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Sediment Core Evidence of Historical Phosphate Mining and Harmful Algal Blooms in Banana Lake, Florida

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Abstract

While most monitoring programs successfully document eutrophication, the development of eutrophic characteristics often occurred prior to recent monitoring efforts. To reconstruct historic lake changes, paleolimnological techniques and the sediment record can provide data preceding monitoring programs. Here, we measured nutrients (C, N, P) and photosynthetic pigments in a sediment core collected from Banana Lake, a shallow (mean depth 1.2m) and hypereutrophic lake located in Polk County, Florida. In the case of Banana Lake, excess nutrients have allowed cyanobacteria to become the dominant primary producers utilizing lake nutrients and creating a positive feedback loop that intensifies eutrophication. By combining nutrient and pigment data, our results show that cyanobacteria existed in the lake long before monitoring efforts began in the system. Maximum P levels appear to be substantially higher than those of comparable lakes, likely caused by the lake's proximity to phosphate mines and the development of a viable meroplankton community. Additionally, toxins associated with cyanobacteria were found in large quantities in sediments spanning the last 30-40 years. An attempt to manage eutrophication was made in 1991 by removing approximately one million cubic yards of sediment through dredging. Despite these efforts, Banana Lake is still classified as an impaired water body with high sedimentary P, viable meroplanktonic cyanobacteria, and high microcystin concentrations; a fish consumption advisory is also in effect. Management efforts would benefit from coupling monitoring and management efforts with sediment analysis in shallow systems where internal nutrient loading could be the primary driver of persistent eutrophication.

Introduction

Alterations to land use and urban development around lake ecosystems can lead to the influx of nutrients and the formation of dense algal and cyanobacteria blooms, called cultural eutrophication. These blooms decrease ecosystem services by depleting oxygen and weakening biodiversity while also impacting human health through the production of toxins called cyanotoxins. While most monitoring programs successfully document eutrophication, the development of eutrophic characteristics often occurs decades prior to recent monitoring efforts. To reconstruct historic lake change, paleolimnological techniques applied to sediment cores can be used to provide data preceding monitoring programs. Our study applied these tools to a sediment core collected from Banana Lake; the lake currently exists in an urban setting and maintains a hypereutrophic state. The history of Banana Lake can be divided into three periods based on land management practices and levels of nutrients: an agricultural period, a quiescent period, and a phosphate mining period.

Beginning in the early 1820s, Creek Indian chief Oponay maintained a large plantation east of Lake Hancock that grew to encompass the area between Lake Hancock and Banana Lake. However, the plantation and the black and native settlements were destroyed during the Second Seminole War from 1835-1842. Banana Lake was left relatively undisturbed until the Southern Phosphate Corporation began mining phosphate on the west side of the lake around 1924. The historical trophic state of Banana Lake, as well as urbanization and land management practices, were investigated as possible causes for the lake's eutrophication. Eutrophication and the presence of toxin-producing cyanobacteria have led to the lake's fish consumption advisory and impaired status. While most monitoring programs successfully document eutrophication, the lake's eutrophic characteristics were present prior to recent monitoring efforts. As a result, the

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primary objective of our study was to determine when the hypereutrophic conditions began in time and to determine if one of the primary land use alterations triggered the decrease in lake health.

Methods

A sediment core was collected from the middle of Banana Lake and sectioned into 4-cm increments. Each section was freeze-dried and ground with a mortar and pestle. Ground sediments were analyzed for nutrients (carbon, nitrogen, phosphorus), photosynthetic pigments, and cyanotoxin, microcystin. Carbon and nitrogen content was determined through elemental combustion analysis, and phosphorus and other elements were determined through Inductively Coupled Plasma analysis. Pigments and microcystin were extracted and measured with High-Performance Liquid Chromatography and spectrophotometry, respectively. Photosynthetic pigment analysis measures a variety of chlorophylls and carotenoids capable of diagnosing total primary producer abundance, phytoplankton community structure, and cyanobacteria presence through time.

Fig. 1 Collection of a sediment core using a core barrel.

Conclusions

Cyanobacteria pigments occurred throughout the sediment core, indicating that Banana Lake has been hypereutrophic as far back as a few hundred years and encompassing the period during which human activities included the historic agricultural period. Surprisingly, the cyanobacteria community has remained dominant and constant despite multiple dramatic changes to nutrient inputs into the lake through time. Whereas the cyanobacteria community has remained dominant, phosphorus data emerged as the most interesting aspect of the lake's history. At approximately 52 cm in depth along the core, total phosphorus dramatically increased beyond levels previously observed in similar lake systems. Nearby Lake Apopka, a lake known for its problematic cyanobacteria community, contains sedimentary phosphorus concentrations around 2 mg/g while the most recent period of P concentrations in Banana Lake are around 30 mg/g. Phosphate mines are the most likely cause for such a large and dramatic shift, with the two mines that would become Stahl Lake and Little Banana Lake being established around 1924. The phosphorus concentration from 52-cm to 8-cm depth is so large that no amount of agricultural input from local orange groves could account for it. While a wastewater treatment plant began discharging effluent into Banana Lake at around the same time, it is unlikely to cause such an increase. Effluent standards became stricter over time, and there is no decreasing trend of phosphorus from 52 cm to 8 cm.

Management decisions have primarily been based on the last ten years of monitoring data. However, understanding the long-term drivers of eutrophication, rather than the endpoint, will better inform such efforts. Our data suggest that Banana Lake has experienced eutrophic events throughout its recent history linked to dynamic changes in lake management and surrounding landscapes. Pigments also show a community shift between species of cyanobacteria; however, this shift does not correlate with the extreme differences in phosphorus and other nutrients. In the presence of unprecedented phosphorus and fluctuating nutrients, the cyanobacterial community in Banana Lake appears relatively unaffected, suggesting a possible ecological threshold was achieved through minimal land use practices of the past. Microcystin, on the other hand, increases logarithmically in the top 32 cm of the sediment. Toxin increases combined with constant cyanobacteria and continued impairment status signal that the dredging of Banana Lake in 1991 was largely ineffective in controlling eutrophication. Attempts to stop or reverse eutrophication may be fruitless in the context of a naturally hypereutrophic lake near phosphate deposits.

Statement of Research Advisor

Susan's work has been extremely extensive in analyzing her sediment core from Banana Lake. Her results have demonstrated evidence of extreme impacts on urban lake systems with a particular focus on environmental analysis of phosphate mining in this area of Florida. In addition, Susan has performed an extensive investigation into historical documents to establish the timeline for changes in her data. This timeline resulted from Susan connecting with local stakeholders and historians in the area, which was above and beyond the expectations of the project. Finally, by coupling her phosphate mining impacts with Banana Lake being in a continual harmful algal bloom, Susan's work is beginning to establish ecological thresholds linking landscape processes with aquatic responses.

- Matthew Waters, Crop, Soil, and Environmental Sciences

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Authors Biography

Susan G. Iott is a senior-year student pursuing a B.S. degree in Environmental Science at Auburn University. As an undergraduate research fellow and student worker in the Auburn Paleoenvironmental Laboratory, she has contributed to research in eutrophication and cyanotoxin production in sub-tropical lakes.

Matthew N. Waters is an Associate Professor of Environmental Sciences at Auburn University, where he leads the Auburn Paleoenvironmental Laboratory. Trained as a classic limnologist and paleolimnologist, Dr. Waters and his students attempt to develop and apply geochemical analysis on sediment cores collected from natural lake systems to understand better the ecological dynamics of cyanobacteria and the triggers of cyanotoxin production. His studies focus on the SE USA and Mesoamerica.

Troy L. Clift is in the second year of his Crop, Soil, and Environmental Science master's program at Auburn University. Originally from Virginia, he attended Longwood University, where he was awarded a B.S. in Integrated Environmental Science. His research investigates the drivers of cyanotoxin production in sub-tropical lakes in central Florida, USA.