THE RATE OF NUTRIENT CHANGE IN STORMWATER PONDS IN RESPONSE TO ABUNDANCE OF VARIED VEGETATION TYPES

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Introduction

- Increased impervious surface area due to urbanization causes increased stormwater runoff (Figure 1).
- Urban aquatic ecosystems are susceptible to flooding and pollution from urban stormwater runoff, particularly pollution in the form of nitrogen (N) and phosphorus (P) that leads to eutrophication.

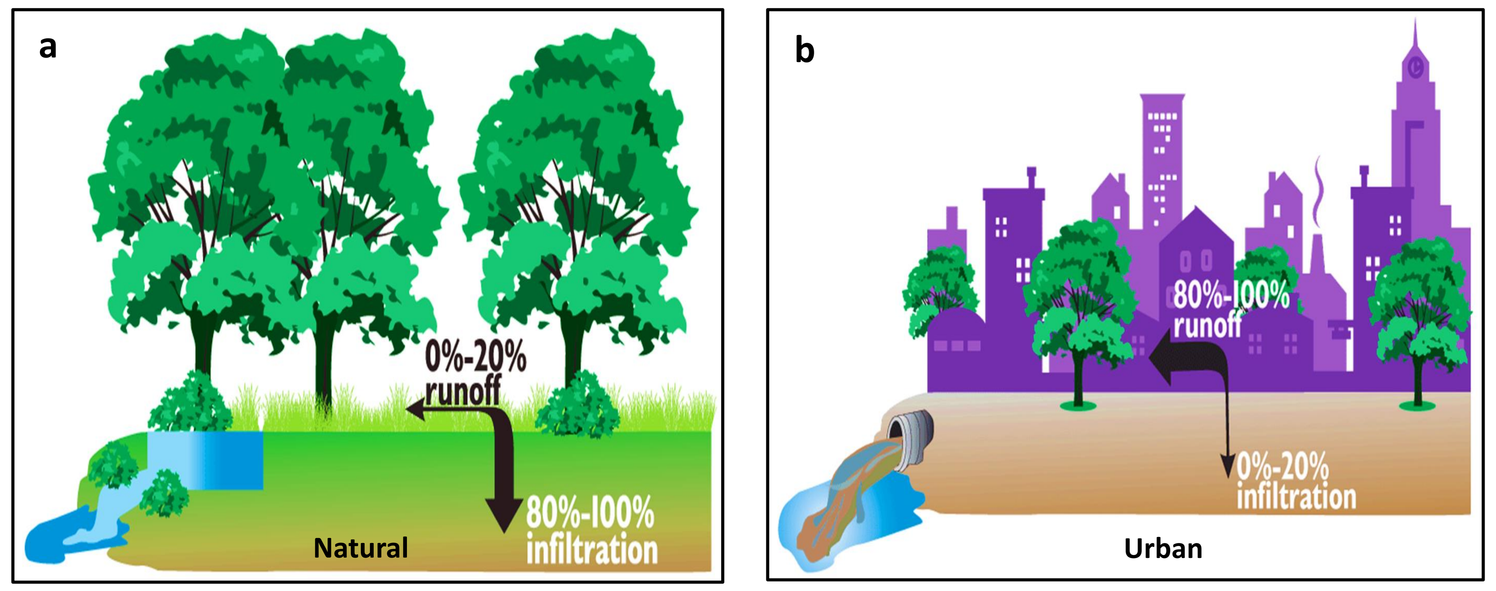

Figure 1: (a) In natural environments, the majority of stormwater infiltrates into the groundwater, while (b) in urban areas, the majority of stormwater runs over impervious surfaces into nearby waterbodies creating downstream flooding and concerns of water quality.

- Stormwater ponds are engineered ecosystems designed to mitigate impacts of urbanization by preventing downstream flooding and removing nutrients from urban stormwater runoff (Figure 2).
- Stormwater ponds in Florida:

Accredited for removing > 80% Total Nitrogen (TN) and Total Phosphorus (TP)

Current removal estimates: TP = 60-65%
TN = 12-63% (Harper & Baker, 2007)

- New approaches for stormwater ponds are needed to achieve nutrient removal goals.
- Stormwater pond plantings have been proposed as a potential BMP to aid in nutrient removal, as plants and their associated microbes can uptake nutrients (Yang & Lusk, 2018).

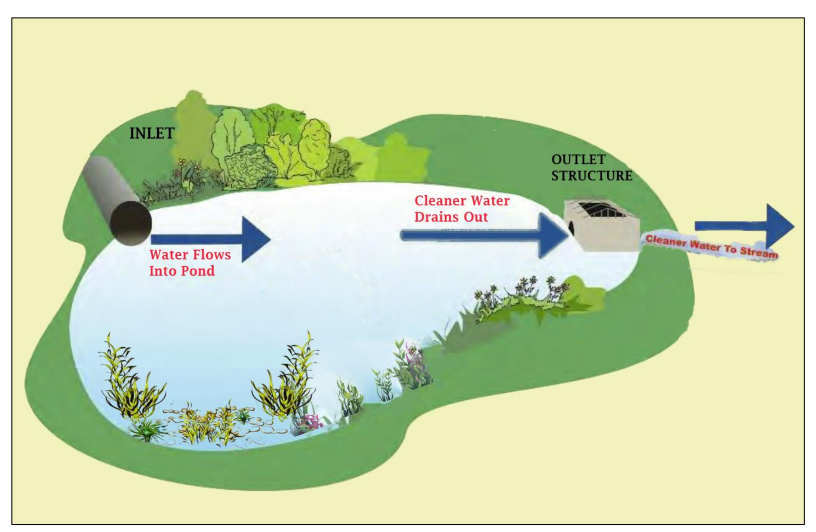

Figure 2: Function of stormwater ponds in removing nutrients from urban stormwater runoff. Processes such as nutrient uptake by vegetation, microbial activity, and sediment trapping can enhance nutrient removal rates to improve downstream water quality.

Objectives and Hypotheses

1) To estimate the difference in nutrient removal rates between planted stormwater ponds and conventional stormwater ponds with only turfgrass banks.

H1: Stormwater ponds with planted banks and littoral zones (Figure 3a) or with no-mow buffer zones and planted littoral zones (Figure 3b) are more effective at removing nutrients compared to conventional stormwater ponds with only turfgrass banks (Figure 3c).

Predicted rankings of nutrient removal rate for three different planting styles:

Conventional turfgrass < no-mow buffer zones and planted littoral shelves < Planted banks and planted littoral shelves

2) To quantify the relationship between nutrient removal rates and the abundance of pond bank plant, floating plants, submerged plants and emergent plants in the littoral zone.

H1: Higher plant abundance on pond banks decrease nutrient influx, whereas greater abundance of floating, submerged, and emergent plants in the littoral zone increase nutrient removal rates.

Methodology

Study Location: Manatee County and Sarasota County, FL, USA

Monitored water quality during summer 2023 in stormwater ponds having one of 3 planting styles (N = 8) (Figure 3).

Figure 3: Three planting styles studied (a) stormwater ponds with planted banks and planted littoral zones., (b) stormwater ponds with no-mow buffer zones & planted littoral zones, and (c) conventional stormwater ponds with only turfgrass banks

Stormwater sampling: A total of 63 storm events were sampled.

- Water samples were collected from the center of ponds at the beginning and at three-hour intervals for up to 18 hours after the storm ceased (Figure 4a).
- Autosamplers triggered by GatorByte microcontrollers were used to collect water samples (Figure 4b).
- Quantified dissolved and particulate TN (Total Nitrogen) and TP (Total phosphorus).
- Utilizing Chloride concentration as a conservative tracer to address fluctuations in nutrient levels linked to variations in pond water volume (e.g., due to evaporation).

Vegetation sampling: Measured plant cover visually in distinct sections of each stormwater pond: Turfgrass bank, eroded exposed bank, no-mow buffer zone, planted bank, floating, submerged, and emergent plants in the littoral zone.

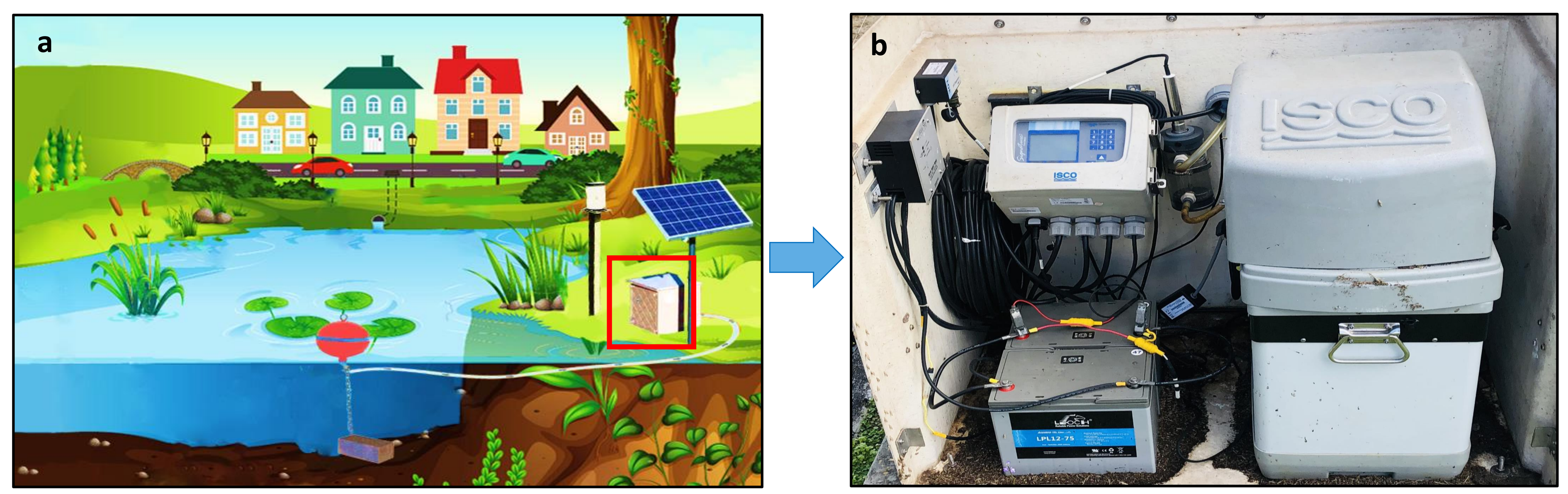

Figure 4: (a) Storm event sampling using a rain gauge, GatorByte sensor, and the autosampler powered by a solar panel to collect water samples as stormwater enters the pond and (b) an autosampler with the GatorByte sensor enclosed in a box.

Determining nutrient removal rates

Nutrient removal efficiency (R): The proportion of nutrients removed from the stormwater pond (Equation 1).

Equation 1:

$$R = \frac{M_{in} - M_{out}}{M_{in}}$$

R: Nutrient removal efficiency
Min: Inflow nutrient mass
Mout: Outflow nutrient mass

- M_{in} was estimated as the maximum Nutrient:Cl ratio among the water samples collected within the time intervals of 6 to 18 hours.
- M_{out} was estimated as the Nutrient:Cl ratio of the water sample taken prior to the occurrence of the subsequent storm event.
- The Continuous Stirred-Tank Reactor (CSTR) model was utilized to calculate the first-order removal rate constants (k) for both TN and TP for each storm event.
- This calculation utilized the nutrient removal efficiency (R) as determined in Equation 1 (Cheng & Basu, 2017).

Equation 2:

$$k = \frac{R}{(1-R)} * \frac{1}{T}$$

k: Rate constant (day^{-1})
R: Nutrient removal efficiency
T: Residence time (days)

Rate constant (k): The rate at which nutrients are removed from the water within stormwater ponds (Equation 2).

- A linear mixed-effects model was used for the statistical analysis.
  Rate constant (k) ~ Plant Abundance + (1|Site)

Results

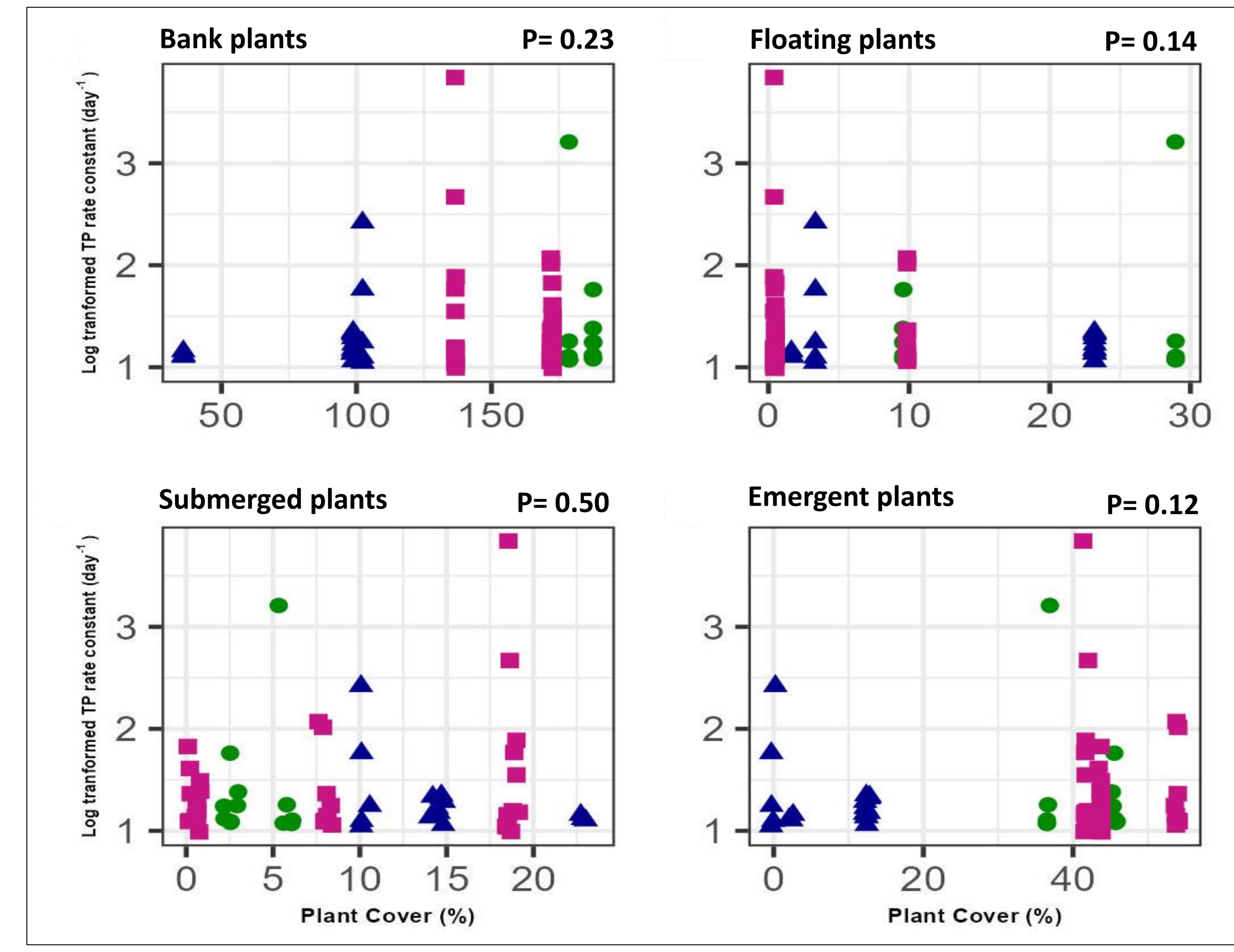

Figure 5: The relationship between dissolved TN removal rates and plant cover types across eight stormwater ponds, categorized into three distinct planting styles. Each point represents the TN rate constant measured for a specific stormwater event.

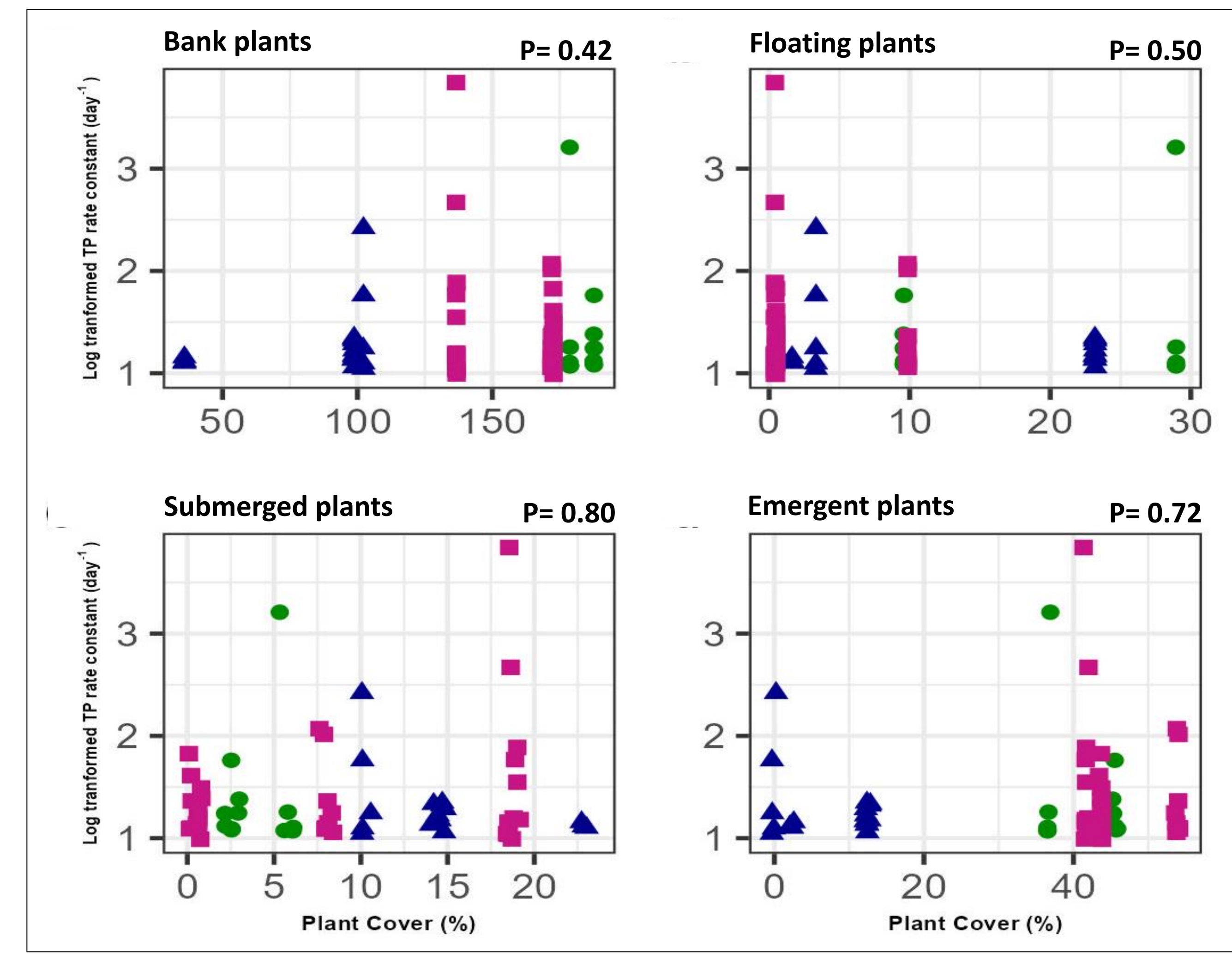

Figure 6: The relationship between dissolved TP removal rates (k) and plant cover types across eight stormwater ponds, categorized into three distinct planting styles. Each point represents the TP rate constant measured for a specific stormwater event.

Conclusion

- Modeling TN and TP in responses to plant abundance on banks and littoral zones is more appropriate than categorical planting styles.
- There is no evidence to show that planted stormwater ponds and no-mow buffer zone ponds outperform conventional turfgrass ponds in nutrient removal. However, we know they are an economically viable solution to prevent bank erosion a growing concern.

Next steps

- Calculate nutrient removal rates for particulate TN and TP.
- Determine other sources/activities in the urban landscape that can contribute to nutrient loads in stormwater ponds
- Identify additional benefits of stormwater plantings for stormwater ponds.
- Explore alternative study designs to enhance water quality in stormwater ponds.

References

- Harper, H. H., & Baker, D. M. (2007). *Evaluation of Current Stormwater Design Criteria within the State of Florida*. Florida Department of Environmental Protection.
- Yang, YY., Lusk, M.G. Nutrients in Urban Stormwater Runoff: Current State of the Science and Potential Mitigation Options. Curr Pollution Rep 4, 112–127 (2018).
- Cheng, F. Y., & Basu, N. B. (2017). Biogeochemical hotspots: Role of small water bodies in landscape nutrient processing. Water Resources Research, 53(6), 5038–5056.