Total nitrate removal by flocculent organic sediments in shallow freshwater ecosystems

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1 WHAT IS FLOC?

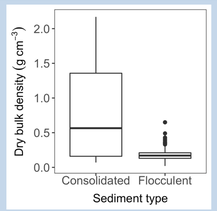
persistently unconsolidated mixture of organic debris, particulate mineral matter, and inorganic matter of biogenic origin that accumulates atop consolidated materials in flooded habitats

Floc is abundant on our landscape

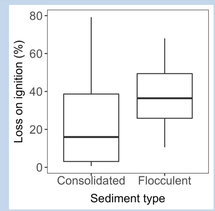
Flocculent sediment readily occurs in water bodies with: high primary productivity or allochthonous inputs; semi-permanent to permanent flooding; protected zones.

Floc is loosely consolidated

The dry bulk density of flocculent sediment is much lower relative to other organic sediments found in similar water bodies.



Floc layers have high levels of organic materials



2 RATIONALE & QUESTIONS

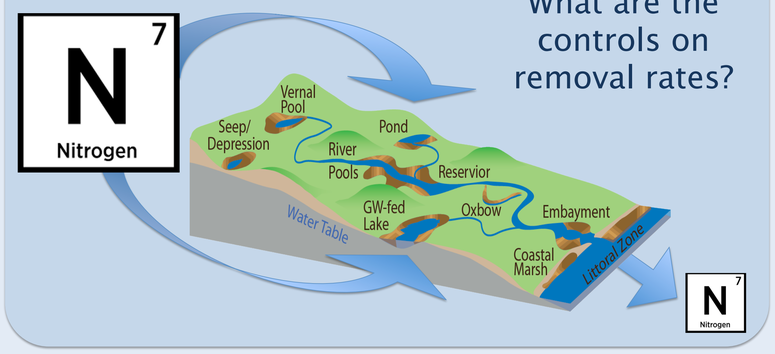
Anthropogenic activities have drastically increased the availability of nitrogen (N) to the biosphere. Recipient networks of lakes, wetlands, and fluvial systems retain a large portion the N that would otherwise be transported to coastal ecosystems. Smaller water bodies are ideal locations for these retentive processes. **We know this is true for streams, but what about small lentic water bodies?**

Floc may promote rapid removal of nitrate (NO_3^-) from overlying water. Floc layers have high levels of organic matter (OM), which supports heterotrophic activity, thereby stimulating assimilatory uptake of NO_3^- and respiratory denitrification.

The OM also indirectly enhances denitrification potential by increasing sediment oxygen demand. Further, density-driven exchanges associated with diel and episodic overturn of water are likely to enhance fluid and solute exchange between overlying water and loosely-consolidated floc layers.

Do floc layers promote rapid removal of NO_3^- from overlying water columns?

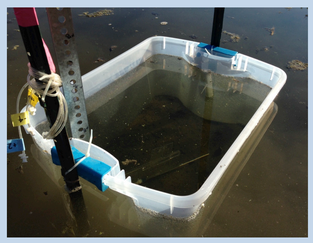
What are the controls on removal rates?



3 METHODS

In situ NO_3^- removal experiments

In Fall 2015 & 2016, we measured potential NO_3^- removal rates *in situ* using bottomless mesocosms (right) at several sites in SW Michigan with thick (>10 cm) floc layers and water columns <1 m. We enriched the overlying water to ~2 mg/L NO_3-N and Br^- and monitored changes in concentrations over 3 diel cycles



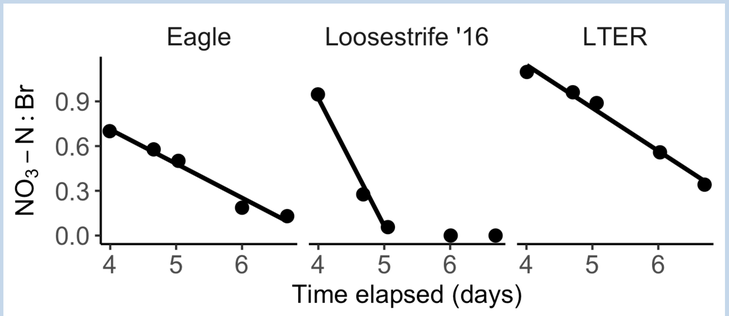


Figure 1. Examples of NO_3^- removal at three sites. We calculated areal NO_3^- rates using first order removal constants (*k*; slope of the lines).

4 RESULTS

Controls on NO_3^- removal rates

(Negative values indicate flux into sediments)

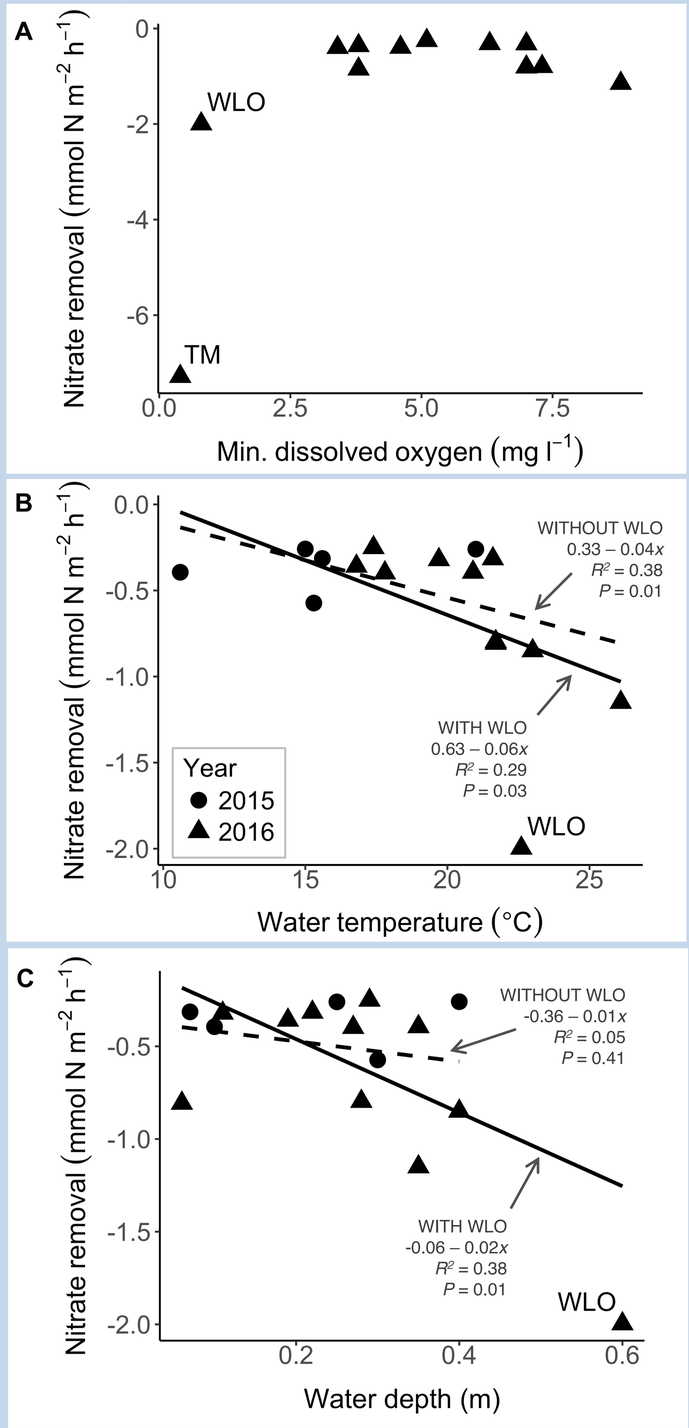


Figure 2. Relationships between NO_3^- removal rates and (A) minimum surface water (SW) diss. oxygen conc., (B) mean SW temp., and (C) SW depth. Site TM is an outlier and was excluded in B and C. Lines in B and C indicate relationships between removal rates and the covariate including site WLO (bold) and excluding site WLO (dashed).

5 DISCUSSION

Surface water dissolved oxygen and temperature are most apparent potential controls on NO_3^- removal rates

- Temperature is often the most important predictor of NO_3^- removal rates
- Studies have demonstrated that surface water (SW) DO conc. <3 mg/L enhance NO_3^- fluxes into sediments; likely due to increases in denitrification
- SW depth, background SW NO_3^-, NH_4^+, and SRP concentrations, and sediment properties like OM and chl *a* content had no relationship with removal rates

Floc may remove NO_3^- more quickly than other sediment types reported in the literature, though this may be because we enriched water column NO_3^- levels

- Floc NO_3^- removal rates were significantly different than rates for other sediment types (Fig. 2A). But when comparing measurements made with enriched NO_3^- levels (Fig. 2B), there are no differences between enriched floc measurements and enriched measurements made in other sediment types.
- Several sediment uptake studies have shown that enriching NO_3^- levels to any significant degree (e.g., 20-50 µmol/L $^{15}NO_3^-$) enhances removal rates

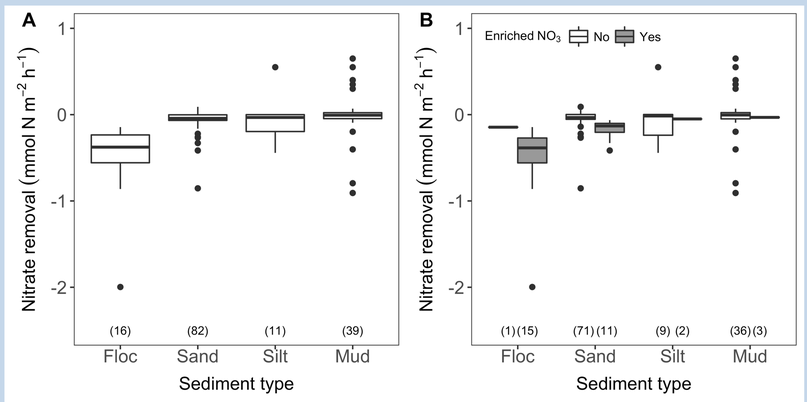


Figure 3. Nitrate removal rates reported in the literature for sediment types in freshwater and marine environments. Two of the floc measurements are from the literature, the remaining 14 are from this study. Measurements were made using different methods (i.e., *in situ* mesocosms and benthic chambers and in the lab using sediment cores). We classified any measurement made by adding any amount of NO_3^- as enriched.

6 CONCLUSION

Floc layers have the potential to remove NO_3^- from overlying water columns, but we cannot conclude that removal rates are much higher than those measured with other sediment types. While floc layers may be important interfaces for NO_3^- removal in small water bodies, we cannot say what fraction of the NO_3^- is potentially removed from these systems permanently because our measurements include both temporary storage (assimilation) and permanent removal via denitrification. An approach that includes the use of isotopically-labeled N might give us a better understanding of actual removal rates and fates of NO_3^- in floc.

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