Benthic Herbivory in Lake Littoral Zones

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Abstract

The role of grazing herbivores was examined at three sites in the littoral zone of Bay Lake in the upper peninsula of Michigan. Clay tiles were used as artificial substrates for algal and invertebrate colonization. Grazer-exclusion treatments involved raising tiles above the substratum thereby eliminating access by grazing benthic invertebrates.

Significant differences between grazed and ungrazed plots were observed on only one of three sampling dates. On day 44 of the seven week study, the average chlorophyll a concentration on the grazed tiles was higher than that on the ungrazed tiles at site 3. Also on day 44, algal biomass on the grazed tiles was higher than on the ungrazed tiles at site 2. Algal community structure was indirectly influenced by invertebrate and vertebrate predation on herbivores as well as grazing activity by small fish. Odonata, predaceous chironomids (Diptera chironomidae), largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieui), bluegill (Lepomis macrochirus), and pumpkinseed (Lepomis gibbosus) eliminated small invertebrates while immature bluegill and perch were involved in grazing activity.

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Introduction

Biomass produced by algal communities forms the trophic base of the overlying food chain within an aquatic habitat. Thus, factors which affect algal growth ultimately have a profound impact on the trophic structure of an aquatic ecosystem. This study examined the influence of herbivores on algal growth.

Grazer-exclusion plots have been used to analyze the influence of herbivore activity on algal colonization. Cubit (1984) found that grazing by limpets reduced algal cover in control plots as compared to experimental plots. Lamberti and Resh (1983) conducted a study to assess the interactions between a herbivore and its periphyton food source. They reported a higher algal biomass on ungrazed tiles compared to grazed tiles.

Streams have been the primary focus for examining the effect of grazing herbivores on freshwater algal communities. Georgian and Wallace (1983) concluded that grazers play an important role in virtually all streams of intermediate size. Some studies have been conducted in lakes to examine the influence of grazers on their food resources. In a study in Lake Memphremagog (Canada), Cattaneo (1990) concluded that grazers probably contributed to the decline of periphyton in sites exposed to wave action. Similarly, in a study conducted in Lake Kasumigaura, Japan, a sharp decline in epiphytic algae was explained by the grazing of chironomids (Aizaki et al. 1990).

This study was designed to look at the influence of grazer activity on algal colonization within the littoral zone of a lake. The littoral zone extends from the edge of the water to the depth point at which sunlight no longer reaches the benthic region. The objective of the study was to determine the importance of herbivory in structuring algal communities. This experiment concentrated on the effects of grazers on algal biomass, chlorophyll a concentration, and algal composition in grazed versus ungrazed plots.

Materials and Methods

The effects of abiotic factors and herbivory on algal colonization in the littoral zone of a lake were studied using clay tiles as artificial substrates. In a study in Big Sulphur Creek, California, Lamberti and Resh (1983) observed that algae grew and colonized on clay tiles much as they did on natural stream rocks.

The seven week study was conducted in Bay Lake at the University of Notre Dame Environmental Research Center, Gogebic County, Michigan. Three sites were established within the littoral zone of the lake. Site 1 was unshaded, wind-exposed and had a flocculent muck substrate. Dense populations of macrophytes were present at this site. This site was located within a cove area of the lake. Site 2 was in a shaded area in the same cove as site 1. Site 2 also was exposed to the

wind with a similar flocculent muck substrate. This site was populated by vegetation similar to site 1. Site 3 was unshaded and exposed to the wind. In contrast to sites 1 and 2, site 3 possessed a cobble substrate with no significant macrophyte population.

Two plots were established at each site, one control (grazed) plot and one experimental (ungrazed). Each plot was constructed by placing twelve clay tiles on plastic-coated fencing. The edges of the fencing were folded over to secure the tiles in place. The fencing was attached to four rebar stakes using electric fence insulators. The grazed plots were constructed by laying the fencing on the sediments and pounding the rebar stakes into the sediments. The ungrazed plots were constructed by elevating the fencing to approximately 50 cm above the sediments and pounding the rebar into the sediments. The control and exclusion plots at each site were placed side by side to make conditions as uniform as possible.

Sampling was conducted on three occasions during the eight week study period. Samples were taken on days 14, 28, and 44 of the colonization period. On each sampling date, three tiles were chosen randomly from each plot. Each tile was placed in a clear plastic bag, and then put into a styrofoam cooler until all sites had been sampled. Upon immediate return to the laboratory, the styrofoam cooler was placed in a refrigerator. Within 24 hours, each tile was scraped with a razor blade and the material was dispersed in 45 ml of water. This volume was then separated into three portions. The three portions were used to determine algal biomass (dry weight), chlorophyll a concentration, and algal composition. Portions used for biomass measurements and chlorophyll a determinations were filtered onto GF/F glass fiber filters. The portion used for biomass was filtered onto filter paper, wrapped in aluminum foil, and placed in the freezer. All biomass samples were returned to the University of Notre Dame at the end of the study period. The samples were dried in an oven at 60^0 C for 24 hours, then allowed to cool for another 24 hours before being weighed. The portion of the sample used for chlorophyll a measurement was filtered onto a GF/F glass fiber filter, placed in a film canister, and put into the freezer. Following freezing for a minimum of 24 hours, 25 ml of MeOH was added to each canister and the samples were refrigerated for 24 hours. A Turner 112 fluorometer was used to determine chlorophyll a concentration of the samples. The portion of each sample used for algal identification and enumeration (5 ml of the 45ml sample volume) was placed in a vial and preserved using formalin. Algal taxa were identified to division and counted by making passes on a Sedgwick-Rafter cell using a compound microscope. All algal counts are presented as numbers/ml.

Statistical analyses were performed using SYSTAT whereas graphical

output was generated using SYGRAPH.

Results

A. Algal biomass:

ANOVA results for algal biomass differences between treatments regardless of date showed no significant treatment effects at sites 1, 2, or 3. Table 1 illustrates Tukey results for algal biomass differences between treatments at site 2. A significant difference between treatments was noted at site 2 on day 44 of colonization; (p=.041, Tukey). On this date, the ungrazed plot had an average biomass less than that of the grazed tiles (Figure 1). {Place Figure 1 Here}

B. Chlorophyll a :

ANOVA results for differences in chlorophyll a concentrations between treatments regardless of date showed no significant differences at any site. Table 2 shows Tukey results testing the difference in chlorophyll a between treatments on at site 3. At site 3, after 44 days of colonization, a significant difference was noted between grazed and ungrazed plots (p=.040,Tukey). After 44 days of colonization, the ungrazed plot at site 3 had a lower average chlorophyll a concentration than the grazed plot (Figure 2). {Place Figure 2 Here}

C. Algal density:

Table 3 illustrates Tukey results comparing the counts of three different taxa of algae [bluegreens (Cyanophyta), diatoms (Chrysophyta), and green algae (Chlorophyta)] at site 1. A significant difference was noted between numbers of bluegreens and diatoms (p=.027). There was also a significant difference between numbers of bluegreens and numbers of green algae (p=.020). Figure 3 shows that at site 1, the density of bluegreens was higher than that of both diatoms and green algae. {Place Figure 3 Here} No significant differences were noted at sites 2 or 3. ANOVA results examining the composition of algal assemblages between treatments showed no significant differences.

Discussion

The objective of this experiment was to investigate the effect of grazing herbivores on algae in the littoral zone of a lake. Sites were placed in one lake to avoid any inter-lake variability which could confound the experimental results. Each site differed in one major abiotic variable (i.e. amount of sunlight or substrate type) so the effect of grazers could be observed under various conditions.

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At site 2 after 44 days of colonization, the grazed plot had higher algal biomass than the ungrazed plot. The reduced amount of algal biomass on the raised tiles suggests the presence of grazers. This contradicts the original hypothesis that grazers only exert an influence below a specific level in the water column. At site 2 vegetation populated the area around the raised plot. Invertebrates were frequently noted on the raised tiles. It is likely that they dropped onto the raised tiles from nearby vegetation or climbed up the rebar stakes to reach the raised tiles (Lamberti and Resh 1983). While the reduced amount of algae on the raised plot suggests the presence of grazers, the higher algal biomass on the control plot suggests a minute grazer effect. One possible explanation for this result is the presence of predators. Predatory invertebrates, specifically Odonata and predaceous chironomids (Diptera Chironomidae), were noted in the area of site 2. It is likely that these predators fed on small invertebrates that would otherwise have grazed on the control plot (Westfall 1984, Loffman and Ferrington 1984). Vertebrate predation on herbivorous insects also likely influenced the growth of algae. Largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieui), bluegill (Lepomis macrochirus), and pumpkinseed (Lepomis gibbosus) inhabit Bay Lake. These fish feed on aquatic insects, thereby eliminating potential grazing activity by the insects (Becker 1983).

After 44 days of colonization at site 3, a significant difference was noted between treatments. The ungrazed tiles had a lower chlorophyll a concentration than the grazed tiles. At this site, substantial numbers of damselfly exuviae were stuck to the rebar stakes. Similar to the situation at site 2, the presence of these invertebrates offers a possible explanation for lower chlorophyll a readings on the raised plots. Grazing activity by small fish could also explain the low chlorophyll a concentration on the raised plots. Schools of immature fish, particularly bluegill, frequently were noted at site 3. Immature bluegill are known to consume a small amount of filamentous algae, thus influencing chlorophyll a concentration of algal assemblages (Becker 1983). Furthermore, bluegill are known to prey on herbivorous aquatic insects which would have fed on the control tiles (Becker 1983).

Site 1 displayed no significant differences between treatments for biomass, chlorophyll a concentrations, or algal taxa. It is suggested that the lack of significant results is not due to a lack of grazer activity, but rather to high variability and the influence of predators at this site. Nuphar and Sparganium both populated the area of site 1. During the seven week study period, stands of both species both grew in size and increased in number. Nuphar have especially large leaves that could cause a shading effect resulting in low levels of biomass

and chlorophyll a. The results showed no significant differences in total biomass or chlorophyll a concentrations between sites 1 and 2. The two sites differed in the amount of sunlight they received. Because of the comparable results, it is likely that the Nuphar formed a cover that limited the amount of sunlight at site 1.

Immature fish, specifically bluegill and pumpkinseed, were frequently observed at site 1. The fish likely fed on grazing herbivores, resulting in substantial variability (Becker 1983). Immature bluegill and pumpkinseed are known to consume a small amount of filamentous algae, thereby exerting a minute grazing effect (Becker 1983). Site 1 was also a popular fishing site. Because of the flocculent sediment, increased activity at this site would easily stir up sediment in the area of the tiles resulting in variable results.

Although results were variable, the presence of grazing activity in this experiment is still noteworthy. On day 44, the raised tiles at both sites 2 and 3 showed some evidence of grazers. Grouping treatments together, there was a significant difference between amounts of bluegreen and other taxa of algae at site 1. Bluegreens were evidently dominant as compared to greens and diatoms. Because bluegreens typically are the least edible form of algae, the fact that diatoms and green algae were lower in number supports the hypothesis of grazer activity.

At the onset of this study, the intent was to look at the effects of grazing activity of herbivorous insects on littoral zone algal assemblages. However, results from this experiment clearly include invertebrate and vertebrate predation effects on herbivores as well as grazing activity by small fish.

A major source of variability in this study can be attributed to incomplete exclusion of grazers at the experimental plots. Insects could have reached the raised tiles by climbing up the rebar stakes or crawling from nearby vegetation. Also, at site 3 wave action was sufficient to provide a mechanism for the grazers to reach the raised tiles. To decrease the variability of a follow-up study, more complete exclusion at an experimental plot needs to be achieved. It is suggested that a set-up similar to the one used by Lamberti and Resh (1983) in Big Sulphur Creek, California be constructed. Their design used an arching bar that protruded above the water surface to eliminate the possibility for insects to crawl up to the raised tiles. A follow-up study should extend for at least one more sampling date since significant results began to be noted on the last sampling date. Furthermore, a future experiment needs to examine the effects of fish predation on insects. Each site could consist of two sets of plots with each set containing one ungrazed and one grazed plot. One set would be excluded from fish activity while the other would allow for the normal presence of fish. Through this method, the

effects of grazing herbivores could be examined in an isolated setting. In addition, the influence of fish predation in structuring algal assemblages could be evaluated.

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Table 1. Tukey results
Biomass differences between treatments
Site 2.

Odd numbers= ungrazed tiles
Even numbers= grazed tiles
Day 14 =1,2 day 28 =3,4 day 44 =5,6

	1	2	3	4	5	6
1	-					
2	NS	-				
3	NS	NS	-			
4	NS	NS	NS	-		
5	NS	NS	NS	NS	-	
6	NS	NS	NS	NS	.041	-

NS= not significant

Table 2. Tukey results
Chlorophyll a
Site 3.

Odd numbers= ungrazed tiles
Even numbers= grazed tiles
Day 14= 1,2 day 28= 3,4 day 44=3,4

	1	2	3	4	5	6
1	-					
2	NS	-				
3	NS	NS	-			
4	NS	NS	NS	-		
5	NS	NS	NS	NS	-	
6	NS	NS	NS	NS	.040	-

NS= not significant

Table 3. Tukey results
Algal species counts
Site 1.

Bluegreen= 1.
Diatom= 2.
Green= 3.

	1	2	3
1	-		
2	.027	-	
3	.020	NS	-

NS= not significant

Figure 1. Algal Biomass: site2, day 44.

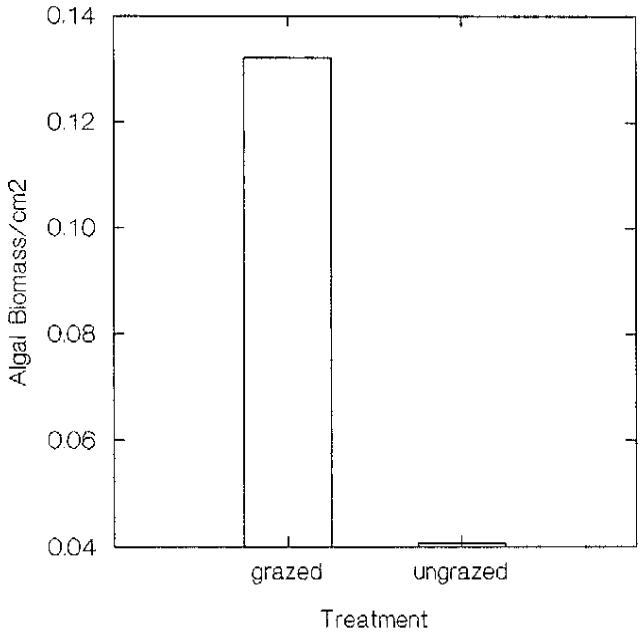

Figure 2. Chlorophyll a: site3, day 44.

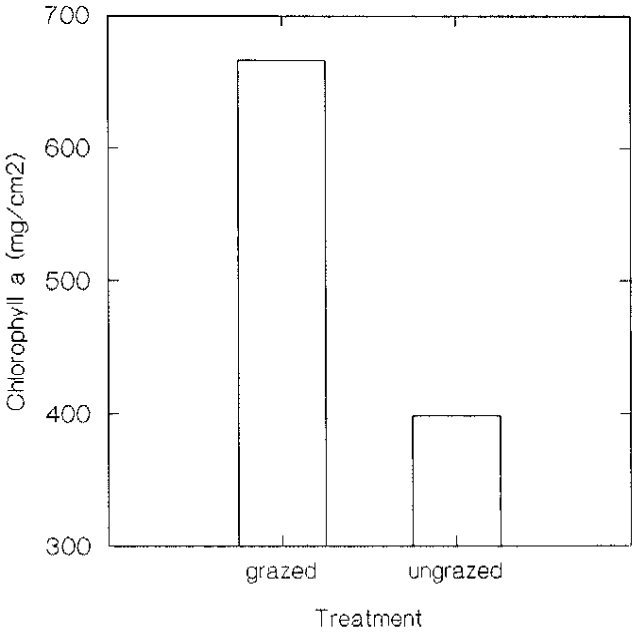

Figure 3. Density of Algal Taxa: site 1.