New algal diversity records for the Lake of the Clouds, Porcupine Mountains Wilderness State Park, Michigan

Kevin Anderson[1], Mark Fate[2], Ching-Han (Eric) Hsieh[3], Lorenz Kim[4], and Katy Lazarus[3]

[1] Undergraduate student at the University of North Carolina at Chapel Hill
[2] Undergraduate student at the University of Michigan at Ann Arbor, Program in the Environment, MI, USA
[3] Undergraduate students at the University of Michigan at Ann Arbor, Dept. of Ecology and Evolutionary Biology, MI, USA
[4] Undergraduate student at the University of Michigan at Ann Arbor, College of Literature, Science and the Arts, MI, USA

Abstract: The Lake of the Clouds, located within the Porcupine Mountains and two miles away from Lake Superior, is a famous vista site of the Porcupine Mountains Wilderness State Park, Michigan. Even though several fishery surveys have been released by the Michigan Department of Natural Resources on the lake in the 1940s, no known algal studies have been conducted. The Porcupine Mountains Wilderness State Park has a relatively small level of anthropogenic disturbances compared to other regions around the Great Lakes, which makes the site appealing for algal studies. This paper reports the exploratory research done by the professors and students at the University of Michigan Biological Station on the algal diversity of the Lake of the Clouds. In this study, 7 algal divisions were observed. The inventory showed that, based on number of genera recorded, the green algae (Chlorophyta) is much more diverse than the other algal divisions in Lake of the Clouds. A significant number of diatom (Bacillariophyta) species were also observed, though omitted from this paper for future analysis and identification. A total of 88 genera (excluding Bacillariophyta genera) and 34 species were identified. This rich list of algal taxa is only the first step in exploring the algal diversity, microhabitats, and ecosystem of the Lake of the Clouds. The diversity of algae found in this study suggest that further algal research needs to be conducted on the Lake of the Clouds.

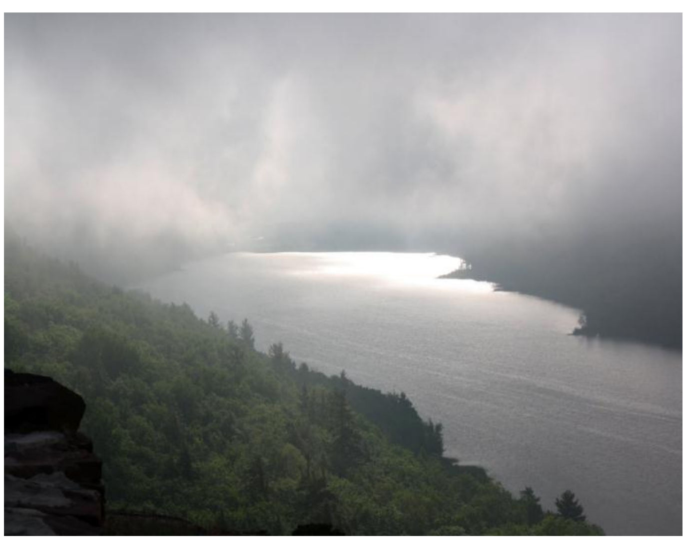
Introduction

The Porcupine Mountains contain one of North America's largest old growth stands of northern hardwood forests, stretching over 31,000 acres (Davis, 2008). The Porcupine Mountain range is on the southern edge of the Canadian Shield, a vast region of common geologic origin. The bedrock in and around the Porcupine Mountains is primarily Precambrian, making it over 3.5 billion years old (Ojakangas, 1982).

Porcupine Mountains Wilderness State park was established in 1945 and has experienced relatively little human disturbance. The first European contact was the fur trade in the 1700-1800s, which attracted settlers in small numbers, relative to subsequent waves of miners. Between 1845 and 1910, 45 copper mines operated on present day park land. Most mines went bankrupt or closed before the mid 1900s. The area is still extremely rich in copper ore, in part because the copper particles are particularly fine and difficult to mine (Courter, 1992). White pines (*Pinus strobis*) along the shore of Lake Superior were targeted by loggers for their ease of harvest and drew contact to the area in the early 1900s (Davis, 2008).

Lake of the Clouds is one of the four lakes in the Porcupine Mountains Wilderness State Park, is located in Section 22 of Township 51 North, Range 43 West, Ontonagon County of Michigan's Upper Peninsula (Taube, 1949), and is a part of the Carp River Valley. The lake is in a deep valley, approximately 330 metres above sea level with an escarpment rising an additional 120 meters overhead (Taube, 1949), with a surface area of 133 acres and a maximum depth of 12 feet (Moffett, 1940). Lake of the Clouds drains into Lake Superior to the north. The lake has high enough dissolved oxygen levels to support fish life at all depths, a circumneutral acidity, and a soft water composition at approximately 25 ppm dissolved salts (Moffett, 1940). Around two dozen species of aquatic plants occupy the littoral zone. The three-way sedge (*Dulichium arundinaceum*), spike rush (*Eleocharis* sp.), yellow water lily (*Nuphar* sp.), and a pond weed (*Potamogeton Angustifolius*) are the most prevalent macroflora species. Perch, smallmouth bass, and brook trout represent the major fish biota of the lake (Moffett, 1940).

No known previous effort to catalog the algal diversity of Lake of the Clouds has been undertaken. Due to its unknown algal ecology and relatively short history of human interaction, Lake of the Clouds presents an ideal environment for conducting a survey of algal diversity.



Lake of the Clouds, Porcupine Mountain Wilderness State Park, MI, U.S.A.

Materials and Methods

On July 9, 2012, a survey of the algal diversity in the Lake of the Clouds was conducted. A large variety of microhabitats were sampled. These microhabitats included: epiphytic, epipelic, epilithic, deep benthic, and planktonic microhabitats.

Collection Sites

A total of five collection sites were chosen for this study. Four of them were located across a ~1290 meter transect along the southern shore of Lake of the Clouds. The fifth site was sampled at the bridge over the outflow of the lake (Carp River Outflow). The five sites were chosen taking into consideration vegetative density, water current, sunlight intensity, and substrate availability. Spacing out our collection sites w as necessary for gaining a fairer representation of the entire lake.

Sampling Process for Epiphyton

Each sample of epiphyton (algae attaching to aquatic vegetations) was collected by squeezing liquid out of aquatic plants into 100 mL whirl packs. A small sample of each plant was also collected in the same whirl pack.

Sampling Process for Epipelon

Each sample of epipelon (algae growing on fine sediment in the littoral zone) was collected from the first few millimeters of the sediment with a turkey baster and stored in a 100 mL whirl pack.

Sampling Process for Plankton

Each sample of plankton (algae drifting in the water column) was collected with a size 25 plankton net with 64 micrometer mesh openings. Planktonic samples were stored in 100 mL whirl packs.

Sampling Process for Deep Benthos, Epidendron and Epilithon

Each sample of epilithon (algae attaching to rock), epidendron (algae attaching to wood) and deep benthos (algae living in the sediment surface of the lake) was collected from sites 2 - 3 meters below lake surface. For sampling the epilithon and epidendron, a pocket knife was used to scrape off specimens. A snorkel, set of diving goggles, and turkey baster were used for diving into the lake and collecting all samples from the three algal habitats above.

Sampling Process for Water Temperature and pH

At each site, temperature and pH were measured and recorded. A Fisher Scientific Accumet portable meter was used to measure both the pH and the temperature. Water samples were kept in 250 mL and 1 L plastic nalgene bottles.

Documentation of Samples

At each sample collection site, water depth, description of algal substrate, method of collection, vegetation density, and site location were noted in waterproof notebooks.

Whirl packs of each sample were labeled with date, collector’s initials, sample number and sample’s microhabitat.

Preservation of Samples

All samples were brought back to the lab on ice for analysis and stored in a refrigerator. Approximately 5 mL of several rich samples were preserved with glutaraldehyde so that the soft algae could be later identified.

Samples Analysis

The samples were examined with microscopy using microscope slides, pipettes, cover glasses, and an American Optical Spencer light microscope. Genera and species were documented by site number and habitat, and some photomicrographs were taken to document taxa.

To identify the algal taxa in the samples, the texts listed below were used: *How to Know the Freshwater Algae* (Prescott, 1978), *British Desmidiaceae* (West, 1923), *Algae of the Western Great Lakes Area* (Prescott 1962), *A Synopsis of North American Desmids* (Prescott, Croasdale, Vinyard, Bicudo 1983), *Freshwater Algae of the Southeastern United States* (Dillard, 1993), *Freshwater Algae of North America* (Wehr, Sheath 2003), *Freshwater Algae: Their Microscopic World Explored* (Canter-Lund, Lund 1995) and *Cyanoprokaryota* (Komarek, Anagnostidis 2000).

Genera and species were identified and recorded on a master list. Photomicrographs of specimens were taken with the cellSens entry program and the Olympus BX51 microscope.

Additional sub samples were allocated for making microscope slides for diatoms (Bacillariophyta). These samples were sent to Boulder, Colorado for cleaning and permanent slide preparation. With the organic material cleaned out, the remaining silica wall morphology of the diatoms could be analyzed.

Results

The Lake of the Clouds had a wide variety of algae. A total of 7 divisions and 88 total genera from the 5 collection points along the lake's southern shore were identified. As shown in Figure I, the most prolific division found within the lake was the Chlorophytes, with 46 genera. 18 Cyanophyte genera, 11 Bacillariophyte genera (prior to cleaning), 4 Euglenophyte genera, 4 Pyrrophyte genera, 3 Chrysophyte genera, and 2 Xanthophyte genera were identified.

Division Chlorophyta

Based on Table I, Chlorophyta had the most orders of any division with 12 orders identified in our survey. Ranked based on the number of genera identified, the orders in Chlorophyta found were: 16 genera of Desmidiales; 8 genera of Sphaeropleales; 5 genera of Zygnematales; 4 genera of Chlorococcales; 2 genera each of Volvocales, Oedogoniales, Coleochaetales, Chlorellales, and Chaetophorales; and 1 genus each of Chlamydomonadales, Glaucocystales, and Ulotrichales.

Division Cyanophyta

Based on Table I, Cyanophyta had the second most orders of any division. Ranked based on number of genera identified, the orders in Cyanophyta found were: 8 genera of Nostocales; 4 genera of Chroococcales; 3 genera of Synechococcales; 2 genera of Oscillatoriales; and 1 genus of Pseudanabaenales.

Division Euglenophyta

Based on Table I, the only Euglenophyte order observed was: 4 genera of Euglenales.

Division Pyrrophyta

Based on Table I, the three Pyrrophyte orders observed were: 2 genera of Phytodiniales and 1 genus each of Gonyaulacales and Peridiniales.

Division Chrysophyta

Based on Table I, the two Chrysophyte orders observed were: 2 genera of Chromulinales and 1 genus of Hibberdiales.

Division Xanthophyta

Based on Table I, the two Xanthophyte orders observed were: 1 genus each of Mischococcales and Trebouxiales.

Most abundant genera

Based on Table I, *Microcystis, Staurastrum, Mougeotia,* and *Desmidium* were the only four genera found in all five collection sites. Of those, *Microcystis* and *Mougeotia* were found in several different microhabitats in each site. 11 genera were found in 4 of the 5 collection sites: *Fragilaria, Tabellaria, Bulbochaete, Closterium, Cosmarium, Hyalotheca, Pediastrum, Pleurotaenium, Zygnema, Gloeotrichia, Oscillatoria*. Of those, *Fragilaria, Tabellaria, Closterium, Cosmarium, Hyalotheca, Pediastrum,* and *Zygnema* were found in many different microhabitats.

Microhabitats

Based on Figure I, epiphyton has the greater number of genera (68 genera) found than any other microhabitat. Metaphyton also has a high number of genera found (38 genera). Over all, 22 genera were found as benthos, 21 genera were found as epipelon, 18 genera were found as plankton, and 15 genera were found as epidendron.

Based on Figure I, Chlorophyta was the most abundant division across all microhabitats. Cyanophyta was the second most abundant division across most microhabitats. All recorded divisions were found as epiphytes. All divisions except for Euglenophyta and Pyrrophyta were found as metaphytes. All divisions except for Xanthophyta were found as plankton. Only Chlorophyta, Cyanophyta and Euglenophyta were found as epipelon.

Water Chemistry

Water samples were taken to determine the chemistry of the lake. The lake has a moderate water temperature (23 Celsius) and a circumneutral pH (7.7).

Discussion

Lake of the Clouds Water Profile

Circumneutral pH often coincides with high algal diversity. According to the research results, Lake of the Clouds satisfied this correlation. Its moderate temperature is also a probable cause of the wide range of genera we observed within Chlorophyta in Lake of the Clouds (Sibaja-Corder and Cortes, 2010).

Chlorophyta and the Aquatic Ecosystem of the Lake of the Clouds

Based on the number of observed genera, Desmidiales was the most abundant order within Chlorophyta found in the Lake of the Clouds. Desmids can indicate good water quality because they do not prefer anthropogenically disturbed or extremely eutrophic bodies of water (Ngearnpat and Peerapornpisal, 2007). Most of the samples we collected were from the eulittoral zone, the relatively shallow portions of the lake. This study suggests that the Lake of the Clouds has a soft water quality because an abundance of desmids in the eulittoral zone can indicate a calcium poor water body (Stevenson, Bothwell, and Lowe, 1996). The lake’s geology is a potential cause of its lack of calcium.

The Lake of the Clouds bedrock is part of the Canadian Shield which contributes monovalent cations instead of divalent cations to water bodies. A higher divalent cation concentration would lead to harder water, reduce desmid occurrence, and increase the prevalence of cyanobacteria (Molot 2008).

Based on the number of genera, Chlorophyta was the most abundant algal division in the Lake of the Clouds. The abundance of Chlorophyta matches the soft water chemistry of the lake as soft water lakes often have algal distributions characterized by *Mougeotia* and other filaments, *Cosmarium*, and *Staurastrum* (Stevenson, Bothwell, Lowe, 1996).

Cyanophyta and the Aquatic Ecosystem of the Lake of the Clouds

Based on the number of genera, Cyanophyta was the second most abundant algal division in the Lake of the Clouds. A few genera of Cyanophyta such as *Microcystis* and *Anabaena* produce toxic metabolites that can be hazardous to the ecosystem (Burgess, 2001). While the research found some Cyanophyta, these taxa were only observed in relatively small amounts. Other observed indicator taxa like desmids (which prefer soft water and a lower calcium level) and members of the Zygnemataceae (which also dominate the littoral zone of soft water lakes) were more common than Cyanophyta (Stevenson, Bothwell, Lowe, 1996).

Comparing Algal Taxa between Lake of the Clouds and Other Lakes in the Midwest

Unlike the Lake of the Clouds, *Bambusina* and *Desmidium* were not observed in great number in Michigan lakes such as: Wycamp Lake, Lark's Lake, Paradise Lake, Monro Lake, Lancaster Lake, Walloon Lake, Burt Lake, Long Lake, or Douglas Lake (Warren, 1995). *Scenedesmus, Oscillatoria*, and *Anabaena*, which were abundant in Douglas Lake (Gulley and Kennedy, 1987), were not found in the Lake of the Clouds in large numbers. Similarly, *Anabaena*, *Oscillatoria*, and *Schizothrix*, which were abundant in Northern Lower Michigan groundwater springs and seeps (Smith, 1995) were not common in Lake of the Clouds.

Sources of Errors and Future Study

A few possible error sources should be addressed and considered for future investigations. A more comprehensive flora survey could have been documented with more diversity in collection sites. For instance, the northern shoreline of the lake and the inflow have not yet been investigated for algal flora. Considering that the inflow is a transition point from a river to lake ecosystem, unique algae may be present due to changes in both biotic and abiotic conditions. Additionally, it may be interesting to compare inflow taxa data with the outflow data. Collecting near the landslide on the northern shoreline could show what impact this particular disturbance has on the flora, and the area could be a unique habitat for algae.

The abundance and distribution of algal species will vary seasonally in the lake. This is partly due to the availability of various nutrients, such as nitrogen and phosphorus, which are necessary in different quantities for different taxa. The abundance of a nutrient might benefit one alga more than another, conferring a competitive advantage. For example, an aquatic system low in nitrogen greatly limits the ability of green algae (Chlorophytes) to photosynthesize and thus grow and reproduce, but does not affect some blue-green algae (Cyanophytes) since they have the ability to fix their own nitrogen via use of a heterocyte (Canter-Lund, Lund, 1995). Sampling at various times throughout the season would increase the likelihood of finding more types of algae, leading to a more complete floral record and understanding of the algal ecology in the lake.

Conclusion

Since no previous studies of algal flora have been conducted in the Lake of the Clouds, the location was suitable for a biodiversity survey. In this research, the Green Algae (Chlorophyta) were the most abundant and diverse in genera. The presence of several Chlorophyta taxa indicated that the Lake of the Clouds has a soft water body and relatively low levels of pollutants. In summary, 7 algal divisions and 88 genera were observed. Several genera such as *Staurastrum*, *Mougeotia*, *Desmidium*, and *Microcystis* were widely dispersed in various microhabitats.

The research results showed that the Lake of the Clouds is a clean water body and a relatively rich algal community. Our records of rich algal taxa matches the lake's historical records of relatively few anthropogenic activities on the Porcupine Mountains Wilderness State Park. Because this study is not exhaustive, we recommend further algal diversity research on Lake of the Clouds.

Acknowledgements

We would first like to acknowledge and thank our two Phycology Professors, Dr. Rex Lowe from the University of Wisconsin and Dr. Patrick Kociolek from the University of Colorado, for the countless hours they have spent on teaching, mentoring, advising, and inspiring this research project and the student team that conducted this project.

We additionally recognize the assistance of Tyler Elias and Michael Grant who conducted water chemistry tests for this study. We would also like to acknowledge Katie Kavulic, graduate student from University of Colorado at Boulder, for sampling the water chemistry of the Lake of the Clouds, collecting pH and GPS measurements, and accompanying us on the trip. We would also like to acknowledge Carla Kociolek for photographing the study site and the research team. We would also like to thank Bob Anderson whom we met at the study site for his assistance. We would like to thank the University of Michigan Biological Station and all of its faculty who have supported us with the study. This includes, but is not limited to, Sherry Webster, the stock room manager and Karie Slavik, the Associate Director of the Station.

Appendix

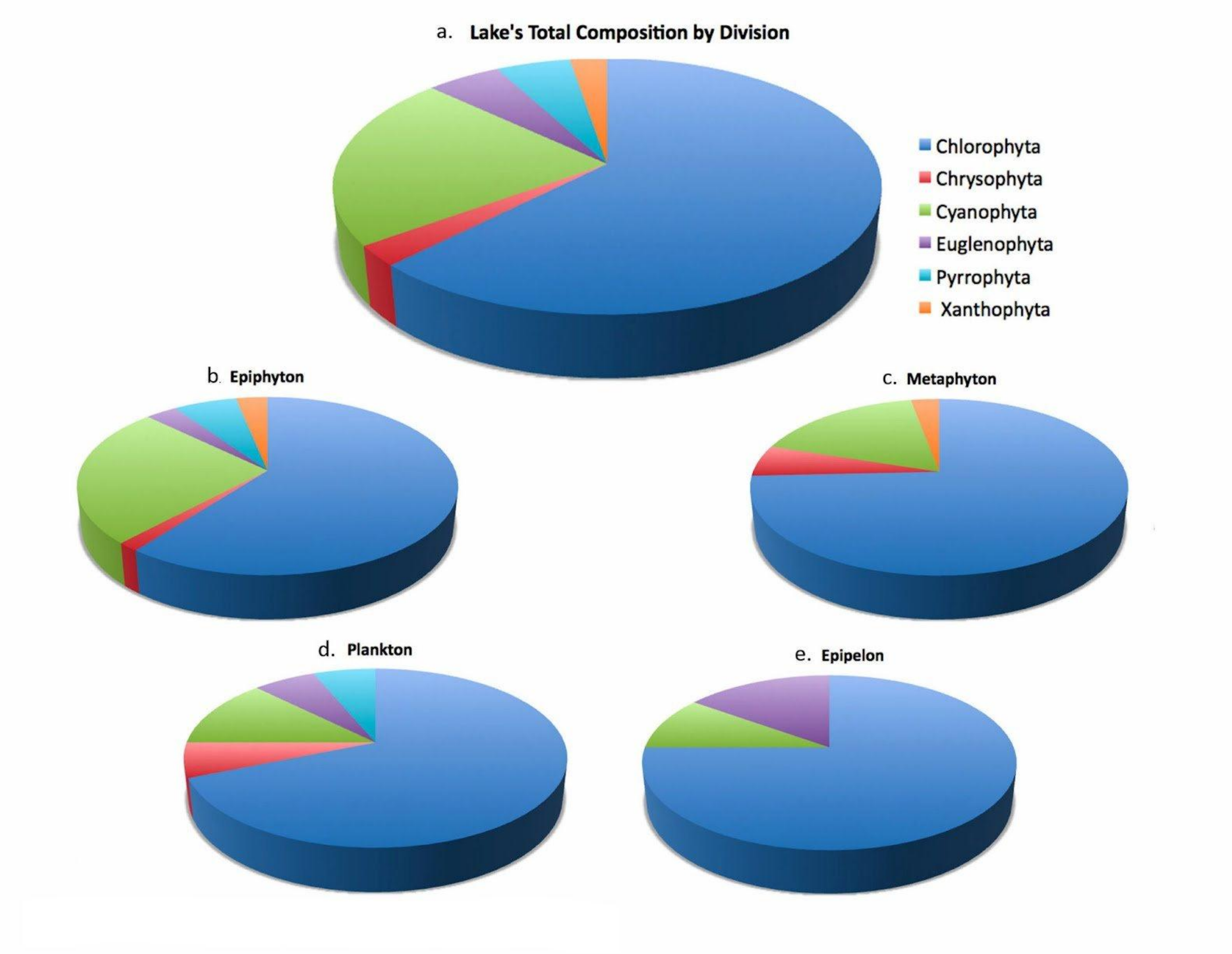


Figure 1. b-e microhabitat composition by division. Wedge size represents number of recorded genera.

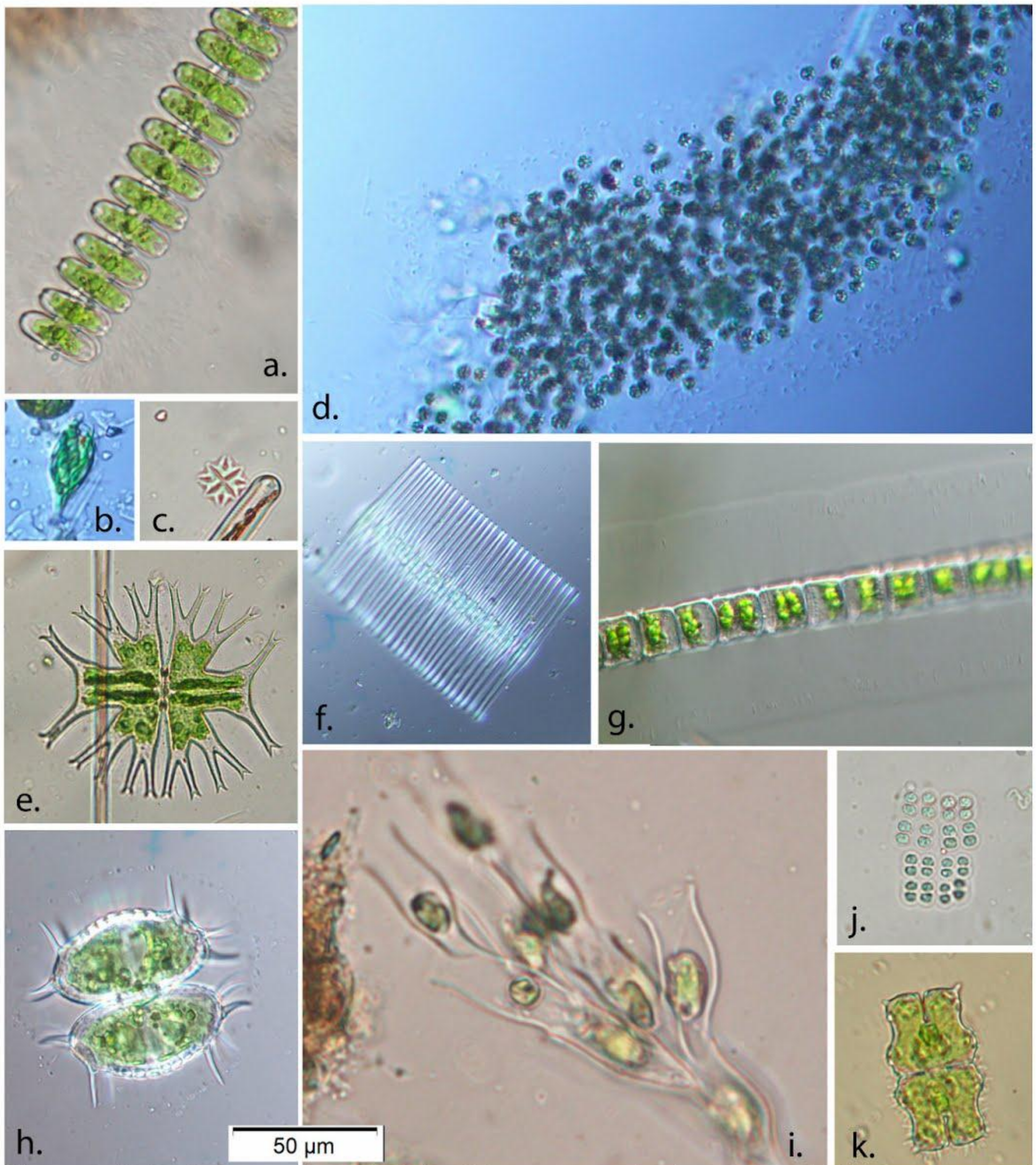


Figure 2. Light microscopy photos (200x) a. *Sphaerozosma aubertianum var. archerii* b. *Lepocinclis acuta* c. *Pediastrum tetras* d. *Microcystis aerugianosa* e. *Micrasterias radiata* f. *Fragilaria crotonensis* g. *Hyalotheca mucosa* h. *Xanthidium brebissonii* i. *Dinobryon cylindricum* j. *Merismopedia glauca* k. *Euastrum insulare*

Table 1: List of identified taxa. Columns 4-8 show the microhabitats in which the genera were found in each site (phy – epiphytic, meta – metaphytic, pla - planktonic, ben - benthic, pel - epipelic, den - epidendric). It is sorted by alphabetically by division, then family, then genus. In situations where several species were present but only some were identified, both the genus and the identified species are listed. "X" represents an identification but the microhabitat is unknown.

Taxon	**Division**	**Order**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Aulacoseira	Bacillariophyta	Aulacoseirales	phy	ben	ben		
Nitzschia	Bacillariophyta	Bacillariales		ben			
Gomphonema	Bacillariophyta	Cymbellales	phy	ben			
Fragilaria	Bacillariophyta	Fragilariales	pla, phy	pla,ben	pla	pla,meta	
Fragilaria crotonensis	Bacillariophyta	Fragilariales	phy				
Meridion	Bacillariophyta	Fragilariales			phy,den		
Navicula	Bacillariophyta	Fragilariales		ben			
Gyrosigma	Bacillariophyta	Naviculales		ben	ben	ben	
Pinnularia	Bacillariophyta	Naviculales			ben		
Asterionella	Bacillariophyta	Pennales	meta	pla	pel, pla		
Asterionella formosa	Bacillariophyta	Pennales			pel, pla		
Stenopterobia	Bacillariophyta	Surirellales			ben,phy		
Tabellaria	Bacillariophyta	Tabellariales	phy,pla,meta	ben	ben	pel	
Aphanochaete	Chlorophyta	Chaetophorales	meta				
Chaetophora	Chlorophyta	Chaetophorales		phy		phy, den	
Eudorina	Chlorophyta	Chlamydomonadales	meta				
Nephrocytium	Chlorophyta	Chlorellales	pla				
Zoochlorella	Chlorophyta	Chlorellales					pel
Characium	Chlorophyta	Chlorococcales	phy				
Coelastrum	Chlorophyta	Chlorococcales					pel
Dictyosphaerium	Chlorophyta	Chlorococcales	phy, meta				
Dictyosphaerium pulchellum	Chlorophyta	Chlorococcales	phy				
Radiofilum flavescens	Chlorophyta	Chlorococcales	phy				
Chaetosphaeridium	Chlorophyta	Coleochaetales	phy				
Coleochaete	Chlorophyta	Coleochaetales	phy				
Bambusina	Chlorophyta	Desmidiales	phy, meta				pel,phy
Closterium	Chlorophyta	Desmidiales	phy	ben	ben		pel,phy
Closterium kutzingii	Chlorophyta	Desmidiales	phy				
Cosmarium	Chlorophyta	Desmidiales	phy, meta	pla		phy, den	pel
Cosmocladium	Chlorophyta	Desmidiales	meta				
Desmidium	Chlorophyta	Desmidiales	pel, phy	ben	pel, phy	phy	phy
Desmidium cylindricum	Chlorophyta	Desmidiales			phy,den	phy	
Euastrum	Chlorophyta	Desmidiales	phy, meta				phy
Euastrum dubium	Chlorophyta	Desmidiales	phy				phy
Gonatozygon	Chlorophyta	Desmidiales	phy				
Hyalotheca	Chlorophyta	Desmidiales	phy	phy, pla		pla,meta,phy	pel, phy

Hyalotheca mucosa	Chlorophyta	Desmidiales	phy	pla		pla,meta,phy	
Micrasterias	Chlorophyta	Desmidiales	phy, meta	phy			phy
Micrasterias laticeps	Chlorophyta	Desmidiales	phy				
Micrasterias radiata	Chlorophyta	Desmidiales	phy				
Onychonema	Chlorophyta	Desmidiales	phy				
Pleurotaenium	Chlorophyta	Desmidiales	phy	ben	phy, den	phy	phy
Pleurotaenium ehrenbergii	Chlorophyta	Desmidiales	phy				
Pleurotaenium trabecula	Chlorophyta	Desmidiales		ben			
Sphaerozosma	Chlorophyta	Desmidiales	phy, meta	phy		phy, den	
Sphaerozosma vertebratum	Chlorophyta	Desmidiales		phy		phy, den	
Spondylosium	Chlorophyta	Desmidiales	phy, meta			phy	pel
Spondylosium aubertianum var. archerii	Chlorophyta	Desmidiales				pla,meta,phy	
Spondylosium undulatum	Chlorophyta	Desmidiales	phy				
Staurastrum	Chlorophyta	Desmidiales	pla,phy,meta	ben	pla, phy	pla,meta,phy	phy, pel
Triploceras	Chlorophyta	Desmidiales	pel				
Xanthidium	Chlorophyta	Desmidiales	meta, phy	ben			phy
Xanthidium brebissonii	Chlorophyta	Desmidiales	meta	ben			
Glaucocystis	Chlorophyta	Glaucocystales	phy, meta				
Glaucocystis nostochinearum	Chlorophyta	Glaucocystales	phy				
Microspora	Chlorophyta	Microsporales	meta				
Bulbochaete	Chlorophyta	Oedogoniales	phy	phy	phy	phy, den	
Oedongonium	Chlorophyta	Oedogoniales	phy, meta		phy		
Ankistrodesmus	Chlorophyta	Sphaeropleales	phy, meta				pel
Gloeocystis	Chlorophyta	Sphaeropleales	Meta		pla		
Kirchneriella lunata	Chlorophyta	Sphaeropleales	phy				
Pediastrum	Chlorophyta	Sphaeropleales	pla,phy	ben	pla, phy		pel,phy
Pediastrum boryanum	Chlorophyta	Sphaeropleales		ben			
Pediastrum duplex	Chlorophyta	Sphaeropleales	phy, meta				
Pediastrum tetras	Chlorophyta	Sphaeropleales	phy, meta		phy		
Quadrigula	Chlorophyta	Sphaeropleales	phy				
Scenedesmus	Chlorophyta	Sphaeropleales	pel,meta,phy		ben,phy		pel,phy
Scenedesmus quadricauda	Chlorophyta	Sphaeropleales	phy				
Sorastrum americanum	Chlorophyta	Sphaeropleales	phy				
Tetraedron	Chlorophyta	Sphaeropleales	phy				
Tetraedron minimum	Chlorophyta	Sphaeropleales	phy				
Ulothrix	Chlorophyta	Ulotrichales		pla		pla,meta	
Ulothrix variabilis	Chlorophyta	Ulotrichales		pla			
Pandorina	Chlorophyta	Volvocales	meta, phy				
Volvox	Chlorophyta	Volvocales			pla		
Cylindrocystis	Chlorophyta	Zygnematales	phy				
Mougeotia	Chlorophyta	Zygnematales	phy,pla,meta	ben,phy	phy,den	pla,meta,phy,den	phy
Netrium	Chlorophyta	Zygnematales	phy		phy, den		phy

Spirogyra	Chlorophyta	Zygnematales	phy, meta			phy, den	phy
Zygnema	Chlorophyta	Zygnematales	phy, meta	ben		phy	pel
Chrysosphaerella	Chrysophyta	Chromulinales	meta				
Dinobryon	Chrysophyta	Chromulinales	meta		pla		
Derepyxis	Chrysophyta	Hibberdiales	phy				
Aphanothece	Cyanophyta	Chroococcales	phy, meta			phy	pel
Chroococcus	Cyanophyta	Chroococcales	phy, meta			phy	
Dactylococcopsis fascicularis	Cyanophyta	Chroococcales	phy			pel	
Microcystis	Cyanophyta	Chroococcales	pla,meta,phy	ben,pla	ben,pla	pla,meta	phy
Amphithrix	Cyanophyta	Nostocales			phy,den		
Anabaena	Cyanophyta	Nostocales	phy, meta	pla,ben	pla,pel,den		
Anabaena spiroides	Cyanophyta	Nostocales		ben			
Calothrix	Cyanophyta	Nostocales	phy		phy,den	phy	
Gloeotrichia	Cyanophyta	Nostocales	phy	ben	phy,den	phy, den	
Hapalosiphon	Cyanophyta	Nostocales	phy				
Nostoc	Cyanophyta	Nostocales	phy	phy			
Stigonema	Cyanophyta	Nostocales	phy			phy	
Tolypothrix	Cyanophyta	Nostocales	phy				
Lyngbya	Cyanophyta	Oscillatoriales	phy			phy	
Oscillatoria	Cyanophyta	Oscillatoriales		ben	ben	ben, phy	phy
Spirulina	Cyanophyta	Pseudanabaenales	meta				
Aphanocapsa	Cyanophyta	Synechococcales	phy, meta	phy			
Coelosphaerium	Cyanophyta	Synechococcales	phy				
Coelosphaerium kutzingianum	Cyanophyta	Synechococcales	phy				
Merismopedia	Cyanophyta	Synechococcales	phy, meta		phy		
Euglena	Euglenophyta	Euglenales	pel,pla,phy				pel
Euglena acus	Euglenophyta	Euglenales	phy				
Lepocinclis acuta	Euglenophyta	Euglenales	pel				
Phacus	Euglenophyta	Euglenales		X		phy	
Trachelomonas	Euglenophyta	Euglenales	pel				
Ceratium hirudinella	Pyrrophyta	Gonyaulacales		pla, ben	pla	phy	
Peridinium	Pyrrophyta	Peridiniales	phy			phy	
Cystodinium	Pyrrophyta	Phytodiniales	phy				
Stylodinium	Pyrrophyta	Phytodiniales	phy				
Ophiocytium	Xanthophyta	Mischococcales	phy, meta				
Ophiocytium bicuspidataum	Xanthophyta	Mischococcales	phy				
Botryococcus braunii	Xanthophyta	Trebouxiales	phy	phy			

Literature Cited
(in the Michigan Botanist format)

Burgess C. (2001). A Wave of Momentum for Toxic Algae Study. Environmental Health Perspective 109: a160-a161.

Canter-Lund, H and Lund, J. W. G. (1995). Freshwater Algae: Their Microscopic World Explored. Biopress Limited. Berkeley, CA. 360 pp.

Courter, E. W. (1992). Michigan's Copper Country. Michigan Dept. of Natural Resources, Geological Survey Division. Lansing, MI. 144 pp.

Davis, M. B. (1993). Old Growth in the East: A Survey. Cenozoic Society. Madison, WI. 150 pp.

Derouin, S. A., Lowell, T. V., and Hajdas, I. (2007). Landscape evolution and deglaciation of the upper peninsula, Michigan: An examination of chronology and stratigraphy in kettle lake cores. Journal of Great Lakes Research 33(4): 875-886.

Dillard, G. E. (1993). Freshwater Algae of the Southeastern United States. Bebruder Borntraeger, Berlin. 284 pp.

Gulley, A. R. and Kennedy, C. A. (1987). Comparison of phytoplankton, periphyton, and benthic algae in two different pools off of Douglas Lake. Available online at http://hdl.handle.net/2027.42/53911; last accessed Jul. 19, 2012.

Komárek, J. and Anagnostidis, K. (1999, 2000). Cyanoprokaryota 1 Teil: Chroococcales. Pp. 111. In: Ettl, H., Gärtner, G., Heynig, G.H., and Mollenhauer, D. Süßwasserflora von Mitteleuropa Band 19/1. Spektrum Akademischer Verlag: Berlin. 548 pp.

Moffett, J. W. (1940). A fisheries survey and management suggestions for some lakes of the Ottawa National Forest, Michigan. Department of Natural Resources - State of Michigan. Fisheries research report: 630. Available online at http://name.umdl.umich.edu/AAG2862.0630.001; last accessed Jul. 18, 2012.

Molot, L. A. and Peter, J. D. (2008). Long-term trends in catchment export and lake concentrations of base cations in the Dorset study area, central Ontario. Canadian Journal of Fisheries and Aquatic Sciences 65(5): 809-820.

Ngearnpat, N. and Peerapornpisal, Y. (2007). Application of desmid diversity in assessing the water quality of 12 freshwater resources in Thailand. Journal of Applied Phycology 19(6): 667-674.

Ojakangas, R. W. and Matsch, C. L. (1982). Minnesota's Geology. University of Minnesota Press. Minneapolis, MN. 268 pp.

Prescott, G.W. (1962). Algae of the Western Great Lakes Area. Wm. C. Brown Company Publishers. Dubuque, IA. 977 pp.

Prescott, G.W. (1978). How to Know the Freshwater Algae. Wm. C. Brown Company Publishers. Dubuque, IA. 304 pp.

Prescott, G.W., de M. Bicudo, C. E., Vinyard, W.C., and Croasdale, H. T. (1983). A Synopsis of North American Desmids. University of Nebraska Press. Lincoln, NB. 128 pp.

Rominger, C. L. (1895). Geological report on the Upper Peninsula of Michigan: Exhibiting the progress of work from 1881 to 1884. Vol. V, Part I. Iron and copper regions. R. Smith & Co. Lansing, MI. 179 pp.

Sibaja-Cordero, J. A. and Cortes, J. (2010). Temporal comparison of the composition and zonation of rocky intertidal organisms at Cocos Island National Park, Pacific, Costa Rica. Revista Biologica Tropical 58(4): 1387-1403.

Smith, B. (1995). A Survey of Algal Flora in Ground Water Springs and Seeps in Northern Lower Michigan. Available online at http://hdl.handle.net/2027.42/54635; last accessed Jul. 19, 2012.

Stevenson, R. J., Bothwell, M. L., and Lowe, R. L. (1996). Algal Ecology: Freshwater Benthic Ecosystems. Academic Press, Inc. San Diego, CA. 788 pp.

Taube, C. M. (1949). The fishes and the physical aspects of Lake of the Clouds, Mirror Lake, Big Carp River, and Little Carp River, of the Porcupine Mountains State Park. Department of Natural Resources - State of Michigan. Fisheries research report: 1211. Available online at http://name.umdl.umich.edu/AAG2862.1211.001; last accessed Jul. 17, 2012.

Warren, M. (1995). A survey of phytoplankton communities in ten northern Michigan lakes. Available online at http://hdl.handle.net/2027.42/54642; last accessed Jul. 19, 2012.

Wehr, J. D. and Sheath, R. G. (2003). Freshwater Algae of North America. Elsevier Science. New York, NY. 917 pp.

West, W. (1923). A Monograph of the British Desmidiaceae (Volumes I-V). Adlard and Son, London. 424 pp.