Floating wetlands for treatment of urban and agricultural runoff in Virginia

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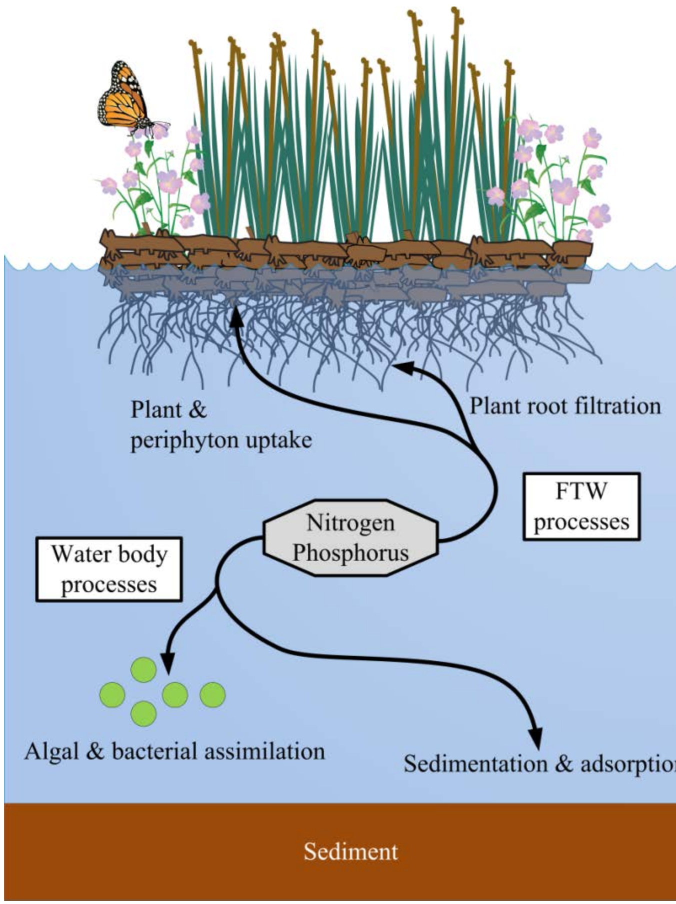
Advantages of Floating Wetlands

- 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

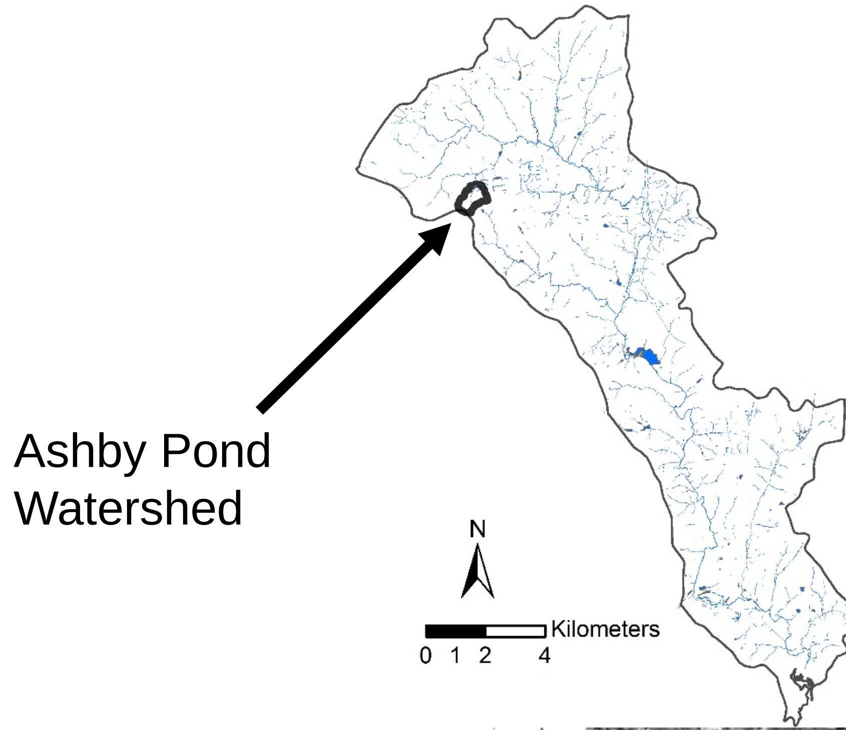


Virginia Tech FTW Research Program

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).
3. STAC Expert Panel model, 2013-2016.
4. USDA-NIFA funded mesocosm study at HRAREC, Virginia Beach, VA (2015-2017).

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 m^2
    Pond volume: 2,470 m^3



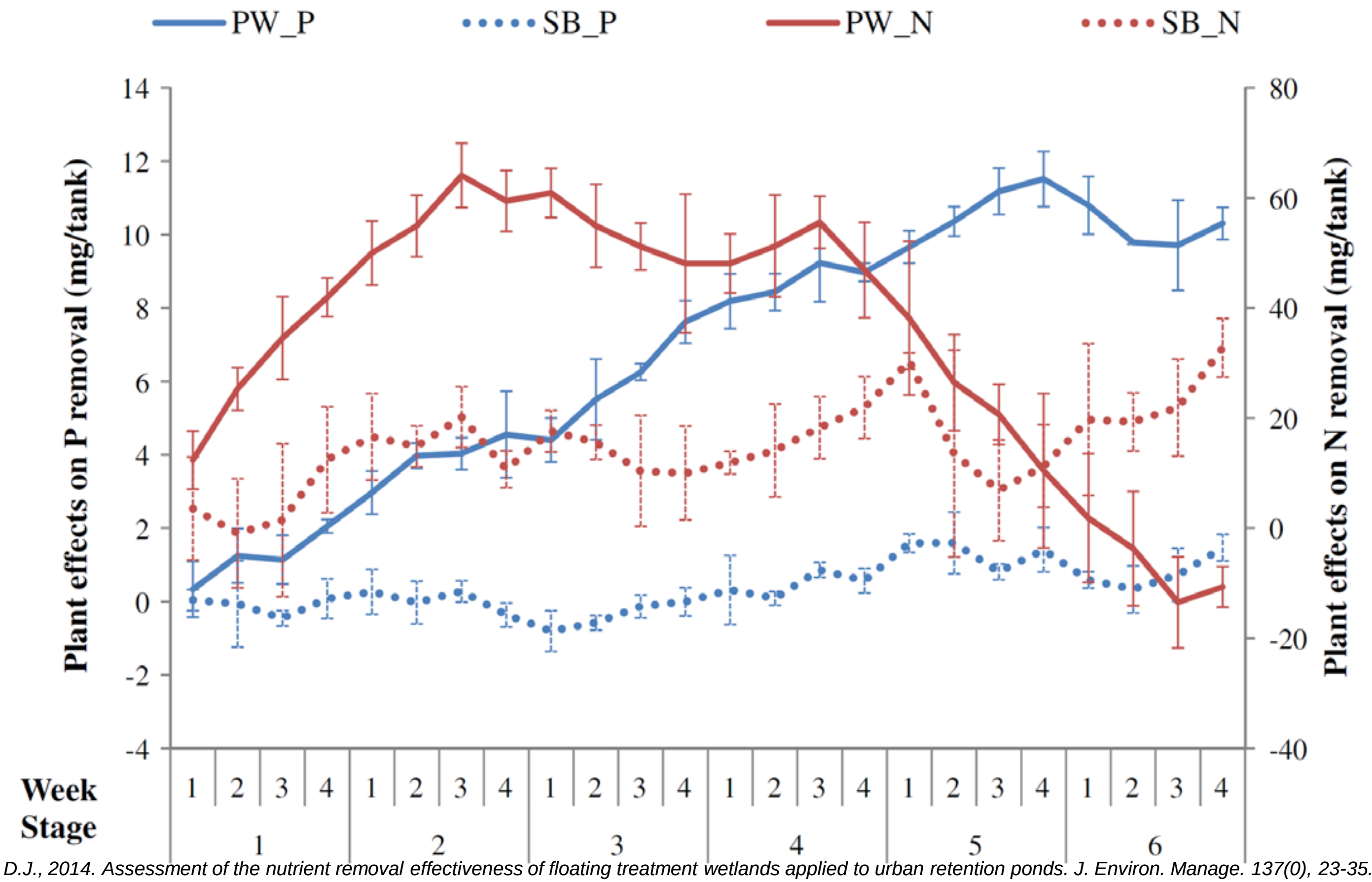
NFWF
Chesapeake Bay Program
Chesapeake Bay Stewardship Fund

Fairfax Study Setup

- Field demonstration and mesocosm evaluation
- FTW evaluation:
  - Softstem bulrush (*Schoenoplectus tabernaemontani*)
  - Pickerelweed (*Pontederia cordata L.*)
- Pond retrofit
- Water quality evaluation

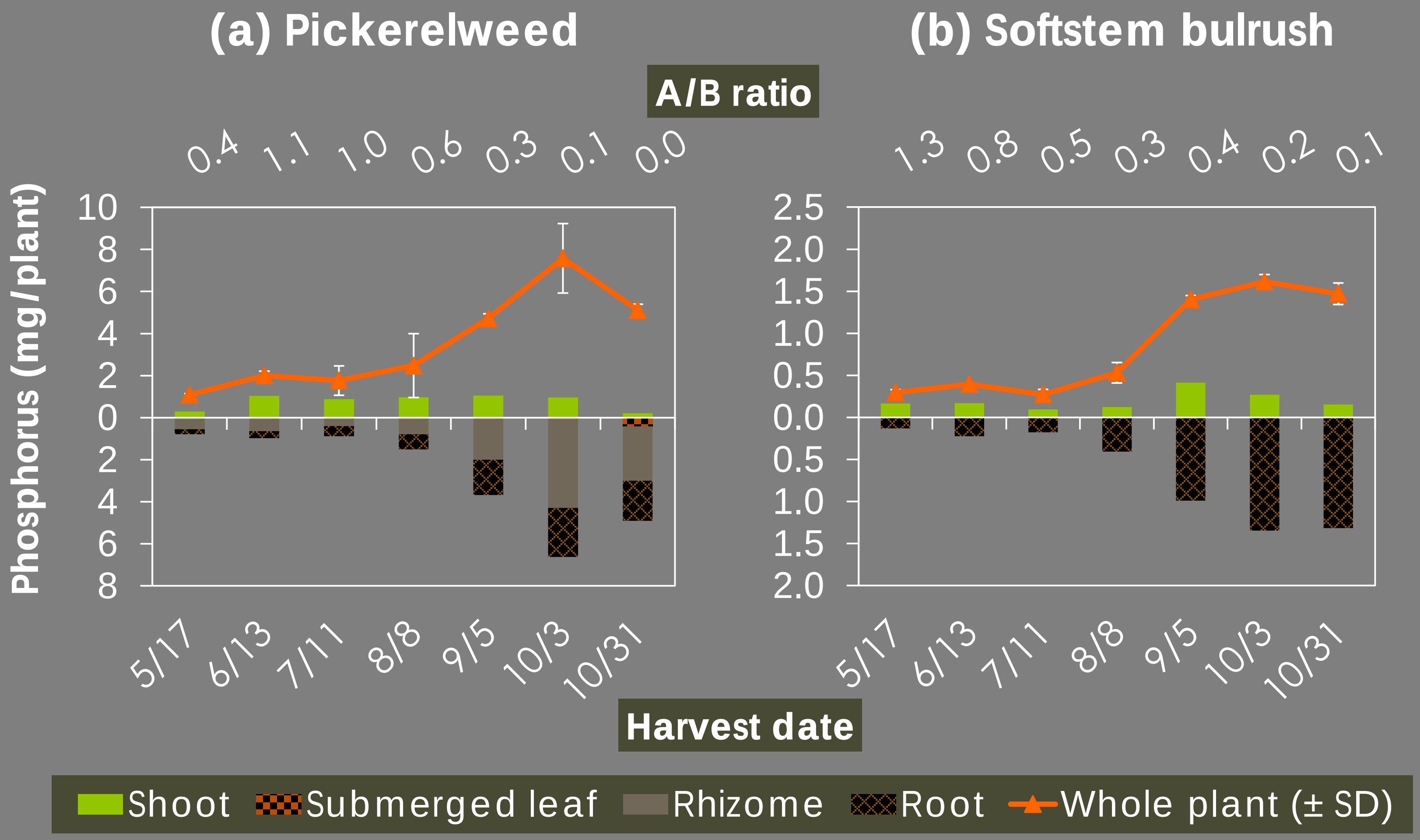
Fairfax, VA Study Results

- 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.



Wang, C.-Y., Sample, D.J., 2014. Assessment of the nutrient removal effectiveness of floating treatment wetlands applied to urban retention ponds. J. Environ. Manage. 137(0), 23-35.
Graphic: Wang, C.-Y., Sample, D.J., Bell, C., 2014. Vegetation effects on floating treatment wetland nutrient removal and harvesting strategies in urban stormwater ponds. Sci. Total Environ. 499(0), 384-393.

Phosphorus Distribution through Growing Season



Source: Wang, C.-Y., Sample, D.J., Day, S.D., and Grizzard, T.J. In review. Floating treatment wetland nutrient removal through vegetation harvest and observations from a field study, submitted, November, 2013, Ecological Engineering.

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

Lynch, J., Fox, L.J., Owen Jr, J.S., Sample, D.J., 2015. Evaluation of commercial floating treatment wetland technologies for nutrient remediation of stormwater. Ecol. Eng. 75(0), 61-69.

Mesocosm Improvements

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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.

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STAC Expert Panel: Calculating FTW improvements

i-FTW model

$$\boxed{c_{t,i-FTW} = c_0 e^{-(k_{i-FTW})t}}$$

$$= c_0 e^{-(k_w + v_f \frac{A_f}{V})t}$$

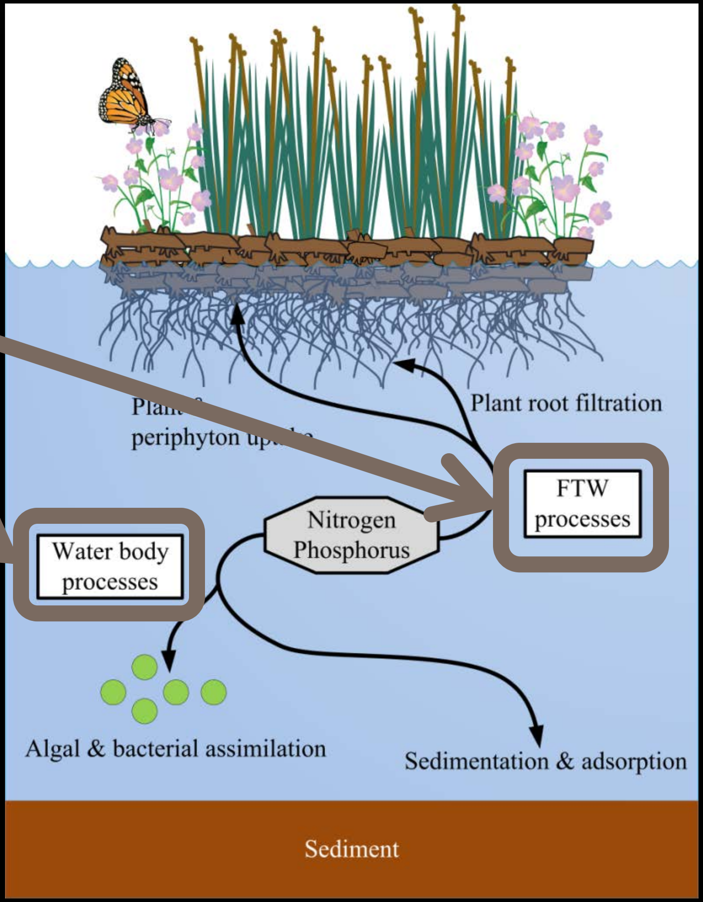
k_w = water reaction rate(1/d);

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).



Wang, C.-Y., Sample, D.J., 2013. Assessing floating treatment wetlands nutrient removal performance through a first order kinetics model and statistical inference. Ecol. Eng. 61, Part A(0), 292-302.

Combined Model Assumptions

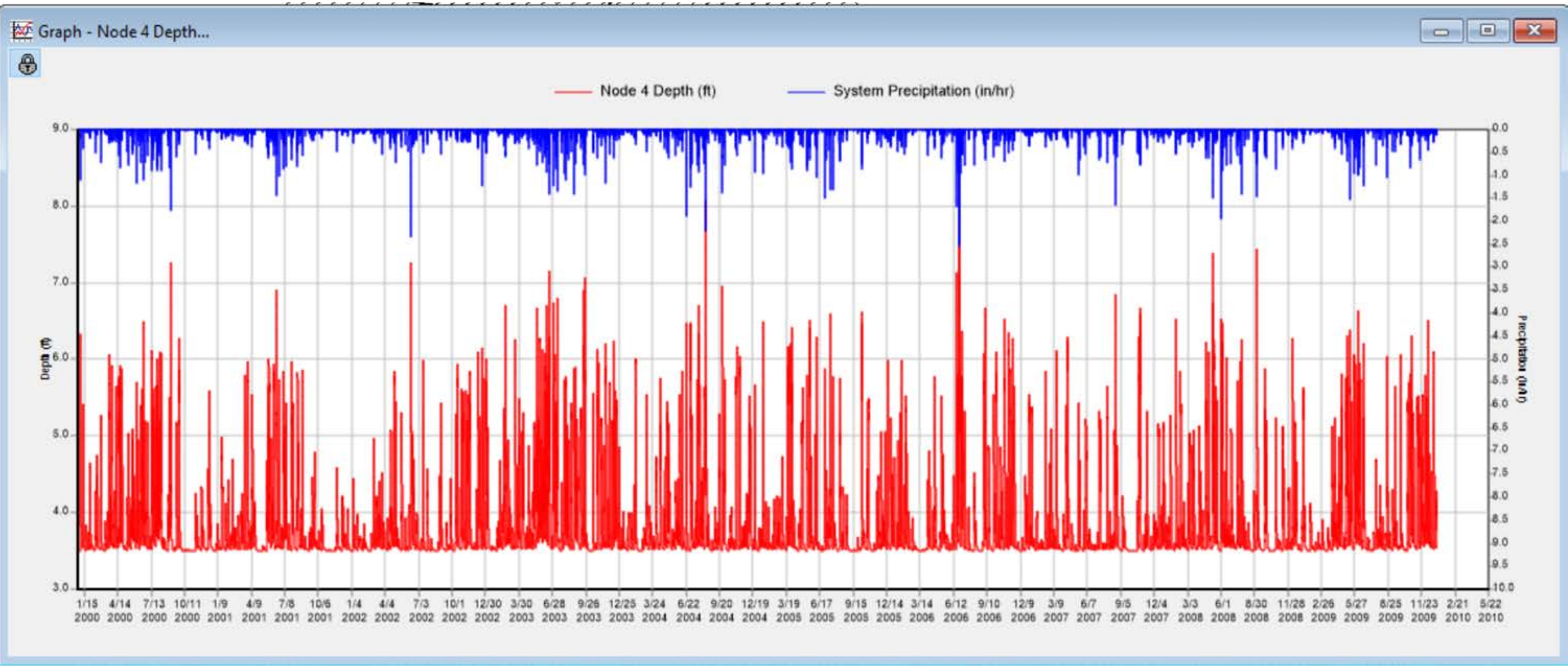
- Time for treatment:

$$\sum \{interevent\ time, 50\%\ of\ storm\ duration\}$$

- 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 1/d, P k_w=0.026 1/d (avg., literature values)

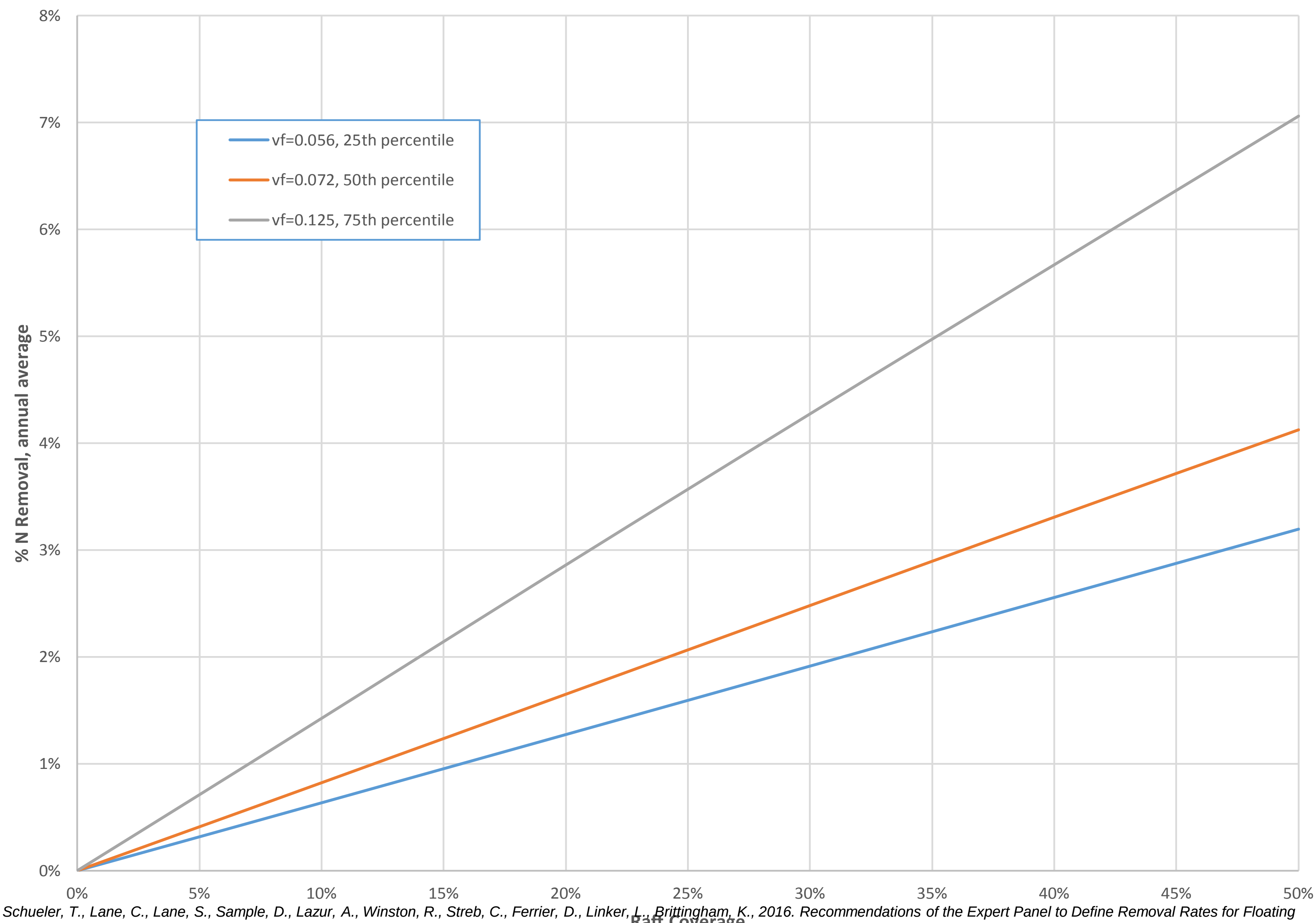
Schueler, T., Lane, C., Lane, S., Sample, D., Lazur, A., Winston, R., Streb, C., Ferrier, D., Linker, L., Brittingham, K., 2016. Recommendations of the Expert Panel to Define Removal Rates for Floating Treatment Wetlands in Existing Wet Ponds, Final Report. p. 91.

SWMM Output: Simulated Pond Volume



Schwartz, D., Sample, D.J., Grizzard, T.J., 2017. Evaluating the performance of a retrofitted stormwater wet pond for treatment of urban runoff. Environ. Monit. Assess. 189(6), 256.

N Removal as a function of v_f, Coverage



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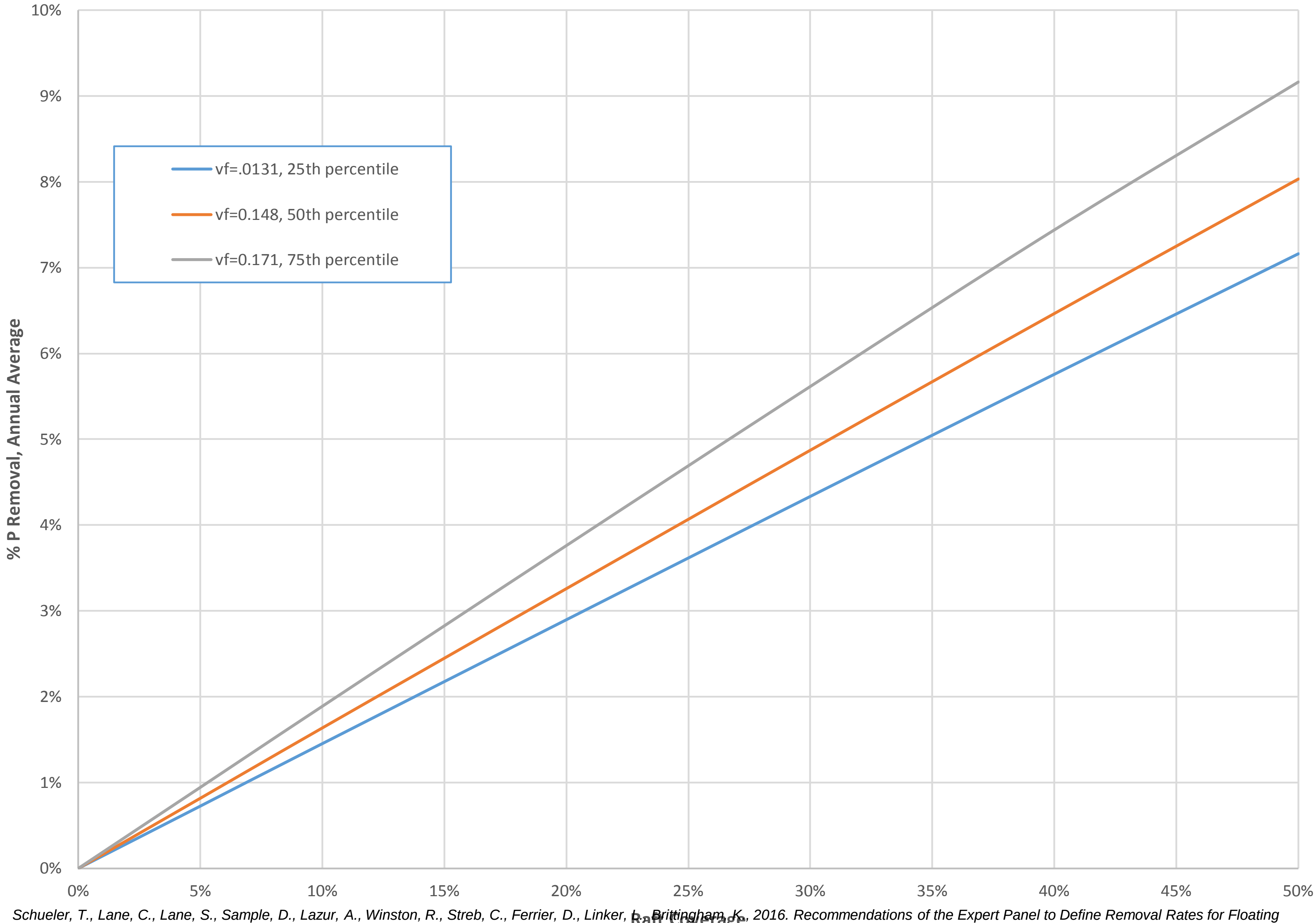
P Removal as a function of v_f, Coverage



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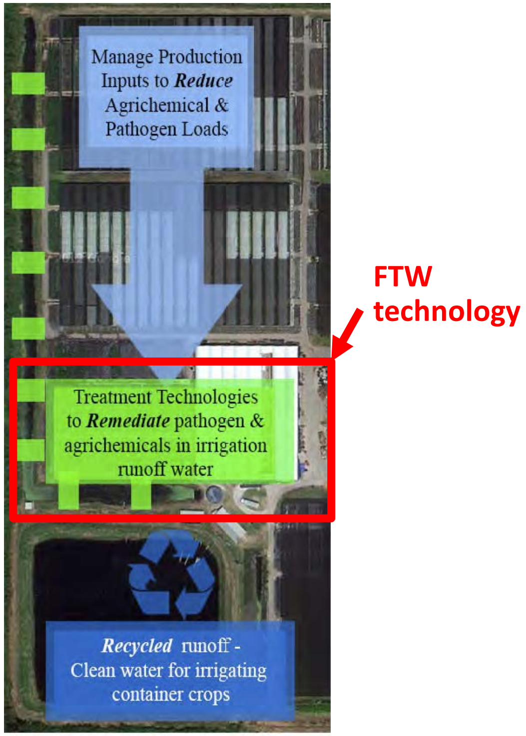
Clean WateR3 – Reduce, Remediate, Recycle – USDA SCRI Project Overview

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



White et al. Clean WateR3

SCRI - CLEAN WATER³
REDUCE, REMEDIATE, RECYCLE

USDA NIFA SCRI Project Setup

- Developed and ran experiment with 4 replications utilizing P*ontederia 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

Treatment	Mat	Plants	Species	Concentration	Reps
1	Yes	Yes	*Pontederia*	Low	4
2	Yes	Yes	*Pontederia*	High	4
3	Yes	Yes	*Juncus*	Low	4
4	Yes	Yes	*Juncus*	High	4
5	Yes	No	n/a	Low	4
6	Yes	No	n/a	High	4
7	No	No	n/a	Low	4
8	No	No	n/a	High	4

Spangler, J.T., 2017. An Assessment of Floating Treatment Wetlands for Reducing Nutrient Loads from Agricultural Runoff in Coastal Virginia, MS Thesis, Virginia Tech, Blacksburg, VA.

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

06/29/15 07/27/15 08/24/15 09/21/15

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

06/29/15 07/27/15 08/24/15 09/21/15

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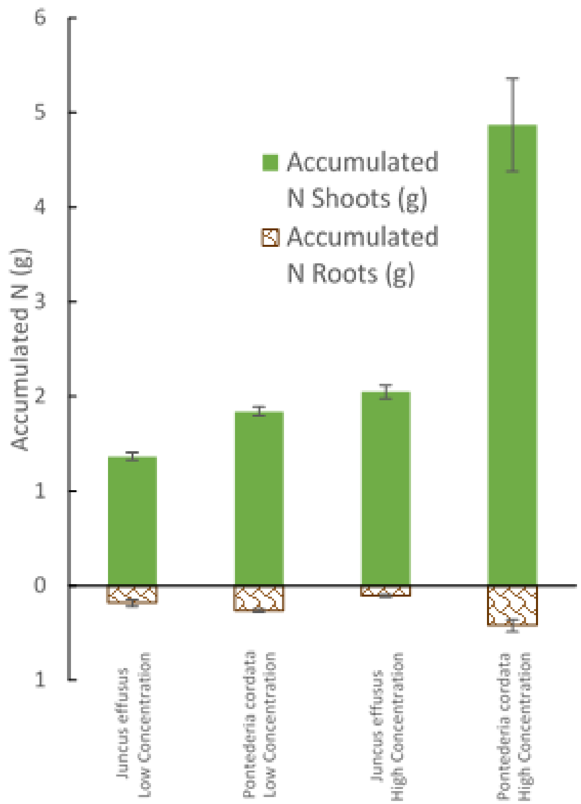
Pontederia cordata given high nutrient loads accumulated more N and P in the roots and shoots than other treatment combinations

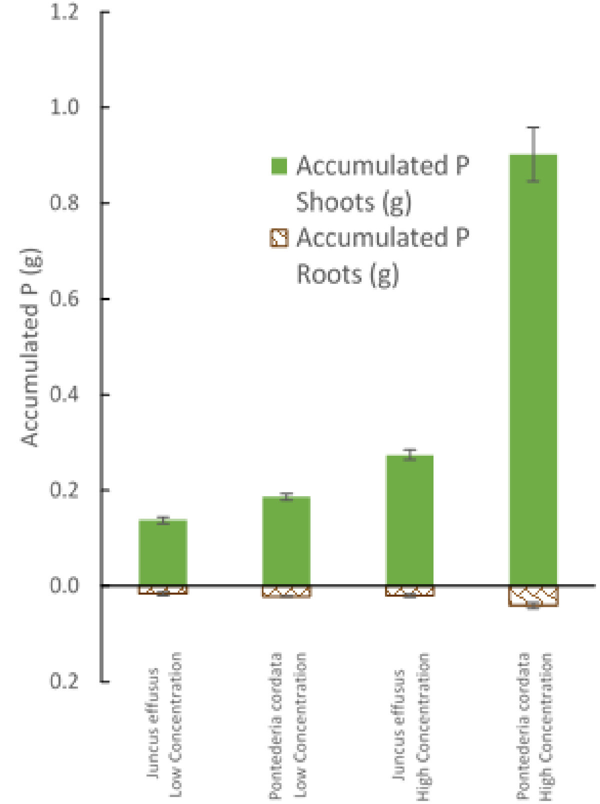
High concentration *Pontederia cordata* accumulated 4.87 g N and 0.42 g N in the shoots and roots, respectively

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**

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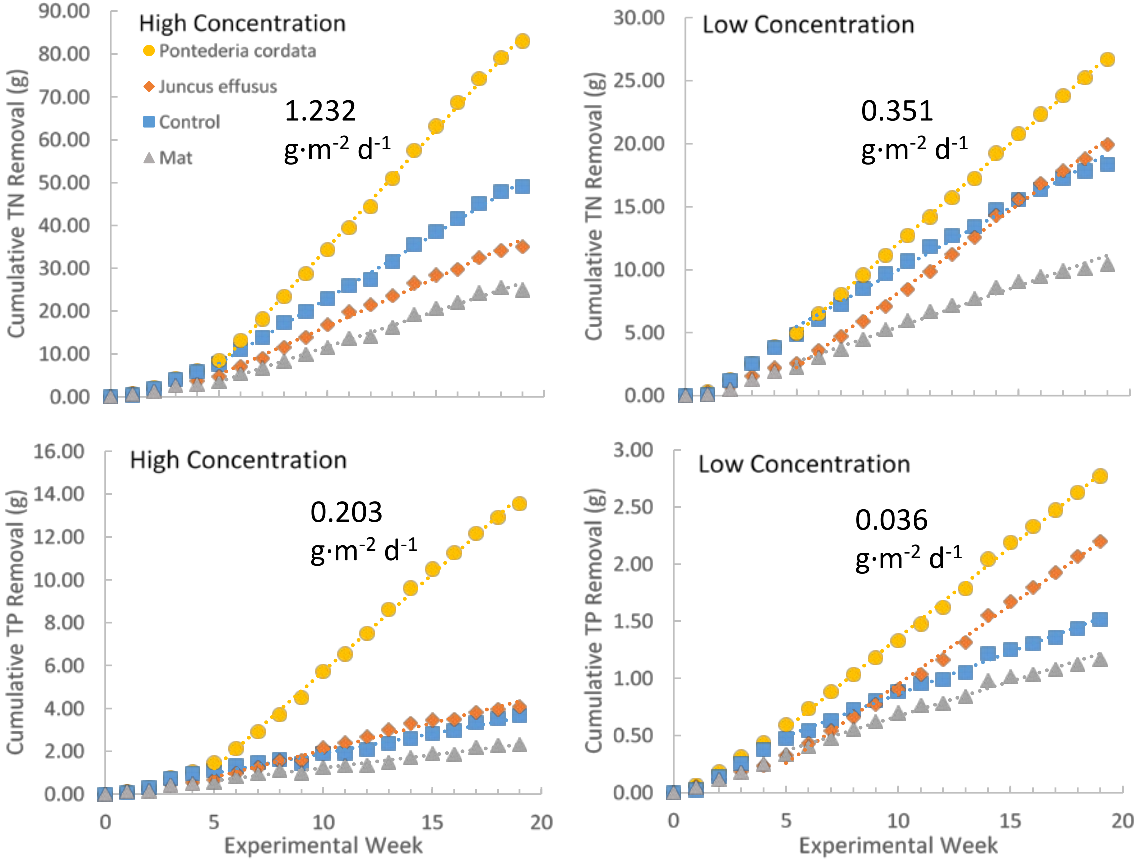

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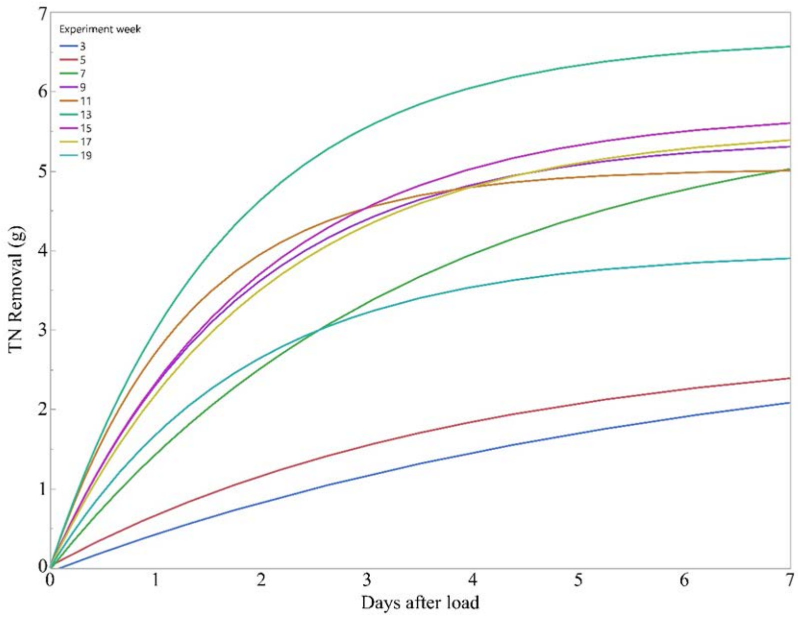
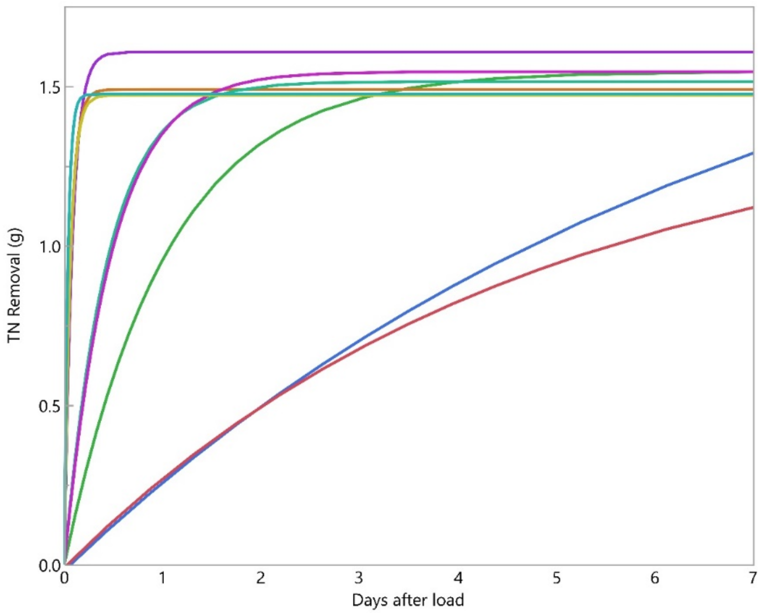
Nutrient uptake as a function of days after load fits an exponential-type model

High Concentration *Pontederia cordata*



Low Concentration *Pontederia cordata*



$$\boldsymbol{Nutrient\ removal = a * \left(1 - b * e^{-c*days\ after\ load}\right)}$$

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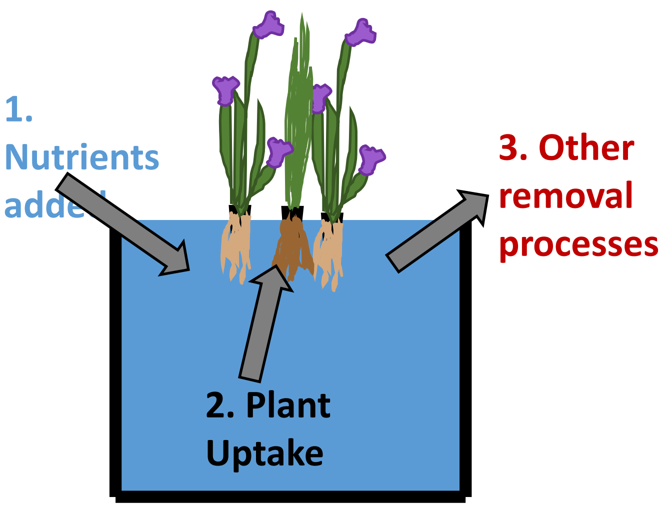
Mass balance results suggest other nutrient removal processes occurred in addition to plant uptake



	High Nutrient Concentration		Low Nutrient Concentration	
	TP (g)	TN (g)	TP (g)	TN (g)
1. Total initial load[1]	15.02	98.55	3.00	30.04
Pontederia cordata				
Total load after 7-day HRT	1.46	15.52	0.23	3.33
2. Load reduction	13.56	83.03	2.77	26.71
3. Plant uptake[2]	9.43 (69.5)	52.91 (63.7)	2.08 (75.1)	21.06 (78.8)
Other removal processes	4.13	30.12	0.69	5.65
Juncus effusus				
Total load after 7-day HRT	10.94	63.59	0.80	10.11
2. Load reduction	4.08	34.96	2.20	19.93
3. Plant uptake[2]	2.94 (72.1)	21.57 (61.7)	1.54 (70.0)	15.49 (77.7)
Other removal processes	1.14	13.39	0.66	4.44

[1]n = 1 for initial load data. [2]Mean uptake (% of total load reduction)

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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 $g{\cdot}m^{-2}\ d^{-1}$ for the high (Ag) and low (urban) concentrations, respectively. P removal for *Pontederia* was 0.203 and 0.036 $g{\cdot}m^{-2}\ d^{-1}$ 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.

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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

Wang, C.-Y., Sample, D.J., Bell, C., 2014. Vegetation effects on floating treatment wetland nutrient removal and harvesting strategies in urban stormwater ponds. Sci. Total Environ. 499(0), 384-393.

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