Chapter 6: Ecology of the Everglades Protection Area

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SUMMARY

The studies and findings discussed in this chapter of the *2005 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 (CERP).

Wildlife: Monitoring of wading bird nesting success is a coordinated effort between the District, Everglades National Park (ENP), the Florida Fish and Wildlife Conservation Commission, (FWC), University of Florida, National Audubon Society, and the U.S. Fish and Wildlife Service (USFWS). Each year, this coordination results in the production of the Annual Wading Bird Report. In 2004, this collaboration reported a total of 54,159 wading bird nests in South Florida. This is a 61-percent increase from 2003, and one of the best breeding years in recent decades in terms of total number of nests. However, it should be noted that this is a 21-percent decline on the record year of 2002, which was the best nesting year since the 1940s. This year's increase can be attributed primarily to greater nesting effort by white ibis (*Eudocimus albus*) in the Water Conservation Areas. During a typical nesting season, numbers of wading bird nests peak in April, then rapidly decrease. This year, wading birds initiated new nests throughout the entire breeding season, even as late as mid June. This delay may have been due to the many water depth reversals that occurred during the 2004 dry season. This year was notable for an exceptionally dry June and, therefore, optimal feeding conditions in the Everglades were extended far longer than normal. Consequently, many wading birds that delayed or reinitiated nesting were able to fledge their offspring successfully.

Plants: Previous Everglades Consolidated Reports (ECRs) discussed plant biomass allocations, 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 described an experiment to assess the flood tolerance of first year seedlings of three dominant tree island species.

It was reported last year, in the 2004 Everglades Consolidated Report, that hydrologic restoration in the Rotenberger Wildlife Management Area has led to an increase in hydroperiods and water depths and to more desirable plant species. This trend has continued with 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. Analysis of surface water quality samples collected during the hydrologic restoration period (July 2001–June 2003) shows that phosphorus concentrations are elevated near the inflow. Based on these results, continued monitoring of the system is recommended.

Ecosystem: Previous periphyton studies have focused on community structure (McCormick et al., 1998), biogeochemistry (Reddy et al., 1999), and the importance of periphyton as an indicator of environmental degradation (McCormick and Stephenson, 1998). Last year, the District presented evidence for alternative ways to evaluate the role of periphyton as the base of the food web. Included in this chapter is a discussion of periphyton ecology in relation to water hardness. Historically, the northern Everglades was a softwater peat ecosystem with a periphyton assemblage dominated by acidophilic diatoms and desmids. With the implementation of CERP and future operations of Stormwater Treatment Areas 1 East and West (STA-1E and STA-1W), concern has arisen that hard water may intrude into softwater portions of the Everglades and change ecosystem structure and function. This intrusion of hard water was documented in February 2004 when the District, USGS, and USFWS conducted a plant, soil, and water quality synoptic survey of the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). To address the ecological significance of this intrusion, the District conducted a laboratory experiment to assess changes in periphyton species composition solely as a function of the mineral content of surface waters. Exposing Refuge periphyton mats to high conductivity marsh water negatively affected many species. Diatom, desmid, and coccoid cyanobacteria densities significantly declined when specific conductance exceeded 230 microsiemens per square meter per second ($\mu S\ m^{-2}\ sec^{-1}$). Alternatively, filamentous cyanobacteria and filamentous chlorophyte (green algae) densities did not decline until specific conductance exceeded 310 $\mu S\ m^{-2}\ sec^{-1}$. Periphyton structural changes were also observed over a temporal period of less than one month. Thus, short-duration pulsed events may have ecological consequences. These consequences are unknown, but may include changes in primary production, nutrient cycling, and food web dynamics.

Previous tree island studies found a significant decline in the abundance and aerial extent of these biodiversity "hotspots." 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 data set; (3) relating patterns of distribution and abundance to hydrology; and (4) evaluating performance measures and alternatives for preservation and restoration. This year, the District presents the results from four years of litterfall collection on tree islands located on Water Conservation Area 3 (WCA-3). These data indicate that litterfall pattern is strongly seasonal with the highest litterfall production occurring during the dry season month of March and that daily litterfall production is significantly higher ($p < 0.05$) for tree islands subjected to short hydroperiods (2.1 grams per square meter, or $g\ m^{-2}$), than tree islands subjected to medium or long hydroperiods (1.5 and 1.1 $g\ m^{-2}$, respectively). When litterfall was separated into its different components (leaves, reproductive, woody, and miscellaneous), the reproductive component (seeds, flowers, and fruits) was relatively higher on short hydroperiod tree islands. Data from the first year of the SFWMD's belowground studies is also presented. Root ecology may hold the key to why islands are disappearing and how they can be restored. Preliminary data indicate that despite the stress of low oxygen, the moderate and long hydroperiod islands had significantly greater amounts of live roots than the short hydroperiod islands. The long hydroperiod islands also had more dead roots. The lack of oxygen on long hydroperiod islands may slow decomposition rates, and cause a buildup of dead roots over time. Similarly, the abundance of oxygen on short hydroperiod islands may increase decomposition rates, and cause nutrients to be more available and assessable; hence, fewer live roots are needed to sustain growth.

Landscape*:* The District is continuing to observe the total hydro-biogeochemical system of the Everglades Protection Area. Previous ECRS have shown vegetation maps created with specially developed remote sensing and photointerpretation techniques. This chapter presents new information on a complete Geographic Information Systems vegetation database of WCA-3 utilizing 1:24,000 scale color infrared (CIS) aerial photographs and using a single comprehensive classification system. WCA-3 is a 234,944-hectare impoundment. Sawgrass accounted for the greatest area (141,093 hectares, or 60 percent) of the polygons categorized, wet prairie was the second greatest area (64,469 hectares, or 27 percent), and cattail was the third greatest (11,750 hectares, or 5 percent). Most of these cattail polygons (6,856 hectares) were found in the Water WCA-3NE sub-compartment. Also, the District has described a new mapping project for CERP. The objective of this new vegetation mapping project is to produce a spatially and thematically accurate vegetation map for the 4,218-square mile CERP boundary area using 1:24,000 scale CIS aerial photography, and a minimum mapping unit of 50 meters x 50 meters. Each distinct vegetation community will be designated according to the Vegetation Classification System for South Florida National Parks (Jones et al., 1999). Additionally, the District outlines its responsibilities for the recovery of impacted areas as stipulated in the Long-Term Plan for Achieving Water Quality Goals in the Everglades Protection Area (Long-Term Plan).

INTRODUCTION

Drainage of the Everglades has 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; Gunderson and Loftus, 1993; 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 approaches.

Direct cause-and-effect relationships between altered drainage and ecosystem disturbance are not always easily shown. It is difficult because many factors are associated with an altered hydrologic regime and there needs to be a long period of record in order to filter out changes due to climatic variability. 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 which key ecological driving forces will be restored to guide future succession in the remaining Everglades.

The following chapter should be viewed as a brief overview of some recent ecological research programs that are sponsored by the South Florida Water Management District (SFWMD or District). This chapter is divided into four sections: (1) wildlife ecology; (2) plant ecology; (3) ecosystem ecology; and (4) landscape ecology. In the *Wildlife Ecology* section, current wading bird statistics are presented. The *Plant Ecology* section summarizes efforts to restore Rotenberger Wildlife Management Area (WMA) hydrology. The *Ecosystem Ecology* section presents the influence of water hardness on periphyton, and the influence of hydroperiod on ecological processes that are associated with tree island health and sustainability. In the *Landscape Ecology* section, the results of the WCA-3 vegetation mapping program and designs for the Comprehensive Everglades Restoration Plan (CERP) long-term monitoring of vegetation change are presented.

WILDLIFE ECOLOGY

In previous Everglades Consolidated Reports (ECRs), the District has demonstrated that the distribution of wildlife is a function of water quality, hydrology, climate, and habitat conditions. Wildlife within this context includes fish, invertebrates, reptiles, 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 continues to focus on wading birds, their prey, and their association with tree islands.

This section does not discuss Everglades wildlife broadly, but instead focuses on wading birds as indicators of the overall health of the ecosystem. Wading birds exhibit a suite of characteristics that render them particularly suitable for monitoring wetland ecosystem function. They are conspicuous, easy to count, quite numerous, and respond rapidly to hydrologic and ecological conditions of the ecosystem. As the numerically dominant group of top predators, they have significant effects on food webs through predation and nutrient transport, and can reflect the health of lower trophic levels through changes in their population dynamics. They also range widely over the landscape and have been monitored for almost 100 years, allowing comparisons of ecological conditions across large areas of time and space. By examining long-term, system-wide trends and the range of variability in nesting effort by wading birds, in conjunction with current studies of their prey (fish and macro invertebrates) distribution and ecology, ecologists can gain greater understanding of how hydrologic conditions and other ecological processes affect Everglades' function. Future studies in this section will examine the relationship between wading bird prey availability and breeding success, and the role of invasive animals on Everglades wildlife communities.

WADING BIRD MONITORING

Because wading birds are excellent indicators of wetland ecosystem health, they play a central role in CERP. The timing of breeding, the number of nests, and the location of nesting colonies within the Everglades, are used as CERP targets to evaluate the progress of the Everglades restoration effort (see Chapter 7 of the *2005 South Florida Environmental Report – Volume I*). 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 counts include all wading bird species (except cattle egret, *Bubulcus ibis*) nesting throughout the region (Crozie and Cook, in prep.). However, nesting figures for CERP performance measures are restricted to five species – great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), tricolored 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 (WCAs) and the ENP. The period covered in this chapter is the nesting season from February 2004 through July 2004.

In 2004, the estimated number of wading bird nests in South Florida was 54,159. This is a 61-percent increase from 2003, and one of the best breeding years in recent decades in terms of total number of nests. Notably, this is a 21-percent decline on the record year of 2002, which was the best nesting year since the 1940s. This year's increase continues a recent trend towards larger numbers of total nesting attempts and can be attributed primarily to greater nesting effort by white ibis in the WCAs. Number of ibis nests rose by nearly 18,000 this year, and the total number of nests approached that observed in the record year of 2002. However, the total number of nests for other wading bird species was low compared to recent successful years. For example, the number of wood stork nesting attempts was down by 26 percent and 41 percent compared to 2003 and 2002, respectively. Nesting attempts by snowy egrets, tricolored herons, and little blue herons were also relatively low.

Nesting effort differed among regions in the Everglades. WCA-3 supported the largest number of nests (64 percent), and WCA-1 supported 29 percent of nests, while the ENP supported the lowest number of nests (7 percent). This pattern is similar to 2003 (52 percent of nests in WCA-3, 36 percent in WCA-1, and 7 percent in the ENP) and is almost identical to the record year in 2002 (69 percent of nests in WCA-3, 25 percent in WCA-1, and 5 percent in the ENP).

Heavy rains caused water levels to increase rapidly multiple times during the breeding season, and as a result, breeding success varied among species in 2004 similar to 2003. A high proportion of wood stork nests were abandoned after water level reversals occurred in late February and early April 2004, when birds were brooding eggs or small chicks. No abandonment was observed by wood storks during a water reversal in May 2004, when chicks were older. These observations are consistent with information gathered in previous years, and suggest that storks may be more sensitive to water level reversals during the earlier part of the nesting cycle. In contrast to wood storks, large-scale abandonment by white ibises was not evident, which is somewhat puzzling because nest desertion by these two species in a local area usually co-occurs. However, this year's timing may have been crucial because most stork nest desertion occurred early in the season before the onset of ibis nesting.

The 2004 nesting season was also similar to 2003 in that higher than normal nesting asynchrony occurred compared to previous years. During a typical nesting season, numbers of wading bird nests peak in April, and then rapidly decrease. This year, wading birds initiated new nests throughout the entire breeding season, even as late as mid June 2004. The cause of this asynchrony in white ibis is unknown, although for wood storks, it was probably related to birds renesting after abandoning nests.

During an average year, the summer rainy season begins in early June and feeding conditions for wading birds deteriorate rapidly thereafter. Wading birds that initiate breeding late in the breeding season and still support nestlings by June often abandon their offspring. Notably, June 2004 was exceptionally dry, and optimal feeding conditions in the Everglades were extended much longer than normal during this year. As a consequence, many wood storks that delayed nesting as a result of water reversals were able to fledge their offspring successfully. Optimal feeding conditions in June 2004 were also beneficial to the large numbers of nestling white ibis that began to fledge during that month. Ibis fledglings require a number of months to develop feeding skills, and good feeding conditions during their initial period of independence are likely to increase survival probability significantly.

Two groups of species, great egret and white ibis, met the numeric nesting targets proposed by the South Florida Ecosystem Restoration Task Force (SFERTF), whereas wood stork and snowy egret/tricolored heron did not achieve their targets (**Table 6-1**). Two other targets for Everglades restoration include 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 2004 nesting year showed no improvement in the shift of colony locations or the timing of wood stork nesting.

Table 6-1. Numbers of wading bird nests in the South Florida ecosystem compared to Comprehensive Everglades Restoration Plan (CERP) targets in the Water Conservation Areas (WCAs), and Everglades National Park (ENP or Park).

Species	1995–1997	1996–1998	1997–1999	1998–2000	1999–2001	2000–2002	2001–2003	2002–2004	Target
Great Egret	4,302	4,017	5,084	5,544	5,996	7,276	8,460	9700	4,000
Snowy Egret/ Tricolor Heron	1,488	1,334	1,862	2,788	4,269	8,614	8,089	8067	10,000–20,000
White Ibis	2,850	2,270	5,100	11,270	16,555	23,983	20,758	25.000	10,000–25,000
Wood Stork	283	228	279	863	1,538	1,868	1,596	1133	1,500–2,500

PLANT ECOLOGY

The major research objective of the District's plant ecology studies is to understand vegetation dynamics in relation to water management. This requires examining the physiological and biological processes that cause vegetation replacement, degradation, and premature death in relation to environmental disturbances, such as phosphorus enrichment and altered hydrologic regimes that cause peat fires or stress. Previous ECRs 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. This report describes an experiment to assess the flood tolerance of first year seedlings of three dominant tree island species, and how the hydrologic restoration in the RWMA has led to an increase in hydroperiods and more desirable plant species. Future studies will continue to explore the multi-faceted biology of both native and invasive plants in relation to current and predicted hydrological and biogeochemical regimes.

RESTORATION OF THE ROTENBERGER WILDLIFE MANAGEMENT AREA

The Rotenberger Wildlife Management Area (RWMA) (**Figure 6-1**), part of the northern Florida Everglades, is an extensively degraded 29,120-acre marsh. Historical landscape patterns and reports indicate the northern portion of the RWMA area was a sawgrass-dominated (*Cladium jamaicense*) community, while the southern portion was a ridge and slough community. Since the 1950s, the RWMA has been cut off from surface water inflows and only received direct rainfall SFMWD, 2001). As a result, the RWMA has experienced marked disturbances such as increased drainage, decreased hydroperiod, drought, and fires, resulting in an increase and transition to upland vegetation species, and impacted areas facilitating the need for hydropattern restoration.

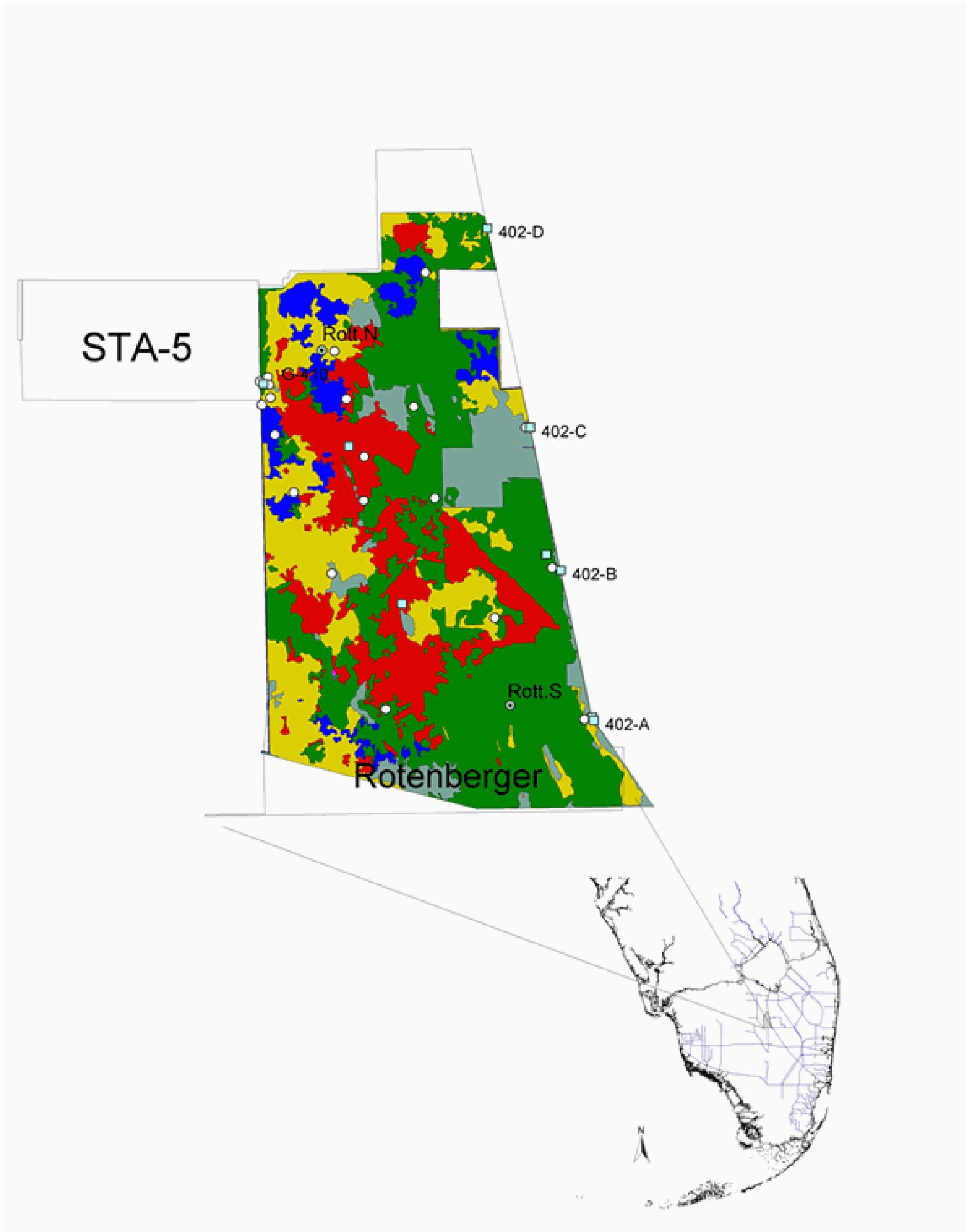


Figure 6-1. The vegetation map for the Rotenberger Water Management Area indicates the prevalence of cattail (red) downstream of the inflows from Stormwater Treatment Area (STA) Five. Other vegetation types include mixed graminoids (yellow), sawgrass (green), shrubs (gray) and open water (blue).

While a 1983 Memorandum of Agreement (MOA) outlining the restoration plan for the RWMA specified in general terms the need to manage this system in a manner that attempts to restore and preserve natural Everglades habitat, a specific ecosystem restoration target (i.e., defining the target habitat and specific vegetation cover) for the RWMA has not yet been established. An interim hydropattern target was established using the Natural System Model (NSM) to predict monthly stage targets based on a 31-year calibration period to minimize the potential for excessive dryout during the dry season (approximately October through May). However, the Stormwater Treatment Area 5 (STA-5) discharge permit (Permit No. 0131842) requires the District to monitor downstream receiving areas, such as the RWMA, in order to assess for any ecological effects from discharge. Therefore, the monitoring and research program was designed to assess not only the success of hydropattern restoration but also the ecological effects of inundation. This information will provide decision makers with the ecological data needed to implement sound environmental management decisions that will aid in the restoration of the Everglades.

Rainfall was the main source of water into the RWMA during the pre-discharge period (November 1997–June 2001). The internal stage gauge readings indicated the system had no standing water much of the year, resulting in a shortened hydroperiod that promoted the growth of several species indicative of drier habitats. Data collected during this period support that the RWMA was an impacted wetland trending toward an upland area and that changes in operation and management of this area were needed to ensure the protection of this area's natural resource value.

Post-discharge period (July 2001–June 2003) data indicated a significant increase in hydroperiod, from 3 to 7 months, and was further supported in a doubling of the mean water depth from 0.4 ft during the pre-discharge period to 0.8 ft during the post-discharge period. Preliminary analysis has indicated that in addition to natural factors (e.g., below average rainfall, evapotranspiration rates, and seepage), the opening of the G-402 outflow structures when stages reach 12.3 ft was a contributing factor that led to a decrease of water depth and not attaining the NSM target stages. However, the comparison of the monthly mean stage levels during the pre- and post-discharge periods (**Figures 6-2** and **6-3**, respectively) clearly indicates that the system is trending toward hydropattern restoration, most likely increasing soil moisture and decreasing the possibility of soil loss through muck fires. Furthermore, this increased hydroperiod during the post-discharge period resulted in the increase of obligate wetland species, such as cattail (*Typha* spp.) and sawgrass. Cattail and sawgrass were the dominate vegetation present, collectively representing about 70–75 percent of the RWMA, while a mix of grasses and facultative wetland species inhabited the remainder of the area.

Preliminary analysis of the surface water quality samples collected during the post-discharge period show that total phosphorus (TP) concentrations near the inflow (mean of 0.056 milligrams per liter, or mg/L) were elevated relative to G-402 outflow TP concentrations (mean of 0.033 mg/L). Therefore, continued monitoring of the system is recommended to assess if this is a temporary and/or spatially stationary condition, or is indicative of a moving front. Future analyses will evaluate plant recovery times in relation to both hydrology and nutrient status.

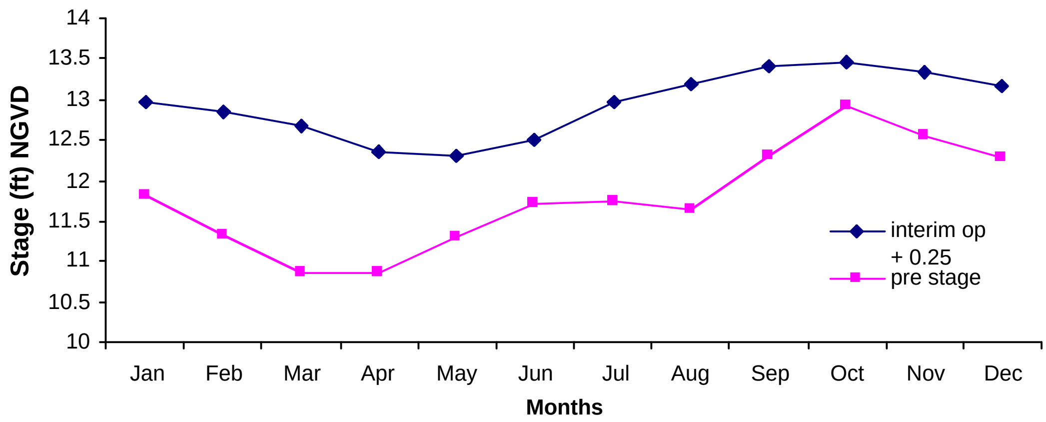


Figure 6-2. Monthly mean stage target elevations determined by the NSM are shown for the RWMA. To minimize the potential for dryout a 0.25-ft offset was added to the NSM generated target stage to obtain the interim operational schedule. Also shown are the monthly mean stage levels recorded within the RWMA during the pre-discharge period, which extends from November 1997 through June 2001.

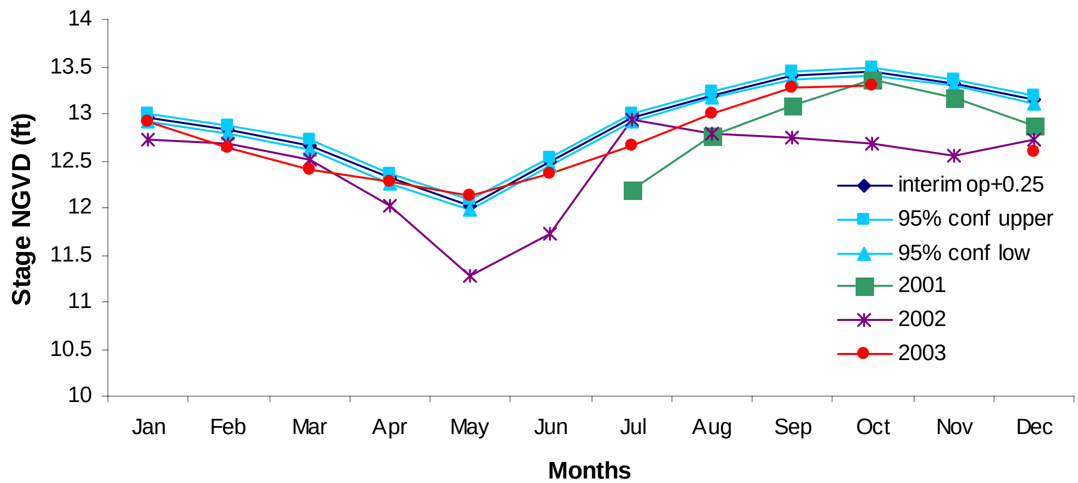
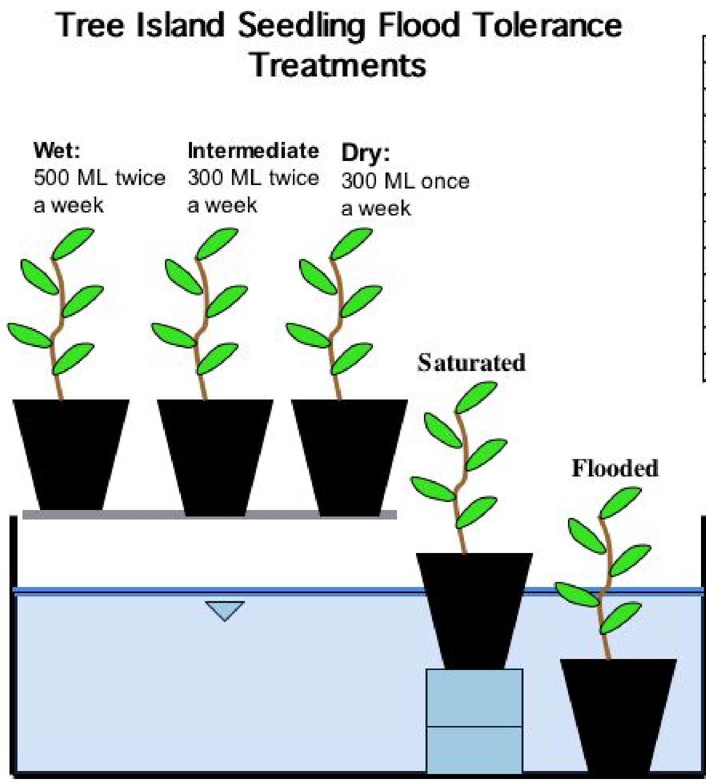


Figure 6-3. Monthly mean stage target elevations with 95-percent confidence intervals (95% C.I.) determined by the NSM are shown for the RWMA. Target stage includes a 0.25-ft offset to minimize dry-outs. Also shown are the monthly mean stage levels recorded within the RWMA during the post-discharge period, which extends from July 2001 through June 2003.

TREE ISLAND SEEDLING STUDIES

Tree islands are a cornerstone of Everglades ecology. The integrity and overall number of the tree island habitats are crucial for many species that use these sites for mating, nesting, and foraging. Although they possess some inherent resilience to changes in water depth, many of these sites are highly susceptible to degradation and species loss as a result of drought and erratic fluctuations in hydroperiod. 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. Furthermore, water managers in charge of regulating flow to the Everglades must achieve a delicate balance between meeting the water needs of the urban environment, as well as the needs of the Everglades ecosystem. Therefore, it is essential that water managers understand the thresholds of water depth and hydroperiod needed to sustain healthy tree island habitats.

In the fall 2003, the District began a greenhouse study to assess the flood tolerance of first year seedlings of three tree island species (**Figures 6-4** and **6-5**). The study species are pond apple (*Annona glabra*), red maple (*Acer rubrum*), and gumbo limbo (*Bursusera simaruba*). The seedlings are being grown under five basic treatment conditions: (1) flooded, inundated with 10 cm of water above the soil surface; (2) saturated, inundated with 5 cm of water below the soil surface; (3) a hand-irrigated soil moisture regime that is dry, receiving 300 ml of water once a week; (4) a hand-irrigated soil moisture regime that is wet, receiving 300 ml of water twice a week; and (5) a hand-irrigated soil moisture regime that is very wet, receiving 500 ml of water twice a week. In addition, twelve compound treatments were created by changing the hydrologic conditions of seedlings in the flooded, very wet, and dry treatments after four and eight months. Growth and development of seedlings, as well as leaf transpiration and soil redox, for each species in each of the five basic treatments are being recorded. The results of this study will document the least possible stress on tree island species regeneration capabilities thereby providing the District with critical information necessary to meet Everglades water needs.



0 Month	4 Month	8 Month
Dry	Wet	Wet
Dry	Flooded	Flooded
Dry	Wet	Flooded
Dry	Wet	Dry
Dry	Flooded	Wet
Dry	Flooded	Dry
Flooded	Wet	Wet
Flooded	Dry	Dry
Flooded	Wet	Flooded
Flooded	Wet	Dry
Flooded	Dry	Flooded
Flooded	Dry	Wet

Tree island seedling treatments: The five basic treatments are shown graphically (left); the 12 compound treatments are shown in the table (above). Each treatment is replicated 12 times totaling 612 seedlings.

Figure 6-4. Greenhouse design to access the flood tolerance of first year seedlings of three dominant tree island species: pond apple (*Annona glabra*), red maple (*Acer rubrum*), and gumbo limbo (*Bursusera simaruba*).

Figure 6-5. Ongoing greenhouse study to assess the flood tolerance of first year seedlings of pond apple, red maple, and gumbo limbo.

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 to focus research in that direction. In this year's report, highlighted areas include 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 Arthur R. Marshall Loxahatchee National Wildlife Refuge (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 not possible, so it is important to understand to what extent the system can withstand alterations in surface water chemistry without degrading its structure and function. Tree islands continue to be a major focus of research because these biodiversity hotspots 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 (see previous ECRs for additional details). 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.

INFLUENCE OF WATER MINERAL CONTENT ON PERIPHYTON STRUCTURE

Historically, the northern Everglades was a softwater, peat ecosystem with a periphyton assemblage dominated by acidophilic diatoms and desmids (Slate and Stevenson, 2000). The building of canals and pumps to manage water in South Florida has led to the intrusion of hard water into the WCAs. As a result of water chemistry changes, periphyton composition in phosphorus-limited portions of WCA-2A and 3A has shifted to calcium carbonate mats dominated by filamentous cyanobacteria, which are very similar to those found in the southern Everglades (Browder et al., 1994; McCormick et al., 2002). Additionally, soil accretion has changed from a peat-accumulating environment to one with both organic soil and marl accumulation. In contrast, portions of WCA-3A and the Refuge (distant from current discharge points and canals) still maintain softwater periphyton assemblages. With the implementation of CERP and future operations of STA-1E and STA-1W, concern has arisen that further intrusion of hard water into softwater portions of the Everglades, particularly the Refuge, may occur resulting in changes in ecosystem structure and function. Previous research in the Refuge has examined the influence of phosphorus enrichment, yet there is limited information on the ecological change in response to mineral enrichment. As a result, a synoptic survey was conducted to assess the spatial distribution of hard water in the Refuge. In addition, changes in periphyton species composition in response to altered mineral contents of surface waters were examined in a laboratory experiment. This information, along with subsequent synoptic surveys, will allow the refinement of a water movement model in the Refuge. It is required to interpret long-term datasets in which strong relationships between surface-water mineral content and species composition have been observed.

Synoptic Survey: In February 2004, the District, USGS, and USFWS conducted a synoptic survey of the Refuge. Surface water, plant, and soil chemistry, along with periphyton taxonomy, were determined at 130 sites within the marsh, and an additional 37 conductivity readings were obtained from samples distributed throughout the perimeter canal. To date, only marsh surface water parameters (conductivity, chloride, total phosphorus, sulfate, and canal conductivity) were available for interpretation. Conductivity and chloride exhibited higher values within an approximate 5-km width along the western boundary of the Refuge, in close association with the highest conductivity measurements within the western boundary canal (> 800 microsiemens per centimeter, or $\mu S\ cm^{-1}$) compared to the relatively lower values on the east side of the Refuge (388–800 $\mu S\ cm^{-1}$). Overall, values ranged between 60–1,017 $\mu S\ cm^{-1}$ for conductivity, and between 14–147 mg L^{-1} for chloride (**Figures 6-6** and **6-7**, respectively). Conductivity and chloride were significantly positively correlated ($r^2 = 0.98$). This strong relationship suggests that, at least in the Refuge, conductivity may be used as a tracer for canal water input.

The pattern of sulfate distribution was similar to that observed for both chloride and conductivity, with the highest concentrations occurring in proximity to the western canal boundary (**Figure 6-8**). Sulfate concentrations ranged between 0–72 mg L^{-1}, with the majority of the marsh interior exhibiting concentrations < 1 mg L^{-1}. Sulfate concentrations were strongly related to chloride concentrations, fitted via a second order polynomial curve ($r^2 = 0.94$).

In contrast, there was no distinct spatial pattern in TP concentrations (**Figure 6-9**). TP concentrations ranged between 0.005–0.37 mg L^{-1}, with the highest values occurring in the southeastern and northern portions of the Refuge. Due to logistic constraints, surface water samples were collected as grab samples as opposed to using a more precise peristaltic pump system. This may have contributed to the higher TP values observed at interior sites, where long-term averages are closer to 10 $\mu g\ L^{-1}$ (see below).

The February 2004 sampling event occurred when there was no surface exchange between the marsh and the surrounding canal and, therefore, high conductivity in the overlying water may indicate a change in ecosystem characteristics at these sites. It is hypothesized that change is related to one of the constituents of mineral content, and not conductivity. Conductivity is used as a surrogate of mineral content for the simple reason that it is easy and simple to measure, and is highly correlated with the constituents of mineral content. It is unclear how or why mineral content alters the species composition of periphyton. Extensive literature searches have been conducted, and very little information has been found that identifies a physiological mechanism for negative impacts of mineral content on certain types of algae. The data collected during this sampling event represents only one point in time, and additional sampling events at different marsh and canal stages will be conducted throughout 2004 and 2005 to determine if conductivity and chloride can be used to trace surface exchange in this system. Assuming conductivity is a sensitive measure of canal intrusion, continuous monitoring may be used to optimize operational decisions to protect the softwater nature of the Refuge. Further sampling will also shed light upon the identity of the hardwater source (end member), which is suspected to be groundwater, and will eventually lead to a biological indicator model that will address how operations and restoration alternatives will effect periphyton composition.

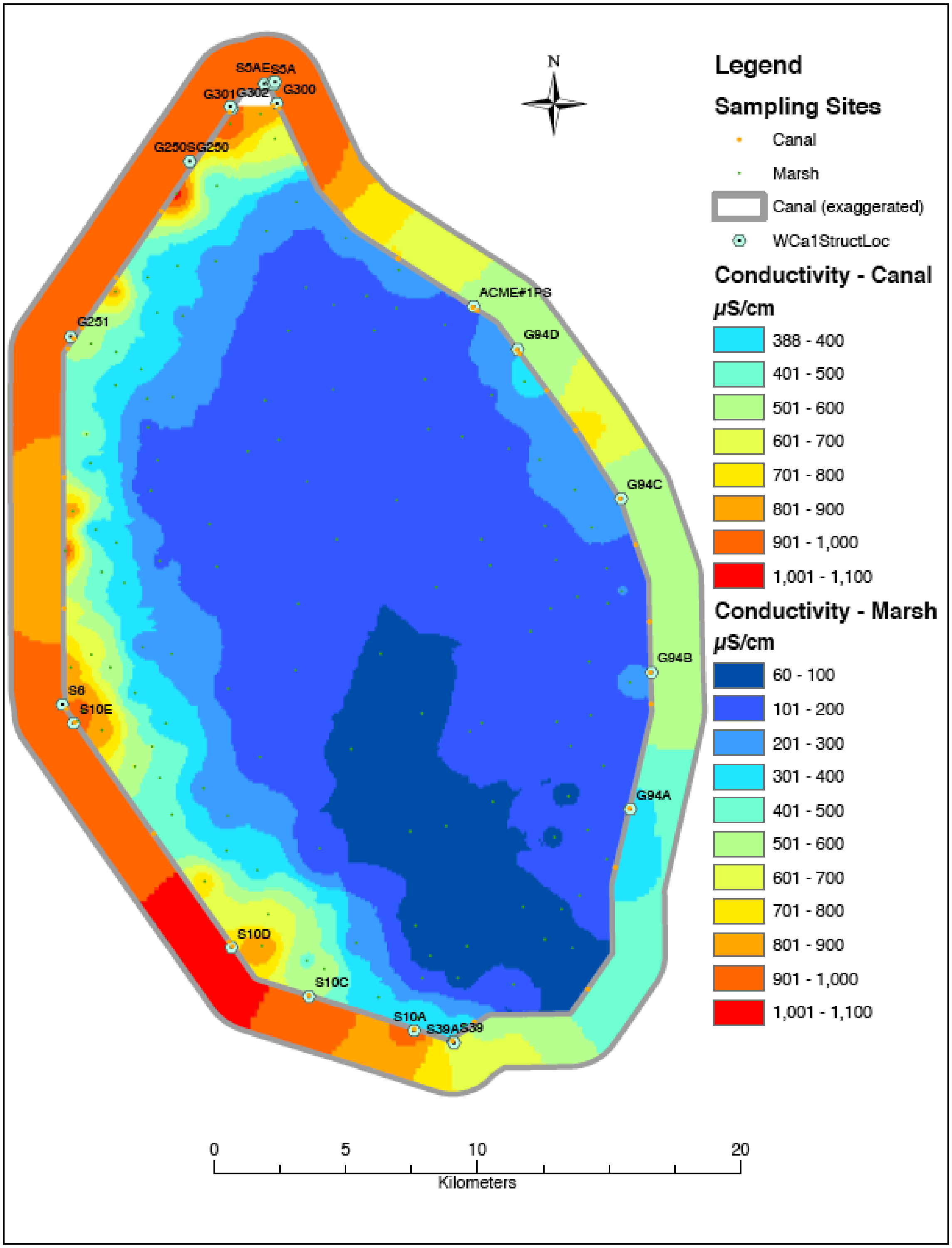


Figure 6-6. Spatial distribution of conductivity in surface water in the Refuge (samples collected from February 25–27, 2004).

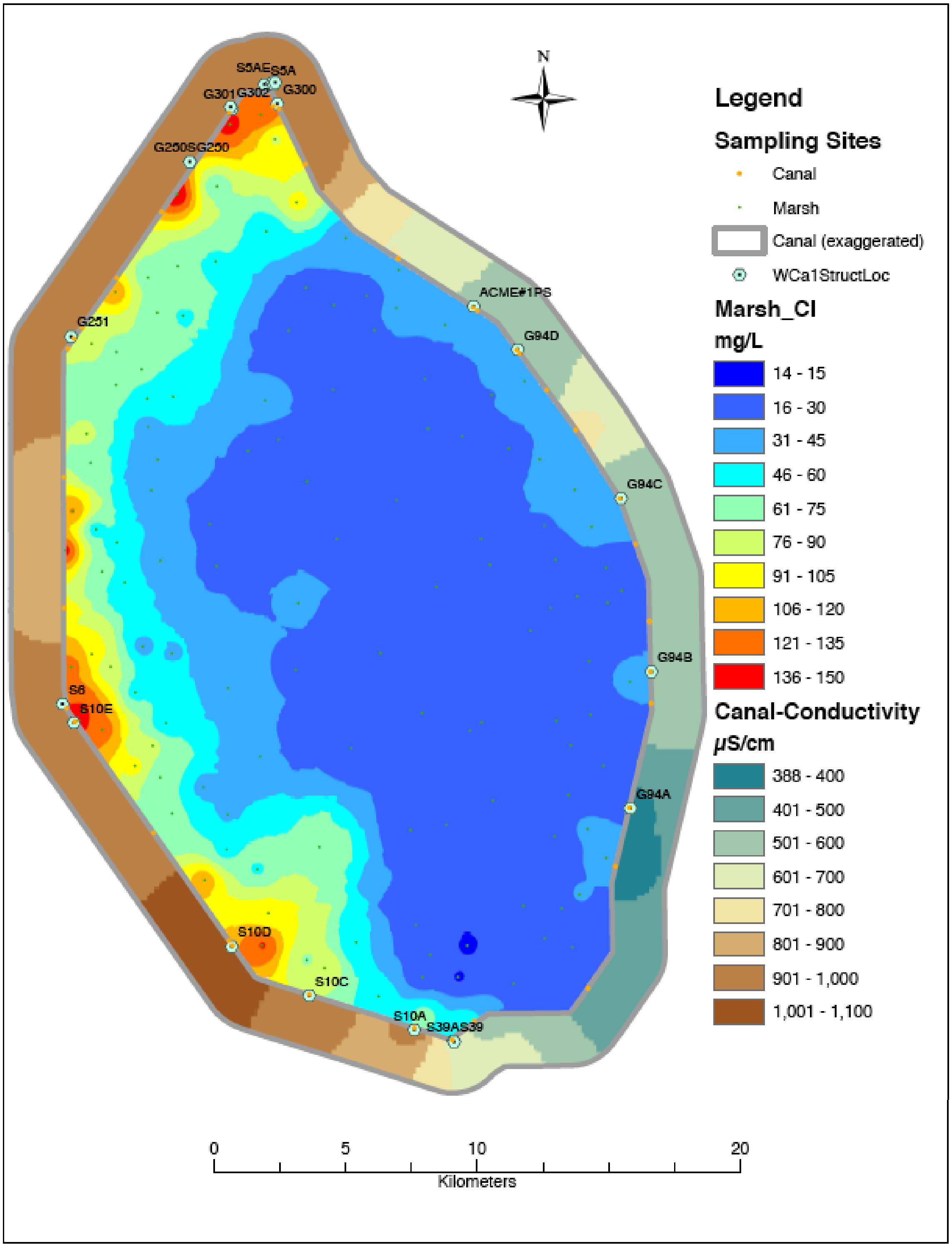


Figure 6-7. Spatial diston of chloride concentrations in surface water in the Refuge (samples collected from February 25–27, 2004).

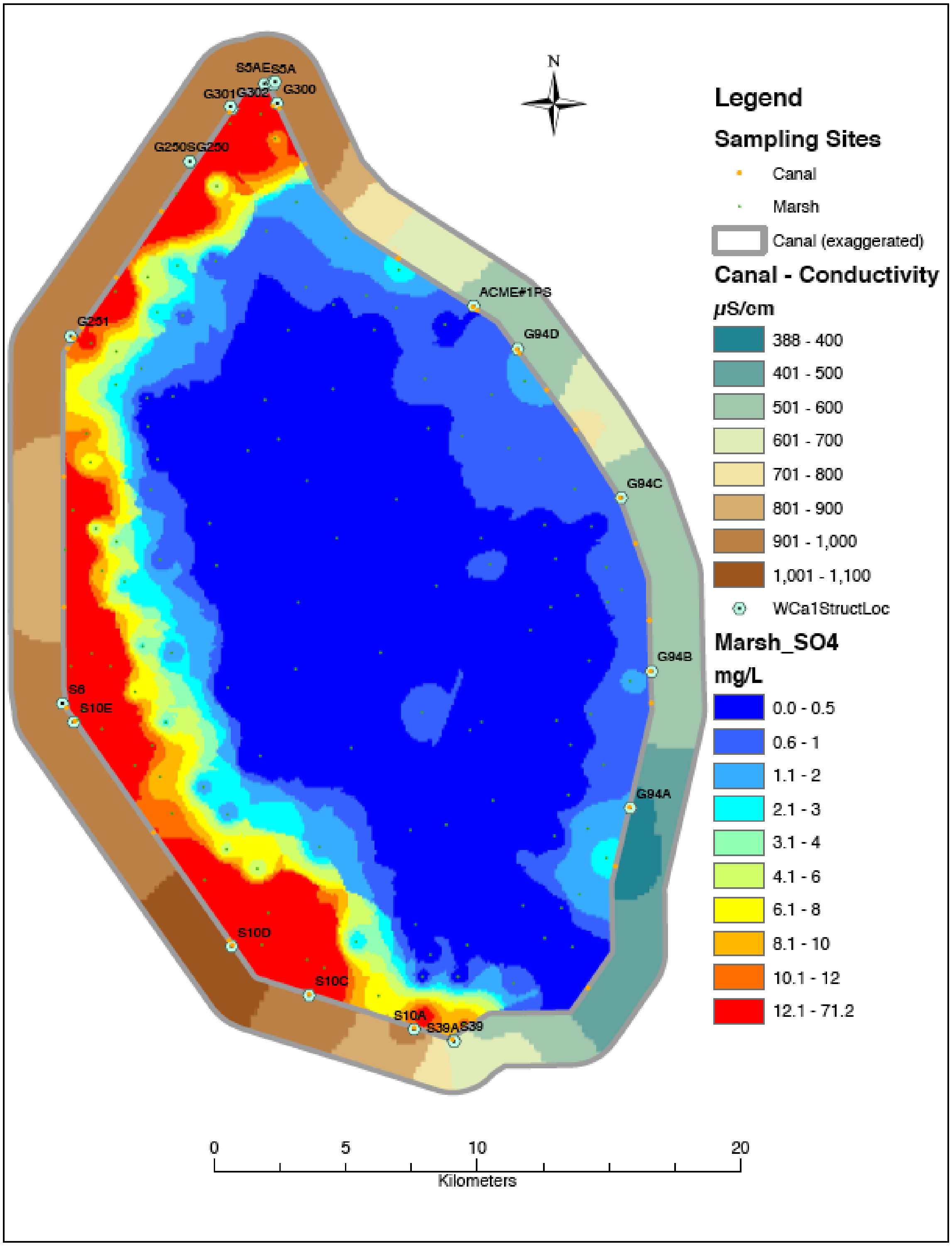


Figure 6-8. Spatial distribution of sulfate concentrations in surface water in the Refuge (samples collected from February 25–27, 2004).

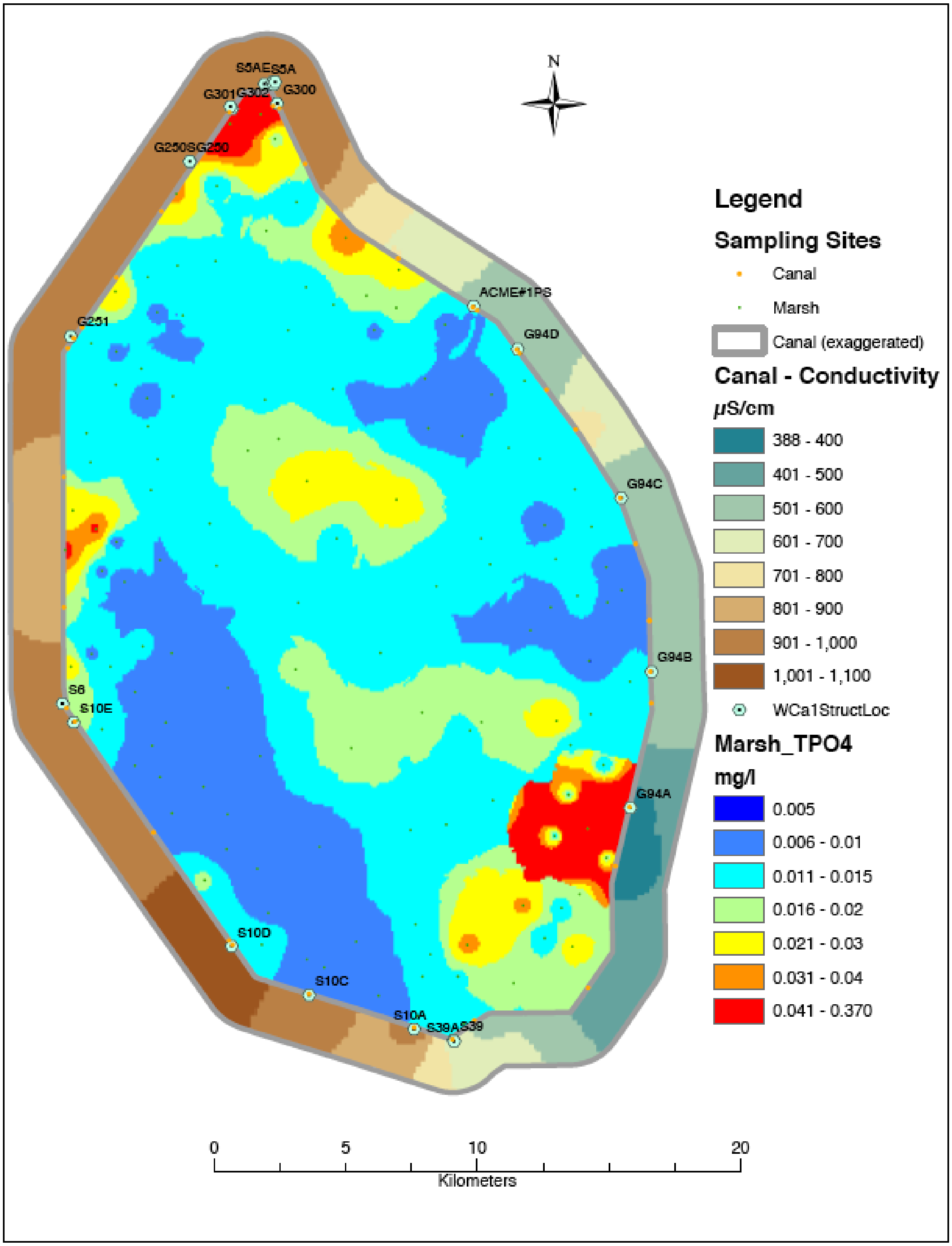


Figure 6-9. Spatial distribution of TP concentrations in surface water in the Refuge (samples collected from February 25–27, 2004).

Mineral Adjustment Laboratory Experiment: Using several years of surface water data, the chemical characteristics of the Refuge and WCA-2A were compared. Interiors of the Refuge and WCA-2A have TP concentrations < 9 µg/L, but differ dramatically in mineral content (**Table 6-2**). This chemical difference was used to examine how the softwater periphyton assemblages in the Refuge might change as a consequence of mineral content. A specific conductivity gradient was established that spanned mean values within the Refuge (approximately 80 µS cm^{-1}) and WCA-2A (approximately 900 µS cm^{-1}). Seven treatments were made by diluting water collected from the interior of both regions. The target-specific conductivity values (µS cm^{-1}) for each treatment were: (a) 77, (b) 230, (c) 310, (d) 425, (e) 540, (f) 610, and (g) 842. It was assumed that other measures of mineral content (e.g., calcium, magnesium, chloride, potassium, and alkalinity) would concomitantly be diluted, and that TP concentrations would remain low. Thus, periphyton response would be solely due to mineral content. Periphyton mats collected from the interior of the Refuge on October 8, 2003 were incubated in butyrate core, 4-in diameter tubes in the laboratory that contained treatment water. The softwater periphyton in the Refuge is a floc-like assemblage that is loosely attached to bladderwort (*Utricularia* sp.), and is comprised mostly of diatoms, desmids, and coccoid cyanobacteria. Triplicate cores were incubated for one month in a Percival Scientific growth chamber (Model: E-36HID) at near-natural light intensities (> 1100 µmoles m^{-2} sec^{-1}) on a 12:12 (light:dark) cycle. Specific conductivity and pH were measured twice weekly. Treatment water was added to each core once a week to maintain conductivity and account for evaporative losses. Various water quality parameters were measured weekly, and then each treatment was adjusted to maintain both volume and conductivity. After one month, periphyton samples were collected and species composition determined.

Concentrations for most of the water quality parameters followed the expected pattern (**Table 6-3**). Specific conductance, alkalinity, calcium, chloride, silica, and total nitrogen increased with treatment level, and final concentrations for the end members were similar to long-term average concentrations. Values for pH did not exhibit a gradient among treatments, and they were one to two units higher then the long-term means. This was likely due to photosynthesis and the relatively small volume (2 L) of the core tubes. Uptake of carbon from the water column would increase the pH. Similarly, TP concentrations were greater than expected, but did not differ among treatments. However, because pH and TP did not differ significantly among treatments, it is likely that any difference in periphyton composition among treatments was the result of mineral content.

Increasing conductivity led to significant changes in the structure of Refuge periphyton mats. A multivariate ordination analysis (non-metric dimensional scaling) revealed that the seven treatments were grouped into three distinct assemblages based on species composition similarity. Group 1 was comprised solely of the 77 µS m^{-2} sec^{-1} treatment. Group 2 consisted of the 230 and 310 µS m^{-2} sec^{-1} treatments. Group 3 was comprised of the treatments with specific conductance values greater than 425 µS m^{-2} sec^{-1}. The major changes in composition were the result of decreases in all the major algal groupings (**Table 6-3**). Diatom, desmid, and coccoid cyanobacteria densities significantly declined when specific conductance exceeded 230 µS m^{-2} sec^{-1}. Alternatively, filamentous cyanobacteria and filamentous chlorophyte (green algae) densities did not decline until specific conductance exceeded 310 µS m^{-2} sec^{-1}.

Table 6-2. Summary of water quality (mean ± SE) in the interior of the Refuge and WCA-2A. Values for the Refuge were collected from 1998–2001, and values for WCA-2A were collected from 1994–2003.

Parameter	**Refuge (Mesocosm)**	**WCA-2A (U3)**
pH	6.19 ± 0	7.60 ± 0
Specific Conductivity (µS/cm)	78.4 ± 0.41	928 ± 17
Alkalinity (mg/L)	7.8 ± 0.3	209.8 ± 5.4
Chloride (mg/L)	17.9 ± 0.4	134.8 ± 3.0
Calcium (mg/L)	4.8 ± 0.1	65.9 ± 1.2
Magnesium (mg/L)	1.4 ± 0.02	26.2 ± 0.5
Potassium (mg/L)	0.4 ± 0.02	7.1± 0.1
Sodium (mg/L)	10.3 ± 0.2	97.7 ± 2.0
Iron (mg/L)	60.7 ± 3.1	11.8 ± 0.8
Total Phosphorus (µg/L)	8 ± 0.3	8 ± 0.4
Total Nitrogen (mg/L)	1.4 ± 0.03	2.4 ± 0.04
Dissolved Silica (mg/L)	1.8 ± 0.2	17.2 ± 0.4

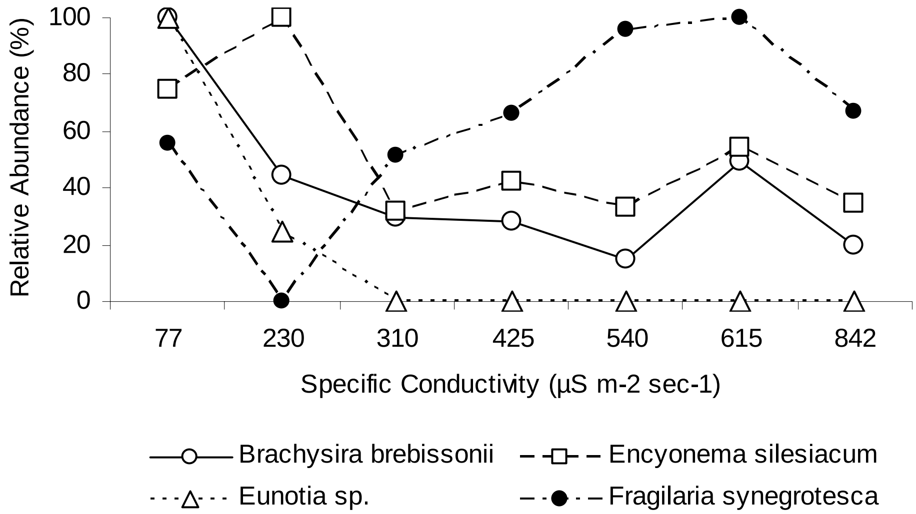
Table 6-3. Summary of water quality (mean ± SE; n=3) for each targeted mineral content treatment (T1 through T7). Values reflect water quality at the end of the experiment. Units for all parameters are in mg/L with the exception of specific conductivity (μS m^{-2} sec^{-1}) and TP (μg/L). Diatom, desmid, filamentous cyanobacteria, and filamentous chlorophytes cell densities are expressed as x 10^7 cells per core.

Parameter	T1 77	T2 230	T3 310	T4 425	T5 540	T6 615	T7 842
pH	8.7 ± 0.0	9.0 ±0.0	9.1 ± 0.0	9.0 ± 0.0	8.9 ± 0.0	8.8 ± 0.0	8.9 ± 0.0
Specific Conductivity	91 ± 2	252 ± 7	335 ± 3	442 ± 4	567 ± 1	630 ± 6	861 ± 4
Alkalinity	5.7 ± 0.2	38.4 ± 4	56.4 ± 0.8	84.8 ± 1.2	110.0 ± 1.5	129.1 ± 1.3	175.8 ±1.0
Calcium	4.4 ± 0.1	13.4 ± 0.3	17.9 ± 0.2	26.0 ± 0.5	32.1 ± 0.4	37.6 ± 0.4	49.6 ± 0.5
Chloride	19.3 ± 0.5	45.3 ± 0.9	57.3 ± 0.7	75.0 ± 1.9	90.7 ± 1.4	104.0 ± 0.2	137.1 ± 2.3
Total Phosphorus	13 ± 1	14 ± 2	27 ± 5	23 ± 9	15 ± 3	23 ± 8	13 ± 4
Total Nitrogen	1.5 ± 0.1	1.7 ± 0.1	1.8 ± 0.1	1.8 ± 0.1	2.0 ± 0.1	2.1 ± 0.1	2.2 ± 0.1
Silica	2.3 ± 1.0	12.8 ± 2.2	14.8 ± 1.5	17.8 ± 0.7	11.6 ± 2.9	14.7 ± 0.6	21.4 ± 1.1
Diatom	95.7 ± 12.7	75.6 ± 25.8	48.7 ± 11.4	40.1 ± 2.7	39.9 ± 5.8	57.2 ± 6.1	39.8 ± 11.9
Desmid	21.5 ± 4.1	25.4 ± 4.1	14.6 ± 4.2	11.3 ± 4.4	10.9 ± 0.6	9.9 ± 1.2	12.3 ± 0.8
Cyanobacteria (Filaments)	81.2 ± 24.1	74.7 ± 15.3	62.7 ± 21.2	35.6 ± 7.1	38.8 ± 5.8	38.8 ± 5.6	39.2 ± 1.7
Chlorophytes (Filaments)	30.2 ± 6.1	21.8 ± 6.0	31.3 ± 6.0	15.1 ± 1.2	11.5 ± 0.2	12.6 ± 4.7	18.3 ± 1.2

As presented in **Figure 6-10**, exposing Refuge periphyton mats to high conductivity marsh water negatively affected many species. For example, the diatoms *Brachysira brebisonii, Encyonema silesiacum*, and *Frustulia rhomboides* and two species of *Eunotia* densities were highest for the low conductivity treatments. These taxa are commonly associated with low conductivity water (Slate and Stevenson, 2000; Potapova and Charles, 2003). Similar patterns were observed for several desmid genera including *Cosmarium, Staurastrum,* and *Onychonema*. A few taxa responded positively to conductivity (e.g., the diatom *Fragilaria synegrotesca* and the filamentous cyanobacteria *Lyngbya*), or were associated with narrow ranges of conductivity (e.g., the desmid *Genicularia*).

These results confirm that the mineral content of water negatively affects the structure of Refuge periphyton. Significant changes in species abundances were observed with seemingly minute increases in conductivity (77 to 310 $\mu S\ m^{-2}\ sec^{-1}$). More importantly, periphyton structural changes were observed over a temporal period of less than one month. Thus, these results suggest that diatom and desmid densities can be used to monitor the biological response to hardwater intrusions into the Refuge as a result of water management operations. Furthermore, the relatively short response time of periphyton to conductivity indicates that short-duration, pulsed events less than or equal to one month may have ecological consequences. These consequences are unknown, but may include changes in primary production, nutrient cycling, and food web dynamics and will ultimately depend on how resilient the assemblages are to fluctuations in mineral content. These results may aid in the management of the Everglades to prevent the loss of peat-dominated regions due to long-term exposure to mineral-rich surface waters.

A



B

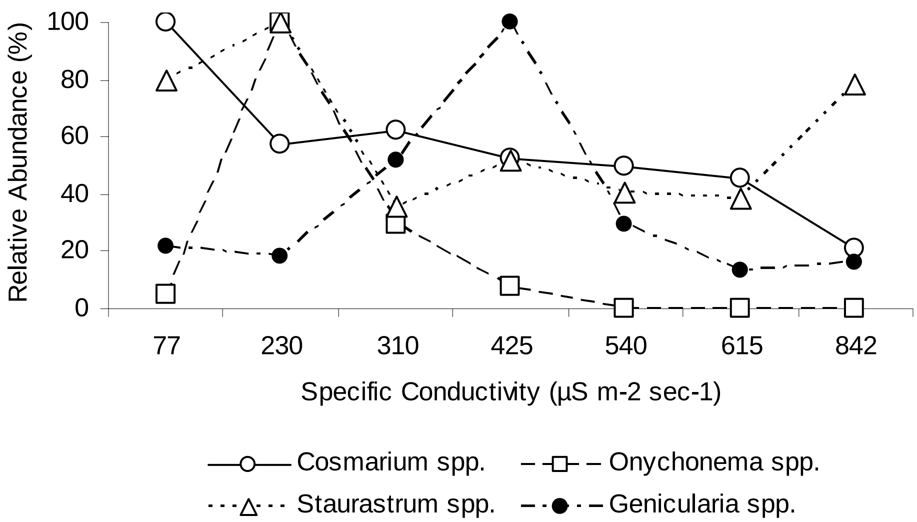


Figure 6-10. Responses of individual diatom (A) and desmid (B) algal taxa to increases in conductivity. Densities were normalized for each taxon by dividing the cell density for each treatment by the maximum value, and multiplying by 100.

TREE ISLAND ECOLOGICAL PROCESS

Previous ECRs have shown maps of tree island loss, described community structure, and discussed the importance of tree islands in terms of conservation of biodiversity and habitat sustainability. This ecosystem update of the District's tree island research program highlights the results of four years of litterfall collection and one year of a new study to examine belowground processes. Both components of this program will help us understand how and why tree islands lose elevation, "drown," and convert back to marsh vegetation. In turn, this may alter how the Everglades is managed and restored.

Litterfall Production

Primary production, a critical index of system health, in forest wetland ecosystems is often evaluated by measuring litterfall rates. However, litterfall represents just a fraction of the total dry matter production, and is but one component of the larger dynamics of soil formation and wetland elevation change. Production of leaves in the canopy and subsequent litterfall to the soil surface, combined with processes of decomposition and factors that control the export of materials from tree islands, describes the function and relative importance of litterfall for different types of forested wetland ecosystems. The measurement and analysis of litterfall for tree islands in the Everglades represents a needed approach to: 1) describe litterfall function, 2) understand litterfall influence upon island structure, and 3) evaluate how environmental conditions shape island structure and function. Specifically, the study of litterfall dynamics will contribute to a better understanding of the temporal and spatial patterns of primary production in relation to hydroperiod fluctuations, the dynamics of short-term peat accumulation in relation to water depth, and tree island nutrient and biogeochemical cycling in relation to island productivity and health.

The main objective of the tree island program is to determine plant community responses to changes in water level, timing and frequency of inundation. Of particular interest is to assess the effects of hydroperiod on both above and belowground processes, such as litterfall production, tree growth, seedlings recruitment, root production, and decomposition. To accomplish these goals, in 2003 the District began the process of establishing permanent vegetation plots on tree islands located in WCA-3, where extant woody vegetation has been characterized. Tree species composition, height, basal area, density, and distribution have now been surveyed on nine tree islands in WCA-3A and 3B in the central Everglades.

In order to determine how changes in hydrology affect both above and belowground process in tree islands, sampling plots were grouped into three distinct hydrologic environments: short, medium, and long hydroperiods. Tree island grouping was based on water depth data measured on each of the nine tree islands. These data, combined with data from nearby SFWMD stage gauges, were used to create regressions equations to estimate number of days of inundation and water depths on the islands over the past 14 years. Based upon this analysis, it was found that short hydroperiod environments are inundated for less than 25 percent per year, with average water depths of less than 25 cm; medium hydroperiod environments are inundated between 25 percent and 50 percent per year, with an average water depth of 25 cm, and long hydroperiod environments are inundated more than 50 percent per year, with average water depth exceeding 25 cm. It was also found that study sites represent a spatial gradient ranging from low water levels with short hydroperiods in the northern regions of WCA-3A, to high water levels with longer hydroperiods in the southern regions of WCA-3A.

Results from four years of litterfall collection on WCA-3 tree islands indicate that litterfall pattern is strongly seasonal, with a short burst of high litterfall production occurring in the spring. During the rainy season, high litterfall production was sustained from June through October. This temporal pattern was similar among the three hydrologic environments (**Figure 6-11**). Analysis of variance indicated a significant difference between dry season and rainy season litterfall ($p < 0.05$). Litterfall production was also found to be significantly higher ($p < 0.05$) for tree islands with short hydroperiods (average 2.1 g m^{-2} day^{-1}), compared with tree islands with medium or long hydroperiods (average 1.5 and 1.1 g m^{-2} day^{-1}, respectively). Litterfall was separated into their different components (leaves, reproductive, woody, and miscellaneous), and leaf fall contributed the most to the total litterfall (i.e., 75 percent of the total litterfall production). The reproductive component along with the woody component contributed about 15 percent of the total litterfall, and miscellaneous contributed some 10 percent. (**Figure 6-11**). It was interesting to note that the reproductive component (seeds, flowers, and fruits) was relatively higher for short hydroperiod islands than for medium and long hydroperiod islands.

Species composition is an important biotic factor in determining litterfall patterns for tree islands. For instance, out of fifteen species, four contributed more than 50 percent of the total leaf fall production. Specifically, pond apple and willow (S*alix. caroliniana*) contributed 70 percent of the total leaf fall for long hydroperiod sites, while cocoplum (*Chrysobalanus icaco*) and wax myrtle (*Myrica cerifera*) contributed 60 percent of the total leaf fall for short and medium hydroperiod sites. At the population level, these results indicate that litterfall production is strongly related to the abundance and distribution of tree species. Assuming that wetland trees can acclimate, to some degree, to a particular hydrological regime, the District hypothesizes that for each species, maximum litterfall occurs when their ecophysiological (and hence, hydrological) needs are optimized. These results suggest that the spatial and temporal pattern of litterfall production is directly linked to both current forest structure and hydrologic regime, which in turn implies that hydrologic restorations may (initially) produce both positive and negative impacts upon tree island aboveground processes.

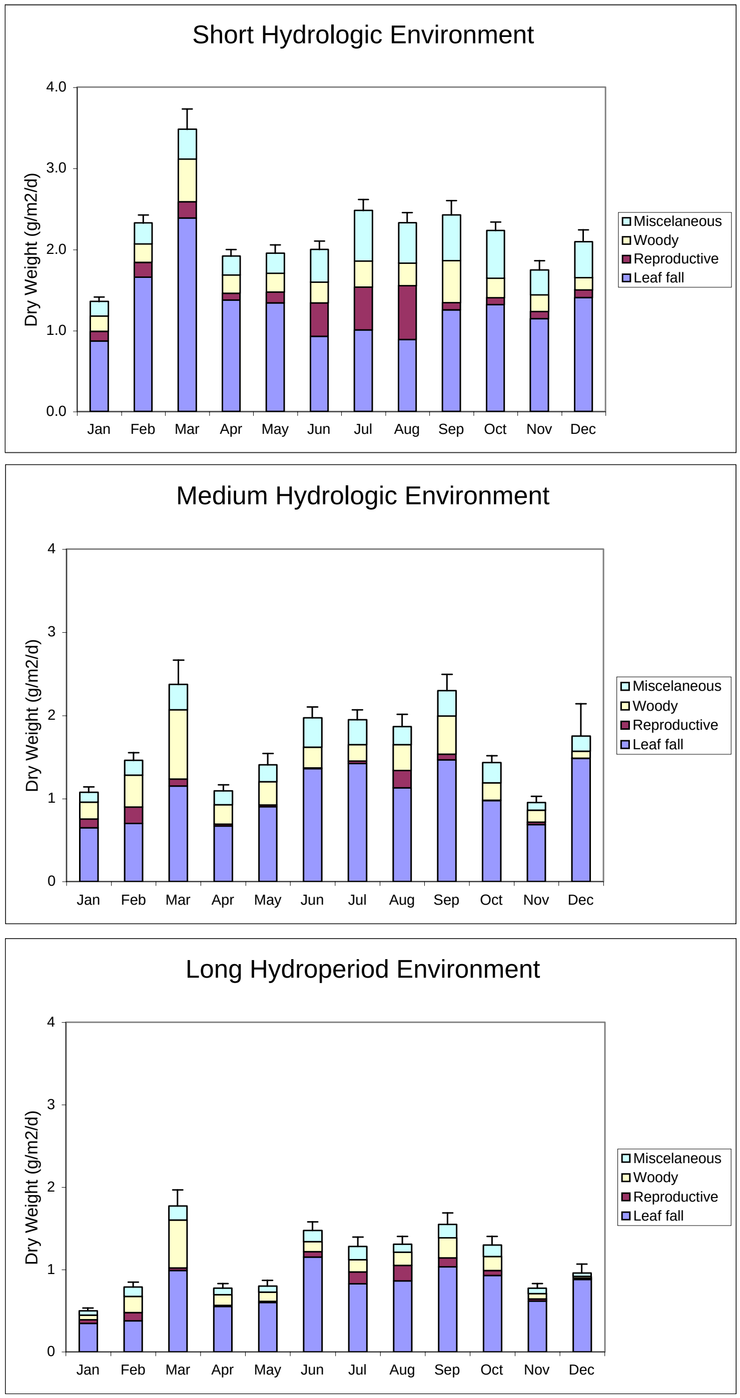


Figure 6-11. Litterfall, indicative of tree island productivity and health, has a slight seasonality and greatest on short hydroperiod islands. Note: Error bars represent standard deviation.

Belowground Biomass

Accurate measure of belowground biomass is necessary to understand how tree islands maintain or loss elevation, as well as to predict their function and structure as a result of daily operational decisions and long-term restoration plans. Processes controlling root dynamics and their functional significance are very poorly understood, which is mostly due to the difficulties associated with measuring belowground processes such as production, decomposition, and root longevity. Estimates of root biomass and productivity have not been included in ecological studies because of a lack of appropriate methods, the tremendous amount of labor involved, and the assumption that roots contribute less to carbon and nutrient storage processes than aboveground compartments. However, this assumption may be wrong for the Everglades; this hypothesis can be tested because the District has also discovered a new technique that will make live and dead root identification easier (Robertson and Dixon 1993; Vogt et al., 1998).

Wetland hardwoods allocate biomass to different components such as flowers, leaves, roots, etc. in response to (1) resource gradients, such as nutrients and light, and (2) regulator (stress) gradients, such as salt, hydrogen sulfide, and flooding. Regulators may affect patterns of belowground biomass and productivity and thus shift the relative allocation of biomass to deal with stress instead of growth or reproduction. Belowground biomass is measured by the presence or absence of roots on tree islands. It is crucial to understanding both root and organic matter dynamics, which is directly related to tree health and island elevation, respectively.

The District hypothesized that there is a difference in belowground biomass among short, medium, and long hydroperiod environments. To test this hypothesis, four 10 m x 10 m plots were established on each of nine tree islands, with two plots on the head (the topographical high) and two plots on the near tail (a topographical low). Four random soil cores (20-cm depth) were taken from a previously established grid system in each plot. Cores were then rinsed with water to remove soil and excess organic matter, and remaining roots separated into live and dead components using colloidal silica (Robertson and Dixon, 1993; Vogt et al., 1998). The separated roots were rewashed, dried at 60˚ C, and weighed.

Because these data are still being analyzed, preliminary results from only four of the nine islands are presented. The short hydroperiod environments had significantly less live roots than long or medium hydroperiod environments (**Figure 6-12**). This may be due to differences in ecophysiological responses to anoxic conditions and inundation (i.e., flooding) stress. The low live roots biomass measured on short hydroperiod environments may be due to 1) higher soil oxygen and the promotion of high soil respiration and root turnover rates; 2) high re-mineralization of peat soils and enhanced nutrient availability (i.e., fewer roots are needed to support production); and 3) a reduced need for roots as a support mechanism. Dead biomass results (**Figure 6-12**) indicated an opposite trend. That is, long hydroperiod environments had significantly more dead roots than short or medium hydroperiod environments. It may be that trees from long hydroperiod environments: 1) produce more roots in response to anoxic conditions (i.e., they must “mine” for nutrients and oxygen), and 2) decompose very slowly due to long periods of anaerobic conditions.

Until recently, aboveground studies were the primary source of data for forested ecosystems, and belowground processes were poorly understood and mostly ignored. The failure to include belowground data may seriously underestimate forest ecosystem primary production and peat-forming dynamics. The proportion of organic matter input to the forest floor due to aboveground processes (i.e., litterfall, decomposition, and export) and belowground processes (i.e. root production, mortality, and turnover) are not fully understood for tree islands. Thus, in order to understand the effects of hydrology on the above and belowground processes of peat accumulation, data needs to be collected on the chemical composition of litterfall and roots, the decay rates of litter and roots, and the environmental factors that affect these processes. Most importantly, an understanding of the role of belowground biomass is needed for a complete picture of the ecological processes that determine tree islands sustainability.

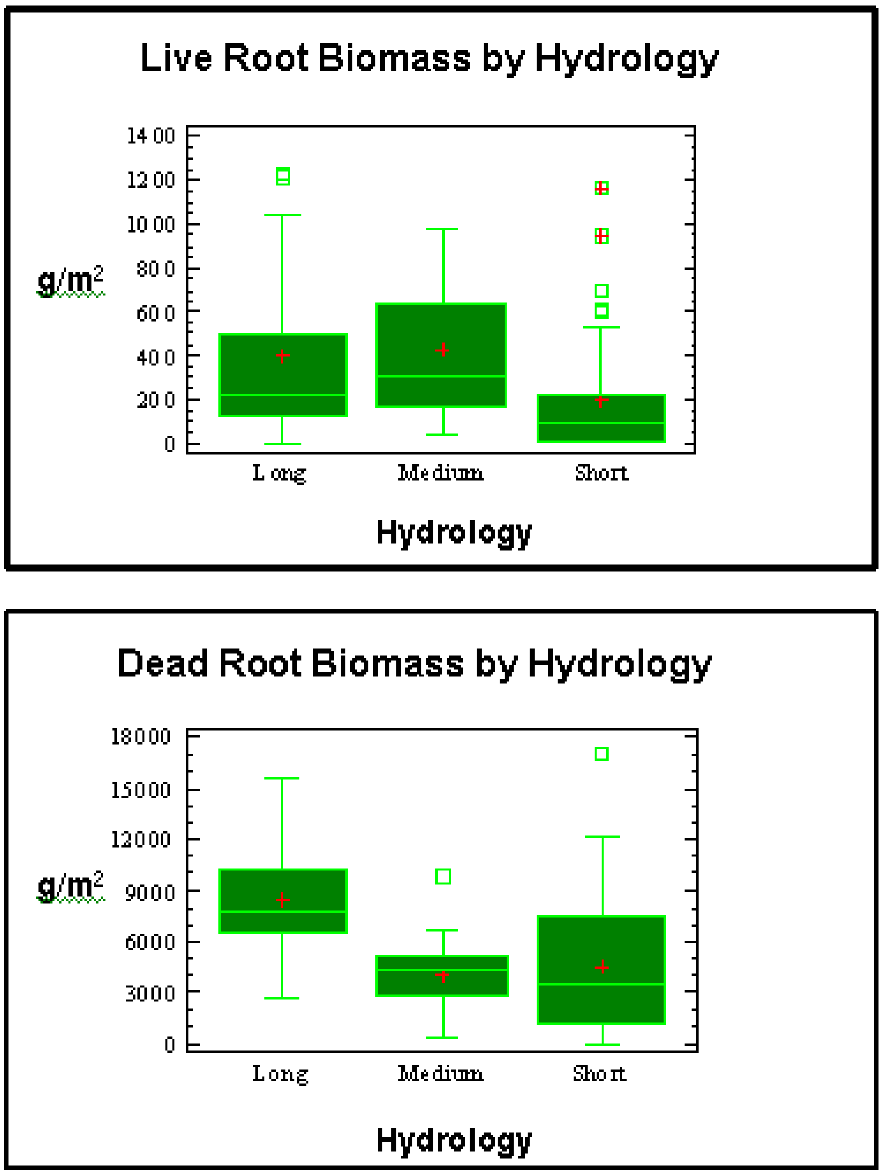


Figure 6-12. The statistical summary (mean, median, 25 and 75 percentiles, and ranges) shows that live root biomass on tree islands is significantly less in short hydroperiod environments, and dead root biomass is significantly greater in long hydroperiod environments.

LANDSCAPE ECOLOGY

The District is continuing to observe, analyze and simulate the total hydro-biogeochemical system of the EPA. Previous ECRs have shown vegetation maps created with specially developed remote sensing and photointerpretation techniques, calculated spatial indices of landscape characteristics to identify degraded regions of ridge and slough habitat, and reviewed the output of large-scale models and habitat suitability indices to determine change as a function of water management. In this chapter, new information is presented on: 1) a complete Geographic Information Systems (GIS) vegetation database of Water Conservation Area 3 (WCA-3); 2) the design for a new mapping project that will enable CERP to track landscape-level changes and integrate these changes with CERP monitoring and assessment programs; and 3) an outline of the District's responsibilities for the recovery of impacted areas as stipulated in the Long-Term Plan.

WCA-3 MAPPING PROJECT

One project considered by many to be the environmental "jewel" of CERP (http://www.evergladesplan.org) is the WCA-3 Decompartmentalization and Sheet Flow Enhancement (DECOMP) project. Impoundments such as WCA-3 (**Figure 6-13**), originally designed for flood control and water supply, are now being recognized for their ecological value in restoring the Everglades. In order to help document the potential benefits of the DECOMP project; a vegetation map was needed to establish baseline conditions for WCA-3. Until this mapping project was initiated in 1994, a comprehensive, detailed vegetation map had not been produced for WCA-3. The objective of this project was to create a seamless and complete GIS vegetation database of WCA-3 utilizing 1:24,000 scale CIR aerial photographs using a single, comprehensive classification system. Vegetation was delineated and classified using a Vegetation Classification System for Southern Florida's National Parks and Preserves (Jones et al., 1999). A hierarchy of up to three codes of vegetation representing the dominant, co-dominant, and third dominant vegetation type was included to label any polygon. Results for the overall map classification accuracy for polygon labels with up to three codes are as follows:

Label Codes			Accuracy
Dominant	Co-Dominant	Third-Dominant	
correct	correct	correct	89.70%
correct	correct	incorrect	90.70%
correct	Incorrect	incorrect	93.10%

The final product (**Figure 6-14**) of this effort is also presented in this chapter and documented in Rutchey et al. (in prep. a) for historical purposes.

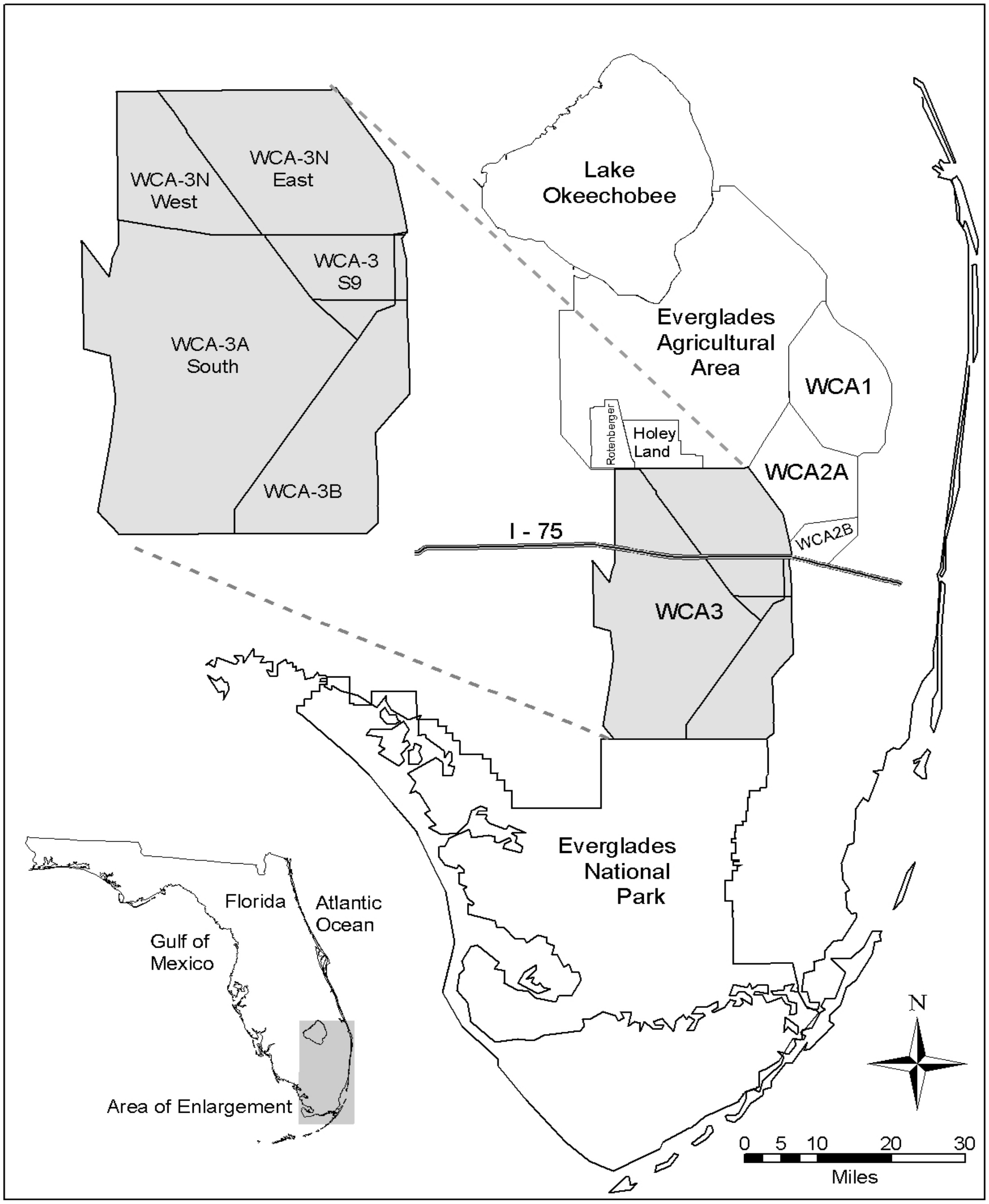


Figure 6-13. An environmental "jewel" of CERP is the WCA-3 Decompartmentalization and Sheet Flow Enhancement (DECOMP) project.

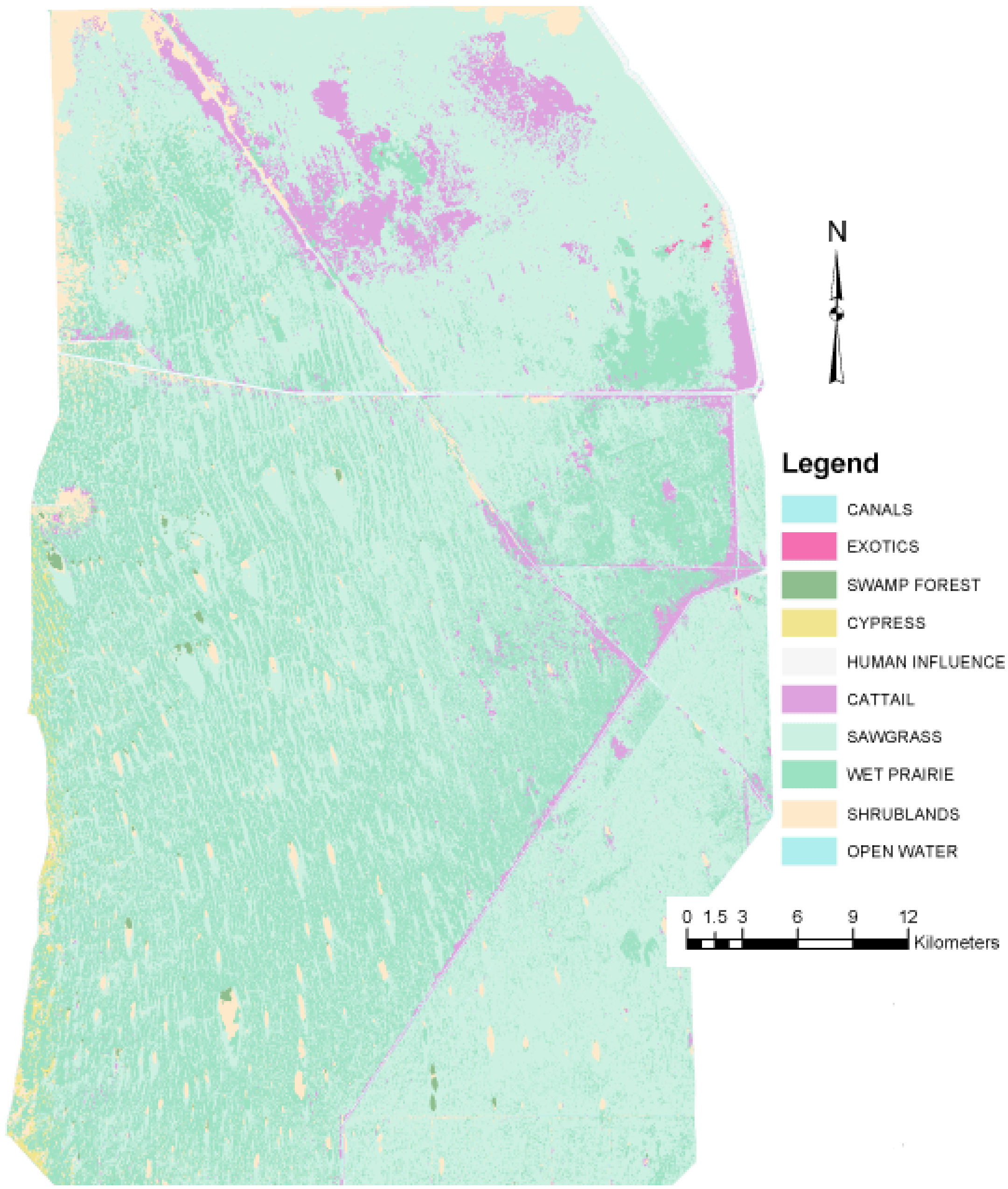


Figure 6-14. In order to help document the potential benefits of the DECOMP project, a vegetation map was needed to establish baseline conditions for WCA-3. Notably, until this mapping project was initiated in 1994, there had never been a comprehensive, detailed vegetation map produced for WCA-3.

WCA-3 is a 234,944-hectare impoundment located in the central portion of the remnant Everglades. In the late nineteenth century, human efforts began to control the timing, quantity, flow, and distribution of water within the once vast and pristine marshland. Impounding and partitioning activities were completed in phases resulting in each sub-compartment developing its own unique hydrologic characteristics. In general, WCA-3N East and West and the WCA-3B sub-compartments have historically been altered the most, due to hydrologic reductions in flow and duration. WCA-3A South is considered to be one of the relatively least impacted areas within WCA-3. Nonetheless, due to the sloping topography from north to south and the barrier of Tamiami Trail, there has been substantial ponding of water in the southern end of this sub-compartment. The WCA-3 S-9 sub-compartment typically exhibits the longest inundation of standing water. This is due to backpumping water into the impoundment from the east through the S-9 pump station, in addition to the flow of water entering the area from the S-11 structures in the north.

More important than the effects of altered hydrology on plant community structure may be the changes in phosphorus concentration and load into this oligotrophic environment. Increases in soil and water column phosphorus levels that have resulted from point source inflows of nutrient runoff from drained agricultural lands to the north (Davis et al., 1994), and from water that is backpumped in from the east through the S-9 structure for flood attenuation in the C-11 basin nutrient enrichment, have been shown to alter the vegetation complex of the Everglades (Davis, 1994; Doren et al., 1997; Newman et al., 1996; Miao and DeBusk, 1999; Rutchey and Vilchek, 1999). Elevated soil phosphorus at interior sites away from inflow structures has also been found in some areas, hypothesized to be due to dry conditions and the resultant soil oxidation and compaction.

Polygon number and size distributions for the entire WCA-3 project area along with calculations for each of the five sub-compartments are found in **Table 6-4**. Results show that 155,455 polygons were digitized and labeled as part of this project. The majority of the polygons digitized (52,683, or 33.9 percent) ranged from 0.01–0.05 ha in size. Separate calculations for areas north (Phase I) and south (Phase II) of I-75 were also performed. There was a major difference in the number of polygons labeled during Phase I (12,589 polygons) and Phase II (142,938 polygons) of the project. Phase II is approximately 2.3 times larger than Phase I. Phase I had the greatest percent of polygons digitized in the 0.1 to 0.25 ha category, as was the case for each of its sub-compartments. Phase II also had the greatest percentage of polygons digitized in the 0.01 to 0.05 ha category, as was the case for each of its three sub-compartments.

Polygon species categorization for the entire project area, along with hectare calculations for each of the five sub-compartments of the WCA-3 project, is found in **Table 6-5**. The total area mapped was 234,944 ha. Results show that sawgrass and wet prairie communities accounted for the greatest area (205,563 ha) or 87.9 percent of polygons categorized for the entire project. This was also true for each of the sub-compartments, where these combined communities accounted for 76.15–94.71 percent of the polygons. However, the sub-compartments differed in the relative composition of these communities. Sub-compartments WCA-3B and WCA-3N East each had much more sawgrass than wet prairie, whereas WCA-3N West and WCA-3 S-9 had ratios similar to the entire area. WCA-3 South had an even mixture of sawgrass and wet prairie communities. 11,750 ha of cattail were mapped, and encompassed 5 percent of the area. Most of the cattail (6,856.37 ha) was found in the WCA-3N East sub-compartment with each of the other sub-compartments having 605 to 1,634 ha of cattail. These species configurations and polygon size distribution data are being analyzed extensively (Rutchey et al., in prep. b) for determining the minimum mapping unit that is needed in order to capture trends in spatial structure and composition through time.

Table 6-4. (a) Polygon number and size distributions for the entire WCA-3 project area along with (b) calculations of percentages for the five sub-compartments.

a

# of Polygons	WCA3	WCA3S	WCA3B	S9	WCA3NE	WCA3NW
Total	155455	102677	25180	15081	7552	5037
# > =10ha	1182	747	87	138	140	124
# <10 >= 1ha	10650	5918	1369	1479	915	982
# < 1ha >=.5ha	10438	5864	1580	1516	720	759
# < 0.5ha >=0.25ha	16027	9043	2741	2138	1042	1064
# < 0.25ha >=0.1ha	29789	17890	5526	3373	1660	1343
# < 0.1ha >=0.05ha	27157	17223	5185	2625	1472	655
# < 0.05ha >=.01ha	52683	39018	8294	3678	1586	110
# < 0.01ha >=.005ha	6732	6199	384	133	16	0
# < 0.005ha >=0.001ha	791	775	14	1	1	0

b

Percent	WCA3	WCA3S	WCA3B	S9	WCA3NE	WCA3NW
# > =10ha	0.76	0.73	0.35	0.92	1.85	2.46
# <10 >= 1ha	6.85	5.76	5.44	9.81	12.12	19.50
# < 1ha >=.5ha	6.71	5.71	6.27	10.05	9.53	15.07
# < 0.5ha >=0.25ha	10.31	8.81	10.89	14.18	13.80	21.12
# < 0.25ha >=0.1ha	19.16	17.42	21.95	22.37	21.98	26.66
# < 0.1ha >=0.05ha	17.47	16.77	20.59	17.41	19.49	13.00
# < 0.05ha >=.01ha	33.89	38.00	32.94	24.39	21.00	2.18
# < 0.01ha >=.005ha	4.33	6.04	1.53	0.88	0.21	0.00
# < 0.005ha >=0.001ha	0.51	0.75	0.06	0.01	0.01	0.00

Table 6-5. (a) Polygon species categorizations for the entire WCA-3 project area, along with (b) calculations of percentages for the five sub-compartments.

a

Percentages						
	WCA3S	**WCA3B**	**S9**	**WCA3NE**	**WCA3NW**	**WCA3**
Trees/shrub	3.45	1.45	0.76	2.72	9.73	3.39
Cypress	1.40	0.00	0.00	0.00	0.00	0.63
Sawgrass	47.79	82.38	49.77	73.12	59.79	60.05
Wet Prairie	43.68	12.33	33.11	3.03	24.53	27.44
Broadleaf	1.71	0.93	4.14	4.41	0.03	2.13
Cattail	1.43	1.52	9.33	14.52	4.86	5.00
Exotics	0.00	0.03	0.02	0.17	0.04	0.04
Other	0.53	1.37	2.88	2.03	1.02	1.30

b

Hectares						
	WCA3S	**WCA3B**	**S9**	**WCA3NE**	**WCA3NW**	**WCA3**
Trees/shrubs	3671.22	575.85	132.46	1284.06	2309.60	7973.20
Cypress	1486.23	0.11	0.00	0.00	0.00	1486.35
Sawgrass	50896.91	32767.97	8713.80	34525.83	14188.79	141093.30
Wet Prairie	46519.26	4903.02	5795.80	1431.63	5820.10	64469.80
Broadleaf	1824.23	369.53	723.95	2084.27	7.52	5009.36
Cattail	1527.20	605.18	1633.73	6856.37	1153.86	11750.56
Exotics	0.91	10.33	2.72	79.94	9.22	103.11
Other	564.59	543.20	504.18	957.31	241.87	3058.53

RECOVER VEGETATION MAPPING UPDATE

CERP, authorized as part of the Water Resources Development Act (U.S. Congress, 2000), is an extensive hydrologic restoration project for the entire South Florida region. CERP includes 68 separate projects that will be managed over the next 30 years by the SFWMD, USACE, and other partnering agencies (see Chapter 2 of the *South Florida Environmental Report – Volume II*). RECOVER is an interagency, interdisciplinary team sponsored by the SFWMD and the USACE, which is designed to organize and provide the highest quality scientific and technical support during CERP implementation (RECOVER, in prep.; also, see Chapter 7 of the *2005 South Florida Environmental Report – Volume I*). To accomplish this task, RECOVER has developed a systemwide Monitoring and Assessment Plan (MAP) (RECOVER, 2004), which is designed to document how well CERP is performing in meeting its objectives for ecosystem restoration. One component of MAP will involve vegetation mapping, which will be utilized as a monitoring tool to document any changes in the spatial extent, pattern, and proportion of plant communities within the landscape.

The objective of the vegetation mapping project is to produce a spatially and thematically accurate vegetation map of the MAP boundary areas (**Figure 6-15**). Vegetation communities will be mapped from 1:24,000 scale CIR aerial photography. Spatial heterogeneity analysis of the Everglades landscape suggest that a minimum mapping unit on the order of 0.25 ha (50 m x 50 m) would appropriately capture the spatial heterogeneity of vegetated communities (Rutchey et al., in prep. b). Each distinct vegetation community will be designated according to the Vegetation Classification System for South Florida National Parks (Jones et al., 1999). The MAP boundary areas encompass approximately 4,218 square miles. Current staffing levels at the SFWMD will allow for approximately 1,571 square miles of this vegetation mapping effort to be completed in-house over a period of five years, while the remaining 2,647 square miles will need to be outsourced over this same time period.

CIR aerial photography was flown during December 2003 and January 2004 for the purpose of vegetation monitoring. The flights were flown at an altitude of 12,000 ft above the mean terrain height, producing a photo scale of 1:24,000, or 1 in. = 2,000 ft.

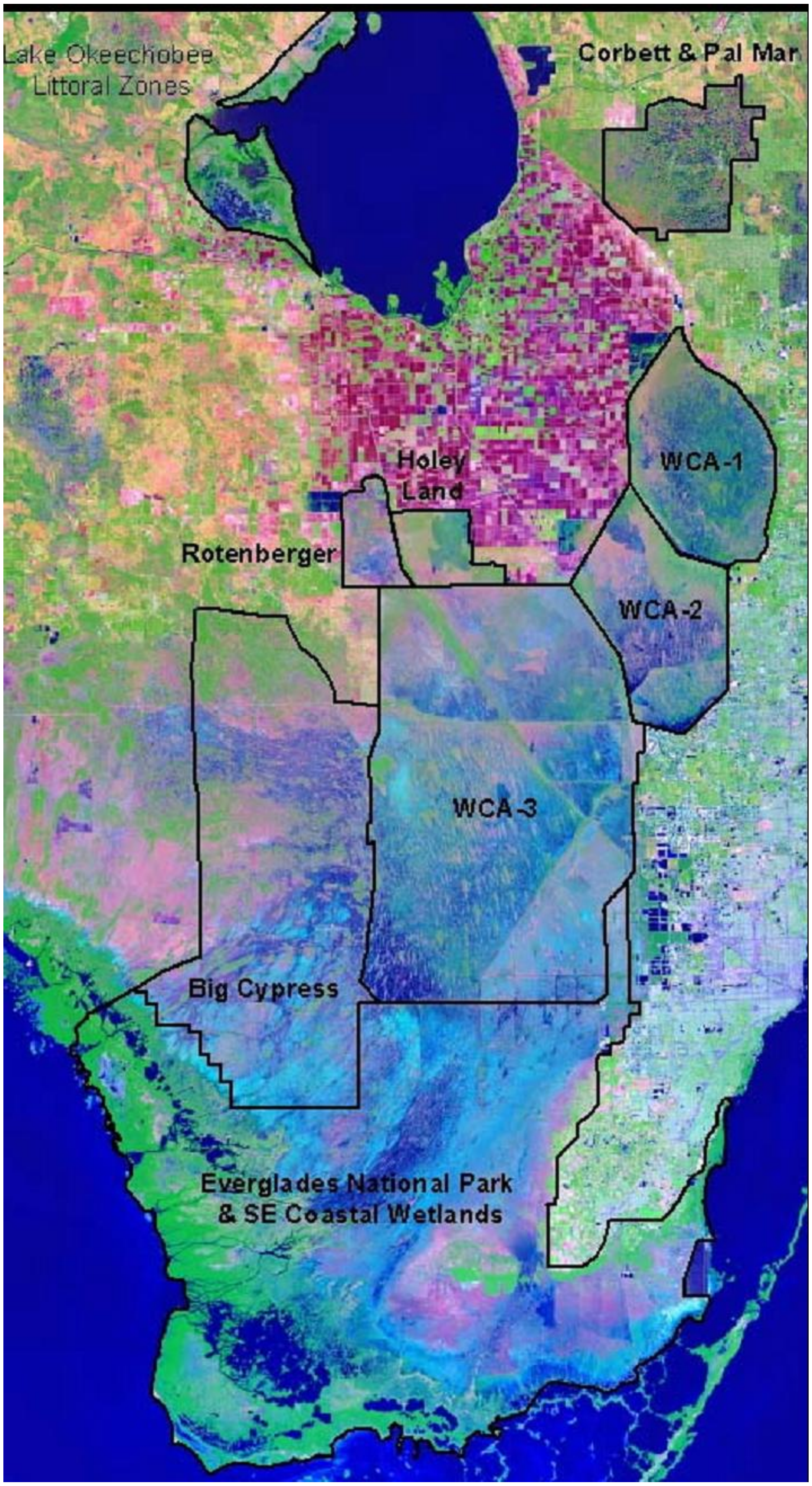


Figure 6-15. To produce a spatially and thematically accurate vegetation map of the CERP RECOVER boundary areas, vegetation communities will be mapped from 1:24,000 scale color infrared aerial photography, and each distinct vegetation community will be designated according to the Vegetation Classification System for South Florida National Parks (Jones et al., 1999).

LONG-TERM PLAN UPDATE: RECOVERY OF IMPACTED AREAS WITHIN THE EVERGLADES PROTECTION AREA

The 1994 Everglades Forever Act (EFA) directs the implementation of the overall strategy for water quality improvement and hydropattern restoration, as outlined in the Everglades Protection Project, Conceptual Design (Burns & McDonnell, 1994). In addition to the various STAs constructed under the Everglades Construction Project, this conceptual design includes work specifically intended to restore a sheet flow approximation to various areas along the northerly boundary of the EPA. The hydropattern restoration features contemplated in the EFA will distribute water along a broad boundary of the water conservation areas, restoring a more natural hydroperiod throughout the northern Everglades. However, the hydropattern restoration works will redistribute flow to areas in the EPA not previously impacted by high phosphorus discharges and, therefore, it is desirable to understand the potential effects of this discharge on downstream areas. Additionally, areas of the EPA currently impacted will be undergoing natural recovery, and will require an extended period of time. Therefore, the District has funded research for investigating methods to accelerate recovery through the Long-Term Plan (Burns & McDonnell, 2003; also, see Chapter 8 of the *2005 South Florida Environmental Report – Volume I*). Updates for the six relevant components of the Long-Term Plan are presented below.

Recovery Model Development and Calibration [BC87(1)]

The objective of this project is to develop and calibrate a simulation model to predict the response of impacted areas in the EPA to improved water quality. The model is to have the function to evaluate the spatial extent and temporal distribution of recovery. The District has updated the process-based ecological model Everglades Landscape Model (ELM) (version 2.2) with best current available data. Preliminary calibration and validation with extended period of records (from 1981 through 2000) have been done. Simulation results have shown significant improvements over the previous version. Final model calibration and sensitivity analysis for ELM (version 3.0) is expected to be completed before October 2005. A contract has been executed to develop a prototype database system partially integrated into model code, and populated with example subset of process rates, parameters, and observed time series data. It is anticipated that the first component of this database development will be completed in September 2005. Further data synthesis and algorithm enhancement for the model on soil-surface interactions and vegetation succession have begun, and they are scheduled to be completed in 2005.

Downstream Influences of Adding Clean Water to Previously Impacted Areas [BC87(2)]

The major objectives of this project are to determine the ecological response of impacted areas following the addition of treated water and to conduct in-situ experiments that will assist in the full development and calibration of the recovery model in BC87(1). Currently the downstream monitoring and research work has focused on marsh conditions during two time periods: (1) prior to receiving treated water, and (2) after receiving treated water. The primary samples collected are water column, soil, plant, and periphyton nutrients, as well as plant biomass, vegetation composition analysis, and periphyton taxonomy. Based on this data, a phosphorus gradient exists with respect to water, soil, and plant tissue nutrients when sites are grouped by distance from water inflow.

Beginning in October 2004, several in-situ experiments will be started to quantify potential phosphorus flux and sediment transport to interior marsh sites. The phosphorus flux experiment will determine if the soils in the impacted areas are acting as a source of phosphorus or as a sink, and will define its adsorptive capacity with respect to phosphorus. Additionally, the downstream areas are experiencing higher than expected flow velocities, which is transporting sediment further into the interior of the marsh. Ongoing vegetation and soil nutrient sampling will assist in capturing the effects of sediment transport, particularly in the transition areas located between impacted and non-impacted sites. Each study will aid in model calibration by providing information on vegetation community response to STA effluent and movement of the phosphorus front through species composition analysis, tissue nutrient analysis, changes in biomass, and soil nutrient analysis.

Options for Accelerating RECOVER [BC87(3)]

The major objective of this project is to conduct and analyze research of various management scenarios for accelerating recovery of impacted areas within the EPA. Current efforts have targeted identification of environmental parameters necessary for reestablishing and supporting vegetation and animal communities that comprise those areas of the EPA where historically human influence has been minimal. These coefficient values, when integrated into the ELM, will provide a method for evaluating long-term ecological response to varying management scenarios. The District will develop a draft matrix to explore possible strategies and effective approaches to accelerate the natural recovery processes of such areas via human manipulations.

Intensive analysis of other restoration efforts has identified a variety of potential management scenarios. These efforts fall into two categories, passive and active management. Passive management is often referred to as “natural recovery” or “self-organization.” Passive management, or natural recovery, creates questions as to whether current management of hydrology and nutrients in the STAs, can restore the soils, flora, and fauna. Passive management may be the most cost-effective method for restoring the Everglades, but may occur more slowly. Active management includes chemical, mechanical, and biological techniques applied at the appropriate stage of ecosystem recovery. The matrix mentioned above will be used to implement environmentally and economically sound strategies and effective management approaches to accelerate the recovery process has been developed. An interagency workshop is planned to solidify expectations for specific recovery targets, evaluate the proposed strategies, and identify assessment metrics. The consensus reached at the workshop will finalize the matrix and implementation plan to drive research experiments evaluating the efficacy of each management scenario.

Alternatives Analysis and Plan Formulation [BC87(4)]

Following the development of the planning and analytical tools covered in Recovery Model Development and Calibration, Downstream Influence of Adding Clean Water to Previously Impacted Areas, and Options for Accelerating Recovery, a full alternatives analysis and plan formulation will be conducted preparatory to design. The Long-Term Plan recommendation is for this analysis and plan formulation activity to occur in Fiscal Year 2008 (FY2008). No FY2004 activities were scheduled for this project.

Hydropattern Restoration Work [BC87(5)]

The Long-Term Plan includes a recommendation for construction of the Hydropattern Restoration Work components to begin in FY2011, to follow detailed engineering, and to design in FY2009 and FY2010. No FY2004 activities were scheduled for this project.

Implement Steps to Accelerate Recovery of Impacted Areas [BC87(6)]

The Long-Term Plan includes a recommendation for implementation of the most promising techniques to accelerate recovery of impacted areas beginning in FY2010, and continuing through FY2014. No FY2004 activities were scheduled for this project.

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