Effects of Shade, Depth and Substrate on Algal Colonization in Douglas Lake

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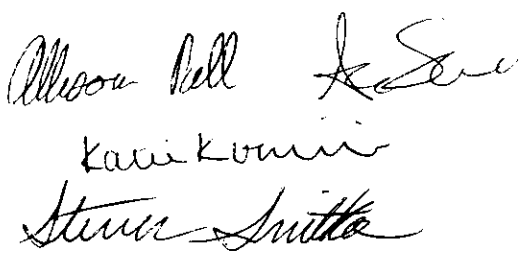
Abstract

Algae are a diverse group of photosynthetic organisms that fulfill significant ecological functions within aquatic systems. The simplest classifications of algae are as either benthic or pelagic. The majority of past algal research has focused on pelagic or free-floating algae, as it is the simplest to sample. This investigation aimed to expand the knowledge of benthic algal growth within a dimictic freshwater lake in Northern Michigan. We compared three divisions of algal growth on varying substrates while controlling for depth and light intensity over a 14 day growth period. Because depth and light intensity are limiting factors to algal growth, we anticipated the greatest colonization to occur on the most accurate substrate in the habitat with the most abundant limiting resources. We observed minimal colonization. However, the distribution and abundance followed out hypothesized trends.



Introduction

Douglas Lake is a dimictic freshwater ecosystem that promotes the growth of 108 species of benthic and pelagic algae. This investigation includes observations of three divisions of benthic algae: blue-green algae in the Cyanophyta division, green algae in the Chlorophyta division, and diatoms in the Chrysophyta division. Green algae and diatoms are eukaryotic phytoplankton; diatoms have silica in their cell walls which gives them a distinct structure from green algae (Bold & Wynne, 1985). Blue-green algae are prokaryotic cyanobacteria that perform the same ecological functions as green algae and diatoms, and thus all are studied collectively (Bold & Wynne, 1985). Additionally, these three divisions of algae share the same limiting resources that affect abundance and distribution including light intensity, nutrient quality and availability, water turbulence and temperature, and substrate (Bold & Wynne, 1985). Within lake systems, basin morphometry greatly influences algal colonization and abundance. As depth increases, nutrient levels increase while water turbulence, temperature, substrate availability, and light intensity decrease (Stevenson et. al, 1996). Another factor that affects algal growth is substrate type. Two substrate attributes important for algae to colonize are accuracy and precision (Lamberti & Resh, 1985). Accuracy refers to the extent to which the substrate resembles the natural environment of the algae, whereas precision is the notion that variability between the substrates should not be higher than that of the natural environment of the algae (Lamberti & Resh, 1985).

Nutrient availability is a limiting factor in algal growth and changes according to the depth of the water (Stevenson et al., 1996). However, we did not expect nutrient levels to differ between the two depth treatments due to the spring turnover Douglas Lake was experiencing while the experiment was conducted. Therefore, we did not investigate the influence of varying

nutrient availability on algal growth within our experiment. Another limiting factor for algae is water turbulence and wave action. However, water near the shore is presumed to be more turbid compared to deeper water as a result of constant wind from the northeast creating waves that affect water in the upper eulittoral zone.

A previous study conducted by Beaudry et al. (2012) similarly examined the growth of these three algal divisions in Douglas Lake while controlling for growth period and depth. The results of their study indicated no significant difference in algal growth at the two depths (0.55 m and 1.10 m). Beaudry et al. (2012) suggested that increasing the difference between depths may lead to more significant results.We incorporated their recommendation into our experimental design by increasing the difference between depth treatments. In addition to controlling for depth, we examined the effects of light intensity without changing depth, which was not considered in the previous study.

Methods

Twelve 40cm x19.5cm x9cm concrete blocks were affixed with 10.16cm x10.16cm pieces of plywood and tile. A 10.16cm x10.16cm section of the concrete block was marked off as the concrete treatment. Six blocks were submerged on the Eastern Big Shoal of South Fishtail Bay at a depth of 2.6m. The remaining six blocks were submerged at a depth of 0.6m along the Pine Point shore of South Fishtail Bay. Blocks were placed five meters apart. Every other block in the shallow treatment was covered with a shade screen suspended 6 in. above the blocks using PVC pipes. The shade screens had a large enough surface area to prevent sunlight penetration at differing angles of the sun throughout the day. All of the blocks were oriented in the same direction (North-South) and submerged for two weeks. During this two week growth period, light was measured with a photometer in Watts/m^2 and temperature was recorded at both depth

treatments. In order to obtain accurate measurements, readings were taken for 1.5 minutes in 15 second intervals at each treatment and then averaged. We took measurements at two different times during the day --10:30 and 19:30 -- to obtain a standard light intensity ratio between treatments.

We hypothesized the growth of all algal divisions to be greater at the shallower treatments than the deep treatment due to increased light intensity, water turbulence, and greater temperature in the upper eulittoral zone (Stevenson et al., 1996). Furthermore, we expected greater green algae growth in the shallower treatment and greater blue-green algae growth in the deeper treatment, with roughly equal growth of diatoms at both depths. According to Stevenson et al. (1996), habitat ranges for algae depend in part on the ability to adhere to substrata in different turbidities. Green algae tend to be found in shallower depths because they tolerate greater light intensity, turbulence, and temperature fluctuation. Comparatively, blue-green algae are more common at deeper depths due to preferred conditions of lower light intensity, turbulence, and narrow temperature fluctuations. On the other hand, diatoms have greater plasticity, allowing for greater distribution throughout the lake system (Stevenson et al., 1996). We also predicted greater growth of all three algal divisions in the unshaded shallow water treatments compared to the shaded treatments at equal depth. Reduced light availability is expected to inhibit photosynthesis, thus hindering algal growth (White et al., 1991). Finally, in regard to the differing substrates, we anticipated the greatest growth to occur on the concrete, an intermediate amount of growth on the wood, and the least amount of growth on the tile. We predicted that the algae would grow best on the concrete because it most closely resembles their natural habitat of the sandy and stony lake bottom, as opposed to the tile which is the most inaccurate substrate (Lamberti & Resh, 1985).

The blocks remained in Douglas Lake for two weeks. Upon removal, scrub samples were collected from each substrate and examined under a compound light microscope to identify the algal divisions present. The collection process began by rinsing and scrubbing each substrate from each block and collecting the material that came off into individual petri dishes. We then used a pipette to place a sample from the dish onto a microscope slide for examination. Two one-drop samples from each substrate on each block were examined under 100x magnification in order to assess algal presence, and identify divisions.

Results

The ratio of light intensity between the deep treatment and the shallow unshaded treatment was approximately 2:7, and the ratio of light intensity between the shallow unshaded and shaded treatments was approximately 1:3. The average light intensity throughout the day for the unshaded 0.6m treatment was 128.4 Wm^{-2}, the average for the shaded 0.6m treatment was 46.17 Wm^{-2}, and the average for the 2.6m depth was 36.57 Wm^{-2}. All of the shade treatments were not functional throughout the experiment. Therefore we had to eliminate the shade variable from our analysis. The temperature at both depths was recorded as 22°C.

There was no visible algal growth after collecting the substrates. Therefore, we were unable to perform quantitative statistical analyses. However, trends in the distributions of algal divisions were observed between the different treatments. Since diatoms were found consistently throughout all treatments, we recorded their relative abundance. When the other two divisions were found, they were always in low abundance; therefore, we only recorded their presence or absence. All algal divisions were more abundant at the 0.6m depth compared to the 2.6m depth (Fig. 1). Diatoms were found in nearly all samples, but in greatest abundance at the shallow

treatment (Fig. 2). Finally, we found the most algae on the cement substrate, an intermediate amount on the wood, and the least on the tile (Fig. 3).

Discussion

There was a greater abundance of all algal divisions in the shallow treatment, which supported our first hypothesis (Fig. 1). We expected relatively greater blue-green algal growth in the deeper treatment, and comparatively more green algae growth in the shallower treatments due to physiological differences between these two divisions. However, we were unable to statistically analyze these differences due to low algal growth. Our data also supported our hypothesized trends in terms of algal growth on the different substrates (Fig. 3), suggesting algae prefer to colonize on more accurate substrates.

Originally, we planned to analyze percent coverage of each algal division on each of the various substrates. However, upon removal of the substrates, no significant colonization was observed. There are many factors that may have affected algal colonization resulting in low growth. Algae have the ability to acclimate to colder temperatures (Davison, 1991). However, the algae must make a great trade-off by investing more nitrogen and energy into the synthesis of proteins necessary for biological functions in cold conditions, deflecting resources away from photosynthesis and growth (Davison, 1991). Therefore, lower algal colonization can be expected during times of lower average temperature. A study by White et. al (1991) found that algal biomass decreases with decreasing water temperature. As a result of record-breaking snowfall and temperatures, the ice-out occurred later than average this spring, which may have affected algal growth rates.

Another important factor that may account for the low algal colonization is grazing by herbivores. At the deeper treatment, we observed snail egg masses attached to both the blocks

and the substrates. A block from the deeper treatment had a log perch inside of it when we removed it from the lake. The presence of these egg masses and fish could indicate herbivory by either of these two taxa. In a study by Connor et. al (1982), snails were found to have a significant grazing pressure on algae during the early stages of succession. Similarly, zebra mussels found attached to these blocks consume algae (Madenjian, 1995) and are extremely efficient at filtering water, which may alter concentrations of nutrients that are essential to algae (Kirsch and Dzialowski, 2012).

There were many possible sources of error throughout this study. First, the shade treatment failed and had to be removed from our analysis. Substantial variation was observed while measuring light intensity between the two treatments, which may result from wave action, shading by the canoes from which we took the readings, or human error. Also, the samples under investigation may not have been an accurate representation of the entire substrate, which could result in an underestimation of which algae were present. There was a 20 hour time period between the two sets of samples taken leading to loss of some algae, especially the green and blue-green divisions. Additionally, there may have been errors in identification.

If this study were to be repeated, we suggest that it be done with longer growth periods to allow greater colonization. This would increase the amount of algal growth, making identification and abundance calculations possible and more accurate. Another recommendation we have is to use chlorophyll indicator to calculate biomass of the algae present on each substrate more accurately. Chlorophyll is a photosynthetic pigment found in algae and can be measured using spectrophotometry, high performance liquid chromatography, and fluorometry (YSI). We also suggest an increased sample size, which would facilitate statistical testing to be performed on the data and more definitive results to be discussed. Finally, we recommend a

different shading technique, such as natural shading, to be used to ensure constant, secure shading throughout the colonization period.

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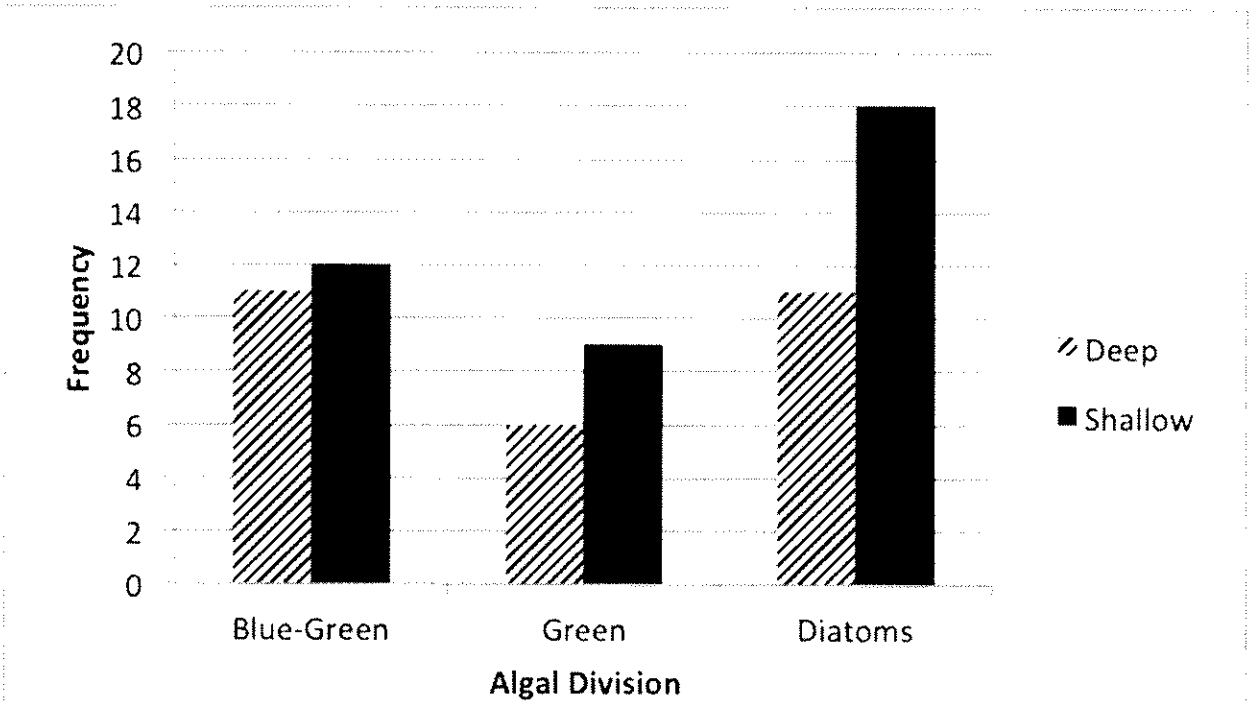

Figure 1. Frequency of algal divisions in each treatment

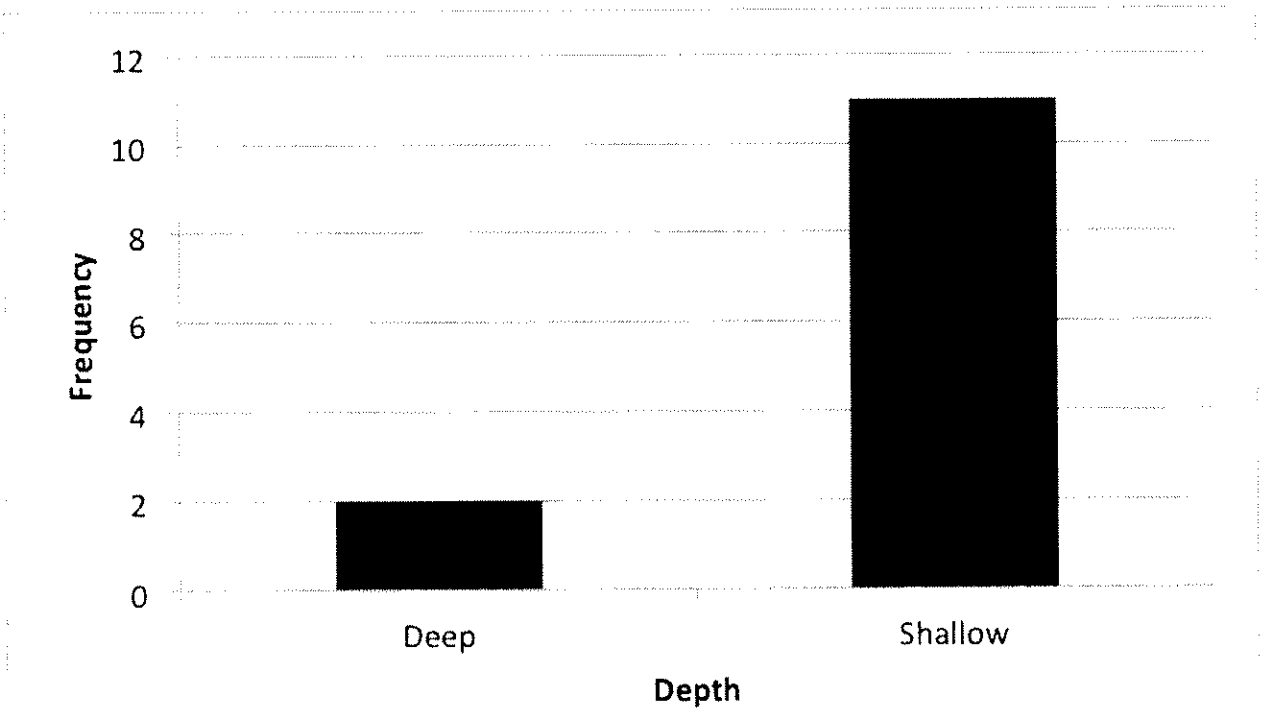

Figure 2. Numbers of treatments at each depth with a high number of diatoms (greater than 5 per sample)

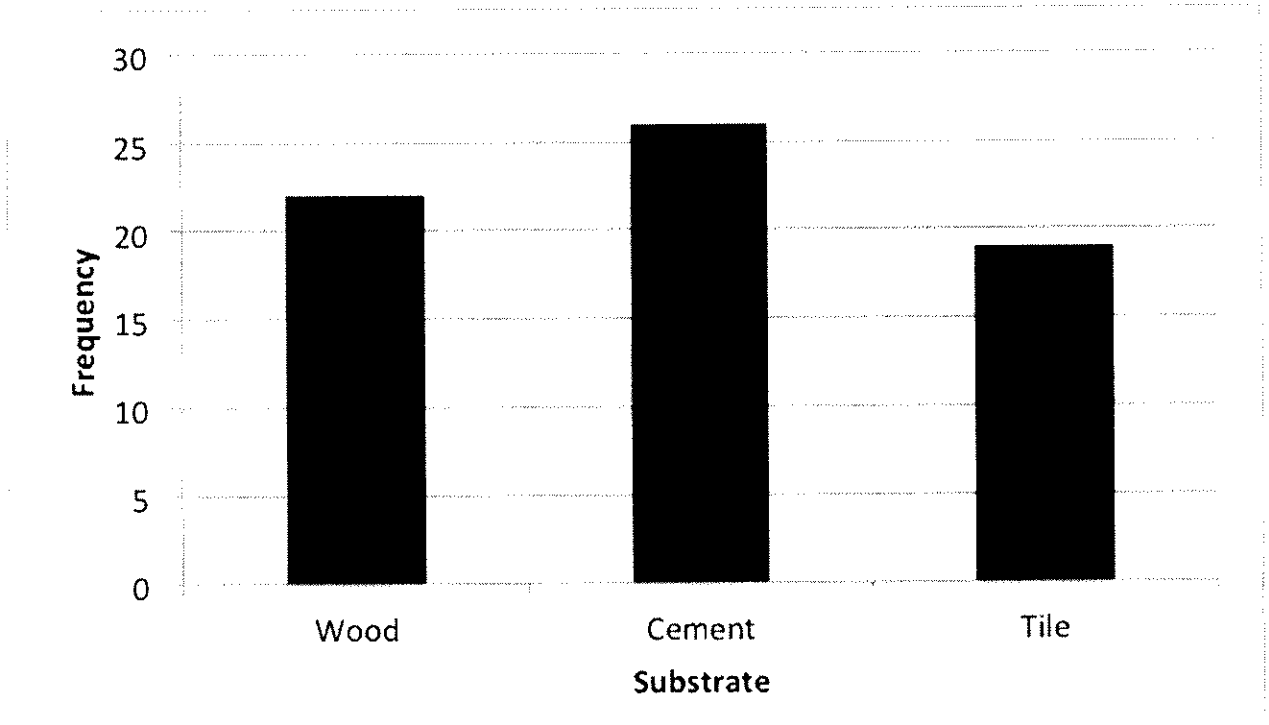

Figure 3. Frequency of algal growth on each substrate