Deliverable A-6-C: PSTA Research Update for the South Florida Environmental Report

Inter-Agency Agreement to Conduct Scientific Studies Relevant to the Stormwater Treatment Areas

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CHARACTERIZATION OF INTERNAL PHOSPHORUS LOADING FROM PSTA SEDIMENTS

Introduction

A field-scale periphyton-based stormwater treatment area (PSTA) was constructed from 2004 to 2005 for the purpose of addressing uncertainties associated with large-scale implementation of periphyton-based treatment technology. The PSTA Cell in STA-3/4 is unique among STA treatment cells in that the extant peat was scraped to expose the underlying rock (**Figure DBE-1**).

A key aspect of the PSTA concept is that either the removal of muck soils to expose underlying limerock substrate, or the addition of limerock to effectively cap the existing muck soils, is thought to be necessary for optimal P removal. This is based on the premise that successful removal of P to ultra-low levels depends on limiting internal P loading sources.

The STA-3/4 PSTA facility has developed an accrued marl sediment layer on top of the bedrock that was exposed during project construction. This new material is different than the underlying limerock surface upon which the PSTA community was first established, and may affect both water column nutrient exchange and macrophyte and periphyton growth. It is important to understand how the accumulation of new sediment over the original substrate can influence outflow TP concentrations and sustainability of P removal performance.

The two SAV species most common to the PSTA Cell are *Potamogeton illinoensis* and *Chara* sp. It should be noted that the former is a vascular plant, with true roots and internal translocation of nutrients, whereas the latter is a non-vascular macro-algae, with holdfasts, rather than true roots. Without roots, *Chara* relies on direct uptake of nutrients from the surrounding water. Because of these morphological differences, the soil nutrient "mining" potential of *Potamogeton* may theoretically be greater than that of *Chara*. In the following sections, macrophyte and water column responses to substrate conditions are described from a replicated outdoor soil core study.

Figure DBE-1. Photo of substrate preparation during PSTA Cell construction. Organic soils were scraped from limerock, then removed or formed into berms that extend perpendicular to the dominant (north-to-south) flow direction.

Methods

A sediment core incubation study was established using *Potamogeton*, *Chara*, and unvegetated controls as "plant" treatments coupled with three separate "substrate" treatments. For the first substrate treatment, intact marl/muck cores were obtained from the outflow region of a well performing muck-based SAV cell (STA-2 Cell 3). For the second treatment, bare limerock represented the initial (startup) PSTA Cell condition after removal of the overlying muck. Sediments that had accrued in the PSTA Cell over more than 7 years of operation were selected for the third substrate treatment. This material was used to represent long-term, or "steady state" physico-chemical conditions for sediments in a PSTA-type system.

The 3 x 3 factorial design was conducted as a batch study in 15-cm diameter cores, outdoors in a water bath and under partial shade (to minimize water temperature fluctuations). In "PSTA" treatments, the sediment depth was 10 cm of limerock, covered by an additional 10 cm of accrued sediment from the outflow region of the PSTA Cell. For "Muck" treatments, intact cores were collected from STA-2 Cell 3 to a depth of 26 ± 1 cm, from an area where *Potamogeton* was the dominant SAV (*Najas guadalupensis* was also present). The accrued soil layer in these cores was a greyish marl typical of SAV-dominated STAs, and averaged 11.4 ± 0.4 cm. Plants were carefully removed from all cores, leaving the accrued sediment layer intact. A 30-cm water column was established above the sediment surface in triplicate cores under each treatment. Plants were added as 20 g wet weight per core, which consisted of several *Chara* strands or three *Potamogeton* plants with both new root growth and healthy apical leaf tips. Water (originating from the PSTA Cell) in the cores was sampled weekly for TP concentrations, and exchanged every 2 weeks with care to avoid physical disturbance to plants and sediments. Six water exchanges were performed over 84 days, after which the plant responses were evaluated.

Soil P content was determined from cores collected and sectioned in the field into the accrued layer (both sites), and underlying muck layers (0-10 cm and 10-20 cm layers) in STA-2 Cell 3. Plant chemistry was measured at the beginning (initial inoculum) and end of the study.

Results

Water column phosphorus dynamics

During the initial cycle, surface water TP concentrations in the core reflood water, collected from the PSTA Cell outflow (G388), were quite low (14-15 ppb). The core study water source subsequently was changed from the PSTA Cell outflow to the inflow (G390B structure) for the subsequent 5 water exchanges, to provide more elevated inflow TP levels (17-26 ppb). During the batch incubations, the limerock-based cores were able to maintain very low TP concentrations throughout the study, regardless of vegetation presence or type (**Figure DBE-2**). With the exception of the first exchange cycle, initial (day 0) TP levels averaged 20 ppb, and final (day 14) TP values averaged 11 ppb. By contrast, on muck soils, TP concentrations increased over 5 of the 6 cycles for the unvegetated controls. *Chara* provided lower water column TP levels than did *Potamogeton*, with greater vegetation treatment differences observed on muck substrates toward the end of the study. Among all muck treatments, initial mean water TP concentrations of 20 ppb increased to an average of 25ppb.

On PSTA sediments, the differences in water TP levels between *Chara* and *Potamogeton* treatments were smaller than for muck treatments, but showed the same overall trend. Within each plant treatment, PSTA sediments provided lower water TP concentrations overall than muck, but higher than for the limerock substrate treatments (**Figure DBE-2**). Among all PSTA sediment treatments, mean TP levels at day 14 were 20 ppb, essentially the same as day 0 TP concentrations.

Vegetation response to sediment conditions

Higher TP levels were observed for soils from STA-2 Cell 3 (472 ± 5 mg/kg for the accrued layer, 456 ± 11 mg/kg in upper muck 0-10 cm, and 407 ± 48 mg/kg in the lower 10-20 cm muck layer) than for the PSTA sediments (322 ± 3 mg/kg). Soil P in the deeper muck layers was potentially available to *Potamogeton*, which was seen to extend new root tissues into the soil below the accrued layer.

At the end of the 84-day study, *Chara* and *Potamogeton* exhibited biomass increases on muck soils, while no change in biomass was observed on PSTA sediments. The two vegetation types on limerock exhibited a slight decline in biomass.

Tissue P contents were also affected by substrate type, indicating that low P substrates are important for maintaining low P conditions in macrophyte tissues. *Chara* and *Potamogeton* tissue P contents were elevated in muck treatments as compared to the tissue P levels of the originally stocked plant materials (**Figure DBE-3**). No such increase was noted for macrophytes grown on limerock, indicating that the marl/muck soil, rather than the reflood water in the cores, was the principal source of the P that accumulated in the plant tissues. PSTA sediment treatments were intermediate with respect to P content of macrophyte tissues.

On all soils, the calcium contents of the plants changed little during the study, so the changes observed in dry weight biomass were likely the result of growth or senescence, rather than gain or loss of calcium carbonate encrustations commonly associated with macrophytes in alkaline waters. *Potamogeton* tissue on PSTA sediment showed the greatest change in calcium contents, increasing from 5.5 ± 0.2 percent Ca to 8.0 ± 0.6 percent Ca over the course of the study. The Ca content of *Chara* tissues were higher initially (23 percent), then decreased slightly to 21 percent on all substrates (**Figure DBE-3**).

Discussion

These findings provide some insight into the sustainability of effective P removal by PSTA systems. The limerock substrate, representing the "original condition" of the PSTA Cell, provided the best water column P removal performance, as well as lowest tissue P concentrations for the incubated SAV species. The muck substrate clearly provided greater P enrichment, as manifested both in the water column and macrophyte tissue P levels. The accrued PSTA sediments caused an intermediate response. These data suggest that as sediments have accrued in the PSTA wetland, the growth rate and nutrient content of macrophytes may have increased, relative to initial conditions on the "raw" calcareous substrate. Macrophytes can act as a nutrient "pump" in low nutrient environments by using sediment P for tissue growth, then releasing P species into the water column upon senescence. Low tissue nutrient contents are likely to exhibit minimal internal P loading from senescent vegetation, whereas high tissue P contents suggest that the macrophyte community can be an important source of internally recycled P to a water body.

Since its inception, the STA-3/4 PSTA Cell has produced a sediment that, despite being low in TP content, appears capable of supporting modestly higher macrophyte growth rates and tissue P contents than would be expected on the original, bare limerock substrate. However, there is no indication that the PSTA Cell P removal performance is declining over time: annual mean outflow TP levels for each of the five WYs from 2011 through 2015 were 11, 12, 11, 13 and 11 ppb, respectively. Further research is needed to better clarify the substrate and vegetation (macrophyte/periphyton) relationships in the STA-3/4 PSTA Cell, but to date, the accumulating PSTA sediments appear reasonably well-suited for limiting the effects of internal P loading, while supporting modest SAV growth in the treatment wetland.

Reference

Burkholder, J. M., and R. G. Wetzel. 1990. Epiphytic alkaline phosphatase on natural and artificial plants in an oligotrophic lake: Re-evaluation of the role of macrophytes as a phosphorus source for epiphytes. Limnology and Oceanography 35(3): 736-747.

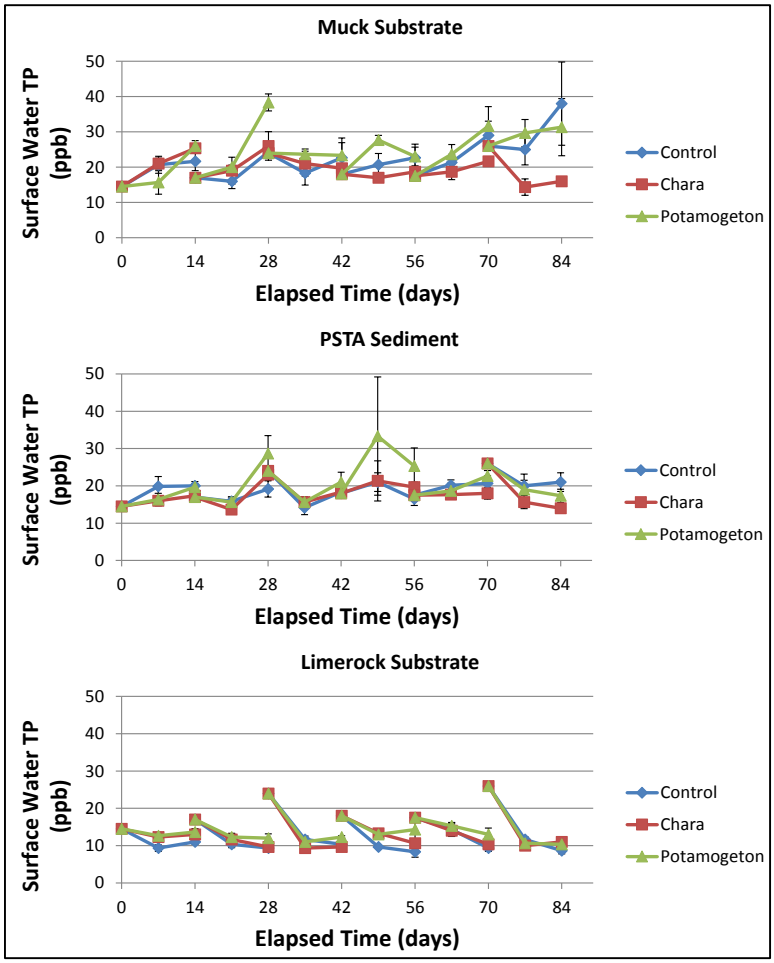

Figure DBE-2. Surface water total phosphorus (TP) concentrations in cores incubated outdoors with one of three substrates (limerock (LR), PSTA sediment, or muck), and one of three vegetation treatments, during a 12-week study period. The control cores were unvegetated. Error bars denote ± 1 SE around the mean of triplicates under each treatment.

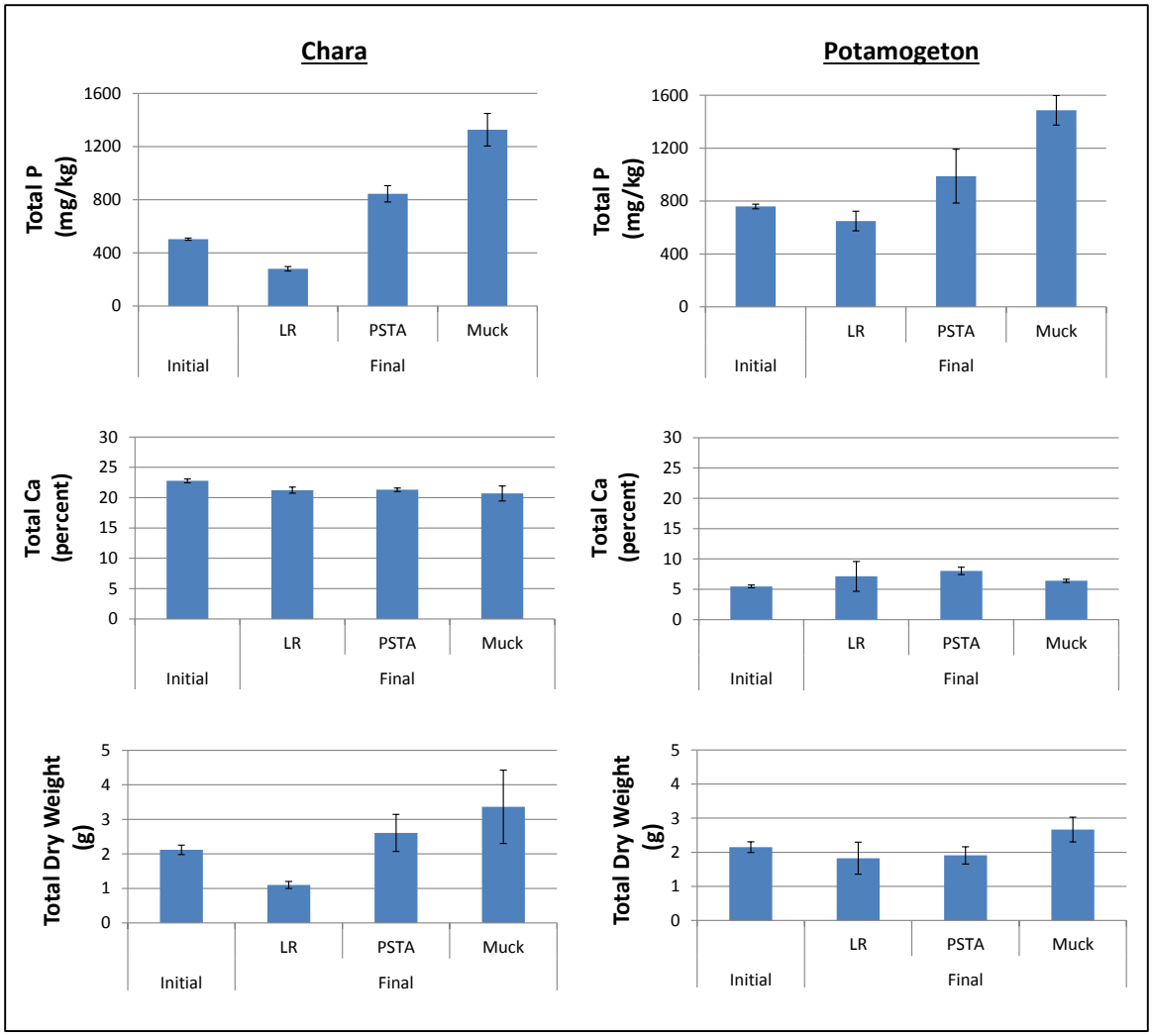

Figure DBE-3. Chemical composition and dry weights of *Chara*, and *Potamogeton* tissues in cores incubated outdoors for 84 days, compared to the initial conditions of the inoculum, as a function of sediment type. Error bars denote ± 1 SE around the mean of triplicates under each treatment.