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**Florida International University
Southeast Environmental Research Center**

and

**United States Department of the Interior
National Park Service
Everglades National Park**

**Evaluation of the Potential Use of Periphyton-dominated Storm Water
Treatment Areas (PSTAs) for Phosphorus Reduction in the Southern
Everglades**

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By

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Summary

Current design criteria for macrophyte-based STAs are expected to yield effluent TP concentrations of $50 \mu\text{g L}^{-1}$. This is five times greater than the $10 \mu\text{g L}^{-1}$ TP generally believed to be the background TP concentrations in pristine Everglades. We propose that periphyton-dominated areas be evaluated as a means of reducing the P content of water entering the Everglades to the background level of $10 \mu\text{g L}^{-1}$. The purpose of this project is to determine the feasibility of periphyton-based STA technology by addressing the following questions: (1) what mass P has accumulated in the existing periphyton since berm removal, (2) how does periphyton growth stage affect the rate of P accumulation within it, (3) how does the hydroperiod (and seasonality) affect growth, structure, and P retention of periphyton, (4) what is the efficiency of P removal as affected by the distance from the source (5) how does the hydraulic retention time affect the periphyton growth rate and efficiency of P removal, (6) what effect does periodic drying have on P release, and (7) how do variations in P concentration affect uptake rates. The field research will be carried out at the southern edge of the C-111 canal in the levee removal area. This site is characterized by the presence of abundant, distinct, coherent benthic mats (epipelton) and sporadic growths of floating periphyton (metaphyton). Field studies will be augmented with laboratory experiments where periphyton will be manipulated under controlled conditions to determine processes and mechanisms. Periphyton, water, and marl samples will be collected. Analysis will include chemical, biological, and taxonomic composition where appropriate.

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Introduction and Project Background

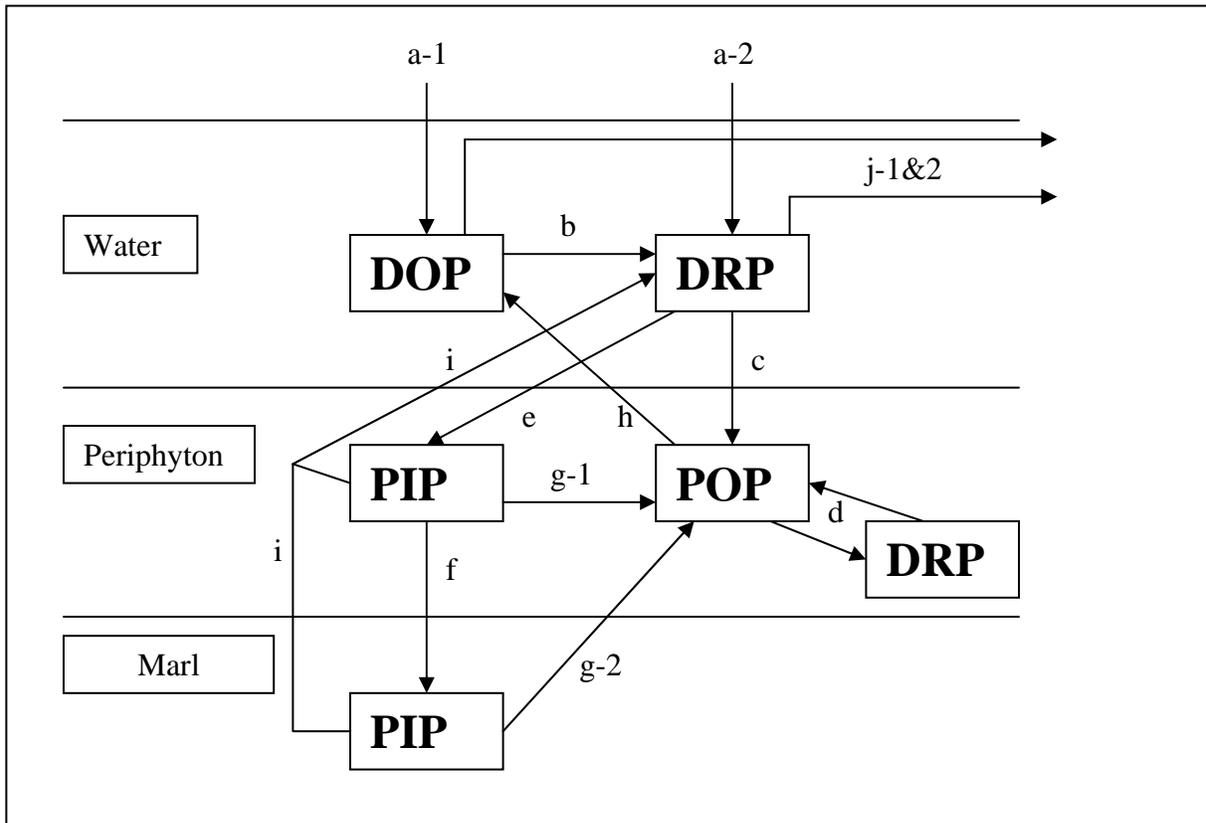
Phosphorus has generally been identified as the nutrient limiting the productivity of the Everglades ecosystem. Increased loading of P to the Everglades is suspected in causing numerous changes including increased heterotrophy of the system, changes in periphyton composition and function, and the encroachment of cattail in areas historically dominated by sawgrass. The water supplied to the Everglades to aid in the reestablishment of “more natural” sheet-flow contains P in excess of historic P loads.

Periphyton-dominated storm-water treatment areas have been proposed as a means to reduce excess P from water being supplied to the Everglades. Periphyton-dominated areas of the oligotrophic Everglades typically contain P at levels $< 10 \mu\text{g L}^{-1}$. There have been relatively few studies concerned with P and periphyton in the Everglades. Most previous work sought to identify periphyton species composition and compositional changes with variations in P supply (McCormick and O'Dell 1996; Vymazal et al. 1994). The mechanisms and rates of P uptake by periphyton have recently been studied (Scinto 1997). There have been a few attempts at evaluation of intensely managed periphyton systems for wastewater treatment (Adey et al. 1993). However, the cycling of P in periphyton-dominated systems can be complex, involving numerous interactions between biotic and abiotic components. How these interactions vary with changes in physicochemical conditions, which possibly can be manipulated for increased P sequestration, deserves serious attention. The purpose of this project is to identify the mechanisms involved in P cycling in periphyton-dominated areas underlain by limestone and to determine design conditions where surface water P removal is maximized.

We propose to conduct several field trials in the area of spoil mound removal adjacent to the C111 canal. Field trials will be augmented with laboratory studies when needed. Three major components exist in this system: the water, the periphyton, and the substratum. The movement of P between these components, especially regarding P removal from the water will be studied.

The hypothetical P cycle in this three-compartment system involves a complex set of interactions (Fig. 1). Phosphorus in dissolved form, either organic (dissolved organic P, DOP) or inorganic (dissolved reactive P, DRP), enters the systems as canal discharge and as wet and dry deposition (a-1&2). Dissolved reactive P is the P form most easily used by living organisms. Under P-limited conditions the enzymatic hydrolysis of organic P forms to dissolved inorganic forms (mineralization) can be rapid (b). Phosphorus removal from the water column occurs by competing biotic and abiotic mechanisms. Biotic removal mechanisms include the incorporation of P into the biomass of periphytic organisms (c) forming particulate organic P (POP). Internal cycling of P occurs within the mat, the magnitude of which increases with mat age and development (d). Abiotic mechanisms include adsorption/coprecipitation (e) occurring between P and the surfaces of marl substratum or calcite crystals biogenically produced in the periphyton matrix (due to the photosynthetic activity of calcareous cyanobacteria) or to calcite precipitated in the water column. These forms are considered particulate inorganic P (PIP). Calcite and associated P settles to the substratum surface or is deposited as crusts during dry periods

(f). Phosphorus associated with solids may remain bioavailable i.e. a substantial portion of adsorbed P may move from PIP into the biota when demand is high (g-1&2).



Numerous mechanisms release P to the water column. Living tissue decays losing nutrients stored within cells. If not sequestered by other organisms or adsorbed to a solid this P is released to the water column (h). Physicochemical variations can cause release of abiotically bound P. Periods of relatively clean water, i.e. water with P concentrations lower than that in equilibrium with adsorbed P, can cause desorption. Changes in pH or alkalinity can cause the dissolution of calcite with subsequent release of associated P (i). Finally, P is exported from the system in the effluent water (j-1&2).

Objectives

The overall objective of the proposed work is to quantify the rates and amounts of P sequestered by each of the several retention mechanisms during different seasons, hydrologic conditions, and management manipulations. Specifically, we will assess the effects of: periphyton growth stage, photosynthetic activity, hydroperiod, water depth, adsorption/coprecipitation processes, hydraulic retention time (HRT), and harvesting rates on P removal.

We plan to conduct a series of field and laboratory tests at several spatial and temporal scales. Field stations will be located south of the C-111 canal on limestone substrata exposed as a result of spoil mound removal. Three sites will be selected according to physical conditions and experimental objectives. Three manipulated units of different scales will be used to determine processes and rates important in P removal from the water column. These are: i) large scale harvestable plots for long-term and gross estimates, ii) small enclosure plots and experimental channels for diurnal analyses, tracing studies, and mass balances, and iii) laboratory scale experiments for mechanistic determinations and comparisons.

Site Description

The C-111 canal was dredged to aid in flood protection for the extreme southern portion of mainland Florida. As a consequence a berm 10-20 ft high was created on the southern edge of the canal that restricted water flow into the Everglades National Park (ENP) Panhandle Region. This berm was later punctuated with 50 gaps to allow some water flow although inundation of this area continued to be greatly restricted. A product of Everglades Restoration efforts has been to remove the C-111 berm thereby restoring water to the ENP panhandle. The berm removal project, a joint activity between the Army Corps of Engineers (ACOE) and the South Florida Water Management District (SFWMD) was initiated in 1995 and with most of the levee being removed in 1997. The levee removal was completed by November 1997. During the process of berm removal the overburden was removed to the level of the limerock substrata. Overburden was deposited in the areas that previously were gaps in the berms. These manipulations resulted in areas of nearly flat hard limestone punctuated with soft areas of relatively unconsolidated material. Dramatic growth of periphyton has occurred on the levee removal area since the project completion in 1997.

An initial survey was conducted on September 25, 2000 to assess conditions and identify site characteristics for this study. Four locations were visited, the first located at the western end of the levee removal area proximal to the S-18C structure with the remaining lying east of this. At each site water levels were measured and periphyton samples were collected. Water depths were collected by walking a transect perpendicular to and starting at the canal with each successive measurement being spaced by approximately 3m.

Table 1. Water depths at four sites in the C-111 levee removal area on September 25, 2000.				
	Mean (cm)	Min. (cm)	Max. (cm)	n
Site 1	51	42	70	11
Site 2	44	35	57	12
Site 3	12	9	15	5
Site 4	15	10	21	9

The water depths are greater towards the western side of the levee removal area and become more shallow moving eastward towards the S-197. Distinctly different periphyton forms exist at the “deep” water sites as compared to the shallow water sites.

Site 1 is located approximately 200 m east of the meteorological station. The substrate is rocky limestone with some pebbles. There is not a distinct coherent benthic mat (epipelon) but instead is a friable, loose accumulation of golden-brown periphytic material overlying a black more highly decomposed flocculent detrital-like material (floc). Floating periphyton mats (metaphyton) were present and are associated with *Utricularia gibba*. Macrophytes, (*Eleocharis* spp. and *Typha* spp.) are present and are easily uprooted. Some areas consist of organically enriched, very soft, muddy material, which is likely a result of saturated overburden filling and not of pedogenesis.

Site 2 is east of site 1 at the small boat dock. As with site 1 the benthic periphyton is a loose accumulation of golden-brown “oatmeal”. The benthic periphyton (0.5 – 1.0 cm) overlies a black floc-like layer (3 – 4 cm), which overlies a marl layer. This site is more sparsely vegetated than site 1 and has higher vegetation evenness. Vegetation includes *Eleocharis*, thin-bladed *Saggeteria*, and a prominent bed of *Chara* (not heavily encrusted).

Site 3 is approximately 200 m east of the dock. The substrate is hard limerock with shallow water. A very cohesive, stratified epipellic mat exists (Fig. 2). A subsample of this material had a freshweight bulk density of 0.869 g cm⁻³, a dry bulk density of 0.169 g cm⁻³, and a water content of 80.5 %.

Site 4 was several hundred meters east of site 3 and was very similar in characteristics. This site had the most cohesive of mats seen this day. Epipelon (2 cm) overlies a hard limerock substrate in shallow water. Visual inspection of a subsample under a dissecting scope (20x) showed seven distinct layers, which varied from a light-brown surface covering thick green and ending in black organic material. Fresh weight bulk density was 0.752 g cm⁻³ with a water content of 74.7%.



Fig. 2 Cross section of epipellic mat from site 3

Site characteristics, especially concerning benthic periphyton, are obviously influenced by hydroperiod. The mean water depths at each site were used in conjunction with stage recorded at the downstream side of S-18C (SFWMD data in meters NGVD) to estimate hydroperiods (Fig. 3). The upstream sites (Sites 1 and 2) were generally inundated for approximately 8 months during the period from mid July 1999 through the end of February 2000 with water depths averaging just over 30 cm. Conversely, the downstream sites (Sites 3 and 4) were only inundated for approximately 3 months during 1998 and 1999. Average water depths during these periods were around 25 cm. Site characteristics and hydrographs show that there is variation in conditions based to some extent on the depth and duration of water along the levee removal area. Although experiments may not be planned at these exact sites this information necessitates that research must include considerations for changing hydroperiods.

We will identify three separate locations along the levee removal area where we will conduct the bulk of our fieldwork. These areas will be outfitted with Hydrolabs, stage recorders, acoustic water velocity meters, and ISCO automated water samplers. Frequent monitoring of periphyton and water samples will allow assessment of processes that will aid in further adaptations and development of our work plan.

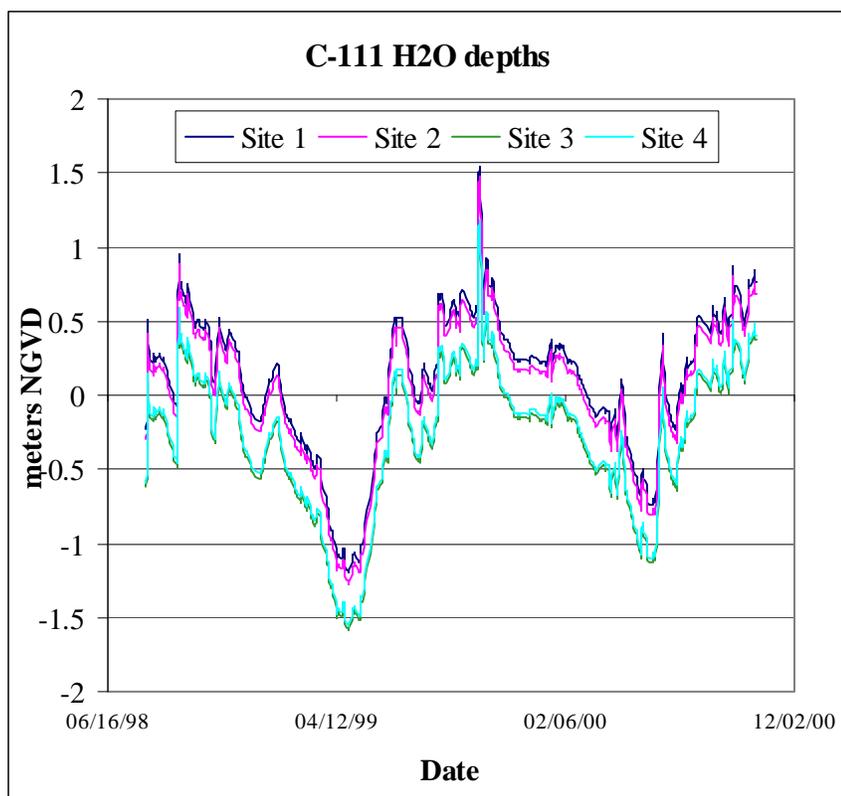


Fig. 3. Water stage data (SFWM) normalized to each of four sites along the C-111 levee removal area showing depth and duration of inundation.

Experimental Designs

Task 1. Quantification of phosphorus sequestered in periphyton in the C-111 levee removal area.

Processes leading to the accumulation of periphyton in the C-111 levee removal area began with the removal of the overburden. Since that time, water has periodically and for varying durations inundated the limestone substrata allowing the “natural” regrowth and development of epipelton. Regardless of variations in hydroperiod and prolonged drying, these areas have been acting as defacto PSTAs. That is, P contained in the standing stock of periphyton represents that removed from overlying water since levee removal.

This first experiment involves assessment and evaluation of the effects uncontrolled conditions have had on periphyton development and P accumulation. We can use this information to further develop our experimental plan. As previously suggested, elevational differences (thus hydroperiod) greatly affects periphyton. Our experiments must include adaptation in design such that variations in hydroperiod are acceptable. Samples collected during this initial survey will allow comparisons between periphyton of varying forms (i.e. dense cohesive mats vs. loose, friable accumulations vs. metaphyton) for the mass P accumulated per unit area. This information, when combined

with hydroperiod data, will enable evaluation of P accumulation efficiencies based on form. Additionally, periphyton can be analyzed and sampled, within a given elevation (water depth), with distance away from the canal to determine if gradients in nutrient concentrations are forming. That is, does the periphyton proximal to the canal contain proportionally higher mass of P than similarly inundated periphyton farther from the canal. If so does this lend credence to the development of flow-through systems for periphyton P removal.

Our experimental design is based on a grid oriented such that there are cells arranged in rows with increasing distance from the canal. The size of the grid and arrangement will vary depending on site conditions. Samples of periphyton will be collected from random cells within the grid for a given distance from the canal. Several small cores of known volume will be collected and composited from the grid cells. The number of core collected and composited will depend on an analysis of variation at the project initiation. Epipelton and, when present, metaphyton will be collected and quantified. Results will be compared to other cells from farther distances from the canal within a site to determine gradients. Cells at a given distance will be compared among the three sites to determine differences in hydroperiod and periphyton form. Periphyton from all cells will be used to determine mass P accumulated per unit area since berm removal.

Periphyton samples will be analyzed for bulk density (BD), biomass, water content (%H₂O), total P (TP), acid-extractable P (Ca-P), total C (TC), total inorganic C (TIC), total organic C (TOC), total N (TN), ash content (ASH), and Chlorophyll a (Chlor) content. Additionally, subsamples will be frozen and archived in the event that species composition is needed on selected samples.

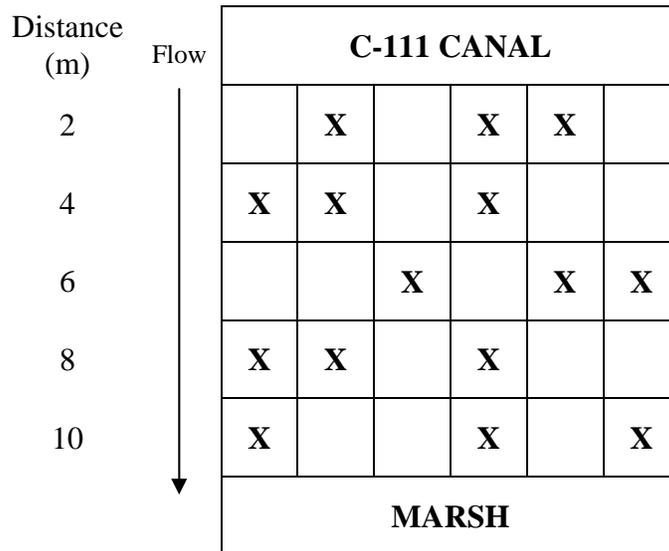


Fig. 4. Conceptual layout of initial periphyton monitoring and assessment study.

Task 2. Phosphorus accumulation in periphyton as affected by periphyton growth stage and seasonality.

Factors affecting P uptake by periphyton include: growth stage and size of the periphytic mat, physiological activity, water column and mat P concentrations, physicochemical conditions, and hydraulic retention times (Cotner and Wetzel 1992; Horner et al. 1983; Sand-Jensen 1983). In thin periphyton layers there is good exchange between the mat and the overlying water, the nutrient stores in the mat are small, and growth and productivity are relatively dependent upon allochthonous nutrient inputs (Wetzel 1993). As the mat becomes thicker and nutrient stores develop, periphytic organisms rely more heavily on internal nutrient cycling (Wetzel 1993). Water depth affects the growth and physiological activity of Everglades periphyton presumably due to reduced light levels (Gleason and Spackman 1974). Gleason and Spackman (1974) and Browder et al. (1994) suggest optimal conditions for the development of calcareous benthic mats in the Everglades occurs in water < 60 cm in depth.

Conditions that favor periphytic CaCO_3 encrustations and subsequent P coprecipitation are high Ca concentrations, high alkalinity, high pH, low partial pressure of CO_2 , high levels of CaCO_3 saturation, and high temperatures (Gleason and Spackman 1974; Browder et al. 1994; Otsuki and Wetzel 1972; House 1990). Precipitation of CaCO_3 in periphyton leads to biogenic marl formation and soil accretion (Gleason 1972). The efficacy of this abiotic process for the removal of P from the water column needs to be determined.

Periphyton growth and physiological activity have been shown vary seasonally in temperate lake littoral zones (Burkholder and Wetzel 1989). Seasonal variations in periphyton biomass were observed in the northern Everglades with highest biomass generally occurring during the wet season (McCormick et al. 1998). However, the seasonal biomass was also affected by variations in nutrient (P) supply.

At each of the three sites, cells within the grid (Task 1) will be scraped clean of all material that has accumulated since spoil mound removal. The cells will be oriented parallel to the canals and perpendicular to the direction of flow (Fig. 5). If a significant gradient exists in periphytic P contents with distance from the canal then a series of cells will be selected proximal to the canal and another series will be selected near the marsh. Cells will be assigned a treatment based on harvesting. Each cell is a replicate (3 per treatment) of one of four harvesting (growth stage) treatments. Harvesting rates are harvested: monthly (A), seasonally - 3 months (B), annually (C), and one treatment that is not harvested (D). Treatments will be randomly assigned to plots within a distance from the canal category. Several small cores of known volume will be collected and composited from the middle of each cell. The center of each plot (approximately 2 m^2) will be quantitatively removed according to the harvesting schedule. At this time any remaining periphyton and marl will be scraped and removed to again expose bare substratum. The harvesting schedule is set, regardless of hydroperiod or inundation.

Samples will be collected from all cells prior to a harvesting event and before and after major wetting and drying events (i.e. at the end of the dry and wet seasons, respectively based on stage information). The plot arrangement will include buffer zones surrounding each cell to minimize disturbance during sampling. The plots will then be left to accumulate material until the next harvesting.

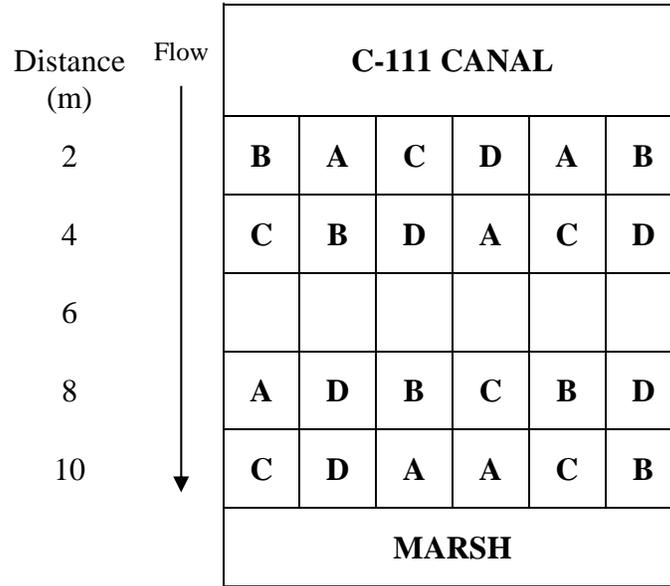


Fig. 5. Diagrammatic representation of large scale harvestable plots.

Plots will be measured for depth of water, periphyton, and marl at each sampling event. Periphyton samples will be analyzed for BD, biomass, %H₂O, TP, Ca-P, TC, TIC, TOC, TN, ASH, Chlorophyll a, and species composition (on selected samples or on composites). Marl will be analyzed for BD, %H₂O, TP, TC, TIC, TOC, and ASH. Surface water will be collected and analyzed for TP, dissolved reactive P (DRP), dissolved inorganic N (DIN = NO₃⁻ + NO₂⁻ + NH₄⁺), TC, TIC, TOC, TN, total dissolved C (TDC), dissolved inorganic C (DIC), dissolved organic C (DOC), and dissolved organic N (DON). Additionally, site equipment (autosamplers, stage recorders, etc.) will provide measurements of water dissolved O₂ (DO), electrical conductivity (EC), pH, temperature (°C), depth, and flow.

Initially the removed material will consist entirely of periphyton (epilithon). It is hypothesized that marl will be deposited on the limestone surface with time. The harvested plots yield information on the sizes of each of the P storage compartments with the relative age of periphyton development. We hypothesize that at any given time the mass of P stored in periphyton and marl will be greatest in the non-harvested plot but that the areal accumulation rates in mass P m⁻² day⁻¹ will be greatest at some intermediate stage of development. Phosphorus removal rates and mass P stored will change seasonally. During the summer, weekly or monthly growths of periphyton might incorporate P most rapidly whereas in winter there may not be sufficient colonization and growth in these short-harvesting intervals to allow the development of efficient P removal

mechanisms. The relative importance of retention mechanisms i.e. abiotic vs. biotic also may change with mat development and season. The harvested plots will enable comparisons of P removal mechanisms such that management decisions can be adapted to enhance abiotic vs. biotic P removal or vice versa. These plots will help determine harvesting frequency for the most efficient removal of P.

Task 3. Efficiencies of phosphorus removal by periphyton as affected by distance from source, variations in development, seasonality, and hydraulic retention time.

To assess probable design criteria for periphyton treatment areas it is necessary to quantify changes in P retention with increasing distance from a source. The harvested plots (Task 1) yield P retention per unit area. In Task 3 we seek to evaluate spatial differences in P removal rates in periphyton mats of varying degrees of development and seasonality and to determine the effects of water and velocity.

In addition to the grid set up for task 1, at the initiation of our research program, we will also establish 3 large (at least 10x10 m) areas adjacent to the grids at each of the 3 sites from which periphyton will be removed monthly, seasonally (dry season) and never. Establishing these areas at the initiation of the study will allow us to create experimental plots in subsequent years that have received various harvesting treatments for a sustained period. These plots can then be manipulated based on results from pilot and first year studies.

Experiments involving flow manipulations will depend on adequate flow rates from the C111 canal, through the levee removal areas and into adjacent marshland. These experiments may need to incorporate subtle manipulations in stage in the proposed reaches of the C111 in order to maintain adequate flow rates for the examination of hydrologic residence time (HRT) on periphyton P removal, an integral, critical component of PSTA research.

Once measurable flows ($>2 \text{ cm s}^{-1}$) are maintained at in the 3 levee removal sites we will be able to implement HRT experiments, including the following. We will establish three flow-through channels in each of the (i) frequently harvested, (ii) seasonally harvested and (iii) unharvested plots at each site. Channels will be walled by plastic sheeting anchored in sediment and will be approximately 5 m long and 2 m wide. Channels will be open at both ends to allow the free flow of water. Flow meters will be positioned at the head of each channel and rates will be adjusted at three levels (one HRT for each of the 3 channels in each harvesting treatment), which will range from $1-10 \text{ mm s}^{-1}$, $1-2 \text{ cm s}^{-1}$, $> 2 \text{ cm s}^{-1}$. Flow will be reduced and the systems isolated by installation of walls at the upstream and downstream ends.

Experiments within walled channels will include i) ^{31}P flow through each harvesting treatment at three HRT levels, ii) ^{32}P depletion and tracing with distance, iii) ^{32}P depletion curves from cores within each channel. The first experiment will be conducted over a 1-month period. Channels will receive ambient P concentrations ($10 - 30 \mu\text{g L}^{-1}$) and we will measure water column TP from the inflow, middle, and outflow of each

channel every two days. Hydrolabs will be used to record the diurnal variation in water physicochemical properties (pH, DO, EC, °C) at one location (middle) of each channel. Cores of periphyton mat will be taken weekly at 1-meter intervals down the length of the channels and analyzed for TP. Upon completion of the above work, a HRT will be chosen for flow and trace studies using additions of ^{32}P . A single ^{32}P addition will be made to each channel. Water samples and small (2.5 cm dia.) cores of periphyton will be collected at 1, 2, 4, 8, 12, and 24 h after introduction at 1, 3, and 5m. The periphyton will be digested by ashing for T^{32}P and extracted for dilute acid-extractable ^{32}P . Marl will also be collected and quantified, if present, and will be digested and analyzed for TP and T^{32}P . This, along with water data, should provide for a mass balance on ^{32}P and point to important mechanisms involved in P retention. Similarly, ^{32}P will be added to isolated columns within each channel and ^{32}P depletion from the water with time will be determined. Several depletion trials will be run throughout a 24 h period to determine diurnal variation in uptake and release. Periodic physicochemical measurements will be made in the columns. At the conclusion of a column depletion study, subsamples of water, periphyton, and marl will be collected and analyzed for ^{31}P and ^{32}P contents. Columns provide areal estimates of P removal/release with time and changes in physicochemical conditions.

Task 4. Phosphorus release rates from periphyton during drying

During seasonal periods of low water flow many relatively short-hydroperiod (flooded < 6 months per annum), periphyton-dominated, marl-forming areas undergo dry down. The periphyton mats become increasingly dry until there remain calcareous crusts on the surface of the substratum. It is important to know whether there is a release of biotically incorporated P during the dry down. Additionally, the crusts may adsorb a substantial portion of the biotically released P. An evaluation of the stability of P associated with the crusts especially during reflooding is important in understanding long-term retention mechanisms and seasonal P dynamics.

The flume and plot experiments should provide a framework where the dry down phenomena can also be studied. Crusts, and P within them, will be quantified on areal basis from the field sites. The fieldwork will be augmented with laboratory batch and aquarium studies. The stability of P in the crusts will be determined in laboratory desorption experiments. This will involve subjecting crusts to sequential extractions with P-free water and monitoring the appearance of P in solution.

Task 5. Periphyton phosphorus uptake as affected by variations in concentration.

In addition to the above tasks it is important to determine maximum uptake rates and how these rates are affected by P concentration. The above trials involve P removal at ambient concentrations (10 – 30 $\mu\text{g L}^{-1}$). We will collect subsections of variously aged periphyton and marl by intact coring and subject them to several P concentrations in excess of field concentrations. These trials will provide information as to the maximal capacity for periphyton removal of water column P. Scinto (1997) found in greenhouse

experiments using periphyton that the P uptake rate and capacity were at least partially dependent upon water P content and that uptake rates changed with continued P dosing.

Research Schedule

Rudimentary characterization of periphyton and site conditions has recently been completed. Initiation of tasks in this proposal will begin after acceptance of this work plan and when field conditions allow. We foresee 24 months of field and laboratory experimentation.

Analytical Protocols and Methods

Water

Where appropriate, unfiltered samples will be analyzed for pH, electrical conductivity (EC) (Method 2510, APHA, 1995), total carbon (TC), total inorganic C (TIC), and total organic C (TOC) via standard combustion techniques in a Shimadzu TOC analyzer (Method 5310, APHA, 1995). Total nitrogen (TN) will be analyzed on unfiltered samples via an Antek TN Analyzer Model 7000N. Filtered samples will be analyzed for total dissolved C (TDC), dissolved inorganic C (DIC), dissolved organic C (DOC) and dissolved organic N (DIN) as above. Dissolved inorganic N ($\text{DIN} = \text{NO}_3^- + \text{NO}_2^- + \text{NH}_4^+$), and dissolved reactive P (DRP) will be analyzed by standard colorimetric methods (Methods 4500-N and P, respectively, APHA, 1995). Water total P (TP) will be analyzed according to Solorzano and Sharp (1980).

Periphyton

Species composition will be determined by identification and enumeration of live algal cells on formalin preserved subsamples. Productivity will be measured by oxygen exchange in light and dark bottles (Wetzel and Likens 1992). Periphyton will be analyzed for Chlorophyll *a* content, and for bulk density, ash content, TC, TN, TP by methods similar to those used in marl soils (below).

Marl

Bulk density (Blake and Hartge 1986), ash content (Method D2974-87, ASTM, 1995) and soil pH (Thomas, 1996) will be determined. Soils will be dried, and analyzed for TC, TN, and TP. Total C (Nelson and Sommers, 1996) and TN (Bremner, 1996) will be analyzed by dry combustion in a Carlo-Erba Elemental Analyzer Model NA 1500. Total P will be determined after ashing according to the methods of Solorzano and Sharp (1980). The presence of CaCO_3 in marl warrants the determination of total inorganic C (TIC). TIC will be analyzed by ashing samples at 550°C (to remove organic C) then analyzing by dry combustion, as above. Total organic C (TOC) will be determined by difference.

Statistical Analysis

Statistical analysis will vary according to the experiments conducted.

Quality Assurance and Quality Control

All data will be analyzed under appropriate QA/QC.

Permit Requirements

All pertinent permits will be obtained.

Electronic Data Storage

The obtained data will be made available to scientific community through a web site that will be created and linked to the SERC web page (<http://www.fiu.edu~serc>). Documentation will be consistent with “Content standard for digital geospatial metadata, Part 1 “biological data profile” (http://www.fgdc.gov/standards/status/sub5_2.html).

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