Restoration Strategies Science Plan
Detailed Study Plan- Revised 8/3/2022

Phosphorus Removal Performance of Ecotopes in the STAs

OVERALL STUDY PLAN SUMMARY

The purpose of this study is to estimate the phosphorus (P) treatment performance of different ecotopes commonly found in Everglades Stormwater Treatment Areas (STAs). Ecotopes are contiguous homogenous vegetation communities of similar structure under similar abiotic conditions. In this study P treatment performance comprises two components, the first being the reduction in P concentration in the water column over a given distance (e.g. the length of the ecotope), the second is the lowest P concentration reached at the outflow of the ecotope. This study will provide much needed P treatment performance information at ecotope scale to guide STA management decisions critical to achieving the STA's mandated water quality-based effluent limit (WQBEL).

Data collected from the first year of this study suggests that there are differences in P treatment performance by ecotope and that these differences change seasonally. Additionally, STA discharge rate and water depth were identified as factors that influence treatment performance to a greater degree than ecotope type. More data is needed to strengthen evidence supporting the initial findings and estimate effects from these other hydrologic factors. In the second year of this study, data will be collected from the same sites under a broader range of hydrologic conditions as well as new sites in different STAs.

BACKGROUND

To assist with Everglades restoration, STAs were designed to reduce total phosphorus (TP) from agricultural and urban stormwater runoff prior to release into the Everglades. Since their inception in the early 1990s, an optimal mix of vegetation has been sought to help achieve maximum P removal. In the STA's original design EAV would attenuate flows and provide initial treatment of high nutrient inflow waters through direct P uptake and sedimentation (Walker 1995). Following EAV, SAV would further reduce nutrient concentrations at outflow regions of the STAs. Over time, EAV and SAV communities have become more intermixed than originally conceived, although EAV is more predominant at inflow regions and SAV mixed with EAV is typically found further down the STA cell flow path (Kharbanda 2015). The P removal performance of these vegetation communities can be roughly inferred from performance of the entire STA cell or flow-way. STA cell and flow-way level performance are well documented but because STA cells or flow-ways are large often covering thousands of acres and encompass a heterogeneous landscape, the individual P removal performance of distinct ecological areas cannot be distinguished. At a much smaller spatial scale many studies have evaluated the P removal of individual plant species, and typically this research has occurred in mesocosms. This smaller-scale mesocosm research has provided insight into water column P responses to water-depth conditions, species composition, nutrient loading regimes, substrate composition, and other environmental conditions (White, Reddy et al. 2006). However, mesocosm research often lacks the environmental factors and ecological feedbacks that exist within the larger extent of an STA, sometimes making it difficult to apply these findings at a larger scale (Ahn and Mitsch 2002, Hastings, Byers et al. 2007). Because studies at a large spatial scale do not have resolution required to distinguish between distinct ecological landscape features and small-scale studies using mesocosms lack some environmental factors and ecological feedbacks present in the STAs, a study of the P removal performance of distinct ecological areas between these two scales is needed.

The vegetation community not only directly affects P treatment performance through P uptake, it indirectly affects P treatment performance by influencing a number of P removal processes; flux from soil/water interface (Bostic and White 2007), resuspension of particulates (Dieter 1990), and faunal activity (Naiman 1988, Evans N 2019). Since P removal is the result of complex and interrelated processes (Bhomia and Reddy 2018) influenced by the distinct ecology of the area, it is important that the ecological processes within the vegetation community are relatively similar when estimating the P treatment performance of the community. The ecotope is a landscape class ideally defined to demarcate vegetation communities based on distinct ecological processes. Because ecotopes are defined as "the homogeneous spatial units as to vegetation structure, succession stage and the main abiotic site factors relevant for plant growth" (Stevers 1987), and are "ecologically distinct features that are potentially stable over ≥2 years and are consistently and repeatably identifiable by both ecologists and land managers in the field and in ≤1 m resolution imagery as an ecotope" (Ellis, Wang et al. 2006), ecotope boundaries delineate where P removal processes likely change. It is expected that there will be less variation in the ecological processes responsible for P removal within an ecotope than between ecotopes, and for this reason, the study will find differences in P treatment performance between ecotopes. The temporal dimension of the ecotope definition is also important since it can take years for wetlands conditions where these are to become relatively steady. Processes like soil diagenesis that affect P retention mechanisms (e.g. porewater flux) will change over time (D'Angelo and Reddy 1994), and their effects will be missed in shorter term experiments. Ecotope scale is needed to not only capture P treatment performance differences of a spatially heterogenous landscape but a time long enough for temporal trends to reach an approximate equilibrium (Craft 1996). Because ecotopes are areas where ecological features are potentially stable, estimates of P treatment performance will capture the aggregate result of these P removal processes where and when spatial and temporal variation are at a minimum.

GOALS AND OBJECTIVES

The primary goal of this study is to identify ecotopes with the best P treatment performance in the outflow regions of the STAs. Secondary goals are to determine the influence stage and discharge rate have on TP concentration within ecotope.

KEY SCIENCE QUESTIONS

Key Science Plan Question Study Plan Addresses

- What measures can be taken to enhance vegetation-based treatment in STAs and FEBs?

Science Plan Sub Questions Study Plan Addresses

- Can various vegetation types (subtypes) enhance P uptake and retention in SAV cells?
- What are the short-term and long-term P retention capacities of the dominant and other vegetation species in the STAs?

- What is the role of vegetation in modifying P availability in low-P environments, including the transformation of refractory forms of P?
- What factors determine spatial and temporal variability of SAV community structure (species composition, cover, density)?
- How do water depths and soil characteristics affect sustainability of dominant vegetation?

HYPOTHESIS

H_0: There are no P treatment performance differences between ecotopes.
H_1: There are P treatment performance differences between ecotopes

WORK PLAN

Stop/Go Phases:

This study uses a phased approach to assure that findings are meaningful and applicable to STA management. In Phase I of the study, ecotope sites were selected and mapped by vegetation type, water quality monitored biweekly, physicochemical parameters logged, and soils analyzed for nutrients. A stop/go meeting was conducted where it was determined to continue the study into Phase II. Phase II consists of Tasks 1-4. Another stop/go meeting will be held one year from the start of Phase II to determine if further research is warranted.

Phase II Tasks

Task 1: Continued monitoring of existing ecotope sites

In Phase I of the study, five ecotope types were selected in STA-3/4 Cell 2B for biweekly water quality sampling. Ecotopes types selected were *Chara sp*., *Najas guadalupensis*, a *Chara sp./ Najas guadalupensis* mix, *Typha*, and bare ground. Small differences were found between the ecotopes, but a greater number of samples is required to confirm these results statistically. Collection from these sites will continue with an adjustment to the parameters collected (**Table 1**). Also, the *Najas guadalupensis* site will be dropped as *Chara sp.* intermixed at the site created a mixed *Chara sp./Najas guadalupensis* ecotope. The overall number of sampling trips will remain the same (no more than 26 trips) over a year, however, the frequency of collection will also be changed from biweekly to flow triggered sampling upon desired hydrologic conditions. P treatment performance during flow has the greatest contribution to the flow weighted mean P concentration (FWMC) and therefore should be the focus of sampling efforts. A higher proportion of the sampling trips will be scheduled during high flow periods but low and no-flow periods also will be sampled, just infrequently Also, there is significant collinearity between stage and flow which makes the individual influence on P treatment performance from these factors difficult to estimate. Samples from a greater range of hydrologic conditions are needed to evaluate these effects. A best effort will be made to collect during periods of high-flow but low-water depths and periods of low-flow with high-water depths (**Table 2**). Samples will be collected from sites upstream and downstream end of the ecotope (**Figure 1)**. In addition, automated equipment and instrumentation will be deployed at these sites: EXO sondes to measure pH, dissolved oxygen, specific conductivity, turbidity, and temperature; leveloggers to measure changes in water depth; and HOBO light sensors to measure the light intensity. Documentation will be a combination of electronic and hard copy formats. All data will be collected according to District-approved SOPS.

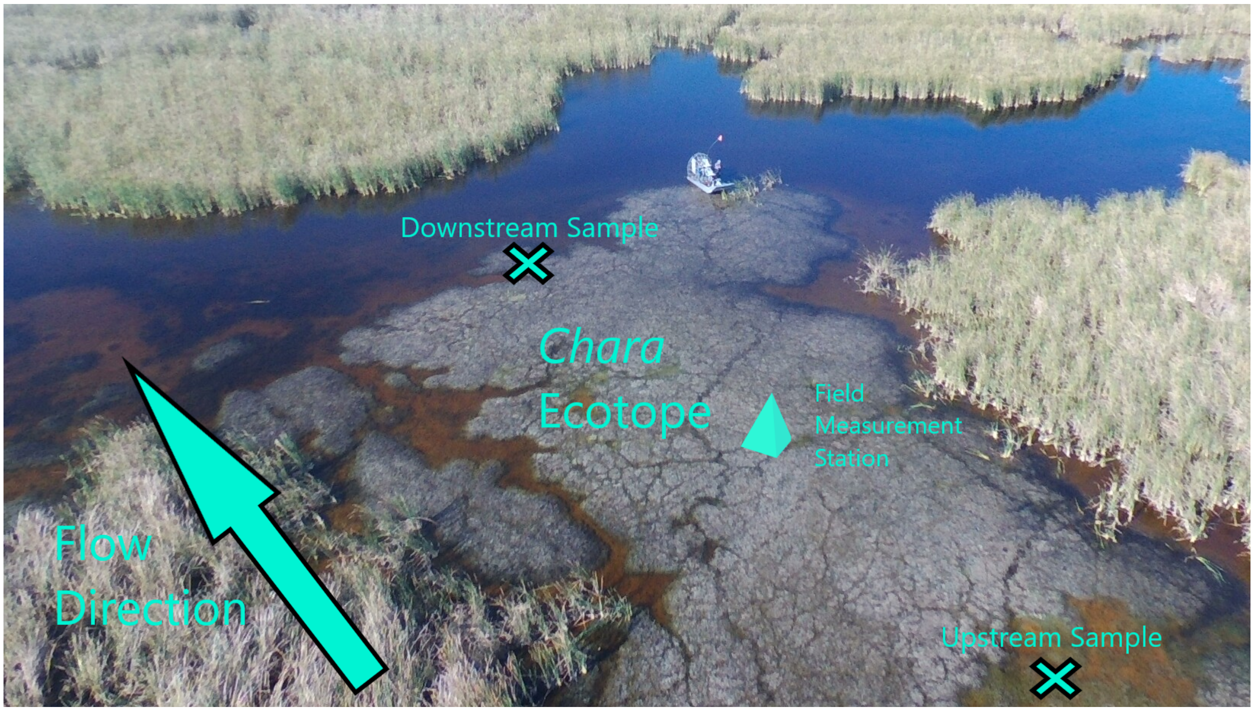

Figure 1: Example Ecotope Sampling Diagram

Task 2: WQ sampling and mapping of previously sampled ecotopes in new areas

Ecotopes of the same type but from different STA cells will be selected and sampled for the same water quality parameters (**Table 1**). The purpose of this sampling is to determine if findings from STA-3/4 Cell 2B are consistent with and applicable to other STA cells. Preferably a single outflow region of an STA that contains all ecotopes types will be found to minimize confounding environmental factors. Once sites are found, they will be mapped to measure spatial characteristics of the ecotopes. They will be mapped and classified to macrophyte species level using high resolution aerial imagery. This imagery will be collected using Unmanned Aerial Vehicle (UAV) and will be verified for accuracy through ground truthing in the field. Ecotope characteristics to be documented include density, coverage, species richness, diversity, age, and spatial dimensions. This imagery will be updated on quarterly basis to track ecotope characteristics.

Task 3: Exploratory sampling of new ecotope types

There are many ecotope types in the STAs, only 5 have been evaluated in this study to date. An exploratory sampling of unstudied ecotopes prevalent in the outflow regions of the STAs will be conducted to look for well performing ecotopes. This exploratory sampling will provide information on which ecotopes should be evaluated in more detail in in future studies. Due to resource limitations, we will limit the number of ecotopes in the exploratory study at no more than 10 and will collect samples quarterly for TP only. Based off the relatively good P treatment performance of the cells in which these unstudied ecotopes reside several ecotopes are of interest. There are several varieties of mixed marsh ecotope in cells with good performance. In the mixed marsh emergent plants like *Sagittaria lancifolia, Pontederia cordata, Scirpus sp., panicum sp.* or *Eleocharis sp.* intermix with SAV species. In these marshes the EAV is not dense enough to shade out the SAV living in the water column under these plants and P treatment may benefit from both vegetation types. *Nuphar advena,* a rooted floating aquatic species also intermixes with SAV and can form a mixed marsh. Additional SAV species of interest for exploratory sampling include *Hydrilla verticillate* and *Ceratophyllum demersum.*

Task 4: Spatial sampling

By definition ecotopes are "homogeneous spatial units as to vegetation structure, succession stage and the main abiotic site factors relevant for plant growth", so abiotic and biotic conditions within the ecotope should exhibit a greater uniformity than transitory areas between ecotopes. To test hypothesis spatial sampling of the ecotopes and transition areas around the ecotopes will be conducted to investigate P variation within the ecotope compared to surrounding areas. Up to twenty-five TP samples will be collected from in and around each ecotope in a grid pattern to test this hypothesis.

Table 1. Sampling frequency and measurements for water column ecotope sites during the established monitoring periods.

<table>
<tr><th>Matrix</th><th>Parameter</th><th>Collection method</th><th>Frequency</th><th>Estimated # samples per year</th></tr>
<tr><td rowspan="5">Task 1 and 2
Surface Water</td><td>TP</td><td rowspan="3">Grab</td><td rowspan="3">Flow Triggered</td><td rowspan="3">13 trips x 2 paired sites at 8 ecotopes = 208 Samples</td></tr>
<tr><td>TDP</td></tr>
<tr><td>SRP</td></tr>
<tr><td>TP</td><td rowspan="2">Grab</td><td rowspan="2">Flow Triggered</td><td rowspan="2">13 trips x 2 paired sites at 8 of patches = 208 Samples</td></tr>
<tr><td>TDP</td></tr>
</table>

	SRP			
	NH4			
	NOx			
	TN			
	Ca			
	Mg			
	Sulfate			
	DOC			
	Dissolved Iron			
	Chloride			
	Alkalinity			
	Dissolved Aluminum			
	Chlorophylls			
Task 3 Exploratory Ecotope Sampling	TP	Grab	Quarterly	4 trips x 2 paired sites at 10 ecotopes = 80 Samples
	TDP			
	SRP			
Task 4 Spatial Sampling	TP	Grab	Annual	1 trip x 4 Sites x 25 subsamples = 100 samples
Field measurements – Surface water	pH	In-situ EXO Sondes	2-week deployments every month	Continuous
	Sp. Conductivity			
	Dissolved oxygen			
	Temperature			

	Turbidity			
	Light			
Ecotope Mapping	Density	High Re	Quarterly	4 mapping trips
	Coverage			
	Richness			
	Diversity			
	Size			
	AFDW			
	TP			
	TN			

Table 2. Number of sample trips for each hydrologic conditions defined by flow and water depth. Hydrologic Condition	***Depth (cm)**	**£Flow (cfs)**	**Sample Trips**
High depth & high flow	>75	>500	5
High depth & low flow	>75	<300	8
Low depth & high flow	<65	>500	8
Low depth & low flow	<65	<300	5
*Water depth is defined as the depth to consolidated substrate which is measured at the sample sit at the time of collection. £Flow is defined as the total discharge in (cfs) from all stations at cell outflow.			

References

Ahn, C. and W. J. Mitsch (2002). "Scaling considerations of mesocosm wetlands in simulating large created freshwater marshes." Ecological Engineering **18**(3): 327-342.

Bhomia, R. and K. R. Reddy (2018). "Influence of Vegetation on Long-term Phosphorus Sequestration in Subtropical Treatment Wetlands." Journal of Environmental Quality **47**(2): 361-370.

Bostic, E. M. and J. R. White (2007). "Soil Phosphorus and Vegetation Influence on Wetland Phosphorus Release after Simulated Drought." Soil Science Society of America Journal **71**(1): 238-244.

Craft, C. B. (1996). "Dynamics of nitrogen and phosphorus retention during wetland ecosystem succession." Wetlands Ecology and Management **4**(3): 177-187.

D'Angelo, E. M. and K. R. Reddy (1994). "Diagenesis of Organic Matter in a Wetland Receiving Hypereutrophic Lake Water: I. Distribution of Dissolved Nutrients in the Soil and Water Column." Journal of Environmental Quality **23**(5): 928-936.

Dieter, C. D. (1990). "The Importance of Emergent Vegetation in Reducing Sediment Resuspension in Wetlands." Journal of Freshwater Ecology **5**(4): 467-473.

Ellis, E. C., H. Wang, H. S. Xiao, K. Peng, X. P. Liu, S. C. Li, H. Ouyang, X. Cheng and L. Z. Yang (2006). "Measuring long-term ecological changes in densely populated landscapes using current and historical high resolution imagery." Remote Sensing of Environment **100**(4): 457-473.

Evans N, T. J., Cook M, Newman S (2019). Effects of Abundant Faunal Species on Phosphorus Cycling in the Stormwater Treatment Areas. South Florida Environmental Report. West Palm Beach, Fl, 33406, South Florida Water Management District **Volume I Appendix 5C-4:** 1-32.

Hastings, A., J. E. Byers, J. A. Crooks, K. Cuddington, C. G. Jones, J. G. Lambrinos, T. S. Talley and W. G. Wilson (2007). "Ecosystem engineering in space and time." Ecol Lett **10**(2): 153-164.

Kharbanda, M., J. Henry, and T. DeBusk (2015). Evaluations of Spatial Patterns of Phosphorus removal in STA-1W Cell 5B. South Florida Environmental Report. West Palm Beach, FL, South Florida Water Management District**:** 51-55.

Naiman, R. J. (1988). "Animal Influences on Ecosystem Dynamics." BioScience **38**(11): 750-752.

Reddy, K. R., L. Vardanyan, J. Hu, O. Villapando, R. K. Bhomia, T. Smith, W. G. Harris and S. Newman (2020). "Soil phosphorus forms and storage in stormwater treatment areas of the Everglades: Influence of vegetation and nutrient loading." Sci Total Environ **725**: 138442.

Stevers, R. A. M., Runhaar, J., Udo de Haes, H.A. and Groen, (1987). "ecotopensysteem, een landelijke ecosysteemtypologie toegespitst op the vegetatie." Landschap **4**(2): 135-150.

Villapando, O. K., Jill (2018). 2018 South Florida Environmental Report. Evaluation of Phosphorus Sources, Forms, Flux, and Transformation Processes in the Stormwater Treatment Areas West Palm Beach, Fl, South Florida Water Management District. **Volume I:** 2-16.

Walker, W. W. (1995). "Design basis for Everglades Stormwater Treatment Areas." Water Resources Bulletin **31**(4): 671-685.

White, J. R., K. R. Reddy and J. Majer-Newman (2006). "Hydrologic and Vegetation Effects on Water Column Phosphorus in Wetland Mesocosms." Soil Science Society of America Journal **70**(4): 1242-1251.