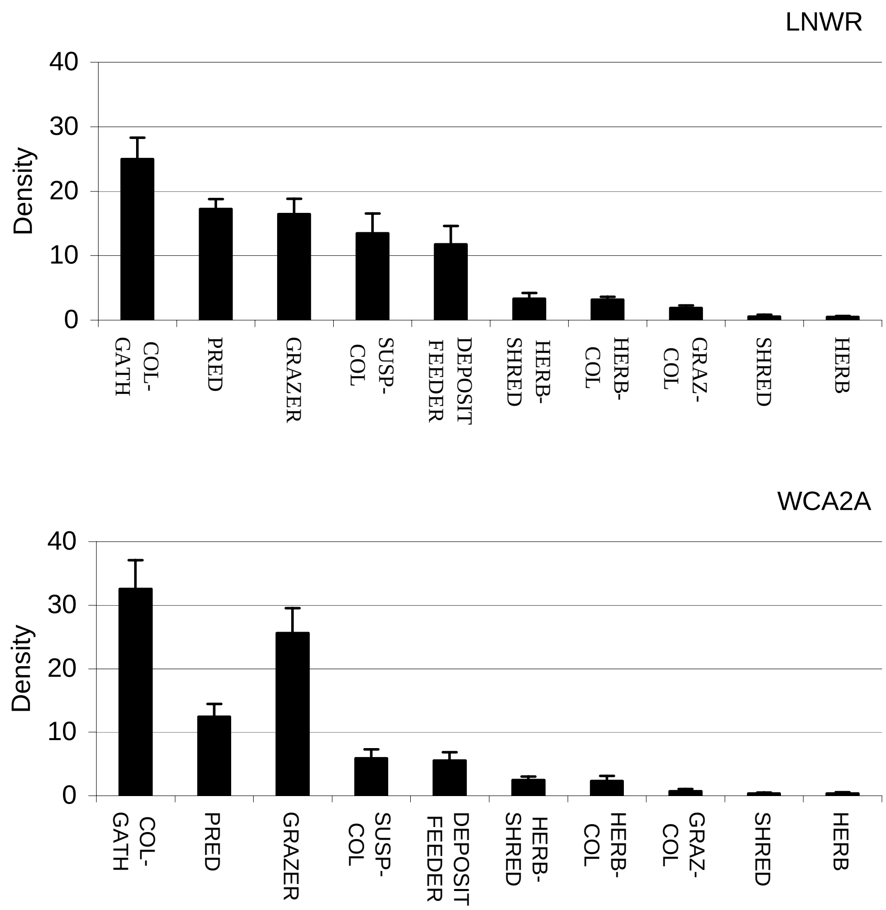


Figure 6-8. Functional feeding group distribution (number per sweep) in the Refuge and WCA-2A.

NONINDIGENOUS FISHES IN THE CENTRAL EVERGLADES

At least 36 nonindigenous fish species (NIF) have become established in South Florida through anthropogenic introductions (USGS, 2005), and many species are now abundant within the canal system that surrounds and dissects the EPA (USGS, 2004). NIF are often detrimental to their host communities (Ogutu-Ohwayo, 1993; Clavero and Garcı´a-Berthou, 2005) and have the potential to significantly impact aquatic communities of the Everglades. This concern led CERP to set NIF population levels in the EPA as an ecological performance measure (RECOVER, 2003).

Most NIF in South Florida are tropical in origin and their populations are considered to be regulated by annual minimum temperatures and reliant on deep water thermal refugia (Trexler et al., 2000). Consensus contends that thermal constraints and the difficulty associated with migrating within the ridge and slough landscape limit their distribution to within approximately 1 km of canals. As such, their impact on the marsh community is considered to be minimal (Trexler et al., 2004). A number of NIF species have been recorded in low relative abundance within certain marshes of the EPA (e.g., Chick et al., 2004; Kobza et al., 2004), but no survey has been conducted that specifically targets NIF, and the sampling methods employed to date have biases that potentially under-sample NIF (Loftus, 1986). Therefore, the distribution, abundance, and species diversity of NIF in the EPA may be considerably underestimated, and there is very little understanding of what species are established in the marsh.

This past year, the District's Everglades Division investigated NIF species diversity in WCA-3A and examined whether NIF species are established in the marsh or restricted in distribution by proximity to a canal. To determine establishment, the NIF relative abundance was evaluated in relation to distance from the L-67A canal. Species were considered established if its relative abundance beyond 1 km of the canal was equal to or greater than that within 1 km of the canal.

Methods: A stratified random sampling design was used to examine relative abundance of NIF in relation to distance from canal. Three distance categories of 0–1 km, 2–3 km, and 4–5 km from the central portion of the L-67A canal were established. Each sampling category was 15 km long by 1 km wide and divided into thirty 500 x 500 m primary sampling units (PSU). Within each distance category, 14 PSU were randomly selected, and within each PSU, a sample slough was randomly selected. On each of the 14 sampling events, a slough from each of the three distance categories was sampled. To examine the potentially limiting effects of low temperature on NIF distributions, the survey was conducted from December 2004–April 2005.

Two types of passive trapping gear capable of capturing a range of NIF sizes and ages were deployed in each sample slough. Two modified Fyke nets (33-ft lead, 3-ft height, 7 hoop, 3-in diameter, 1/4-in mesh) were used to capture fish of broad size classes (> 45 mm) and eight Gee minnow traps (1/8-in mesh) were set at top and bottom of the slough to capture fishes of mid-small size class (< 45 mm). Fyke nets were positioned in the deepest section of the slough and spaced at least 30 m apart. Two minnow traps were positioned on either side of the slough in wet prairie adjacent to each Fyke net. Minimum temperature was recorded from the bottom of the slough.

Relative NIF abundance was based on catch-per-unit effort (CPUE) over a 24-hour sampling period. The entire catch from each trap was bagged, placed on ice, and subsequently analyzed in the lab. Fish species were identified and total length (TL) and wet mass (g) were measured.

Results: This survey captured both native and nonindigenous fishes within a broad range of size classes (4–368 mm total length) representing 26 species and 2,636 individuals. The NIF captured in this study included three species of cichlid, a carp, and a catfish. These species were an important component of the marsh fish community, accounting for 20 percent of the species count, 6 percent of the total biomass, but less than one percent of the total fish count (**Figure 6-9**). The CPUE of all species was relatively low, possibly due to high water levels in the marsh during the sampling period (CPUE is negatively related to water depth). The low CPUE for each NIF species precluded statistical analyses.

The CPUE for NIF was highest for the black acara (*Cichlasoma bimaculatum*) (16 individuals). Its CPUE was highest at distances beyond 1 km from the canal, suggesting it is established in the marsh (**Table 6-3**). Moreover, juveniles were captured 3–4 km from the canal, providing further evidence of establishment. It is notable that this species was caught up to 2 ºC below its published minimum lethal temperature. The Mayan cichlid (*C. urophthalmus*) had the second largest CPUE (four individuals), and the highest biomass (**Figure 6-9**; **Table 6-4**). Indeed, it was the eighth most abundant fish of the entire marsh fish community in terms of biomass. Mayan cichlids were distributed equally among the three distance categories, juveniles were captured 3–4 km from the canal, and it is likely that this species is established in the marsh. It was captured up to 4 ºC below its published minimum lethal temperature.

A single juvenile spotted tilapia (*Tilapia mariae*) was captured within 1 km of the canal. While this species is possibly established in the southern Everglades (Kobza, 2004), its minimum thermal tolerance (17 ºC) is far higher than the average minimum water temperature for WCA-3A and its distribution is likely restricted to the marsh bordering the canal.

A single juvenile brown hoplo (*Hoplosternum littorale*) was captured 2–3 km from the canal (**Table 6-3**). While a single individual reveals little about possible establishment, its capture 2–3 km from the canal and observations of bubble nests in other areas of WCA-3A suggest that this species is established and warrants further investigation.

An immature grass carp (*Ctenopharyngodon idella*) was captured within 1 km of the canal and represents a potential new record for the region. This species is not tropical in origin and would not be limited by minimal lethal limits. However, its limited distribution in WCA-3A suggests other environmental constraints may limit its invasion into the marsh.

Although this survey was unable to statistically determine establishment for these NIF species, they suggest that at least two species, and possibly a third, are getting established in the marsh. Future studies will be needed to focus on the ecological factors determining the distribution of these NIF species and to reevaluate species-specific physiological tolerances to seasonal minimum temperature.

Table 6-4. Distribution of nonindigenous fish in relation to the L67-A canal in WCA-3A and related information on establishment.

Species	CPUE in relation to canal (1km,3km,5km)	Minimum Lethal Temperature (ºC) [Range]	Minimum Temperature at Capture (ºC)	Established
Black acara	(3, 9, 4)	8.9[1] [8-11]	11	Yes
Mayan cichlid	(1, 2, 1)	15.0[2] [14-15]	11	Yes
Brown hoplo	(0, 1, 0)	18.0[3] estimate	19	Possibly
Spotted tilapia	(1, 0, 0)	11.2[1] [10-12]	17	No
Grass carp	(1, 0, 0)	0.0[4] [0-100]	20	No

Shafland and Pestrak 1983[1], Stauffer and Boltz 1994[2], Froese and Pauly 2005[3], Indiana DNR, AIS 2005[4]

Loftus 1987[a] , Nico et al. 1996[b], Hogg 1974[c], Fuller et al. 1999[d]

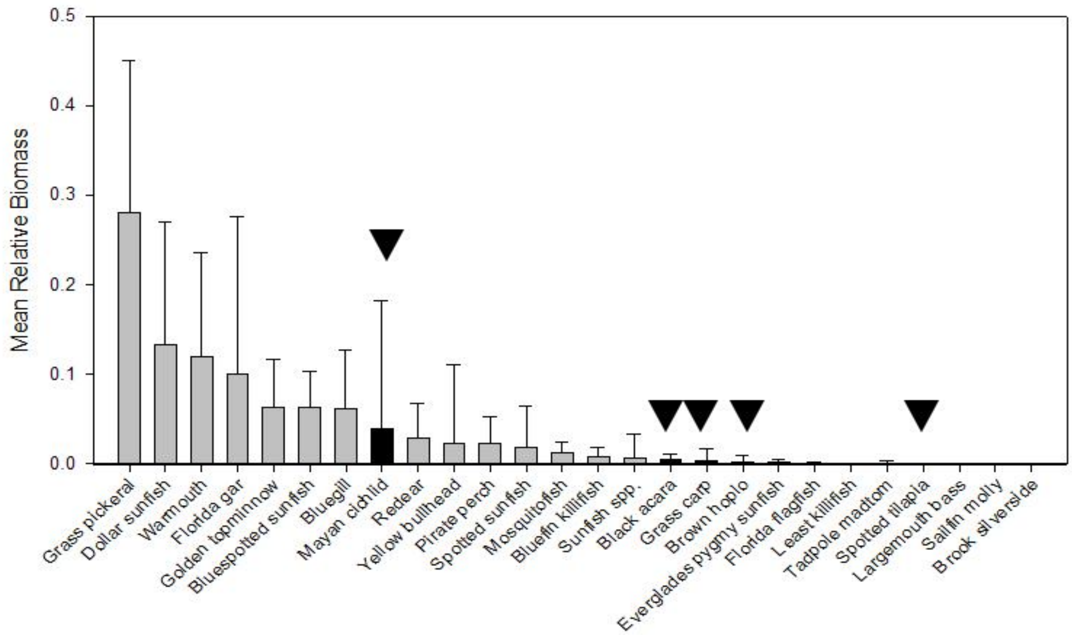


Figure 6-9. The mean (± S.D.) biomass of all fishes captured, with nonindigenous species indicated by diamonds. The Mayan cichlid constituted a relatively large fraction of total biomass, and rare nonindigenous fishes were as common as generally ubiquitous native species.

PLANT ECOLOGY

The major research objective of our plant ecology studies is to understand vegetation dynamics in relation to water management. This requires that the physiological and biological processes that cause vegetation replacement, degradation, and premature death be examined in relation to environmental disturbances, such as phosphorus enrichment and altered hydrologic regimes that cause peat fires or stress. Previous reports have shown how phosphorus enrichment contributes to cattail expansion and the disappearance of ridge/slough communities. Life history characteristics of cattail and sawgrass were found to be significantly different. Processes of root oxygenation during extreme hydrologic events favor cattail growth when phosphorus concentrations in the soil and water are high. In this report, an experiment to access the flood tolerance of first-year seedlings of three dominant tree island species, and how the hydrologic restoration in the Rotenberger Wildlife Management Area has led to an increase in hydroperiods and more desirable plant species is described. Future studies will continue to explore the multifaceted biology of both native and invasive plants in relation to current and predicted hydrological and biogeochemical regimes.

LILA TREE SEEDLING EXPERIMENT

Tree islands are an important component of the greater Everglades ecosystem that has disappeared at an alarming rate (Sklar and van der Valk, 2002). The slightly higher elevation of the tree islands than surrounding sloughs, wet prairies, and sawgrass flats enables a variety of terrestrial plant and animal species to persist in the Everglades (Davis, 1943; Loveless, 1959; McPherson, 1973; Zaffke, 1983; Heisler et al., 2002). Tree islands are also important habitat, at least seasonally, for many animal species. Deer, alligators, small mammals, reptiles, and many bird species use tree islands for nesting, foraging, and resting. For example, more songbird species are found on tree islands than any other habitat in the central Everglades (Gawlik and Rocque, 1998). In short, tree islands provide essential habitat for many species of animals in the Everglades sometime during their life cycles.

The restoration of the Everglades, if it is to be truly successful, will require not only preventing additional tree island losses, but also restoring tree islands where they have been lost, and possibly creating tree islands to mitigate for losses. Information needed to design and implement a tree island restoration or creation project is generally not available, and there have been very few attempts to either restore or create tree islands. The few attempts that have been made are not well documented, and their goal was not to create or restore an island that was functionally equivalent to existing fixed tree islands. Consequently, there are many uncertainties about their restoration and creation. Cost-effective and reliable protocols for both are urgently needed. A pilot project to assess tree island restoration techniques is an essential first step for developing these protocols. Such a pilot project is one of the main features of the LILA facility.

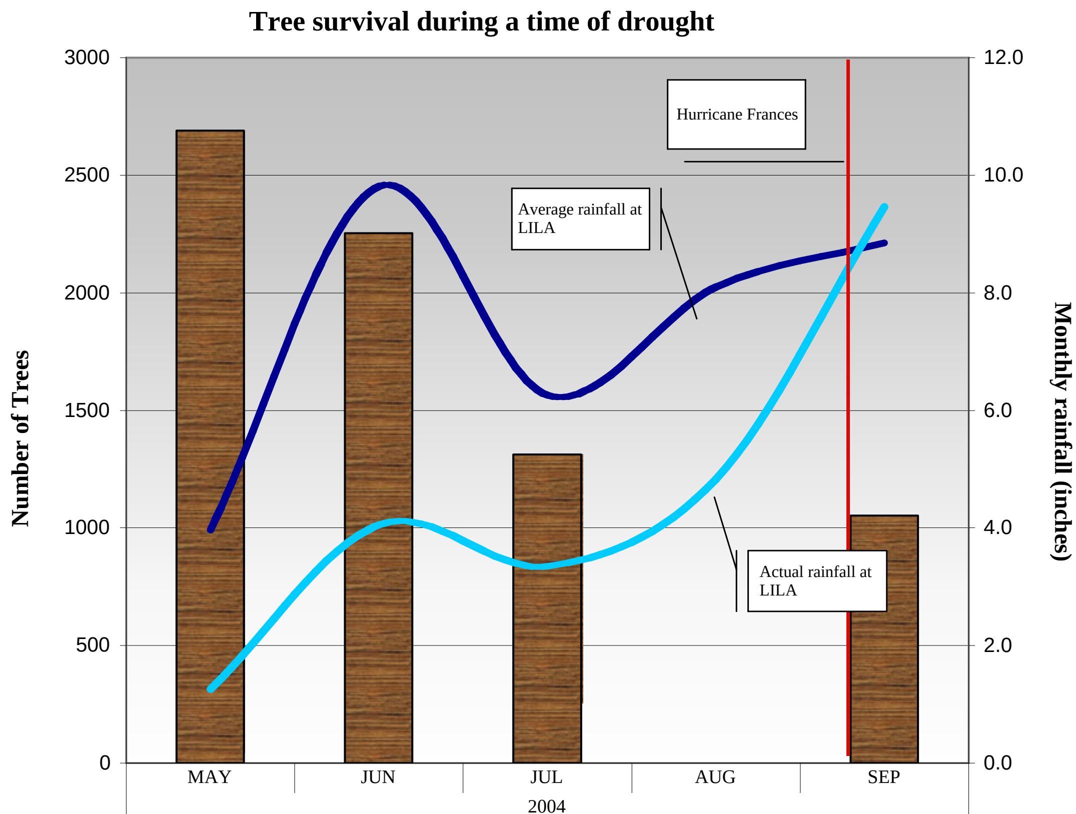
Whether a tree island is created or restored, suitable tree species must be planted. However, flooding tolerances of most common tree island trees are not well known. A recent study at LILA was initiated in 2004 in order to assess the water tolerances of woody species found on tree islands in the northern Everglades **(Table 6-5**). The six-month-old seedlings were planted in May 2004 in rows across a hydrologic gradient stretching from the island center to the edge. Over time, the trees were monitored for structure and survivorship.

Table 6-5. Woody species that were planted in the LILA tree seedling experiment.

Scientific Name	Common Name
Acer rubrum	Red Maple
Annona glabra	Pond Apple
Salix caroliniana	Coastal Plain Willow
Chrysobalanus icaco	Coco Plum
Ilex cassine	Dahoon Holly
Magnolia virginiana	Sweet Bay
Myrica cerifera	Wax Myrtle

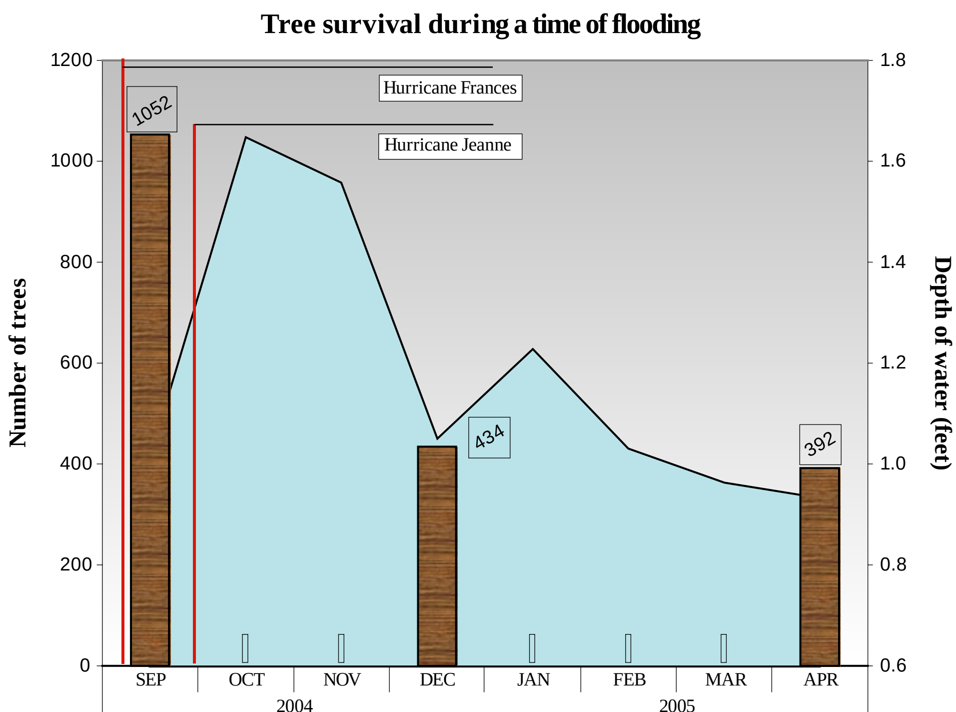
The trees planted in LILA were propagated from local stock. During the week of May 24, 2004, trees were planted on both sides of each island, from the center, all the way down the sides, to the slough bottom. They were planted on 1.75 m centers in rows perpendicular to the long axis of each island. Planting individuals 1.75 m apart results in an elevation change of 0.25 m between the 20 trees planted along each transect. Transects were spaced 2 m apart on the long axis of the islands. This resulted in 25 transects across each island, for a total of 200 transects (or 400 half-transects) across the eight islands. For each tree species, a total number of 50 trees were planted on each island for a total of 400 individuals of each species on all eight islands.

A summary of the results are shown as a time series divided into a period of drought (**Figure 6-10**) followed by a period of flooding (**Figure 6-11**). The drought lasted from May–August 2005, produced a cumulative below-normal deficit of 14 inches, and it caused severe desiccation of the peat soils in LILA. As a result, the survival rate was only 39 percent and 1,638 tree seedlings died (**Figure 6-10**). All species were impacted and some were nearly eliminated including wax myrtle (*Myrica cerifera*) (20 percent survival) and sweet bay (*Magnolia virginiana*) (12 percent). The most drought-resistant species was dahoon holly (*Ilex cassine*) with a survival rate of 63 percent. Similarly, flooding due to hurricanes reduced survival of seedlings. Hurricanes Frances and Jeanne submerged the islands by 1.0–1.5 feet of water for six months, which completely submerged most of the hardy seedlings that were able to survive the drought. The result was a further reduction of 660 individuals and a general survival rate of only 37 percent. All remaining species also were impacted, and some were completely eliminated. The most flood-resistant species after the drought was coastal plain willow with a survival rate of 65 percent. The preliminary conclusion is that recruitment of tree seedlings to natural islands in the Everglades is hindered by the hydrologic extremes that were experienced in the LILA experiment. This may explain why most islands do not have a broad range of species or numerous cohorts of age groups. As the District's tree island program continues, more detailed studies will elucidate natural patterns on tree islands and the potential to restore islands that have been lost.



	MAY	JUN	JUL	AUG	SEP
Number of trees surviving	2690	2253	1313		1052
15 year average rainfall at LILA	4.0	9.8	6.3	8.1	8.8
Actual rainfall at LILA	1.3	4.1	3.4	4.8	9.5
Cumulative diff. between actual and ave.	2.7	8.5	11.4	14.6	14.0

Figure 6-10. Average and actual rainfall, and its cumulative difference is used to illustrate the impacts of the 2004 drought on 2,690 tree island seedlings that were planted on eight LILA islands.



	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
Depth of water over the marsh surface	1.0	1.6	1.6	1.1	1.2	1.0	1.0	0.9
Number of trees surviving	1052			434				392

Figure 6-11. Average monthly water depth of the LILA tree islands and its cumulative impacts on the survival of the 1,052 tree island seedlings that survived the 2004 drought.

PLANT DISTRIBUTIONS ON WCA-3B TREE ISLANDS

Restoration activities related to CERP include plans to hydrologically reconnect WCA-3A and 3B. The SFWMD will undertake long-term monitoring of tree island health in order to assess the success of restoration activities. Twelve tree islands in WCA-3B and four in WCA-3A were selected for this monitoring program (**Figure 6-12**). Selection criteria included current island condition and potential for change after hydrologic modifications occur. Additionally, it was important that these islands were not used for any active recreational purposes.

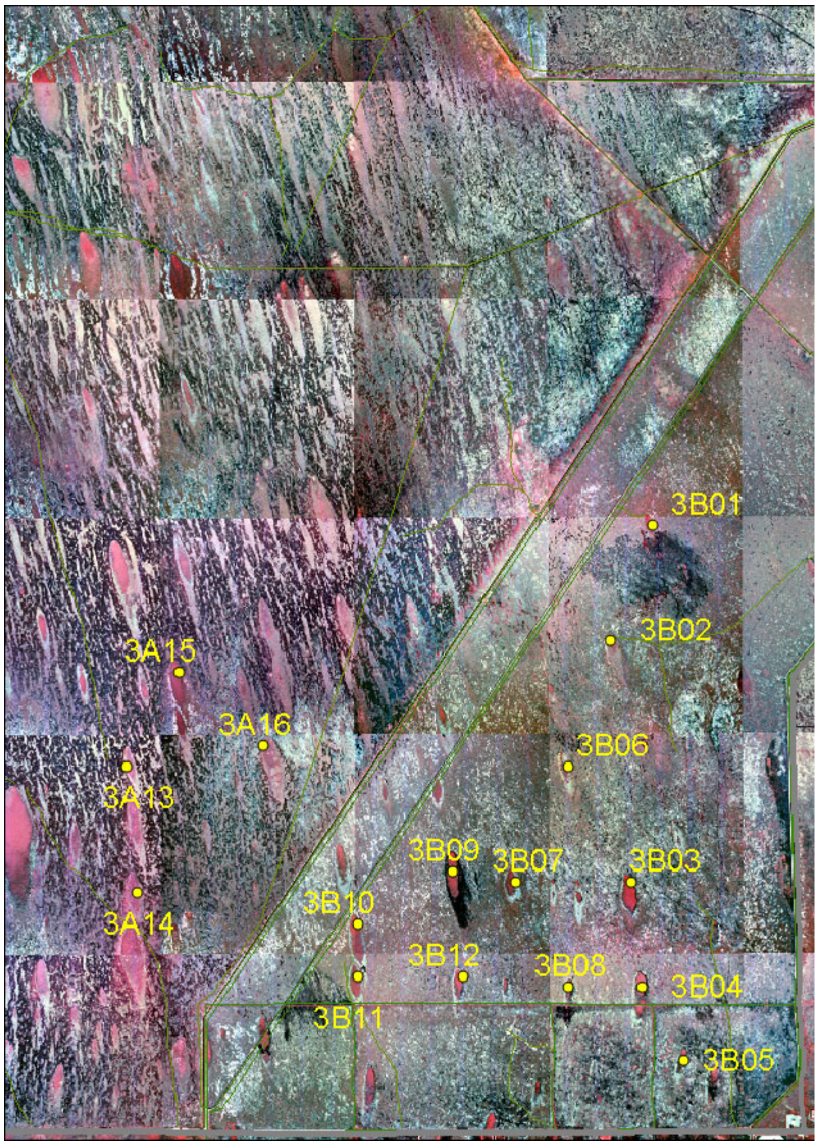


Figure 6-12. Twelve fixed tree islands in WCA-3B and four in WCA-3A were selected for the establishment of tree island base conditions for understanding the impacts of the Combined Structural and Operational Plan (CSOP) and the Comprehensive Everglades Restoration Plan (CERP).

Data were collected in two adjacent 10 x 10 m (0.01 ha) plots at the head, and two adjacent 10 x 10 m (0.01 ha) plots at the near tail of each tree island. Each tree in each plot was tagged, identified to species, and height and diameter at breast height (dbh) were recorded. A tree was defined as any woody species with a dbh greater than 2.5 cm. Each tree was tagged with a unique number at breast height (approximately 1.4 m) and dbh was measured 4 cm above and 4 cm below the tag. Additionally, each tagged tree was assessed for infestation of lobate lac scale (*Paratachardina lobata lobata*). Water depth was measured 1.0 m to the north of each tree.

In order to sample understory vegetation, which includes herbaceous seedlings and saplings, one 4 x 4 m subplot was established within each of the larger 10 m^2 plots. Dominant herbaceous and shrub vegetation rooted within the subplot were identified to species. Species with greater than 33 percent cover were considered a dominant species and cover was recorded. An average of the herbaceous and shrub species heights was obtained by collecting five height measurements, one in each corner and one in the subplot center. Individual tree seedlings and saplings found within the subplot were identified to species and their height was recorded. Seedlings and saplings were also assessed for infestation by lobate lac scale. Endangered species encountered were noted and their locations recorded using a Global Positioning System (GPS) unit, where possible. Exotic species encountered were noted and their locations were also recorded.

Nine tree species were found to dominate on the four tree islands presented in this report. All species are common to tree islands throughout the Everglades. Unfortunately, Brazilian pepper (*Schinus terebinthifolius*) was present on one of the four islands. An extensive population of Lygodium was discovered on one island in WCA-3B. Details of this infestation will not be covered in this report. All data reported to date is currently in the quality assurance/quality control (QA/QC) process; therefore, all results should be considered preliminary. Preliminary analysis indicates that there are no significant differences between islands in terms of basal area and stem densities. However, in some cases there are significant differences in forest structure between the tree island heads and near tails.

The basal area of each woody species was estimated by converting the diameter of each tree at breast height (dbh) to cross-sectional (basal) area. Basal areas for the four islands varied from 302 m^2/ha to 14 m^2/ha (**Table 6-6**). This large variation can be explained by the presence of a few large ficus (*Ficus aurea*) trees with an average diameter of 71.53 ± 9.70 cm, which suggests that the head of island 3B10 may be suitable for tree species that tolerate dry conditions.

Table 6-6. The diameter at breast height for mature woody species was used to calculated basal area on heads and near tails of tree islands.

Basal Area (m2/ha)

	3A15		3A16		3B10		3B11	
	Head	Neartail	Head	Neartail	Head	Neartail	Head	Neartail
Ficus aurea	0	0	0	0	289.46	0	0	0
Persea borbonia	0.24	0.61	0	0.32	0	0.80	0.54	2.64
Salix caroliniana	4.50	13.99	5.53	1.45	1.81	8.99	5.45	12.48
Ilex cassine	0.36	0.84	0	0.67	0	10.03	0	5.27
Myrica cerifera	0.05	0.68	0.56	0	3.94	5.03	2.43	0.79
Annona glabra	65.74	0	15.04	0	7.07	1.96	5.27	1.46
Acer rubrum	0	0	3.73	0	0	0	0	0
Schinus terebinthfolius	0	0	0	0	0	2.83	0	0
Magnolia virginiana	2.21	0	11.54	0	0	1.78	0	0
Total (BA)	73.10	16.12	36.40	2.44	302.28	31.42	13.69	22.64

Stem densities (**Table 6-7**) were calculated by counting the number of individuals found within each of the 10 m^2 plots. An estimate of the number of individuals was calculated to estimate the number of stems per 100 m^2 or hectare (ha). Tree islands in the Everglades ecosystem will typically have a higher number of individuals on the near tail than on the head. Forests located on the elevated head of the islands have low density, high basal area, and are dominated by few tree species, which are considered biological parameters that lead to a more mature forest. In contrast, in the longer hydroperiod portion of the island, tree density is high and basal area low, leading to a younger forest relative to that of the head. Two of the islands presented in this report follow this trend (3AS15 and 3B10); however, only 3A16 had stem densities relatively higher compared to the near tail. Such differences may suggest that this island may be a young forest and in the process of becoming more mature and dominated by few tree species (i.e., *A. glabra* and *M. virginiana*) (**Table 6-7**).

Table 6-7. The stem density for all woody species will be used to evaluate tree island bio-complexity and maturity.

Stem Density (# stems/ha)

	3A15		3A16		3B10		3B11	
	Head	Neatail	Head	Neatail	Head	Neatail	Head	Neatail
Ficus aurea	0	0	0	0	600	0	0	0
Persea borbonia	200	400	0	100	0	100	300	850
Salix caroliniana	1450	4200	800	1550	200	1000	1050	900
Ilex cassine	250	750	0	250	0	1700	0	1500
Myrica cerifera	100	700	200	900	700	2150	1100	800
Annona glabra	2300	0	1050	0	750	433	2200	200
Acer rubrum	0	0	400	0	0	0	0	0
Schinus terebinthfolius	0	0	0	0	0	50	0	0
Magnolia virginiana	300	0	2000	0	0	300	0	0
Total (stem density)	4600	6050	4450	2800	2250	5733	4650	4250

Understory vegetation surveys have found that all four of these islands contain species typical of other islands in the system. Twelve herbaceous species were found on the four islands: *Blechnum serrulatum, Pontederia lancifolia, Acrostichum danaeifolium, Saururus cernuus, heylpteris interrupta, Nephrolepis biseratta Boehmeria cylindrica, Peltandra virginica, Cephalanthus occidentalis, Aster carolinianus, Vallisneria americana, Osmunda regalis,* and *Smilax* spp. A seedling and sapling component was also included in the understory survey. Seedling and saplings studies are required to determine how current hydropatterns impact tree island regeneration in terms of seedling recruitment, survival, and aboveground production. All islands included in this report have an existing population of seedlings and saplings that need further analysis to understand how successful the recruitment process is on tree islands subjected to long hydroperiods.

With their extreme sensitivity to water levels, the health of tree islands can be a good indicator for the overall condition and success of hydrological management of the Everglades. Determining the causal background of the current forest structure through long-term research and monitoring before and during CERP will help predict how these ecosystems will change in response to alterations in the system.

ECOSYSTEM ECOLOGY

While the Everglades is often called the "River of Grass," it is in fact a heterogeneous ecosystem with a range of chemical, biological, and physical characteristics. The goal of ecosystem research is to identify ecotypes of special concern in Everglades restoration and focus research in that direction. Two issues that are highlighted this year are the impacts of hard water and the importance of tree islands. As a whole, the Everglades is considered a hardwater ecosystem; however, in reality, the northern extent was historically soft water. This was recognized early in the CERP process, with the decision not to convert the Refuge into a sheetflow system, but to retain its impounded nature in order to protect this sole remaining softwater environment. However, complete isolation from surface water discharges is currently not possible, so it is important to understand to what extent the system can withstand alterations in surface water chemistry without degradation in structure and function. Tree islands continue to be a major focus of research because these biodiversity hot spots are crucial for many animals that use these sites for mating, nesting, and foraging. The threat to the species that depend on tree islands is exacerbated by the fact that there are far fewer tree islands today than in previous years (Sklar and van der Valk, 2002). Decreasing tree island elevations, relative to water levels, may explain the 60 percent loss of islands in WCA-3 since 1940. As described below, comparisons of above and belowground productivity and biomass accumulation indicate that root production and decay may play a more important role than aboveground processes in contributing to soil formation and elevation of tree islands.

HYDROPATTERN RESTORATION DOWNSTREAM OF STAs

Northwest Water Conservation Area 2A

In accordance with the Everglades Forever Act (EFA; Permit No. 0126704), the South Florida Water Management District began operating Stormwater Treatment Area 2 (STA-2) in July 2001 with the objective of restoring the hydropattern and ecological functionality to the northwestern portion of WCA-2A. As a result, a monitoring and research program was established to document existing marsh conditions before July 2001 and evaluate hydrologic and biological changes occurring in the downstream areas receiving STA effluent after July 2001.

In 1997, three monitoring transects (North, Central and South) were established in the direction of water flow from the L-6 levee, southeast towards the interior of the marsh (**Figure 6-13**). As a result of operational changes, an additional transect (404Z) was established in 2000. In July 2001, STA-2 became operational and began discharging effluent through six box culverts spaced over a 3.7 km section of the L-6 levee. When water levels in the distribution canal reach 14.0 ft NGVD, water flows toward the southwest section of WCA-2A and enters the marsh via a degraded portion of the L-6 levee. There are no stage gauges within the vicinity of the monitoring area; therefore, hydrologic changes, specifically water depth and duration, are measured monthly at each site during water quality sampling. The mean water depth pre-STA-2 operation was 0.09 m, while the mean water depth post-STA-2 operation was 0.28 m (**Figure 6-14**). All monitoring stations demonstrated an increase in the number of months each site was inundated after receiving STA-2 effluent. These stations were consistently monitored before and after STA-2 began operating.

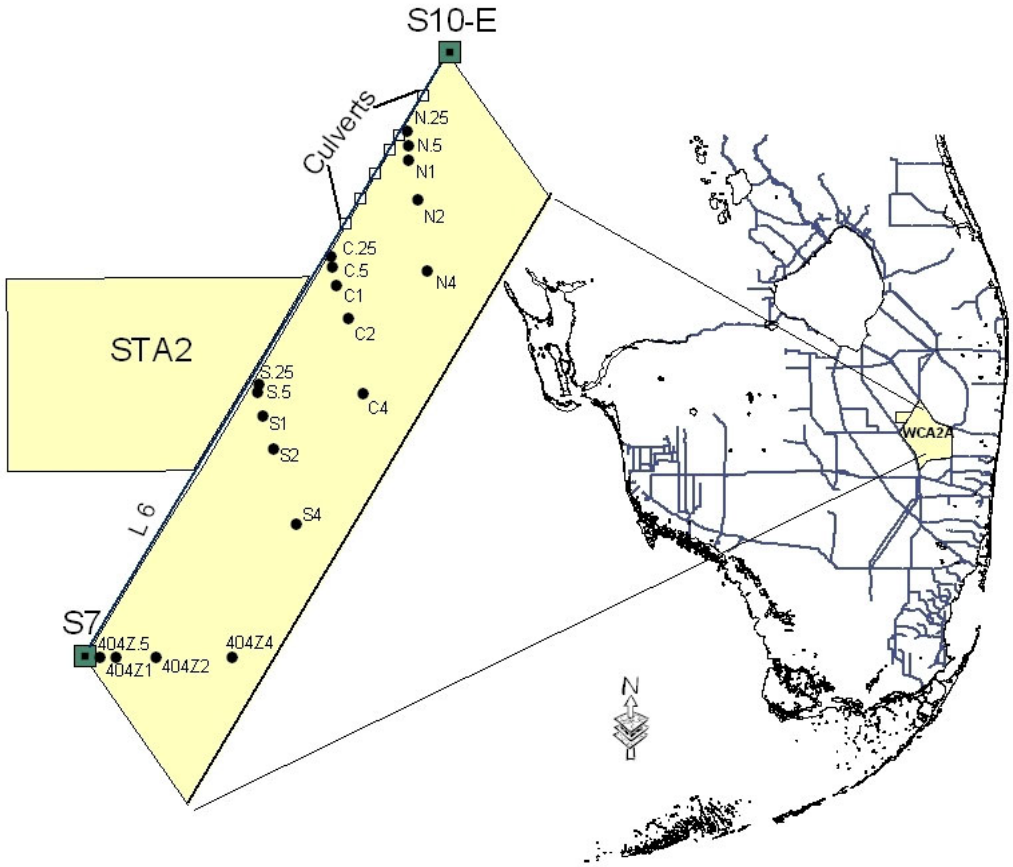


Figure 6-13. Map of WCA-2A showing the locations of all stations used to monitor STA-2 discharge.

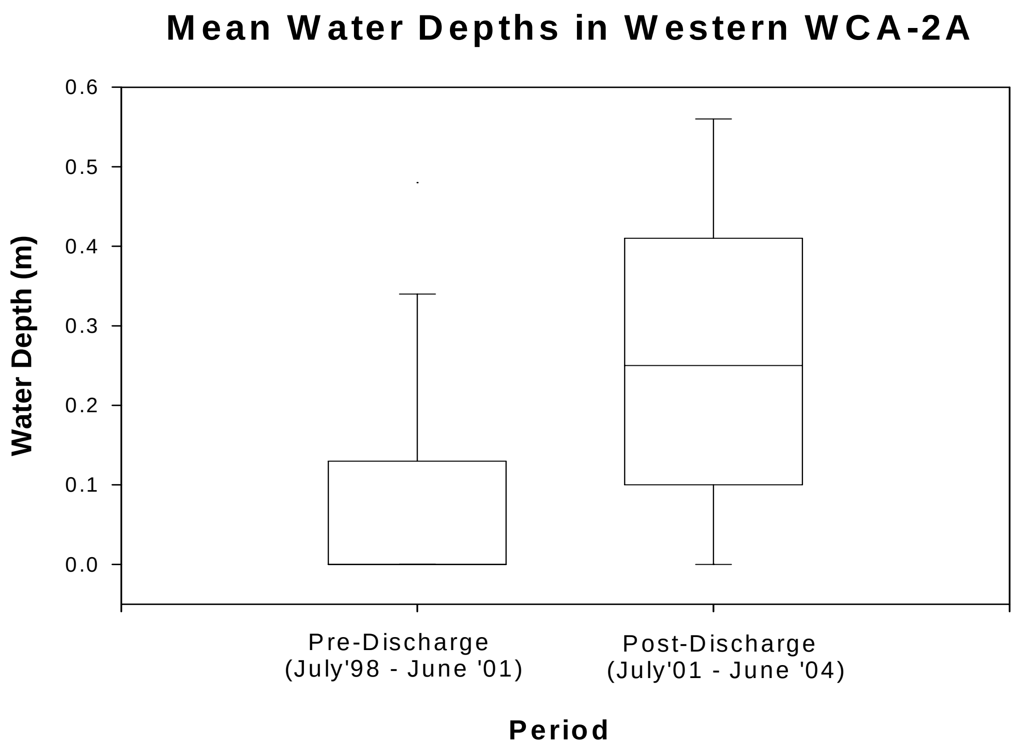


Figure 6-14. Mean water depths (meters) pre- (N=349) and post-STA (N=339) discharge periods calculated combining the N.25, N1, N2, N4, C.25, C1, C2, C4, S2, and S4 sites.

Water quality samples were collected monthly at the N.25, N1, N2, N4, C.25, C1, C2, C4, S2, and S4 stations pre- and post-STA-2 operations. The combined mean total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations for these stations during the pre-discharge period were 0.0396 and 0.0201 mg/L, respectively. In the post-discharge period between July 2001 and June 2004, the mean TP and SRP concentrations were 0.0188 and 0.0064 mg/L, respectively. Each transect exhibited a phosphorus gradient, with elevated phosphorus concentrations at sites near the L-6 levee and decreasing at sites further into the marsh interior (**Figure 6-15**).

There were no significant differences in soil phosphorus concentrations from year to year; consequently, data from all years was combined for each station to generate mean soil phosphorus concentrations. Results are not bulk-density corrected, as measurements were fairly uniform throughout the transects. Soils were cored to 20 cm and then sectioned into 0–2 cm, 2–10 cm, and 10–20 cm layers. For comparative purposes, data from the 0–2 cm and 2–10 cm layers were combined, creating a 0–10 cm layer of soil (**Table 6-8**). A soil phosphorus gradient exists spatially north to south and from west to east, with higher TP concentrations in the north and west portions of the marsh. Similarly, the 404Z transect stations closest to the S-7 structure have a higher soil TP concentration compared to sites further from the structure, toward the marsh interior.

Soil TP concentrations in the Everglades greater than 500 mg/kg are considered high nutrient, impacted soils (DeBusk et al., 1994). According to Wu et al. (1997), soil TP concentrations greater than 650 mg/kg in the 0–10 cm layer are conducive for accelerating cattail (*Typha domingensis* Pers.) expansion. The monitoring stations near the S10-E and S-7 pump station (N.25, N.5, N1, 404Z.5, 404Z1, 404Z2) have mean soil TP concentrations in the 0–10 cm layer greater than 650 mg/kg and are dominated by cattail or a cattail/sawgrass mixture. All other sites are dominated by sawgrass.

Table 6-8. Mean total phosphorus (TP) concentrations of the 0–10 cm layer of soil with standard deviations for each monitoring station in northwestern WCA-2A. Soil was sampled during 1998, 1999, 2000, 2002, 2003, and 2004.

Station	Mean Soil Phosphorus Concentrations (mg/kg)	Station	Mean Soil Phosphorus Concentrations (mg/kg)
N.25	787 ± 181	S.25	501 ± 54
N.5	751 ± 87	S.5	545 ± 49
N1	663 ± 120	S1	457 ± 50
N2	643 ± 80	S2	539 ± 59
N4	539 ± 75	S4	393 ± 48
C.25	550 ± 53	404Z.5	1496 ± 175
C.5	542 ± 44	404Z1	1398 ± 134
C1	456 ± 39	404Z2	1082 ± 131
C2	458 ± 47	404Z4	548 ± 150
C4	459 ± 66		

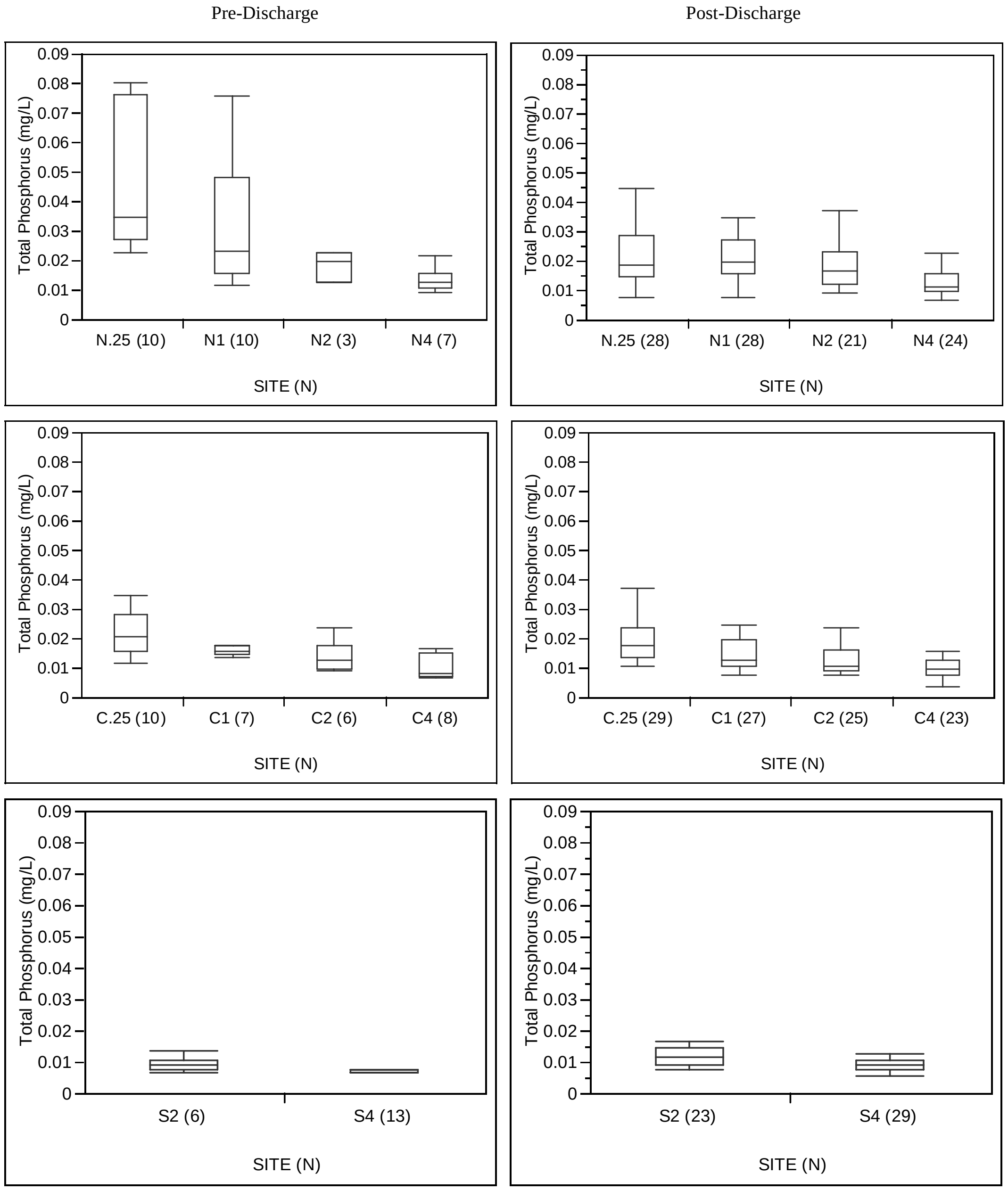


Figure 6-15. The mean TP concentrations for surface water samples collected at the N-transect, C-transect, and S-transect sites during the pre-discharge (July 1998–June 2001) and post-discharge periods (July 2001–June 2004). Number of samples taken is designated within parentheses.

The N1 station, which contains soil TP concentrations slightly above 650 mg/kg, has alternated between cattail and sawgrass (*Cladium jamaicense crantz*) as the dominant species between 1998 and 2004 (**Figures 6-16** and **6-17**). Currently, the N1 station is dominated by a mixture of sawgrass and cattail (**Figure 6-18**). However, there have been several events affecting the cattail coverage during this time period. Severe drought conditions in 1999 and 2000 eliminated live aboveground biomass. A surface burn in 2000, followed by a rapid rise in water depth to over 70 cm, eradicated the remaining cattail in the immediate vicinity. As water levels receded, sawgrass became the dominant species until 2001–2002, when hydrologic conditions became more conducive to cattail with water levels consistently above 60 cm for longer periods of time.

Figure 6-16. Photo of station N1 in March 1998; the dominant macrophyte community is cattail (SFWMD photo).

Figure 6-17. Photo of station N1 in July 2002; the dominant macrophyte community is sawgrass (SFWMD photo).

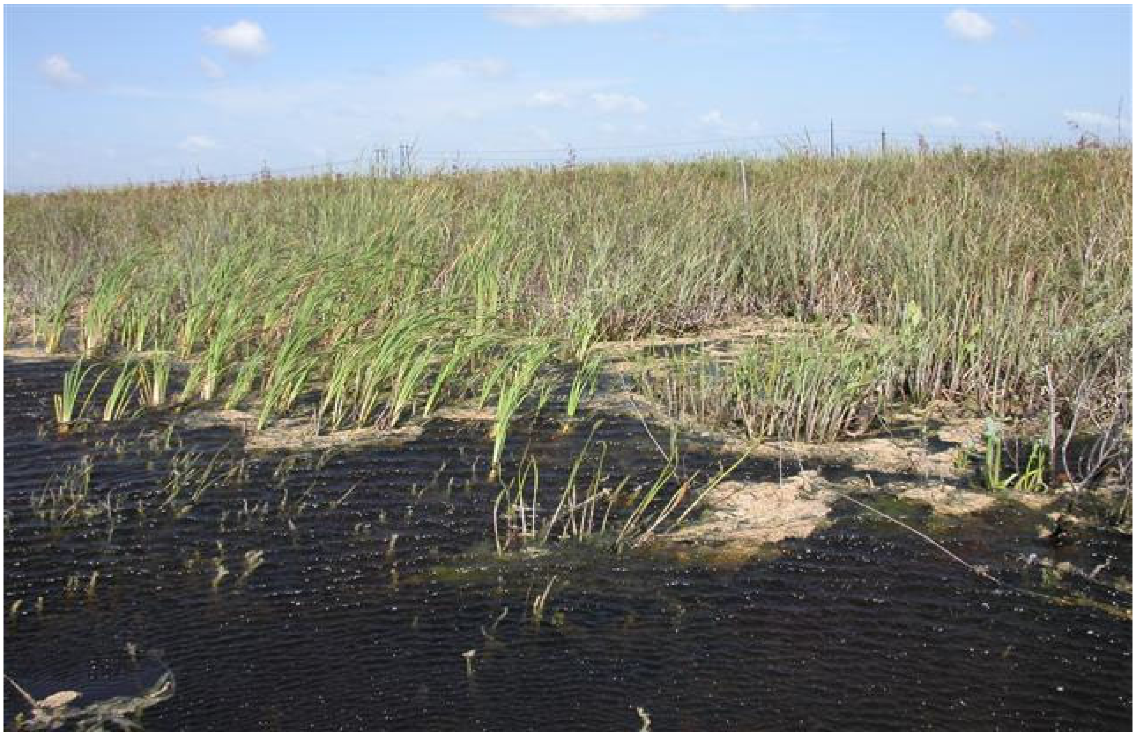


Figure 6-18. Current photo of the N1 station (July 22, 2005); the dominant macrophyte community is a mix of sawgrass and cattail (SFWMD photo).

Tissue samples of live leaves and roots were collected biannually from sawgrass and cattail plants at every site, if available. All stations with sawgrass measured a significant increase (P = 0.0067) in TP concentrations within root tissues during the post-discharge period (**Figure 6-19**, Panel a). Cattail roots did not display this same change (**Figure 6-19**, Panel b). There were no significant changes in sawgrass or cattail live leaf tissue TP concentrations between the pre- and post-discharge periods. Macrophyte community studies utilizing line intercept methods are currently being performed to follow dominant species per site, define the cattail/sawgrass transition areas along each transect and associated movement, as well as measure plant densities.

Ongoing research includes several experiments designed to assist the monitoring program to quantify STA impacts in downstream areas. These include: (1) a phosphorus-flux experiment using intact soil cores that should determine under what conditions soils within the downstream area serve as a phosphorus source or sink, (2) absorption experiments that will provide measurements of the equilibrium phosphorus concentration (EPC), and (3) a two-year particle transport study that is designed to track the movement of phosphorus particles associated with different types of STA discharge flow patterns.

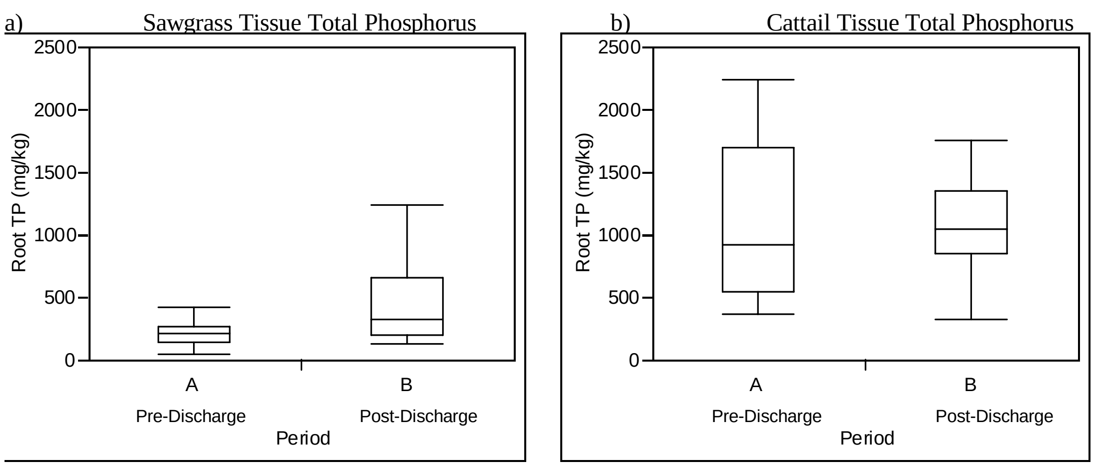


Figure 6-19. Mean TP root tissue concentrations of sawgrass (a) and cattail (b) from stations N.25, N1, N4, C.25, C1, C4, and S4 pre- and post- STA-2.

Rotenberger Wildlife Management Area

The Rotenberger Wildlife Management Area (RWMA), located in the northern Everglades, is a 29,120-acre marsh undergoing hydropattern restoration via inflows from STA-5 in accordance with the Everglades Forever Act Permit No. 0131842. The EFA permit requires the District to monitor the downstream receiving area of STA-5 for ecological effects associated with discharges which began in July 2001. In 1997, the Downstream Monitoring and Research Program was implemented and charged with this task.

Initial monitoring activities in the RWMA focused on the immediate downstream area of STA-5. The first two and a half years of monitoring data were compiled into a technical report required by the EFA permit and submitted to the Florida Department of Environmental Protection (FDEP) in June 2004 (Newman et al., 2004). Based on the results of this report, the determination was made to extend the monitoring transects from the immediate downstream area, across the marsh, beginning from inflow point (G-410) to the four outflow structures (G-402A–D) (**Figure 6-20**). Furthermore, the Downstream Monitoring and Research Program was adjusted to concentrate in the key areas of water quality, vegetation nutrients, and community composition, in addition to soil nutrients that would experience significant effects by alterations in hydrology. The initial evaluation of the soil and water quality data suggests a phosphorus front may be developing at sites closest to inflow. Additional spatial analysis of the extended transect sites will ascertain the establishment of a phosphorus front and, over time, potential movement.

Each year the RWMA experiences drawdowns during the dry season, which, as reported in Chapter 6 of the 2005 SFER – Volume I, has decreased in length and severity since receiving STA-5 effluent. Moreover, the inundation period recorded at the two stage gauges (Rott.N and Rott.S) is defined as the number of days each stage gauge records water levels above ground elevations. Since hydropattern restoration began, water levels measured at the stage gauges indicate ponding in the southern areas of the marsh for longer periods of time (345 days) than in the northern areas (245 days) (**Figure 6-21**).

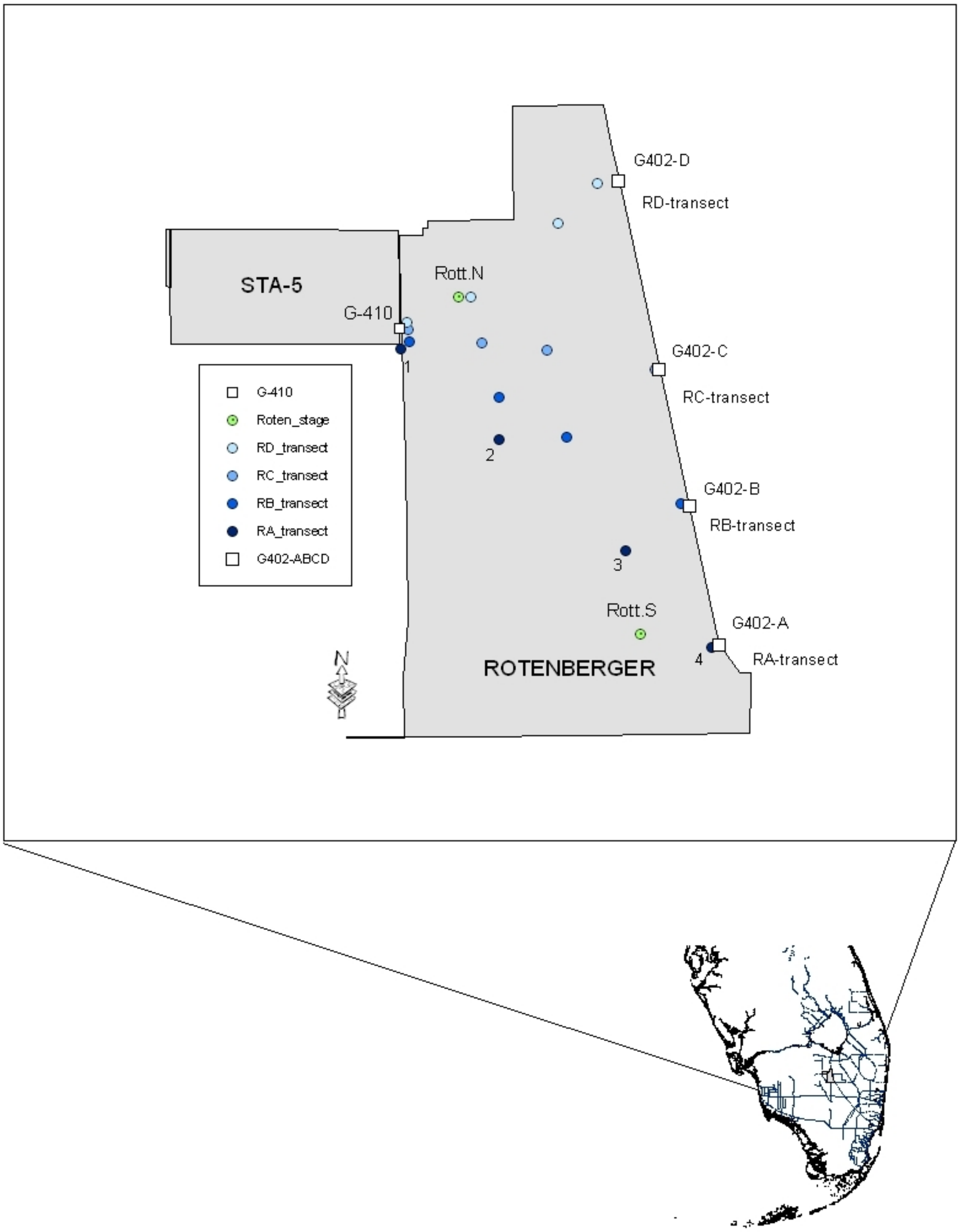


Figure 6-20. Outline and location of the Rotenberger Wildlife Management Area (RWMA) shown with the G-410 inflow structure, the G-402A–D outflow structures, stage gauges Rott.N and Rott.S, as well as the Downstream Monitoring and Research Program transect sites.

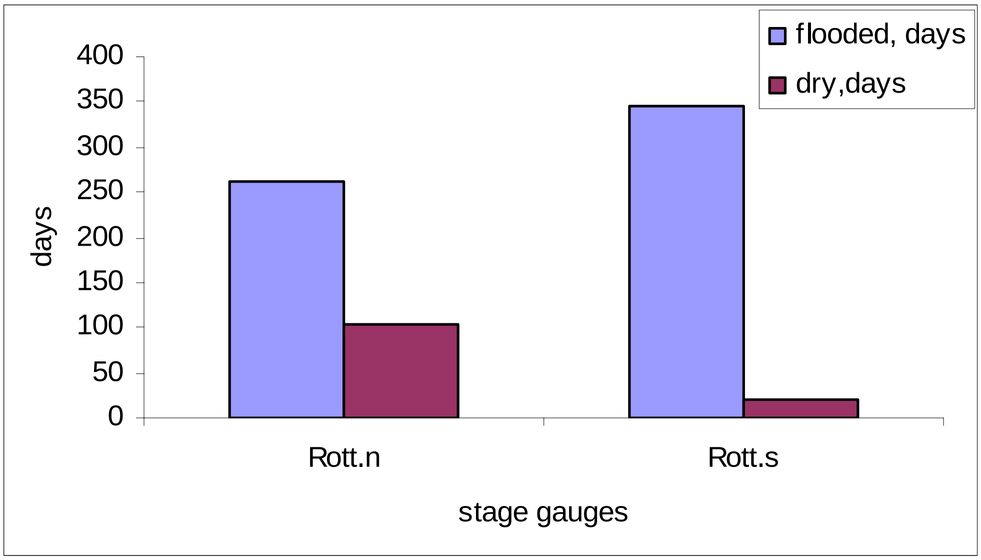


Figure 6-21. Number of days the marsh experienced standing water in the northern and southern areas of the marsh as recorded by the two stage gauges Rott.N and Rott.S.

The hydropattern restoration target for the RWMA was established using the Natural System Model (NSM) (SFWMD, 2001), which dictates according to a wet season/dry season average stage level when the G-410 inflow structure should operate and the outflow G-402A–D structures, gated box culverts, should open. The 2004 stage levels were trending toward hydropattern restoration; however, in July, the G-402 outflow structures opened and stage levels decreased. Despite heavy rains during the month of September, associated with two hurricanes, NSM targets were not achieved. In an effort to reach NSM targets, the Downstream Monitoring program is recommending operational adjustments of the G-402A–D outflow structures for a one-year evaluation period. One-year modifications include G-402A–D operations based on the Rott.N (north) gauge versus an average of the two, as elevations in the northern portion of the marsh are higher, drying the marsh out quicker than the southern portion. This change in operation of the outflow structures would retain more water within the RWMA, thereby increasing water levels and allowing for a full wet season evaluation of NSM target attainment. The data will be utilized in formulating long-term operations of the system.

As a direct result of improved hydrology, the frequency and severity of fires has been reduced, and no peat fires have been recorded in the RWMA since July 2001. The previous peat fires created shallow depressions in the soil surface into which cattail rapidly expanded. In spring 2004, almost 90 percent of the RWMA burned; however, much of the marsh contained standing water or saturated soil and, as a result, only the aboveground vegetation burned and did not become a peat fire. The mix of cattail, sawgrass, and panicum species remains the dominant vegetation present, representing approximately 75 percent of the RWMA, with the remainder a mix of obligate and facultative wetland plants. Several noteworthy species occurring with an increased frequency throughout the area in 2004, compared to previous vegetation surveys, are carolina willow (Salix caroliniana) and primrose willow (*Ludwigia peruviana*), both associated with disturbed wet areas (Tobe et al., 1998) as well as an increase in lance-leaf arrowhead (*Sagitarria lancifolia*), pickerelweed (*Pontederia cordata*), and green arum (*Peltandra virginica*), all of which are indicative of longer inundation periods.

TREE ISLAND ECOLOGY

Previous reports have shown maps of tree island loss, have described community structure, and have discussed the importance of tree islands in terms of conservation of biodiversity and habitat sustainability. These reports have also characterized existing vegetation, created a baseline data set, described patterns of distribution and abundance of aboveground biomass, and related forest structure to hydrology. This ecosystem update of the District’s tree island research program will produce a more complete picture of tree island processes and dynamics, particularly assessing the effects of hydroperiod on both above and belowground processes. Thus, to understand better those processes, multiple aboveground and belowground parameters have been measured within permanent 10 x 10 meters vegetation plots on eight core tree islands located in WCA-3A and 3B. To assess the effect of hydrology on both below and aboveground processes, the head and near tail of each tree island were categorized into two distinct hydrologic environments: short and long hydroperiod (see **Table 6-9**). Tree islands characterized by a short hydroperiod are inundated for less than six months per year and have average annual water depths of less than 20 cm. In contrast, long hydroperiods have standing water present for 7–12 months per year and have average annual water depths exceeding 20 cm.

Table 6-9. Tree island survey data sample. Data is reported for the head (H) and near tail (NT) of the eight study tree islands, including hydroperiod, average leaf fall, leaf fall to litterfall ratio, average total (live + dead) root biomass, average root total phosphorus, average soil nitrogen, bulk density of soil and water content of soil.

Island	Area	Hydro period	Leaf Fall (g/m2/y)	Leaf Fall: LitterFall	Total Root Bio(g/m2)	Total Root TP (mg/kg)	Soil TN (mg/kg)	B.Dens. (g/cm3)	Water Content (%)
3AN1	H	Short	568±280	71	2008±1493	6670±7513	16480±5379	0.4±0.2	65±11
	NT	Short	458±265	59	1601±1252	1640±930	26600±3099	0.3±0.1	75±9
3AN2	H	Short	436±213	53	1597±908	4563±4738	11330±2217	0.6±0.2	49±11
	NT	Short	266±202	57	950±856	2077±703	13118±4347	0.7±0.2	45±7
3AS1	H	Short	440±237	69	1238±565	7680±6125	22771±2859	0.2±0.1	78±8
	NT	Long	209±213	64	1942±1108	4107±3054	25516±1668	0.1±0.0	86±2
3AS2	H	Short	368±263	51	391±375	14236±6047	17316±5900	0.7±0.1	41±4
	NT	Long	293±196	69	2138±816	1065±198	26717±1883	0.2±0.0	84±4
3AS3	H	Short	474±133	63	1147±729	13418±6698	12388±2610	0.6±0.2	53±8
	NT	Long	246±150	74	2255±946	1123±388	34642±3016	0.1±0.0	87±3
3AS4	H	Short	575±211	66	904±718	8968±7491	18015±5839	0.5±0.2	56±10
	NT	Long	414±191	73	2164±1295	2253±1443	24825±2588	0.2±0.1	80±5
3AS5	H	Long	306±209	69	3603±1220	10324±5335	32133±2265	0.1±0.0	86±3
	NT	Long	165±117	67	3088±1166	6140±7758	30617±2309	0.1±0.0	84±4
3BS2	H	Long	373±204	61	1564±593	4190±2427	29042±1247	0.1±0.0	86±3
	NT	Long	354±166	65	1454±812	1731±781	28496±1131	0.1±0.0	85±2

The spatial patterns observed in soil, roots, and leaf fall have noteworthy similarities. **Figures 6-22** through **6-24** show that roots, soil, and leaf fall TP concentrations have comparable spatial patterns within islands in which TP concentrations are higher on the heads than on the near tails. These results strongly indicate that those islands with contrasting short/long hydroperiods show not only higher amounts of TP overall, but the greatest difference in TP levels between the heads and near tails. On the other hand, those islands experiencing similar hydroperiods, either short/short or long/long hydropattern, have lower amounts of nutrients and less contrasting levels of nutrients between heads and near tails. This pattern suggests that hydrology plays an important role in driving nutrient patterns on tree islands with higher nutrient concentrations measured on short hydroperiod locations (heads) and lower on long hydroperiod locations (near tails). In turn, this hydrology and nutrient spatial patterns are reflected on leaf fall production being higher on tree islands with contrasting head-near tail hydropattern and lower on tree islands with similar head-near tail hydropattern (**Table 6-8**). In contrast to leaf fall production, belowground root biomass is higher in long hydroperiod environments and lower on short hydroperiod environments (**Figure 6-25**). The spatial pattern of root biomass and leaf fall suggests that tree species located on tree islands have different resource allocation strategies in response to the hydrology pattern measured on the head and near tail within each tree island.

Not only does hydropattern play an important role in determining resource allocation strategies, soil properties such as total phosphorus, total nitrogen (TN), and water content play an important role in resource allocation patterns. For instance, belowground root biomass was significantly higher on environments where total phosphorus was the lowest (high N:P ratio). In contrast, root biomass was significantly lower on environments where total phosphorus was the highest (low N:P ratio). **Figure 6-26** shows this trend of nutrient limitation: as N:P ratios increase (as phosphorus becomes more limiting) total root biomass increases, especially evident on the more nutrient-poor near tails. This pattern indicates that not only does hydrology play an important role in determining resource allocation patterns, but soil nutrient characteristics measured on tree islands do as well. It is hypothesized that tree species living on nutrient-poor environments, which are also characterized by long hydroperiods may be mining for nutrients in order to sustain themselves in a more stressful environment.

The concept of nutrient limitation brings about the question of the mechanism responsible for phosphorus redistribution. Wetzel et al. (2005) suggest that a sharp nutrient gradient exists within a given tree island, with phosphorus levels highest on the head, low at the near tail and lowest at the marsh surrounding tree islands. In fact, soil phosphorus levels on the heads and near tails of tree islands are much higher (6 to 100 times) than in the surrounding marsh (Orem et al., 2002; Jayachandran et al., 2004). Thus, high nutrient environments, such as tree islands, are hypothesized to be biogeochemical hot spots because they concentrate more nutrients when compared with the surrounding marshes and sloughs (Wetzel et al., 2005). Tree islands serving as these functional nutrient hot spots incorporate multiple biological, chemical, and geological pathways in order to concentrate phosphorus in one small area. The ability of tree islands to do this could possibly contribute to the maintaining of the Everglades as an oligotrophic ecosystem. With the loss of large numbers of tree islands, the local redistribution of nutrients in the Everglades meta-ecosystem also ceased in many places, reducing the effectiveness of an important internal phosphorus sink. This could result in increasing nutrient levels in the rest of the Everglades (Wetzel et al., 2005).

Understanding how nutrient dynamics and hydroperiod determine ecological processes on tree islands is a central step in maintaining and restoring these environments. Therefore, due to their extreme sensitivity to water levels, tree islands can provide a good indication of the overall condition and success of hydrological management of the Everglades.

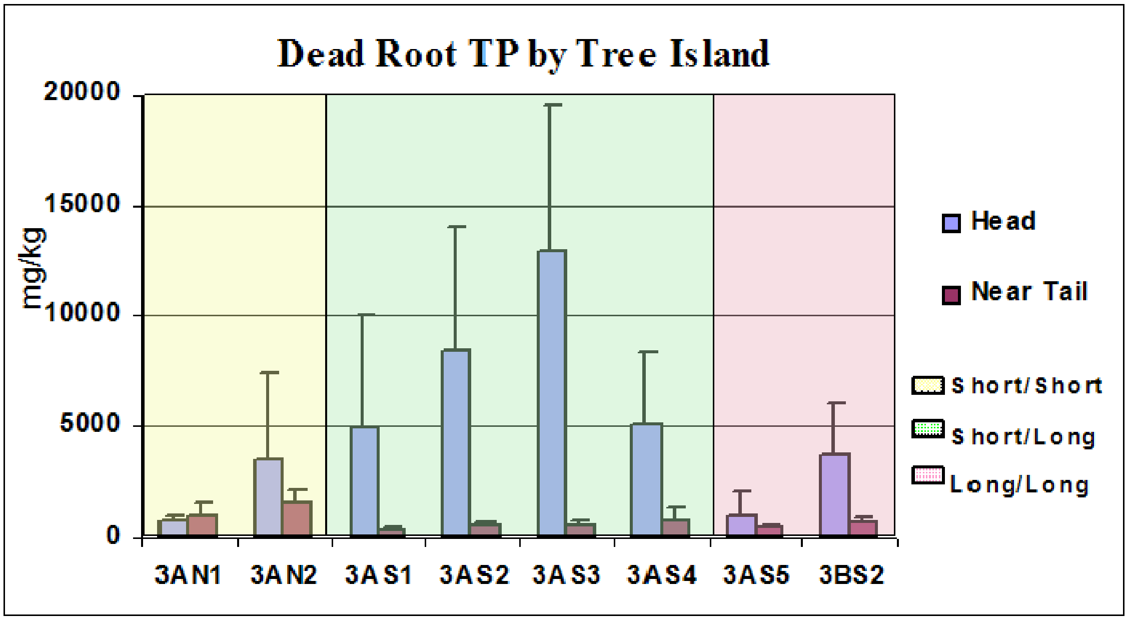


Figure 6-22. Average TP in dead roots on study tree islands. Background colors denote specific hydrological and topographical conditions. Short/Short: similar short hydroperiods, head = near tail. Short/Long: contrasting hydroperiods, head ≠ near tail. Long/Long: similar long hydroperiods, head = near tail.

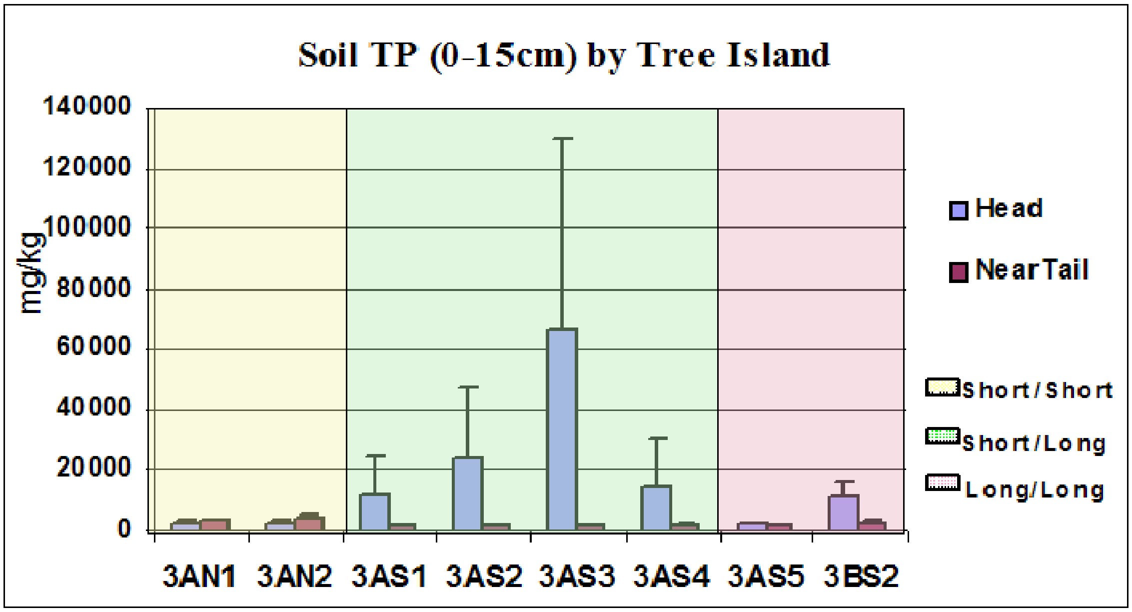


Figure 6-23. Average TP in top 15 cm of soil on study tree islands. Background colors denote specific hydrological and topographical conditions. Short/Short: similar short hydroperiods, head = near tail. Short/Long: contrasting hydroperiods, head ≠ near tail. Long/Long: similar long hydroperiods, head = near tail.

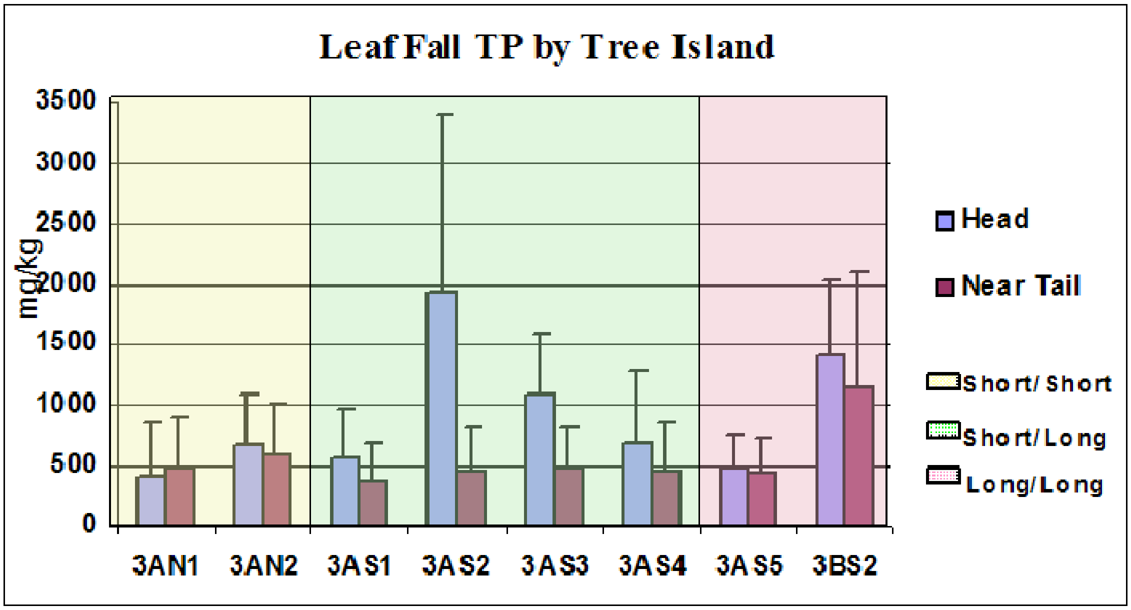


Figure 6-24. Average TP in leaf fall on study tree islands. Background colors denote specific hydrological and topographical conditions. Short/Short: similar short hydroperiods, head near tail. Short/Long: contrasting hydroperiods, head ≠ near tail. Long/Long: similar long hydroperiods, head = near tail.

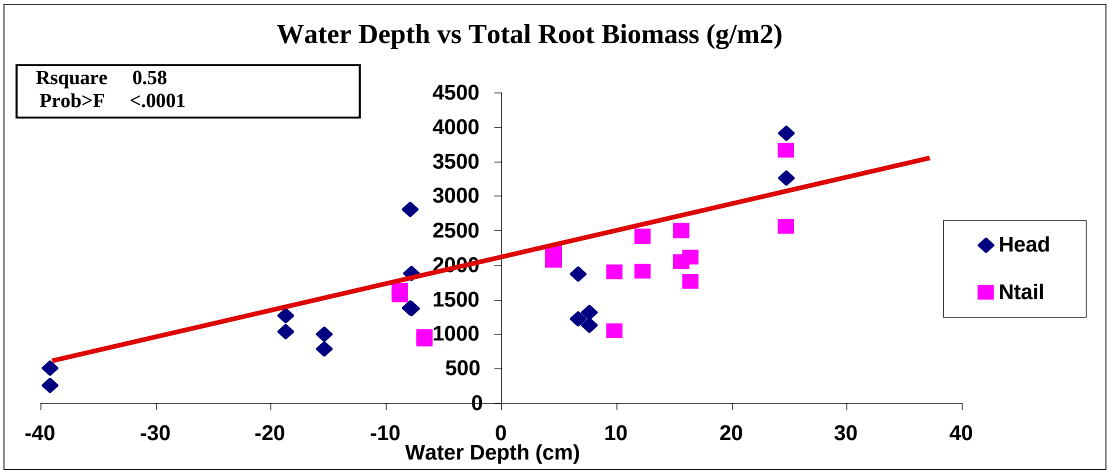


Figure 6-25. The relationship between average total root biomass and average water depth of study tree islands.

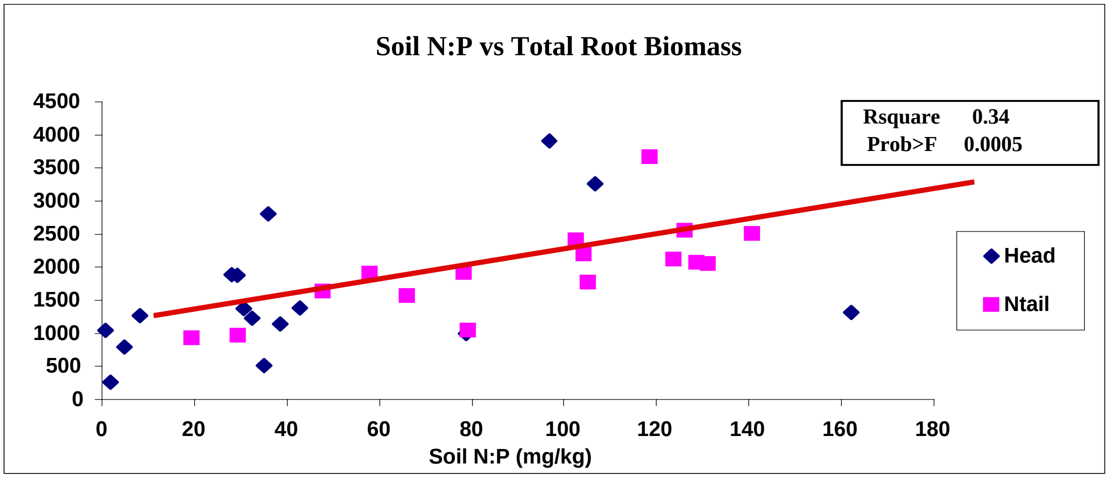


Figure 6-26. The relationship between average total root biomass and average soil nitrogen:phosphorus (N:P) of study tree islands.

LANDSCAPE ECOLOGY

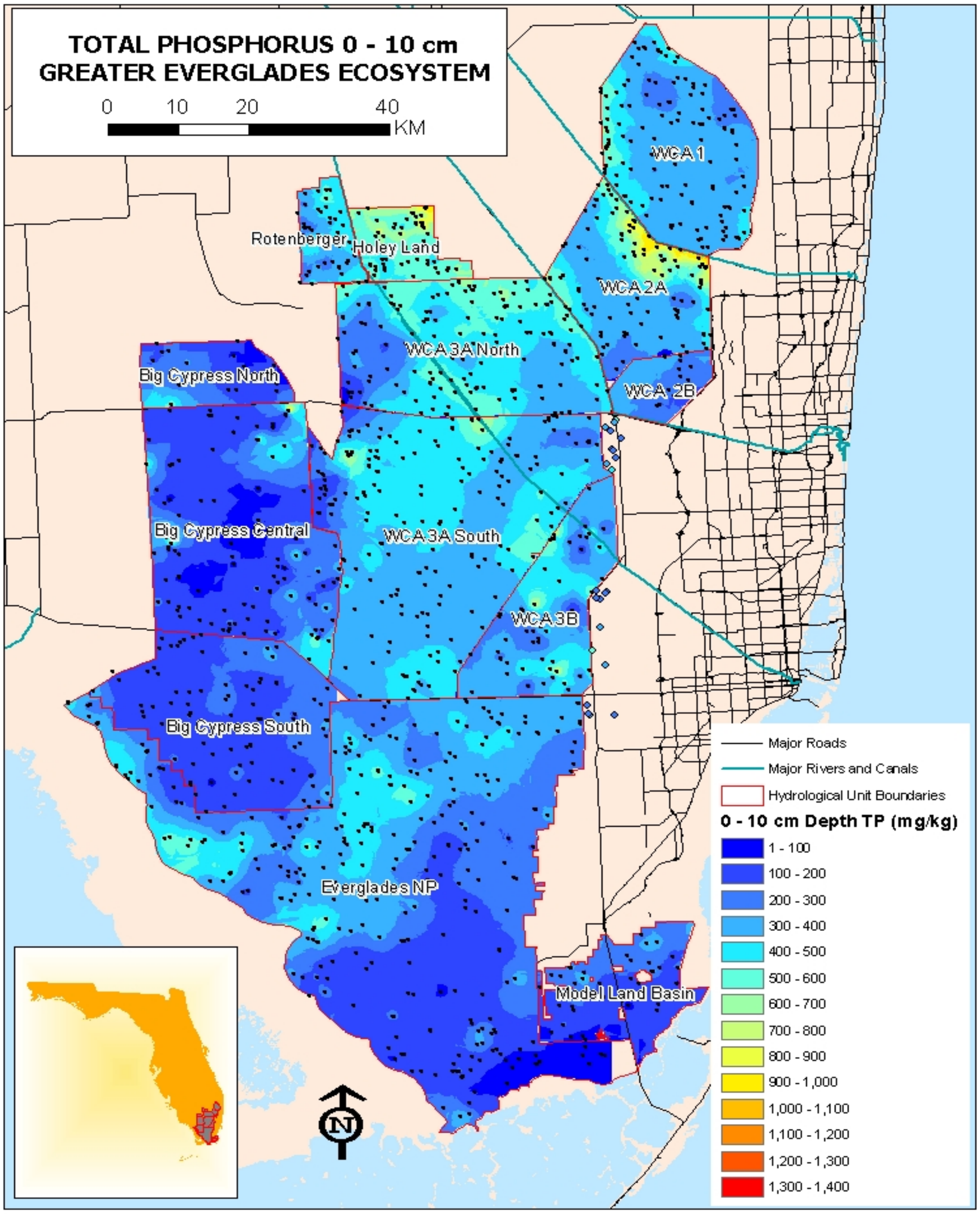
The District is continuing to observe the total hydro-biogeochemical system of the Everglades Protection Area. Previous studies of soil nutrients have been significantly updated this year with the completion of a comprehensive spatial analysis of the upper 30 cm of soil across the entire Everglades. Previous ECRs have shown vegetation maps created with specially developed remote sensing and photo-interpretation techniques. This chapter presents some of the first completed grid-based vegetation mapping projects for WCA-2A and the Rotenberger Wildlife Management Area, utilizing 1:24,000 scale color infrared aerial photographs and using a single comprehensive classification system. The District also has initiated a new program to evaluate and monitor tree island hydrology by completing the construction of 31 new Class B benchmarks in the interior of WCA-3. To continue the analysis of the pre-drainage system and develop a better understanding of the ecological processes that drive the Everglades, the District has completed a dramatically new (and in need of peer-review) elevation contour that, when used with the Natural System Model, will help set restoration performance goals.

SOIL MAPPING IN THE WATER CONSERVATION AREAS

As part of the ongoing effort to understand the extent of nutrient impacts, as well as establish baseline conditions from which future recovery or impacts can be assessed, an intensive soil nutrient mapping project was conducted throughout the greater Everglades. The spatial distribution of the sampling network was developed, using a stratified random design. Strata were defined using neural nets to produce a self-organized feature map that clustered together several ecological attributes (e.g., vegetation, elevation, soil bulk density). Variability in soil TP and strata size were then used to assign the sampling density to each stratum. Soil TP variability was selected as a primary driver in determining the number of samples assigned to each stratum because increased TP loads to the historically phosphorus-limited Everglades is one of the key forcing functions influencing the distribution of flora and fauna within the ecosystem.

Phosphorus enrichment effects were most evident in the northern portions of the ecosystem (**Figure 6-27**), with soil TP concentrations ranging from 24 milligrams per kilogram (mg/kg) in Big Cypress to 1702 mg/kg in WCA-2A. As has been observed in earlier area-specific studies (DeBusk et al., 2001; Newman et al., 1997; Qualls and Richardson, 1995; Reddy et al., 1998), the highest concentrations were associated with discharge points or adjacent to canals. Recent studies indicate that in peat soils, increased phosphorus loading increases nitrogen mineralization (Newman et al., 2001; Newman et al., 2004; White and Reddy, 2000). The soil mapping data suggests this may be occurring systemwide as lower soil nitrogen concentrations were apparent in organic-rich portions of the Everglades, such as northeast WCA-2A; regions that have high soil TP concentrations (see **Figures 6-27** and **6-28**). A regression of soil nitrogen versus phosphorus concentrations indicated that TP concentrations explained 57 percent of the variability in TN content (**Figure 6-29**). Throughout the landscape, TN concentrations ranged from 0.26 to 46 g/kg, with highest concentrations measured in the peat-based areas: WCA-1, WCA-2A, Holey Land, Rotenberger, WCA-3A, Shark River Slough, and Taylor Slough. The lowest concentrations were measured in marl areas of the ENP and the mineral-rich soils of Big Cypress (**Figure 6-28**).

Unlike phosphorus that had a diffuse distribution pattern in the southern Everglades, elevated TN concentrations were clearly confined within the sloughs. There was a strong relationship between TN and total carbon (TC) concentrations, with TC accounting for 89 percent of the variability in TN concentration (**Figure 6-30**). The link between TN and TC likely explains the lower TN concentrations observed in northwest WCA-3A, an area that has experienced considerable muck burns in recent years. The tight coupling between carbon, nitrogen, and phosphorus within the Everglades ecosystem emphasizes the need to conduct integrated studies that focus on the biogeochemical cycling of all three elements.



[1] Black circles denote location of sampling sites. N = 1334

Figure 6-27. TP distribution within the surface soils (0–10 cm) of the greater Everglades.[1] Source: Unpublished data, UF/IFAS, Soil and Water Science Department and SFWMD, Everglades Division. Sample collection during April–December 2003, with supplemental samples collected in August 2004.

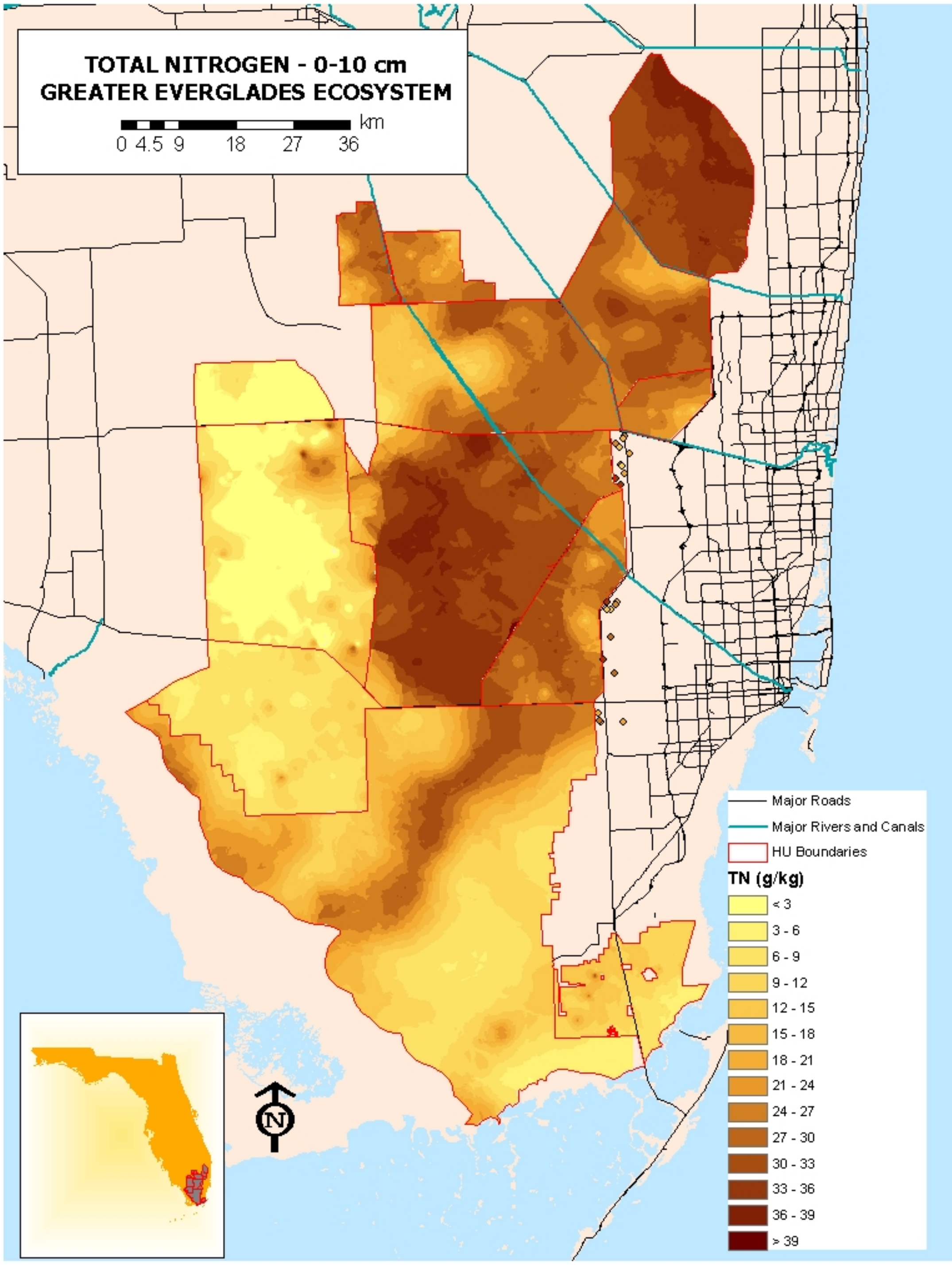


Figure 6-28. Total nitrogen (TN) distribution within the surface soils (0–10 cm) of the greater Everglades. Source: Unpublished data, UF/IFAS, Soil and Water Science Department and SFWMD, Everglades Division. Sample collection during April–December 2003, with supplemental samples collected in August 2004.

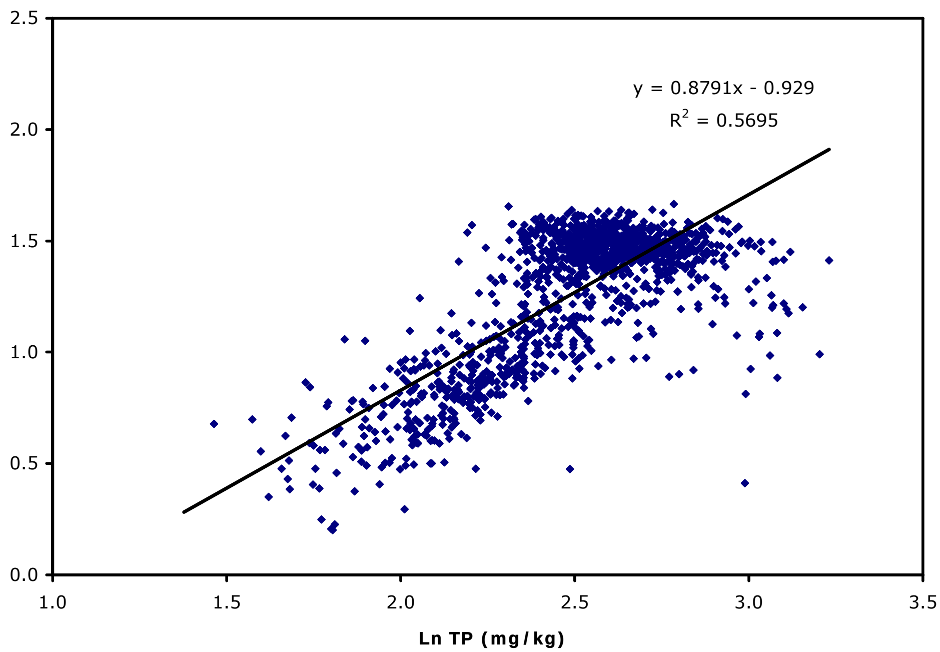


Figure 6-29. Relationship between TN and TP in soil samples collected throughout the greater Everglades (0–10 cm soil depth). Source: Unpublished data, UF/IFAS, Soil and Water Science Department and SFWMD, Everglades Division.

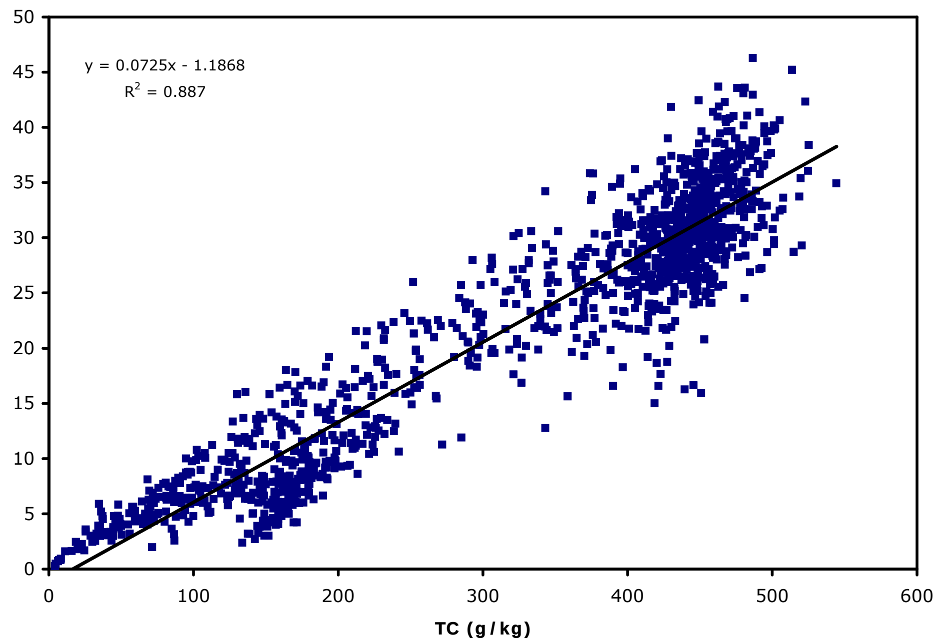


Figure 6-30. Relationship between TN and total carbon (TC) in soil samples collected throughout the greater Everglades (0–10 cm soil depth). Source: Unpublished data, UF/IFAS, Soil and Water Science Department and SFWMD, Everglades Division.

VEGETATION MAPPING UPDATE

Restoration Coordination and Verification (RECOVER) is designed to organize and provide the highest quality scientific and technical support during the implementation of CERP (see Chapters 7A and 7B of this volume). RECOVER has developed a systemwide Monitoring and Assessment Plan (MAP), which is designed to document how well CERP is performing. The Water Resources Development Act of 2002 authorized CERP as a framework to restore the Everglades and established the U.S. Army Corps of Engineers (USACE) together with the SFWMD as co-sponsor agencies responsible for MAP implementation. One component of the MAP will involve vegetation mapping to be utilized as a monitoring tool, and to document any changes in the spatial extent, pattern, and composition of plant communities within the landscape. Some of the first vegetation mapping projects have now been completed for WCA-2A (**Figure 6-31a**) and the RWMA (**Figure 6-31b**).

Both mapping efforts involved generating a quarter hectare grid (50 x 50 m) and superimposing it over 1:24,000 scale aerial photography. This resulted in 170,500 and 49,117 individual grid cells covering all of WCA-2A and Rotenberger, respectively. Vegetation within each individual grid cell was photo-interpreted utilizing an analytical stereo-plotter and labeled with the majority vegetation category observed. Overall map accuracy for the WCA-2A mapping was 90.7 percent. Overall map accuracy of the Rotenberger map still needs to be determined.

Advantages of the grid system for vegetation mapping include greater time and cost efficiency, and the unique ability to classify vegetation within the same quarter-hectare grid cells from this analysis and during future mapping efforts. Initial cost savings of 25–50 percent were predicted, with actual cost savings now approaching 75 percent. In addition, the grid system more accurately depicts the overall heterogeneity of Everglades vegetation. These vegetation mapping products will provide a baseline for the RECOVER vegetation mapping project and will fulfill FDEP permit requirements for downstream receiving areas.

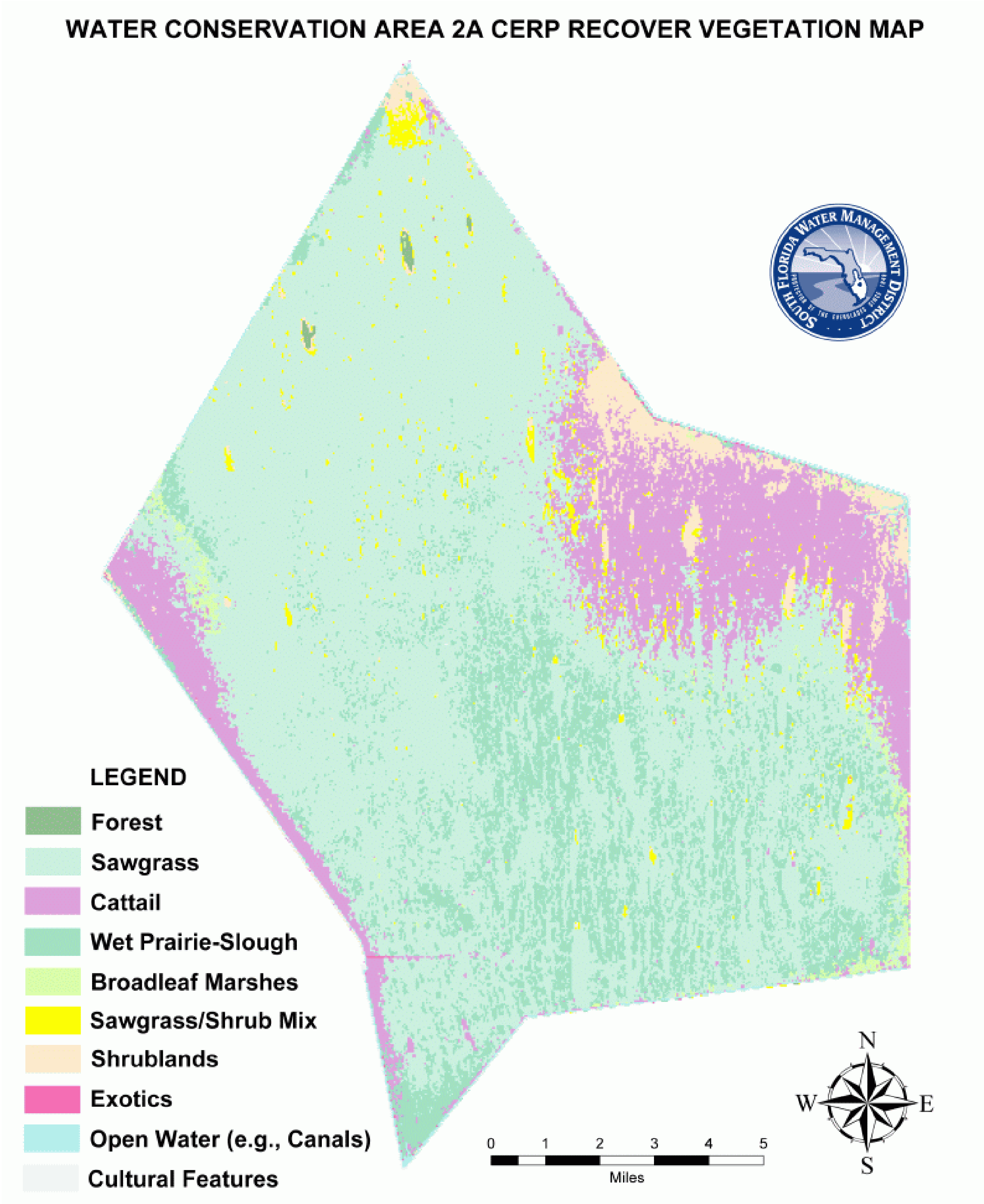


Figure 6-31b. Final vegetation map for WCA-2A that will be used as a CERP baseline and as an assessment tool for detecting change.

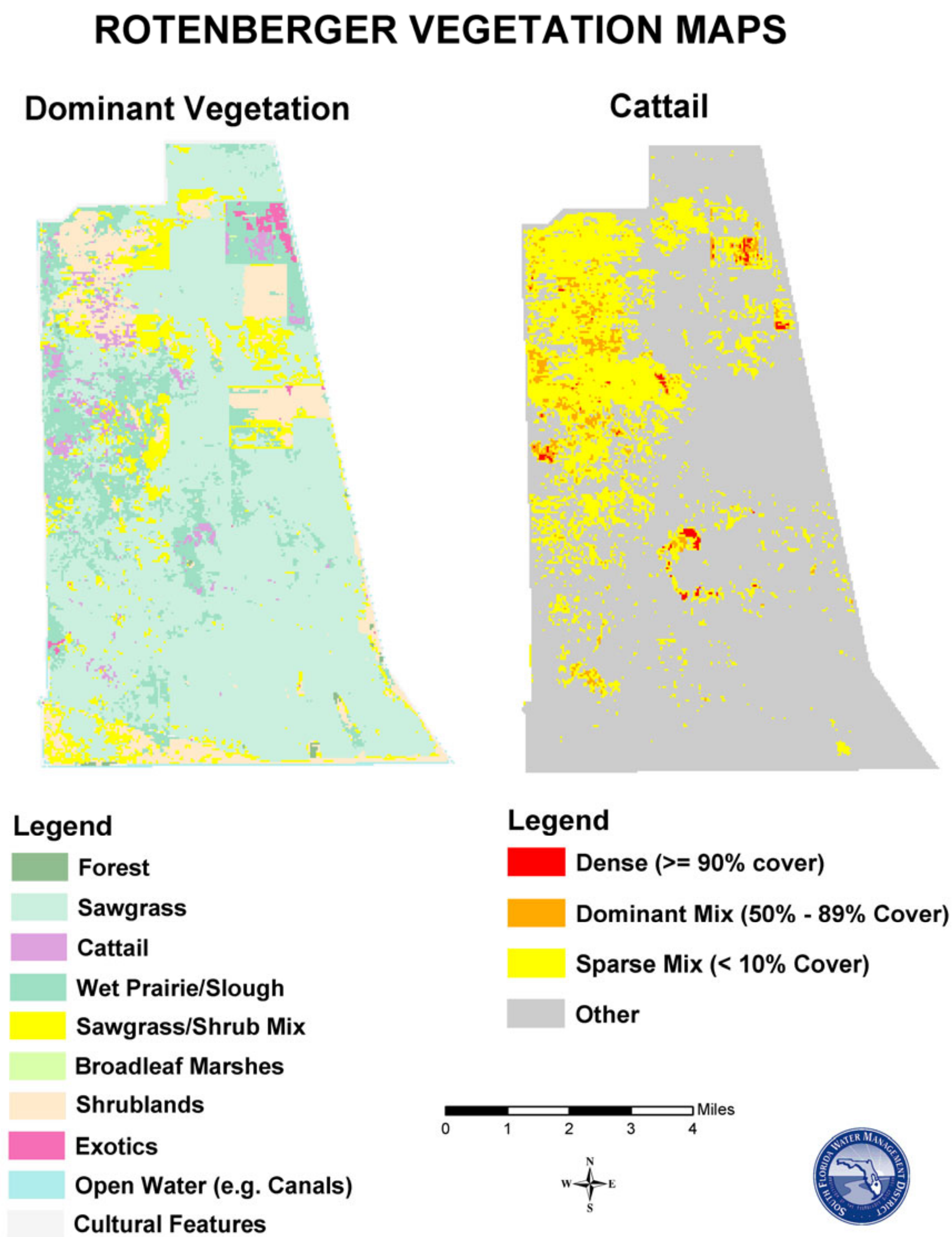


Figure 6-31b. Final vegetation maps for the RWMA that will be used as a CERP baseline and as an assessment tool for detecting change.

BENCHMARKS IN WCA-3

Tree islands are a unique and important component of the Everglades landscape (Loveless, 1959; Zaffke, 1983; Sklar and van der Valk, 2002). Tree islands support high plant species diversity, provide nesting habitat for a variety of fauna associated to forested wetlands, and serve as wet season refuges for upland animals such as white-tailed deer. Even though the total area of all tree islands combined may be only 5–10 percent of the Everglades, this small portion of the Everglades landscape supports more species of flora and fauna than any other habitat (Gawlik and Rocque, 1998). The elevation of tree islands are usually 1.0–3.0 ft higher than the surrounding wetlands (Loveless, 1959); however, some islands rise as much as 5 feet or more above the marsh, particularly tree islands located in the ENP (Heisler et al., 2001). Changes in surface elevation, which are extremely gradual (less than a few inches per mile), are associated with gradients in vegetation, especially along the long axis of the many teardrop-shaped islands of the central Everglades (Sklar and van der Valk, 2002). Thus, relatively small changes in water depths and durations can produce distinct shifts in island hydroperiods, which in turn determine the vegetation communities, health, and sustainability of tree islands (McPherson, 1973).

Current restoration plans predict dramatic changes in depth patterns over portions of the ridge and slough landscape that have large numbers of tree islands. Thus, reliable topographic elevation of tree islands is needed to predict the effects of proposed hydrologic changes on island species composition, hydroperiod, health, and spatial extent. Predicting effects of changes in water depths and hydroperiods on tree islands, or managing water to restore tree islands, cannot be accomplished until the spatial distribution of the different types and sizes of islands are better known. Therefore, a major objective is to obtain reliable elevation measurements for tree islands located within WCA-3A and 3B and create a tree island elevation distribution map. This is essential information and is in agreement with the Monitoring and Assessment Plan (MAP Module 3.1.4.4).

This work established 31 new Class B (stainless-steel rod driven to refusal) National Geodetic Survey (NGS) stability standard monuments (**Figure 6-32**). The FDEP and the District shared the cost of this project and submitted all 31 locations to the NGS in Bluebook format for inclusion into the National Vertical Network and database. All aspects of the NGS requirements were met, including procedures, mark ties, closures, instrumentation, electronic note-keeping, and online recording. A minimum of 20 existing NGS control stations were tied as part of this project.

Now that the benchmarks are in place, the next phase will be to obtain reliable elevation measurements on tree islands that involve the measurement of water depth at the closest of 31 benchmarks, and at one point located at the edge of the tree island, which will be used as a benchmark to measure water depth using at least 10 points around the head of some 600 tree islands in WCA-3.

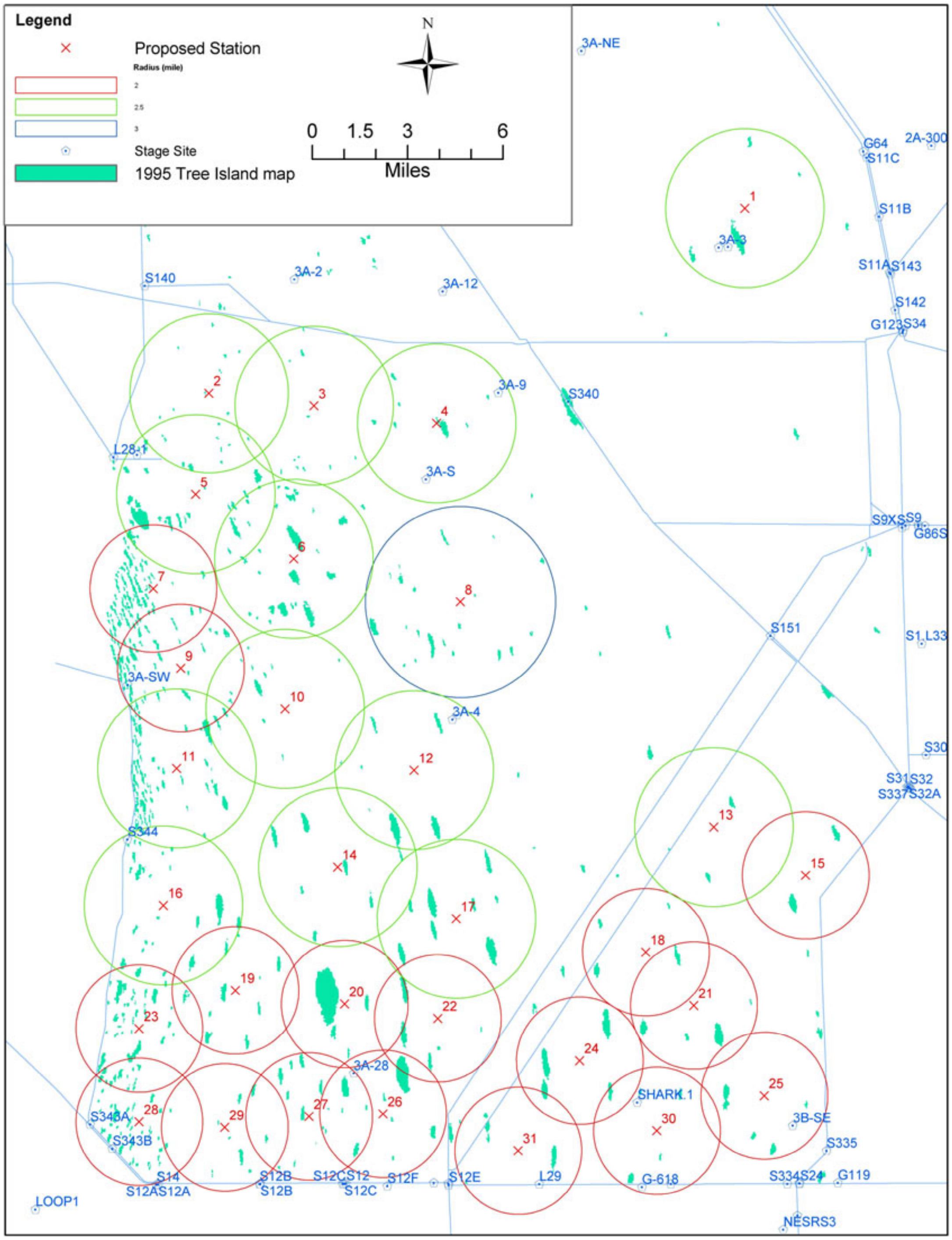


Figure 6-32. The location of 31 new Class B benchmarks in WCA-3A and 3B that will be used to monitor and assess the hydroperiods on all of the tree islands within a 2- to 3-mile radius of each benchmark.

PRE-DRAINAGE ELEVATIONS

The District and the USACE continue to refine techniques for understanding and modeling the pre-drainage (pre-1880) Everglades. Improved understanding leads to clearer knowledge of the defining characteristics of the pre-drainage Everglades that need to be restored for a sustainable Everglades. The two elevation contour maps shown below (**Figure 6-33**) highlight the differences between an older and a more recent estimate of pre-drainage topography. The contour map on the left is the one currently used in the NSM (Natural System Model version 4.6.2) and is based on the best information available as of 2002. Surveys carried out in 1913 along the four main “muck canals” was a central information source for this estimate of topography.

In **Figure 6-33**, the map shown on the right is the product of a collaborative effort initiated by Winnie Said and led by Christopher McVoy, SFWMD; Victor Engel, ENP; and Jim Vearil, USACE. This effort also made use of the 1913 surveys, but first corrected the lower reaches for peat subsidence and then applied the additional criteria that contours should be perpendicular to the pre-drainage landscape directionality. Landscape directionality, which by all accounts was equivalent to the down-slope direction and to the pre-drainage flow directions, was quantified using 1940s aerial photography. Elevations were estimated consistently for the complete Everglades, from Lake Okeechobee south to Florida Bay. Elevation contours crossing the peat portions of the Everglades (potentially areas of peat subsidence) were tied to the elevations of the unsubsided mineral soil substrates bordering the peatlands.

The resulting “Sens4” estimate of pre-drainage Everglades elevations is currently under review by multiple agencies to determine if it is more consistent with all available pre-drainage information. NSM simulations made using these elevations were separately evaluated and appear to more closely resemble the available information on pre-drainage flow directions. Concerns, however, were raised that some aspect of the NSM causes simulated water depths, particularly during the wet season, to be substantially lower than indicated by an extensive dataset of observed pre-drainage water depths. This occurred in both sets of simulations (Sens4 and 4.6.2), so it may not be related to topography. Once the Sens4 topography is approved, it will be used for incorporation into the Initial CERP Update and for consideration of hydrologic targets.

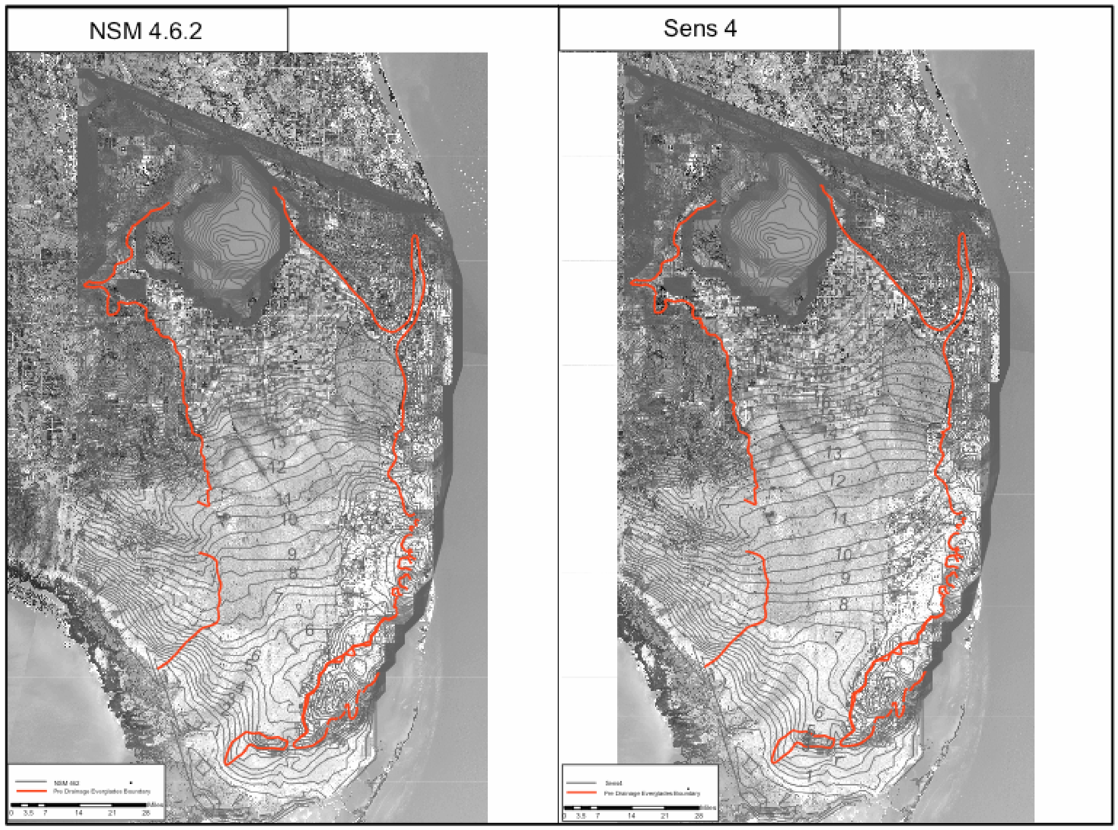


Figure 6-33. The contours on the left are currently used by the Natural Systems Model to help set CERP restoration targets. The contours on the right are being considered by the SFWMD as an alternative pre-drainage description.

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