Extreme changes in water level and nutrient loading can shift freshwater coastal wetlands from nutrient sinks to sources

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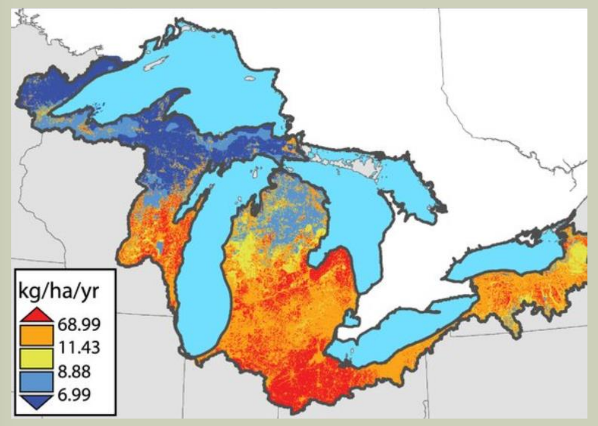
Introduction

Global change drivers, such as drastic water level alterations and nutrient loading, can potentially transform coastal wetlands from nutrient sinks to sources. Elevated coastal water levels lead to wetland plant mortality, triggering changes in nutrient mineralization and export. Furthermore, flood-induced anaerobic conditions can enhance denitrification and lead to phosphorus release through iron reduction. In the Great Lakes, extreme lake-level rise interacts with other drivers of change, such as invasive species or increased nutrient inflow from the landscape, influencing overall nutrient function. Simulation modeling can help unravel these interactions and enhance our understanding of field observations.

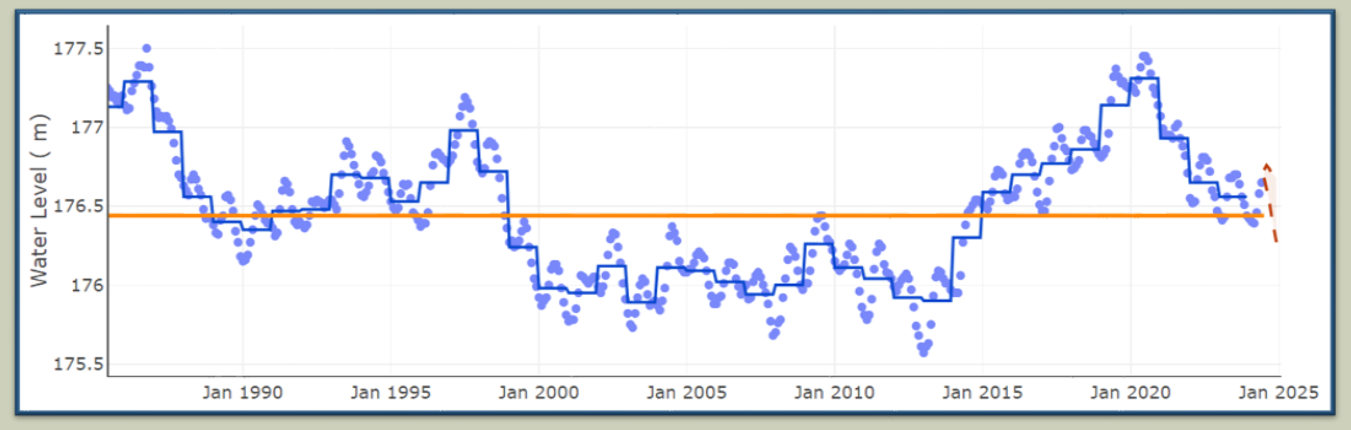
Elevated coastal water levels

Increased nitrogen input



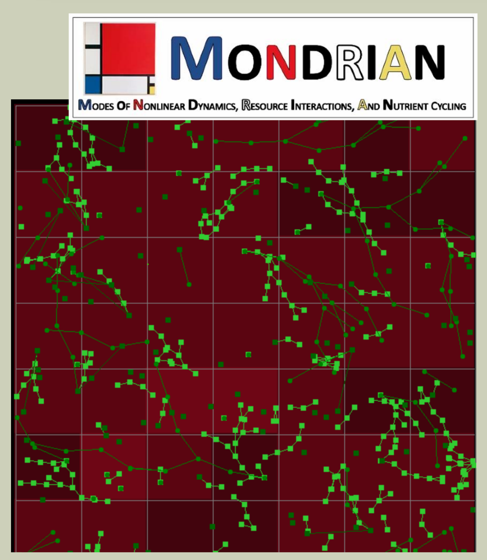
Invasive species

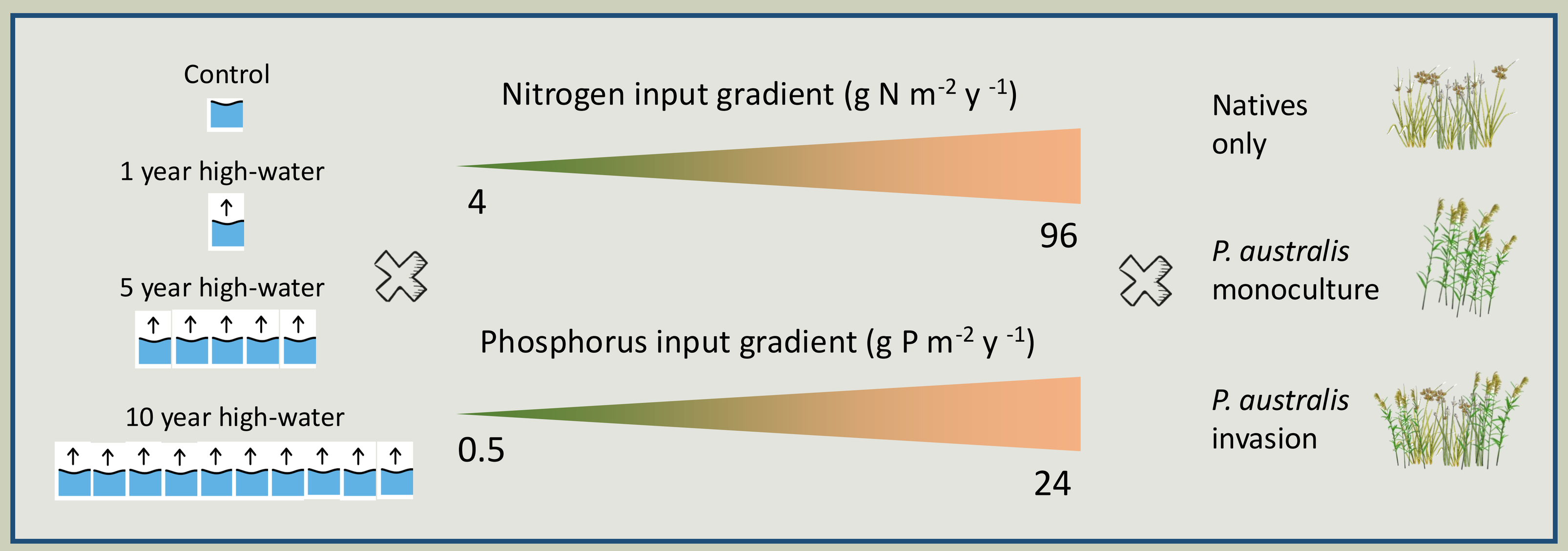
Lakes Michigan and Huron water levels



Methods

MONDRIAN is a processed-based computational model that simulates individual plants of multiple species and their interactions with various environmental factors. Our *in-silico* experiment considered four different simulated water conditions: control (normal seasonal variation) and three high-water level treatments characterized by extreme conditions (representative of observed Great Lakes levels) lasting 1, 5, and 10 years, where water levels reached thresholds initiating emergent plant mortality. Additionally, we simulated seven nutrient input levels, focusing on nitrogen (N) and phosphorus (P), ranging from low to extremely high. We further examined the influence of three different plant community scenarios: native plants only, *Phragmites australis* monoculture (a common invader), and *P. australis* invasion into a pre-established native community.





Funding: NASA OCEAN, Grant: 8000003824, Fund: 8000101000.

Results

We completed over a thousand MONDRIAN simulation runs, fully crossing water levels, nutrient inputs, and plant communities. **We found evidence of wetlands switching from N and P sinks to sources during extremely high lake levels**, specially for P (Fig 1, Fig. 2). The response to high-water periods was similar and consistent among plant communities, and more extreme with higher nutrient inputs for P.

<u>Nutrient balance:</u> difference between the amount of nutrients entering the system and the amount of nutrients leaving.

Balance > zero, wetland acts as a nutrient sink.

Balance < zero, wetland functions as a nutrient source.

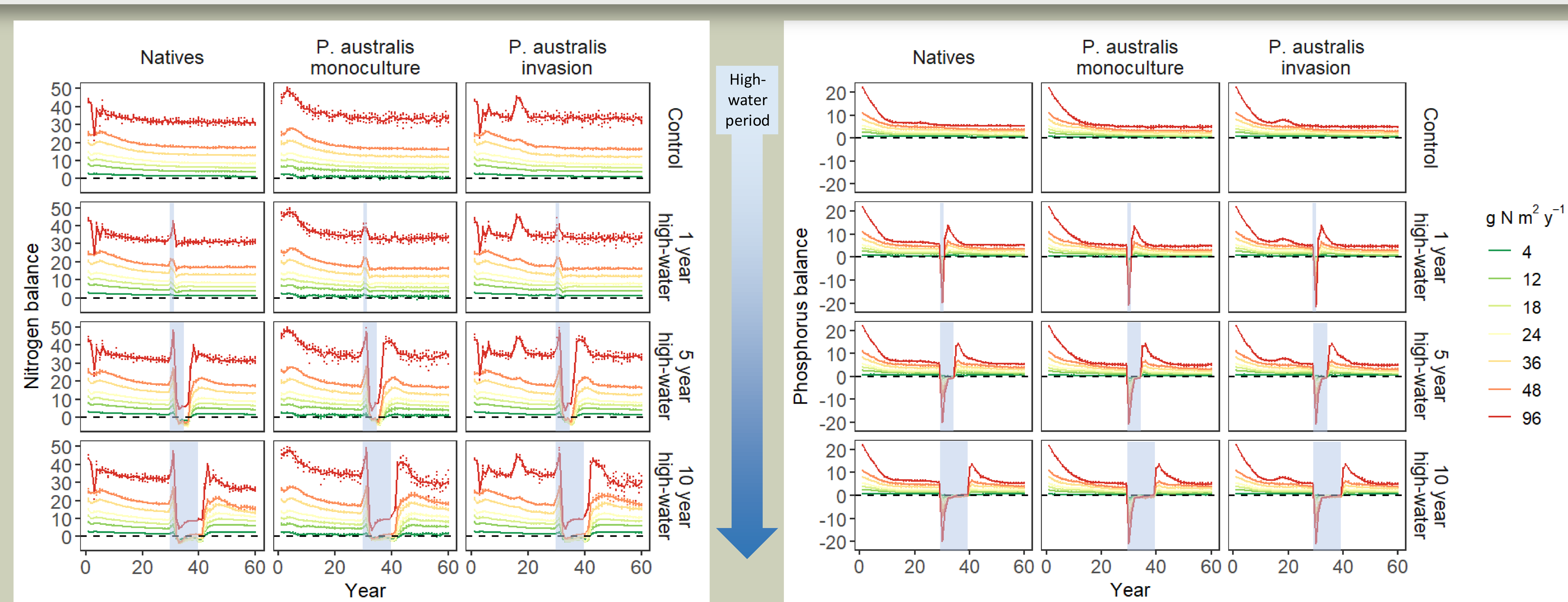


Figure 1. Nitrogen and phosphorus balance for the three communities and the four water level scenarios.

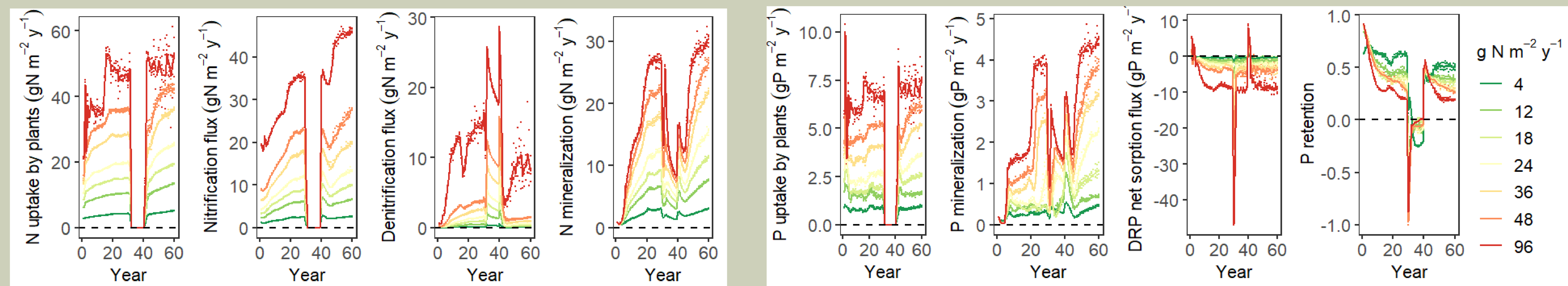


Figure 2. Nitrogen uptake, Nitrification flux, Denitrification flux, N mineralization, P uptake, P mineralization, dissolved reactive P (DRP) net sorption, and P retention for the invasion scenario under a 10-year high-water period.

Discussion

The shift is primarily attributed to reduced plant uptake, increased denitrification, and P desorption. The magnitude of both high-water duration and nutrient input played a crucial role in influencing nutrient dynamics, either by amplifying or diminishing various processes. Notably, our findings suggest that wetlands may revert to their pre-state as nutrient sinks within a year following the end of the elevated water level. The patterns were generally consistent across the three tested communities.

Take home messages

- Hydrologic regimes can regulate the internal nutrient dynamics of coastal wetlands.
- Potential of climate-induced changes in water level, nutrient loading, and invasive plants, on shifting coastal wetlands from nutrient sinks to sources.
- Simulation modeling offers valuable insights for future wetland management and conservation research.