Floating wetlands for treatment of urban and agricultural runoff in Virginia

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Webinar
U.S. Environmental Protection Agency
May 23, 2017
Advantages of Floating Wetlands

- Adaptable to most pond sites
- Not dependent on hydrology
- Sustainable removal process
- Enhance existing BMPs nutrient removal
- Little to no opportunity costs
- Additional benefits:
  - Riparian habitat
  - Shoreline stabilization
  - Aesthetics
Virginia Tech FTW Research Program

1. NFWF funded field demonstration and mesocosm study in Fairfax, VA (2009-2012).

2. CALS funded field demonstration and mesocosm study at HRAREC, Virginia Beach, VA (2012-2013).


Fairfax, VA FTW Study

- Ashby Pond, City of Fairfax, VA
- Accotink watershed, Daniels Run
- Headwater catchment

Characteristics:
- Watershed: 54.7 ha
- Impervious: 38%
- Pond area: 5700 m²
- Pond volume: 2,470 m³
Fairfax Study Setup

- Field demonstration and mesocosm evaluation
- FTW evaluation:
  - Softstem bulrush (*Schoenoplectus tabernaemontani*)
  - Pickerelweed (*Pontederia cordata* L.)
- Pond retrofit
- Water quality evaluation
The TP and TN removal, over that of the control, was enhanced by 8.2% and 18.2% in the FTW treatments planted with the pickerelweed and softstem bulrush, respectively.
Phosphorus Distribution through Growing Season

(a) Pickerelweed

Harvest date

Virginia Beach, VA FTW Study

- Purpose: Assess 2 types of rafts
- Species
  - Soft rush (*Juncus effusus*)
- Materials
  - Beemat
  - Biohaven®
  - May 13-Sep 16, 2013
- 7-day retention time
Mesocosm Improvements

Results

- The BioHaven® FTW nutrient removal was lower over the entire experimental period than the Beemat treatment, possibly due to additives.
- The BioHaven® FTWs removed 25% and 4%, while the Beemat removed 40% and 48% of the TN and TP, respectively.
- A control treatment, meant to reflect nutrient removal within the pond without the presence of plants, yielded 28% and 31% removal of TN and TP, respectively.
- The BioHaven biomass was significantly greater than the Beemat treatment.

i-FTW model

\[ C_{t,i-FTW} = c_0 e^{-(k_{i-FTW})t} = c_0 e^{-(k_w + v_f \frac{A_f}{V})t} \]

- \( k_w \) = water reaction rate (1/d);
- \( v_f \) = FTW apparent uptake velocity (m/d);
- \( A_f \) = area of the FTW (m\(^2\));
- \( V \) = volume of water (m\(^3\));
- \( t \) = reaction time (day).

Combined Model Assumptions

- Time for treatment:
  \[ \sum \{ \text{interevent time, 50\% of storm duration} \} \]

- 10-year simulation (2000-2010)
- Annual harvesting
- Constant removal rate
- Watershed load: TN=3.0 mg/L, TP=0.3 mg/L
- Pond initial load: TN=1.0 mg/L, TP=0.1 mg/L
- \( N k_w = 0.021 \text{ 1/d} \), \( P k_w = 0.026 \text{ 1/d} \) (avg., literature values)

SWMM Output: Simulated Pond Volume

N Removal as a function of $v_f$, Coverage

P Removal as a function of $v_f$, Coverage

Clean WaterR3 – Reduce, Remediate, Recycle – USDA SCRI Project Overview

Goal: Enhancing alternative water resources availability and use to increase profitability in specialty crops

Objectives:

- Reduce contaminant loading by managing irrigation volume and chemical inputs and installing treatment technologies
- Identify and develop treatment technologies that remediate pathogen, pesticide, and nutrient contaminants and integrate into existing operations
- Develop decision support tool for growers, informed stakeholders, and students
USDA NIFA SCRI Project Setup

- Developed and ran experiment with 4 replications utilizing *Pontederia cordata* (Pickerelweed) and *Juncus Effusus* (Soft Rush) as FTWs
- Evaluated the performance of the FTWs versus two controls for high and low nutrient concentrations
- Used a 7 day retention time for water that is being sampled
- Analyzed TN and TP removal for each treatment technology throughout the growing season

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mat</th>
<th>Plants</th>
<th>Species</th>
<th>Concentration</th>
<th>Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>Pontederia</td>
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<td>4</td>
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<tr>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
<td>Pontederia</td>
<td>High</td>
<td>4</td>
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<tr>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>Juncus</td>
<td>Low</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Yes</td>
<td>Juncus</td>
<td>High</td>
<td>4</td>
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<tr>
<td>5</td>
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<tr>
<td>8</td>
<td>No</td>
<td>No</td>
<td>n/a</td>
<td>High</td>
<td>4</td>
</tr>
</tbody>
</table>

Plant growth throughout the growing season for *Pontederia cordata* plants with high fertilizer concentration

Plant growth throughout the growing season for *Pontederia cordata* plants with low fertilizer concentration

*Pontederia cordata* given high nutrient loads accumulated more N and P in the roots and shoots than other treatment combinations.

High concentration *Pontederia cordata* accumulated 4.87 g N and 0.42 g N in the shoots and roots, respectively.

Low concentration *Juncus effusus* shoots accumulated significantly less N than other treatments.

High concentration *Juncus effusus* roots accumulated significantly less N than other treatments.

High concentration *Pontederia cordata* accumulated 0.9 g P and 0.04 g P in the shoots and roots, respectively.

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*Pontederia cordata* FTWs removed significantly more TN and TP from the water than other treatments

Initial loads of 0.52 mg/L TP and 5.22 mg/L TN for low concentration and 2.61 mg/L TP and 17.13 mg/L TN for high concentration

*Pontederia cordata* removed 90.3% and 92.4% TP and 84.3% and 88.9% TN from the high and low concentrations, respectively after 19 weeks

*Juncus effusus* removed significantly more TP than the control treatments at low concentration

*Juncus effusus* performed no better than the controls for TN and TP removal at high concentrations and TN removal at low concentrations

*Pontederia cordata* removed significantly more TN and TP than other treatments.

**High Concentration**
- TN Removal: 1.232 g·m² d⁻¹
- TP Removal: 0.203 g·m² d⁻¹

**Low Concentration**
- TN Removal: 0.351 g·m² d⁻¹
- TP Removal: 0.036 g·m² d⁻¹
Nutrient uptake as a function of days after load fits an exponential-type model

\[ N(t) = r \cdot (1 - b \cdot e^{-c \cdot t}) \]

High Concentration *Pontederia cordata*

Low Concentration *Pontederia cordata*

Mass balance results suggest other nutrient removal processes occurred in addition to plant uptake.

<table>
<thead>
<tr>
<th></th>
<th>High Nutrient Concentration</th>
<th>Low Nutrient Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TP (g)</td>
<td>TN (g)</td>
</tr>
<tr>
<td>Total initial load(^1)</td>
<td>15.02</td>
<td>98.55</td>
</tr>
<tr>
<td>Pontederia cordata</td>
<td></td>
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<tr>
<td>Total load after 7-day HRT</td>
<td>1.46</td>
<td>15.52</td>
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<tr>
<td>Load reduction</td>
<td>13.56</td>
<td>83.03</td>
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<tr>
<td>Plant uptake(^2)</td>
<td>9.43 (69.5)</td>
<td>52.91 (63.7)</td>
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<tr>
<td>Other removal processes</td>
<td>4.13</td>
<td>30.12</td>
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<tr>
<td>Juncus effusus</td>
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</tr>
<tr>
<td>Total load after 7-day HRT</td>
<td>10.94</td>
<td>63.59</td>
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<tr>
<td>Load reduction</td>
<td>4.08</td>
<td>34.98</td>
</tr>
<tr>
<td>Plant uptake(^2)</td>
<td>2.94 (72.1)</td>
<td>21.57 (61.7)</td>
</tr>
<tr>
<td>Other removal processes</td>
<td>1.14</td>
<td>13.39</td>
</tr>
</tbody>
</table>

\(^1\) \(n = 1\) for initial load data  \(^2\) Mean uptake (% of total load reduction)
SCRI Results Summary

- Depending upon the species, FTWs can reduce N and P loads from urban and nursery runoff.
- Plant species has a significant effect on nutrient removal performance.
- *Pontederia cordata* is better suited for urban and nursery environments than *Juncus effuses*, removing 90.3% and 92.4% TP and 84.3% and 88.9% TN from the high and low concentrations, respectively, after 19 weeks.
- N removal rates for *Pontederia* was 1.232 and 0.351 g·m⁻² d⁻¹ for the high (Ag) and low (urban) concentrations, respectively. P removal for *Pontederia* was 0.203 and 0.036 g·m⁻² d⁻¹ for the high and low concentrations, respectively.
- A similar, second year study using 7 species was conducted, *Panicum virgatum* (Switchgrass) was the overwhelming favorite.
- Further research on retention time may be warranted; much of the removal is happening in the first few days.
Conclusions

- 3 studies have been completed on FTWs for control of N and P loads from agricultural and urban runoff.
- Harvesting is recommended.
- Plant species can make a significant difference in effectiveness. *Pontederia* (Pickerelweed) is a constant high performer.
- Note: Evergreens may perform better in cool season, untested.
- A generalized model was developed for estimating load reductions in the Chesapeake Bay watershed. The model predicts low removals for FTW treatments (on top of what already occurs in pond), on the order of 10% for N and 5% for P. However, because of the large surface area available, larger load reductions could be feasible using this technology.
References


