Predicting the Prevalence of Cyanobacteria in the Upper Mississippi River System

James Pack

September 5, 2020

1 Introduction

Aquatic ecosystems are composed of many different levels, from the large organisms such as fish to the micro-organisms like phytoplankton. Each level is important for the overall health and stability of the ecosystem. Phytoplankton are the foundation for many river ecosystems, and maintaining healthy phytoplankton communities is an important aspect of river management. One of the possible dangers is a low diversity community, which is compounded when the dominant specie(s) is less nutritious or even harmful for the larger organisms that rely on phytoplankton as a food source. Cyanobacteria are a genus of phytoplankton that can sometimes produce toxins as well as out-compete more nutritious phytoplankton species. A large bloom of cyanobacteria that dominates the community can have a strong negative effect on the ecosystem as a whole.

One issue in managing rivers to prevent these kinds of blooms is a lack of research. In the Upper Mississippi River (UMR), for example, very little research currently exists on the phytoplankton communities, with even less focusing on the impact of cyanobacteria and what might cause harmful blooms. Over the summer, I worked with the University of Wisconsin La-Crosse and the USGS to better understand the phytoplankton of the UMR using 181 samples collected by the USGS from 1996 to 2012 spanning from Minnesota to Missouri. This led to the creation of several models that helped to understand what can lead to a rise in cyanobacteria in the communities. These models helped connect the most important environmental factors to changes in phytoplankton genera, which can then be used to estimate future changes in the community.

2 The Problem

Finding out how cyanobacteria are impacted by their environment can reveal what conditions may lead to future blooms of the harmful cyanobacteria. By setting a matrix of these other factors multiplied by a vector of unknown constants $\bar{x}$ equal to the cyanobacteria relative abundance, future scenarios can be identified as potentially leading to cyanobacteria blooms.

3 Methodology

The data, cleaned in R and stored in a .csv file, was loaded into MATLAB and normalized as an A matrix (176 x 8) and b vector (176 x 1) for the environmental factors and relative cyanobacteria abundance, respectively. Both the A and b were normalized to account for the extreme values of some variables (e.g. 4151277 for Northing but 5.1 for dissolved oxygen levels). Finally, using LU Factorization, the coefficients of $\bar{x}$ were found.

4 Results

$$\bar{x} = \begin{bmatrix} -0.055734 \text{ (Dissolved Oxygen)} \\ 0.259284 \text{ (Silica)} \\ 0.191295 \text{ (Temperature)} \\ 0.470027 \text{ (Turbidity)} \\ -0.071356 \text{ (Nitrogen to Phosphorus Ratio)} \\ 0.195163 \text{ (Northing)} \\ 0.235770 \text{ (pH)} \\ -0.446547 \text{ (Suspended Solids)} \end{bmatrix}$$

These results show that Turbidity and Suspended Solids both have a significant impact on the prevalence of cyanobacteria in a phytoplankton community. Each increase in a standard deviation in Turbidity results in nearly a half a standard deviation increase in cyanobacteria abundance, while the opposite is true for Suspended Solids. An interesting result is the smaller coefficient for Temperature, as it has been widely believed that warmer climates will allow for greater abundance of cyanobacteria, but the data collected suggests this may not be as significant of a predictor for cyanobacteria as previously believed.