# Chapter 5: Development of a Numeric Phosphorus Criterion for the Everglades Protection Area

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## SUMMARY

This chapter provides an update on data collection and analyses that will support the derivation of a numeric phosphorus (P) criterion for the Everglades. Due to logistics related to the massive research undertaking necessary to support P-criterion development, data collection and subsequent analyses have occurred in steps beginning in Water Conservation Area (WCA) 2A, and proceeding to WCA-1, WCA-3 and Everglades National Park (the Park or ENP). To date, data from WCA-2A and WCA-1 have been collected and evaluated. The analysis of data collected in WCA-2A was presented in detail in the *1999 Interim Report* and the *2000 Everglades Consolidated Report*, with the evaluation of WCA-1 data reported in the *2001 Everglades Consolidated Report*. A summary of the previous findings for WCA-2A and WCA-1, as well as a discussion of the Department's evaluation of WCA-3 and the Park data relevant to P-criterion development, is provided in this chapter.

The Department has conducted extensive evaluations of chemical and biological data from multiple trophic levels in WCA-2A and the Loxahatchee National Wildlife Refuge (Refuge) to define a set of reference stations that have been minimally impacted by P enrichment. The reference sites in WCA-2A and the Refuge exhibit median annual geometric mean TP concentrations of 8.4 and 9.2 µg/L, respectively, with annual geometric means ranging from 5.9 to 10.5 µg/L. The slight variation between areas is thought to reflect differences in the period of record and sampling methodology between the two areas. Based on the evaluations performed by the Department, the normal structure and function of the natural biological communities in both WCA-2A and the Refuge are adversely altered by similar levels of P enrichment. Results of the WCA-1 and WCA-2A data evaluations indicate that the EFA default criterion of 10 µg/L would be protective of the natural flora and fauna in the Refuge without being overly protective or below the natural background levels. Additionally, results of similar evaluations of limited data available for WCA-3A and ENP, as reported in this chapter, indicate that these areas contain biological communities comparable to those in WCA-2A and WCA-1, being comprised of many of the same dominant taxa. The results also suggest that the biological communities in all areas of the EPA exhibit similar responses to P enrichment. Therefore, a numeric P criterion of 10 µg/L (as determined from WCA-2A and WCA-1 data) to be measured as a long-term (e.g., annual) geometric mean would be protective of the natural flora and fauna throughout the EPA without being overly protective.

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# BACKGROUND

The Everglades Forever Act (EFA, Section 373.4592, Florida Statutes) requires the Florida Department of Environmental Protection (Department) and the South Florida Water Management District (District) to implement the Everglades Program, a comprehensive plan to begin restoration of significant portions of the remnant Everglades. The EFA also specifically finds that waters flowing into a part of the remnant Everglades, known as the Everglades Protection Area, contain excessive levels of phosphorus (P) and that a reduction in levels of P will benefit the ecology of the Everglades Protection Area. As a part of the Everglades Program, the EFA requires the Department and District to complete research necessary to establish a numeric P criterion by December 31, 2001, by which date the Department is also required to file a notice of rulemaking to establish such a criterion. If the Department does not adopt the P-criterion rule by December 31, 2003, the EFA establishes a default criterion of 10 µg/L (parts per billion, or ppb). The EFA requires that the Department's P criterion not be lower than the natural conditions of the Everglades Protection Area and must take into account spatial and temporal variability. The EFA further requires that compliance with the P criterion be based on a long-term geometric mean of concentration levels to be measured at sampling stations representative of receiving waters in the Everglades Protection Area.

To begin this process, a research plan was developed specifically to determine the level of P necessary to prevent an imbalance in Everglades flora and fauna. This plan, the Everglades Nutrient Threshold Research Plan (Lean et al., 1992), was intended to provide appropriate data in support of a numerical interpretation for the existing State of Florida narrative nutrient criterion for P (Rule 62-302.530(48)(b), Florida Administrative Code), which states that "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." This plan was created under the direction of the Department by a panel of eminent scientists appointed by the Everglades Technical Oversight Committee. The Department has been receiving and analyzing data from research groups performing research relative to this plan since 1995.

This chapter provides an update on data collection and analyses performed to date in support of the derivation of a numeric P criterion in the Everglades and fulfills the requirement that the ecological needs of the Everglades be evaluated. General information on the effects of P enrichment on the Everglades and detailed biological and chemical data analyses specific to Water Conservation Area 2A (WCA-2A) and the Arthur R. Marshall Loxahatchee National Wildlife Refuge (WCA-1) were reported in the 1999 Interim Report and the 2000 and 2001 Everglades Consolidated Reports. This report focuses on major developments since the previous reports, including the following topics: (1) summary of previous findings and status of P-criterion development in WCA-2 and WCA-1; (2) discussion of the Department's Evaluation of data from WCA-3 and Everglades National Park (ENP or Park) relevant to P-criterion development; and (3) a review of other information submitted for consideration.

# RESEARCH EFFORTS

To begin the process of establishing a numeric P criterion for the Everglades Protection Area, an Everglades Nutrient Threshold Research Plan was developed (Lean et al., 1992). The research plan involved a three-pronged approach consisting of: (1) field transect monitoring along nutrient gradients; (2) field perturbations (dosing experiments); and (3) laboratory experiments. Due to logistics related to this massive research undertaking, data collection occurred in steps beginning in WCA-2A and proceeding to WCA-1, WCA-3 and Everglades National Park. Criterion development efforts are also being conducted in this order based on the resulting data availability issues. Results of the extensive data evaluation and analyses conducted for WCA-2A and WCA-1 have been discussed in previous reports (McCormick, et al., 1999 and 2000; Payne, et al., 1999, 2000 and 2001). Threshold monitoring in WCA-3A and ENP was initiated in October 1999. Consequently, due to the relatively recent initiation of P-criterion research in WCA-3 and Everglades National Park, there is a limited amount of data available for these areas.

Data collection efforts in the Everglades are being conducted by several independent research groups. However, the majority of research being reviewed for criterion development has been conducted by the District. Their efforts encompass all four areas under review and all three types of research laid out in the Everglades Nutrient Threshold Research Plan. The District maintains two ongoing monitoring programs, including Watershed Research and Planning (WRP) and Environmental Monitoring and Assessment (EMA). EMA began in 1974 and continues for the purposes of determining compliance with state water quality standards and tracking water quality trends. WRP efforts involve a succession of studies, including field experiments and monitoring programs beginning in 1993 and continuing to the present and conducted to support regulatory efforts to define a numeric water quality criterion for P in the Everglades. This includes water, sediment and biological monitoring along P gradients, P-dosing studies using mesocosms and supplemental field and laboratory studies also being conducted.

Another monitoring effort being conducted over the entirety of the Everglades is the EPA's Regional Environmental Monitoring and Assessment Program (REMAP). This monitoring program is designed to monitor and assess the status and trends of national ecological resources. Data collected annually from 1993 to 1996, which included water quality, sediment chemistry, and habitat and fish surveys, are currently available. Sampling ceased during 1997 and 1998 and resumed during 1999. Because the REMAP sampling methodology was designed to monitor regional water and sediment quality changes using randomly selected monitoring sites, much of the data collected are not suitable for evaluation of site-specific changes occurring across a P gradient, as needed for P-criterion development. Only sediment TP concentration data collected during 1995 and 1996 have been reviewed and incorporated.

Florida International University (FIU) has also begun data collection in the Everglades, including gradient and dosing studies. Ongoing gradient research involves revisiting transects originally sampled by Doren et al. in 1988 and 1989 (Doren et al., 1996). These transects were initially sampled to determine spatial patterns of water quality impacts related to canal structures and inflows. However, FIU has expanded its data collection to include not only soil TP and vegetation frequency data, but also structural and functional measures as well. Dry- and wet-season data were collected for 1999. FIU dosing research, located within the Refuge and Everglades National Park, consists of four four-channel flumes, which were designed to maintain experimental concentrations of P. Pre-dosing data were collected and analyzed prior to initiation of dosing. Post-dosing data collection is ongoing, with some very preliminary data being reported in its annual project reports to the District (FIU, 1999 and 2000).

Investigators from the Duke University Wetland Center (DUWC) have also conducted extensive research in WCA-2A, consisting of both gradient and experimental dosing studies. The Department's evaluation of the data and analysis from the DUWC studies is discussed in detail in Chapter 3 of the 2001 Everglades Consolidated Report (Payne et al., 2001).

# PREVIOUS FINDINGS FROM WCA-2A AND WCA-1

The Department is in the process of evaluating and analyzing the available data from the Everglades to support the development of a numeric P criterion, as directed by the EFA. Due to logistics related to the massive research undertaking necessary to support P-criterion development, data collection and subsequent analyses are being performed in a stepwise manner beginning in WCA-2A and proceeding to WCA-1, WCA-3 and the Park. The Department's extensive evaluation and analysis of the biological and chemical data collected in WCA-2 and WCA-1 were presented in previous reports (McCormick et al., 1999 and 2000; Payne et al., 2001), with a more thorough discussion provided in the drafts of the Department's P-criterion development support documents (Payne et al., 1999 and 2000). Since that time, much of the monitoring and research conducted by the District in WCA-2 and WCA-1 has been stopped or modified to monitor the long-term recovery of the system. Additionally, the Department has not performed additional analyses on the data collected by the District in WCA-2 and WCA-1 beyond those presented in previous reports. Researchers from the DUWC have also prepared a report, titled, "The Ecological Basis for a Phosphorus Threshold in the Everglades: Directions for Sustaining Ecosystem Structure and Function" (Richardson et al., 2000), based on their studies in WCA-2A. A brief summary of the Department's previous findings for WCA-2A and WCA-1 is provided in the following discussions.

## WATER CONSERVATION AREA 2A

Phosphorus-enriched water originating in the Everglades Agricultural Area (EAA) enters WCA-2A through the S-10 structures along the northern levee, with lesser amounts entering through the S-7 structure, located on the southwest boundary. Both water and sediment P data show that extensive P gradients have formed in WCA-2A, as the result of settling, sorptive processes and other biogeochemical mechanisms. The primary gradient extends from its source at the S-10 canal inflow structures in a southerly direction toward the marsh interior for a distance of at least eight km. Average TP concentrations, along the primary gradient in WCA-2A, range from less than 10 µg/L at sites located in the interior portions of the marsh to more than 50 µg/L at sites nearer the S-10 inflows. In areas where P enrichment has occurred, a large percentage of the P has accumulated in the sediment through greater production and subsequent higher peat accretion rates, direct adsorption of P into the sediment, and precipitation. Sediment TP levels reflect a similar gradient, with concentrations in the interior marsh generally being less than 400 mg/kg, while sediment TP concentrations of more than 1,800 mg/kg can be found at sites closer to the canal inflows.

The flora and fauna occupying the reference (minimally impacted) areas of WCA-2A are adapted to the natural oligotrophic conditions and respond to P enrichment at varying rates. For example, research conducted in WCA-2A has shown that the microbial and periphyton communities respond to P enrichment within days or weeks, whereas rooted macrophytes and macroinvertebrates may take several years to show a response. Because of the varying sensitivity to P inputs, several trophic levels, including bacteria, algae, vascular plants and benthic macroinvertebrates, were examined to establish how each biological community responds to P enrichment along the P gradient in WCA-2A.

During the evaluation of the research data collected in WCA-2A, extensive changes in the biological communities resulting from P enrichment were documented. Even though different biological communities may exhibit varying sensitivity to P enrichment, the evaluation of the biological and chemical data collected within WCA-2A indicate that many P-induced changes occur at the same location along the gradient and, therefore, under similar levels of P enrichment. Most of the analyses indicate that the biological communities are altered significantly at distances as far as six to eight km from the S-10 inflows (i.e., between Stations E4 and F4 and the E5 and F5 sites).

Since many individual changes observed can be interpreted as constituting an imbalance in the natural flora and fauna, the fact that many of the changes observed in the various trophic levels occur at the same location along the transect makes the definition of the imbalance point more robust and less controversial. Based on the results of this evaluation, Stations E5, F5 and U1 to U3 (located eight km or more from the S-10 structures) are considered to have similar biological and water quality characteristics and can therefore be combined into a single reference group used to characterize the range of P conditions found in the minimally impacted areas of WCA-2A (Payne et al., 1999 and 2001). The TP regime from the five reference sites in WCA-2A is characterized by annual geometric means ranging from approximately 5.9 to 9.0 µg/L, with a median value of 8.4 µg/L during the 1994 to 1999 period of record.

### Duke University Wetland Center Report

Researchers from the DUWC have prepared a report, titled "The Ecological Basis for a Phosphorus Threshold in the Everglades: Directions for Sustaining Ecosystem Structure and Function" (Richardson et al., 2000), based on the results of their research in WCA-2A. The DUWC report presents data analyses that support a P threshold in the range of 17 to 22 µg/L. However, based on a review of the DUWC work, the Department determined that the 17 to 22 µg/L threshold range is likely biased high, due to the experimental design used, as well as inconsistencies of the data analyses with the requirements of the EFA. A more thorough discussion of the DUWC data and analyses relative to the development of P criterion is provided by Payne et al., 1999 and 2001.

## A. R. MARSHALL LOXAHATCHEE NATIONAL WILDLIFE REFUGE (WCA-1 OR REFUGE)

WCA-1 is exposed to the same EAA drainage waters that have caused extensive P enrichment in WCA-2A. Runoff enters WCA-1 through the S-5A and S-6 structures and overflow of the L-7 Rim Canal along the northern and western levees. Water and sediment data indicate that P gradients have formed to the west of the L-7 Rim Canal. Total phosphorus (TP) concentrations in the water range from more than 30 µg/L near the L-7 Canal to less than 10 µg/L in the interior marsh. Likewise, sediment TP concentrations decrease from more than 1,500 mg/kg near the canal to less than 400 mg/kg in the interior of the marsh. The rainfall-driven hydrology of the Refuge results in a much steeper P gradient than that observed in WCA-2A, with water and sediment TP concentrations generally decreasing to background levels within 2.2 km of the L-7 Canal.

Additionally, the rainfall-dominated hydrology of the interior marsh results in a unique acidic soft-water system that contrasts with the alkaline hard-water systems in WCA-2A and other portions of the EPA. The gradual dilution of the canal inflows, comprised of high nutrient/high mineral content agricultural runoff, by the rainfall- derived interior marsh water containing low nutrient and mineral levels, results in water quality gradients for a variety of parameters in addition to P (Richardson et al., 1990). Although numerous water quality gradients exist in the same region as the P gradient, they tend to follow slightly different trends. Phosphorus concentrations decline rapidly within the first kilometer of inflows due to biological uptake and chemical sorption processes in the marsh, while concentrations of other, more conservative parameters such as alkalinity and conductivity decline at more constant rates, largely the result of dilution.

The flora and fauna occupying the minimally impacted areas of WCA-1 are adapted to the natural oligotrophic soft-water conditions and respond to P enrichment at varying rates. For example, the microbial and periphyton communities respond to P enrichment quickly, whereas rooted macrophytes and macroinvertebrates may take much longer to show a response. Because of the varying sensitivity to P inputs, the evaluation was not limited to a single trophic level. Various measures of the periphyton and macrophyte communities, as well as the dissolved oxygen regime, were examined to establish how each biological community responds to P enrichment along the P gradient in WCA-1. Even though the biological communities can exhibit varying sensitivity to P enrichment, data collected along the P gradient in WCA-1, which have been exposed to elevated P concentrations for approximately three decades, indicate that many important changes in natural flora and fauna occur at similar locations along the gradient.

Periphyton is a community of algae, bacteria and other microorganisms that live attached to the surface of aquatic plants or other submerged substrates. Periphyton play many important roles in the Everglades, including production of oxygen, formation of marl soil, P cycling, providing physical habitat for macroinvertebrates and small fish and as a base for the food web in the Everglades Protection Area (Wood and Maynard, 1974; Browder et al., 1994; Rader, 1994; and Scinto, 1997). The characteristic periphyton assemblage in the soft-water portions of WCA-1 is comprised primarily of numerous species of desmids and filamentous green algae that form a thin, hairy, green-to-brown coating on plant stems.

Analysis of the taxonomic data indicates that significant changes in the composition of the periphyton assemblage occur along the gradient in WCA-1. These changes appear to occur in response to changes in the concentration of both P and other major ions such as calcium, sodium, chloride and sulfate, as well as alkalinity and pH levels that exist concurrently with the P gradient. Statistical cluster and change-point analyses indicate that District monitoring stations along the gradient in WCA-1 can be differentiated into three primary groups, with respect to the composition of the periphyton community present. One group consists of the minimally impacted sites located furthest from the canal (i.e., X4, Y4 and Z4) at which the natural periphyton community composition and structure remain relatively unchanged by increases in levels of P or other major ions (low P/low mineral sites). The second group of sites (i.e., X3 and Z3) with significant shifts in the natural periphyton population has occurred in response to increased levels of major ions (low P/high mineral sites). These changes are defined by a replacement of soft-water desmid taxa with numerous species of diatoms. The third group of sites, located nearest the canal (i.e., X1, X2, Z1 and Z2), reflects further changes in the periphyton community caused by P enrichment (high-P/high-mineral sites). The periphyton population at these sites is characterized by the replacement of sensitive diatoms with filamentous blue-green algae that are tolerant of eutrophic conditions.

The macrophyte community of the Refuge is characterized by a complex mosaic of tree islands, wet prairies, sawgrass marshes and aquatic sloughs. Historically, high species diversity and spatial complexity have been distinguishing characteristics of this region. However, recent studies indicate increased nutrient loads entering WCA-1 have caused alterations in macrophyte species frequency and spatial patterns, especially near canal inflows. The P-induced changes observed in the macrophyte community in WCA-1 include declines in the aerial coverage of sawgrass stands, sloughs and wet prairies, increased growth and abundance of water lily and, ultimately, the replacement of native species by monotypic stands of cattail and other invasive species. Because macrophytes are generally less sensitive to the changes in the mineral content of the water than are periphyton, statistical analysis of the macrophytes data collected along the gradient indicate a single shift in the population occurring between Stations Z3 and X3 and Station X2 in response to P enrichment. These findings suggest that the macrophyte communities present at Stations Z3, X3, Z4, Y4 and X4, which are located 2.2 km or more from the canal, have been minimally impacted by P enrichment.

The dissolved oxygen regime is a sensitive, indirect indicator of P enrichment because it is largely controlled by the periphyton and submerged aquatic vegetation communities present. Though dissolved oxygen is not directly influenced by P enrichment, changes in the dissolved oxygen regime reflect changes in the communities responsible for oxygen production and respiration rates. In turn, the dissolved oxygen regime strongly influences other biological communities, from microbes and macroinvertebrates to fish and aquatic animals. Statistical analyses conducted on the daily mean, minimum, first-quartile and third-quartile dissolved oxygen levels measured at the District transect sites in WCA-1 generally show impacted and minimally impacted groupings similar to those determined using other biological measures. The first group was comprised of impacted sites, including X1, Z1, X2, Z2 and X3, while the second group represented minimally impacted conditions and included X3, Z3, X4, Z4 and Y4. The overlap of X3 between both groupings suggests it is an intermediate site with dissolved oxygen characteristics between the impaired and minimally impacted areas of WCA-1 and may reflect changes in the periphyton community in response to the mineral content of the water. These results corroborate other evidence indicating that P-induced changes are occurring between Stations X3 and Z3 (2.2 km from canal) and Stations X2 and Z2 (1.3 and 1.1 km from the canal, respectively). During the 1996 through 1999 period of record, the group of five WCA-1 reference sites exhibited annual geometric mean TP concentrations ranging from 7.8 to 10.5 µg/L, with a median geometric mean concentration of 9.2 µg/L

## CONCLUSIONS FROM THE EVALUATION OF WCA-2A AND WCA-1 DATA

The evaluation of data collected along the gradients in WCA-2A and WCA-1 has used P-induced changes in the structure and function of the various biological communities to differentiate minimally impacted stations from those showing significant departures from the natural, unaltered ecosystem. Based on the results of this evaluation, WCA-2A Stations E5, F5, U1, U2 and U3 and WCA-1 Stations X3, Z3, X4, Y4 and Z4 were designated as minimally impacted reference sites. Sites located closer to the canal were classified as impacted by P enrichment, based on observed changes in the biological communities.

To proceed with the development of a P criterion, the P regime that exists within the set of reference sites must be defined. Based on EFA requirements, the annual geometric mean TP concentrations are used to characterize the P regime in the minimally impacted areas of WCA-1 and WCA-2A. Generally, the annual geometric mean TP concentrations were similar among the WCA-1 and WCA-2A reference sites. In WCA-1, the combined set of reference sites exhibit annual geometric means from 7.8 to 10.5 µg/L, with a median of 9.2 µg/L, compared to a range of 5.9 to 9.0 µg/L and a median of 8.4 µg/L determined for WCA-2A reference sites. The slight variation between areas is thought to reflect differences in the period of record and sampling methodology between the two areas. **Figure 5-1** provides a pictorial summary of the results of the P-criterion development efforts in WCA-2A and WCA-1. Details concerning the DUWC CART analyses are provided in Richardson et al., 2000, with a discussion of the Department's evaluation of the DUWC work provided in Payne et al., 1999 and 2001.

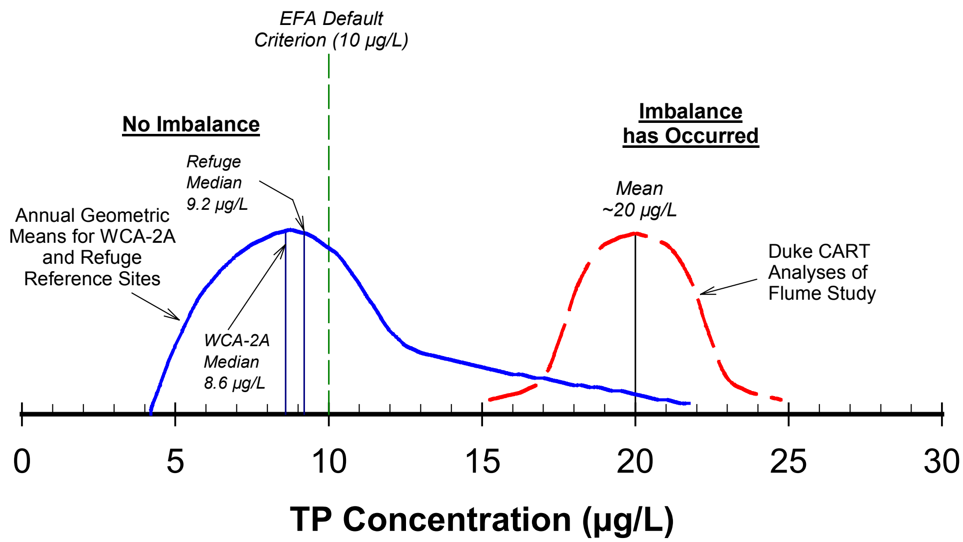


**Figure 5-1.** Pictorial depiction of the results of the P criterion development efforts in WCA-2A and WCA-1. The solid blue line represents the distribution of annual geometric means at the reference sites along the District transects. The dotted red line is a theoretical normal distribution of change points from the Duke CART analyses with an average of 20 µg/L.

Therefore, based on evaluations performed by the Department, the normal structure and function of the natural biological communities in both WCA-2A and the Refuge are adversely altered by similar levels of P enrichment. Results of the WCA-1 and WCA-2A data evaluations indicate that the EFA default criterion of 10 µg/L would be protective of the natural flora and fauna without being overly protective or below the natural background levels. Additionally, attempts to identify the spatial and temporal variation associated with the measured P regimes indicate that the EFA default criterion of 10 µg/L, measured as an annual geometric mean, may not be statistically differentiable from alternative numbers in that range identified through further research.

# UPDATED FINDINGS FOR WATER CONSERVATION AREA 3 AND EVERGLADES NATIONAL PARK

Data analysis in Water Conservation Area 3 (WCA-3) and the Everglades National Park (Park or ENP) (**Figure 1-1**) generally followed the same protocols established for WCA-2A and WCA-1 when data availability permitted. Multiple trophic levels were examined to document the observed responses to P enrichment for various biological communities. Data collected by the District along the P-gradient transects were the primary focus of this analysis and were used to evaluate biological changes occurring along the P gradients. However, the relatively recent initiation of the studies in WCA-3 and the Park, along with the severe drought conditions experienced during much of the study period, have greatly limited the amount of data collected in these areas. This lack of data for WCA-3 and Park prevents the same exhaustive evaluation as was conducted for WCA-2A and WCA-1. Even though an exhaustive evaluation was not possible, many of the same parameters examined in WCA-2 and WCA-1 were analyzed to determine if they exhibited similar responses to P enrichment in WCA-3 and the Park. Additionally, when possible the biological communities found in WCA-3 and the Park were compared to those found in WCA-2 and WCA-1 to determine if they were similar and likely to display similar sensitivity to P enrichment. The results of the analysis of the available data from WCA-3 and the Park are provided below, with a more complete discussion of the results found in Part III of the Department's draft P criterion development support document (Payne et al., 2001).

## EVIDENCE OF PHOSPHORUS ENRICHMENT

### Water Conservation Area 3A

Water Conservation Area 3 is the largest of the WCAs, consisting of approximately 915 square miles (i.e., 585,600 acres) of sawgrass marsh, with scattered tree islands, wet prairies and aquatic sloughs. Historically, WCA-3 was hydrologically interconnected with WCA-1, WCA-2 and the Everglades National Park, which together formed the vast overland flow Everglades system that extended from Lake Okeechobee to Florida Bay. Rain was the primary hydrologic source during most of the year; however, during wetter periods overflow from Lake Okeechobee resulted in occasional pulses, which followed a north-to-south or northwest-to-southeast natural flow pattern (refer to Chapter 6 of this Report).

Approximately half of WCA-3's water budget originates from rainfall, with general water quality characteristics of the interior areas being intermediate to the soft (slightly acidic, low-mineral), low-nutrient water of the interior of WCA-1, and the alkaline hard water found in WCA-2A. Mineral-rich canal water enters WCA-3 at several points around its northern perimeter, giving rise to gradients in concentrations of P and other minerals downstream of the inflows. The combination of the canal inflows and typical rainfall conditions has produced the landscape in this area.

The primary sources of P-enriched surface water to WCA-3 include: the S-11A, S-11B and S-11C structures, which discharge marsh water from WCA-2A and agricultural runoff from the North New River Canal; the S-8 pump, which drains the S-3 and S-8 basins of the EAA; and the S-9 pump, which drains urban areas located in the C-11 Basin (SFWMD 1992; **Figure 5-2**). Additional water is discharged into the conservation area through the L-28 Interceptor Canal, L-3 Canal, S-140 Pump Station, S-150 Pump Station, L-28 Gap and the North New River Canal by way of G-123 and S-142. Discharge P concentrations at these structures have been elevated above background marsh concentrations, since the District began monitoring in the mid- and late 1970s. Phosphorus inflows to WCA-3 during the period from 1995 through the present and the entire historical period of record are summarized in **Table 5-1**.

In support of P-criterion development, the District established fixed sampling stations downstream of the L-28 Interceptor Canal inflow (**Figure 5-3**). Twelve stations were located at distances from 0.6 to 15.5 km south of the L-28 Interceptor Canal along a P-enrichment gradient (**Table 5-2**). Additionally, two stations were located in the canal to monitor inflow water quality. Long-term TP monitoring at the S-190 structure in the L-28 Interceptor Canal indicates the area along the transect has received P-enriched discharge at least since the mid-1980s (**Figure 5-4**).

The District began monitoring efforts along the WCA-3A transect in October 1999. Data from startup through October 2000 are currently available. The data generated from this study are currently of limited utility for the purposes P-criterion development for the following reasons: (1) data are limited to a single annual period, which provides no information regarding interannual variability; and (2) extreme drought conditions which occurred during the period of record resulted in low-water conditions, which hampered data-collection efforts and may have resulted in a portion of the data not being representative of typical conditions. Due to the preceding limitations, the WCA-3A transect data set likely does not adequately characterize long-term conditions (e.g., variance, central tendency) in the marsh. However, the data do have some value in confirming conclusions drawn from studies in WCA-1 and WCA-2A, and provide information on marsh conditions during low stage. Based on the available information, water column P along the WCA-3A transect exhibits a pronounced and steep gradient, which drops from approximately 150 µg/L near the canal to background concentrations within approximately three km of the inflow (**Figure 5-5**).

Additionally, a similar P gradient is observed in the surficial sediments in WCA-3. A sediment TP contour map of WCA-3 (**Figure 5-6**), developed from data available from two previous studies (Reddy et al., 1994 and Stober et al., 1998), shows the existence of P-enrichment gradients associated with inflows of canal water into WCA-3 or areas that have been burned in recent years. The sediment TP concentrations range from 300 to 400 mg/kg in the interior, minimally impacted areas of the marsh, increasing to more than 1,500 mg/kg near some inflows, such as the end of the L-28 Interceptor Canal. Sediment TP concentrations of between 500 and 600 mg/kg have frequently been used by researchers to indicate areas of enrichment in the Everglades (Reddy et al., 1991; Craft & Richardson, 1993). Using the 500 to 600 mg/kg contour from **Figure 5-6**, the sediment P gradient near the District transect monitoring sites in WCA-3 is estimated to generally extend from one to three km into the marsh to the south and east of the end of the L-28 Interceptor Canal.

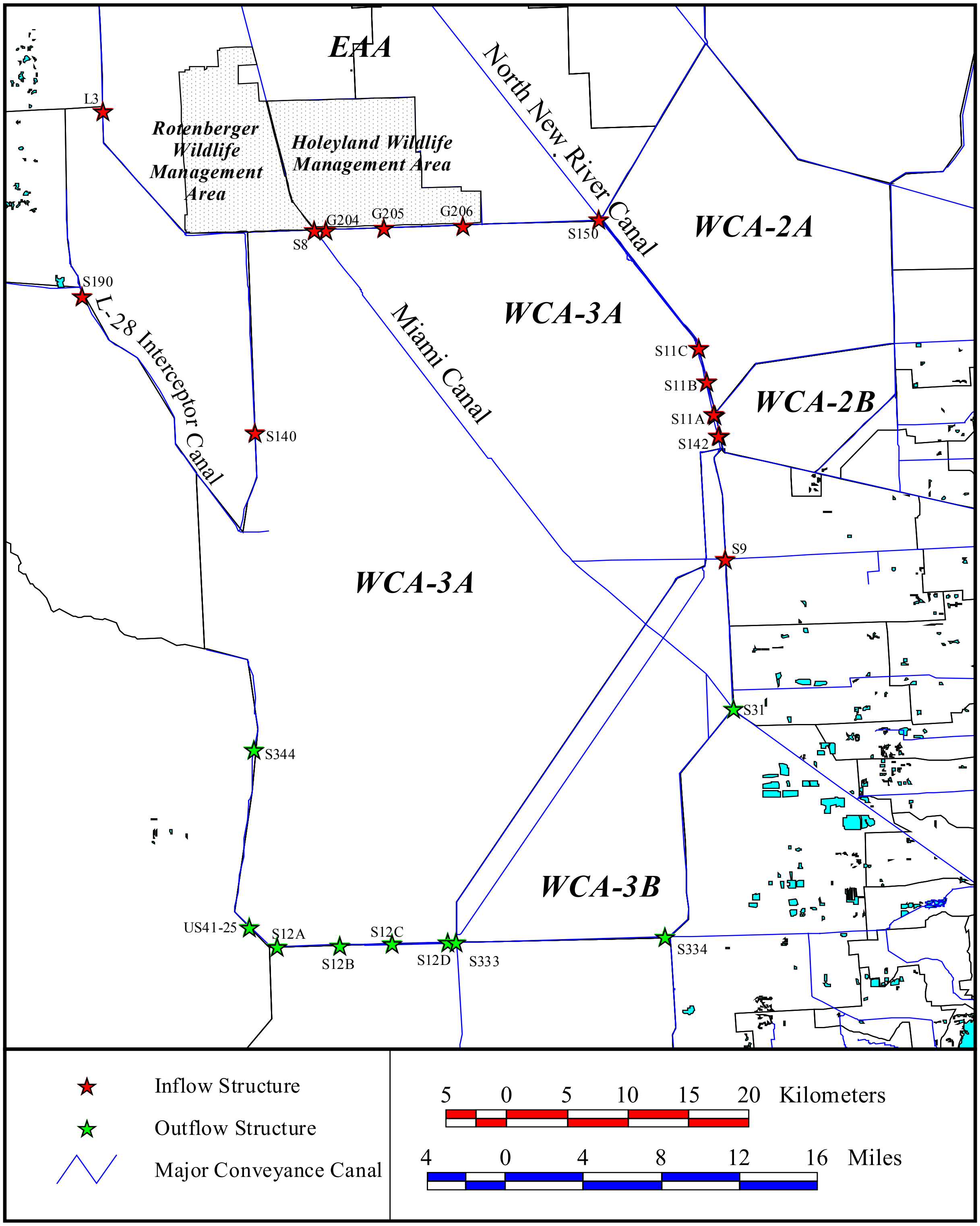


**Figure 5-2.** Location of WCA-3 Inflow and Outflow Structures

**Table 5-1.** Summary of long-term inflow TP concentrations entering WCA-3A. Values are given as the arithmetic mean ± standard deviation for two periods of record. The period from 1995 to present reflects recent conditions. Initial year gives the year SFWMD began water quality monitoring at the given structure and represents the beginning of the entire period of record.

| Station | Initial Year | 1995-Present | | Entire Period of Record | |
|---|---|---|---|---|---|
| | | Mean TP (µg/L) | N | Mean TP (µg/L) | N |
| S-11A | 1978 | 23 ± 26 | 81 | 25 ± 29 | 242 |
| S-11B | 1978 | 27 ± 26 | 62 | 40 ± 48 | 249 |
| S-11C | 1978 | 42 ± 35 | 86 | 52 ± 52 | 333 |
| S-8 | 1973 | 74 ± 76 | 339 | 89 ± 91 | 884 |
| S-9 | 1977 | 16 ± 8.2 | 237 | 17 ± 13.4 | 552 |
| G-123 | 1982 | 15 ± 7.2 | 76 | 17 ± 9.8 | 134 |
| L3 | 1977 | 116 ± 77 | 127 | 112 ± 102 | 358 |
| S-140 | 1974 | 44 ± 41 | 150 | 60 ± 67 | 474 |
| S-150 | 1977 | 52 ± 56 | 165 | 57 ± 47 | 378 |
| S-190[1] | 1987 | 62 ± 49 | 145 | 68 ± 54 | 239 |

[1]S-190 is the primary structure on the L-28 Interceptor Canal.

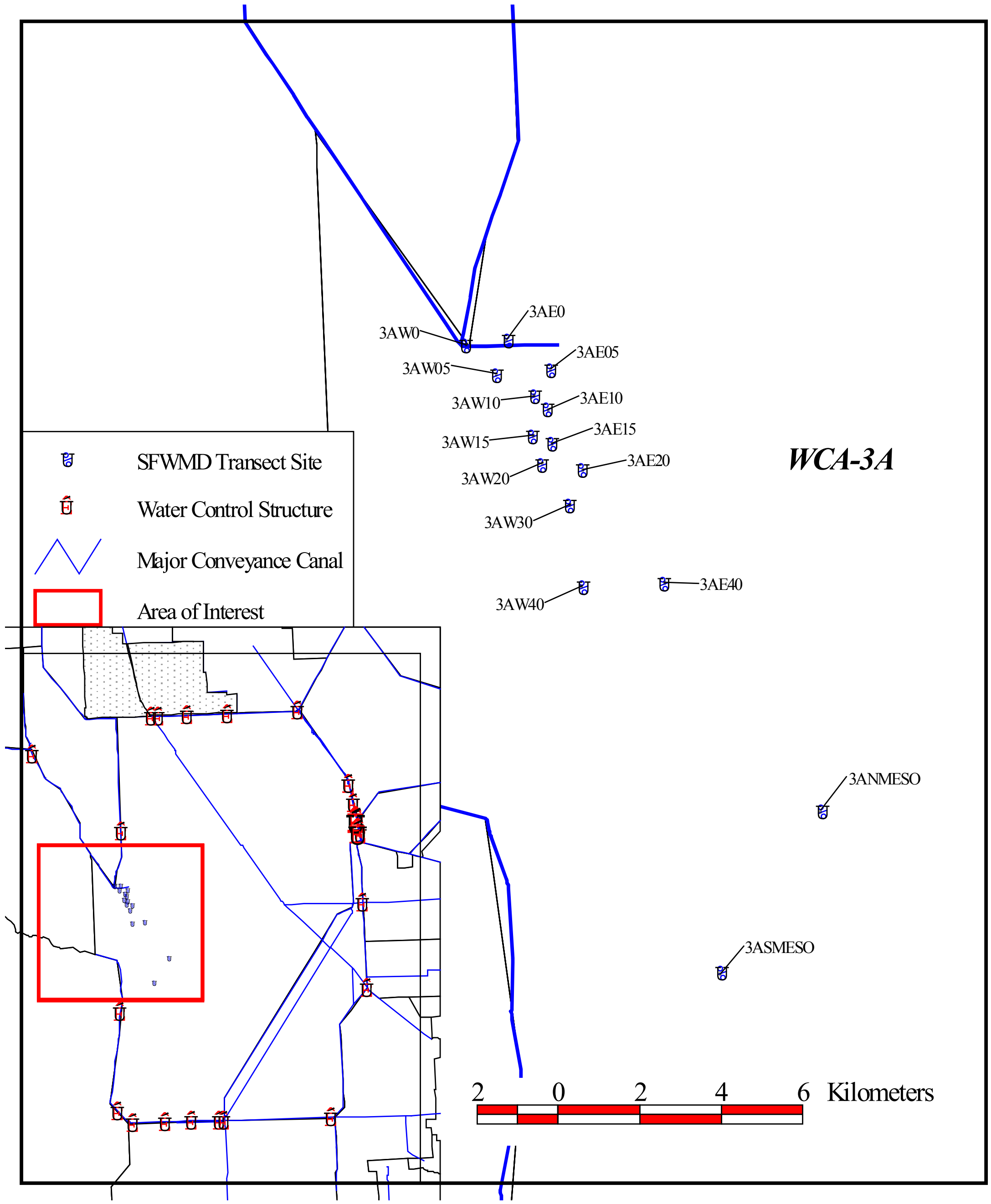


**Figure 5-3.** Location of SFWMD Nutrient Threshold Transect Sites in WCA-3A

**Table 5-2**. Description of District gradient transect monitoring sites in WCA-3A with summary of measured phosphorus concentrations

| Site id | Distance from canal (km) | Site Description | TP Concentration Geometric Mean (Range) (µg/l) | Number of Samples |
|---|---|---|---|---|
| 3AE0 | 0 | Threshold study transect site in WCA-3A on L-28. | 105.8 (54.0 – 240) | 5 |
| 3AW0 | 0 | Threshold study transect site in WCA-3A on L-28. | 72.0 (33.0 – 110) | 4 |
| 3AE05 | 0.6 | Threshold study transect site in WCA-3A 0.5 km east of L-28. | 136.3 (105.5 – 160) | 3 |
| 3AW05 | 0.7 | Threshold study transect site in WCA-3A 0.5 km west of L-28. | NA | 0 |
| 3AW10 | 1.2 | Threshold study transect site in WCA-3A 1.0 km west of L-28. | 82.5 (68.0 – 100) | 2 |
| 3AE10 | 1.5 | Threshold study transect site in WCA-3A 1.0 km east of L-28. | 71.0 (71.0 – 71.0) | 1 |
| 3AW15 | 2.2 | Threshold study transect site in WCA-3A 1.5 km west of L-28. | 24.6 (12.5 – 37.0) | 3 |
| 3AE15 | 2.4 | Threshold study transect site in WCA-3A 1.5 km east of L-28. | 27.8 (17.0 – 70.0) | 3 |
| 3AW20 | 2.9 | Threshold study transect site in WCA-3A 2.0 km west of L-28. | 16.0 (9.0 – 24.0) | 5 |
| 3AE20 | 3 | Threshold study transect site in WCA-3A 2.0 km east of L-28. | 8.8 (6.0 – 11.0) | 6 |
| 3AW30 | 3.8 | Threshold study transect site in WCA-3A 3.0 km west of L-28. | 6.5 (6.0 – 7.0) | 2 |
| 3AW40 | 5.8 | Threshold study transect site in WCA-3A 4.0 km west of L-28. | 10.3 (5.0 – 28.0) | 5 |
| 3AE40 | 6.3 | Threshold study transect site in WCA-3A 4.0 km east of L-28. | 6.3 (2.0 – 32.0) | 5 |
| 3AMESON | 12.9 | Threshold study northern mesocosm site in WCA-3A. | 8.6 (4.0 – 34.0) | 4 |
| 3AMESOS | 15.5 | Threshold study southern mesocosm site in WCA-3A. | 4.4 (2.0 – 10.0) | 6 |

NA = Not Sampled

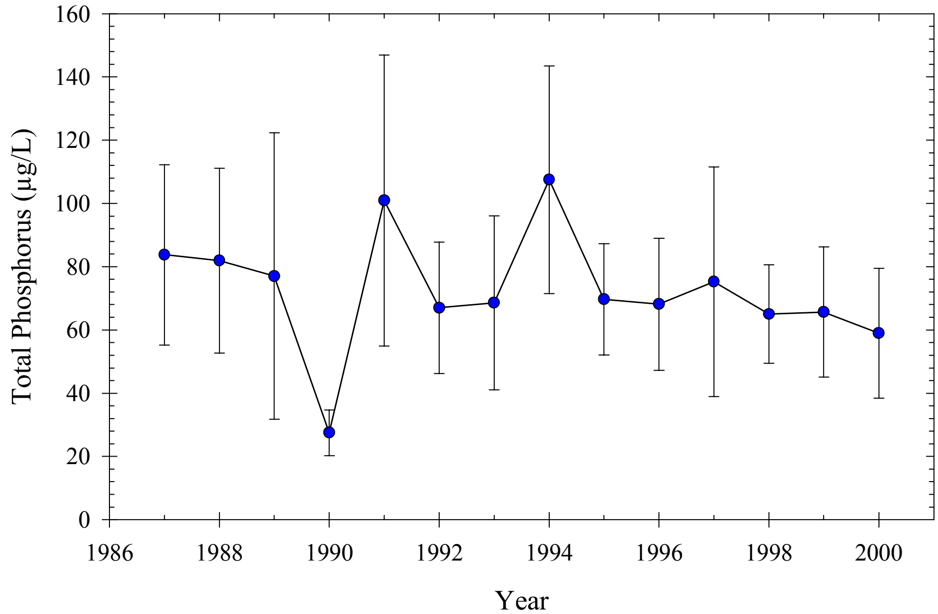


**Figure 5-4.** Annual total phosphorus concentrations (mean ±95% confidence interval) for L-28 Interceptor canal waters entering western WCA-3B through the S-190 inflow structure

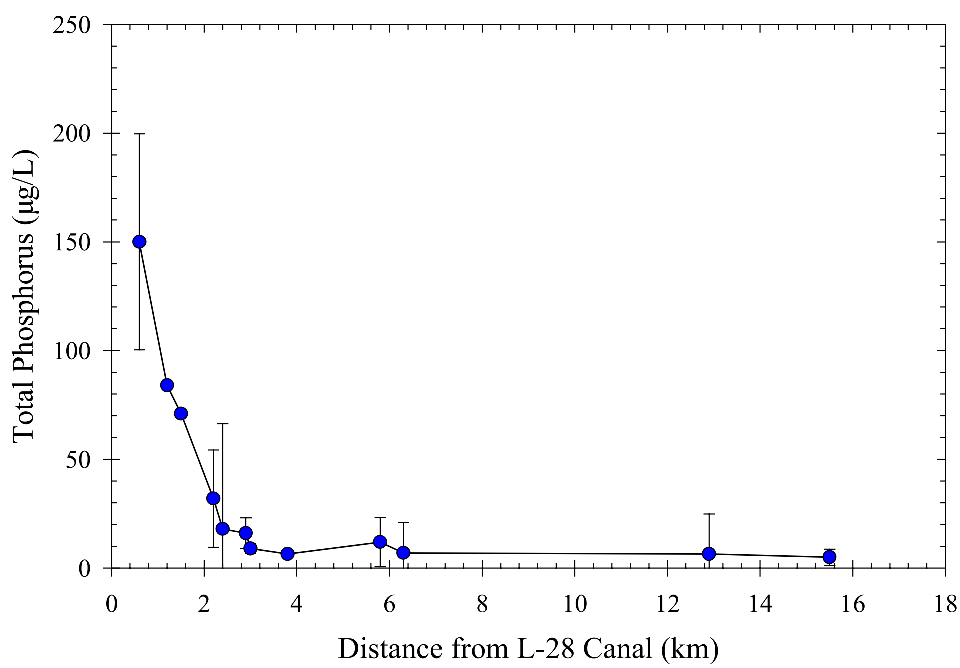


**Figure 5-5.** Total phosphorus gradient (median ±95% confidence interval) in WCA-3A originating from the L-28 Interceptor canal

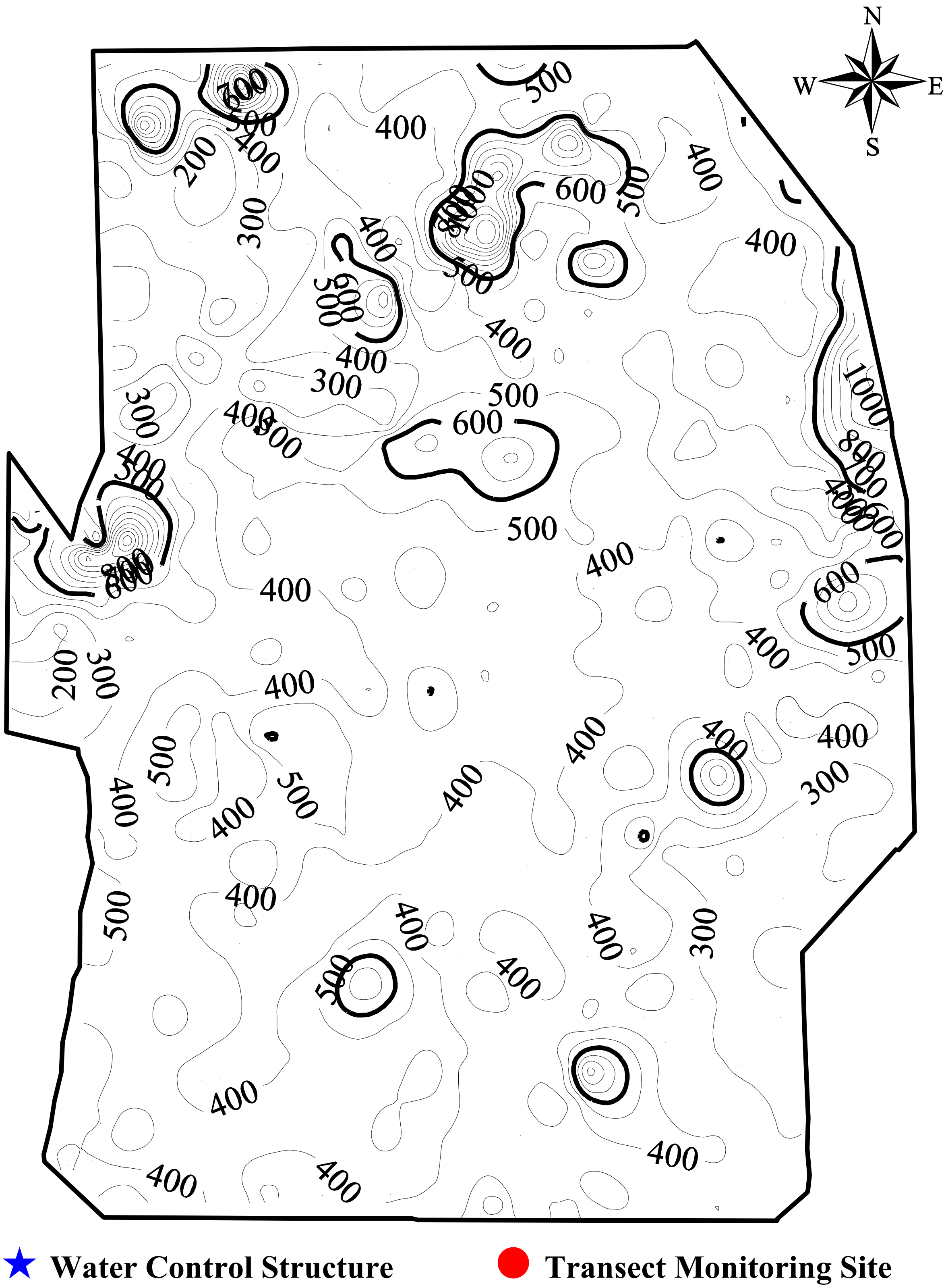


**Figure 5-6.** Map of WCA-3 with Total Sediment Phosphorus Contours (mg/kg) determined from a combination of 1991 Reddy, 1995-96 REMAP and 2000 SFWMD Transect Data (0-10 cm depth),

## Everglades National Park

The Everglades National Park (Park or ENP), created in 1947, is the third largest national park in the continental United States and has been designated as a World Heritage Site, an International Biosphere Reserve, a Wetland of International Importance and an Outstanding Florida Water. Currently, the Park consists of more than 1.5 million acres (610,900 hectares) of wetlands and submerged lands at the southern terminus of the Florida Peninsula. The Park lies just south of the Big Cypress National Preserve and WCA-3 and extends some 60 miles to the south to include much of Florida Bay. There is an estimated 572,200 acres of sawgrass, 231,100 acres of mangrove forest and 484,200 acres of islands and submerged land that comprise the landscape of the Park.

As documented for the Water Conservation Areas, portions of the Park have been impacted to some extent by the inflows of P-enriched water originating from agricultural areas to the north. However, because much of the water has passed through the Water Conservations Areas, the P concentration in the water entering the Park is generally much lower than that entering the northern portions of the system. Waters originating from the Water Conservations Areas flow into the northern portion of the Park (Shark River Slough) through the S-333 and S-12 structures (**Figure 5-7**). Water deliveries to the eastern portion of the Park, known as Taylor Slough, are provided through the L-31W Canal and S-18C structure. Until recently, the primary discharge structure from the L-31W Canal was Pump Station S-332. A new structure (S332-D), constructed by the U.S. Army Corps of Engineers (USACE), began discharging additional water from the L-31W Canal on October 1, 1999. Unlike the Northern Everglades, TP concentrations in surface water inflows to the Park are only slightly elevated above levels found in the interior marsh (**Table 5-3**).

The SFWMD initiated research in support of P-criterion development along two transects 0.3 to 24 km south of the S-332 Pump Station (**Figure 5-8**). Biological and water quality parameters, including TP, were monitored along these transects beginning in October 1999. As previously discussed for the WCA-3A transect study, these data are currently of limited utility for the purposes of P-criterion development and should be used cautiously. Based on the limited data set, no distinct P gradient exists downstream of S-332, though the two sites closest to the inflow (i.e., T05E and T05W) appear to be slightly enriched (**Figure 5-9** and **Table 5-4**). Due to the extremely limited data set, it is currently unclear whether the elevated P concentrations measured at T05E and T05W are representative of the prevalent conditions near the inflow or are the result of a sampling artifact and/or the severe drought experienced during the period of record. Based on inflow TP concentrations measured at S-332, the latter option is most likely. Annual average P concentrations passing through the S-332 have typically been below 10 µg/L, though pulses of substantially higher concentrations are sometimes observed (**Figure 5-10**). Since P concentrations in the inflow to Taylor Slough have been low for an extended period, it is unlikely that water-column concentrations downstream of the inflows would normally be much greater.

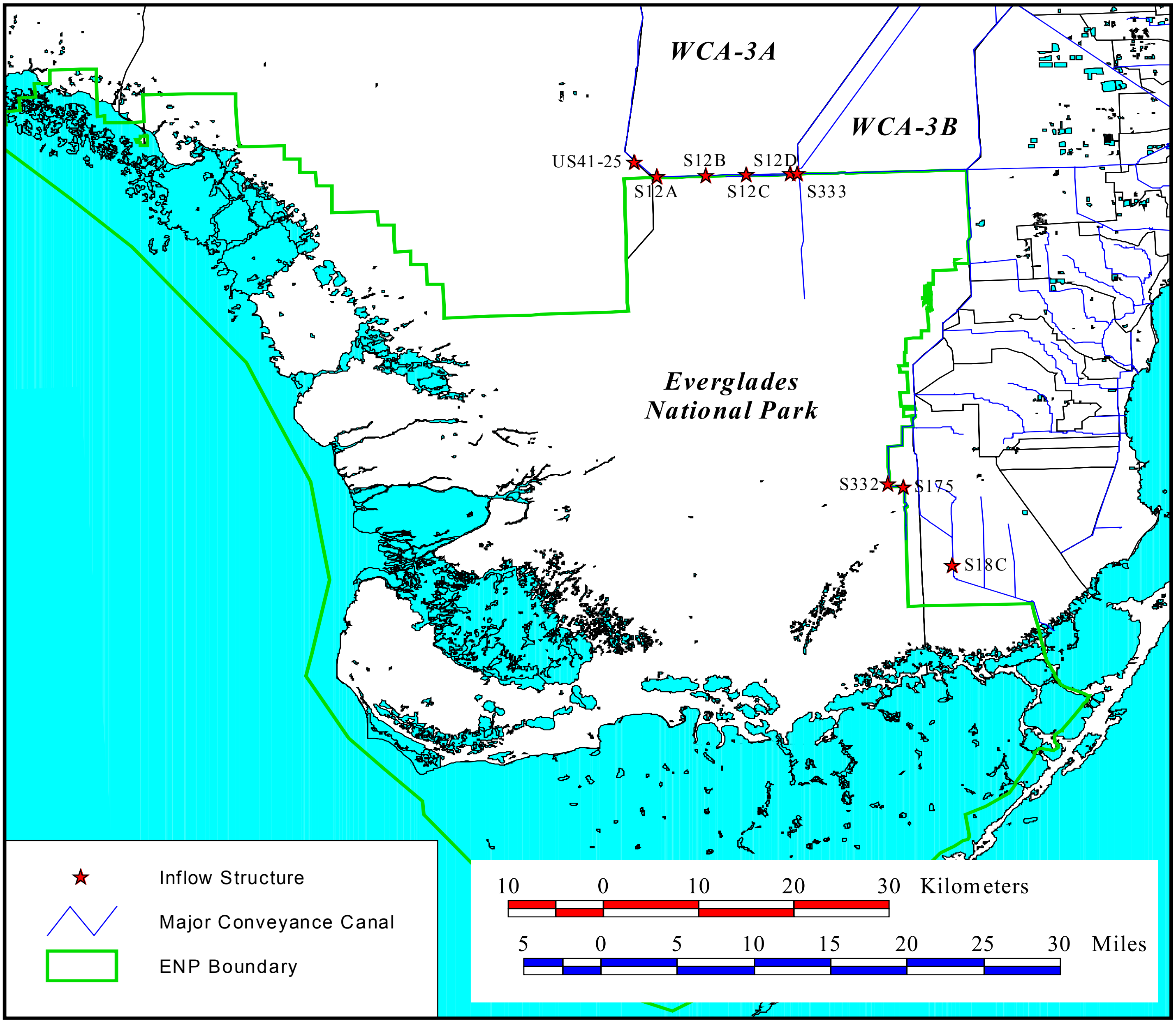


**Figure 5-7.** Location of Inflow Structures to Everglades National Park

Table 5-3. Summary of long-term inflow TP concentrations entering Everglades National Park. Values are given as the arithmetic mean ± standard deviation for two periods of record. The period from 1995 to present reflects recent conditions. Initial year gives the year SFWMD began water quality monitoring at the given structure and represents the beginning of the entire period of record.

| Region | Structure | Initial Year | 1995-Present Mean TP (µg/L) | 1995-Present N | Entire Period of Record Mean TP (µg/L) | Entire Period of Record N |
|---|---|---|---|---|---|---|
| Shark River Slough | S-12A | 1976 | 13.0 ± 12.3 | 196 | 15.5 ± 25.1 | 612 |
| | S-12B | 1976 | 10.1 ± 8.1 | 195 | 14.4 ± 34.9 | 631 |
| | S-12C | 1976 | 9.5 ± 7.2 | 195 | 13.2 ± 14.9 | 661 |
| | S-12D | 1976 | 10.6 ± 6.5 | 197 | 14.1 ± 12.1 | 666 |
| | S-333 | 1978 | 12.1 ± 11.9 | 199 | 15.1 ± 13.9 | 650 |
| Taylor Slough | S-332 | 1983 | 7.4 ± 5.4 | 200 | 8.7 ± 6.8 | 471 |
| | S-332D | 1999 | 7.1 ± 4.2[1] | 108 | 7.1 ± 4.2[1] | 108 |
| | S-18C | 1983 | 6.9 ± 4.9 | 149 | 8.0 ± 6.4 | 373 |

[1] The available period of record for pump station S-332D is October 1999 through the present with sampling occurring at a much higher frequency than for other structures.

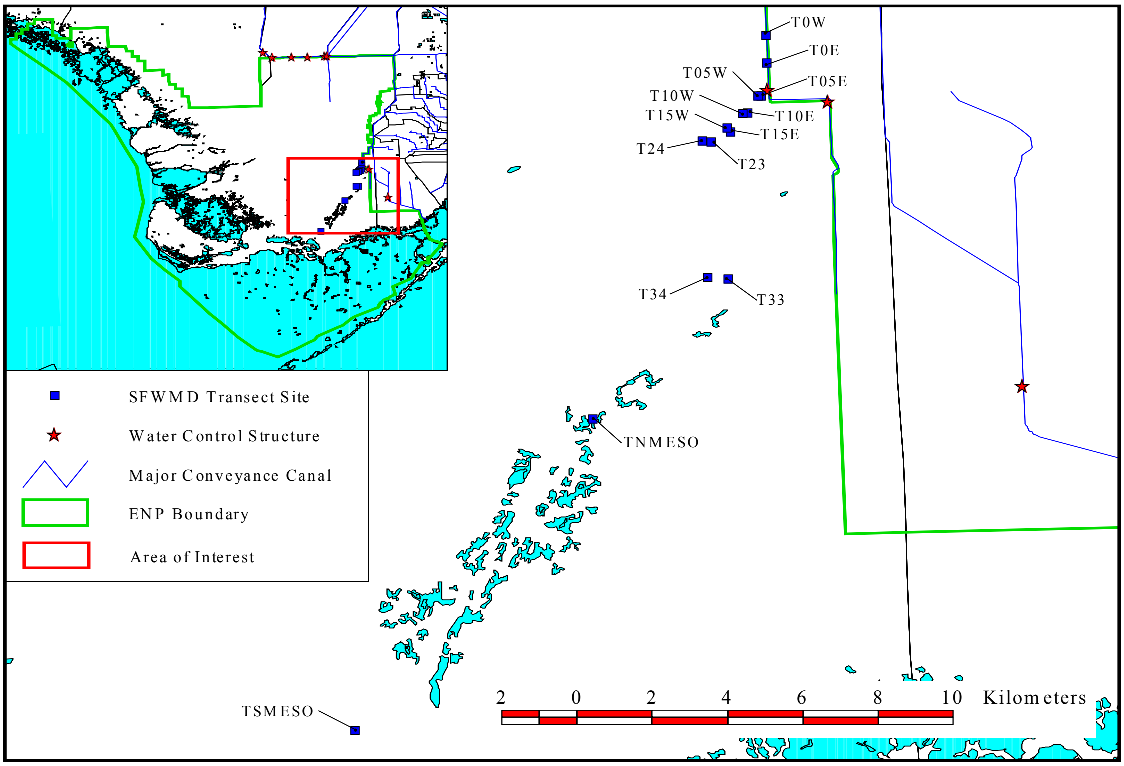


**Figure 5-8.** Location of SFWMD transect sites in Taylor Slough, Everglades National Park

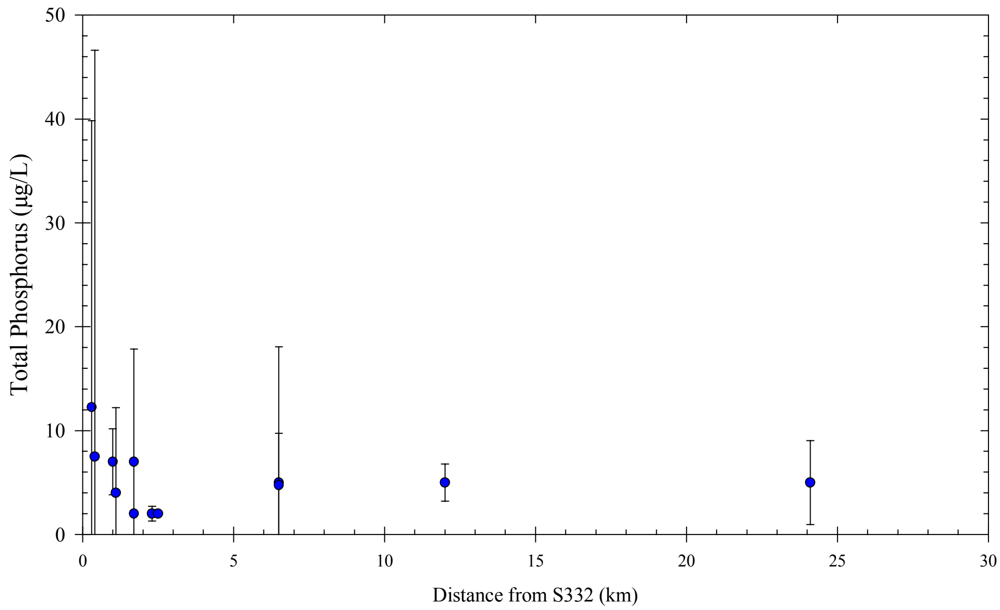


**Figure 5-9.** Total phosphorus concentrations (median ±95% confidence interval) along the SFWMD transect in Taylor Slough.

Table 5-4. Description of District Gradient Transect Monitoring Sites in ENP (Taylor Slough) with summary of Measured Total Phosphorus concentrations.

| Site ID | Distance from S332 (km) | Site Description | TP Concentration Geometric Mean (Range) (µg/L) | Number of Samples |
|---|---|---|---|---|
| T0E | 0 | Threshold study transect site in canal south of S-332, east of Taylor Slough. | 7.5 (5.0 – 12.0) | 5 |
| T0W | 0 | Threshold study transect site in canal south of S-332, west of Taylor Slough. | 8.8 (7.0 – 14.0) | 3 |
| T05E | 0.3 | Threshold study transect site 0.5 km south of S-332, east of Taylor Slough. | 17.4 (7.0 – 64.0) | 6 |
| T05W | 0.4 | Threshold study transect site 0.5 km south of S-332, west of Taylor Slough. | 9.2 (2.0 – 64.0) | 4 |
| T10E | 1 | Threshold study transect site 1.0 km south of S-332, east of Taylor Slough. | 6.9 (5.0 – 10.0) | 5 |
| T10W | 1.1 | Threshold study transect site 1.0 km south of S-332, west of Taylor Slough. | 5.2 (3.0 – 12.0) | 3 |
| T15E | 1.7 | Threshold study transect site 1.5 km south of S-332, east of Taylor Slough. | 6.4 (2.0 – 19.0) | 4 |
| T15W | 1.7 | Threshold study transect site 1.5 km south of S-332, west of Taylor Slough. | 2.0 (2.0 – 2.0) | 5 |
| TMESON | 12 | Threshold study transect (mesocosm) site northern Taylor Slough. | 3.8 (2.0 – 10.5) | 7 |
| TMESOS | 24.1 | Threshold study transect (mesocosm) site southern Taylor Slough. | 4.4 (2.0 – 9.0) | 6 |

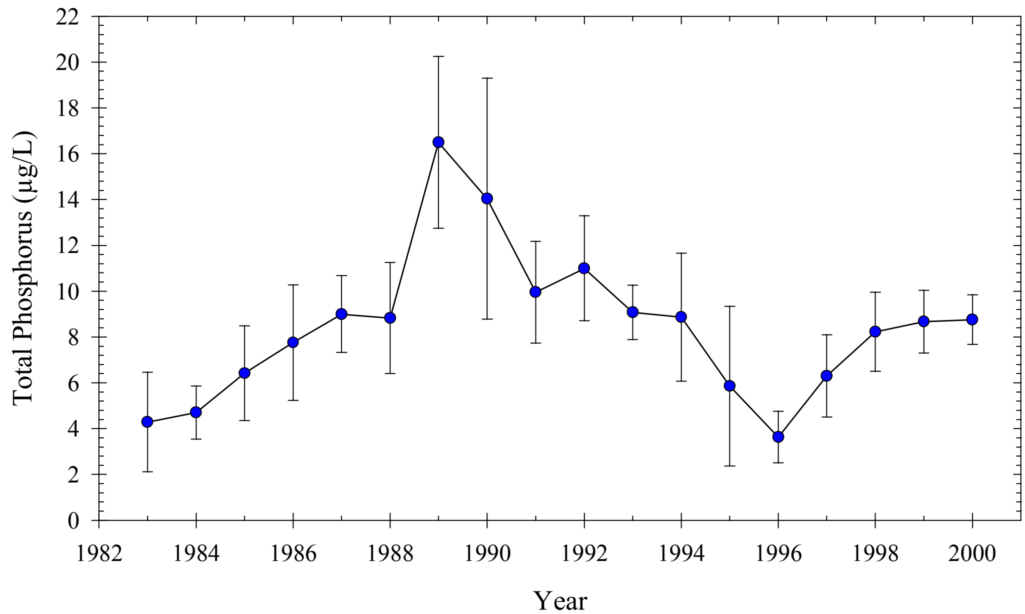


**Figure 5-10.** Annual Total Phosphorus Concentrations (mean ±95% confidence interval) for Canal Waters Entering Taylor Slough through S-332 Inflow Structure

Likewise, sediment TP concentrations also indicate that there is not a well-defined gradient downstream of the S-332 inflow. The sediment TP contour map (**Figure 5-11**) for the freshwater portion of ENP, developed using the 1995-96 REMAP data (Stober et al., 1998), shows sediment P concentrations in the vicinity of the District transect sites adjacent the S-332 inflow structure to be near background levels. The lack of a P gradient is consistent with other reports of limited P enrichment and associated biological impacts in the ENP (McCormick et al., 1999 and 2000). It should be noted that unlike the northern areas of the Everglades, where the sediment is primarily peat, the sediment in the Park is comprised of a combination of peat and marl soils. This change in sediment type, along with the limited amount of data available, may limit the ability to accurately define P-impacted areas in the Park. However, small areas of sediment P enrichment do appear to be associated with the known inflows of canal water into the Park, such as the S-12 structures and the L-67 Extension Canal in the northern-most portion of the Park. Additionally, an area adjacent to the Park facilities on Long Pine Key in the east-central portion of ENP also appears to be P enriched.

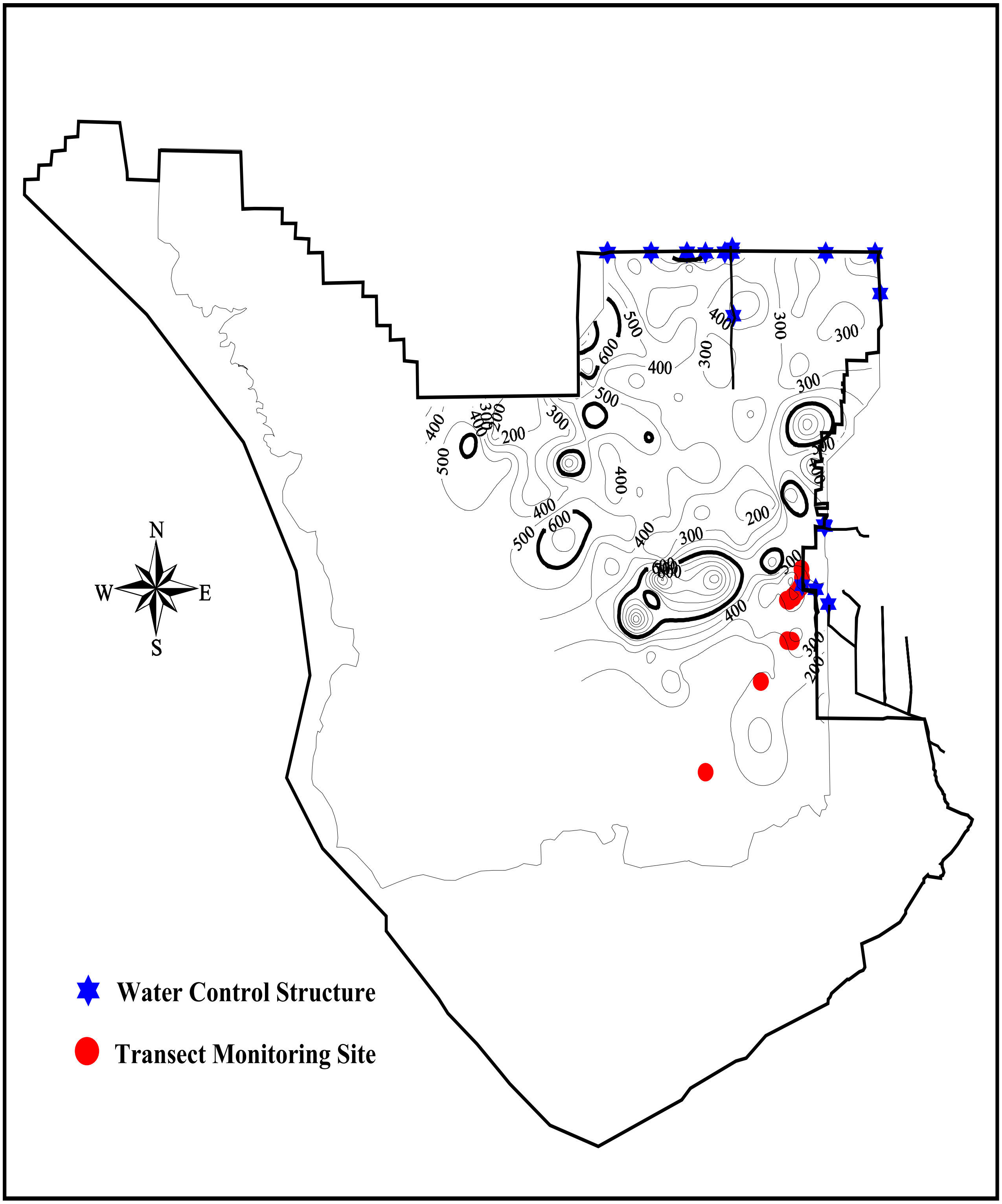


**Figure 5-11.** Map of Everglades National Park with Total Sediment Phosphorus Contours (mg/kg) determined from the 1995-96 REMAP and 2000 SFWMD Transect Sediment Data (0-10 cm depth)

## PERIPHYTON RESPONSE TO P-ENRICHMENT

Periphyton are a community of algae, bacteria and other microorganisms that form either floating or submerged (benthic) mats, or may be attached to the surface of aquatic plants. Periphyton typically account for a large percentage of the vegetative biomass and up to 80 percent of the primary productivity in the shallow oligotrophic areas of the Everglades. Additionally, periphyton exhibit a strong influence on the overall health of the system through their roles in important biogeochemical processes, such as photosynthetic $O_2$ production, soil formation, P cycling, providing physical habitat for macroinvertebrates and small fish and as a base for the food web in the Everglades Protection Area (Wood and Maynard, 1974; Browder et al., 1994; Rader, 1994; and Scinto, 1997).

As discussed in the 2001 Everglades Consolidated Report (Payne et al., 2001), the general water quality characteristics within an area play an important role in the type of periphyton community present. The two most extreme background water quality conditions are represented by WCA-2A and WCA-1. Within the interior portions of WCA-1, where the rainfall-driven hydrology results in slightly acidic water with low- nutrient and low-mineral content, the periphyton assemblage is comprised primarily of numerous species of desmids and filamentous green algae, which form a thin, hairy, green-to-brown coating (sweater) on plant stems (Swift and Nicholas, 1987). At the opposite end of the spectrum, the interior of WCA-2A, where the canal inflows result in alkaline water with low-nutrient/high-mineral content, the periphyton community is dominated by calcareous blue-green algae (particularly *Scytonema* and *Schizothrix*), with numerous diatoms that form a thick, cream-colored to yellowish-brown mat with calcite crystals.

Additionally, the detrimental effects of P enrichment on periphyton communities in the Everglades have been demonstrated by many researchers (Swift & Nicholas, 1987; McCormick & O'Dell, 1996; Flora et al., 1988). Phosphorus enrichment has been correlated with adverse changes in the physical structure, function and taxonomic composition of Everglades periphyton communities, and dosing and fertilization studies have corroborated these conclusions (Steward & Ornes, 1975a,b; Hall & Rice, 1987). Even though the taxonomic composition of the periphyton assemblage found in the interior (unimpacted) portions of WCA-2A and WCA-1 is dramatically different, experimental results indicate that P enrichment produces similar changes in the periphyton communities in both WCA-1 and WCA-2 (McCormick et al., 2000). The periphyton community within the peripheral areas of both WCA-1 and WCA-2A, where canal inflows result in water with high levels of minerals and nutrients, is characterized by a specialized group of pollution-tolerant algae dominated by *Microcoleus lyngbyaceus* (Swift, 1981; Swift and Nicholas, 1987).

Since the general water quality characteristics in WCA-3 and the Park are intermediate to those found in WCA-2A and WCA-1 (i.e., moderate mineral content and pH) and the periphyton community present is comprised of the same dominant species found in other areas, the response to P enrichment is likely to be similar. Based on limited data collected by the District from the P-dosed mesocosms in WCA-3A and the Park, the periphyton in WCA-3A appear to exhibit a response similar to that observed in corresponding mesocosms in WCA-1 because of the similarities in the community composition (lack of dominant calcareous periphyton mat) in the two areas (McCormick, 2001). Likewise, the highly P-sensitive calcareous periphyton dominated communities in the Park and WCA-2 appeared to exhibit a similar, but more rapid response to P enrichment. These observations are based on data collected from mesocosms in WCA-3 and the Park that have received weekly doses of orthophosphate for only a few months. Additionally, even though some periphyton communities may respond more rapidly than the communities in other areas, little can be determined from the mesocosm studies regarding the concentration of P that will elicit a long-term imbalance within the periphyton community in different areas.

During October 1999, the District initiated an investigation of the changes occurring in the periphyton community along the gradient transects in WCA-3A and the Park that involved the collection of periphytometer (artificial substrate) samples during periodic monitoring events. Since the studies in WCA-3 and the Park were initiated, extremely dry conditions have limited the data-collection efforts. Data from only one to two periphyton-sampling events have been collected and analyzed, with some sites having no data available for evaluation. Due to the general lack of data and the abnormal climatic conditions experienced during the studies in WCA-3 and the Park, care must be exercised in interpreting the available data from these areas. A much longer period of record is needed to ensure the data is truly representative of the normal conditions that exist in WCA-3 and the Park. Additionally, due to these problems the Department's evaluation of the data from WCA-3A and the Park relative to the development of a numeric P criterion for the Everglades was limited. The Department's evaluation of the data available from WCA-3 and the Park primarily focused on demonstrating the similarities of the biological communities and their response to P enrichment to those observed in other areas, rather than attempting to define an exact numeric P criterion. The analysis of the limited data available for WCA-3A and the Park are discussed below.

## Water Conservation Area 3A

Despite the limited amount of data available for WCA-3A, changes in the periphyton community in WCA-3A can be observed. For example, the concentration of P in WCA-3 periphyton increases with increasing water column P levels near the L-28 Interceptor Canal inflow. This is reflected in the TN:TP ratios for WCA-3 periphyton measured during October 1999 (**Figure 5-12**). Ratios range from less than 10 at the most P-enriched sites to more than 85 at the site furthest from the inflow (i.e., lowest TP concentrations). The greatest change in the TN:TP ratios appears to occur at geometric mean TP concentrations around 10 µg/L. However, the lack of data from sites with TP concentrations between 10 and 70 µg/L and having more than one sampling date prohibits a more accurate determination of where a significant change occurs.

Changes in the taxonomic composition of the periphyton community can also be observed along the P-gradient transect sites in WCA-3A. Multivariate (cluster) analyses were used to assess similarity in periphyton taxonomic composition among District sampling stations and to determine which stations, if any, could be grouped with respect to the periphyton species found. Analyses performed on the limited data set collected from the WCA-3A transect sites showed two distinct groupings of stations (**Figure 5-13**), based on the complete list of taxa collected. One grouping consists of sites with geometric mean TP concentrations of 10 µg/L or less (i.e., Stations 3A20E, 3A40E, 3A40W, Meso3N and Meso3S). The second group consists of sites nearer the canal, with TP concentrations above 15 µg/L (3A05E, 3A10E, 3A15E, 3A10W, 3A15W and 3A20W), and is distinctly different from the stations further from the canal. Similar results were obtained regardless of whether analyses were based on all taxa or a group of sensitive and tolerant indicator taxa used during the evaluations of WCA-2A and WCA-1 (Payne et al., 1999 and 2000). These results support the finding from WCA-2A and WCA-1 that significant changes in the taxonomic composition of the periphyton communities occur at TP concentrations above 10 µg/L (Payne et al., 1999 and 2000). Additionally, comparing the list of 123 periphyton taxa identified from WCA-3A transect sites to those found along the WCA-2A and WCA-1 gradient, only two taxa were unique to WCA-3A. However, the two taxa, *Acanthosphaera sp.* and *Sphaerozosma vertebratum*, appeared only in a single sample collected at Station W20 and together represented less than one percent of the periphyton present in that sample.

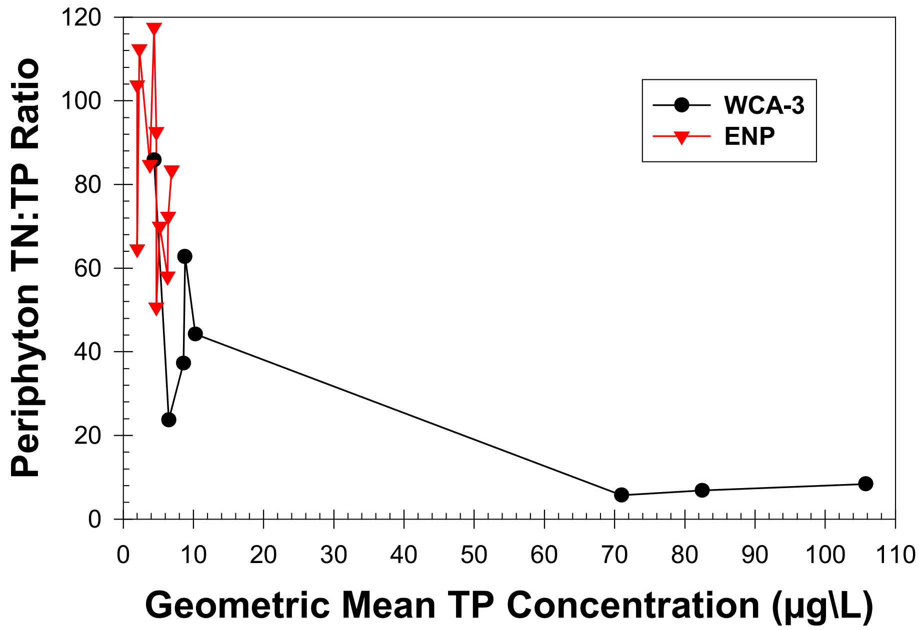


**Figure 5-12.** Periphyton TN:TP ratios in Samples Collected at SFWMD Gradient Transect Sites during Single Event in October 1999

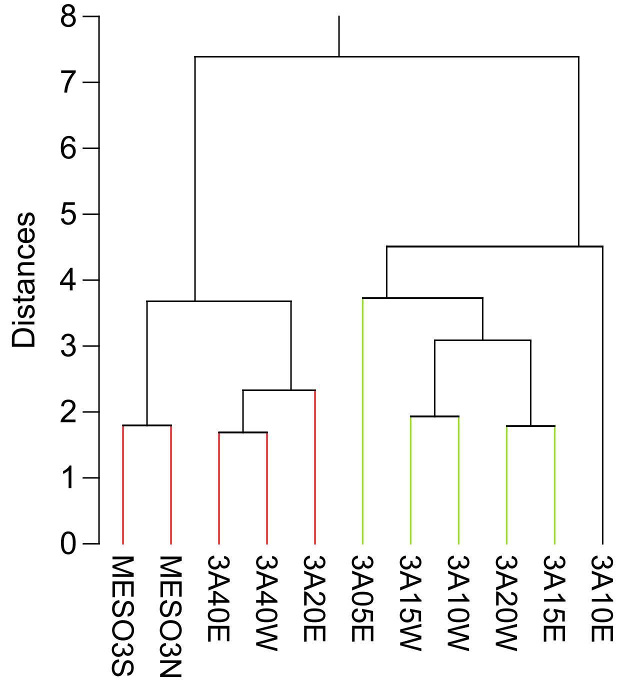


**Figure 5-13.** Results of Cluster Analyses (Ward's Method) Based on Percent Abundance of Periphyton Taxa Identified in WCA-3 Samples from SFWMD Gradient Transect Sites from October 1999 through October 2000

To further assist in interpreting the taxonomic data, the phosphorus-sensitive, pollution-sensitive and pollution-tolerant species lists compiled and used in WCA-2A (Payne et al., 1999 and 2000) were applied to the WCA-3 data. The median percent pollution-sensitive, pollution-tolerant and phosphorus-sensitive (WCA-2 mesocosm) taxa were then plotted by geometric mean TP concentration measured during the October 1999 through October 2000 period of record (**Figure 5-14**). The strongest response to P enrichment along the gradient was observed for pollution-tolerant taxa. The tolerant taxa generally comprised less than 25 percent of the samples collected at sites with geometric mean TP concentrations of 10 µg/L or less (i.e., Stations 3A20E, 3A40E, 3A40W, Meso3N and Meso3S) and increase sharply to represent 50 percent or more of the samples collected at stations with higher mean TP concentrations. Both pollution- and phosphorus-sensitive taxa exhibited an opposite trend, whereby they represented 15 to 30 percent of the periphyton at stations with low TP (i.e., 10 µg/L) and decreased to less than five percent of the population at higher TP sites nearer the canal.

Due to the lack of sufficient data, more definitive statistical evaluations are not possible. However, since the periphyton community in WCA-3A is comprised of the same taxa identified in WCA-2A and WCA-1 and the general water characteristics are within the range found in the other areas, it is not surprising that the response of the periphyton community in WCA-3A to P enrichment appears to be similar to that documented for the other areas. The WCA-3 evaluation is based on very limited amounts of both P and biological data collected under very dry conditions and should therefore be interpreted with caution.

## Everglades National Park

The characteristic algal community in the Park, as in WCA-2A, is dominated by calcareous (calcium precipitating), filamentous blue-green algae, *Scytonema* and *Schizothrix*, and a group of hard-water diatoms (e.g., *Mastogloia*). This periphyton community is adapted to the oligotrophic conditions in the area and quickly removes additional P from the water column as it becomes available. Numerous researchers have shown the calcareous periphyton to be highly sensitive to P enrichment, with the calcareous mat being lost quickly because of P enrichment (Raschke, 1993).

Because most inflows to the Park exhibit P concentrations only slightly above those found in the interior marsh, the P gradients observed in the Park are generally minimal. This is especially true adjacent the S-332 inflow, where the District's transect sites are located (**Figure 5-8**), and is reflected in both the surface water and sediment TP concentrations. The lack of a clear P gradient downstream of the S-332 inflows is also manifested in the TN:TP ratios for the Park periphyton measured during a single event in October 1999 (**Figure 5-12**). The TN:TP ratios measured at all sites were characteristic of highly P-limited conditions and ranged from 50 to 118, with no apparent trend with changes in measured TP concentrations. However, no samples were analyzed from the two stations nearest the canal, where P concentrations are more likely to be elevated above background levels.

Despite the limited amount of data available and the minimal P gradient present, multivariate (cluster) analyses were used to determine if any taxonomic changes in the periphyton community could be detected along the transects. Analyses performed on the Park transect data revealed two distinct groupings of stations (**Figure 5-15**). One grouping consists of the two sites closest to the inflow (i.e., Stations TS-05E and TS-05W), with the second group comprised of the remaining five sites located further away from the inflow. Similar results were obtained regardless of whether analyses were based on all taxa identified or the group of pollution-sensitive, phosphorus-sensitive and pollution-tolerant indicator taxa. The two sites nearest the canal

(Stations TS-05E and TS-05W) exhibited TP concentrations ranging from two to 67 µg/L, with average concentrations of 25.3 and 21.0 µg/L and geometric means of 17.4 and 9.2 µg/L, respectively. In contrast, TP concentrations measured for the second group of stations ranged from two to 19 µg/L, with all arithmetic and geometric means being below nine µg/L. However, the characterization of the P regime is based on three to seven measurements collected during a single year in which abnormal climatic conditions prevailed. Therefore, it is not known if these P concentrations represent the true P regime in the area or are an anomaly resulting from the abnormally dry conditions experienced during the period of record.

As in WCA-3A, most of the 94 periphyton taxa identified in samples collected along the Park transect sites have also been documented in either WCA-2A or WCA-1 transect samples. Only five species identified in the Park samples (i.e., *Closterium infractum, Coleochaete orbicularis, Dimorphococcus lunatus, Ophiocytium parvulum, Sphaerozosma laeve*) are unique to the Park. These five species represent a minor part of the community, with the sum of the five unique species representing less than one percent of the periphyton population in all samples in which they were found.

Even though the data available for the Park transect sites are limited, the evaluation of the available information suggests that the periphyton community identified in the Park is similar to those documented for WCA-2A and WCA-1. Additionally, the available information suggests that the Park periphyton community exhibits sensitivity to P enrichment comparable to that observed along the WCA-2A and WCA-1 gradient transects. Taxonomic changes in the Park periphyton community appear to occur at approximately the same levels of P enrichment (TP concentrations) responsible for similar impacts in WCA-2A and WCA-1.

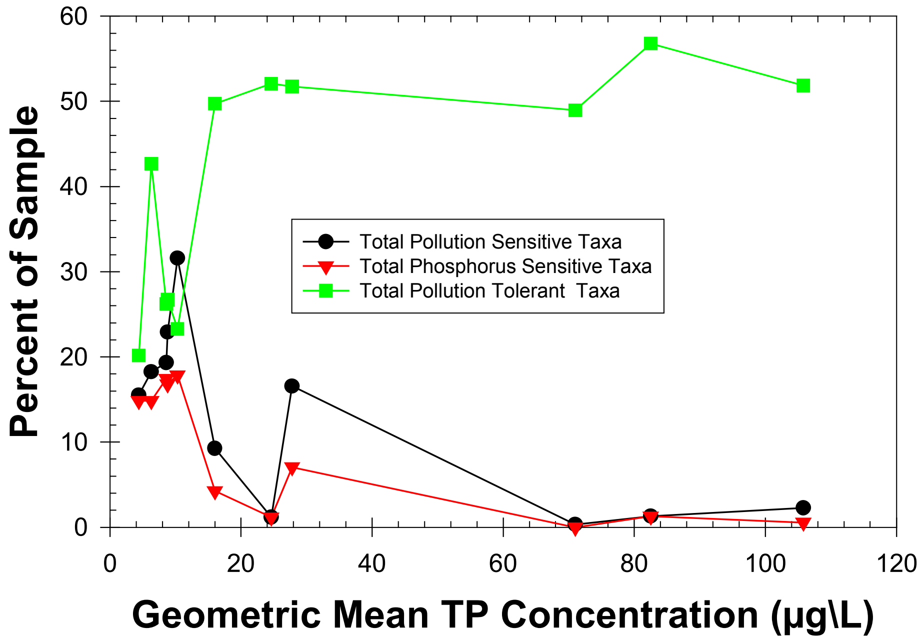


**Figure 5-14.** Median Percent of Pollution Sensitive, Phosphorus Sensitive, and Pollution Tolerant Periphyton Taxa in Samples Collected at SFWMD Gradient Transect Sites from October 1999 through October 2000

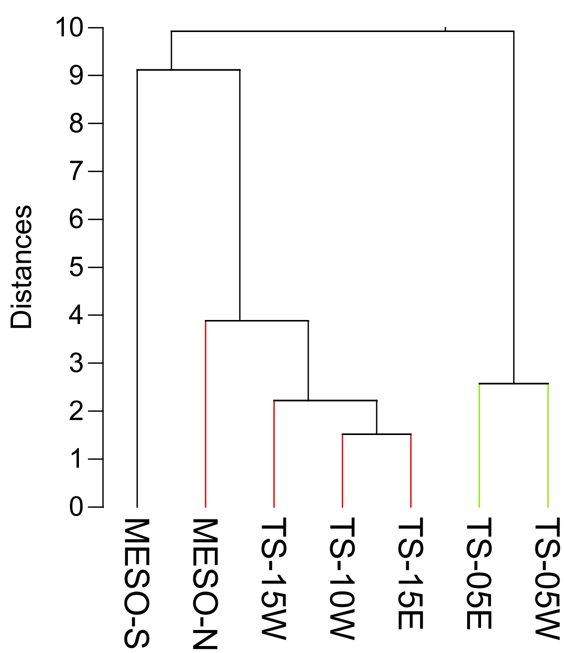


**Figure 5-15.** Results of Cluster Analyses (Ward's Method) Based on Percent Abundance of Periphyton Taxa Identified in ENP Samples from SFWMD Gradient Transect Sites from October 1999 through October 2000

# MACROPHYTE RESPONSE

The emergent macrophyte community is one of the most recognizable features of the Everglades landscape, with the native macrophyte population being dominated by species adapted to low P concentrations, seasonal wetting and drying and occasional disturbances by fire, drought and freezes (McCormick et al., 2000; Duever et al., 1994; and Parker, 1974). Macrophytes are generally considered less sensitive to P enrichment than other biological communities, especially periphyton. Macrophytes often require from several months to years to show a response to P enrichment, whereas changes in the periphyton community may be observed within days or weeks.

Even though macrophytes generally require a greater time for the response to P enrichment to manifest, they often respond to the same levels of enrichment that elicit a response in other communities, as was observed in WCA-2A and WCA-1 (Payne et al., 2001).

## Water Conservation Area 3A

Unfortunately, there are only limited accounts of pre-drainage vegetation composition and patterns in the WCA-3 locale. A pollen, peat and geochemical record study conducted by USGS (Willard et al., Submitted to Geology) found geochronological evidence of freshwater marshes dominated by *Cladium, Sagittaria, Eleocharis* and *Rhynchospora*, and of sloughs dominated by floating aquatics, such as *Nymphaea.* This is consistent with historical descriptions depicting this area as a vast sawgrass marsh dotted with tree islands, wet prairies and aquatic sloughs (Davis, 1943a, b; Loveless, 1959). However, since the early 1900s, WCA-3 has been affected by drainage due to the construction of water management canals and levees. These hydrologic modifications have disrupted water flow in the southerly direction and accelerated the flow of water from the north to the south, rapidly reducing water levels in the north, while impounding water in the southern end (Zaffke, 1983). As a result of overdrainage and a shortened hydroperiod, the area of WCA-3A located north of Alligator Alley has distinctly different vegetative diversity at both community and species levels, an increased frequency of severe muck fires. It has also been invaded by a number of terrestrial species (South Florida Water Management District, 1992; Zaffke, 1983). In contrast, the vegetation in the southern end is subjected to extended hydroperiods and increased water depths, which have resulted in an increase in slough communities and the destruction of many tree islands (Craighead, 1971).

As mentioned previously, another problem stemming from hydrologic alterations to the system is the introduction of nutrient-enriched agricultural runoff. There has been substantial research, predominantly in WCA-2A, to document and study P-induced changes in the native Everglades macrophyte community (Richardson et al., 1997; Doren et al*.,* 1996; Gleason et al*.,* 1975; McCormick et al*.,* 1999; Craft et al., 1995). This research has identified several species that demonstrate distinct responses to P enrichment. Comparative studies suggest these species-specific responses to eutrophication are similar in all areas of the Everglades (i.e*.,* WCA-1, WCA-2, WCA-3, the Park), though other factors, including differences in sediment type, hydroperiod, hydropattern and water quality characteristics, can confound these relationships (Payne et al*.,* 2001; Payne et al*.,* 2000; McCormick, 2001). Numerous studies have documented a link between increased P concentrations near inflows and displacement of native vegetation by the more competitive *Typha* (cattail) species (Davis, 1991a and b; Urban et al., 1993; Richardson et al*.,* 1997, Miao and Sklar, 1998). This is demonstrated in Water Conservation Area 3, where cattail grows in small stands along the western border near inflows from canals that drain agricultural lands to the west and adjacent to the S-339 structure, which receives agricultural drainages from the north (Davis, 1994). Additionally, an extensive cattail stand now exists near the confluence of the Miami Canal and the L-67A (Davis, 1994).

During March 2000, the SFWMD conducted a macrophyte study along the P gradient in WCA-3, extending from the L-28 Interceptor Canal toward the interior, comparable to the transect studies conducted in WCA-2 and WCA-1 (Payne et al., 2001; McCormick et al., 2000). Consistent with the previous studies, the purpose was to determine the effects of P enrichment on open-water slough habitats. However, limited data collection due to dry conditions and the less extensive nature of the P gradient in this area make the data difficult to interpret and make it impossible to derive a numeric P criterion from WCA-3 alone. The most significant deficiency of data exists for water column P, where hydrologic conditions during the study period prevented the collection of many samples. Since biological data are analyzed against measured P levels, the implications of the limited P data set during analyses must also be considered. Nonetheless, results indicate species-specific responses to P enrichment similar to those seen in WCA-1 and WCA-2. Cattail (*Typha)* frequency of occurrence (**Figure 5-16**) is 100 at the site nearest canal inflows (geometric mean TP of 136.3 µg/L), dropping to zero at the most interior stations (geometric mean TP concentrations less than 10 µg/L). *Eleocharis* sp. (spikerush) (**Figure 5-17**) demonstrates the opposite trend, with variable frequencies as high as 100 percent occurring at concentrations less than 28 µg/L and no occurrences at concentrations higher than 28 µg/L.

*Utricularia* (bladderwort), a sensitive native slough species, also responds negatively to increased P concentrations. Variable biomass values (as high as 169 $g/m^2$) are found at interior sites with concentrations below 10 µg/L (**Figure 5-18**). However, the amount of bladderwort drops off quickly with increasing TP levels, with no biomass detected at sites with concentrations exceeding 28 µg/L. *Nymphaea odorata* (water lily), a common floating slough macrophyte, exhibits increased growth and abundance at elevated P levels (**Figure 5-19**), peaking at moderately enriched sites before becoming shaded out by increased stands of emergent macrophytes (e.g., cattail) at higher levels of enrichment. The same response by *Nymphaea* to nutrient enrichment was demonstrated along the P gradients in WCA-1 and WCA-2 (McCormick et al., 2000; and Payne et al., 2001) and by FIU in their dosing-flume studies (FIU, 2000). Although water lily is a native Everglades specie, increased growth rates are detrimental to other species due to increased surface shading and decreased underwater light penetration that inhibits the growth of periphyton and submerged macrophytes.

## Everglades National Park

Historical accounts of vegetation in Everglades National Park indicate a prevalence of sawgrass marshes, hardwood tree islands, wet prairies and open-water sloughs (Davis, 1943; Willoughby, 1898; Craighead, 1971). Wetland species commonly identified included spike rushes, beak rushes, sawgrass and maidencane (Craighead, 1971; South Florida Water Management District, 1992). A study of pollen assemblages from a Taylor Creek core by Willard and Holmes (1997) shows that marsh and slough vegetation, primarily sawgrass, was the dominant vegetation in the area for most of the last two millennia until about 1950 to 1960. Their results indicate that around that time, sawgrass pollen declined to lower abundances than recorded elsewhere in the core (with tree pollen becoming much more abundant) as a result of hydrologic alterations to the system in the last century. These hydrologic modifications generally resulted in reduced freshwater inflows to the Park and modified flow paths. However, instances of hardwood mortality due to unnatural flooding were also reported (Craighead, 1971).

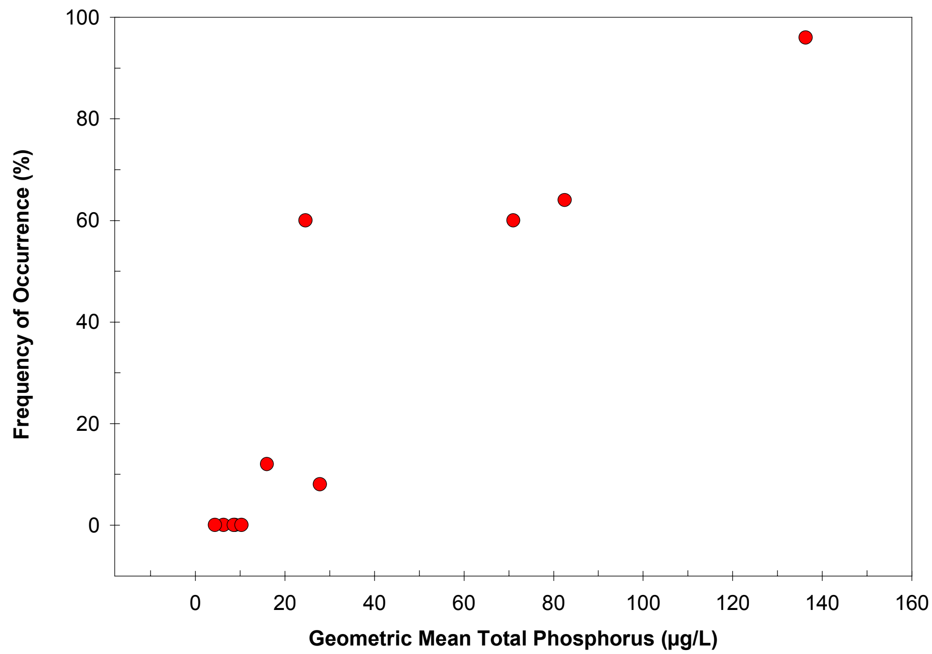


**Figure 5-16.** *Typha domingensis* (cattail) frequency of occurrence at open water sites along the SFWMD transects in WCA-3A. Data were collected during one sampling event in March 2000.

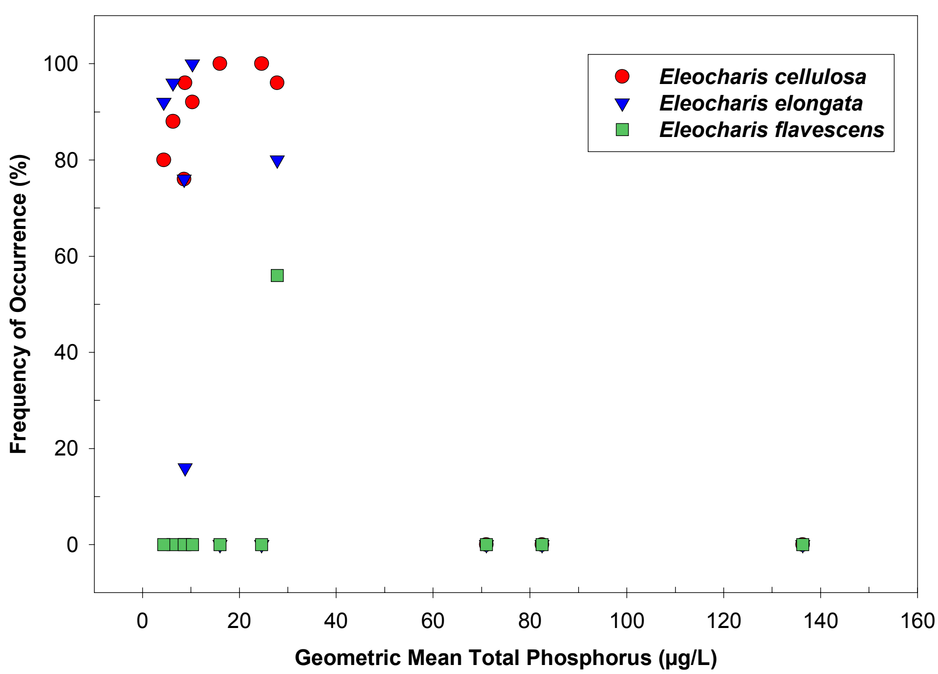


**Figure 5-17.** *Eleocharis* (spikerush) frequency of occurrence at open water sites along the SFWMD transects in WCA-3A. Data were collected during one sampling event in March 2000.

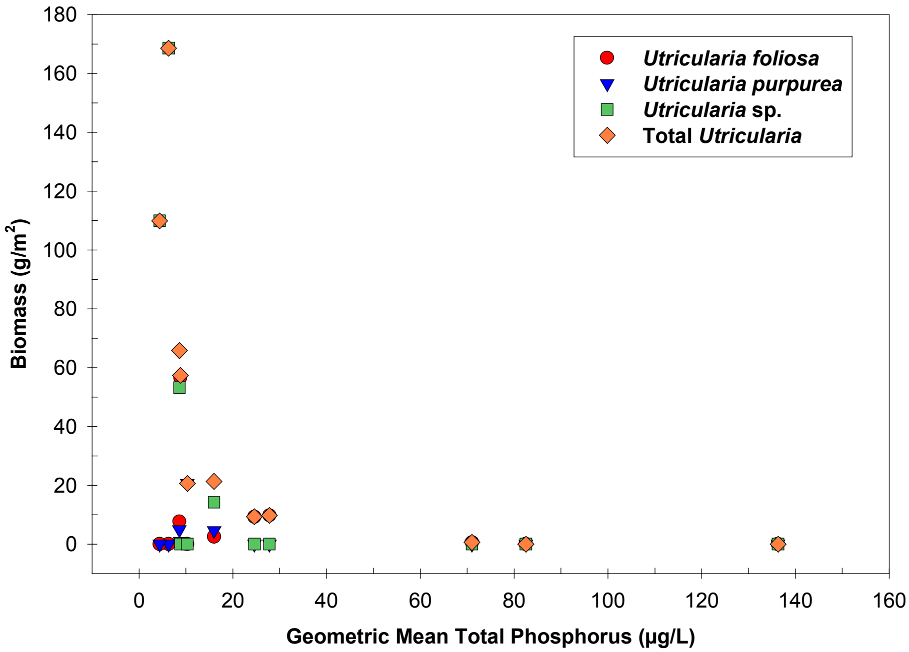


**Figure 5-18.** *Utricularia* (bladderwort) biomass at open water sites along the SFWMD transects in WCA-3A. Data were collected during one sampling event in March 2000.

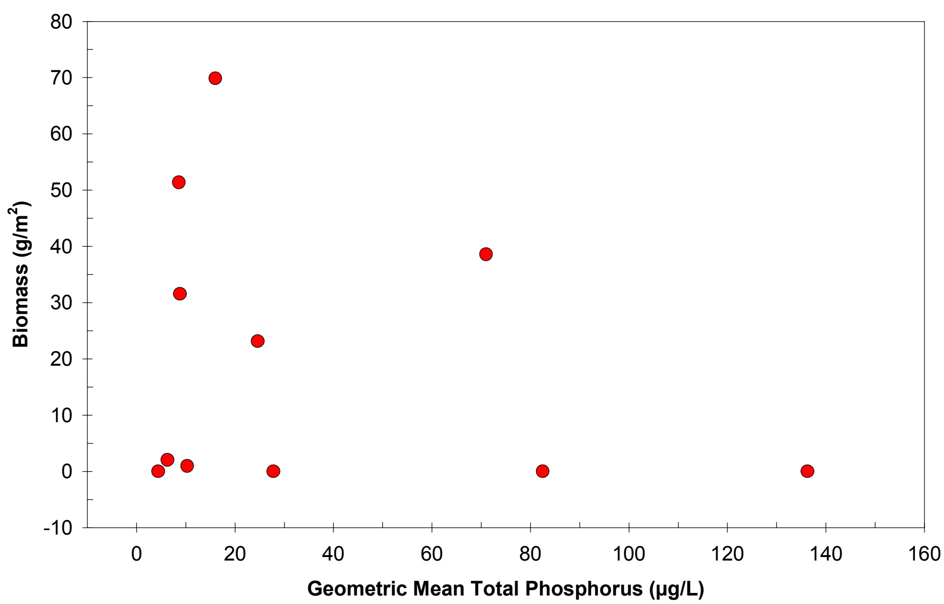


**Figure 5-19.** *Nymphaea* (water lily) biomass at open water sites along SFWMD transects in WCA-3A. Data were collected during one sampling event in March 2000.

Unlike the Everglades areas previously discussed (i.e., WCA-2, WCA-1 and WCA-3), the area within the Park impacted by P-enrichment is limited. However, localized areas of minimal impact have been documented (Davis et al., 1987; Flora et al., 1987; Doren et al., 1996). In 1987, Davis et al. reported cattail expansion had been observed to the west of the L-67 Extension Canal in the Park and was attributable to increased nutrient concentrations emanating from the canal. Limited data on the extent of these P-induced vegetative changes in the Park currently exist.

A study similar to that described for WCA-3A was initiated in Taylor Slough during October 1999. To date, analysis of the limited data collected along the Taylor Slough transect shows no consistent P-induced trends in the macrophyte community. The lack of response in the macrophyte community is likely a reflection of the relatively low P concentrations observed in both the surface water and sediment along the transect. Even the higher geometric mean TP concentrations reported for the two sites nearest the canal result from one or two anomalously high measurements and may be the result of drought conditions, rather than a reflection of prevailing conditions. However, the available data does indicate the freshwater portions of the Park contain many of the same species found in other areas of the Everglades. Additionally, nothing in the available data indicates that the same macrophyte species exhibit differing levels of sensitivity across areas.

A study conducted by the National Park Service on the vegetation of Shark Slough in the northern portion of the Park (National Park Service, 1997) describes the area to be similar to the historical accounts. In describing the findings, the report states that, "Even though the total area of sawgrass marsh is large, the apparent uniformity is interrupted by hundreds of tree islands and, over large areas, masks a mosaic of marsh communities…." The report goes on to describe the extensive periphyton mats, which "usually envelop and combine with well-developed *Utricularia* (usually *U. foliosa* and *U. purpurea*)…." Transect analysis conducted as a part of this study found that sawgrass covered approximately 45 percent of the area, followed by spikerush/sawgrass with 14 percent, tall sawgrass with 13 percent, spikerush with 10 percent, spikerush/maidencane with 6.6 percent and the remaining area composed of a variety of bush and tree communities. A Landsat Thematic Mapper vegetation cover map of Taylor Slough, Everglades National Park, classified the dominant wetland marsh communities as sawgrass/rush, 30.9 percent; sawgrass/bunchgrass, 3.4 percent; sawgrass, 12.9 percent; and rush, 19.1 percent (Carter et al., 2000). In 1989, Gunderson reported that *Cladium jamaicense* was the dominant species at four out of five sites, with relative abundances ranging from 48 to 95 percent. *Typha* was found at only one of the five sites, with an abundance of eight percent. All these descriptions of the vegetative communities present within the Park are comparable to those documented for the other areas of the Everglades, with similar P-sensitive and P-tolerant species being identified at similar frequencies, as well.

## DISSOLVED OXYGEN

Dissolved oxygen (DO) has been considered a sensitive indicator of the biological status of ecosystems because its production is largely controlled by the existing periphyton and submerged aquatic vegetation. Therefore, alterations in the dissolved oxygen regime within an area reflect changes in the status of the communities responsible for its production and consumption. Dissolved oxygen concentrations in macrophyte- dominated wetland environments, such as the Everglades, exhibit wide diurnal fluctuations due to natural processes of photosynthesis and respiration. In open-water slough communities where light penetration is high, high photosynthetic rates by periphyton and submerged aquatic vegetation lead to increasing oxygen concentrations during daylight hours, reaching a maximum near sunset. In contrast, dissolved oxygen concentrations plummet during the night, reaching a minimum within a few hours of sunrise due to respiration, biochemical oxygen demand and sediment oxygen demand. Under natural conditions, oxygen production exceeds respiration during the photoperiod, allowing the accumulation of an oxygen reserve, which prevents concentrations from decreasing to extremely low levels at night (Weaver et al., 2001).

However, under P-enriched conditions a depressed dissolved oxygen regime with less fluctuations throughout the diel cycle result from changes in the biological community, increases in biochemical oxygen demand and sediment oxygen demand and, ultimately, decreased light penetration caused by increased growth of emergent macrophytes. Subsequently, the dissolved oxygen regime adversely affects the macroinvertebrates, fish and other aquatic animals dependent on DO for survival.

## Water Conservation Area 3A

Diel DO measurements were collected by the District at 10 of the WCA-3A transect sites over three periods in 2000 (March, September and November). However, a majority of the sites, including 3A10E, 3A15E, 3A20E, 3A40E and 3A10W, were sampled only during the November 2000 period. As has been discussed for other parameters, the utility of the DO data from WCA-3A for P-criterion development is limited, since the minimal amount of data available probably does not reflect the full range of system variability. In particular, Everglades DO exhibits seasonal variability that requires multiple sample periods within each season (i.e., multiple years) to be adequately characterized. Despite these limitations, diel DO data from WCA-3A appear to exhibit a similar response, as was noted in WCA-2A and WCA-1 (Payne et al., 2001). Dissolved oxygen data from WCA-3A were summarized as daily minimum, mean and maximum for dates with a complete data set (i.e., 24-hour period). All three measures demonstrate a similar inverse relationship with TP concentrations (**Figure 5-20**). At TP concentrations above 10 µg/L, the diel DO regime is depressed, with concentrations rarely exceeding 2.0 mg $O_2$/L and nightly minima well below 1.0 mg $O_2$/L. Below 10 µg P/L, sites exhibited wide daily fluctuations similar to those observed in the minimally impacted areas of WCA-2A and WCA-1. The available WCA-3A DO data support the conclusion that the biological communities in WCA-3A are comparable to those in other areas of the Everglades and exhibit sensitivity to similar levels of P enrichment.

## Everglades National Park

Taylor Slough diel DO measurements were collected in March 2000, September 2000 and February 2001. However, data collected during the September 2000 period failed the oxygen-probe post-calibration test and therefore are not suitable for criterion development. Furthermore, during the March 2000 period, measurements for sites TS-05E, TS-34, MESO-N and MESO-S only were collected, with only MESO-N and MESO-S being monitored during the February 2001 sampling event. Due to the paucity of data down the gradient, it is currently impossible to accurately characterize the DO response to P enrichment in Taylor Slough. However, average minimum, mean and maximum daily DO concentrations for the available dates and sites ranged from 0.6 to 5.5 mg/L, 3.6 to 6.7 mg/L and 5.6 to 8.2 mg/L, respectively. The lowest minimum and mean daily concentrations occurred at TS-34 during the March 2000 sampling. As a point of comparison, average minimum, mean and maximum daily DO from the WCA-2A reference sites (F5, E5, U1, U2 and U3) ranged from 2.9 to 3.6 mg/L, 4.6 to 5.6 mg/L and 6.7 to 7.7 mg/L, respectively, for sampling events conducted between April 1995 and January 2001. The available diel DO results from Taylor Slough generally fall within the range of results from the WCA-2A reference sites, though the high end of each range in Taylor Slough tends to be slightly higher.

This variation at the high end of the ranges is likely due to hydrologic, vegetative and period-of-record differences rather than different responses to P enrichment. Taylor Slough is dominated by larger expanses of open water and slough communities and less emergent vegetation (cattail and sawgrass) than WCA-2A. The less-dense vegetation allows more sunlight to penetrate to the water's surface, allowing for more photosynthetic activity and oxygen production by the SAV and periphyton communities and resulting in lower oxygen demands.

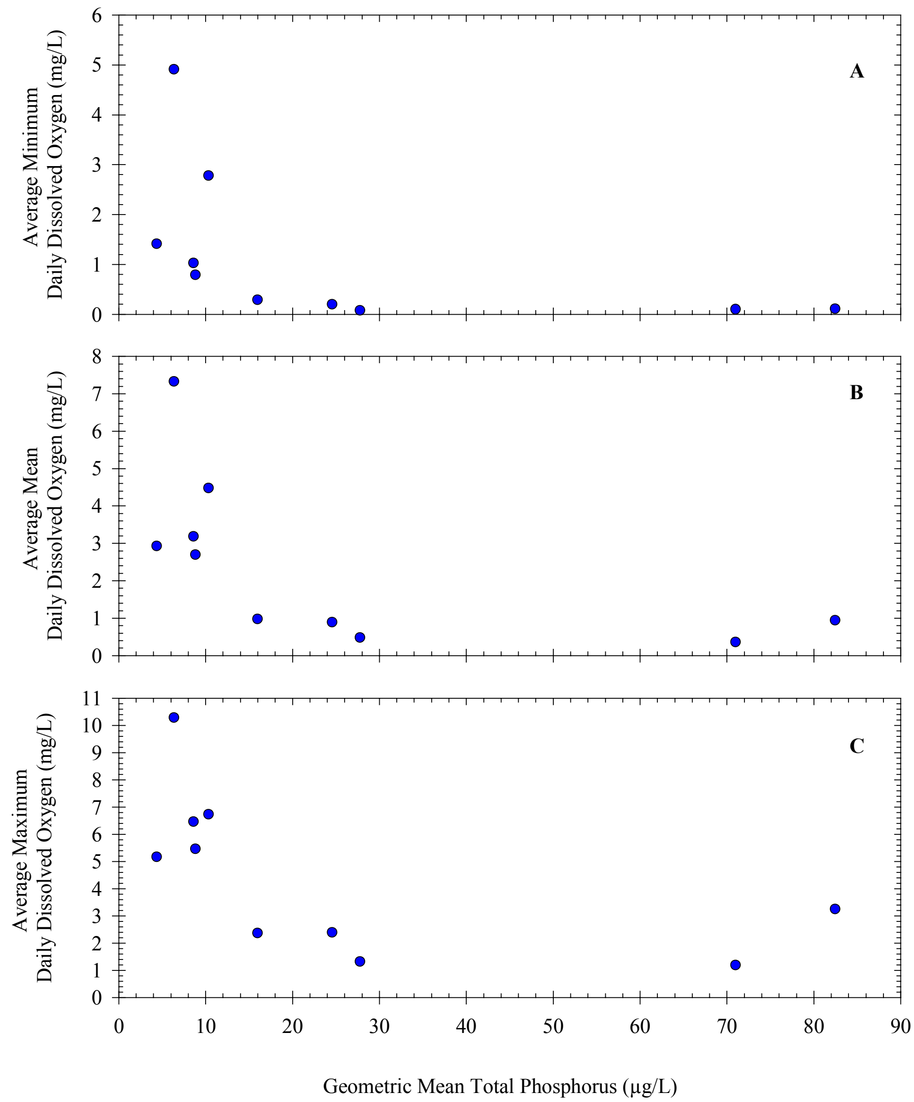


**Figure 5-20.** Relationship between geometric mean TP concentration and minimum (A), mean (B), and maximum (C) diel DO concentrations along the SFWMD transects in WCA-3A; for DO only, dates with complete 24-hour periods of record were included

## CONCLUSIONS

The results of an evaluation of the limited chemical and biological data collected along the District P-gradient transects in WCA-3A and the Park are presented in this chapter. Based on the results of this evaluation, well-defined P gradients are apparent in WCA-3, with minimal levels of P enrichment being observed in the Park, especially adjacent to the S-332 inflow. Additionally, the biological communities (periphyton and macrophytes) present in WCA-3A and the Park appear to be very similar to those found in WCA-2A and WCA-1, with nearly all the taxa identified in WCA-3 and the freshwater portions of the Park also being documented in the northern areas. Even though the sparse amount of data available for WCA-3A and the Park does not allow for a definitive determination of a P-threshold concentration for these areas, analysis of the data suggests that the biological response is comparable to that documented for WCA-2A and WCA-1. Therefore, a P criterion based on the exhaustive evaluations conducted for WCA-2A and WCA-1 would be protective of the flora and fauna throughout other freshwater portions of the Everglades.

# STATUS OF PHOSPHORUS CRITERION DEVELOPMENT

The EFA requires that the Department and the District complete research necessary to establish a numeric P criterion in the Everglades Protection Area by December 31, 2001, by which date the Department is also required to file notice of rulemaking to establish such a criterion. If the Department does not adopt a P criterion by December 31, 2003, the EFA establishes a default criterion of 10 μg/L. The EFA also specifies that the Department's P criterion not be below background conditions in the EPA, while taking into account natural spatial and temporal variability. The EFA also specifies that compliance with the P criterion shall be based on a long-term geometric mean of concentration levels measured at sampling stations representative of receiving waters in the EPA.

**Figure 5-1** provides a pictorial summary of the results of the P-criterion development efforts in WCA-2A and WCA-1. The Department has conducted an extensive evaluation of the biological and chemical data collected along the District P-gradient transects in WCA-2A and WCA-1, with less exhaustive evaluations being conducted for WCA-3A and the Park due to a general lack of sufficient data. Based on the results of these evaluations, a group of ten stations (five from WCA-2A and five from WCA-1) were identified as being representative of the conditions occurring within the minimally impacted portions of WCA-2 and the Refuge. The median annual geometric mean TP concentrations for the reference stations were determined to be 8.6 and 9.2 μg/L for WCA-2A and WCA-1, respectively. To establish a criterion based on this data, an upper bound must be established for this value, taking into account the natural spatial and temporal variations in the P concentration as directed by the EFA but without being so high as to allow imbalances in the native flora and fauna. Preliminary efforts by the Department to determine an appropriate upper limit suggest an annual geometric mean in the 10 to 11 μg/L range, which is supported by the limited data from WCA-3 and the Park. However, several significant issues related to the effects of water level and sampling methodology must be resolved before further advances can be made in defining the upper concentration limit.

Likewise, the DUWC researchers have evaluated the data collected from their flume study in WCA-2A to recommend a P threshold in the range of 17 to 22 μg/L, but they have not attempted to define a lower confidence limit for this range. Additionally, based on the Department's review of the DUWC work this range appears to be biased somewhat high. However, the DUWC data do indicate that the EFA default criterion of 10 µg/L would be protective of the natural flora and fauna without being overly protective or below background levels.

Additionally, the U.S. Environmental Protection Agency has approved the 10 µg/L water quality standard adopted by the Miccosukee Tribe of Indians of Florida, which applies to tribal waters located within WCA-3A. The approval was made based on a review of Everglades studies to determine reference conditions in the area and an evaluation of the effects of P enrichment on various components of the ecosystem. The EPA determined that the 10-µg/L standard was a scientifically defensible value that is not overly protective and yet is sufficiently protective of the water's designated use.

The information evaluated by the Department relative to the development of a numeric P criterion indicates that the EFA default criterion of 10 µg/L would be protective of the natural flora and fauna in the Everglades Protection Area (EPA). Additionally, given the various sources of natural ecosystem variability, laboratory and statistical method uncertainty, as well as other factors causing variability in the research and monitoring results, it is unlikely that additional research will identify a significantly different TP concentration that would be protective and technically-defensible.

## REMAINING CRITERION ISSUES

The expected P water quality standard for the Everglades consists of several parts, one of which is the numeric criterion. Though a numeric P criterion of 10 µg/L has been recommended based on the results of the Department's evaluation of the existing data from all portions of the Everglades, and though it is thought to be highly defensible, there are several issues relating to the P standard that are as important as the numeric criterion and still need to be resolved. Most of the remaining issues focus around the compliance test and how compliance with the standard will be achieved.

The effectiveness of the numeric P criterion in preventing imbalances within the Everglades biological communities will largely depend on how the criterion is applied. For the criterion to achieve the desired result, the compliance measurement methodology needs to be sensitive to changes in P levels without being too restrictive. Therefore, the compliance test should also account for natural variability (temporal, spatial, depth, etc.). The EFA specifies that, "Compliance with the phosphorus criterion shall be based upon a long-term geometric mean of concentration levels to be measured at sampling stations recognized from the research to be reasonably representative of receiving waters in the Everglades Protection Area, and so located so as to assure that the Everglades Protection Area is not altered so as to cause an imbalance in natural populations of aquatic flora and fauna and to assure a net improvement in the areas already impacted. For the Everglades National Park and the Arthur R. Marshall Loxahatchee National Wildlife Refuge, the method for measuring compliance with the P criterion shall be in a manner consistent with Appendices A and B, respectively, of the settlement agreement dated July 26, 1991, entered in case No. 88-1886-Civ-Hoeveler, United States District Court for the Southern District of Florida, that recognizes and provides for incorporation of relevant research." The Department is currently evaluating potential compliance methodologies to ensure long-term progress toward compliance with the P criterion for the EPA, while protecting the unimpacted or minimally impacted areas and assuring the already impacted areas show a net improvement during the interim implementation period.

The EFA recognizes the importance of relating the water discharged to the EPA to the resulting water quality in the receiving waters of the EPA downstream of the inflows. Further, the EFA directs the Department and District to define and use these relationships to establish discharge limits for permitted discharges to the EPA to assure that the receiving waters will comply with the P criterion. The primary discharge to the EPA will be from the Stormwater Treatment Areas (STAs), which are treatment wetlands that treat the water from agricultural and urban areas prior to being discharged to the Everglades.

Research is currently being conducted to optimize Advanced Treatment Technologies (ATTs) with the goal to reduce the TP concentration in EPA discharges to 10 µg/L or less (Chapter 4). To date, ATT research has focused around two basic treatment methodologies (i.e., chemical and biological treatment) to remove P from water moving through the STAs. The chemical ATTs involve adding iron and/or aluminum salts at various levels to chemically bind the P into a precipitate that is subsequently removed by filtration or settling. The biological ATTs use uptake by emergent macrophytes, submerged aquatic vegetation (SAV) or periphyton (PSTA) to remove P from the water as it flows through the STAs. Phosphorus in the biomass is then sequestered through natural peat accretion.

The status of the ATT research indicates that the chemical treatment technologies may achieve P levels below 10 µg/L. However, they do so at a great expense (high initial cost and continued operating expense) and risk of environmental problems associated with handling huge volumes of chemicals and residuals. Additionally, the chemical treatment process may significantly alter the chemistry of the water through removal of constituents other than P. Some of the most notable changes include decreased levels of total dissolved solids, color, pH, TOC, alkalinity and hardness, and increased levels of iron, aluminum and chloride (Coffelt et al., 2001; Chapter 4C of this report). The long-term biological significance of these changes is not well understood at this time. Currently, the P concentrations likely to be achieved by the more environmentally friendly biological, or "green," ATTs (STAs, SAV and PSTA) are above the 10 µg/L EFA default P criterion, but less than approximately 25 µg/L. The overall effectiveness of the biological ATTs is expected to improve as more information is obtained concerning their optimal implementation. A more thorough discussion of ATT research and findings can be found in Chapter 4 of this Report.

The biological ATTs are preferred over chemical treatment for general widespread application due to their lower cost and the limited environmental risk associated with their implementation. However, at this time it appears the use of the biological ATTs will result in an area adjacent to the inflows that has TP concentrations above the 10 µg/L criterion.

## FUTURE SCHEDULE

During July 2001, the Department published a Notice of Rule Development for the numeric P criterion for the Everglades. The Department is currently attempting to resolve the remaining issues concerning the development of the criterion and the associated compliance methodology through workshops with interested parties. Workshops have been conducted on August 23 and 24, September 20 and 21, October 2 and 3 and October 18 and 19, 2001, with an additional workshop scheduled, as needed, during November 2001. It is anticipated that a Notice of Proposed Rulemaking will be published by December 2001, with subsequent approval by the Environmental Regulatory Commission.

# RECOVERY RESEARCH

As previously mentioned, much of the threshold research efforts in WCA-2A and the Refuge have been refocused to examine the recovery of the system as the P concentrations are reduced. The Department, District and agricultural interests are currently developing a plan for a large-scale demonstration project to evaluate potential methods of expediting the recovery of the biological communities in the impacted areas. The primary objective of the project is to accelerate the replacement of the cattail monocultures in the impacted areas with more diverse communities consisting of native Everglades flora and fauna. Current knowledge suggests that a combination of fire to eliminate the existing cattail, and manipulation of the hydrologic regime to promote the establishment of more desirable species and prevent reestablishment of the cattails, will likely be needed in conjunction with the reduction of P levels to successfully promote the system's recovery (Richardson and Huvane, 2001). More details concerning these efforts will be provided in future reports as the scope of work for the project is developed and implemented.

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