Relative species abundance of benthic diatoms across three oligotrophic lakes of varying nutrient composition

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Abstract

Trophic states can be useful indicators as to the health and composition of a system in particular reference to algal communities. Much is known regarding relationships between trophic states and algal productivity and distribution. This study focused on the impacts of nutrient levels on three oligotrophic lakes in Northern Lower Peninsula Michigan on benthic diatom communities. Diatoms were assessed for species richness, abundance, biodiversity, and similarity between community composition. While each we classified each lake as oligotrophic, nutrient levels varied within the classification boundaries. We found that Lancaster Lake had the highest nutrient levels (total phosphorus: 5.75 ug/l) and the highest biodiversity score (1.0208). Walloon Lake had median nutrient levels (total phosphorus: 3.99 ug/l) and the lowest biodiversity score (0.756). Wildwood had the lowest nutrient levels (total phosphorus: 1.98 ug/l) and the highest biodiversity score (1.00). Jaccard's Similarity Index revealed that across all lakes 20.00% of the community composition was shared. Values varied between each lake with the highest scoring relationships being between Wildwood and Lancaster (44.22%) as well as Wildwood and Walloon (44.22%) while the lowest scoring relationship was between Walloon and Lancaster (29.78%). *Navicula radiosa* and *Cymbella affinis* were the dominant species in all three locations. As harmful algal blooms (HAB) and eutrophication become more common it is important to understand how nutrient composition and other variables impact algal communities in systems that are not undergoing eutrophication. The monitoring and maintenance of these systems can prevent HABs from occurring.

Introduction

Extensive research has been conducted regarding the relationships between trophic states and algal communities (Sigee 2007). Benthic diatoms, in particular, are sensitive to changes in nutrient contents and have been used to assess water quality in both freshwater and marine environments (Desrosiers, Leflaive & Euline 2013). Playing an important role as primary producers in aquatic ecosystems, benthic diatoms also contribute to the stabilization of sediment. Algae are often considered keystone species with the capability of both stabilizing and completely derailing ecosystems (Sigee 2007). Harmful algal blooms (HAB) can be large contributors to the destabilization of an ecosystem but are most common in eutrophic systems. While HAB are rare in oligotrophic lakes, many oligotrophic lakes will begin the season with what could be considered blooms of diatoms that continue on into the season (Carey, Weathers, & Cottingham 2009; Sigee 2007). Changing nutrient levels can have severe impacts on aquatic communities, including decreases in biodiversity, but these changes are usually assessed on the level of changing trophic states (Barnett & Beisner 2007).

The differences between trophic states of aquatic ecosystems are based on many factors, such as total phosphorus, dissolved nitrogen (DIN), Chlorophyll a concentration, and volumes of planktonic algae (Bellinger & Sigee 2010). Lakes with lower ranging nutrient contents are classified as oligotrophic, followed by mesotrophic, eutrophic, and hypertrophic as nutrient levels increase. Often times the trophic state of a particular body of water can be indicated by the presence and abundance of a single species of algae. In a study conducted in Ireland it was found that 20% of the variance found in Cladocera and diatom communities was explained by changes in nutrients and Chlorophyll a concentrations (Chen, Dalton, & Taylor 2010).

This study focused on three priorly classified oligotrophic lakes in the northern region of Lower Peninsula Michigan. Biodiversity surveys were conducted on each lake in order to assess their similarity. While each lake was classified as oligotrophic, nutrient concentrations still varied considerably. This study sought to determine whether or not these differences in nutrient concentrations created differences in the three lakes with regards to: species richness, biodiversity, and community similarity. We predicted that within the parameters of a defined trophic state, variations in nutrient levels will reflect variations in benthic diatom community composition and distribution.

Methods

Protocol

Samples were collected from Lancaster Lake (45°37'17.1"N 84°42'28.5"W; Appendix A), Walloon Lake (45°15'42.6"N 84°56'04.2"W; Appendix B), and Wildwood Lake (45°14'13.2"N 84°33'30.7"W; Appendix C) consisting of three rocks from each site of roughly the same size bagged in a Whirl Pak with a small amount of the water from where the rocks were removed. Rocks were taken from along the shoreline at estimated similar depths. Using a knife each rock was scraped in its entirety and the scrapings were placed into a beaker containing the excess water collected in the Whirl Paks. Using hydrogen peroxide and a potassium dichromate catalyst, the organic matter was dissolved and the diatoms' siliceous cell walls were left behind. Samples were then decanted and rinsed every 12 hours over a period of four days. Two dry mounts were made from each sample location and were then mounted using naphrax. The 100x objective was used to count 250 diatoms per slide to reach a total of 500 diatoms counted per location. Diatoms that were too small to discern, broken, or in girdle (side) view were not counted.

For each location, an acid-washed bottle was used to take a water sample to be tested for pH, total phosphorus, total nitrogen, nitrate, and phosphate. pH was measured using a pH meter. Total phosphorus was measured using ICP-MS and recorded in ug/l. Total nitrogen was measured using AA3 and recorded in ug/l. Both nitrate and phosphate were measured using IC-MS and recorded as mg/l.

Data Analysis

Data from the counted diatoms were used to calculate the Shannon-Weiner biodiversity index, assess the species richness, and calculate relative abundance within each location's community. Jaccard's Similarity Index was used to assess the relatedness between lake to lake and across all three.

Results

Shannon-Wiener indices were fairly low and similar across all three lakes (Lancaster: 1.0208; Walloon: 0.7566; Wildwood: 1.0019; Table 1). Species richness was also similar across all three lakes (Lancaster: 33; Walloon: 32; Wildwood: 35; Table 1). Of the species surveyed *Navicula radiosa* accounted for 35.6% of Lancaster's community, 27.8% of Walloon's, and 31.1% of Wildwood's (Figure 1; Figure 2; Figure 3). *Cymbella affinis* accounted for only 5.8% of Lancaster's community but 46.6% of Walloon's, and 25.8% of Wildwood's (Figure 1; Figure 2; Figure 3). The Jaccard's Similarity Index concluded that between all three lakes the similarity in community composition was 20.00% related (Figure 4). Lancaster and Wildwood were 42.22% similar, Lancaster and Walloon 29.78%, and Wildwood and Walloon 42.22% (Figure 4).

Nutrient levels were within similar ranges for total phosphorus (1.98-5.75 ug/l) and indicated that all three lakes are oligotrophic (Table 2; Appendix D; Bellinger & Sigee 2010). However, total nitrogen ranges (151.50-379.26 ug/l) indicated that all three lakes were eutrophic (Table 2; Appendix D; Bellinger & Sigee 2010). Lancaster Lake's pH was just beyond circumneutral while Wildwood and Walloon Lake were slightly alkaline (Table 2).

Discussion

All three lakes were similar in biodiversity, species richness, pH, and nutrient content. However, the Jaccard's Similarity Index indicated that the lakes differed greatly in community composition. Lancaster, the lake with the highest biodiversity score (Table 1), also contained the highest levels of both total nitrogen and total phosphorus (Table 2). Walloon Lake had median nutrient levels (Table 2) but both the lowest biodiversity score and species richness (Table 1). Wildwood had the lowest nutrient levels of the three lakes but a median biodiversity score and the highest species richness (Table 2; Table 1). From these results, the relationship between the lakes and their ability to support communities are similar and we should expect to see similar results among other lakes within the same nutrient parameters. What species can be supported by these nutrient levels was not made clear in this study. Varying nutrient levels seemed to have a greater impact on species composition as opposed to species richness and biodiversity. The community composition of each lake was variable with different species being present and dominating. Across all three lakes, the similarity of species present was low (20.00%) and remained low between each pairing of lakes (Figure 4). The benthic diatoms of Lancaster Lake were dominated by *Navicula radiosa* while Walloon Lake was dominated by *Cymbella affinis* and Wildwood had almost equal proportions of both (Figure 1; Figure 2; Figure 3). *Navicula radiosa* is a symmetric biraphid diatom commonly found in Lakes States in circumneutral freshwater; Lancaster Lake had a pH of 7.98. *Cymbella affinis* is an asymmetric biraphid diatom also commonly found in Lakes States (Patrick & Reimer 1975).

Assessing all three lakes under the assumption of similarity rather than difference was based on the criteria of trophic state classification (Bellinger & Sigee 2010). Total phosphorus levels indicated that each lake was oligotrophic and trophic states were supported by previously recorded data. (Table 2; Tip of the Mitt Watershed Council, 2012). Differences among community composition between the three lakes may be explained by factors other than nutrient variations. Each lake was slightly alkaline but had varying pH values. Lancaster was near neutral (7.98) as opposed to Wildwood and Walloon which were more alkaline (8.15 & 8.47, respectively). Other variables that could have influenced these differences include substrate type, amount of light, and competition. It is also possible that community composition varied due to random causes, such as certain species being introduced to one area but not another by human influences, such as boating and fishing activity.

It is important to note that the total phosphorus levels and total nitrogen levels differed in their assessments of trophic state. In all three lakes total nitrogen indicated that the systems were eutrophic (Table 2; Appendix D) and the use of total phosphorus as the defining variable was based on the observable growth within each of the three lakes. However, while both nitrogen and phosphorus are important in assessing the trophic state of an aquatic ecosystem, Chlorophyll a content and biomass are much stronger indicators of trophic state (Bellinger & Sigee 2010). The constraints of this survey did not allow for these two variables to be measured and as such the assessments of the trophic states of Lancaster, Wildwood, and Walloon Lakes may differ from what was found in this study.

These results indicate that trophic states are a reliable predictor of the richness and biodiversity of benthic diatom species in shallow freshwater lakes. Predictions of algal communities can be used to predict the communities of other groups within the system as well as the system itself (Chen et.al 2010; Bellinger & Sigee 2007; Desrosiers et al 2010). Little is known within the field of phycology despite the major role that algae play in both aquatic and terrestrial systems. Much of the focus is often shifted towards harmful algal blooms while the use of algae as bio-indicators is far less researched. The frequency of eutrophication has increased within the past century and presented problems for ecosystems. Eutrophication can lead to reduced species diversity, high turbidity, and anoxic conditions as plant matter cannot properly decay (Ansari, Lanza, Rast, & Sarvajeet 2011). As eutrophication becomes an increasingly more common issue it is imperative that oligotrophic and mesotrophic systems are thoroughly monitored and maintained in order to avoid the crash of aquatic ecosystems.

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Figures and Tables

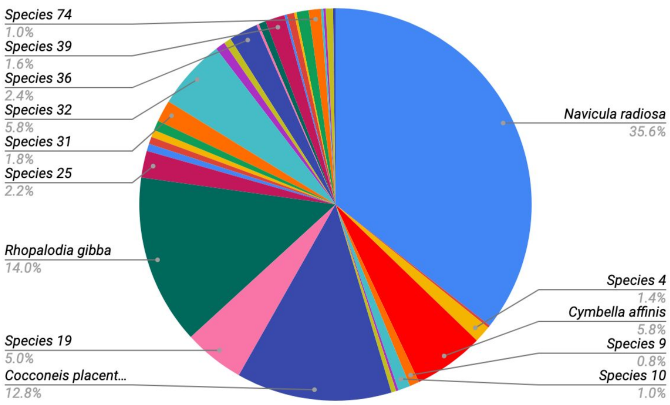


Figure 1. Percent distribution of species in a survey of 500 individuals for Lancaster Lake.

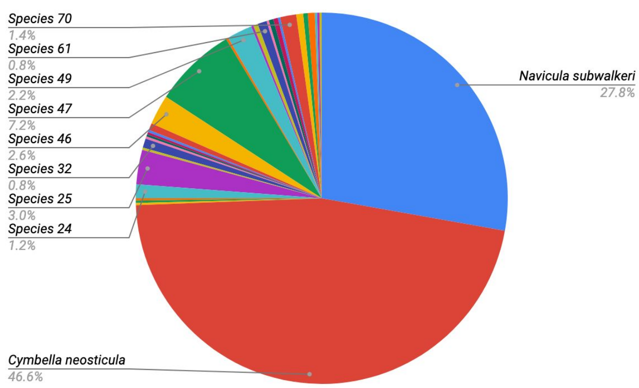


Figure 2. Percent distribution of species in a survey of 500 for Walloon Lake.

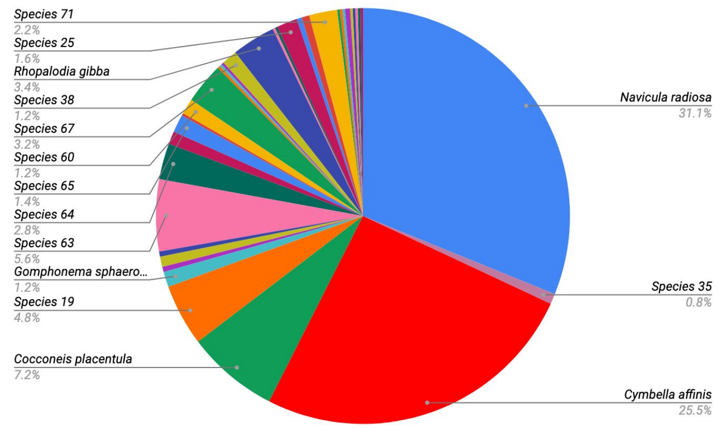


Figure 3. Percent distribution of species in a survey of 500 for Wildwood Lake.

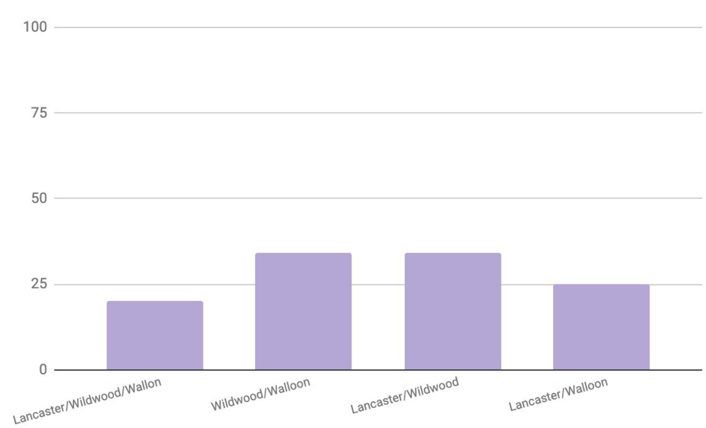


Figure 4. Percent relatedness using the Jaccard Similarity Index.

Table 1. Shannon-Weiner Biodiversity Index & Species Richness.

	Location		
	Lancaster	Walloon	Wildwood
Shannon-Weiner	1.0208	0.7566	1.0019
Species Richness	33	32	35

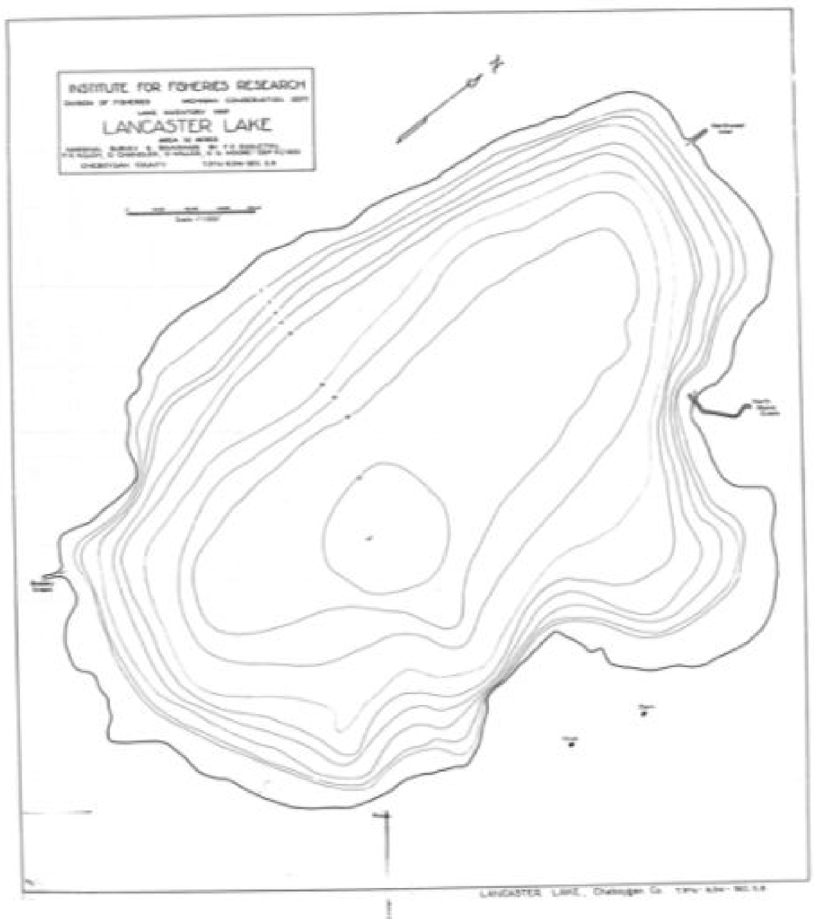
Table 2. Nutrient levels

	Location		
	Lancaster	Walloon	Wildwood
pH	7.98	8.15	8.47
Total P (ug/l)*	5.751946	3.990271	1.983067
Total N (ug/l)*	379.257	201.0209	151.4967
NO3 (mg/l)	0.0442	0.0087	0.1125
PO4 (mg/l)	0.0374	Below Detection	0.0371

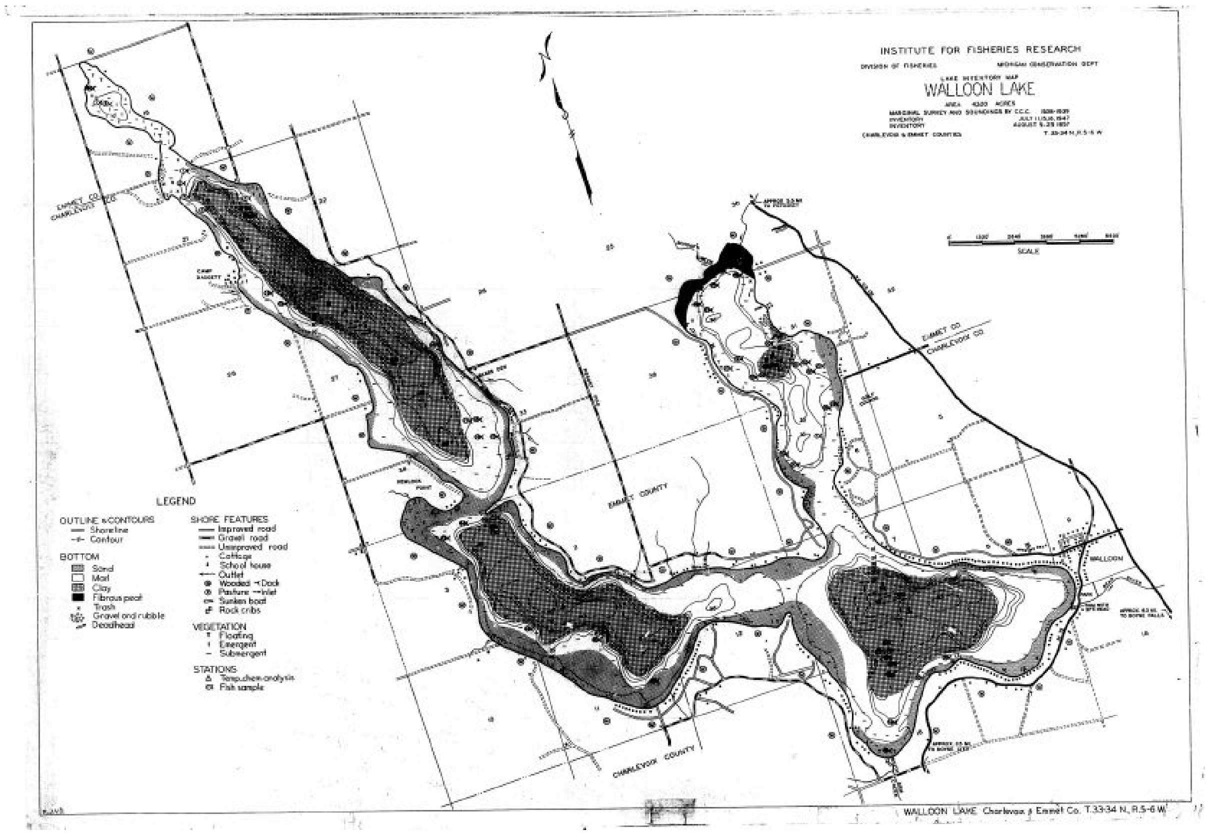
*Total phosphorus was the only variable considered in assessing the trophic state of each lake based on limited amounts of data and correspondence to pre-assessed trophic states for all three lakes.

Appendix

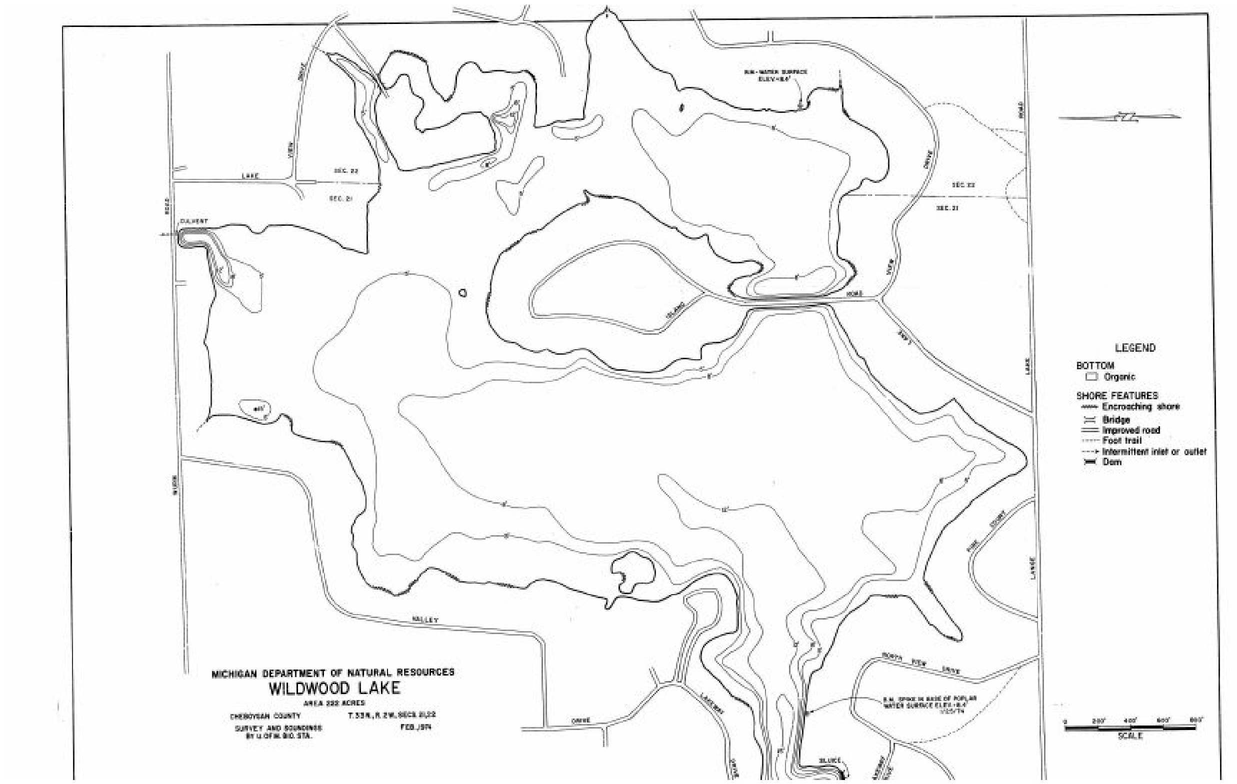
Appendix A. Bathymetric map of Lancaster Lake, retrieved from Michigan DNR.



Appendix B. Bathymetric map of Walloon Lake, retrieved from Michigan DNR.



Appendix C. Bathymetric map of Wildwood Lake, retrieved from Michigan DNR.



Appendix D. Trophic classification of temperate freshwater lakes, based on a fixed boundary system.

	Trophic Category			
	Oligotrophic	Mesotrophic	Eutrophic	Hypertrophic
Total P (ug/l)*	4-10	10-35	35-100	>100
DIN (dissolved N) (ug/l)*	<10	10-30	30-100	>100

Table adapted from Bellinger & Sigee 2010. The table excludes values that were not analyzed during this experiment (such as Chlorophyll a concentration). Boundary values are based on the OECD classification system (OECD 1982). It is standard to use mean amounts of nutrients to assess the trophic state of a body of water but for the purpose of this experiment mean values were not taken nor used.