Nutrient Removal and Greenhouse Gas Fluxes In 19 Year Old Constructed Wetlands: A Temporal Analysis and Comparison

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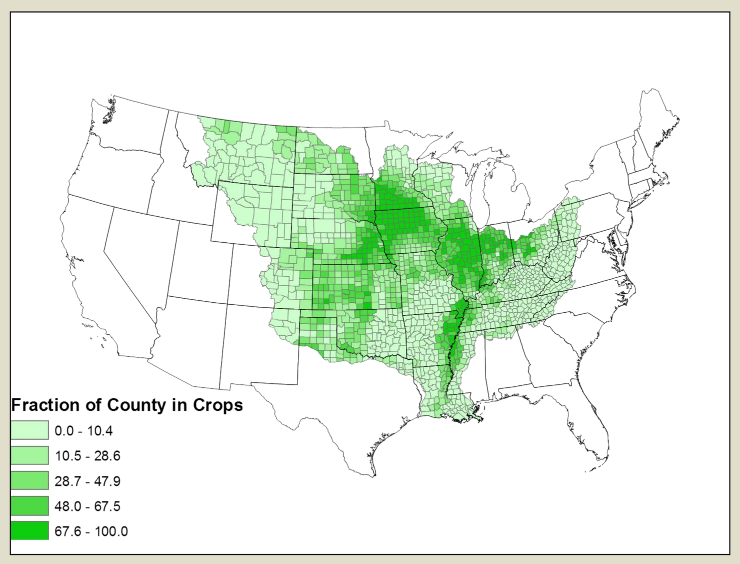
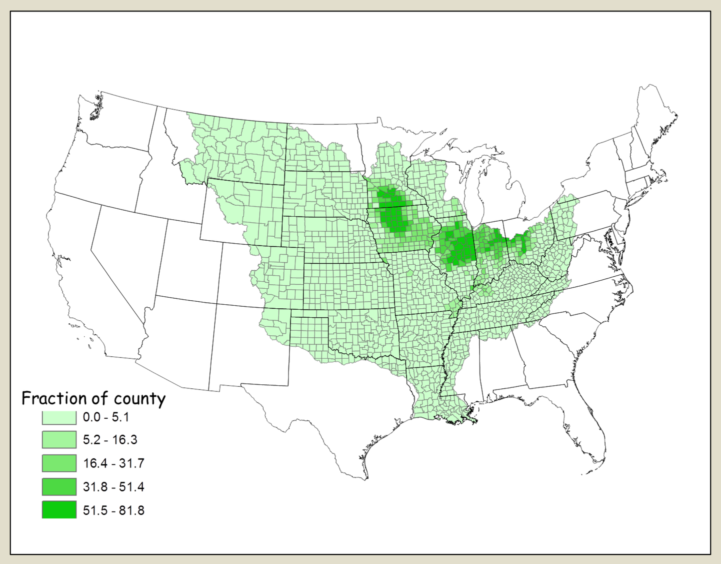
Background

Tile Drainage

- Tile drainage is a common practice for conventional farming in the Upper Embarras Watershed, in east central Illinois, and throughout the Corn Belt.
- These subterranean tile networks allow for rapid drainage from flat land that is naturally poorly drained.
- Nitrate and total P are easily leached with drainage water, leading to downstream water quality problems.


The upper Embarras Watershed in east central Illinois (left). This photo was taken looking west on the eastern moraine that marks the edge of the watershed. Photo of a drainage ditch collecting water from tiles and transporting the water to the closest water body (right).





Maps showing the Mississippi River Basin and the most heavily cropped counties (left) and the most heavily tiled counties (right). The Embarras River Watershed, along with the Corn Belt, show up in both maps in dark colors indicating the heavy crop and tile density.

Embarras Wetland Project

- Six constructed wetlands were built in 1994 to intercept tile drainage water from farm fields before the water reached the Embarras River.
- Tile drainage water had high concentrations of N and P from typical corn/soybean production.
- These wetlands were to function as sinks for both N and P, through denitrification for nitrate, and soil adsorption/biomass burial for P.
- As wetlands age, their removal rates for both N and P will likely change. This study measured N and P removal rates for two of the constructed wetlands, wetlands A and B, 19 years after construction.
- Greenhouse gas emissions, carbon dioxide, methane, and nitrous oxide, also occur due to wetland processes and their release was quantified.

Methods

- Wetlands A and B, 0.6 and 0.3 ha respectively, were equipped with Agri Drain structures for their inlets and outlets. Each inlet and outlet had a v-notch weir, a pressure transducer, and a data logger to measure flow. Nitrate, ammonium, organic N, total N, phosphate, organic P, and total P were determined in water samples collected at each structure. The frequency of sampling depended on inlet flow, and ranged from weekly to several times per day depending on flow.
- Nitrate was determined in water samples collected from seepage wells positioned between the berm and the river to examine seepage.
- To determine greenhouse gas fluxes from the wetlands, both terrestrial and floating chambers were sampled after each precipitation event. The floating chambers were sampled until the wetlands' pools were too shallow.

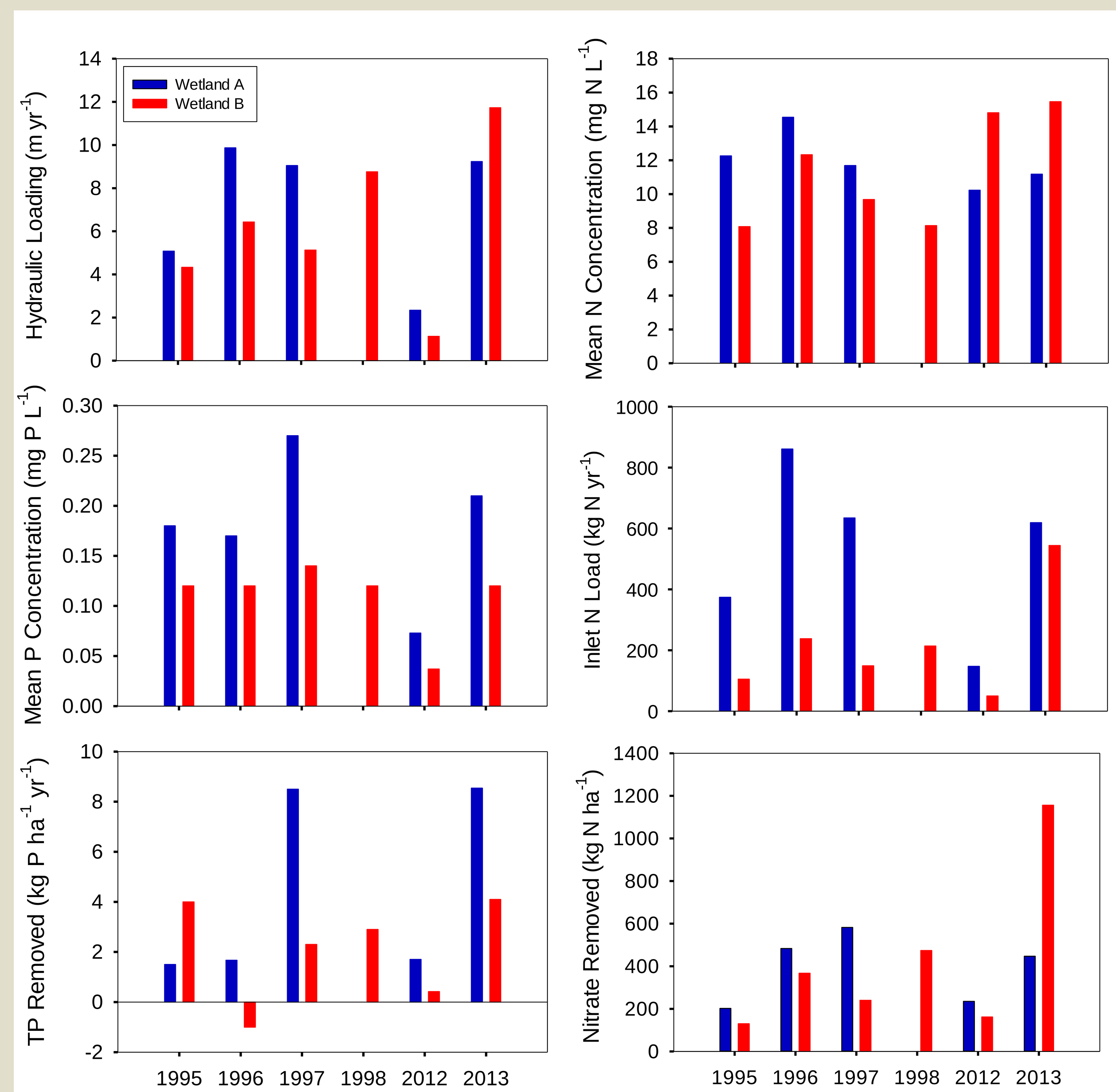

Terrestrial and floating GHG chambers (left). An outlet Agri Drain structure equipped with a V-notch weir, pressure transducer, and data logger (right).

Objectives

- Determine N and P removal rates for wetlands receiving tile drainage, comparing current rates with those just after construction.
- Measure methane, carbon dioxide, and nitrous oxide emissions from both terrestrial and inundated portions of the wetlands.
- Determine how GHG emissions are affected by wetland physical and chemical properties.

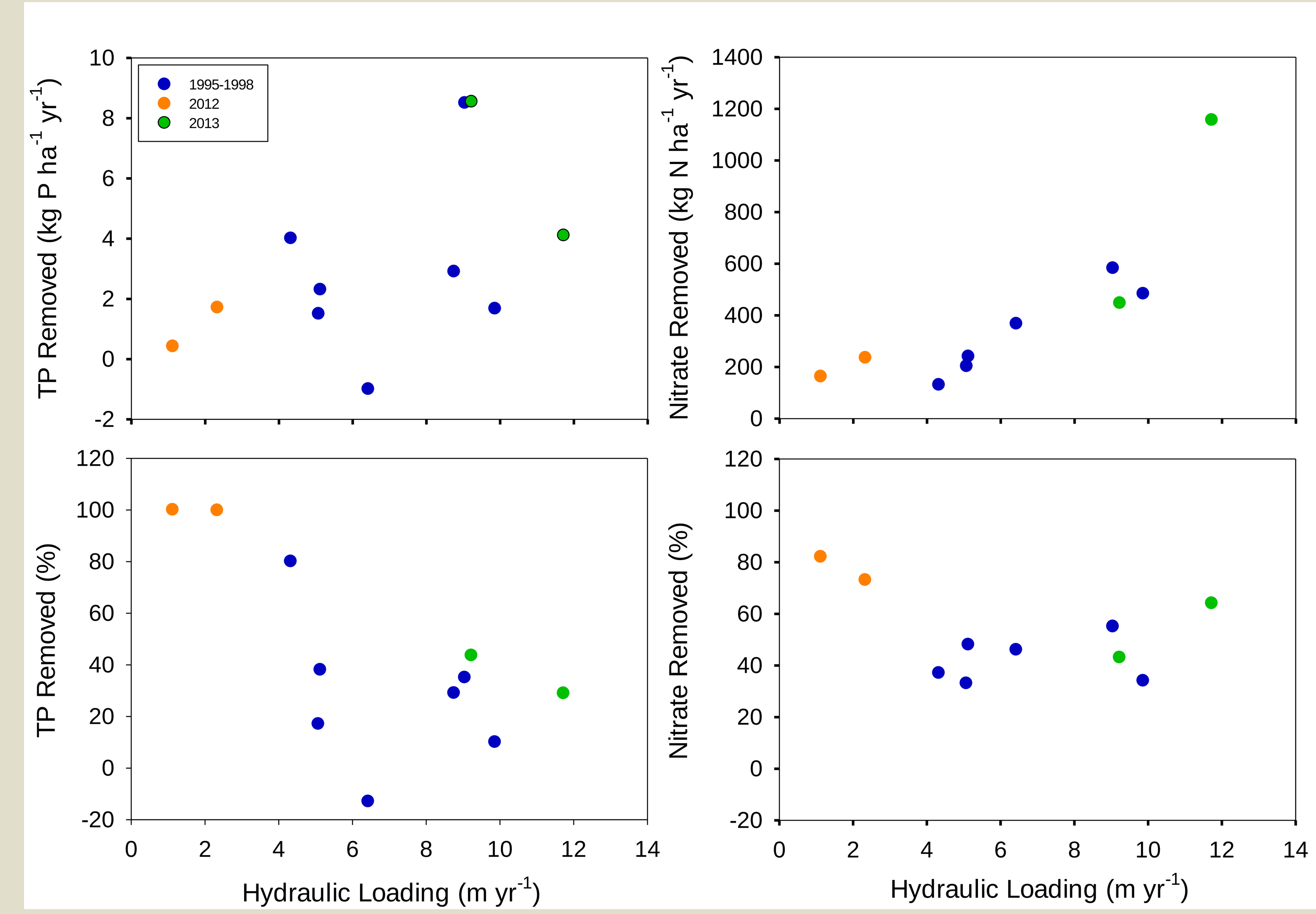
Results & Discussion

- The lowest hydraulic loading rates for both wetlands were in the 2012 drought. However, the 2013 water year had a more average loading rate for wetland A, 9.2 m yr^{-1}, and the highest recorded loading rate for either wetland, 11.7 m yr^{-1}, for wetland B.
- Inlet total P concentrations were 0.21 mg P L^{-1} in wetland A and 0.12 mg P L^{-1} in wetland B, similar to other years and confirming that P does move through tile lines.
- The highest inlet nitrate concentrations were 14.8 and 15.5 mg N L^{-1} for wetland B in 2012 and 2013, respectively. Wetland A had a nitrate concentration of ~10 mg N L^{-1} both years.
- Both wetlands retained P at rates similar to those in 1997.
- Wetland B had the greatest nitrate removal rate of any wetland in this study in 2013 with a rate of nearly 1200 kg N ha^{-1}, demonstrating that N removal processes have not decreased during the nearly 20 years the wetland has been functioning.



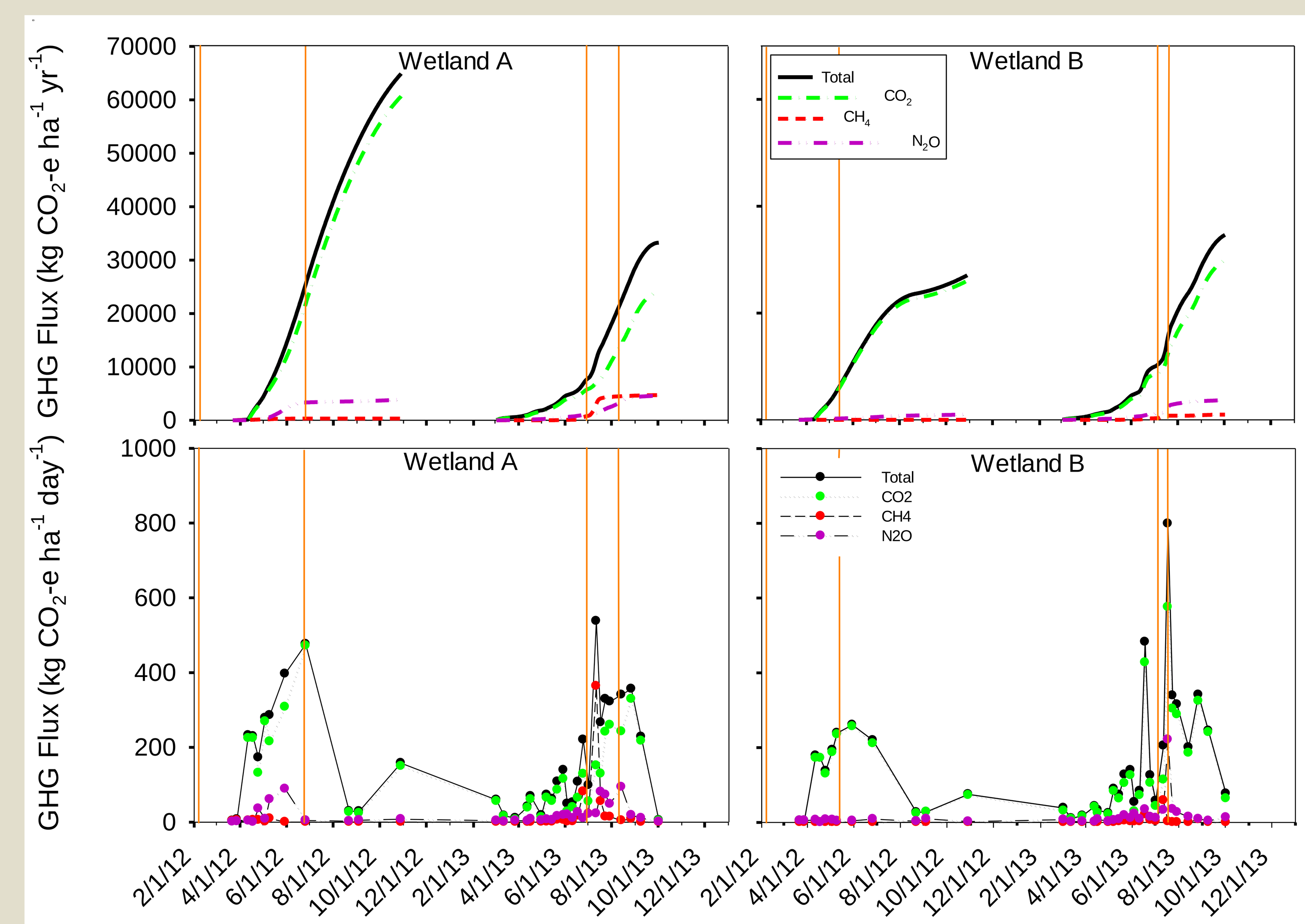
Wetland A and B nutrient removal rates and flow-weighted mean concentrations of total P (left) and nitrate (right). The hydraulic loading rate and inlet N load for both wetlands are also shown. Note that wetland A was not studied in 1998.

- Nitrate and total P removal rates for both wetlands increased with increasing hydraulic loading rates. This may be due to an overall larger nitrate and total P load into each wetland, thus giving the wetlands the potential to remove a greater mass of both nutrients.
- These results suggest that the greater the N and P loads are for a constructed wetland, the greater the absolute nutrient removal rate will be. The extent of this trend is unknown, and may not be true for P as the wetlands continue to age.
- Percent removal for both nitrate and total P, when compared to wetland hydraulic loading, tended to decrease with increasing loading, although this was stronger for P than N. Expressing wetland nutrient removal on a percent basis alone may not be an accurate measure of a wetland's nutrient removal capacity. During a wet year, wetlands actually remove more N and P on a mass basis, but may have an overall lower percent removal.



Wetland nitrate-N and total P removal rates and percent of inlet loads retained as a function of hydraulic loading.

- CO_2 is the most important GHG emitted from both wetland A and B.
- N_2O and CH_4 do not make up a significant portion of the total GHG emissions when wetlands A and B were flooded. During this time, nitrate is at higher concentrations, allowing microorganisms to use it as a terminal electron acceptor without having to resort to methanogenesis. Also, the denitrifiers are most likely converting the majority of nitrate to N_2.
- N_2O and CH_4 fluxes seem to increase during the final dry down period, indicated between the orange lines on the figures below. During the dry down, N_2O emissions increased in the terrestrial portion of the wetland, whereas CH_4 fluxes increased in the inundated portions.



Cumulative GHG fluxes in CO_2 equivalents for both Wetland A and B (top). Wetland A and B GHG fluxes in CO_2 equivalents for each sampling date (bottom). The orange lines indicate the time from the last outlet flow to when the wetlands dried down completely.

Conclusions

- Nitrate and total P removal rates increased with higher concentrations and flows into the wetlands. The larger the nutrient load, the greater the potential for higher removal rates.
- CO_2 is the most prominent GHG for both wetland A and B. CH_4 and N_2O emissions were lowest when the wetland was inundated, and greatest during the final dry down.
- Further research is needed to support both the nutrient removal and GHG emission theory.

Acknowledgements

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References can be found at: https://netfiles.uiuc.edu/mbdavid/www/Biogeochemistry/publications.htm