How do multiple stressors influence riverine algal communities and toxin production?

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ABSTRACT

Harmful algal blooms (HABs) are increasing in prevalence and severity worldwide; however, there has been less research on algal communities and HABs in lotic compared to lentic ecosystems, and the interactions between multiple environmental stressors as drivers of community structure and cyanotoxin production are not well understood. In this study, we characterize community composition of algal assemblages in streams and rivers of the upper Ohio River basin and examine extracellular toxin release using Solid Phase Adsorption Toxin Tracking (SPATT) samplers. We examine relationships between algal communities, cyanotoxin release, and the interaction of multiple stressors such as nutrient concentrations, physical channel alterations, and temperature regimes. We anticipate that algal community composition will be dependent on algal traits related to physiological tolerance to environmental conditions, that cyanotoxin production will be greater where there is high biomass of toxin-producing genera, and that cyanotoxin release will be related to temperature-mediated oxidative stress. Our research will provide insight into the spatial and temporal dynamics of stream and river nutrient enrichment and will inform agencies about nutrient-reduction strategies.

BACKGROUND

- Harmful algal blooms (HABs) are a serious problem for ecosystem and public health.
- Less research has been conducted on algal communities and HABs in lotic compared to lentic ecosystems[1].
- Shifts in algal communities may affect ecosystem functioning, such as nutrient cycling and stream metabolism.
- Multiple environmental stressor interactions can heighten or lessen the effects of individual stressors on algal community composition and extracellular toxin release[2].
- How multiple environmental stressors drive algal community composition, cyanotoxin production and extracellular release are not well understood[3].
- Thresholds of environmental variables that promote cyanotoxin production and extracellular release are not clear.
- Extracellular toxin release has been studied less than intracellular toxin production[4].

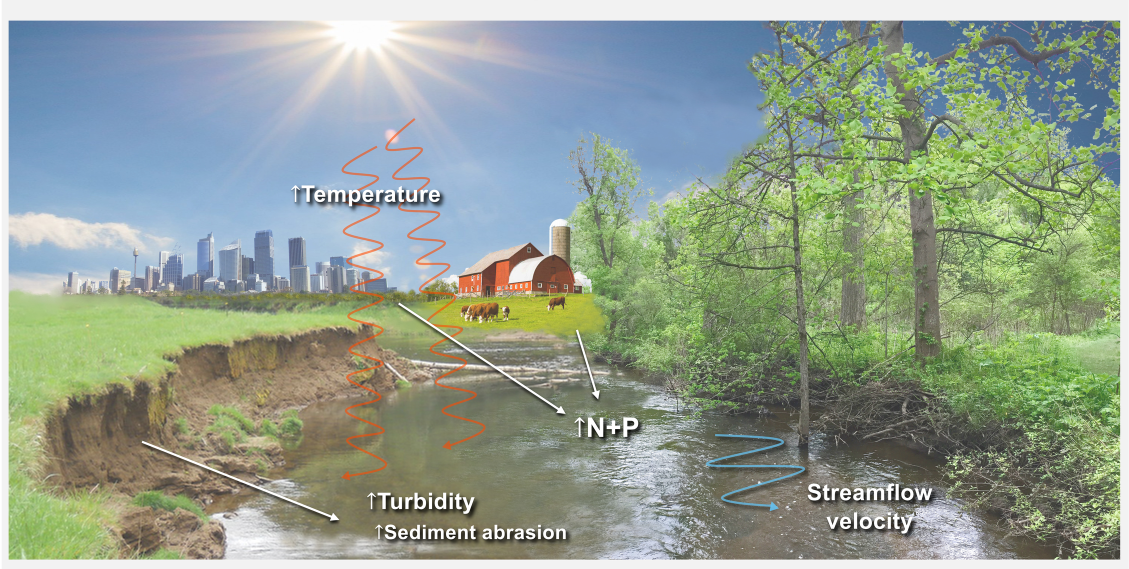

Figure 1. Environmental variables acting as potential stressors on phytoplankton and benthic algae in lotic ecosystems.

STUDY SITES

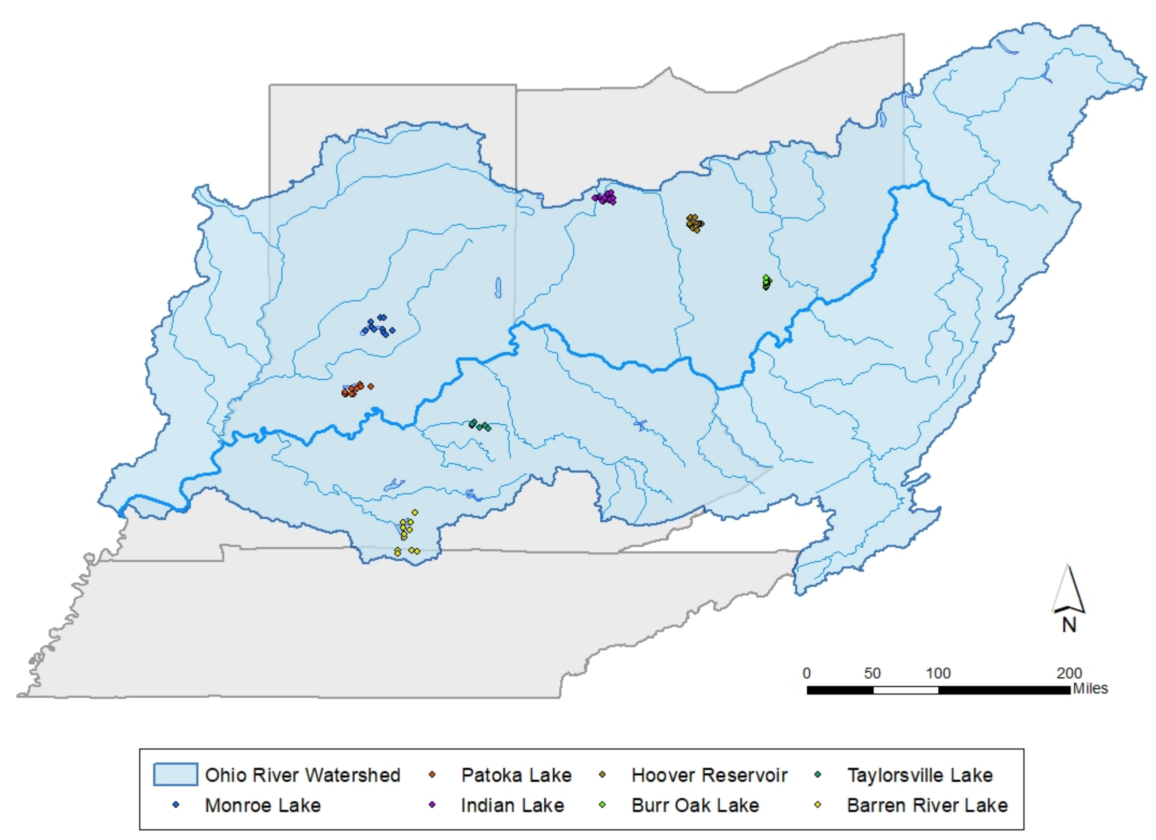

Figure 2. Study sites in Indiana, Ohio, Kentucky, and Tennessee within the upper Ohio River basin.

Figure 3. Sample sites at Patoka (left), Barren River (middle), and Hoover (right).

RESEARCH QUESTIONS AND OBJECTIVES

Field Study

How do algal community composition, toxin production, and extra-cellular release vary across lotic ecosystems in the upper Ohio River basin?

- Characterize benthic and planktonic algal communities (including potential toxin-producing genera) and their environmental drivers.

Does the interaction of multiple stressors, such as elevated nutrients, altered temperature regimes, and physical channel changes influence community composition and toxin production and release?

- Investigate the comparative effects of single vs. multiple stressors.
- Examine how physical channel alterations and physical habitat affect algal community composition.

Laboratory Study

What temperature and nutrient conditions stimulate algae to produce and release toxins?

- Determine the thresholds of temperature and nutrients needed for extracellular toxin release.

How does the interaction of elevated temperature and nutrient levels affect toxin production and release?

- Examine the effects of combined elevated temperature and nutrient levels on extracellular toxin release.

METHODS

Field Study

Water-quality parameters
- Measurement of dissolved oxygen, streamflow velocity, turbidity, and conductivity.
- Continuous temperature monitoring.

Nutrient analyses
- Quantification of TN, TP, nitrate, ammonium, and orthophosphate concentrations.

Solid Phase Adsorption Toxin Tracking (SPATT)
- Capture and determination of microcystin using LC-MS or ELISA.

Algal enumeration and pigment analyses
- Identification of algae to genus and species.
- Calculation of relative abundance of major taxonomic groups.
- Measurement of chlorophyll *a, b,* and *c*.

Stream geomorphology
- Measurement of bank erosion, discharge, scour and fill; longitudinal profiles and cross-sections.

Laboratory Study

- Culture of dominant toxin-producing genus.
- Manipulation of flow, nutrient concentrations, and temperatures at various levels.
- Determination of nutrient and temperature thresholds needed for toxin production.

Figure 4. A SPATT sampler being prepared for deployment to measure cyanotoxins in streams.

RESULTS TO DATE

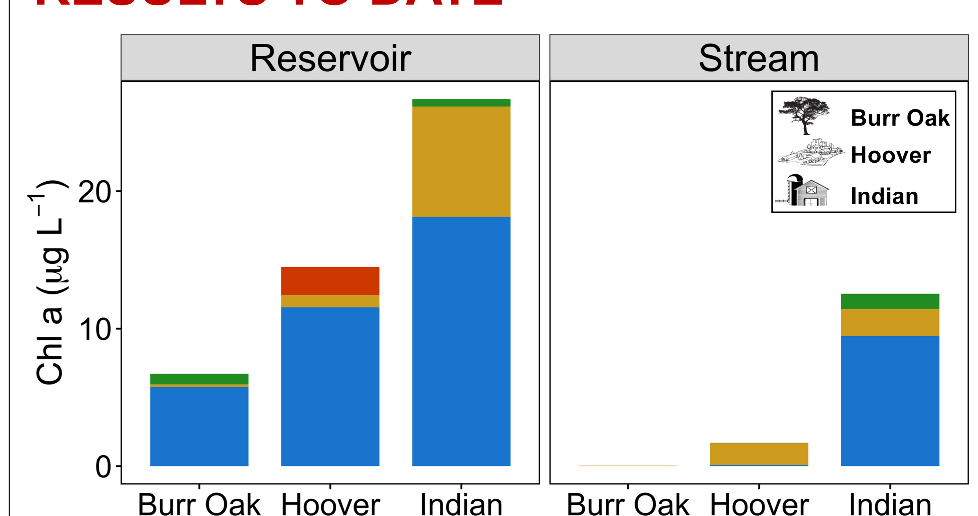

Figure 5. Preliminary results suggest that watershed ($F_{2,176}$ = 2.67, p = 0.071), ecosystem type ($F_{2,176}$ = 3.80, p = 0.052), and algal group ($F_{3,176}$ = 4.87, p < 0.01) may have effects on chl *a* of each taxonomic group. Interactions included in the model were not significant (p > 0.1).

EXPECTED RESULTS

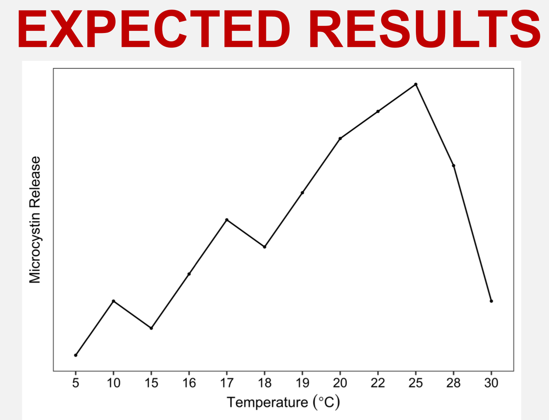

Figure 6. We expect microcystin production and release to increase with temperature, with highest values at 22-28°C (due to increased replication of toxic cells at high temperatures[5]).

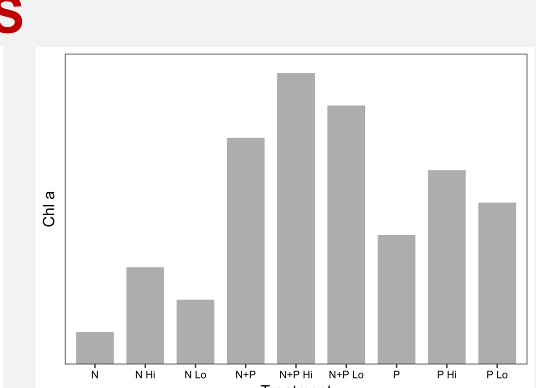

Figure 7. We expect algal biomass to be higher under elevated nutrient and temperature conditions (due to increased assimilation of N and P and optimal growth at the high temperature treatment).

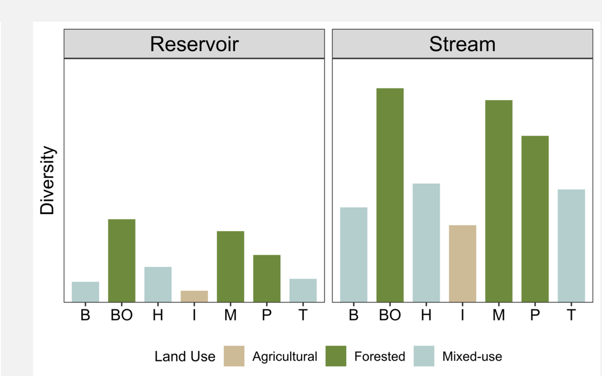

Figure 8. We expect reduced algal diversity in sites receiving run-off from agricultural or mixed-use catchments, and highest diversity in sites in forested catchments receiving less nutrient run-off (due to potential dominance by a low number of taxa in catchments with elevated nutrients).

SIGNIFICANCE

- The results of this research will contribute new information on the drivers of algal community composition and the link between community structure and ecosystem function.
- Our research will provide tools for algal bloom monitoring efforts that protect public health.
- We anticipate that this work will further understanding relative to how stream inputs of nutrients and algal cells contribute to algal assemblages that proliferate to cause HABs.
- Our research will assist local watershed groups and inform state and federal agencies about nutrient reduction strategies to protect water resources and ecosystem biodiversity.

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