Integrating Restoration Strategies Science and STA Management: Part I Synthesis of Findings

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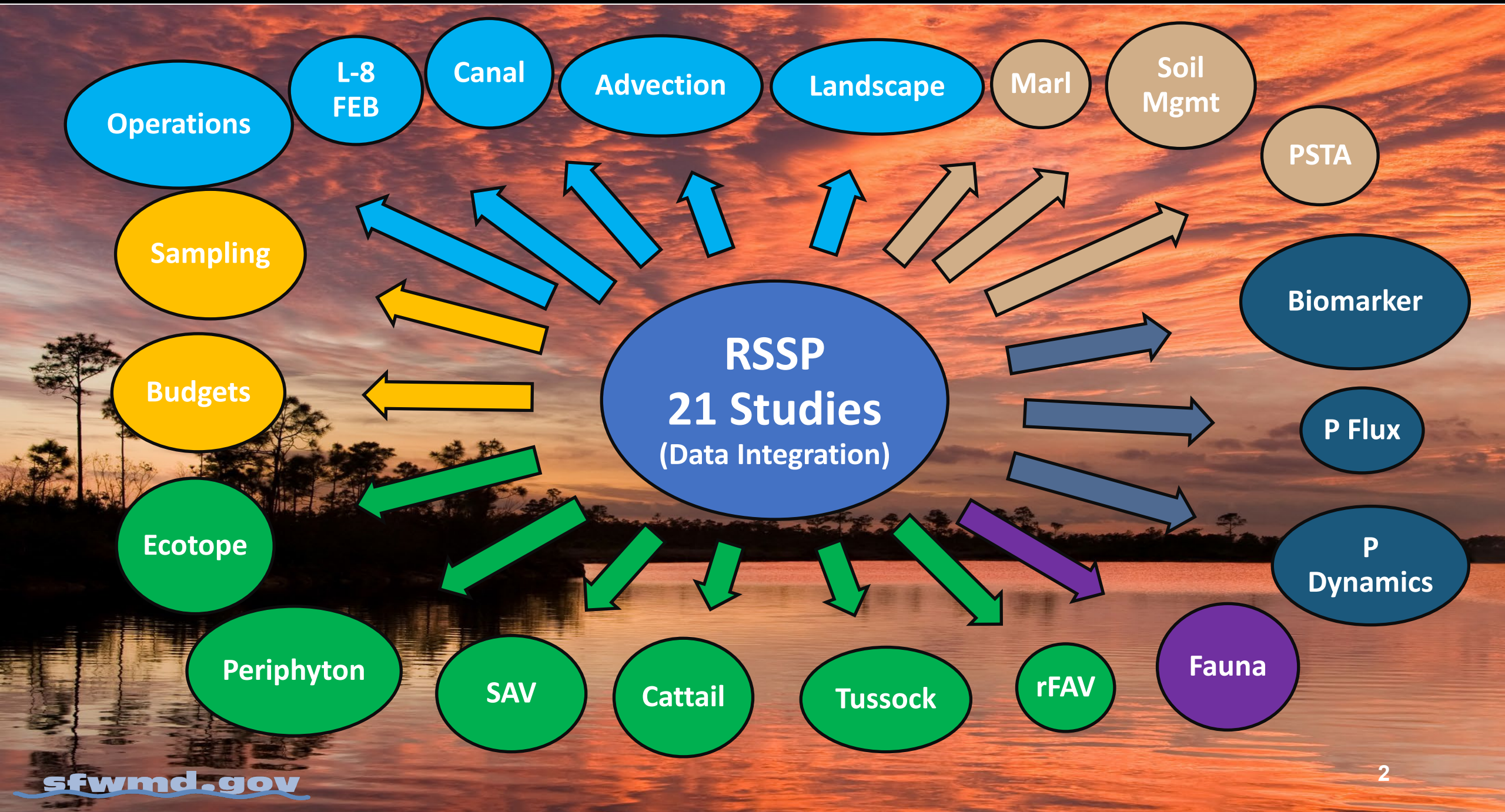
Greater Everglades Ecosystem Restoration 2025 Conference

April 22, 2025


Operations
L-8 FEB
Canal
Advection
Landscape
Marl
Soil Mgmt
PSTA
Sampling
Biomarker
Budgets
RSSP
21 Studies
(Data Integration)
P Flux
Ecotope
P Dynamics
Periphyton
SAV
Cattail
Tussock
rFAV
Fauna

The Team


June 2024 Team of the Month
Ecological Engineering Journal
Special issue on the STA's Team
EXIT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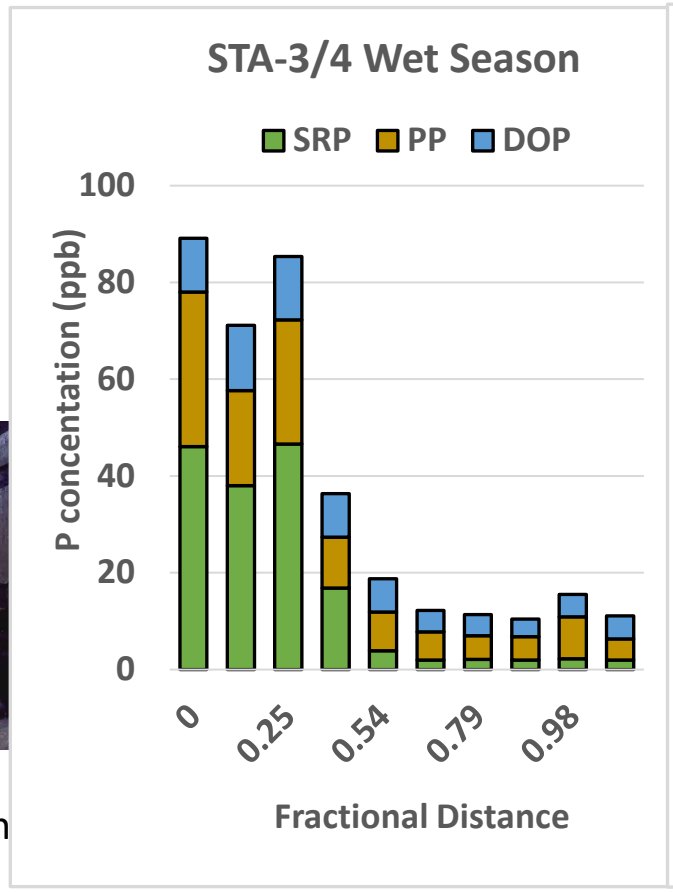
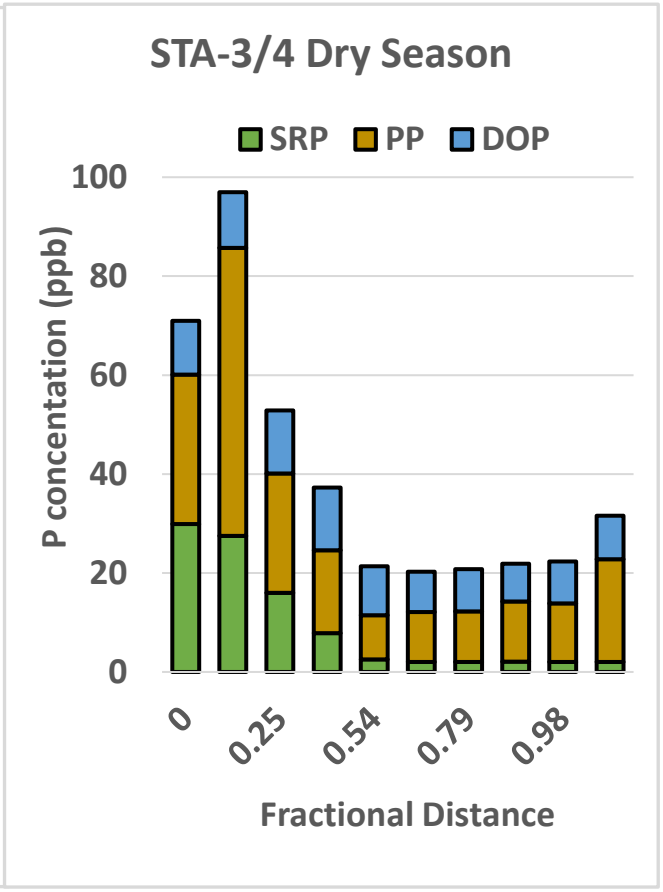
Water Column Phosphorus in a Flow-way (FW)

G-250 inflow pump station

G-251 outflow pump station





- TP reduced by 72 to 85%
- Inflow
  - High in soluble reactive P (SRP)
- Flow path
  - SRP disappears
- Outflow
  - Primarily dissolved organic P (DOP) and Particulate P (PP)
  - PP higher in no-flow (dry season) conditions
  - PP and TP are lower with flow (wet season) conditions)

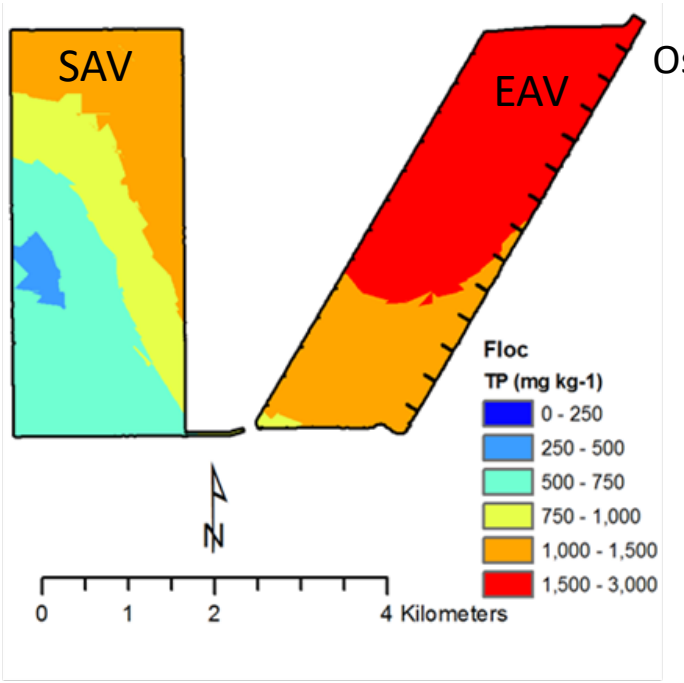
Jerauld et al. (2024)

Phosphorus Trends in Floc and Soils

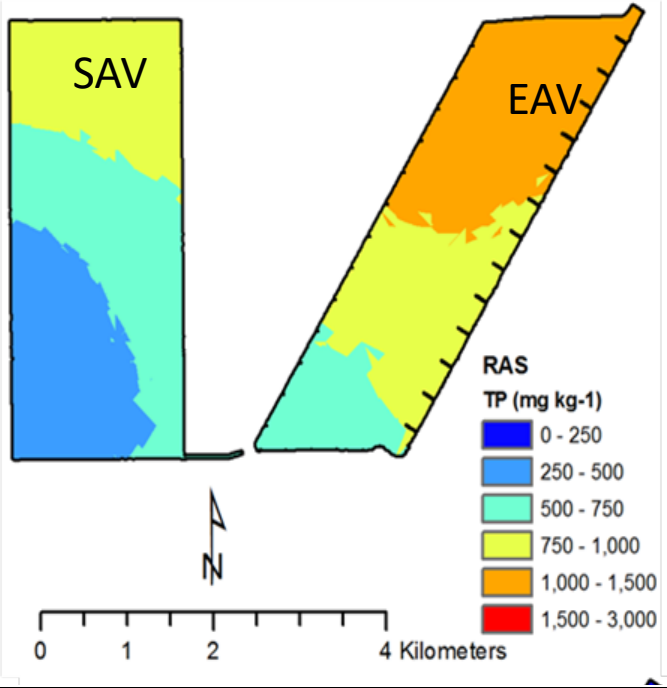
- Accumulation of P in soils is not limited
- Submerged Aquatic Vegetation (SAV)
  - Inorganic (Marl)
- Emergent Aquatic Vegetation (EAV)
  - Organic (plant detritus/floc)
- Along the Flow-way (FW)
  - TP declines in floc and recently accreted soils (RAS)

SAV marl core
DB Environmental
(2023)

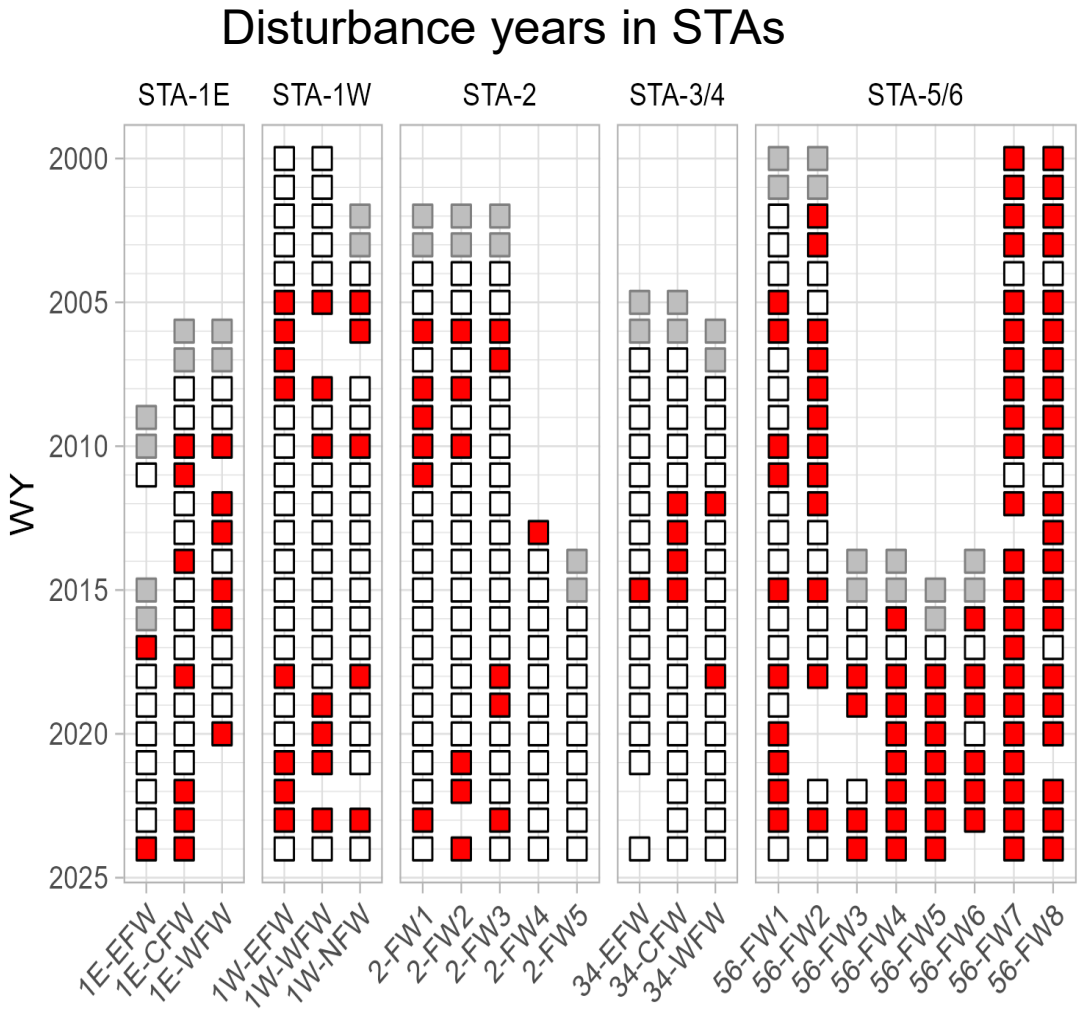
EAV Soil core
STA-2 FW1
(courtesy of Odi
Villapando)



Osborne, et al. (2019)

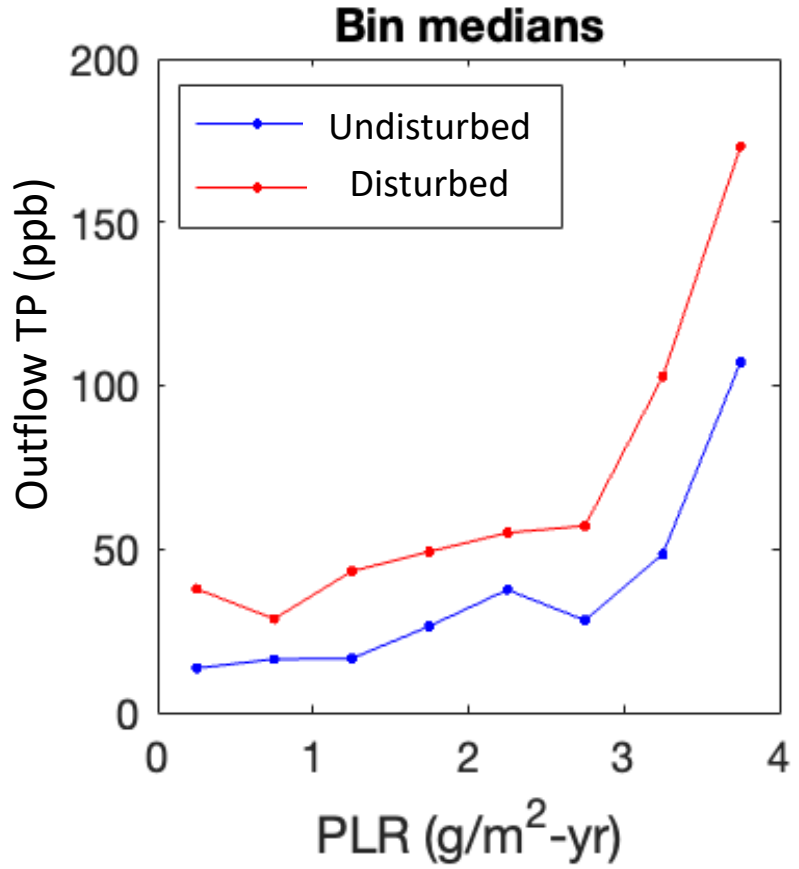


Disturbance and Phosphorus Loads



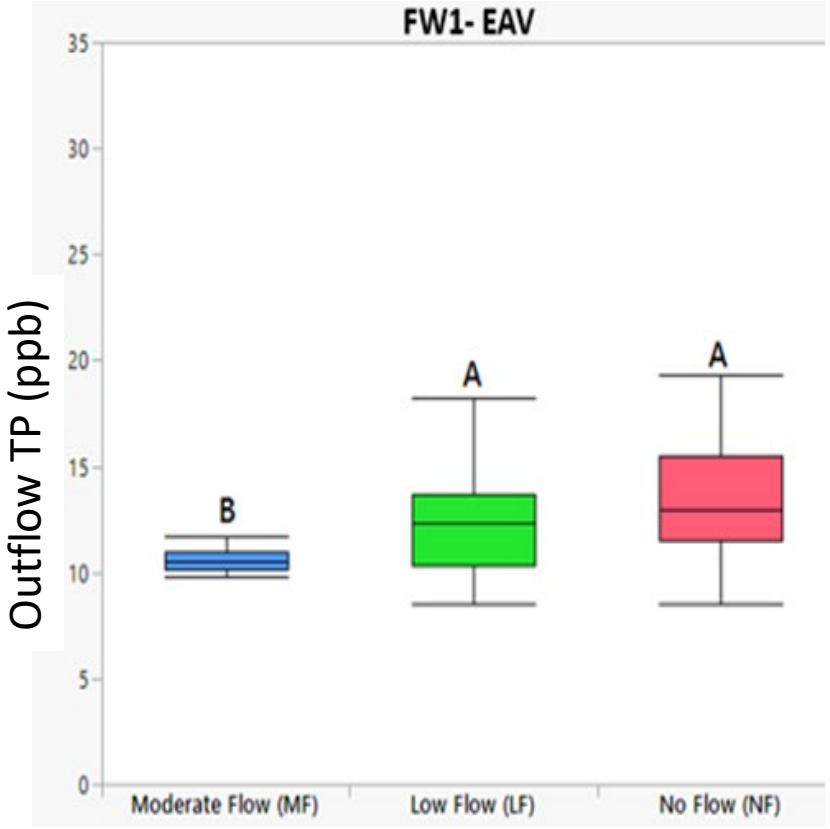
- Disturbed
  - Vegetation loss
  - drydown
  - construction
  - Outflow is above 20 ppb
- Undisturbed with P loads below 1.3 g/m2/yr
  - Outflow is below 20 ppb

Jerauld et al. (2025)

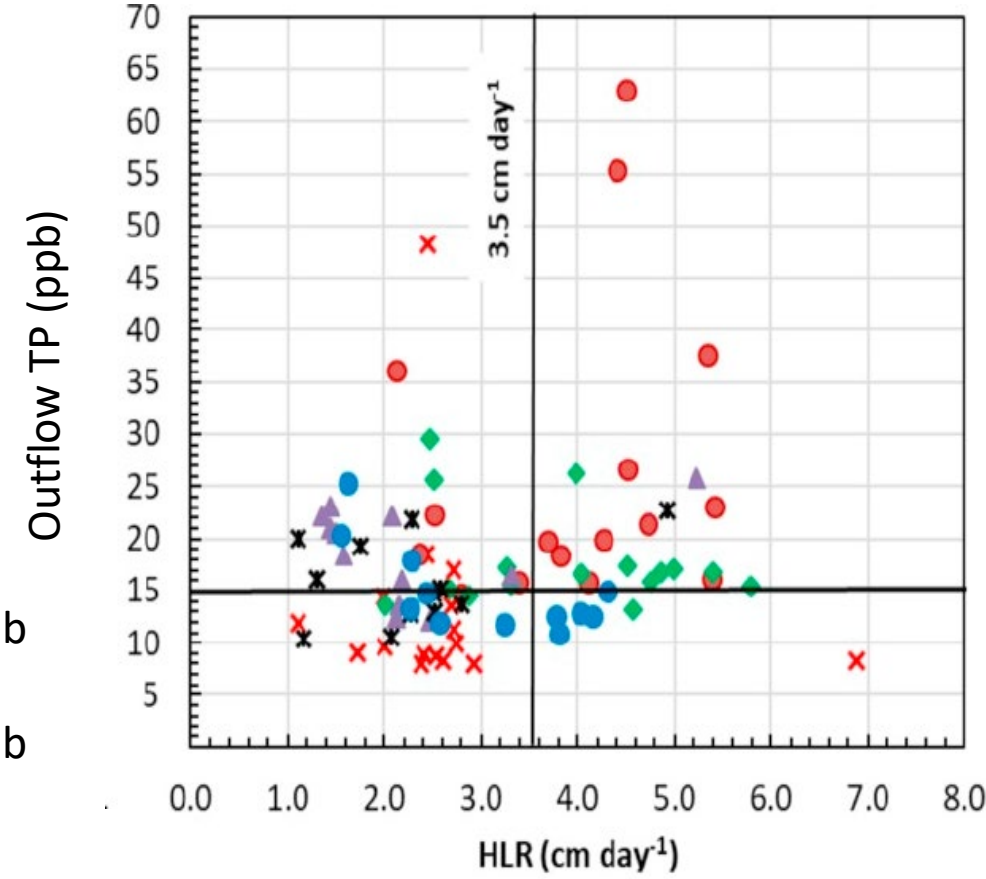


DB environmental. (2024)

Hydrology Loads



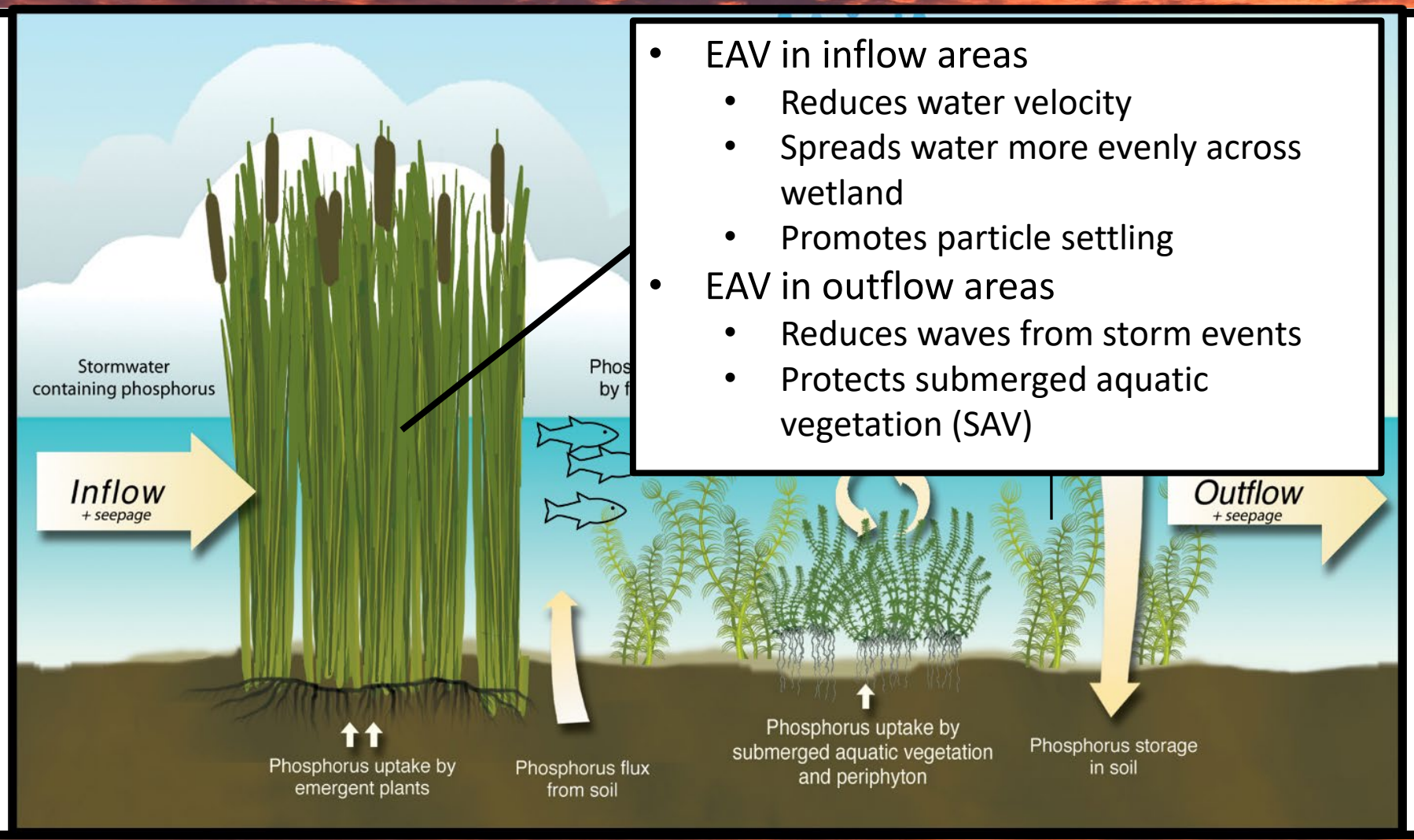
- Daily to monthly flow
  - Moderate flow associated wit lowest outflow TP concentrations
  - HLR between 5 and 15 cm/d
- Annual average
  - HLR <=3.5 cm/d
    - 54% of years TP <= 15 ppb
  - HLR > 3.5 cm/d
    - 29% of years TP <= 15 ppb



Villapando et al. (2024)

Zhao, H., and T. Piccone. (2020)

Vegetation (emergent aquatic vegetation: EAV)



- EAV in inflow areas
  - Reduces water velocity
  - Spreads water more evenly across wetland
  - Promotes particle settling
- EAV in outflow areas
  - Reduces waves from storm events
  - Protects submerged aquatic vegetation (SAV)

Cattail in STA-1W October 2005

Vegetation (EAV)

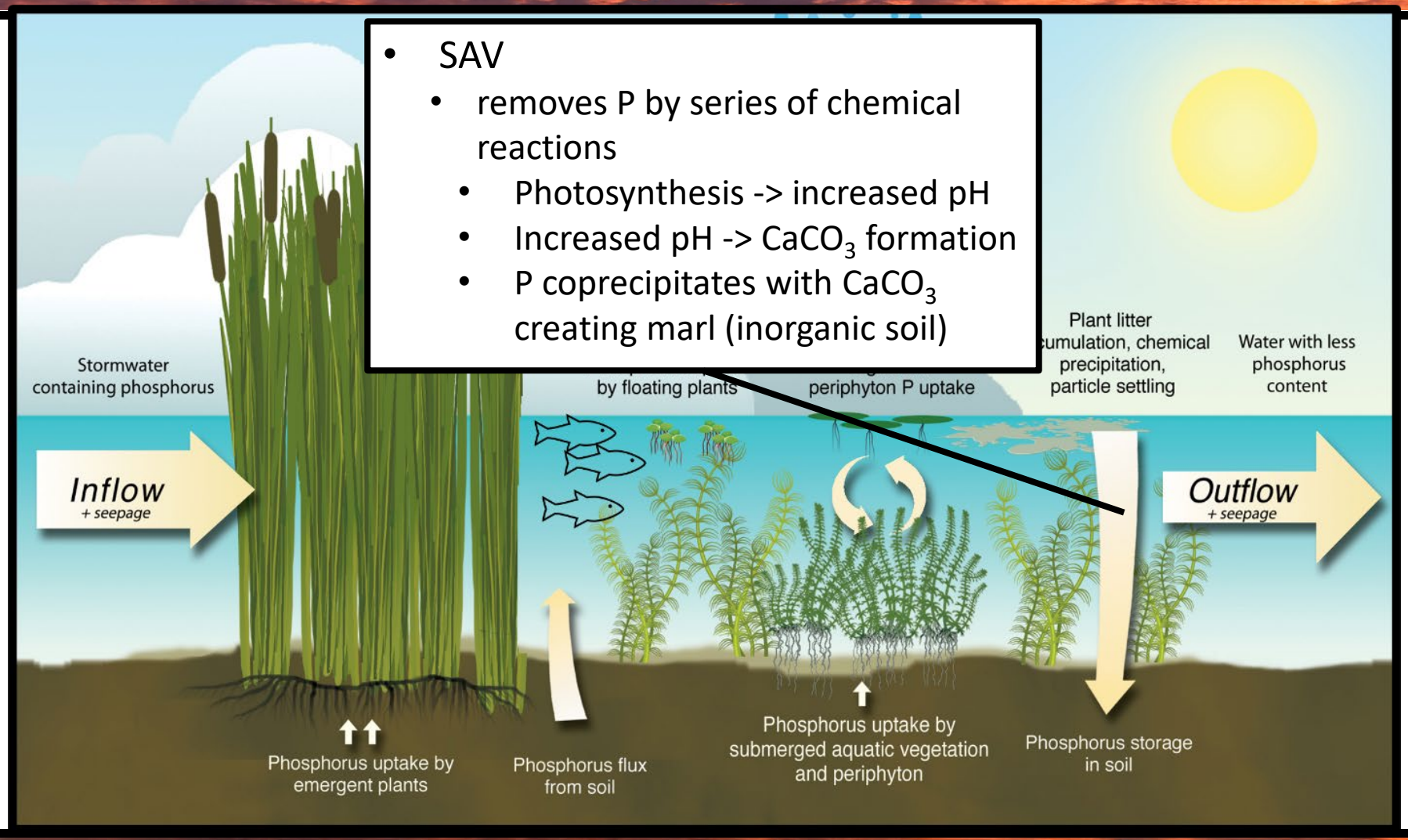
Diaz (2022)

- Water depth at 85 cm (2.8 feet) or more
  - Increased cattail stress, mortality and tussock formation
- Sudden drop in water depth
  - Plants fall over (lodge)

Diaz, et al. (2023)

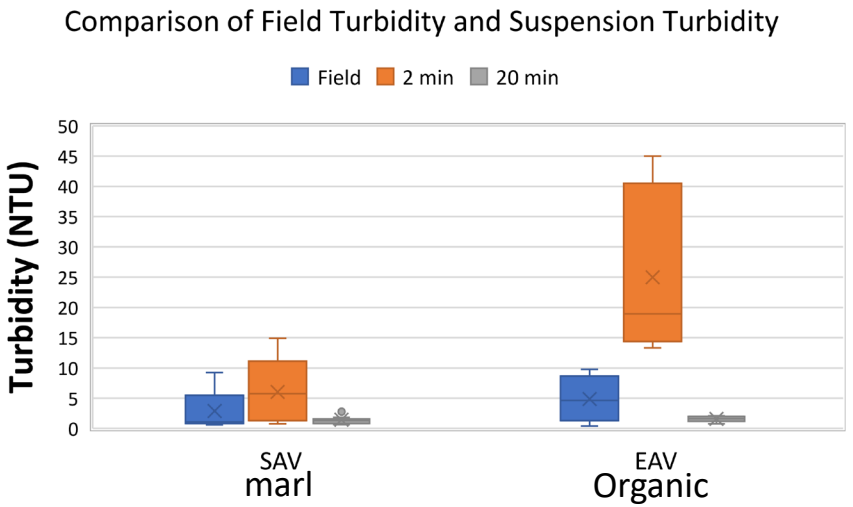
Vegetation (submerged aquatic vegetation: SAV)

- SAV
  - removes P by series of chemical reactions
    - Photosynthesis -> increased pH
    - Increased pH -> $CaCO_3$ formation
    - P coprecipitates with $CaCO_3$ creating marl (inorganic soil)

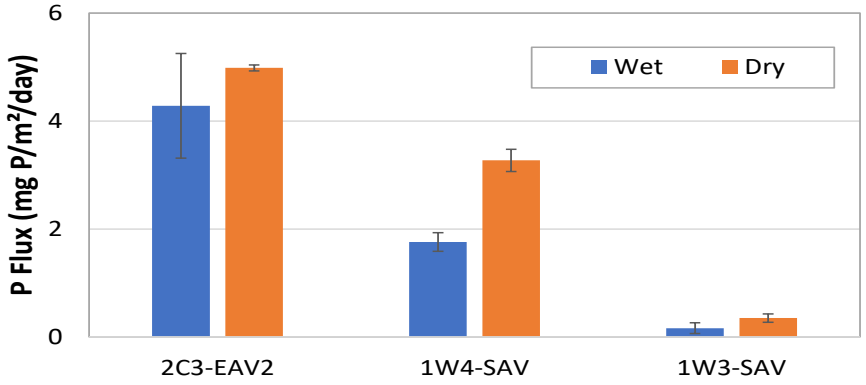


DB Environmental (2023)

Marl Soil Consolidation



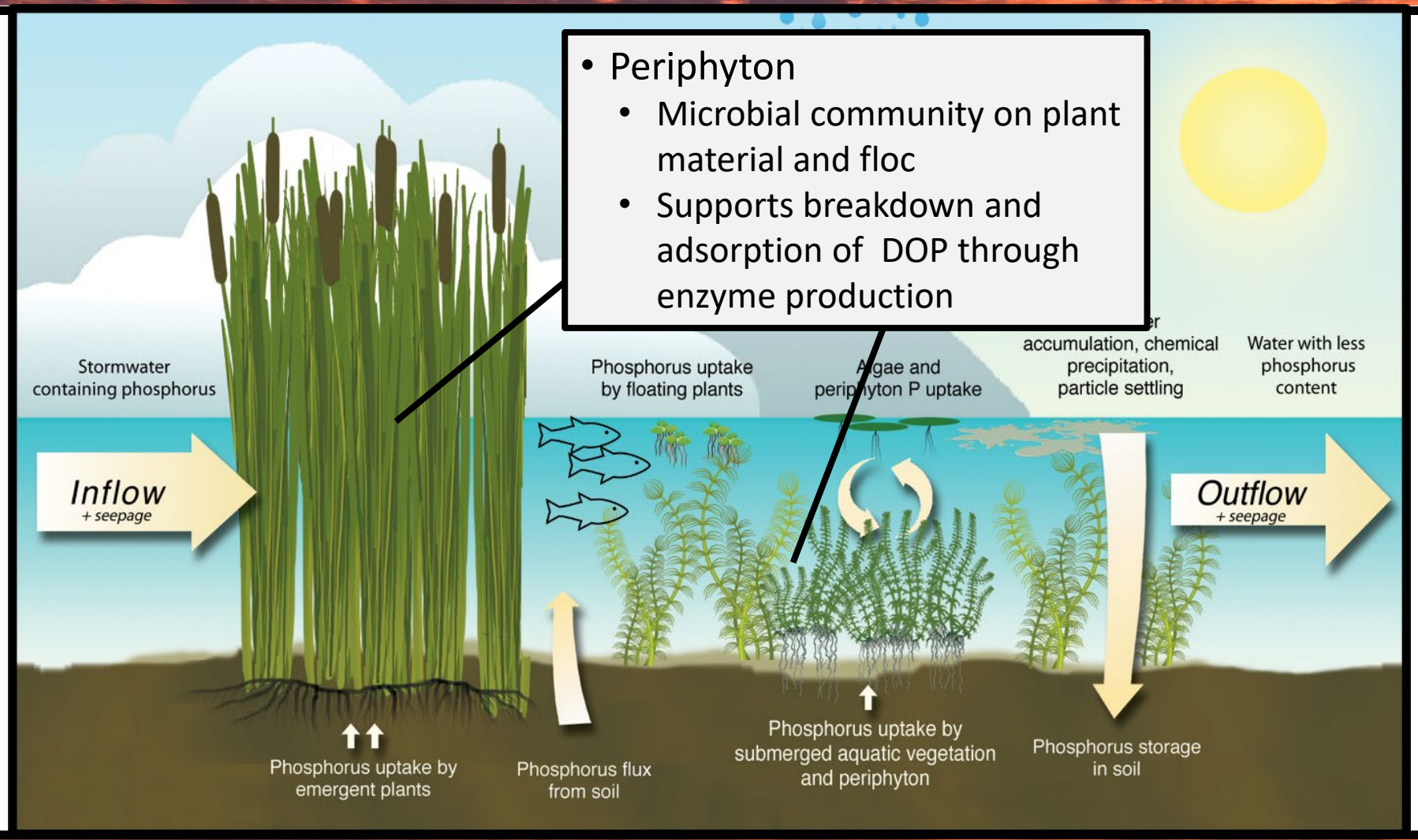
DB Environmental. (2023b)



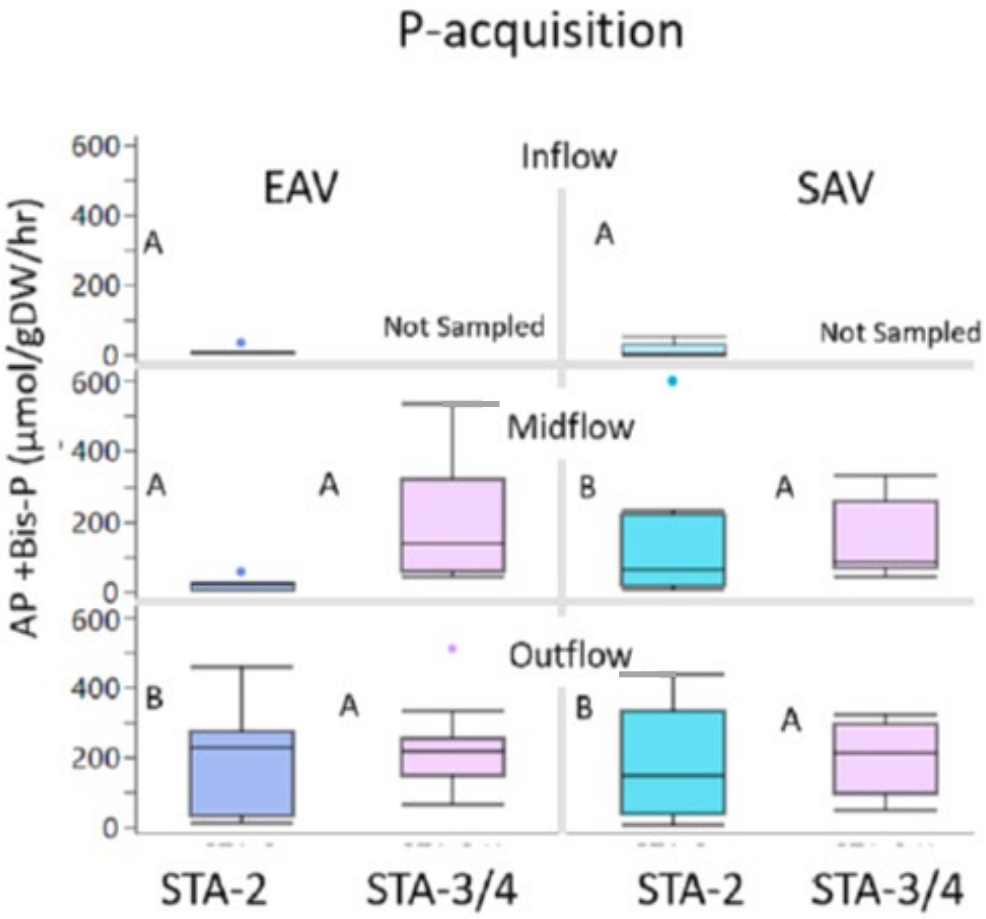
- Organic soils more easily resuspended than inorganic marl soils
- P flux from hydrated marl soils is lower than dried and rehydrated marl soils
- Drying and consolidating marl soil increases SAV germination

DB Environmental (2023a)

Periphyton

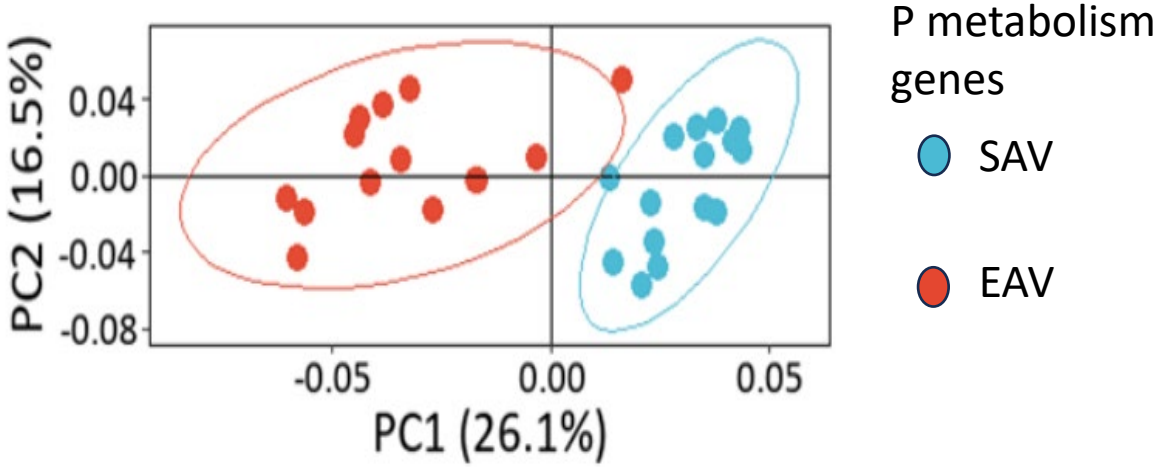

• Periphyton
• Microbial community on plant material and floc
• Supports breakdown and adsorption of DOP through enzyme production
Stormwater containing phosphorus
Inflow
+ seepage
Phosphorus uptake by floating plants
Algae and periphyton P uptake
accumulation, chemical precipitation, particle settling
Water with less phosphorus content
Outflow
+ seepage
Phosphorus uptake by emergent plants
Phosphorus flux from soil
Phosphorus uptake by submerged aquatic vegetation and periphyton
Phosphorus storage in soil

Periphyton: Enzyme Activity



Pietro et al. (2023)

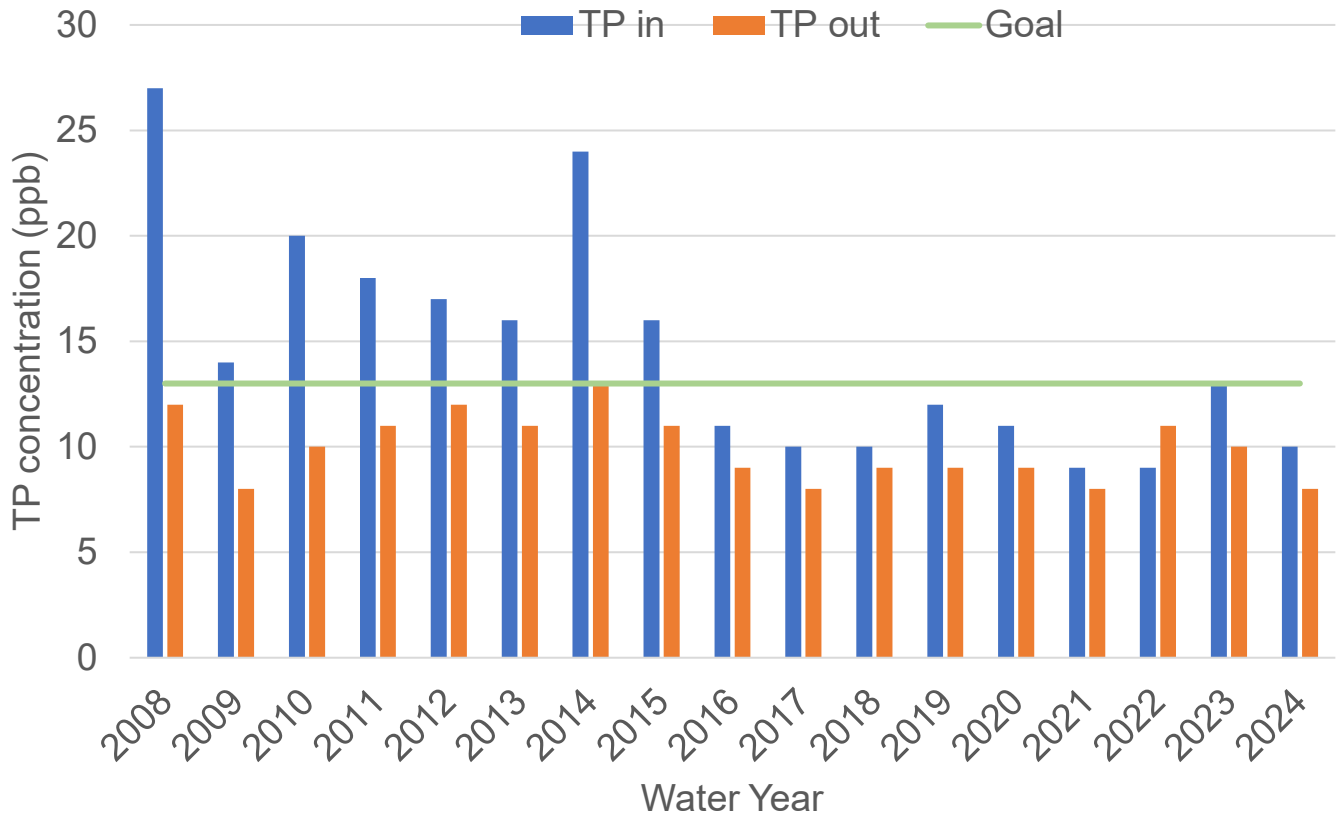
- Periphyton on EAV and SAV support breakdown of DOP
- Enzyme activity increased at the outflow region
  - Low amounts of available phosphorus
  - Use enzymes to degrade organic P
- RNA analyses EAV and SAV periphyton
  - P metabolism and uptake are different



Periphyton-Based STA: PSTA

- Muck soils scraped to bedrock (limestone)
- Located at outflow of STA-3/4
- Annual TP outflow <= 13 ppb
- If needed this tool meets criteria for use in some flow-ways

Piccone and Zamorano (2020)

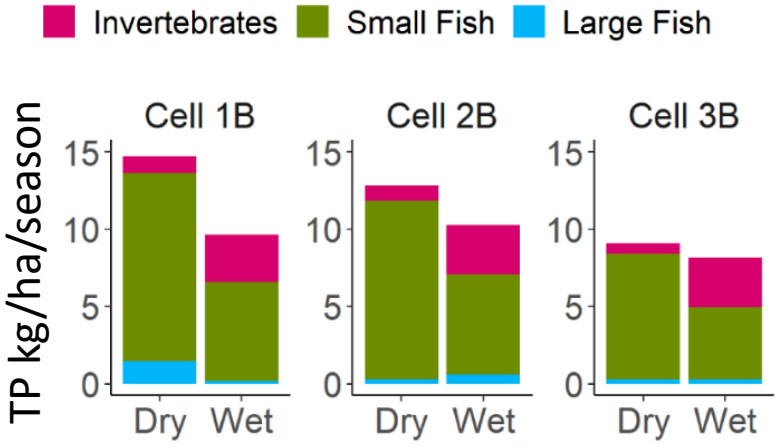


Zamorano et al. (2023)
Dombrowski and Piccone (2025)

Fish Effects

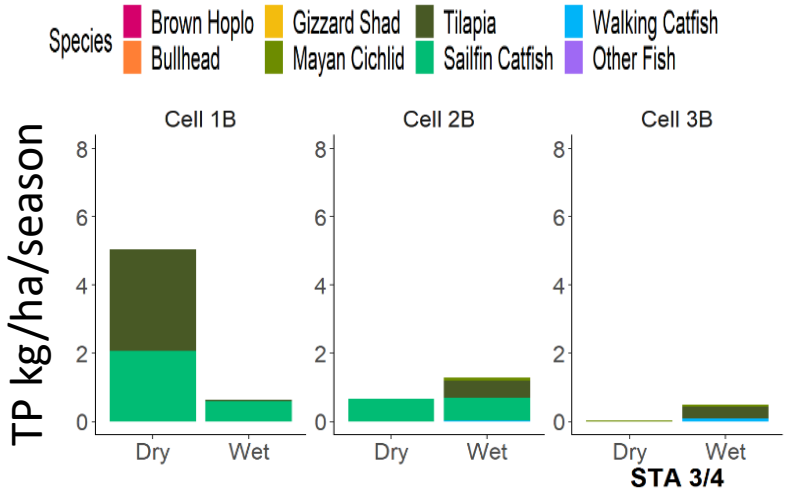



- TP is recycled by fish
  - Not a new source of P to the FW
- Small fish excretion greater than large fish and invertebrates
- Bioturbation by large fish can be a concern in specific circumstances
  - Outflow regions



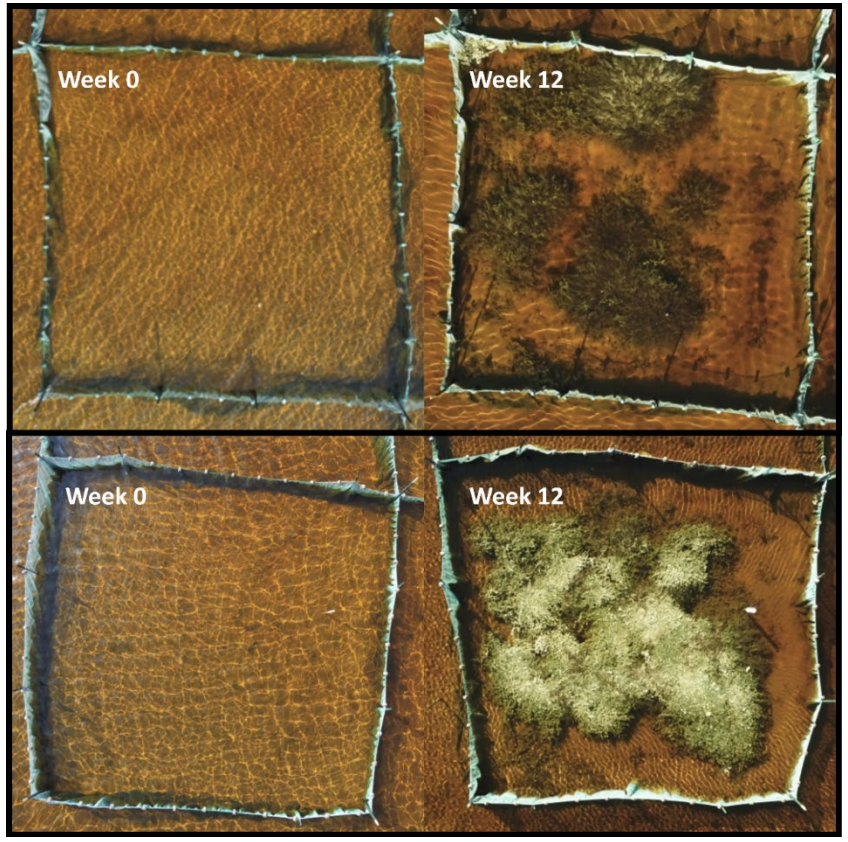
STA-3/4 Excretion rates

Goeke and Dorn. (2024a)



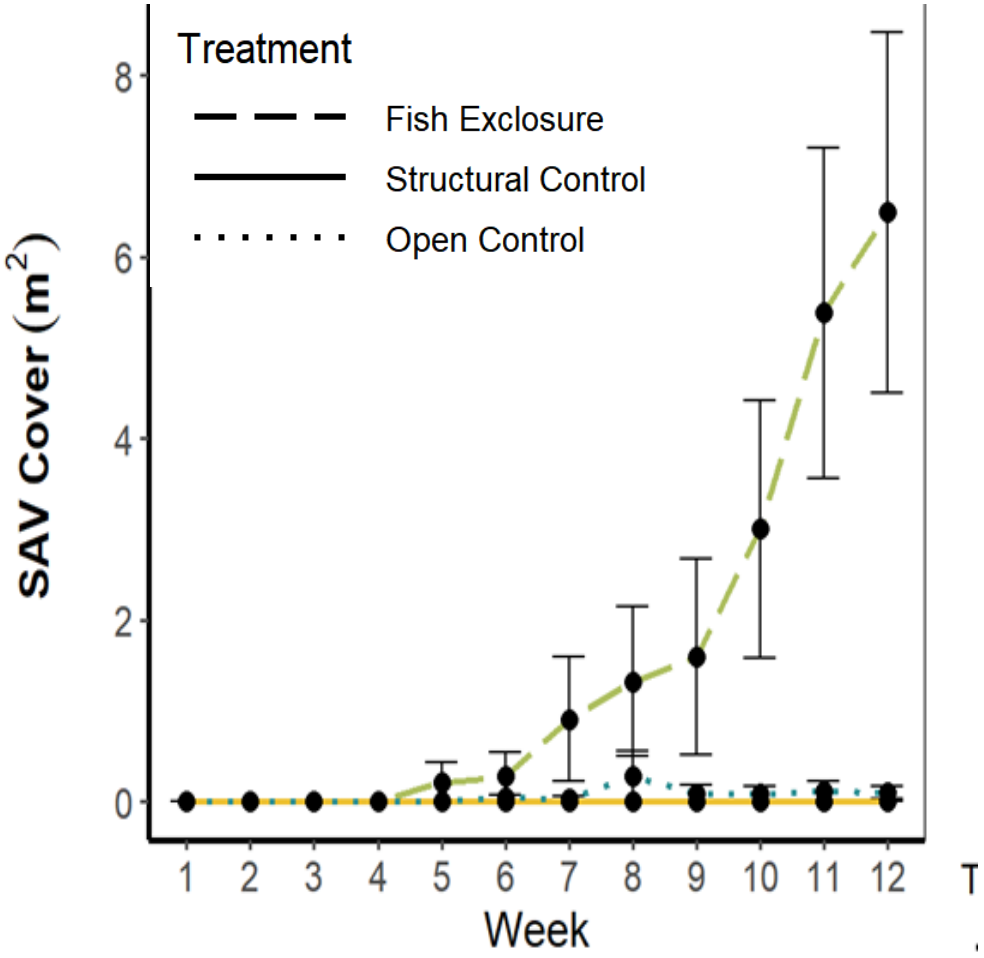
STA-3/4 Bioturbation rates

Fish Herbivory



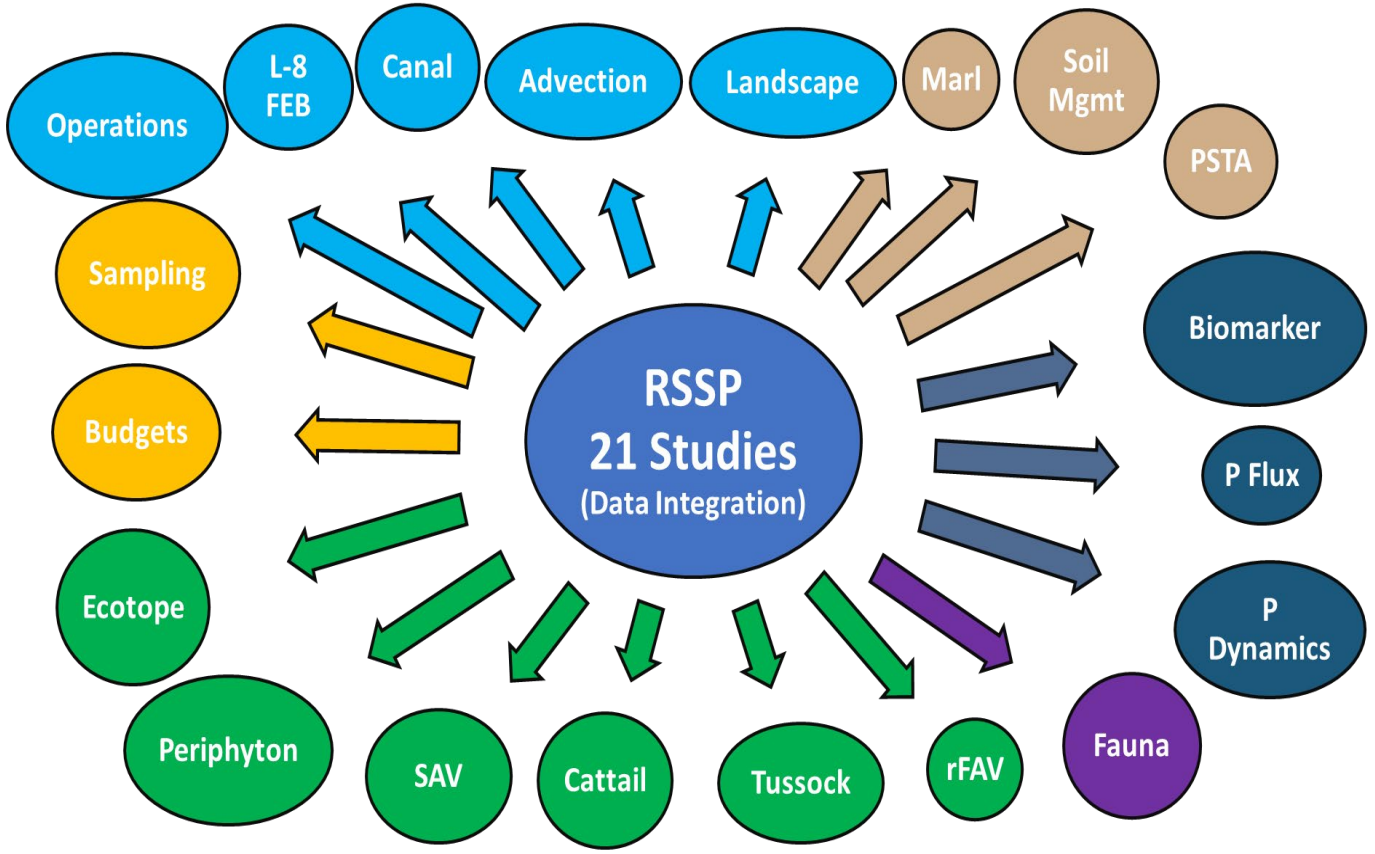
- Herbivory by large fish
  - Reduces SAV regrowth in areas of bare soil
- Excluding Fish
  - Inoculate with SAV
  - 10 to 12 weeks
  - SAV regrew

Goeke and Dorn. (2024b).



Takeaways

- Between 72 to 85% of the P is removed in the STA FWs
- P retention occurs through accumulation of soil, which is not limited
- Proper loading and flow and low disturbance are important to achieve low P discharge
- Vegetation, fauna, biogeochemistry and internal loads affect retention



References

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DB Environmental 2023a. Improving the Resilience of SAV in the STAs Final Summary Report

DB Environmental. 2023b. Marl study Final Summary Report

DB environmental. 2024. Phosphorus Dynamics in the Stormwater Treatment Areas Comprehensive Final Report

Diaz. 2022 Appendix 5C-1: Evaluation of Inundation Depth and Duration Threshold for Typha domingensis (Cattail) Sustainability: Test Cell Study.

Diaz, et al. 2023. Evaluation of Water Depth and Inundation Duration on Typha domingensis Sustainability in the Everglades Stormwater Treatment Areas: A Test Cell Study. Ecological Engineering 195.

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Goeke, J., and N. Dorn. 2024b. Investigation of the Effects of Abundant Faunal Species on P Cycling in the Everglades Stormwater Treatment Areas (STAs) Task 7: Herbivory.

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Piccone, T., and M. F. Zamorano. 2020. Feasibility Study for Periphyton-based Stormwater Treatment Area Implementation in Everglades Stormwater Treatment Areas. SFWMD, West Palm Beach FL.

Pietro et al. 2023. Periphyton enzymatic activities in the water column along internal low-phosphorus nutrient gradients in the Everglades Stormwater Treatment Areas. Ecological Engineering 196.

Villapando et al. 2024. Biogeochemical Response of Subtropical Treatment Wetlands to Different Flow Conditions. Ecological Engineering 198

Zamorano et al. 2023. History and performance of the Everglades STA-3/4 periphyton-based stormwater treatment area (PSTA). Ecological Engineering 194.

Zhao, H., and T. Piccone. 2020. Large scale constructed wetlands for phosphorus removal, an effective nonpoint source pollution treatment technology. Ecological Engineering 145

Thank you!

Contact Information

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Links:

Restoration Strategies Science Plan

South Florida Environmental Report (SFER) Chapter 5C

Ecological Engineering Special Issue:
https://www.sciencedirect.com/special-issue/10B60WZB3QL