The relationship between physical characteristics and a specific algal community on the Moore Feature in Douglas Lake

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INTRODUCTION

The growth of photosynthetic organisms like algae depends on many factors such as light, temperature and nutrient levels. Some algal species have high light, temperature, or nutrient requirements while others are adapted to habitats with relatively low light exposure, low cold temperatures, or low nutrient availability (Dodds, 2002). Lakes are dynamic ecosystems with spatial differences in physical characteristics that result in the growth of diverse algal communities.

The spatial variation of depth within a single lake can affect the distribution of algae. Increasing depth is correlated with increasing light attenuation and decreasing temperature, and light levels and temperature affect the processes that determine the productivity and survival of organisms such as algae. Light wavelengths of varying energy levels penetrate to different depths in water (Dodds, 2002). Algae from different divisions use different sets of pigments during photosynthesis. Green algae harness blue and red light, diatoms specialize in harnessing blue light, and blue-green algae specialize in harnessing green light (Wehr and Sheath, 2003). Because some algae use different pigments, the algae can occupy different niches, based on light levels alone. Thermocline position is important because nutrients can become locked in the hypolimnion. Algae have various nutrient requirements and grow most efficiently under certain nutrient conditions. The low temperature associated with the hypolimnion can also be important to algal growth because low temperatures affect algal metabolism (Wehr and Sheath, 2003). Factors associated with depth shape the algal community on the Moore Feature in Douglas Lake.

The Moore Feature is a reef-like formation located on the western edge of South Fishtail Bay in Douglas Lake and is a habitat for an interesting set of benthic algae. Three genera, representing three separate divisions, dominated the algal flora on the Moore Feature. *Cladophora* was found growing on the Moore Feature and is a member of the division Chlorophyta. Filamentous green algae such as *Cladophora* often grow attached to hard surfaces, but growth on deep, muddy bottoms is possible for members of the genus (Wehr and Sheath, 2003). The rough cellulose walls of *Cladophora* provide excellent attachment surfaces for epiphytic algal species (Stevenson et al., 1996).

The cell walls of *C. profunda* greatly increase the viable surface area available for attachment by epiphytic algae. *Gomphonema*, of the division Bacillariophyta, attaches to *C. profunda* by making a mucopolysaccharide stalk. Also known as diatoms, Bacillariophyta have unique cell walls composed of silicon dioxide (Stevenson et al., 1996). The division Cyanophyta is also represented on the Moore Feature by the epiphytic genus *Heteroleibleinia*. Differences in physical and chemical conditions on the Moore Feature might reveal variation in the distribution of *Cladophora*, *Gomphonema*, *Heteroleibleinia* across the feature.

In this survey, I studied specimens of attached algae removed from five different sites on the Moore Feature. I compared the relative abundance of the three algal genera mentioned above to the physical and chemical conditions of the sites in order to see if a logical pattern between biotic and abiotic characteristics existed across the area of the Moore Feature. I predicted that the spatial variation of the habitat on the Moore Feature resulted in differences in the structure of the algal community living on the feature and that the feature itself supported a unique algal community.

METHODS

In order to provide the most diverse sampling regime possible, we selected five different sites on the feature that differed qualitatively. Sites 1, 3, and 5 contained outcroppings of solid sediment formations. Sites 2 and 4 contained mostly clay. The sites were located at variety of depths ranging between 10.3 and 15 meters. In order to determine how the sites differed chemically, we took several measurements at each site.

We collected chemical information about the five sites at the Moore Feature in Douglas Lake. Using a Hydrolab, we took the following physical measurements at each site: temperature, depth, conductivity, pH, and redox potential. A separate dissolved oxygen meter was used to obtain the dissolved oxygen value at each of the sites. ALWAS buoys allowed us to determine average surface pH and conductivity of the lake water directly above the site. We also took a single light level profile next to the Moore Feature using a photometer. The photometer cable was only ten meters long and could not reach the depths of the Moore Feature, so I constructed a linear regression equation for the percentage of light attenuated in the first ten meters of the depth of the lake. The linear regression allowed me to estimate the percentage of surface light that penetrated at the depths of our five sites on the Moore Feature. With the assistance of Mike Grant at the University of Michigan Biological Station, we measured the total nitrogen, organic carbon, inorganic carbon, phosphorus, and silicon dioxide of water samples taken from each site. Finally, we collected biological samples from each of the five sites.

I processed the samples for algae, scraping attached specimens from the substrate. Because I could not confirm that the very few algae specimens living in loose sediment did not accidentally fall from the water column or drift from another habitat, I did not count the specimens I found in loose sediments. Sites 1, 3, and 5 contained solid substrate and clay sediments. Sites 2 and 4 both contained only clay sediments, but I was able to scrape the more dense clay present at site 2. I made a wet mount of the scrapings I took from the substrate I collected at sites 1, 2, 3, and 5. The algae in the site 3 scraping were known planktonic species and were discarded. Because I could not scrape the loose clay sediments, I did not consider any of the algal specimens at site 4. After collecting the specimens, I determined the relative abundance of the three predominant genera of algae living on the Moore Feature.

Under the microscope, using the 40x objective, I randomly chose five locations on each slide and counted the number of algal specimens in the field of view. I used three different counting units based on the algal species observed. The unit for *Gomphonema* was one cell. The unit for *Cladophora* was one cell; if I could not view at least 90% of a single cell in the randomly chosen field of view, I adjusted the microscope stage to reveal the entire cell nearest the random field of view. The unit for *Heteroleiblienia* was one filament.

RESULTS

The Hydrolab measurements revealed relatively consistent conductivity, pH, and redox potentials among the five sites (Table 1). Conductivity ranged between 235 and 256 μS/cm at the five sites on the Moore Feature. Conductivity of the surface water averaged 238 μS/cm, showing proximity to the Moore Feature did not influence conductivity significantly. However, proximity to the Moore Feature did appear to affect pH, which averaged 8.64 at the surface of the lake and ranged between 7.01 and 7.34 at the five sites. pH values on the Moore Feature did not vary significantly from each other, but pH did decrease slightly as depth increased. There was no clear relationship between redox potential and depth, and the redox potential varied very little among the five sites, ranging between 337 and 352 mV.

According to our measurements, dissolved oxygen levels and temperature showed a significant amount of variation among sites, based on depth (Table 1). The results from the dissolved oxygen meter showed the relationship between depth and dissolved oxygen was inversely proportional at the Moore Feature, as expected. The dissolved oxygen value ranged between 1.04 and 4.78 mg/L. Temperature varied between 11.40 C° and 19.30 C°. The temperature change was most dramatic between 10.3 and 12.5 meters, and temperature was approximately equal at 14.7 and 15 meters. The temperature pattern suggested that the thermocline terminated above 14.7 meters, so sites 3 and 4 are probably located in the hypolimnion.

The plot showing the relationship between depth and relative light level confirmed that light attenuated quickly in Douglas Lake, becoming reduced to 1% at roughly 5.5 meters (Figure 1, Table 3). The attenuation of light levels was exponential, as expected. The linear regression equation showed that light levels at all five sites on the Moore Feature were well below 1% of the surface light (Figure 1, Table 4). The R^2 value for the linear regression for the light profile was 0.9903, so the regression was a good model for predicting light levels below 10 meters.

The water chemistry data provided by Mike Grant showed that nutrient levels varied based on site location (Table 2). Nitrogen concentrations nearly doubled between sites 5 and 4, while nitrogen concentrations were more consistent between sites 1, 2, and 3. There was no clear relationship between depth and nitrogen concentration. There was also a significant amount of variation in phosphorus concentrations at the Moore Feature, with measurements ranging between 9.60 µg/L at site 1 and 14.30 µg/L at site 3. In general, phosphorus concentrations increased as depth increased, and the phosphorus concentration increased dramatically across the 0.3 meters between sites 4 and 3. Phosphorus concentrations were one order of magnitude smaller than nitrogen concentrations. Because carbon concentrations at our five sites were very high and not limiting, according to the Redfield Ratio, carbon availability is not of biological interest on the Moore Feature. The concentration of silicon dioxide varied greatly with depth, more than doubling between the most shallow and deepest sites on the Moore Feature.

Each of the five sites showed a different pattern of algal growth. Sites 3 and 4, the two deepest of the sites characterized, contained no algal growth, despite the presence of solid surfaces at site 3. Sites 1, 2, and 5 contained algal growth of mainly three different genera, but the structures of the algal communities varied (Figure 2). I counted roughly the same number of total algal units at sites 1 and 2. I counted more than twice as many units at site 5 than I did at either site 1 or 2. *Heteroleibleinia* units dominated at site 1, while the blue-green alga was entirely absent at site 2.

Table 1. Temperature, depth, conductivity, pH, and redox potential, and dissolved oxygen at sites 1-5.

Site	Depth (m)	Temp (C°)	Cond. (µS/cm)	pH	Redox (mV)	D/O (mg/L)
1	10.3	19.30	256	7.34	337	4.78
2	12.5	13.72	254	7.06	342	2.14
3	15.0	11.44	236	7.01	349	1.04
4	14.7	11.40	245	7.02	352	1.30
5	11.8	16.00	235	7.12	348	2.25

Table 2. Total nitrogen, organic carbon, inorganic carbon, phosphorus, and silicon dioxide at sites 1-5.

Site	N (mg/L)	OC (mg/L)	IC (mg/L)	P (µg/L)	SiO_2 (mg/L)
1	0.522	8.53	25.45	9.60	3.264
2	0.580	8.09	26.12	10.05	5.601
3	0.596	8.01	25.64	14.30	6.952
4	0.632	8.03	26.00	10.85	7.047
5	0.320	8.58	25.66	10.10	3.779

Table 3. Relative light levels in Douglas Lake.

depth	% light
1	24.675
2	9.740
3	3.961
4	2.662
5	1.429
6	0.844
7	0.539
8	0.299
9	0.156
10	0.099

Table 4. Estimated percentage of light present at the five sites.

site	% light
1	0.073
2	0.016
3	0.005
4	0.006
5	0.030

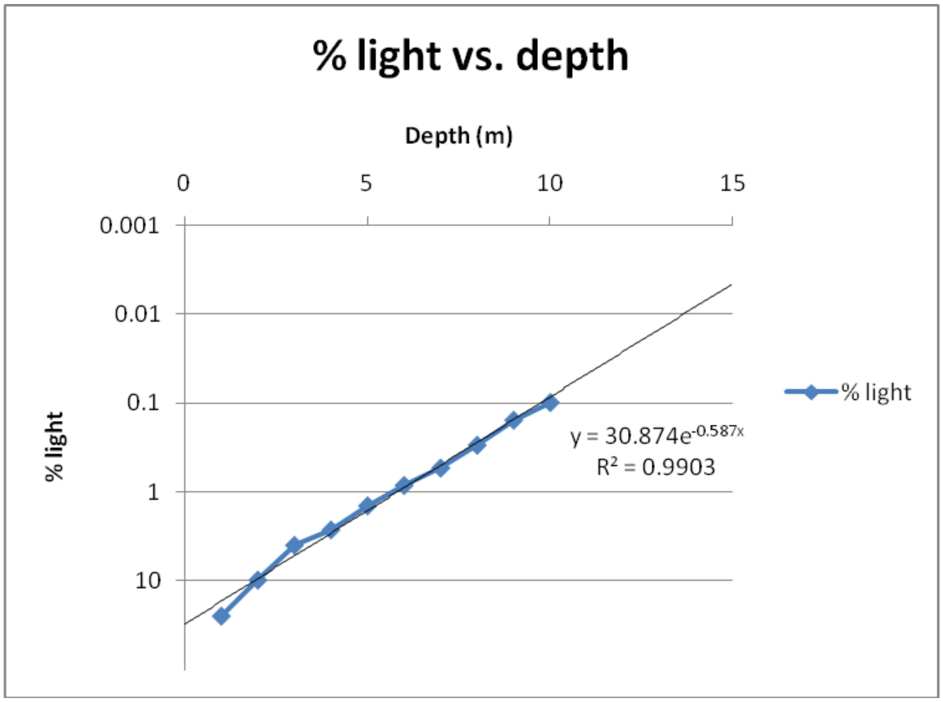

Figure 1 shows the plot of percent of light vs. depth and the linear regression of the % light present between 0 and 10 meters in Douglas Lake. Using the linear regression, I predicted the percent of light remaining at each of the five sites on the Moore Feature.

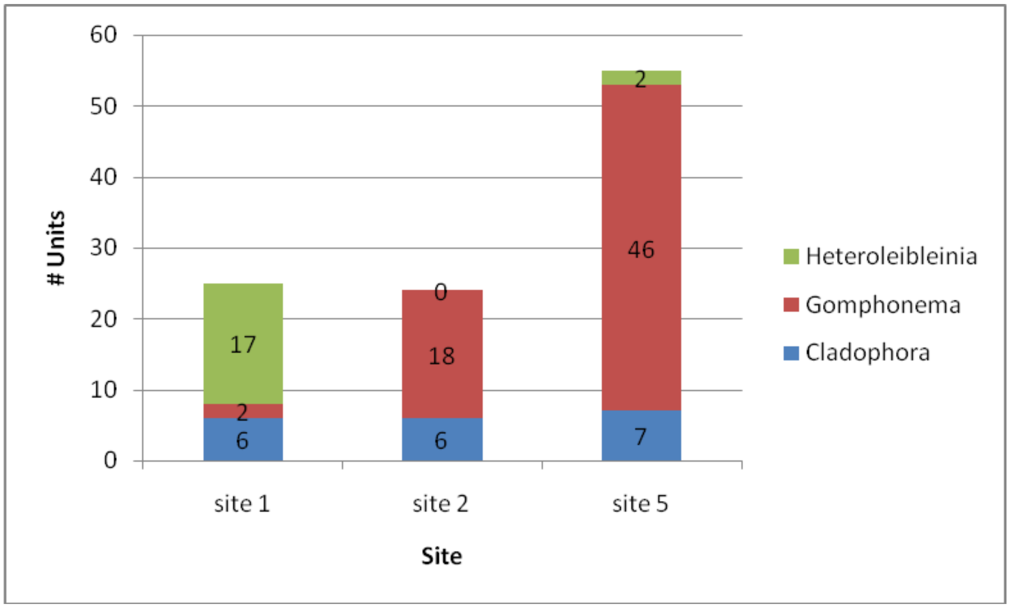

Figure 2 shows the distribution across sites 1, 2, and 5 of the three algal genera that dominate the attached algal community on the Moore Feature. The numbers represent the algal units present.

CONCLUSIONS

The structure of the algal community on the Moore Feature is unique and shaped by the equally unique habitat provided by the feature. The solid substrate outcroppings present at sites 1 and 5 provided excellent attachment sites for *Cladophora profunda*, and those outcroppings are what originally made the Moore Feature contrast physically from the surrounding lake bottom. Because *Cladophora* was able to grow at the Moore Feature, epiphytic taxa were also able to colonize the area, adding another dimension to the algal community (Stevenson et al., 1996). The three genera found at the Moore Feature had different habitat requirements that were reflected in the community structure.

Although much of the Moore Feature was shallow enough to support photosynthetic organisms, part of the feature was located too deep in the lake. *Cladophora profunda* is a species of algae that was previously found growing at depths of 10-15 meters in a Wisconsin lake (Prescott, 1962) so the presence of *C. profunda* at similar depths in Douglas Lake was not surprising. However, the extinction of blue and red light useable by green algae at sites 3 and 4 probably excluded *C. profunda* from the deeper sections of the Moore Feature. The thermocline most likely terminated directly above site 4, affecting the conditions of the water at sites 3 and 4. The presence of the thermocline phenomenon at the Moore Feature was supported by the comparatively high phosphorus levels at site 3 and the high silicon dioxide levels at sites 3 and 4. The cold temperatures in the hypolimnion might have been too low to allow bioaccumulation of either *C. profunda* (Dodds, 2002). The relative abundance of nitrogen, phosphorus, and silicon dioxide at sites 3 and 4 suggested that the lack of algal growth at sites 3 and 4 was not due to nutrient deficiency. *Gomphonema* and *Heteroleibleinia* cannot grow unless a host filament is present, so the absence of the two genera would be expected at sites 3 and 4. Although *C. profunda* was present at sites 1, 2, and 5, populations of the blue-green algae and diatoms at the sites were not homogenous.

There are two possible scenarios explaining the largely unequal ratios of *Heteroleibleinia* and *Gomphonema* at sites 1, 2, and 5: 1.) *Heteroleibleinia* preferred higher light and/or temperature values than *Gomphonema*. 2.) *Gomphonema* was excluded from more ideal light levels and temperatures by *Heteroleibleinia* because the blue-green alga out-competed the diatom. Typically, blue-green algae are best at capturing green light from the water (Wehr and Sheath, 2003), and green light penetrates the deepest in mesotrophic and eutrophic lakes (Dodds, 2002). I expected to find blue-green algae living at greater depths in than diatoms in Douglas Lake, but I found *Heteroleibleinia* living at lesser depths than *Gomphonema*. Perhaps *Heteroleibleinia* was outcompeting *Gomphonema* for higher light levels or higher temperatures. *Gomphonema* has unique abiotic preferences as well.

The difference in pH between the surface waters of Douglas Lake and the waters around the Moore Feature were significant and could have contributed to the large community of *Gomphonema* at site 2 and 5. Because *Gomphonema* prefers circumneutral pH values, one might expect *Gomphonema* to thrive where pH values are close to 7 (Stevenson et al., 1996). The surface waters of Douglas Lake were not circumneutral, while the pH values of the water at the site 2 and 5 were 7.06 and 7.12, respectively. Although *Gomphonema* did grow at site 1, where the pH was a slightly higher value of 7.34, the genus was relatively uncommon compared to *Heteroleibleinia*. Decomposition activity by bacteria at the bottom of the lake contributed to the lower pH values (Bratton, 2006), providing the ideal neutral environment for *Gomphonema*. Decomposition would have been occurring over most of the bottom of Douglas Lake, but the combination of bacteria-dominated sediments and intermediate depths on the Moore Feature created an appropriate habitat for *Gomphonema.*

My results showed that the Moore Feature exhibited multiple habitats that affected the productivity of three algal genera differently. Each section of the feature was better suited to a different algal community. In addition, the solid structures on the feature provided good attachment sites for *Cladophora profunda*. Assuming similar formations of solid structures at 15 meters or shallower are uncommon in Douglas Lake, the Moore Feature might serve as a unique and concentrated habitat for periphytic algal species. Because habitat variation was present on the Moore Feature, my study reinforced the importance of microhabitats to diversity and community structure.

LITERATURE

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