Appendix 5B-6: Evaluation of Phosphorus Removal Performance of *Schoenoplectus californicus* (Giant Bulrush)

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Sequenced communities of emergent aquatic vegetation (EAV), followed by submerged aquatic vegetation (SAV), have provided effective phosphorus (P) removal in many of the Everglades Stormwater Treatment Areas (STAs). However, neither EAV nor SAV communities in the STAs have proven entirely sustainable. Front-end EAV communities[2], typically cattail (*Typha* sp.), at times have been adversely impacted by excessive water depth conditions that occur during wet season flow pulses, and SAV communities have been damaged by hurricane winds, herbivory, and other unknown causes. Beginning in 2005, the South Florida Water Management District (SFWMD or District) began planting stands of giant bulrush (*Schoenoplectus californicus*) within the SAV cells as buffer strips, then later in front-end STA locations where cattail does not thrive due to high flows and depths. While giant bulrush is known to tolerate deeper waters than cattail, its P removal performance in South Florida wetlands is unknown. The objective of this investigation was to characterize the P removal performance of giant bulrush in the Everglades STAs, since it is currently encouraged as a front-end species in selected STA flow paths.

METHODS

In fall 2011, six 4-square meter cylindrical mesocosms containing giant bulrush or cattail (*T. domingensis*) were established at the District's S5A research facility (**Figure 1**). Prior to vegetation planting, muck soil, collected from the upland area of the eastern side of STA-1 West (STA-1W) Cell 1A, was added to each mesocosm to a depth of 30 centimeters (cm). Mesocosms were equipped with adjustable standpipes that allowed water depths to range as high as 100 cm, with an approximate water volume of 4 cubic meters. Triplicate mesocosms were established for both vegetation types. Inflow waters to the mesocosm study were pumped from the West Palm Beach Canal near the S-5A structure into a head tank that in turn delivered flows via gravity into the mesocosms. The timing and duration of flows to the mesocosms were controlled with electronic timers and ball valves, and the actual rate delivered was controlled using varying sizes of pipe apertures. Water exited the mesocosms by flowing over the top and into an adjustable standpipe.

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[2] In the front region of a flow-way, EAV is usually the type of vegetation grown because it tends to be more effective in removing higher phosphorus concentrations and loads.

Figure 1. One of triplicate (A) cattail and (B) giant bulrush mesocosms located at the S5A research facility (photos by DBE Environmental, Inc.).

The STAs are subjected to pulse flow conditions, driven largely by rainfall events in the watershed. In between pulses, flows to the STAs often are minimal, or even totally lacking. Flow pulses often cause dramatic, short-term increases in water depths (Paudel et al. 2013), particularly in the front-end of the STAs. To mimic potential depth and flow variations in the full-scale STAs, the mesocosms were operated according to a predetermined schedule of variable hydraulic loading rates (HLRs) and water depths. This operational regime, in turn, influenced the hydraulic retention times (HRTs). After an initial 60-day establishment phase to allow plant grow-in, the mesocosms were subjected to variable flows and depths between August 2011 and October 2013. This consisted of a series of flow pulses, ranging from 38 centimeters per day (cm/d) HLR to 91 cm/d HLR (at respective water depths of 76 and 91 cm and HRTs of 2 days and 1 day), with each pulse typically lasting one to two weeks, but occasionally four weeks (**Figure 2**). Between pulses, either low flow (2 cm/d) or stagnant conditions (no flows) were provided, at water depths ranging from 15 to 38 cm and HRTs of 8 to 19 days (low flow only). This was followed by a year of steady HLR (10 cm/d), water depths (76 cm), and HRT (8 days). Pulsing resumed in October 2013 and continued through the end of the study (February 2015).

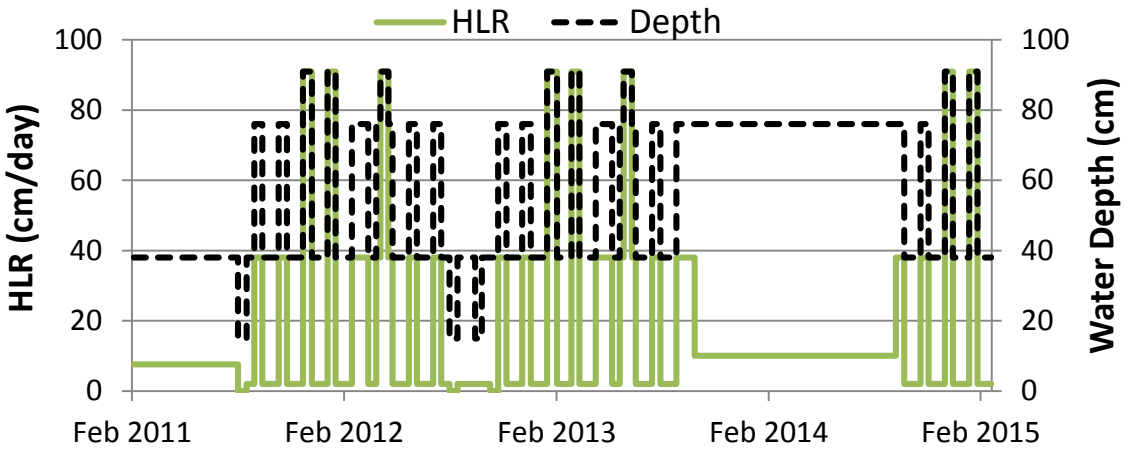

Figure 2. Schedule of HLRs in centimeters per day (cm/day) to the experimental mesocosms during the study.

Inflows and outflows of the mesocosms were monitored for total phosphorus (TP) from August 2011 to February 2015. Measurements of total dissolved P (TDP) and soluble reactive P (SRP) were performed during most, but not all, of the study. Dissolved organic P (DOP) and particulate P (PP) were calculated using the following relationships: DOP = TDP - SRP and PP = TP - TDP. Depending on the flow regime, water samples for P analyses were collected twice weekly, weekly, or biweekly.

RESULTS AND DISCUSSION

For the four-year period of record, P removal performance was similar between giant bulrush and cattail (**Figure 3**). Each vegetation species exhibited a long-term flow-weighted mean (FWM) outflow TP concentration of 52 and 55 parts per billion (ppb; or micrograms per liter, or µg/L) for cattail and bulrush, respectively, after receiving a FWM inflow TP concentration of 107 ppb over the four-year study. The inflow waters contained an average 47, 30, and 28 ppb of SRP, PP, and DOP, respectively. On average, these P forms were reduced to 13, 22, and 18 ppb, respectively, in the outflow waters from cattail treatments, and 12, 21, and 19 ppb in the outflow waters from giant bulrush treatments over the study period.

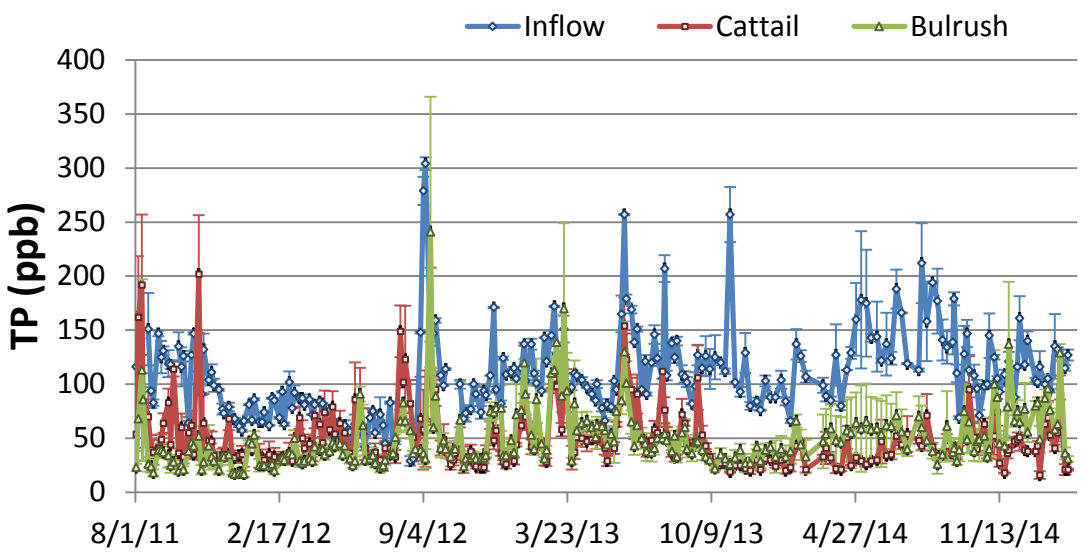

Figure 3. Inflow and outflow TP concentrations from giant bulrush and cattail mesocosms operated at a range of HLRs. Data points represent mean ±1 standard error (S.E.) of triplicate mesocosms.

The pulsing schedule enabled assessment of P removal performance under varying HLR conditions, similar to those observed in full-scale STA flow paths. Performance of the two emergent macrophytes was similar over the range of HLRs provided, with no significant difference observed in outflow TP concentrations between the two species (paired t-test, $p > 0.05$). However, both species exhibited an increase in outflow TP concentrations at high HLRs, as well as at the lowest HLR, as compared to outflow TP concentrations at the moderate (10 and 38 cm/d) rates. For example, at 0–2 cm/d HLR, giant bulrush provided an outflow TP of 54 ppb, but this declined to 45 and 44 ppb at 10 and 38 cm/d HLR, respectively (**Figure 4**). At the higher HLR of 91 cm/d, the outflow TP from the giant bulrush mesocosms was 73 ppb.

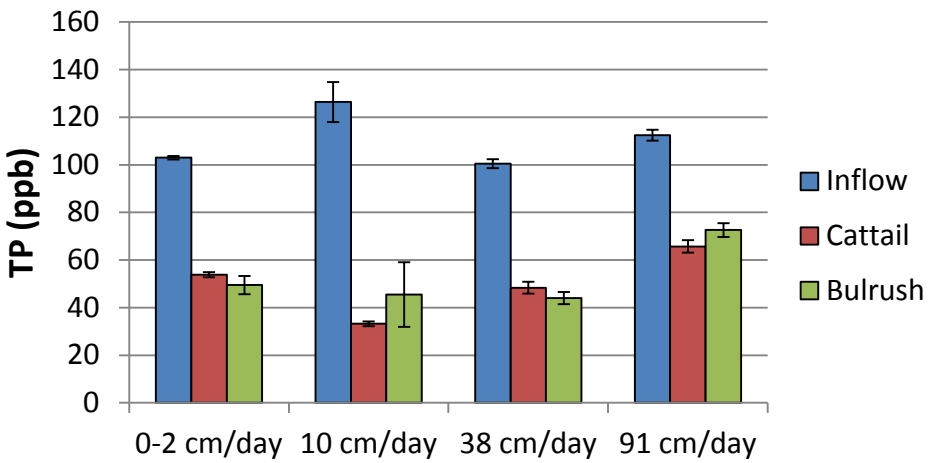

Figure 4. Inflow and outflow TP concentrations from giant bulrush and cattail mesocosms operated at a range of HLRs. Bars represent mean ±1 S.E. of triplicate mesocosms. There were 128, 46, 52, and 24 sampling events performed within the 0–2, 10, 38, and 91 cm/d periods, respectively.

While outflow TP levels increased at the highest HLRs, mass P removal rates increased with increasing HLR. Areal P removal rates for cattail ranged from 0.4 grams per square meter per year ($g/m^2/yr$) at 0–2 cm/d HLR to 15.8 $g/m^2/yr$ at 91 cm/d HLR. Similarly, areal P removal for bulrush ranged from 0.4 $g/m^2/yr$ at 0–2 cm/d HLR to 13.0 $g/m^2/yr$ at 91 cm/d HLR. The P load to the mesocosms ranged from 0.7 to 36.0 $g/m^2/yr$ at HLRs of 0–2 and 91 cm/d, respectively. Percent P load removal was highest at a HLR of 10 cm/d for both cattail (72 percent) and bulrush (62 percent). Lowest percent P load removal for both species was observed at the lowest and highest HLR (45 and 44 percent for cattail and 48 and 37 percent for bulrush, respectively). It should be noted that study manipulation of both HLRs and water depths markedly influenced the HRTs in the mesocosms. At HLRs of 2, 10, 38, and 91 cm/d (and respective depths of 38, 76, 76, and 91 cm), the resulting mesocosm HRTs were 19, 8, and 2 days, and 1 day, respectively.

Inflow and outflow P species were assessed under the HLR regimes of 0–2, 38, and 91 cm/d. Outflow SRP concentration was lowest at lower HLRs (0–2 and 38 cm/d), as expected, but increased at 91 cm/d HLR, where SRP loading and the short HRT conditions may have approached the capacity of SRP removal mechanisms. At the lower HLRs, inflow SRP averaged 44 ppb and was reduced to 11 and 10 ppb in cattail and bulrush mesocosm outflows, respectively. At the highest loading rate, the inflow SRP of 55 ppb was only reduced to 25 ppb in the outflows of both vegetated treatments (**Figure 5**).

In summary, based on this mesocosm study, giant bulrush appeared to provide outflow P concentrations comparable to cattail under a range of HLR conditions. Based on these findings, the incorporation of giant bulrush into the inflow region of STAs to improve vegetation sustainability (due to its greater tolerance of deeper conditions) is not expected to change the level of P removal performance currently attained by cattail communities in these regions.

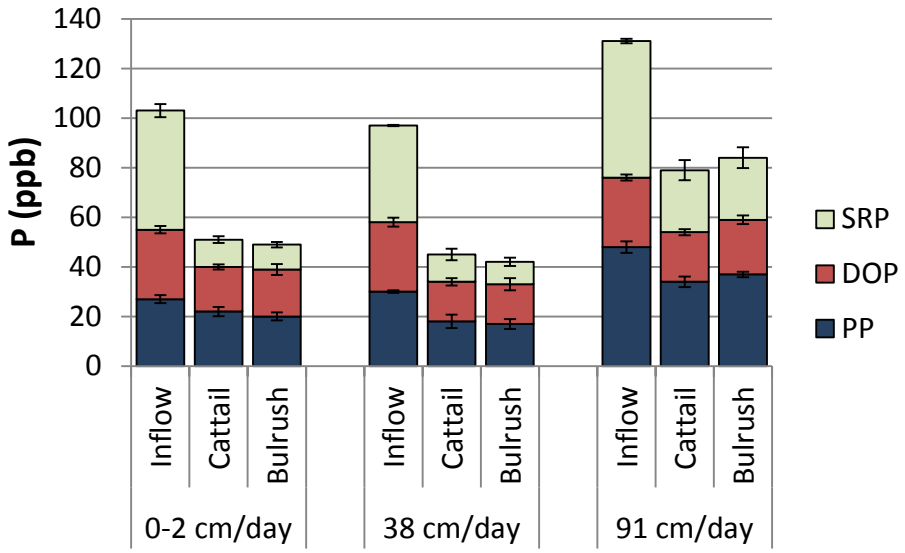

Figure 5. Inflow and outflow P species for cattail and giant bulrush mesocosms at three HLRs. Bars represent mean ±1 S.E. of triplicate mesocosms. There were 97, 40, and 18 sampling events for PP, and 37, 14, and 8 sampling events for DOP and SRP within the 0–2, 38, and 91 cm/d periods, respectively.

LITERATURE CITED

Paudel, R., K.A. Grace, S.J. Galloway, M. Zamorano and J.W. Jawitz. 2013. Effects of hydraulic resistance by vegetation on stage dynamics of a stormwater treatment wetland. *Journal of Hydrology* 484:74-85.