Factors Critical to Long-term Lake and Reservoir Management: Relationships Between Land-use, Nutrient Loading, Inflows, HABs and Anoxia

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USACE Harmful Algal Bloom Research & Development Initiative

Delivering scalable freshwater HAB prevention, detection and management technologies through collaboration, partnership and cutting-edge science

Lakes in the southcentral USA are warm-monomictic systems, many of which have become eutrophic or hypereutrophic, raising concerns about harmful algal blooms (HABs) and hypoxia. HABs associated with prymnesiophytes and cyanobacteria have been recurrently problematic and the frequency, magnitude and duration of HABs are likely to increase with climate change. Here, we seek to better understand the drivers of inland HABs and hypoxia in the southcentral USA, with a particular focus on nitrogen loading. Recent advances in understanding have shown a selection for prymnesiophytes and some toxic cyanobacteria at high N:P. We are sampling twenty reservoirs and their tributaries, spanning a pronounced east-west annual precipitation gradient across Texas. Samplings occur in the spring and summer of each year, and measured parameters include chlorophyll-a, microcystins, inorganic and total nutrients, microbial community composition (using metagenomics), microbial functions (using metatranscriptomics), and several water quality parameters. Inflows and nutrient loadings are being determined using the Hydrologic and Water Quality System (HAWQS) calibrated with USGS gauge data, as well as tributary nutrient samples. Principal component analysis of data collected thus far reveal a positive relationship between NO3/NO2 and total microcystins, though this trend was heavily driven by an ongoing bloom in one lake. Excluding this lake from analysis, a strong relationship still exists between NO3/NO2 and total microcystins in the bottom waters of shallow stations (6 meters, standardized sampling), demonstrating the persistence of these toxins even when mixed to aphotic depths of the water column. Our ongoing work explores whether microcystins are widespread in tributaries to these lakes, as is the case in other regions of the country. We are comparing tributary microcystins to in-lake microcystins to assess the scale of cyanotoxin loading, and comparing land-use practices in the watersheds of these lakes with a focus on agricultural, industrial and municipal practices.

RELEVANCE AND OBJECTIVE: HABs and anoxia events are an ongoing problem in lakes and reservoirs of southcentral USA resulting in economic losses in the $10's millions to regional economies. Managing land-use and nutrient loadings in these watersheds, as well as managing in-lake chemical cycles, vertical mixing and hydrology, to prevent HAB incidence and curb anoxia events is likely far less costly. But development of such management schemes requires a better understanding of the form and functioning of these systems and their sensitivity to environmental factors. That essential knowledge will be discovered in this research. Here, our overarching objective is to advance understanding of how early season nutrient loading magnitude and stoichiometry, and hydraulic residence time in lakes and reservoirs with varied surrounding land-use practices influences HABs, anoxia and microbial functioning.

APPROACH: In this research, we are collecting tributary inflow records, measuring nutrient concentrations, and compiling reservoir volume and discharge data for 20 lakes and reservoirs spanning an east-west precipitation gradient across southcentral USA, which enables estimation of early season nutrient loadings and hydraulic residence times. From these lakes and reservoirs, we are determining in the early season and late summer: estimation of internal loading through sediment resuspension and vertical mixing of nutrient-rich, bottom-waters; total plankton community composition using metagenomics; a suite of water quality parameters that include temperature, conductivity, pH, turbidity, oxygen-reduction potential, and dissolved oxygen, and also cyanotoxins using immunoassays; estimation of important ecosystem functions using transcriptomics; and categorizing land-use practices in areas surrounding each of the lakes and reservoirs. We will quantify relationships between land-use practices, nutrient loading, hydraulic residence time, microbial and bacteriophage composition, HAB species prevalence and microbial functioning, and create quantitative models useful for management decisions accompanied by a user's manual so that non-technical personnel can apply the models.

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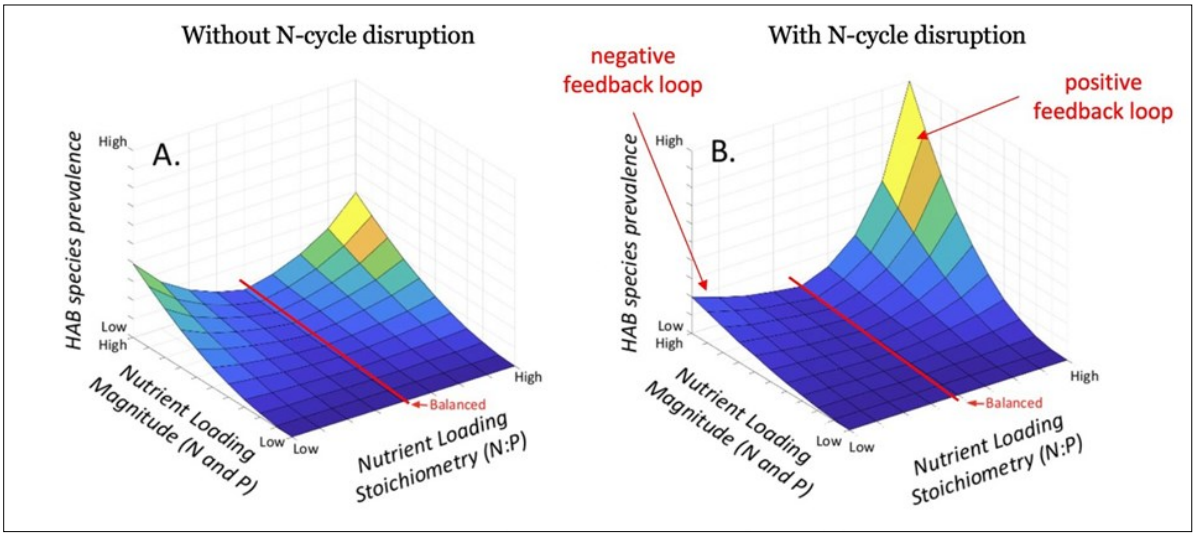

Figure 1: *Our hypothesized conceptual model shows a relationship between nutrient loading magnitude and stoichiometry (in regards to N:P), and the prevalence of HAB species [here, nutrient loading is the combined external and internal loading]. In panel A, a generalized relationship, HAB prevalence is increased at higher nutrient loading and also when loadings have imbalanced stoichiometries. In panel B, a condition where the nitrogen cycle is disrupted due to toxins produced by HABs (leading to the system accumulating N, thereby increasing N:P), the HAB species prevalence is reduced over time when nutrient loading has low N:P and exacerbated over time when nutrient loading has high N:P. Such three-dimensional surface plots can be used to guide within-lake management as well as guide watershed nutrient loading regulations.*

ASSESSMENT: With the exception of the sediment coring, field sampling and collection of samples has gone very well. The only times a station was sampled was because it was inaccessible due to low water levels in the target lake, which prevented launching of the boat. When this occurred, samples were taken by wading into the lake from the shoreline. Regarding, collection of sediment cores for follow-on laboratory experiments, this has proved challenging. The coring methods employed thus far have not been effective at collecting cores given the sediment types of these lakes and the depth of the water column over which the corers are deployed.

With the exception of the sediment coring experiments and the processing of sequenced samples, all samples have been processed and data analyzed in a timely manner. Analysis of this data, thus far, shows support for the primary hypothesis that a relationship between phycotoxins and nitrogen should exist. Regarding the sediment core experiments, these were not conducted yet because of the difficulties encountered collecting cores. Regarding the processing of sequenced samples, this occurred because of personnel issues we encountered that led to the departure of the postdoctoral researcher on the project. This resulted in all DNA extractions having to be redone, among other issues. We are in the search process for hiring another postdoctoral researcher.

The watershed modeling using HAWQS is well underway. A comparative analysis in all stream segments with USGS flow gauges is being performed to calibrate the HAWQS model. Once this is completed, we'll be able to use HAWQS to determine the total inflows into the lakes being studied here.