# Colonization Rates of Algae on Artificial Substrates in Douglas Lake

Suzanne Beaudry, Houraa Daher, Patrick Nolan, & Maggie Petersen

University of Michigan Biological Station, Pellston, MI
EEB 381: General Ecology
14 June 2012
Professor Joel Heinen

*Abstract*

The term 'algae' is applied to a diverse group of photosynthetic, autotrophic organisms. In the temperate kettle-lake Douglas Lake in Pellston, MI there are both planktonic and benthic taxa. The benthic organisms live on the lake floor or to fixed substrata using a variety of attachment techniques and generally follow a typical succession pattern from fast growing diatoms, to green algae and climaxing with the large, colonial blue-green algae. The study examined whether different types of surfaces may be more conducive to colonization and subsequent colony expansion. It also looked at the depth of submergence and the time submerged and their effect on the total algal coverage and the coverage by diatoms, green algae and blue-green algae individually. Results showed that concrete was more likely to support growth, though this was only significant for certain situations. There was no significant difference between depth submerged and only significant difference in time submerged at the deeper depth. There was a significant decrease in diatom coverage of concrete and a biologically significant increase in blue-green algae coverage on concrete over time. The growth of algae on artificial surfaces may have implications for the formation of microenvironments in lentic ecosystems and further study should focus on more diverse substrata and longer testing times.

*Introduction*

The assemblage 'algae' consists of a diverse range of organisms that are primarily autotrophic, photosynthetic and single-cellular (Bellinger & Sigee, 1988). These organisms fix carbon dioxide and are a potential food source for heterotrophs in the ecosystem. Understanding the diversity of taxa and their potential for proliferation, then, is an important factor in understanding aquatic ecosystems. In freshwater environments, such as Douglas Lake, in northern Michigan, algae may be either planktonic or benthic. Planktonic species reside in the water column while benthic taxa live within the sediment of the lake or grow attached to submerged substrata (Stevenson, Bothwell & Lowe, 1996, p 4). Prior surveys have identified 108 algal species within the algal mat that coats the surface of lake bottoms in Douglas Lake (Layne, 1990). Algae can contribute significantly to the primary productivity, in addition to plants and autotrophic bacteria; up to 25 % of primary productivity is due to benthic algae in the littoral zone (Bellinger & Sigee, 1988).

Algae are classified according to the type of substrate and microenvironment they prefer. The benthic algae of interest in this study are those that colonize quickly and utilize hard, stable substrate (Stevenson, Bothwell & Lowe, 1996, p 9). Here we are concerned with epilithic algae that colonize stones or rocks and epidendric algae that colonize organic materials (Bellinger & Sigee, 1988, p 84). Once benthic algae settle upon a naïve surface, there are a variety of techniques used for attachment. Organisms may be filamentous or synthesize and excrete mucilaginous compounds that cement the algae to the surface. Some species are heterotrichous, where some individuals of a colony of a single species act as basal attachment cells and others are apical, photosynthesizing cells (Stevenson, Bothwell & Lowe, 1996, p 5). Succession of algal species generally begins with closely associated adnate taxa, expected in this short, two-week period, and proceeds to faster-growing apically attached and stalked taxa that may overshadow previous, smaller species (Stevenson, Bothwell & Lowe, 1996, p 8).

The authors were interested in determining the variation of algal coverage on different substrates and at different depths over time. Based upon preliminary research and the design of this study, three hypotheses were formulated. First, algal coverage and rate of increase should be higher for those substrata submerged in shallower waters. Light penetration declines quickly through the water column and those colonies that receive more light should grow faster. Second, algal presence and coverage should be highest on the substrate that has the roughest surface and most surface area for attachment, in this case, concrete. Finally, the coverage should be higher in the second week of testing. Initial colonization in the first week takes time, but once established, growth should proceed unhindered.

*Materials and Methods*

The experiment was conducted in Pellston, MI and was set up along the southeastern shoreline of Douglas Lake near Pine Point Trail, on the Big Shoal. The lake water at this location is fairly clear and shallow for roughly 80 meters before reaching a steep drop off. This location was ideal for our study because the algal mat is high in algal diversity and richness.

Three different substrates were tested: cinder block, terra cotta, and plywood. These are similar to natural habitats that benthic algae prefer, but the surfaces and porosity of the artificial substrates differ significantly from natural lake substrates. Eight cinder blocks, each approximately 40 cm by 19.5 cm by 9 cm, were used as both substrate as well as an anchor for the other substrates. Four cinder blocks held terra cotta tiles and four held plywood, all secured with silicone gel, giving a total of 16 terra cotta tile, 16 plywood, and 32 concrete squares to test. The terra cotta tiles and the plywood squares were each approximately 7.5 cm by 7.5 cm. The terra cotta tiles averaged 56.00 $cm^2$ in surface area and the plywood squares were on average 60.16 $cm^2$. These tiles and squares were placed on each cinder block equally spaced from each other in an alternating pattern. The concrete that was left exposed served as the concrete testing surface, these were approximately 7.5 cm by 7.5 cm and averaged 57.32 $cm^2$. All cinder blocks were labeled with permanent marker for future identification and had fishing bobbers attached in order to locate them at the test location. The line was secured in place using silicone gel.

Initially, the depths of submergence were 1.0 m and 2.0 m; however, the drop-off had been reached by 1.20 m. As a result, depths were changed to 0.55 m and 1.10 m to prevent any data loss. Four cinder blocks, two with terra cotta and two with plywood, were placed at 0.55 m and the other four cinder blocks, two with terra cotta and two with plywood, were placed at 1.10 m. After one week, four cinder blocks were removed from the lake after two weeks the other four were removed. Each time, two from each depth were taken, one terra cotta and one plywood. After removing the substrates from the lake, we compared percent coverage of each major taxonomic algal division – diatom, green, and blue-green – to determine algal colonization and succession patterns.

Two small dissecting scope lights were used to illuminate each square and a hand-held 10x magnifying glass was used to ascertain algae coverage. Measurements were taken in square millimeters and classified as green algae, blue-green algae, or diatoms. Area and percent coverage were determined for each algal type individually and for all types combined. Data was collected on a total of sixteen plywood squares and fifteen tile squares; one tile was lost during the experiment when the silicone gel failed. A total of thirty-two concrete squares were used for data collection – including the concrete from the blocks with plywood as well as with terra cotta – to get the largest sample size possible.

After all measurements were taken for the eight cinder blocks, statistical tests were run in order to determine if there was significant correlation between depth, algal coverage, time submerged, and substrate types. To compare the differences in coverage between substrates, an ANOVA test was run, with the data split by depth (0.55 m and 1.10 m) and time submerged (1 week and 2 weeks). All following tests were run with only the data collected from the concrete squares due to a paucity of algal growth on tile and wood, as discussed below.

Three broad categories of algae were assigned: green algae, blue-green algae and diatoms. To compare the total percent algal coverage at the two depths, paired t-tests were run comparing algal coverage at 0.55 m and 1.10 m; the data was split by substrate type and time submerged. Additionally, paired t-tests were run to compare the total percent coverage for 1 week of submergence versus 2 weeks; the data was split by substrate type and depth. Each concrete square was scored as either having each separate type, given the code 1, or not, indicated by 0. Three chi-square tests were run, one for each algae type, comparing the presence or absence of the algae to time in the water. Independent t-tests were also run for each of the three types comparing mean percent coverage of each type to time submerged. Zero values were excluded from these independent t-tests.

*Results*

The ANOVA test yielded four categories: 0.55 m for 1 week, 0.55 m for 2 weeks, 1.10 m for 1 week and 1.10 m for 2 weeks, of which only the data for 1.10 m for 1 week were significant ($F=13.154$, $p < 0.001$), see Figure 1. For the paired t-tests assessing the significance of algal growth at the two depths, the data from one week were not statistically significant and neither were the data from two weeks. The paired t-tests comparing algal growth over one and two weeks of submergence did show statistical significance at the 1.10 m depth ($t=-2.525$, $df=7$, p<0.040), but not at the 0.55 m depth. The chi-square tests showed that the difference in coverage over time was only significant for the diatoms ($X2=14.545$, $p<0.001$), shown in Figure 2; change in coverage over time was statistically insignificant for both green algae and blue-green algae. The independent t-test for diatoms showed that the decrease in diatom coverage from week one (n=16, \`x=0.013 %) to week two (n=6, \`x=0.036) was significant (t=2.219, df = 20, p<0.038). The increase in green algae coverage from week one (n=16, \`x=0.142) to week two (n=15, \`x=0.296) was not significant. The coverage of blue-green algae nearly tripled from week one (n=15, \`x=8.819) to week two (n=11, \`x=23.016), but these results were not statistically significant either; the results from these independent t-tests are shown in Figure 3.

*Discussion*

The first null hypothesis, that there would be no difference in algal growth between substrata submerged at 0.55 m and 1.10 m, could not be rejected. This contradicts what was expected because algae are photosynthetic and require sunlight to survive. While the intensity of light is attenuated when it passes through the water column, the difference of only 0.55 m was not enough to dramatically change the amount of light reaching the substrates (WOW, 2011). The original experimental design, which had the blocks at 1 m and 2 m may have resulted in more significant results between the two, however the slope of the drop-off was prohibitive. In the future, a location that has a gentler slope may allow a greater variety of depth-based testing.

The second null hypothesis studied was that there would be no difference in algal growth on different types of substrata. In this case, the data was only significant at 1.10 m on those squares removed after one week. However, there was a notable trend in all four cases for concrete being more heavily colonized than wood and tile. Since algae require a rough surface for attachment, these results are logical. Terra-cotta tiles are very smooth, and were not conducive to colonization over such a short period of time, though an extended study may show algal growth. The plywood that was used in this study was rougher than the tile, though not as rough as the concrete. Algae colonization on plywood may require more time than was available as the surface is not as conducive to attachment as concrete. Additionally, the formaldehyde adhesives used in plywood manufacturing may have inhibited growth (Dorries, 2007). Because there was so little growth on either tile or wood, these were excluded from further analysis.

The final hypothesis was concerned with the difference in coverage between blocks removed after one week with blocks removed after two weeks. This paired t-test showed that the difference in coverage at 0.55 m was not significant and no apparent trend was observed. There was, however, a significant increase in mean coverage from week one squares to week two squares at 1.10 m. It was expected that both means would increase, so the lack of significance for the shallower depth may be due to a dip in air and water temperatures from June 1st to 5th, when surface temperatures plummeting from 66.39 to 60.82 degrees Fahrenheit in 24 hours (MMHL, 2012). The deeper depth may have avoided the damage from the cold because it was at a slightly more insulated depth. The differences in significance could also be due to small sample sizes and therefore replications should be made with more squares at both depths. A longer period of study could also decrease the influence of individual weather events.

Additionally, trends in relative abundance of the three algal types were observed. There was a significant decrease in the presence of diatoms, as well as a significant decrease in percent coverage by diatoms over time. While the data on the green and blue-algae were not statistically significant for either the presence or for the percent coverage, there was an obvious trend of an increase in blue-green algae coverage over time. The mean percent coverage by blue-green algae nearly tripled over time from one to two weeks, but the small sample sizes led to statistical insignificance. Typical algae succession progresses from rapidly colonizing species such as diatoms, followed by green algae and climaxing with the large blue-green species (Heinen, 2012). The initial high coverage by diatoms and the eventual increase in blue-green coverage is in line with this scenario. Even though the blue-green difference was not statistically significant, it was biologically significant and further investigation may yield enough data to result in statistical significance.

While the University of Michigan Biological Station owns much of the shoreline of Douglas Lake, there are areas that are developed by private homeowners; other similar northern Michigan lakes are even more heavily developed. Artificial structures such as docks, buoys and rafts, as well as litter or garbage dumped in the lakes, may serve as substrata for benthic algae. Determining if this is the case and at what rate algae colonize these materials may help researchers understand the formation of microenvironments within a lentic system that might not have otherwise formed.

Resources

Bellinger E. G. & Sigee, D. C. (1988). *Freshwater Algae: Identification and Use as Bioindicators*. Wiley-Blackwell, West Sussex.

Dorries, Simon. (2007). Formaldehyde emissions get EWPAA tick for safety. Engineered Wood Products Association of Australasia. Newstead, Queensland.

Heinen, J. (2012). Ecological Succession. Ecology and Evolutionary Biology: 381. University of Michigan Biological Station, Pellston.

Layne, C. D. (1990). The algal mat of Douglas Lake, MI: its composition, role in lake ecology and response to chemical perturbations. PhD thesis, University of Michigan, Ann Arbor.

Michigan Marine Hydrodynamics Laboratory. (2012). Ocean Engineering Laboratory Upper Great Lakes Observing System (U-GLOS). Pellston, Michigan.

Munson, L. H., Axler, R., Hagley, C., Host, G., Merrick, G. & Richards, C. (2004). Monitoring Minnesota Lakes on the Internet and Training Water Science Technicians for the Future - A National On-line Curriculum using Advanced Technologies and Real-Time Data. University of Minnesota Duluth and Lake Superior College, Duluth, Minnesota.

Stevenson, R. J., Bothwell, M. L. & Lowe, R. L. (1996). *Algal Ecology: Freshwater Benthic Ecosystems*. Academic Press, San Diego.

Figures

Figure 1. Shows the percentages of algal coverage on the different substrates. Results are split by depth as well as time. Tile and wood had little to no growth, resulting in their data being ignored for most analysis. Only the first column for each substrate, 0.55 m, week 1, showed statistical significance, though there was a trend towards higher concrete growth for all four categories.

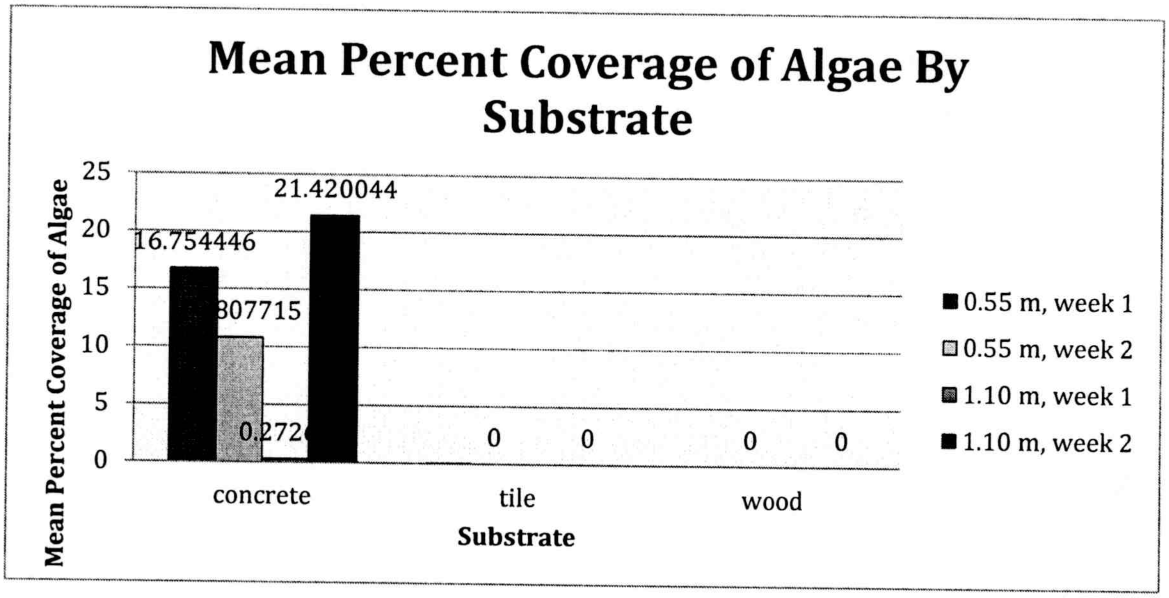



Figure 2. Shows the difference in presence/absence of diatom algae between the two weeks. Week 1 has presence on all sections, but Week 2 has multiple sections that lack diatom algal growth. The chi-square tests for the green algae and blue-green algae were insignificant.

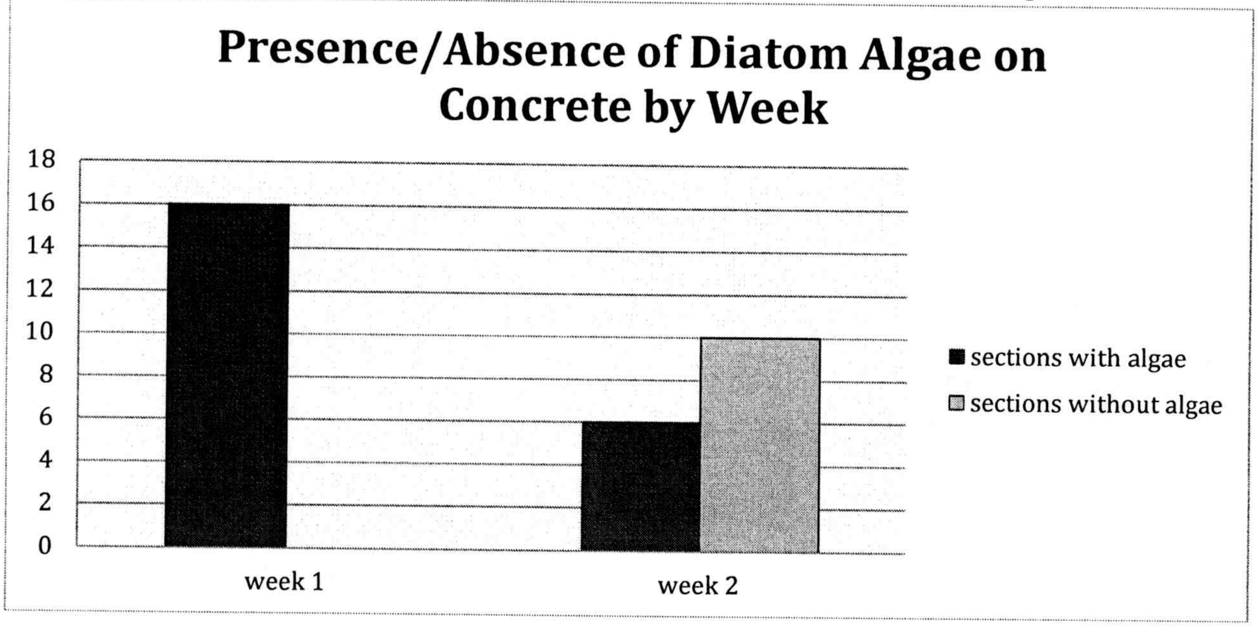
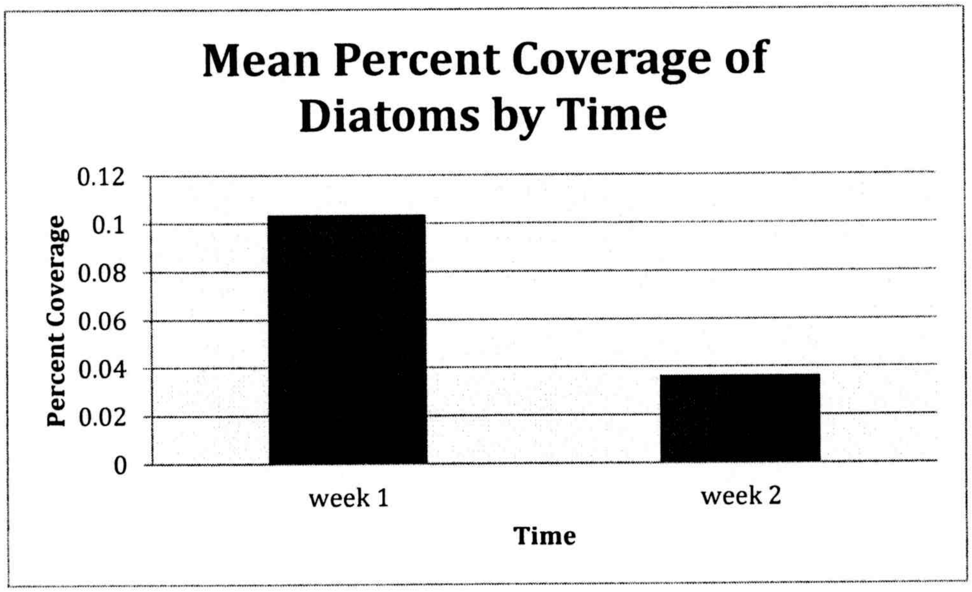
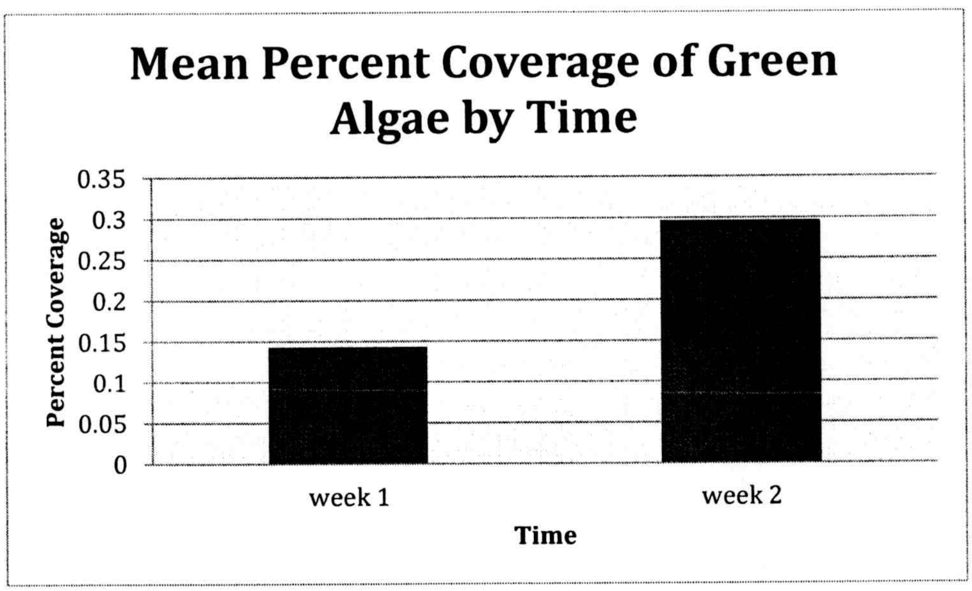


Figure 3. Shows the difference over time in mean percent coverage for each algal type on concrete, excluding zeros. The decrease in diatom coverage (3a) was significant, while the changes in green (3b) and blue-green (3c) were not. However, there is an obvious trend in blue-green algae increase that may be biologically relevant.

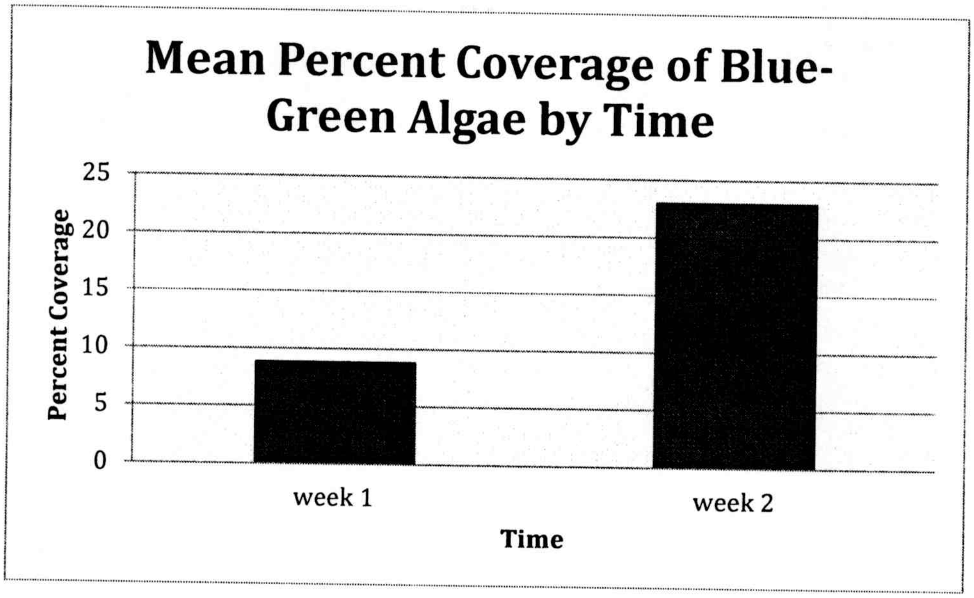



3a.




3b.

3c.


Mean Percent Coverage of Blue-Green Algae by Time
Percent Coverage
25
20
15
10
5
0
week 1
week 2
Time