The Impacts of Seasonality and Nutrient Loading on *Microcystis* Bloom Development in Wall Pond

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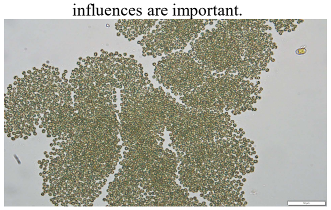
Abstract

The harmful cyanobacteria *Microcystis* globally dominates eutrophic freshwater systems. Eutrophication leading to nitrogen and phosphorus loading into aquatic systems is increasing bloom propagation and shifting diatom/dinoflagellate dominated systems to cyanobacteria dominated systems. Understanding seasonal variability and environmental parameters combined with nutrient loading will allow for better understanding of what factors are influencing *Microcystis* blooms. Biweekly plankton samples and environmental parameters were collected from Wall Pond from spring 2022-spring 2023. Results show that yearly plankton samples shifted from dinoflagellate dominated in the late summer early fall to *Microcystis* dominated in late fall early winter and then dinoflagellate dominated in late winter early spring. Dinoflagellate blooms occurred when N:P ratios were below Redfields and *Microcystis* blooms occurred when N:P ratios were above Redfields. Bioassay results showed dual limitation of nitrogen and phosphorus.

Introduction

The increase of harmful species is largely due to anthropogenic nutrient loading as well as climate warming (Jankowiak et al. 2019). *Microcystis* is a cosmopolitan, colony-forming, toxic cyanobacteria that dominates in eutrophic freshwater systems (Moisander et al., 2009) during the summer and fall months (Affan, et al., 2005). *Microcystis* bloom initiation usually coincides with high pH, high turbidity, low carbon, nitrogen and phosphorus input, and water temperatures above 20°C. *Microcystis* produces a hepatotoxin that impacts aquatic food webs, causes hypoxia, impedes drinking water, and impacts recreation and commercial water use (Leman et al., 2008, Ghaffar et al., 2017, Paerl et al., 2016, Shan et al., 2020, and Hark et al., 2016). Bloom initiation and toxin production vary widely in time and space therefore, studies determining bloom propagation influences are important.



The objective of this study is to determine how seasonal and nutrient variances impact *Microcystis* bloom development and alter phytoplankton assemblages on Coastal Carolina Universities campuses Wall Pond, South Carolina. Special attention was given to harmful cyanobacteria species.

Methodology

Wall Pond is an approximately 9,060 m^2 freshwater system centrally located on Coastal Carolina University campus in South Carolina. The pond is a shallow, closed man-made system with potential storm drainage. The blooms are most likely impacted by fertilizer input from adjacent lawns and biological waste products from the pond's resident turtle population.

Field: Plankton samples and environmental parameters were collected biweekly from spring 2022-spring 2023. Plankton samples were collected using a bucket and a 20µm plankton net. Temperature salinity, and dissolved oxygen were measured using a YSI probe.

Plankton Analysis: Plankton samples were analyzed based on relative abundance of harmful cyanobacteria species and other planktonic groups. Hemocytometer counts were conducted during large dinoflagellate blooms.

Nutrient Analysis: Nitrate + Nitrite and Phosphate concentrations were determined colorimetrically. Ammonium and chlorophyll concentrations were determined using a Turner Trilogy Fluorometer.

Bioassay: Bioassay experiments were preformed by incubating triplicate bottles in a Thermo Scientific Percision incubator set to ambient temperature and light cycle. Nitrate Additions were 25 µM of Nitate and Phosphate concentrations were 5 µM.

Results

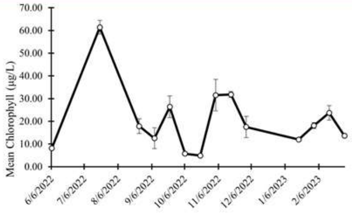


Figure 1: Mean Chlorophyll Concentration (µg/L) in Wall Pond, SC between 6/6/22 and 3/1/23. Error bars represent standard deviation.

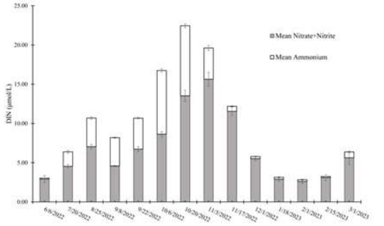


Figure 2: DIN (µmol/L) concentration in Wall Pond, SC between 6/6/22 and 3/1/23. Nitrate and Nitrate concentration is given in the grey bars. Ammonium concentration is given in the white bars. Error bars represent standard deviation.

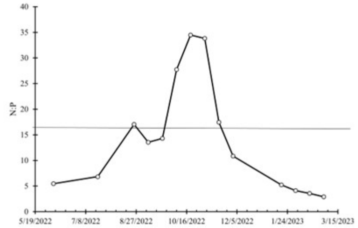


Figure 3: Nitrogen to phosphorus ratio in Wall Pond, SC between 6/6/22 and 3/1/23. The horizontal line indicates the Redfields N:P ratio of 16.

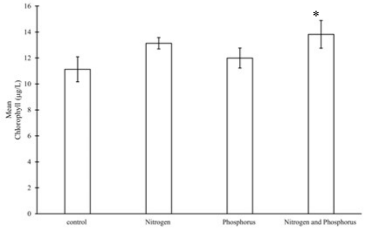


Figure 4: Chlorophyll (µg/L) concentration from a bioassay conducted on 3/1/23. Nitrogen and phosphorus dual treatment had significant difference in chlorophyll concentration. Significant differences are indicated by * (p<0.05, t-test). Error bars represent standard deviation.

Results

- A large bloom of *Microcystis* occurred from 10/6/22 to 12/1/22, peaking on 11/3/22.
- A large peridinium bloom occurred during the summer
- Chlorophyll concentrations were consistently above the eutrophication chlorophyll level of 20µg/L
- DIN concentrations increased during the 10/6/22 to 12/1/22 bloom event with peak DIN on 10/20/22
- N:P ratio was above the Redfield ratio during the Microcystis bloom and below 16 during the peridinium bloom
- Bioassay results showed plankton was dual limited by nitrogen and phosphorus

Discussion

Microcystis bloom events in Wall Pond started at the end of the fall into the beginning of winter. Based on chlorophyll concentrations, Wall Pond is a eutrophic system, becoming hyper eutrophic in the fall (Figure 1). Large bloom events of *Microcystis* as those experienced between 10/6/22 to 12/1/22 were correlated with an increase in chlorophyll, DIN concentration, and nitrogen to phosphorus ratios above Redfield's ratio (Figure 2 and Figure 3). *Microcystis* abundance declined as DIN and the N:P ratio decreased, and dinoflagellate abundance increased. Phytoplankton growth was significantly duel limited by nitrogen and phosphorus (Figure 4). Low limitation differences were present therefore, suggesting other factors might be impacting bloom propagation. Light limitation could be a significant factor limiting phytoplankton. Pollen streaks and an abundance of pollen particles were present during the 3/1/22 sample. Seasonal variation in nitrogen and phosphorus concentrations correlated with environmental conditions is controlling *Microcystis* concentrations in Wall Pond.

Acknowledgements and References

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Jankowiak, J., Hattenrath-Lehmann, T., Kramer, B. J., Ladds, M., Globler, C. J. 2019. Deciphering the effects of nitrogen, phosphorus, and temperature on cyanobacterial bloom intensification, diversity, and toxicity in western Lake Erie. *Limnology and Oceanography* 64: 1347-1370.

Moisander, P. H., Ochiai, M., Lincoff, A. 2009. Nutrient limitation of *Microcystis* aeruginosa in northern California Klamath River reservoirs. *Harmful Algae* 8: 889-897.

Affan, A., Jewel, A. S., Haque, M., Khan, S., Lee, J. 2005. Seasonal Cycle of Phytoplankton in Aquaculture Ponds in Bangladesh. *Algae* 20: 43-52.

Gaffar, S., Stevenson, R. J., Khan, Z. 2017. Effect of phosphorus stress on *Microcystis* aeruginosa growth and phosphorus uptake. *PLoS ONE* 12: e0174349.

Lehman, P. W., Boyer, G., Satchwell, M., Waller, S. 2008. The influence of environmental conditions on the seasonal variation of *Microcystis* cell density and microcystins concentration in San Francisco Estuary. *Hydrobiologia* 600: 187-204.

Paerl, H. W., Scott, J. T., McCarthy, M. J., Newell, S. E., Gardner, W. S., Havens, K. E., Hoffman, D. K., Wilhelm, S. W., Wurtsbaugh, W. A. 2016. It Take Two to Tango: When and Where Dual Nutrient (N & P) Reductions Are Needed to Protect Lakes and Downstream Ecosystems. *Environmental Science and Technology*: 10.1021/acs.est.6b02575

Shan, K., Wang, X., Yang, H., Zhou, B., Song, L., Shang, M. 2020. Use statistical machine learning to detect nutrient thresholds in *Microcystis* blooms and microcystin management. *Harmful Algae* 94: e101807.