Eutrophic and mesotrophic lake water microbiota respond differently to bloom-stimulating levels of supplemental ammonium and nitrate

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INTRODUCTION

Primary producers drive biogeochemical cycling in aquatic systems through nitrogen fixation, denitrification, supplying dissolved oxygen and up taking carbon dioxide, a potent greenhouse gas, by photosynthesis. However, under increased nutrient loading, primary producers can grow unabated creating high amounts of biomass from the excess nutrients (i.e., eutrophication). Human activities such as agricultural development have increased the frequency and intensity of eutrophication. Shifts in primary production can also prompt cyanobacteria harmful algal blooms (cyanoHABs), threatening water quality, with major ramifications for both human and ecosystem health. Reduced water quality can lead to economic burdens including loss of recreation, decreased property values, and degraded drinking water. Therefore, understanding the linkages between the development of shifts in the primary producers induced by nutrient inputs is critical for global health.

Increased phosphorus (P) is known to stimulate algal biomass. Yet, we do not fully understand the effect of nitrogen on a bloom. Therefore, we asked:

(1) What form of nitrogen fuels planktonic microbiome growth?
(2) How does lake bloom history affect the propensity for nitrogen to stimulate blooms?

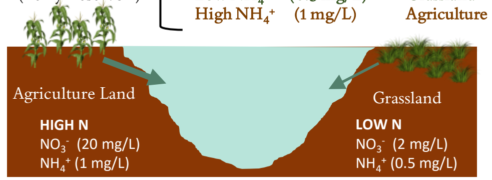
METHODS

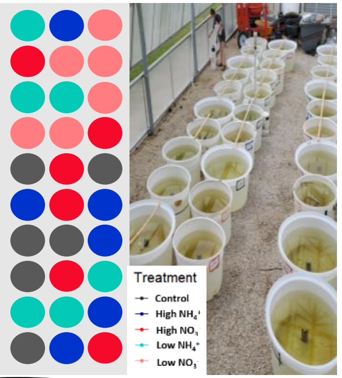
In this study, we ran a 3-week greenhouse experiment manipulating N (question 1) in 300-L mesocosms filled with lake water from either a mesotrophic or a eutrophic reservoir (question 2).

Experimental design

Mesotrophic (Cross Reservoir)
- Control
- Low NO_3^- (2 mg/L) Grassland
- High NO_3^- (20 mg/L) Agriculture
- Low NH_4^+ (0.5 mg/L) Grassland
- High NH_4^+ (1 mg/L) Agriculture

Eutrophic (Perry Reservoir)
- Control
- Low NO_3^- (2 mg/L) Grassland
- High NO_3^- (20 mg/L) Agriculture
- Low NH_4^+ (0.5 mg/L) Grassland
- High NH_4^+ (1 mg/L) Agriculture

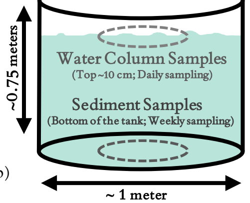




Water and sediment sampling

Chlorophyll-a (chl-a; primary producer biomass)
Microcystin (MC; toxicity measurement)
DNA (microbial community; 16S ILL)

Nutrients (ensuring a treatment affect)
TSS/AFDM
Sensor loggers (DO, light intensity, air temp)
Physiochemical (DO, pH, conductivity, water temp)



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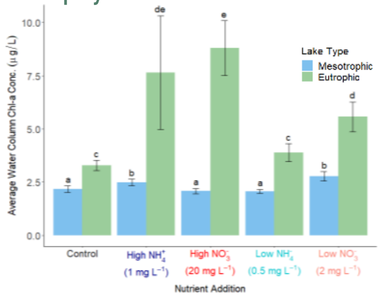
TAKE HOME MESSAGE

N stimulated biomass growth and proliferated a non-toxic bloom, more so in the lake with a high bloom history. Management strategies should be aimed at alleviating eutrophication by managing for excess N.

Results

Chlorophyll-a



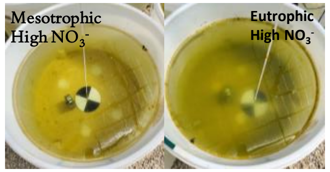


Fig. 1 Water column chl-a had a larger response in the eutrophic than in the mesotrophic (peak chla = 30±11.9 (mean±SD)).

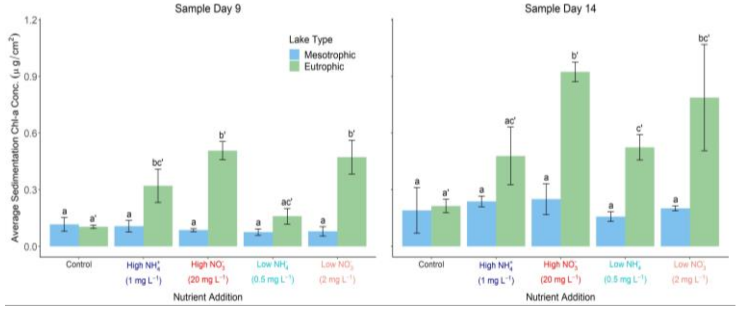


Fig. 2 Sediment chl-a had a larger response in the eutrophic than in the mesotrophic

Microcystin

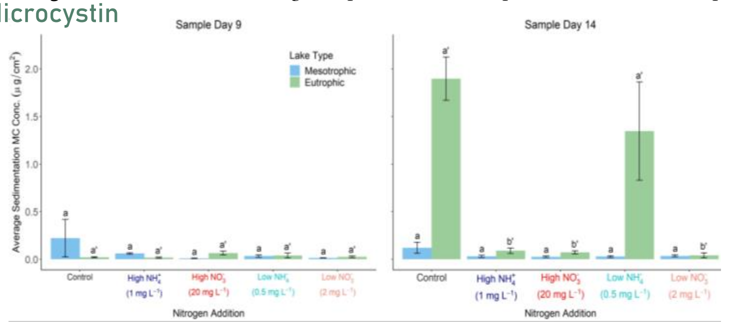


Fig. 3 Overall MC concentrations were low. 48/60 water column samples were below detection (0.15 µg/L). More MC in the sediment than in the water column.

Microbial Community

Fig. 4 In the water column, (A) lake communities are in separate clumps (p = 0.0001).

(B) the eutrophic lake moves across axis 1 ($p < 0.0001$), and the mesotrophic lake moves up axis 2 through time ($p < 0.0001$).

(C) eutrophic community shifts are driven by N additions. Mesotrophic shifts driven by time.

Sediment community data follow the same trends.

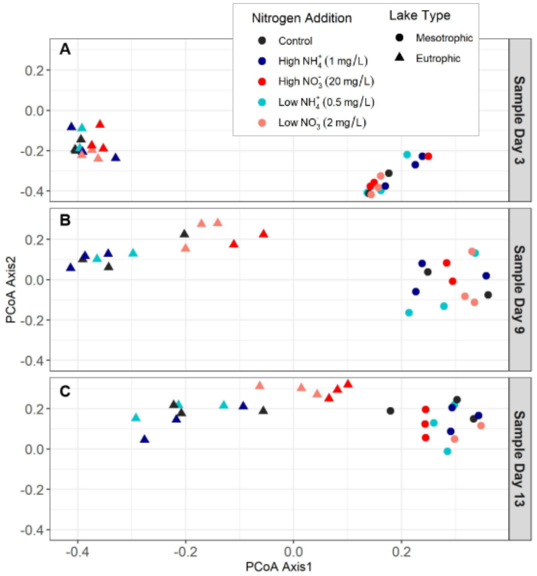
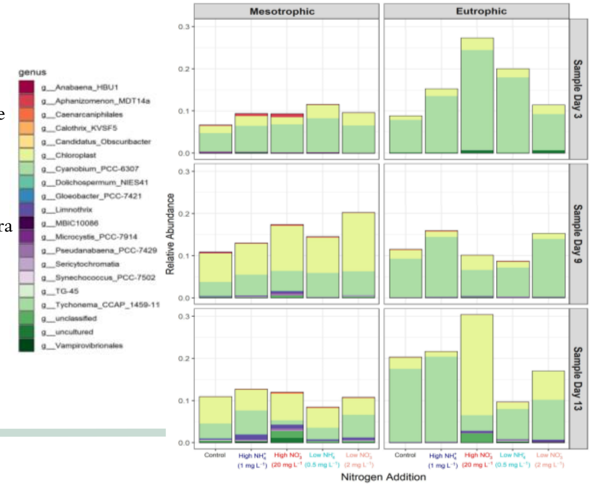


Fig. 5 The relative abundance of the Cyanobacteria Phylum is overall higher in the eutrophic lake than in the mesotrophic.

There are more chloroplasts relative to other cyanobacteria genera in the mesotrophic lake relative to the eutrophic. Chloroplasts are more indictive of a green algae bloom and not a green-algae bloom.



Discussion

Fig. 1 & 2 Primary production increased more in the eutrophic lake than in the mesotrophic under additional nitrate and ammonium. N stimulated biomass growth.
Fig. 3 Toxin production was low and unresponsive to N additions in both lakes.
Fig. 4 N additions drive the changes in microbial community in the eutrophic lake and time drives changes in the mesotrophic.
Fig. 5 Cyanobacteria was present in both lakes and had higher relative abundance in the eutrophic lake.

Our experiment showed that N stimulates non-toxic blooms with the threat of turning toxic suggesting that a eutrophic lake history could cultivate a microbial community with higher bloom propensity.