Metropolitan Water Reclamation District of Greater Chicago

Welcome to the November Edition of the 2025 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- Remote attendees' microphones are muted at entry to minimize background noise. For attendees in the auditorium, please silence your phones.
- A question and answer (Q/A) session will follow the presentation.
- For remote attendees, please use "**Chat**" only to type questions for the presenter. For other issues, please send emails to MnRseminars@mwrd.org. For attendees in the auditorium, please raise your hand and wait for the microphone to ask a verbal question during the Q/A session.
- The presentation slides will be posted on the MWRD website after the seminar.
- This seminar has been approved by the Engineering Society of Illinois (ESI) for one PDH and is pending approval by the IEPA for one TCH. Certificates will be issued only to participants who attend the entire presentation. For PDH certificate seekers, **you are required to complete a brief course evaluation and submit it.**

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Levi Straka. Ph.D., P.E. is a Senior Environmental Research Scientist at the District who works on evaluating emerging wastewater technologies and managing original research projects. Levi received his Ph.D. from Arizona State University where his dissertation was on the growth kinetics of blue-green algae.

Charles Impastato, M.S.
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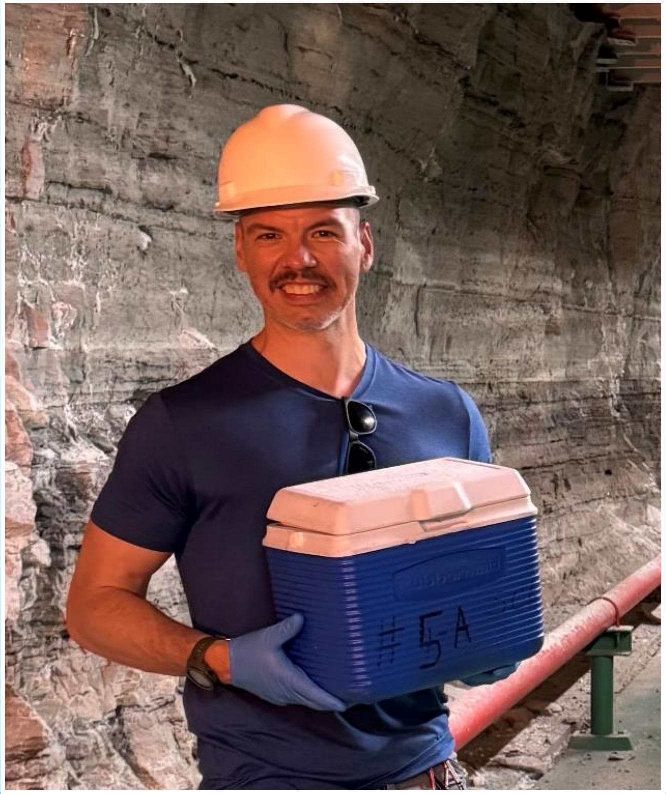


Charles Impastato is a Senior Environmental Research Technician in the wastewater research section at the District who carries out District research initiatives. His master's thesis work was done with native Illinoisian prairie species and helped inspire the design of the Artificial Floating Wetlands.

Phytoremediation using Duckweed and Artificial Floating Wetlands (AFW) for Nutrient Removal at MWRDGC

November 21st, 2025

Levi Straka PhD PE

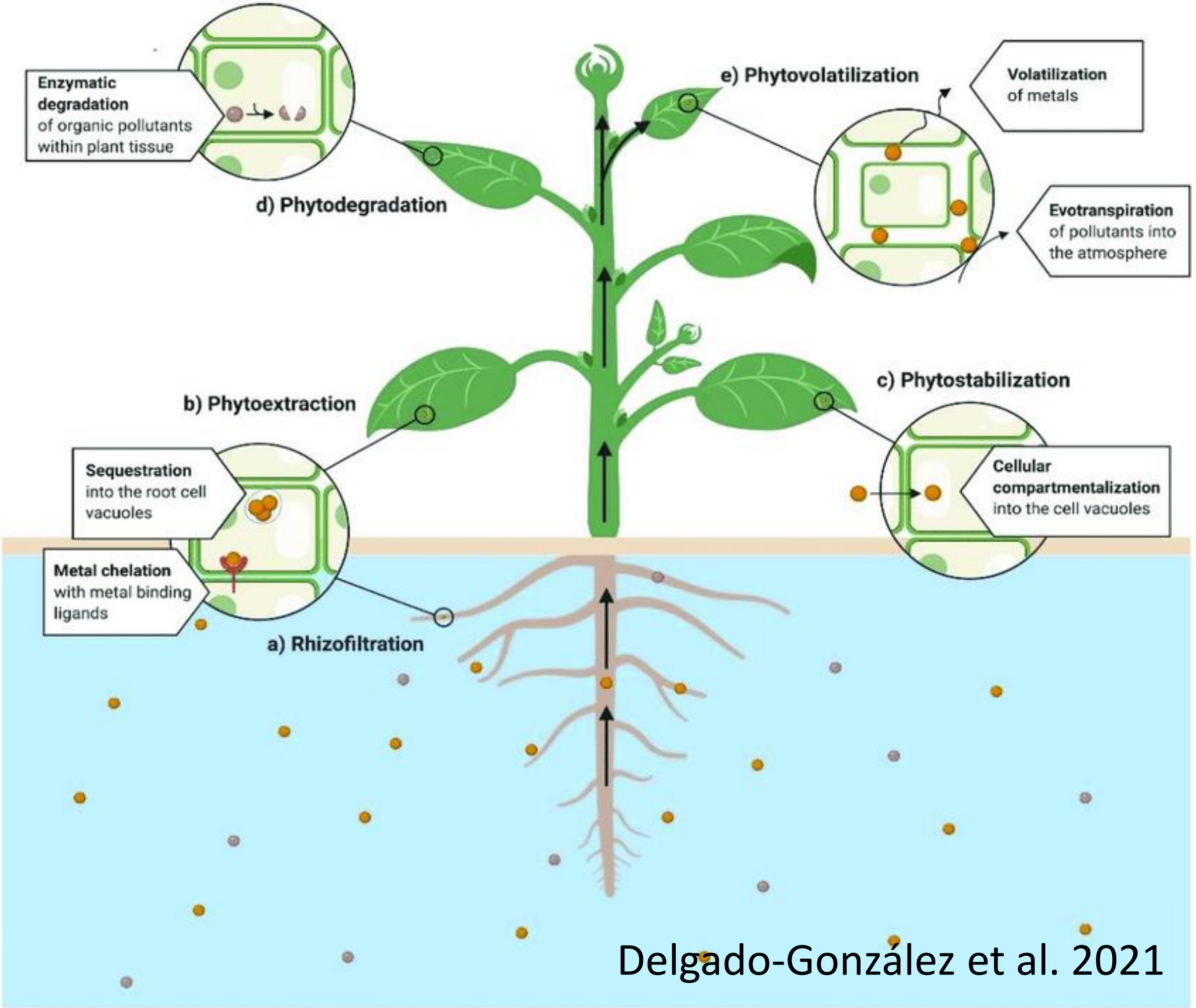
Charles Impastato MSc

Outline

1. Phytoremediation - treatment of pollutants using green plants
2. Duckweed
3. Artificial Floating Wetlands
   - Species Screening
   - Pilot Scale Demonstration

Phytoremediation

- More stringent Phosphorus permits require new solutions
- Phosphorus is a key nutrient for plant growth



Delgado-González et al. 2021

Phytoremediation

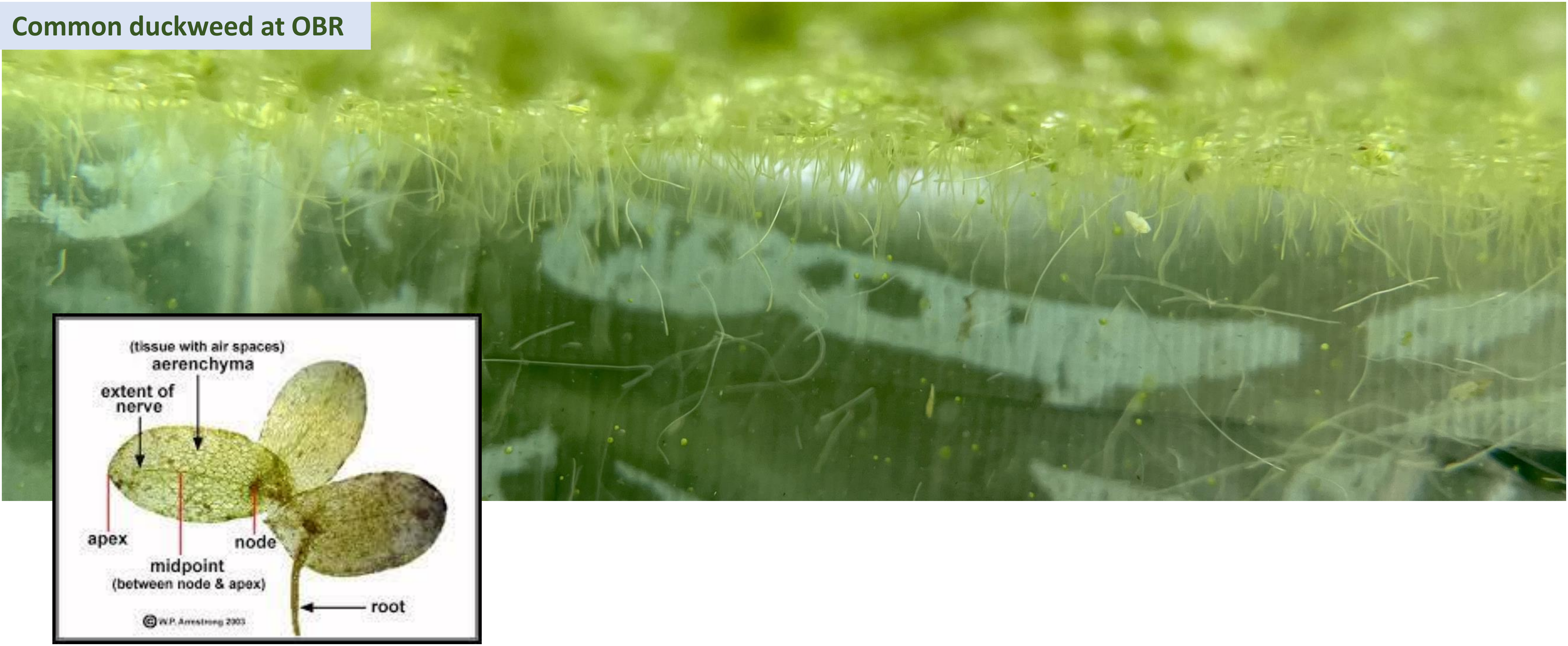
Pros	Cons
Passive and low energy	Requires light and large areas
Harvestable plant biomass	Bioaccumulation of pollutants
Public perception is positive	Limited to growing season

Rotating Algal Biofilm

- Algae/Bacterial consortium
- Achieved 0.22 gP/m^2/d removal
- Requires infrastructure

Duckweed

Common duckweed at OBR



Common Duckweed (*Lemna minor*)

- High growth rates
- Easy to harvest
- No structural tissue
- No serious pests

Lemna Minor (source: azgardens.com)

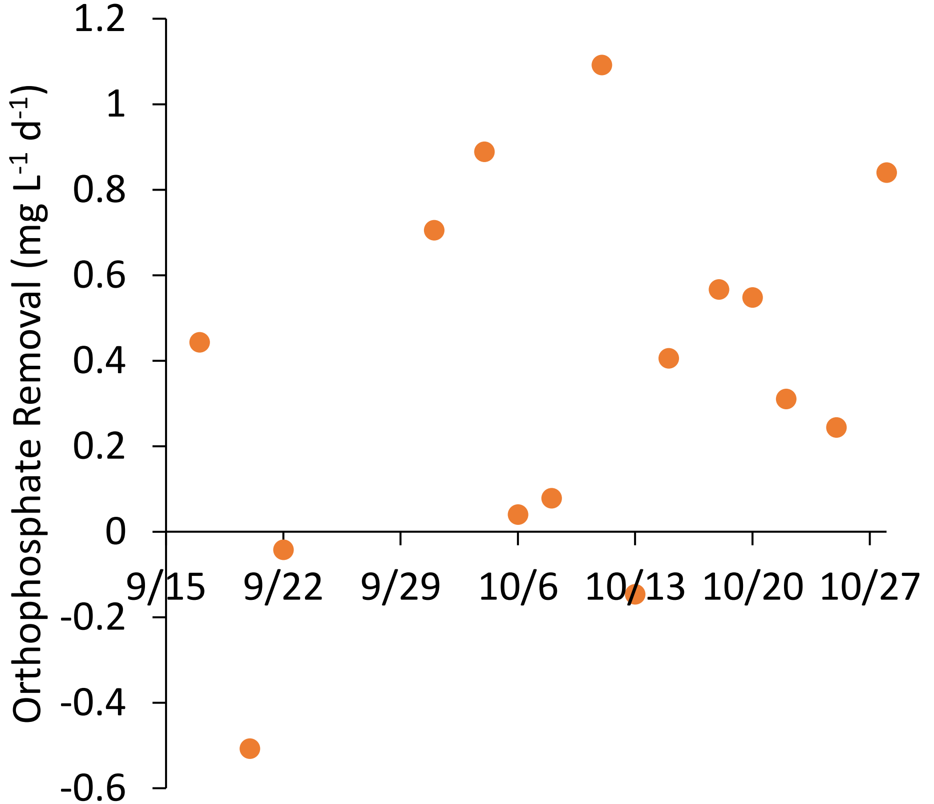
Duckweed

Bucket Testing

- 5-gallon bucket reactor
- Outside in full sun
- Fed with Hanover Park WRP primary effluent
- HRT of 2.8 d
- SRT of 31 days

Bucket Testing

- Average: 0.36 mg/L orthoP

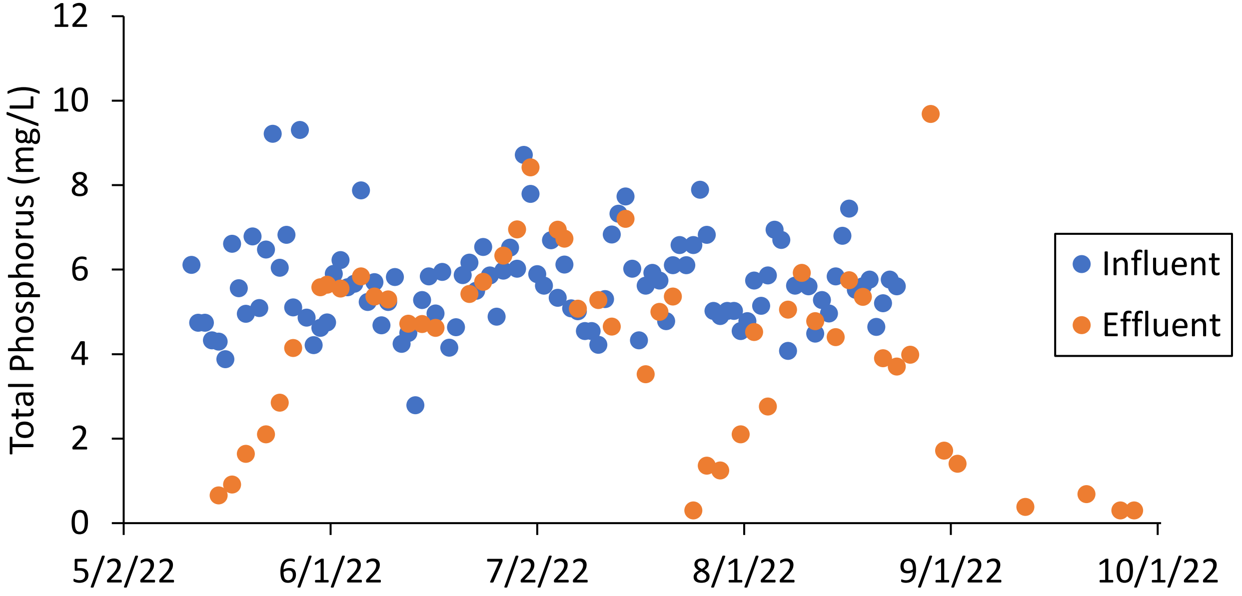


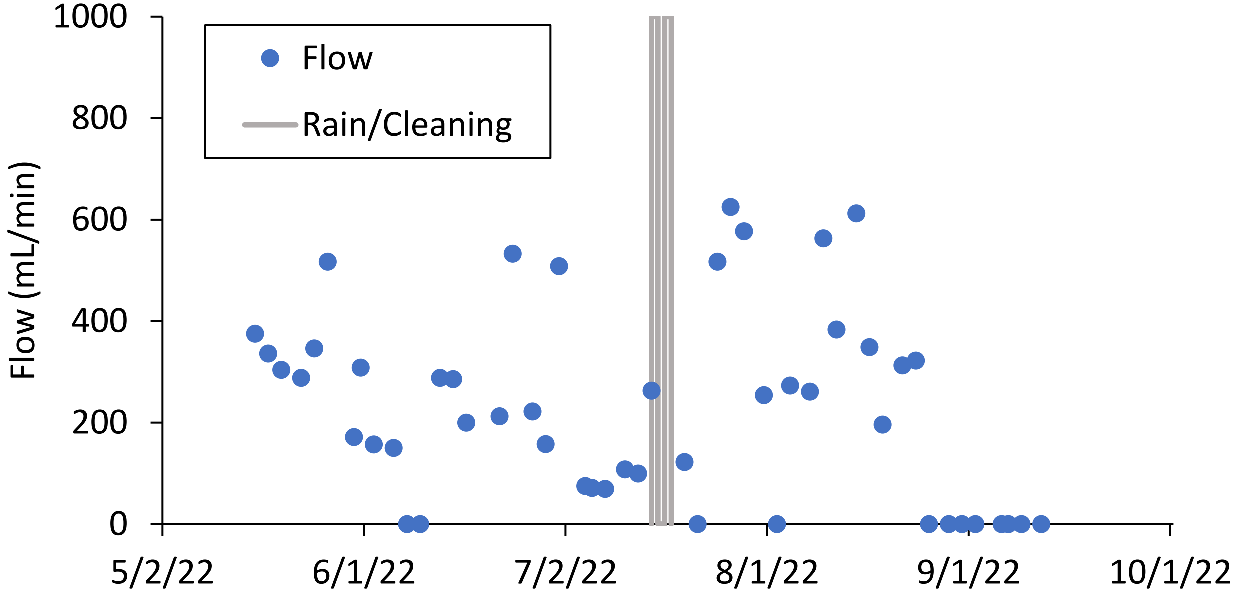
Outdoor Raceway

- 55 ft^2 raceway pond (340-gal) reactor
- Continuously fed Stickney WRP Primary Effluent
- Outside in full sun
- Variable HRT and SRT
- Run for most of the growing season

Outdoor Raceway

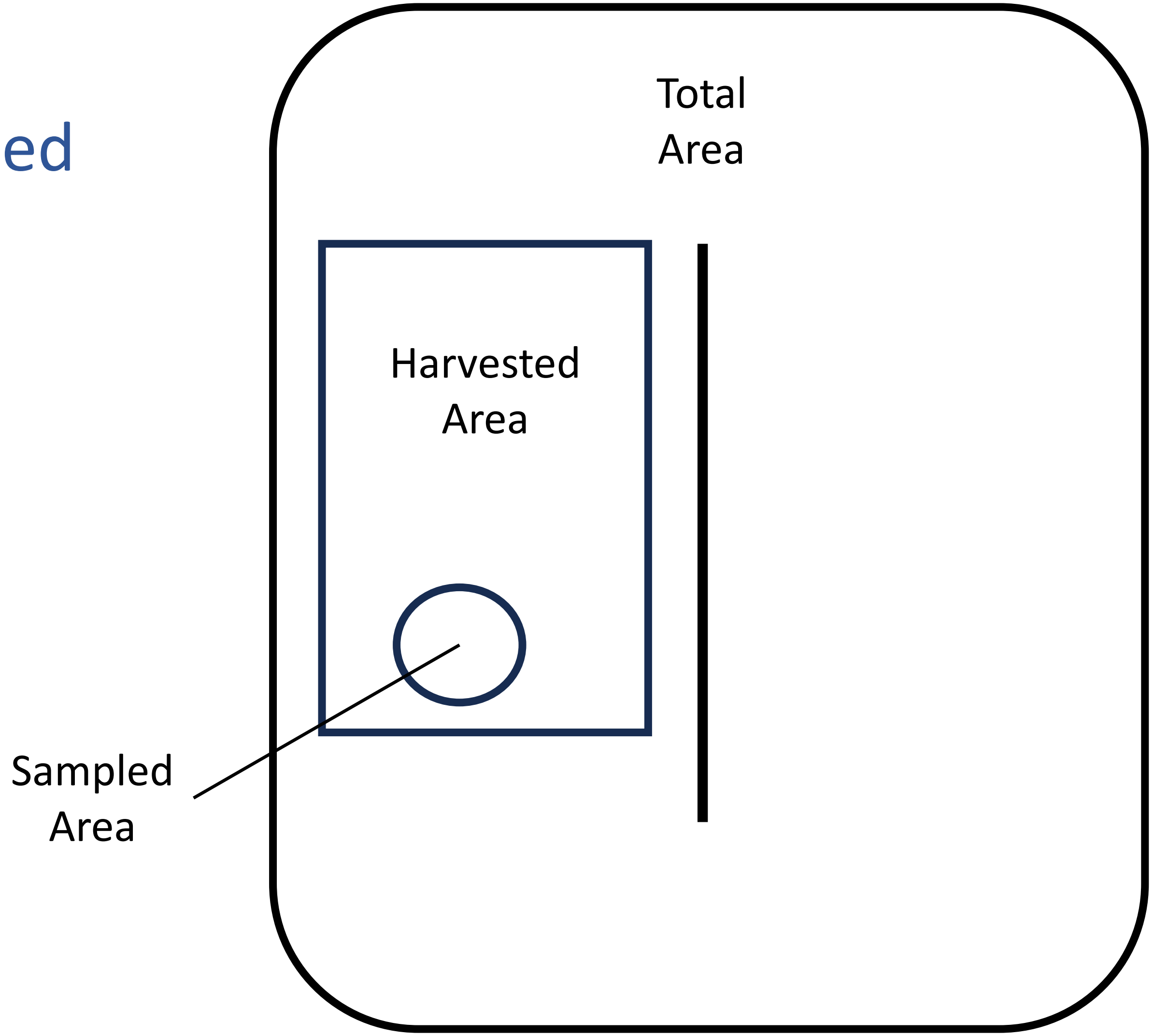
- Phosphorus removal was not apparent
- Influent Flow was not consistent
- Couldn't reliably determine phosphorus removal from liquid data





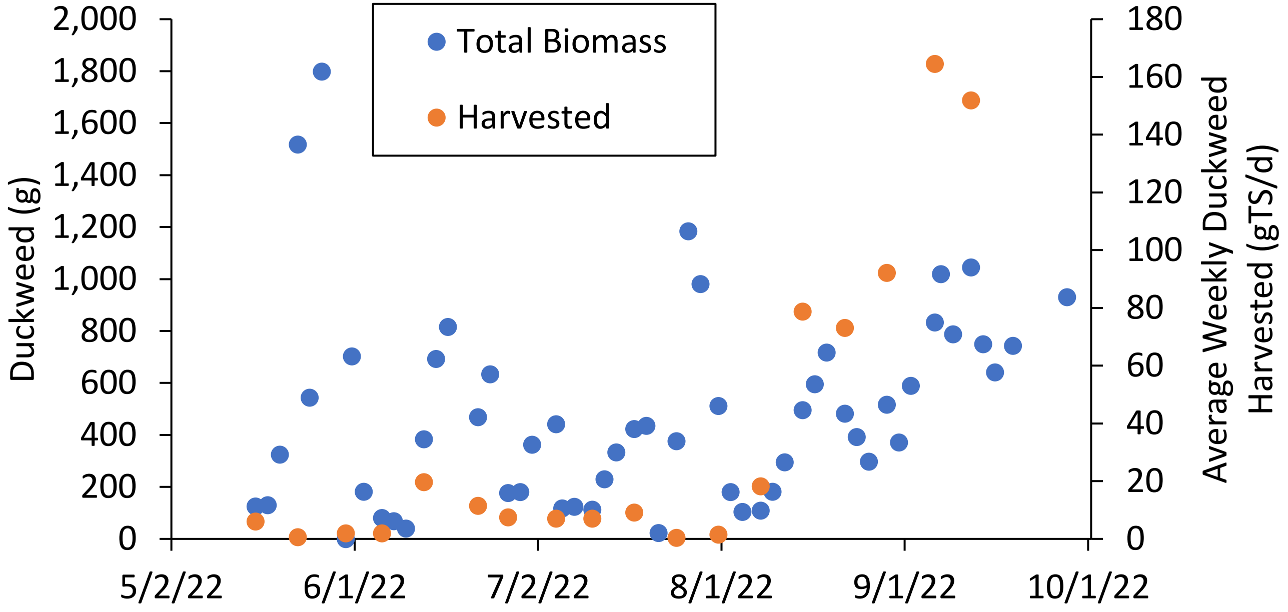
Duckweed Inventory

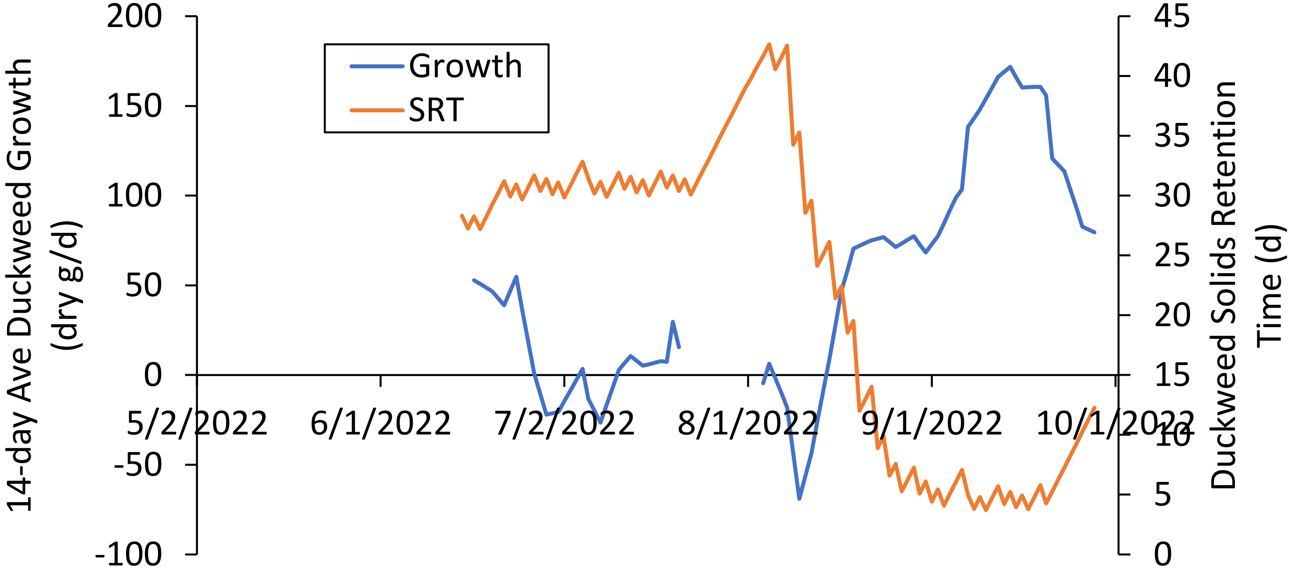
- Determined the total Duckweed and duckweed harvested by extrapolating from a smaller sample area



Duckweed Inventory

- Managing the duckweed inventory was challenging.
- Duckweed growth increased markedly in August
- Duckweed Biomass was 0.97% Phosphorus (gP/g)





Challenges

- algae/slime
- consistent flow
- managing duckweed inventory
- settling sludge
- lose duckweed with rain

Study Site

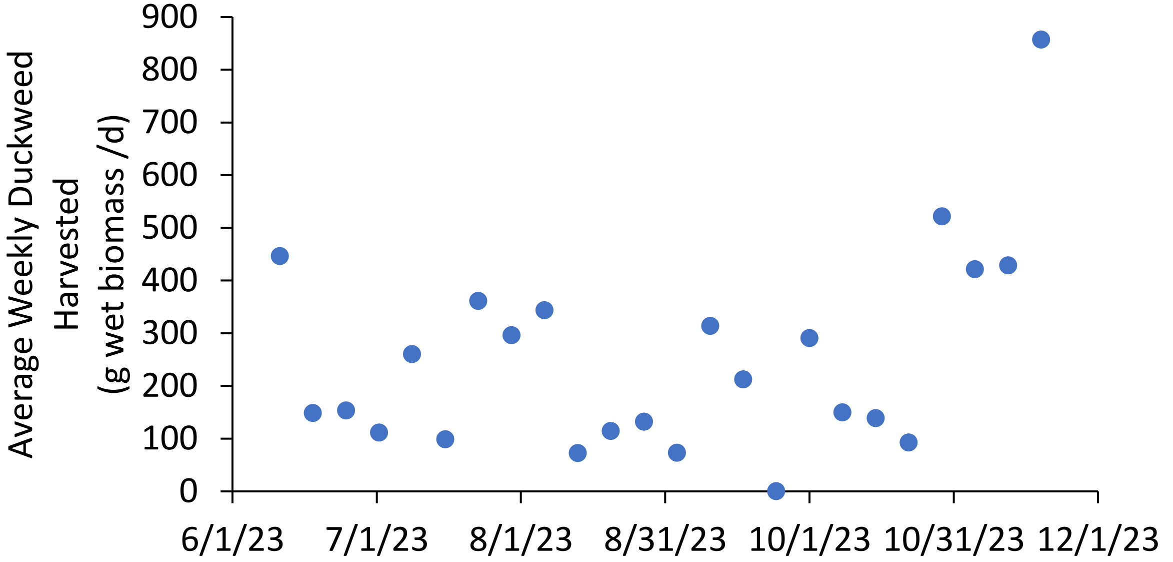
Greenhouse at OBR - Skokie, IL (with artificial lighting system)

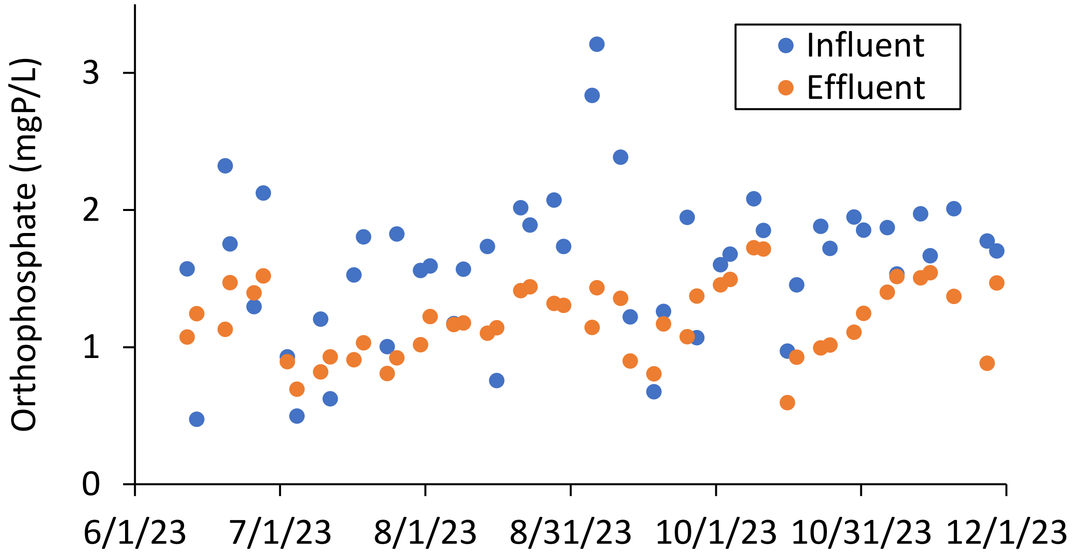
Greenhouse Raceway

- 55 ft^2 raceway pond (340-gal) reactor
- continuously fed O'Brien WRP secondary effluent
- in a greenhouse
- more consistent HRT (3.5 d)
- more consistent duckweed coverage (variable SRT)
- longer growing season

Greenhouse Raceway

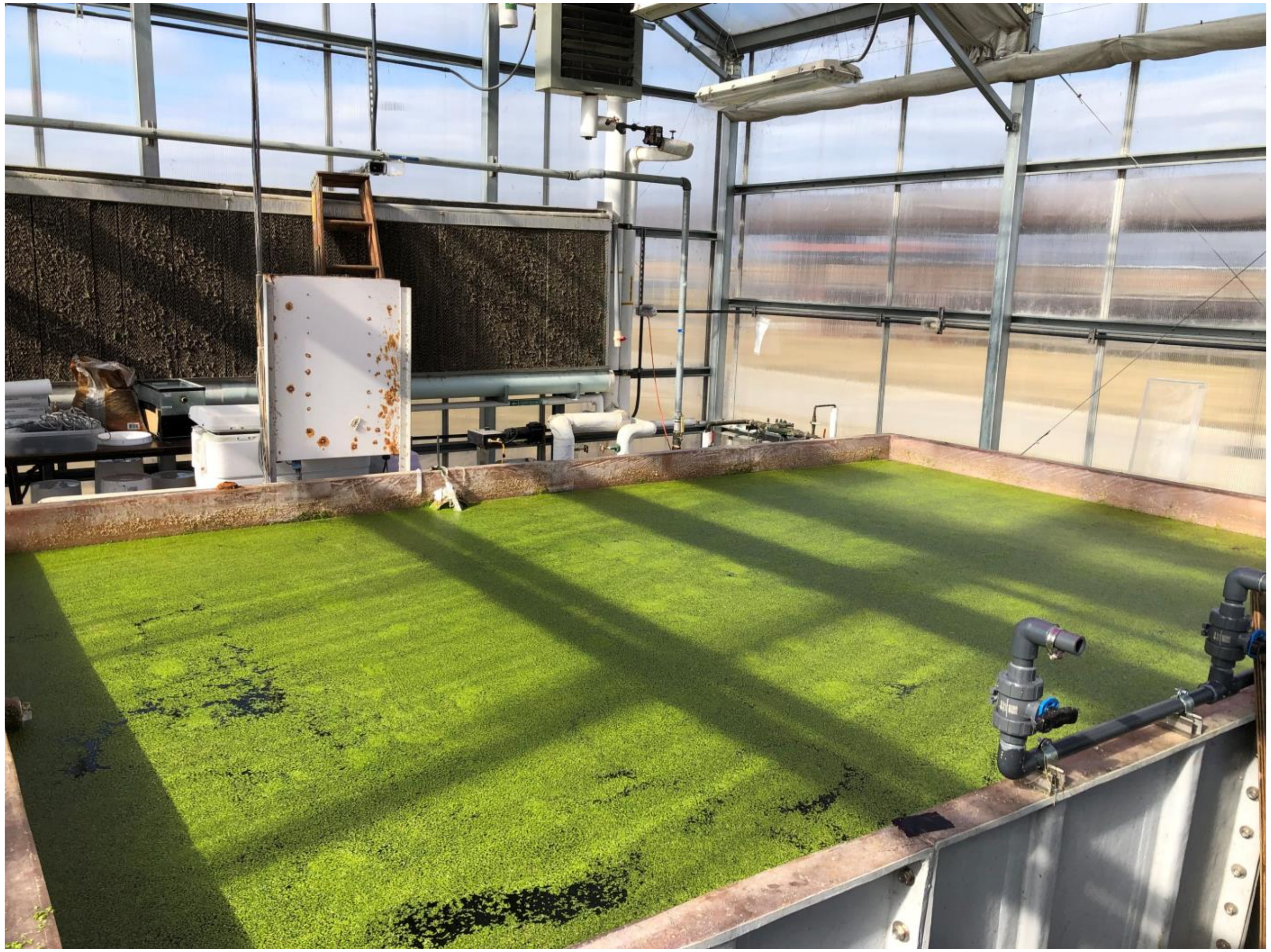
- Saw more consistent duckweed growth, but didn't see the surge in growth in August/September.
- Average Removal 0.43 mgP/L.





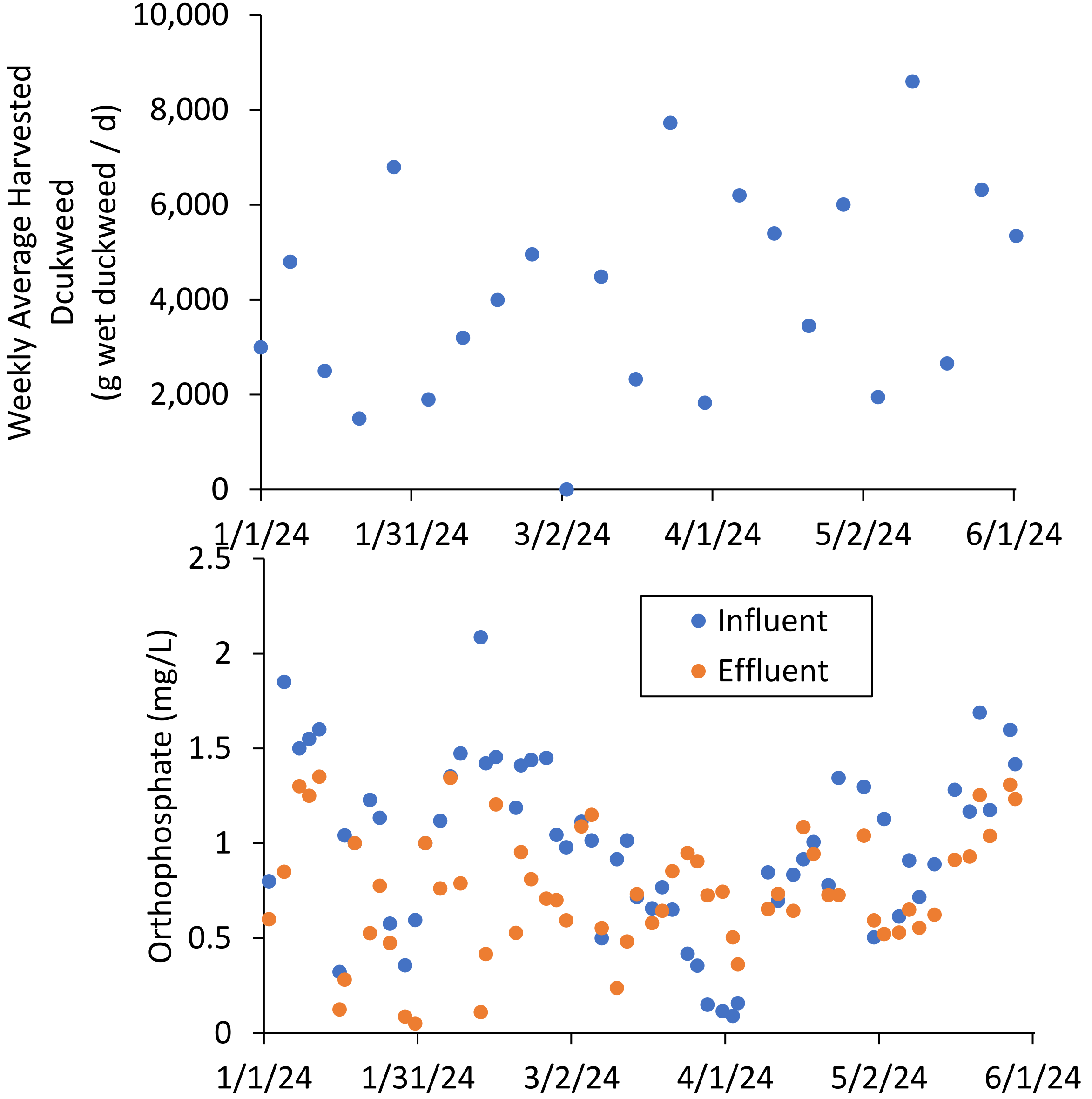
Large Tank Duckweed Study

- 165 ft^2 large tank (3,270-gal) reactor
- Similar operation as raceway
  - in the greenhouse
  - duckweed harvest based on coverage
- 1.5d HRT
- Conducted during the winter
  - Artificial light



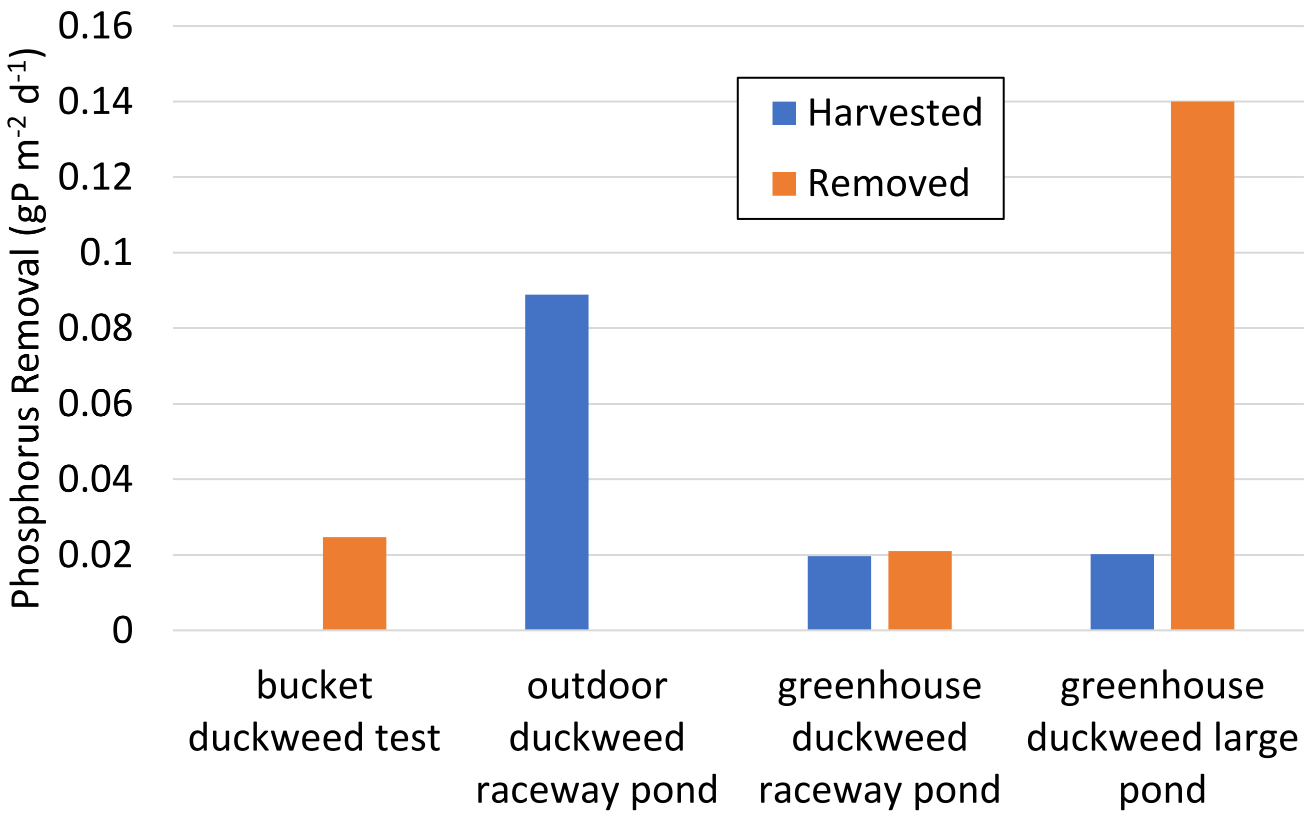
Duckweed Orthophosphate Removal

- Good duckweed growth



Summary

- To remove 1 mgP/L from 1 MGD requires 47 acres at 20 mgP m^{-2} d^{-1}.



Challenges to a Larger Duckweed Application

- Large area
- Need a method for passive harvesting
- Seasonality

Artificial Floating Wetlands (AFW)

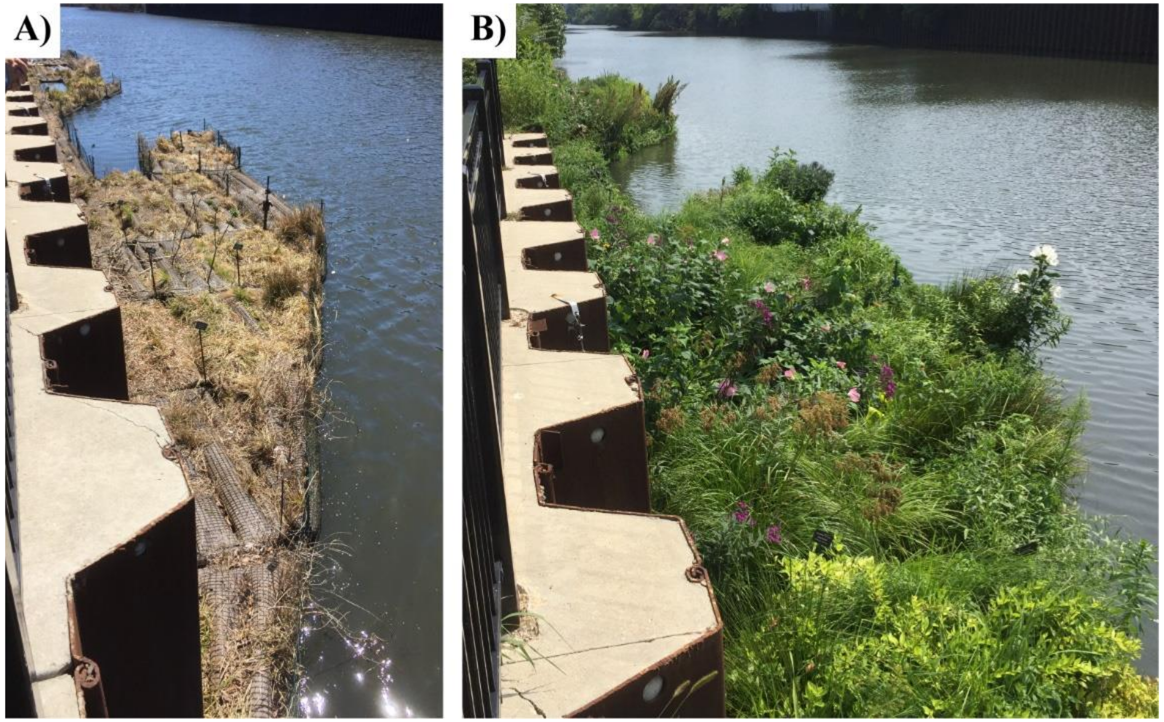
AFW in Baltimore Harbor
Source: Bay Journal

Artificial Floating Wetlands (AFW)

- AFW are structures that allow plants to grow on top of water bodies

Aztec Chiampa

Source: mexicohistorico.com



AFW on the Chicago River

Source: **Peterson, E. W.,** Nicodemus, P., Spooner, E., & Heath, A. (2021). The effectiveness of an artificial floating wetland to remove nutrients in an urban stream: A pilot-study in the Chicago River, Chicago, IL, USA. *Hydrology, 8*(3), 115. https://doi.org/10.3390/hydrology8030115

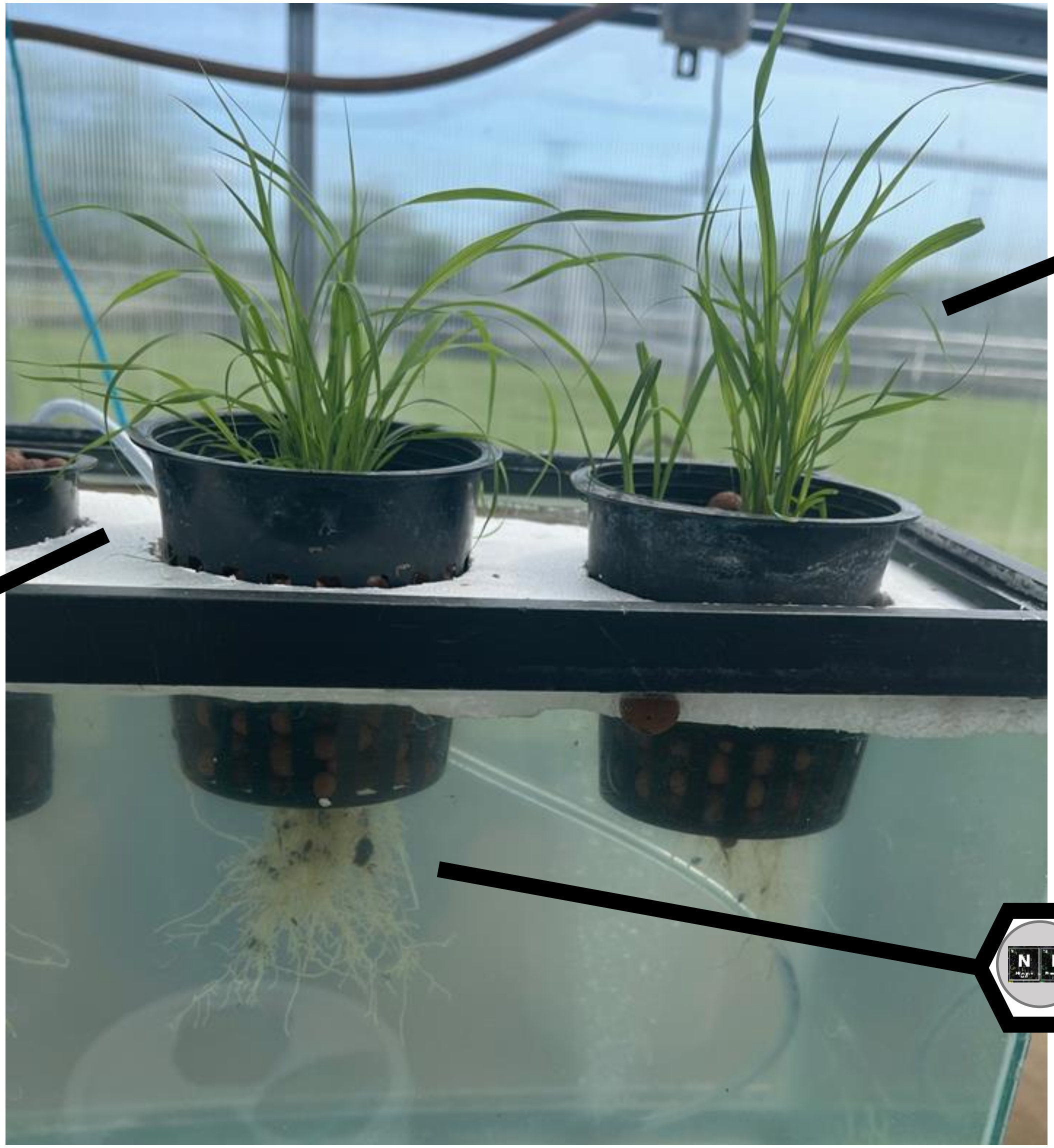
AFW - Hydroponic System

- AFWs are essentially a hydroponic system
- Growing plants without soil using nutrient solution to deliver nutrition

Hydroponic Lettuce

Source: Progressive Grocer

AFW - Hydroponics



Plants utilize light energy to consume carbon dioxide

Plant roots suspended in nutrient rich, oxygenated water

Plant roots uptake nitrogen, phosphorus and other contaminants cleaning the water

AFW – Essential Nutrients

Does final effluent contain enough nutrition to facilitate plant growth?

	N	P	K	Mg	S	Ca	B	Cl	Mn	Fe	Ni	Cu	Zn	Mo
Final Effluent (ppm)	2-10	1-3	7.2	24.6	51.1	67.0	unknown	179.1	0.007	0.1	0.005	0.025	0.1	0.01
Optimal (ppm)	100-200	15-50	150-300	30-75	50-150	100-200	0.3-0.6	0.5-5.0	0.3-0.7	1.0-3.0	0.005-0.1	0.02-0.05	0.05-0.20	0.05-.10

- Macro and Micro Nutrients

Study Goals

1. Species Selection
2. Construct AFW
3. Quantify Nutrient Removal

Goal 1 – Species Selection

First attempts at growing natives hydroponically – Spring 2023

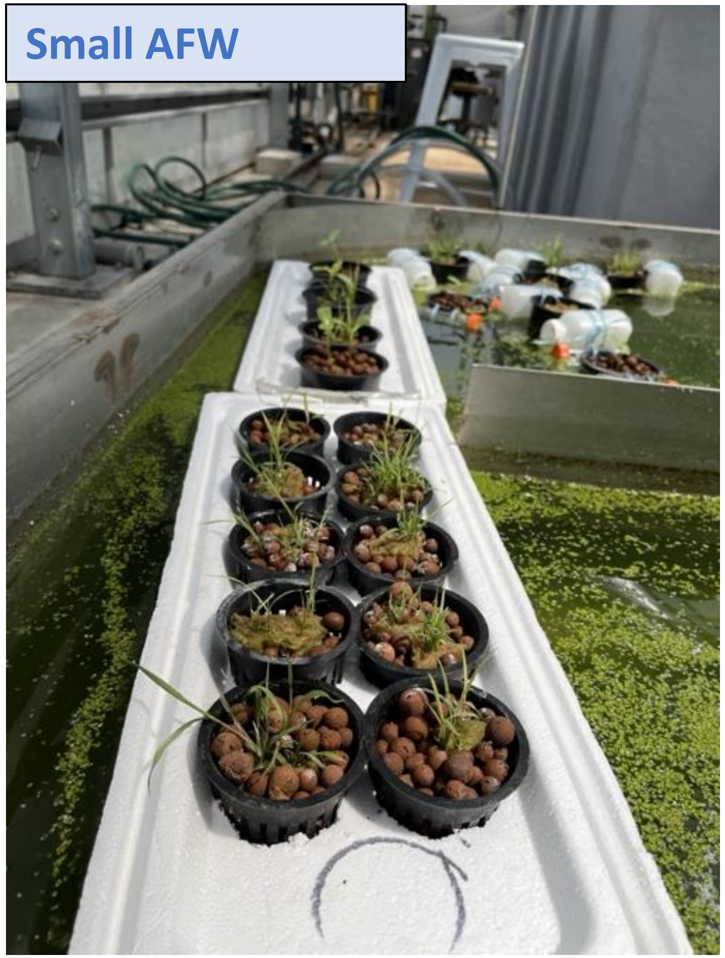
Big Bluestem (*Andropogon gerardi*)

Switch Grass (*Panicum vergatum*)

- Germinated in rockwool
- Grown in net cups with Hydroton clay pebbles in nutrient solutiom

Goal 1 – Species Selection

First attempts at growing natives hydroponically



- Grown in nutrient solution and small islands in raceway
- Both species failed adaptation to aquatic life
- Switched to native wetland species for next trial

Goal 1 – Species Selection

Sedges/Rushes	Grasses	Forbs
Juncus effusus (Common Rush)	*Bromus ciliates* (Fringed Brome)	*Mentha arvensis* (Wild Mint)
Carex stricta (Tussock Sedge)	*Glyceria striata* (Fowl Grass)	*Lycopus americanus* (Water Horehound)
Carex Aquatilis (Water Sedge)	*Muhlenbergia racemose* (Marsh Muhly)	*Helenium autumnale* (Sneezeweed)
Scirpus cyperinus (Wool Grass)	*Spartina pectinata* (Cord Grass)	*Rumex alatissimus* (Pale Dock)
		Hibiscus moscheutos (Swamp Rose Mallow)
		Cephalanthus occidentalis (Button Bush)

- 14 Native Illinoisian wetland species
- Flood tolerable

Goal 1 – Species Selection

Button Bush

Marsh Muhly

- Germinated in soil instead of rockwool

Goal 1 – Species Selection

- Bucket testing
- Tank testing with final effluent

Horehound in Large Tank

Goal 1 – Species Selection: Bucket Testing

- Ortho-P testing : 1-week intervals
- Species isolation
- Morphological characteristics

Wild Mint

Fringed Brome

Goal 1 – Species Selection: Bucket Testing

- 3- and 5-Gallon Buckets
- Grown in net cups with Hydroton clay pebbles
- Plants in ideal conditions

Marsh Muhly

Goal 1 – Species Selection: Bucket Testing

Button Bush – 1 Week

Button Bush – 2 Months

Goal 1 – Species Selection: Bucket Testing

Water Horehound – 1 Week

Water Horehound – 3 Weeks

Water Horehound – 2 Months

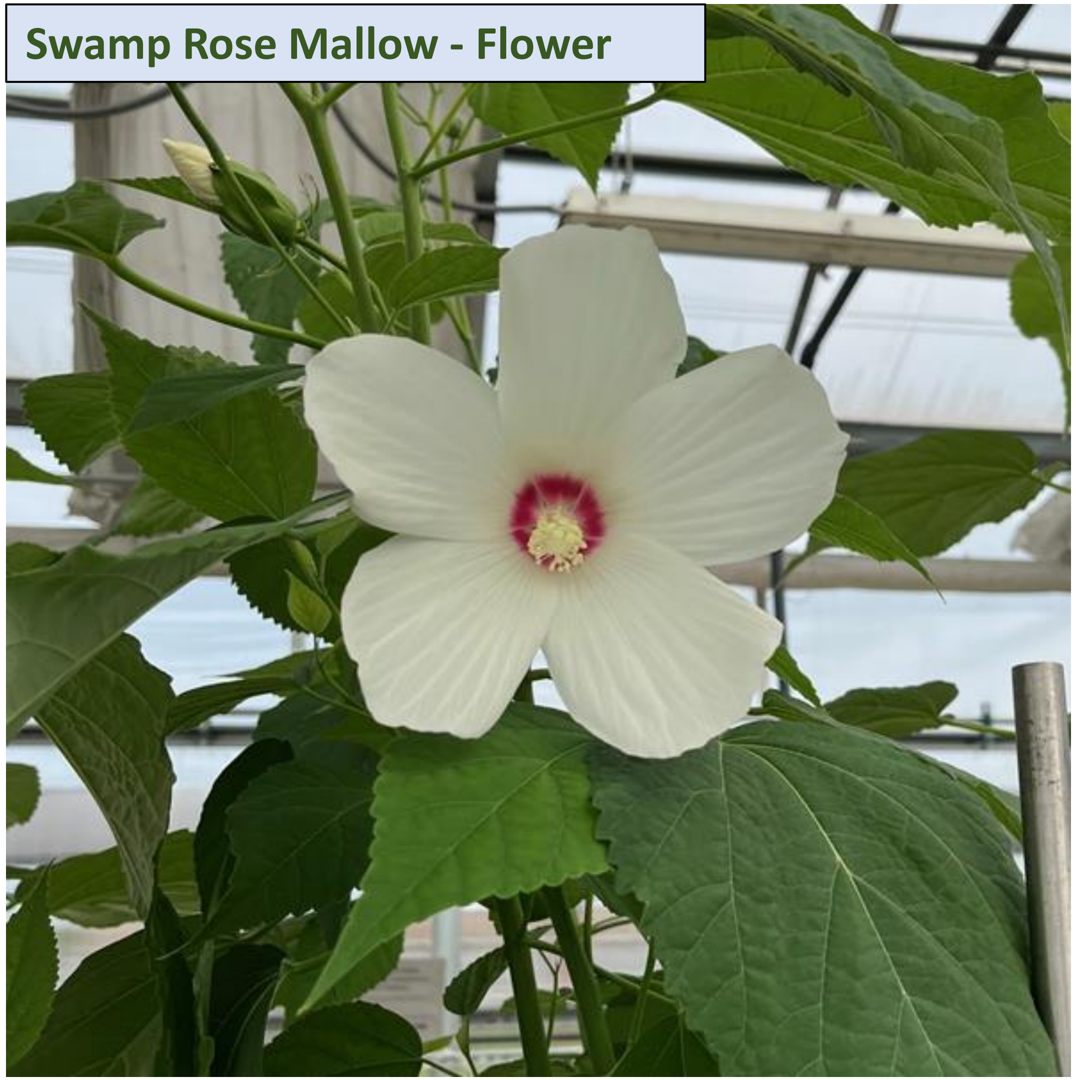
Goal 1 – Species Selection: Bucket Testing

Goal 1 – Species Selection: Bucket Testing

Swamp Rose Mallow - 1 Week

Swamp Rose Mallow – 2 Months

Goal 1 – Species Selection: Bucket Testing


Swamp Rose Mallow - Flower


Swamp Rose Mallow – Flower

Goal 1 – Native Plant Candidates

Blue Vervain – 1 Week

Blue Vervain – 2 Months

Goal 1 – Species Selection: Bucket Testing

Water Sedge – 1 week

Water Sedge – 2 months

Water Sedge – Roots

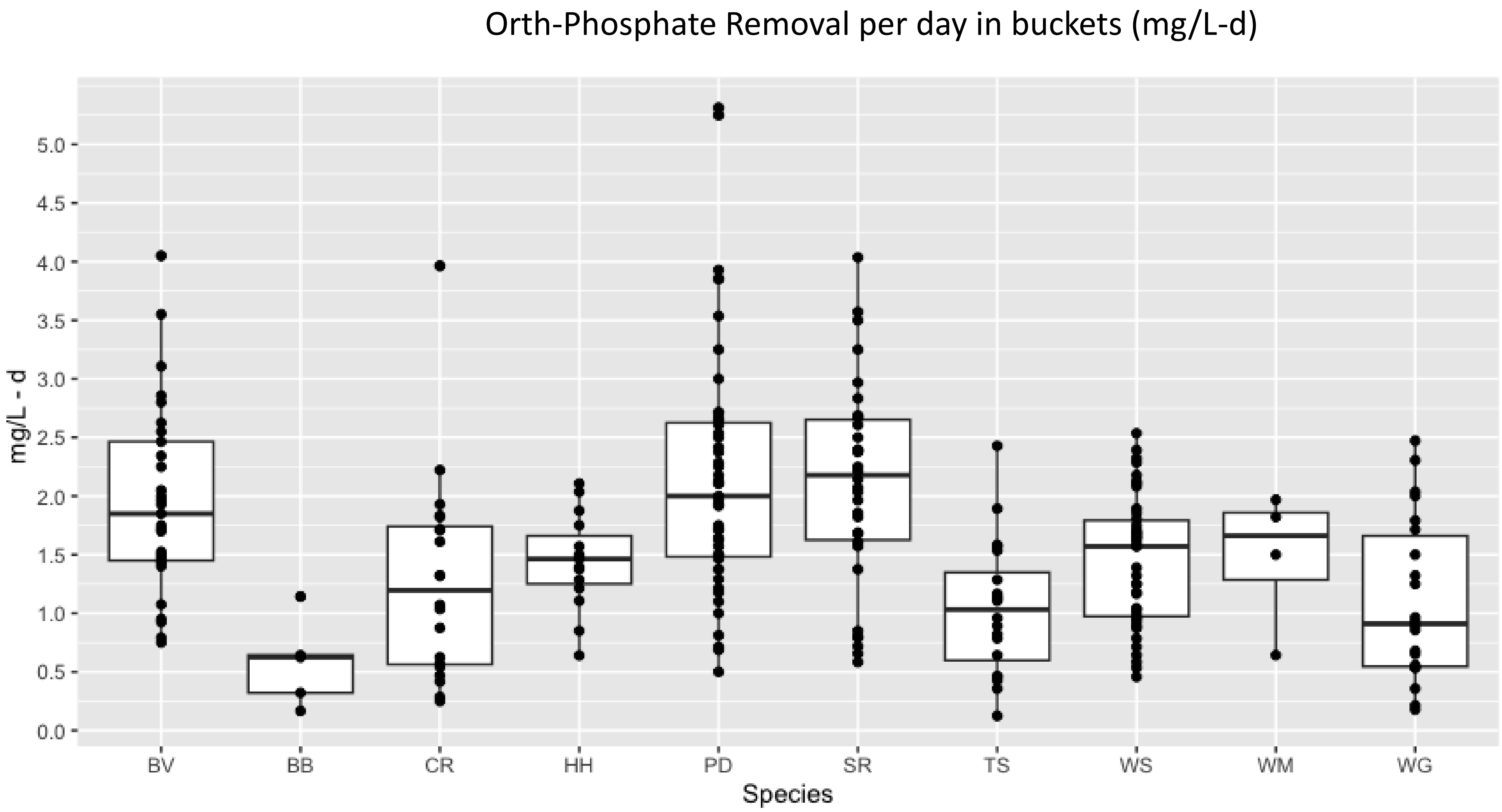
Goal 1 – Species Selection: Bucket Testing

Common Rush

Tussock Sedge

Wool Grass

Goal 1 – Species Selection: Bucket Testing

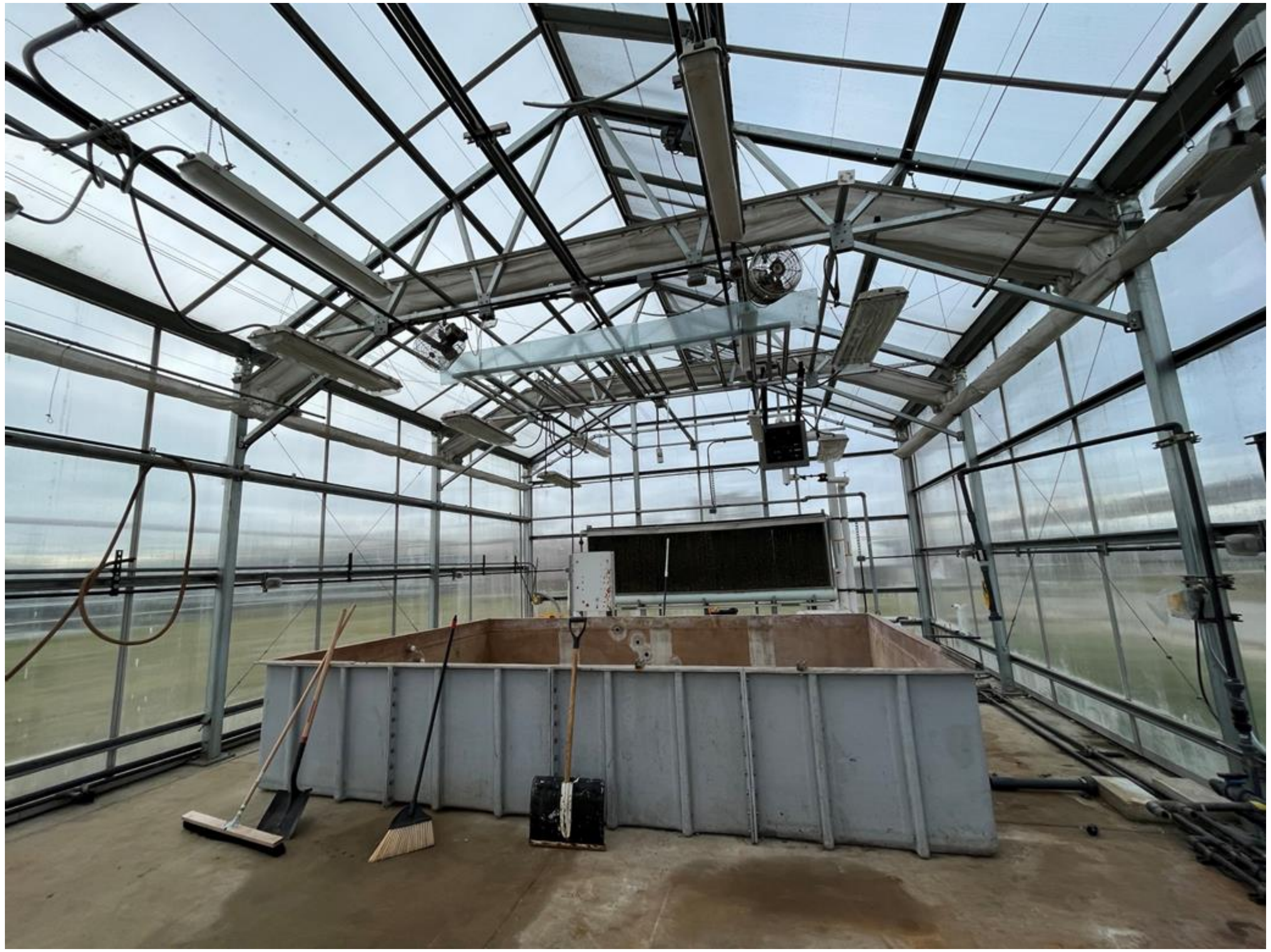


10 species survived bucket testing

BV= Blue Vervain
BB = Button Bush
CR = Common Rush
HH = Horehound
PD=Pale Dock
SR = Swamp Rose Mallow
TS = Tussock Sedge
WS = Water Sedge
WM = Wild Mint
WG = Wool Grass

Goal 1 – Species Selection: Large Tank

- Species that survived bucket testing were introduced into the large tank
- Occurred concurrently as bucket trials



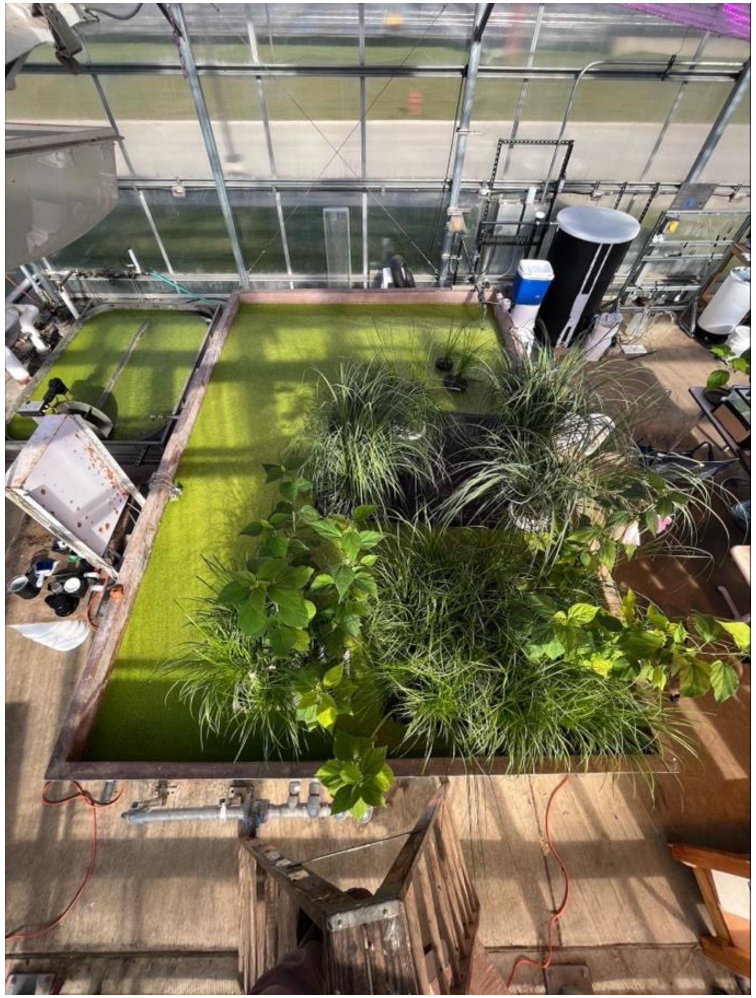
Goal 1 – Species Selection: Large Tank

1 Month Growth Difference

Summer 2023

Goal 1 – Species Selection: Large Tank

Fall – Winter 2023



Goal 1 – Species Selection: Large Tank

- Demonstrated species’ ability to survive and grow on final effluent

Goal 1 – Species Selection

- 3 wetland sedge species were selected : Water Sedge (WS), Common Tussock Sedge (TS), and Wool Grass (WG)
- Disease/Pest resistant
- Morphology
- Hydroponically adaptable

Yellow leaves showing nutrient deficiency in Marsh Muhly

Rocks used to prevent tipping in Pale Dock

Goal 2 - Construct AFW

Water Sedge

Wool Grass

Goal 2 - AFW Construction

- Plants allowed to mature before introduction into large tank

Goal 2 - AFW Construction – July 2024

- Cross linked polyethylene foam mats with a total surface area of 13.36 m2
- 58 WG, 45 WS and 18 TS
- **121 Plants**

Goal 2 - AFW Construction

Goal 2 - AFW Construction

July - November 2024

Goal 2 - AFW Construction

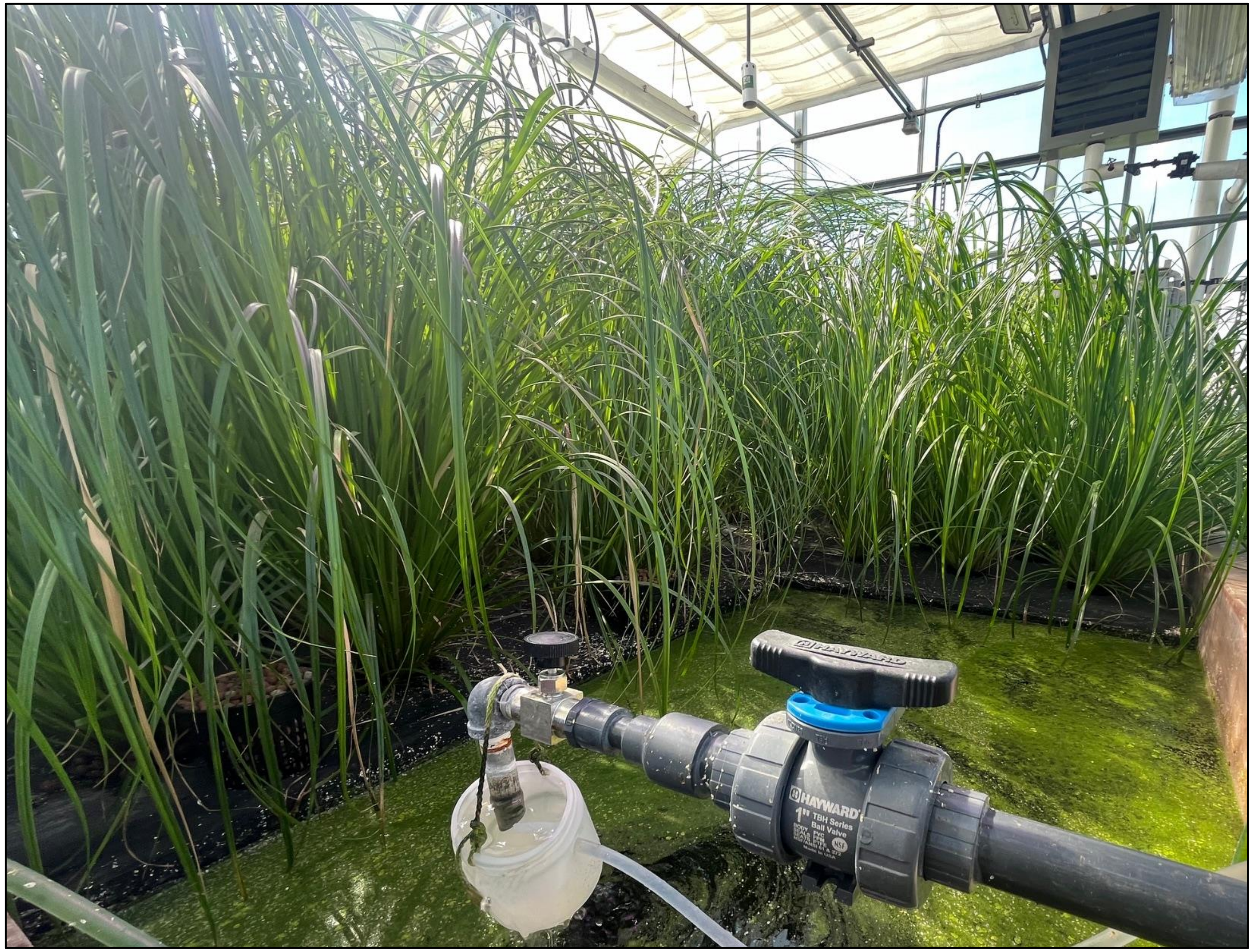
- No major signs of nutrient deficiency , disease or plant death observed

Goal 3 – Quantify Nutrient Removal

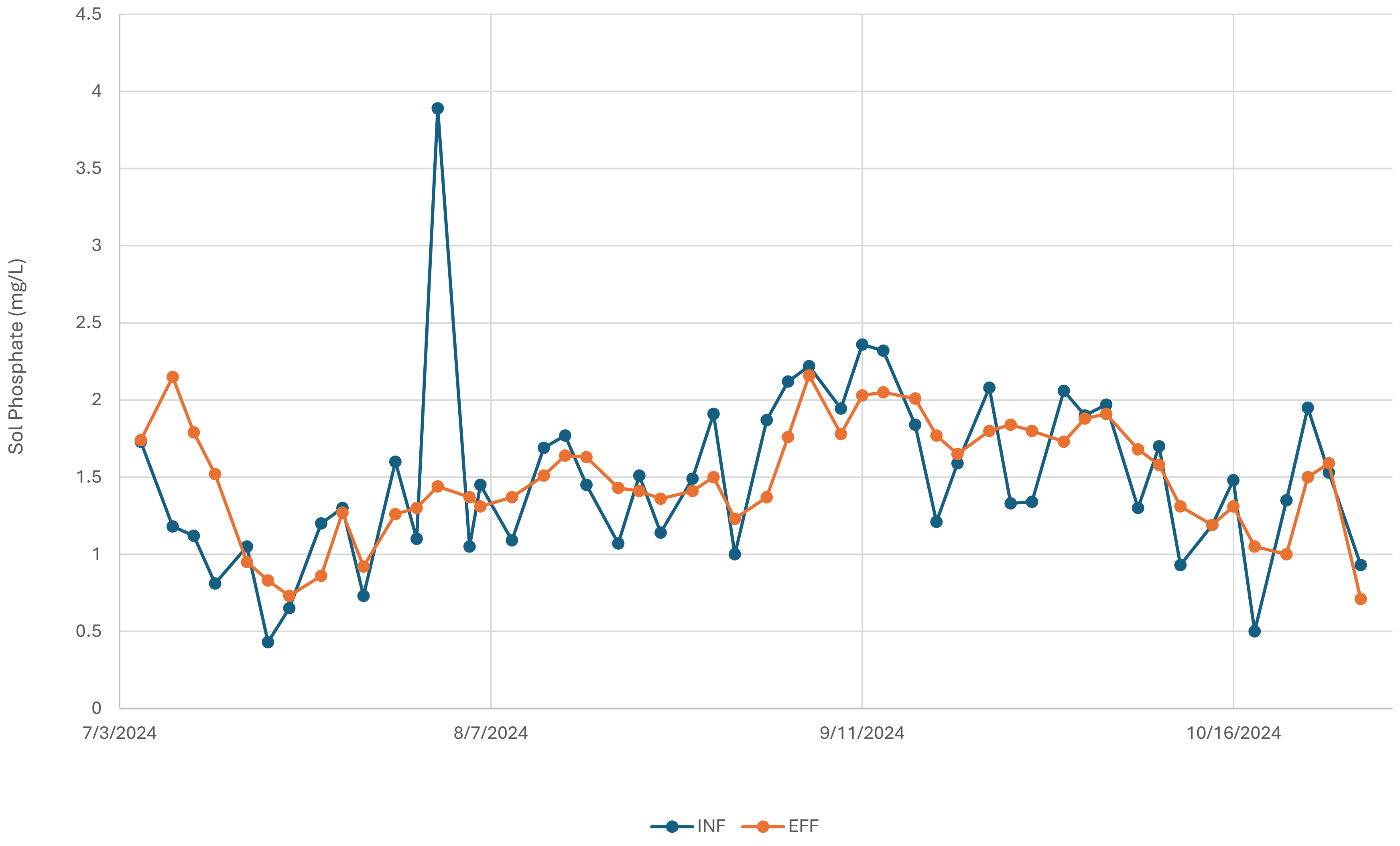
- Effluent Nutrient Data
- Plant Tissue Data

Goal 3 – Quantify Nutrient Removal – Effluent Nutrient Data

- Collected from composite samples
- Analyzed for Soluble Phosphorus (Sol-P), Nitrate + Nitrate + Ammonia by the Analytical Laboratories Division (ALD) of the MWRDGC
- Average Hydraulic Retention Time (HRT) of 2.06 Days
- Average flow of 5,140 L/d



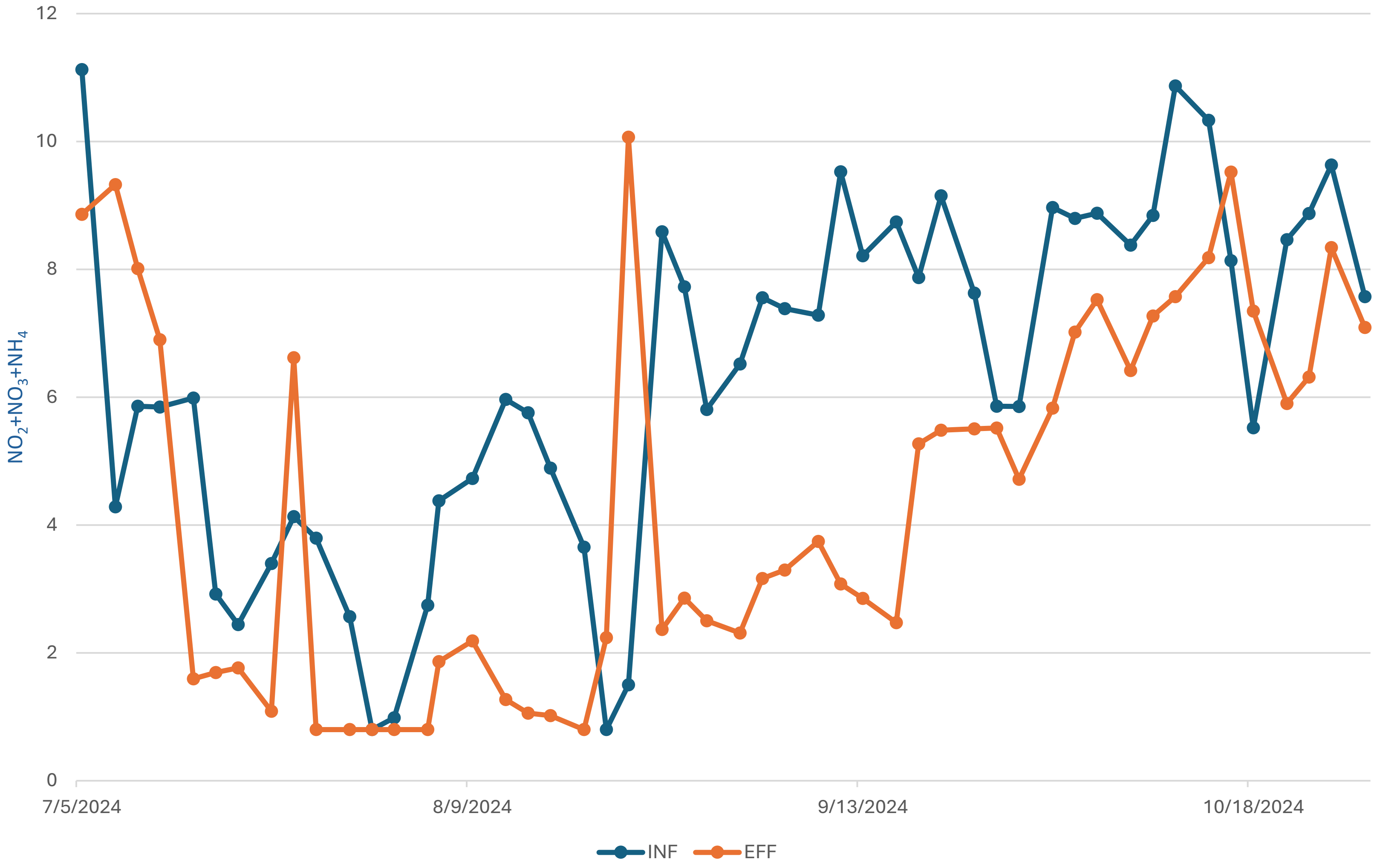
Effluent Nutrient Data - Phosphorus



The average influent Sol-P was 1.49 mg/L (SD=0.58) and average effluent 1.49 mg/L (SD=0.36)

No significant difference
$\alpha = 0.05$
$t(82) = 0.007, p=0.50$

Effluent Nutrient Data – Nitrate + Nitrite + Ammonia



The average influent $NO_2+NO_3+NH_4$ was 6.31 (SD=2.71) mg/L and effluent 4.40 mg/L (SD=2.83)

Significant difference
$\alpha = 0.05$
$T(98) = 3.40$,
$p=0.0005$

Effluent Nutrient Data

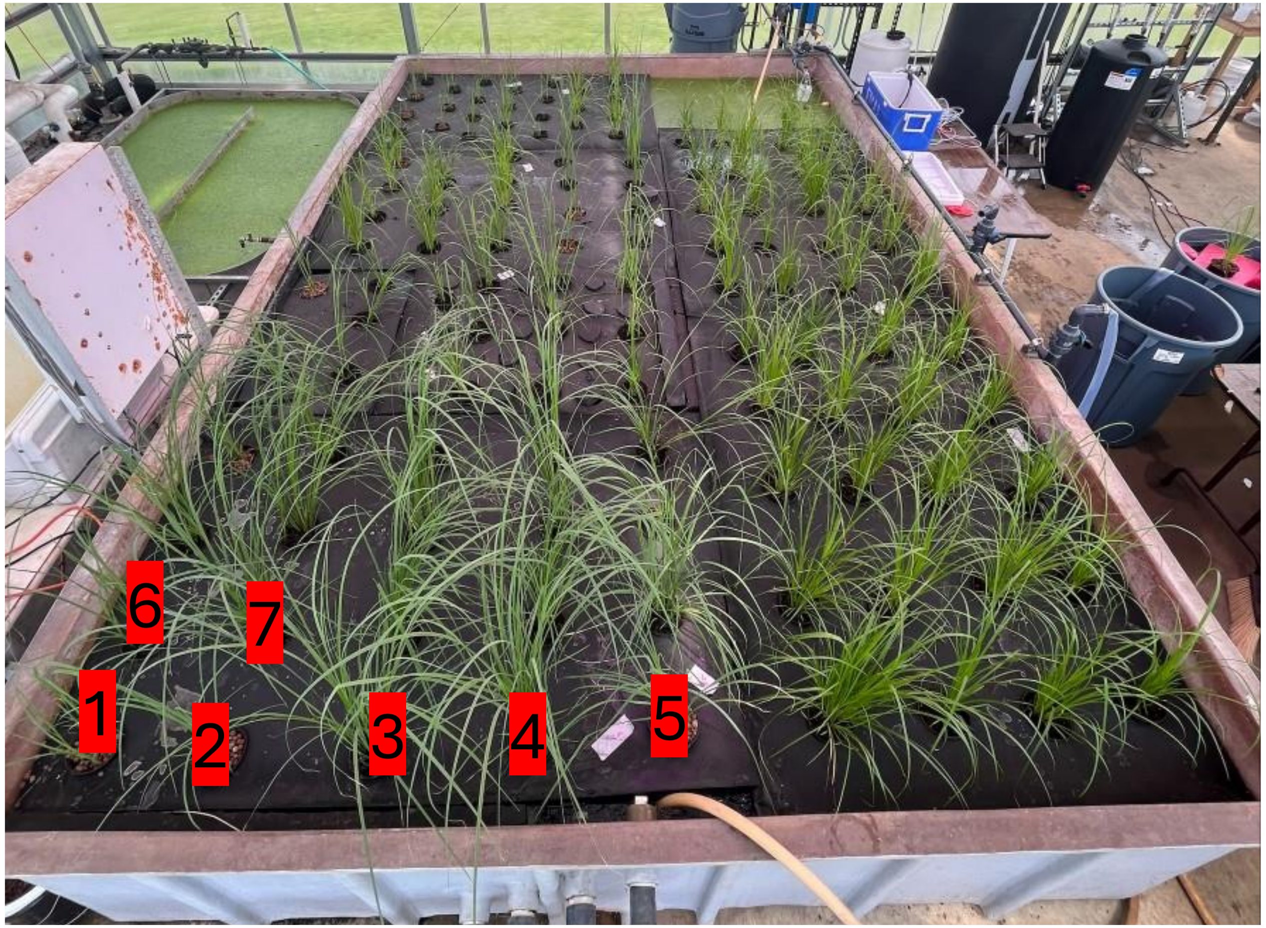
- 139 day-study
- Tank flow
- Nutrient removal estimations:

	Sol-P	$NH_4 + NO_2 + NO_3$
Estimated total removal (g)	**4.72**	**344.3**

Goal 3 – Quantify Nutrient Removal – Effluent Nutrient Data

Plant Tissue Nutrient Analysis

Goal 3 – Quantify Nutrient Removal – Biomass



- Dry biomass determination
- A random number generator was used to select population samples for drying
- 14 WG (24%), 12 WS (27%) and 5 TS (38%) were selected (32 Total)
- Plants were dried at 70 ^{o}C for 48 hours or until constant weight achieved

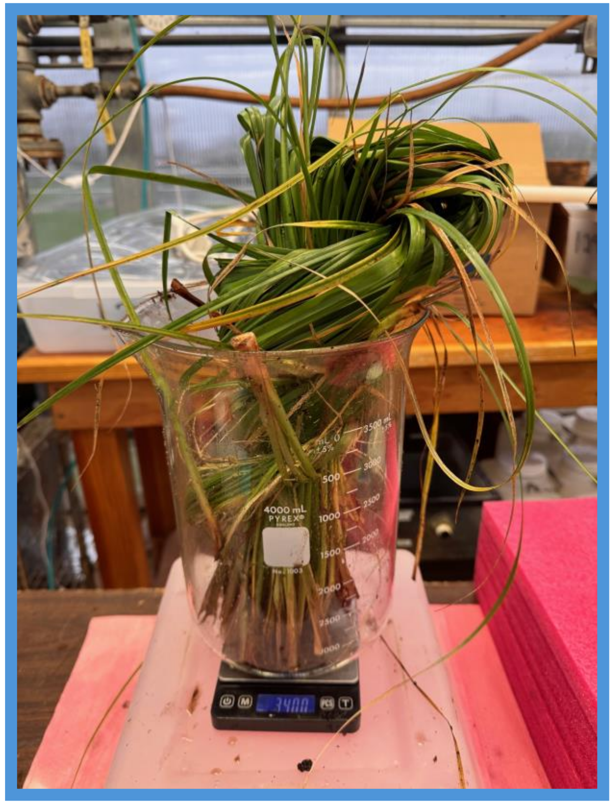
Goal 3 – Quantify Nutrient Removal – Plant Tissue


Side view of Wool Grass shoot and root system

All 151 Plants were harvested

Goal 3 – Quantify Nutrient Removal – Biomass

Roots and shoots were separated and weighed to determine wet biomass



Goal 3 – Quantify Nutrient Removal – Biomass

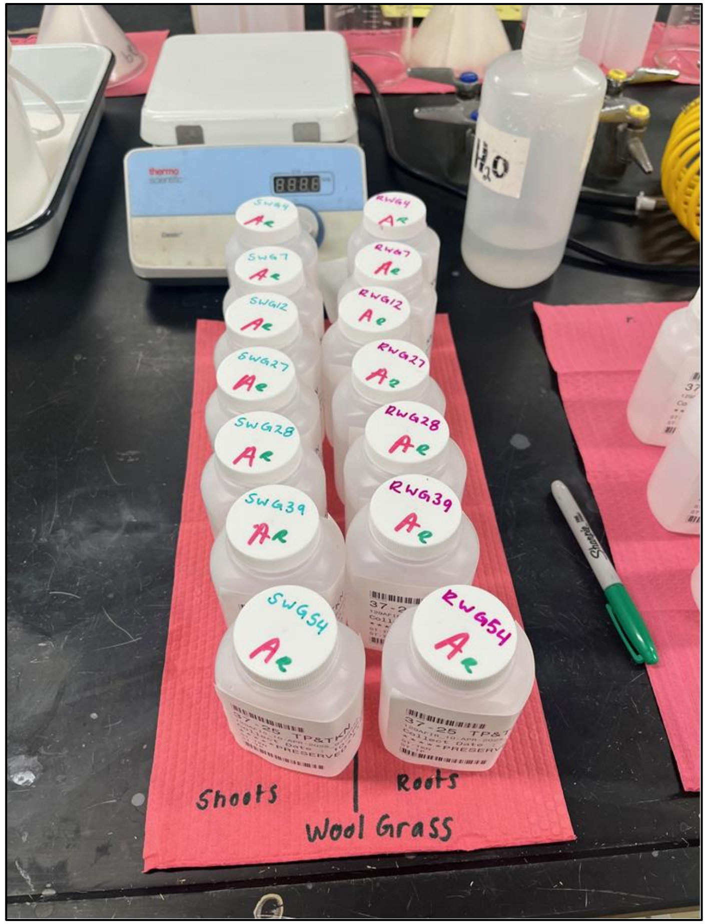
Total dry weight biomass estimated from dried representative population samples

Species	Wet weight (kg)	Dry weight (kg)
Wool Grass	75.8	12.4
Water Sedge	61.1	8.8
Tussock Sedge	9.7	3.3
Total Harvest	146.6	24.5

- 146.6 kg of wet biomass
- Estimated 24.5 kg of dry biomass
- 83% Water

Goal 3 – Quantify Nutrient Removal – Plant Tissue

- Further representative samples of dried plants' shoots and roots were ground up and submitted to ALD for total phosphorus (TP) and Total Kjeldahl Nitrogen (TKN) analysis
- A random number generator was used to select samples
- 10 WG, 7 WS, and 3 TS were tested (20 total)
    - Sample submission limitations



Goal 3 – Quantify Nutrient Removal – Plant Tissue

- %TP and %TKN content was calculated
- Weighted average TP content was 0.31%
- Weighted average TKN content was 1.24%
- This falls within reported literature values of 0.1-0.6% TP and 1.2-2.8% TKN for wetland sedges (Kedlec and Wallace, 2019), (Tanner, 1996), (Vymazal, 2007)

	%TP AVG	%TKN AVG
Tussock Sedge	0.290	1.63
Water Sedge	0.290	1.17
Wool Grass	0.334	1.17

Goal 3 – Quantify Nutrient Removal – Plant Tissue

TP and TKN extrapolated for the entire AFW

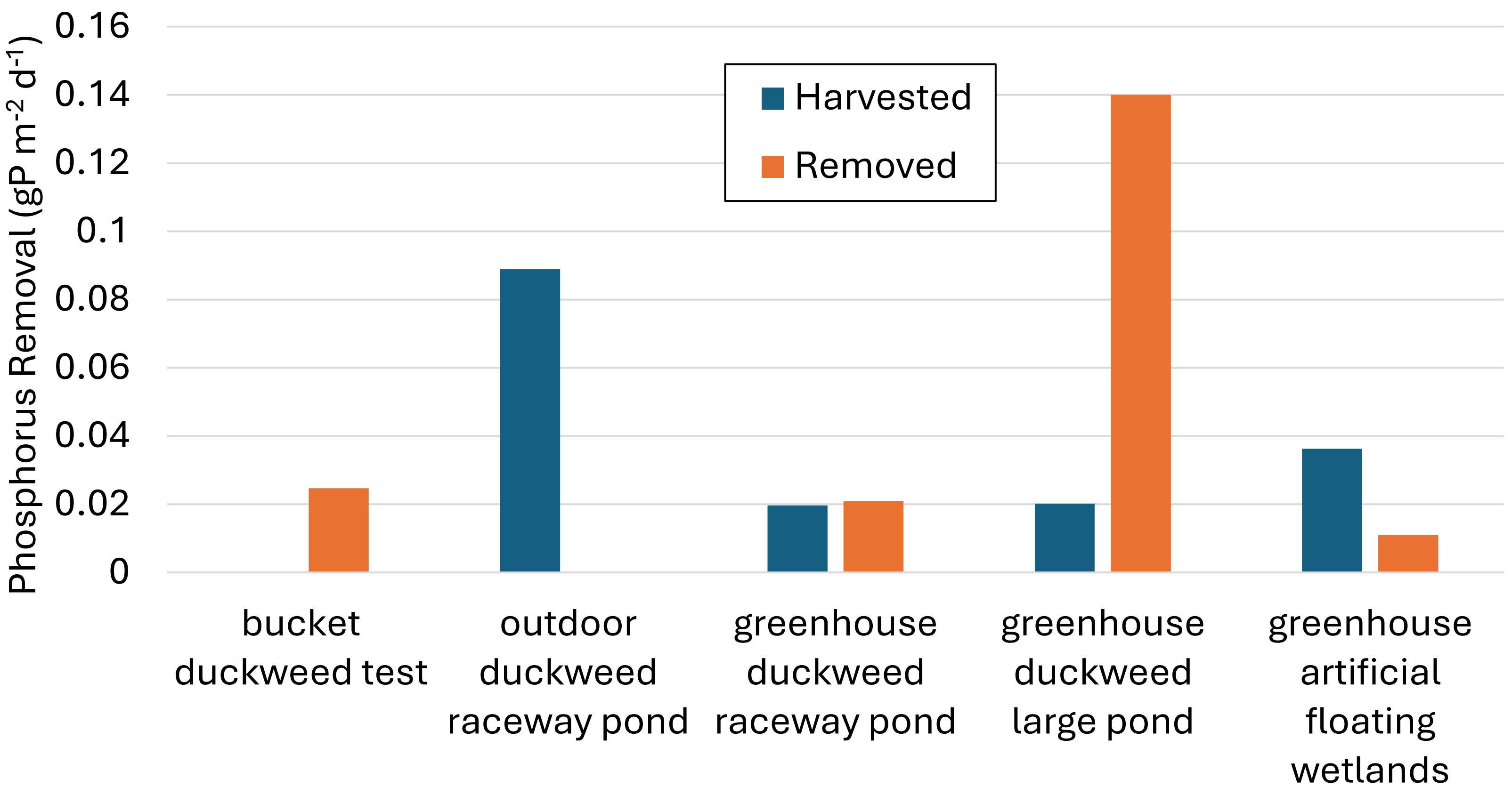
	TP (g)	TKN (g)
Tussock Sedge	3.67	20.7
Water Sedge	26.9	116.5
Wool Grass	40.4	155.0
Total	**71.0**	**282.2**

Goal 3 – Quantify Nutrient Removal

Effluent Nutrient Data vs Plant Tissue Data Removal Estimates		
Plant Tissue (g)	282.2 (TKN)	71.00 (TP)
Effluent Nutrient (g)	344.3 (NH_3 + NO_2 +NO_3)	4.720 (Sol-P)

Plant Tissue Data

- AFW was slightly more efficient than duckweed



Conclusions

- AFW can be successfully grown on final effluent stream and remove nutrients
- Feasibility of implementation related to scalability

Conclusions – Area Required for Treatment

TP(g) / m^2	TKN(g) /m^2	TP (kg) / acre	TKN (kg) / acre	TP (lb) / acre - day	TKN (lb) / acre - day
5.31	21.12	21.44	84.97	**0.330**	**1.390**

- 1 Acre would require approximately 45,560 plants

Conclusions – Area Required for Treatment of 1 MGD

- Maximum literature values for aquatic sedges is 0.99% P and 5.51% N
- The average in this study was 0.31%P and average 1.24% N
- 6,336 Acres (9.9 square miles) to replace traditional phosphorus treatment at SWRP (800 MGD)

(mg/L) removed per MGD	Acres Our results (P)	Acres Maximum Literature Value (P)	Acres Our results (N)	Acres Maximum Literature Value (N)
0.1	3.1	0.99	0.75	0.17
0.25	6.3	1.98	1.5	0.33
1.0	25.27	7.92	6.0	1.35

Conclusions

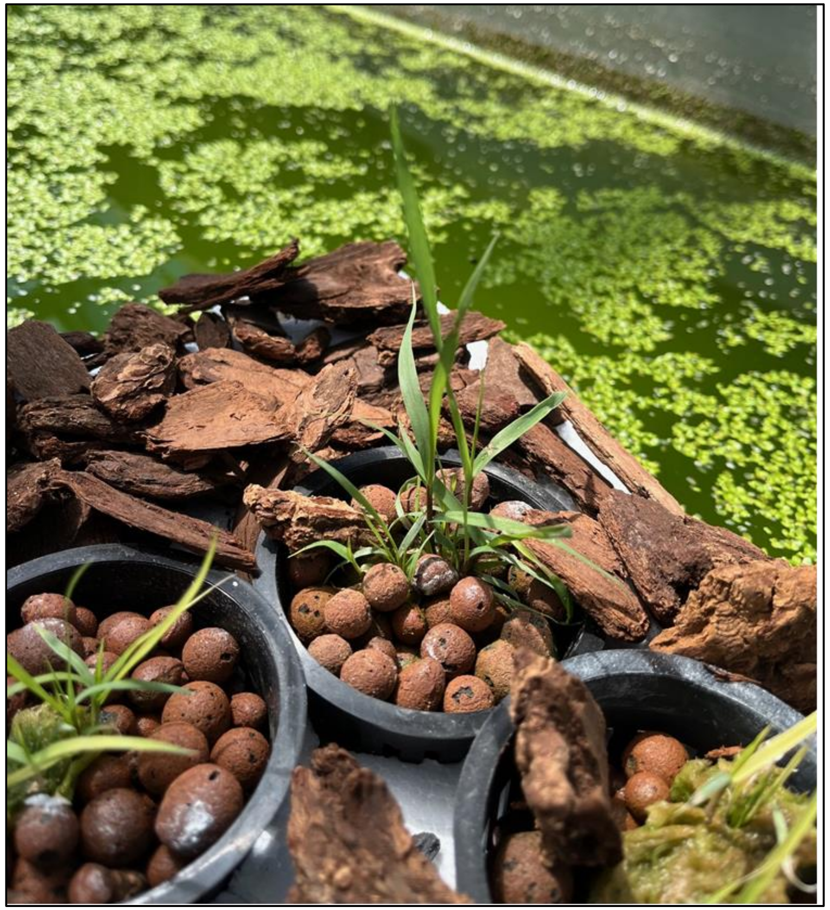
- %P and %N content limiting factor for nutrient uptake
- Biomass and plant density are other options to increase nutrient sequestration
- AFW are not a replacement for traditional treatment at MWRD due to scalability issues

Unanswered Questions

- Outdoor performance and overwintering of AFWs
- Minimum dissolved oxygen requirements
- Performance on other liquid streams (lagoons, primary influent, etc.)
- Role of microbial biofilm and rhizosphere
- Biomass/density increases

Possible practical uses of AFW

- Treatment at ponds or lagoons
- More green space for carbon sequestration
- Algal suppression
- Sequestration of other pollutants (Pb, Zn, Cu, Cd, As)
- Odor reduction – rhizosphere and microbial biofilm



Acknowledgements

- Research Technicians
- O'Brien M&O Staff
- M&R Management
- Analytical Laboratories Division

Thank You!

Questions?

For PDH Certificate seekers,

The link to the new on-line course evaluation form has been posted in the Chat. The link is also available on the District website. The form will only be available online until the start of next month's seminar. Please be sure to fill it out and submit promptly.