# 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.*

## Problem

Lakes in the southcentral US 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. We seek to better understand the drivers of inland HABs and hypoxia in the region, with a particular focus on nitrogen loading. Recent advancements in understanding have shown a selection for prymnesiophytes and some toxic cyanobacteria at high nitrogen-to-phosphorus ratio (N:P). We are sampling 20 reservoirs and their tributaries, spanning a pronounced east–west annual precipitation gradient across Texas. Samplings occur in the spring and summer 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 $NO_3/NO_2$ 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 $NO_3/NO_2$ and total microcystins in the bottom waters of shallow stations (6 m, 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.

## Objective

HABs and anoxia events are an ongoing problem in lakes and reservoirs of the southcentral US, resulting in economic losses in the tens of millions of dollars 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. Our 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

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 the southcentral US, 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 an 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

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## Approach (cont.)

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 nontechnical personnel can apply the models.

## Assessment

With the exception of the sediment coring, field sampling and collection have gone well. The only times a station was notsampled 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. Collection of sediment cores for laboratory experiments 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 sequenced sample processing, all samples have been processed and data analyzed. Analysis of this data, thus far, shows support for the primary hypothesis that a relationship between phycotoxins and nitrogen should exist. Sediment core experiments have not been 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 underway. A comparative analysis in all stream segments with USGS flow gauges is being performed to calibrate the HAWQS model. Once completed, we will be able to use HAWQS to determine the total inflows into the lakes being studied.

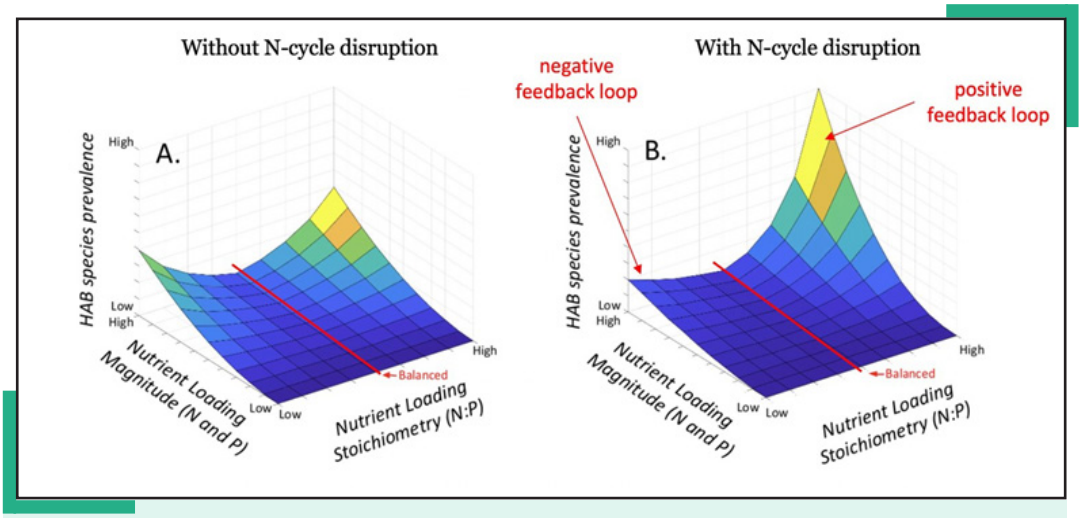


**Figure 1.** *Hypothesized conceptual model shows a relationship between nutrient loading magnitude and stoichiometry (in regards to N:P) and the prevalence of HAB species (here, nutrient loading is the combined external and internal loading): (A) without and (B) with N-cycle disruption.*

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## Major Milestones

| Deliverable | Description |
|---|---|
| Publications | **Tech Report:** Roelke and Labonté. 2023. "Factors Critical to Long-Term Lake and Reservoir Management: Relationships between Land-Use, Nutrient Loading, Inflows, HABs and Anoxia." Submitted Cumulative Quarter Report.<br><br>**Journal Article:** Kieley et al. In prep. "Microcystins Correlate with Nitrate and Nitrite in Warm-Monomictic Lakes of South-Central USA and May Disrupt Denitrification." *Science of the Total Environment*.<br><br>**Journal Article:** Roelke et al. Anticipated. "Biogeography of Toxic Cyanobacteria and Their Phages across Twenty Warm-Monomictic Lakes in Texas."<br><br>**Journal Article:** Klobusnik et al. Anticipated. "Viral Distribution and Lifestyles across a Range of Warm Monomictic Lakes."<br><br>**Journal Article:** Cagle et al. "Modeling Cyanobacteria Bloom Formation and Toxin Production." |
| Products | **Bioinformatic pipeline** to analyze and compare metagenomic and metatranscriptomic data (from quality control, assembly, gene calling, and annotations to genome assembly, phylogenomics, differential expression, and statistical analyses); initial pipeline was developed using Buffalo Springs Lake data sets.<br><br>**GUI-driven computational model** to show relationships between alter inflows, nutrient loadings, and user selected parameters such as HAB species, chlorophyll-a, dissolved oxygen, etc. |
| Tech Transfer & Demonstrations | GUI-driven computational model demonstration (anticipated). |