

Inter- and Intra-Lake Patterns
of Algal Colonization and
Community Structure

Karyn Siemasko

St. Mary's College, Notre Dame, Indiana 46556

ABSTRACT. Clay tiles were used as artificial substrates to observe benthic and planktonic algal colonization patterns in the littoral zones of two lakes.

In summary, some algal colonization patterns differed between the benthic and water column areas in each lake. Cyanophyta increased through the summer on the elevated plots, Chlorophyta was present in higher numbers on the elevated plots compared to that of the bottom plot, and Pyrrophyta was only found on two of the elevated plots. For Bay Lake, which is considered a meso-eutrophic lake, Dinobryon was the dominating chrysophyte. In Morris Lake, a eutrophic lake, Fragilaria was the chrysophyte that dominated. Physical and chemical factors may have influenced the colonization patterns within these lakes.

Key words: Chrysophyta, littoral zone, algae, colonization, Chlorophyta.

INTRODUCTION

Aquatic habitats (marine and freshwater) compose about 70% of the earth's surface and algae within these environments serve as important primary producers. The ability of algal assemblages to produce biomass will control the rest of the trophic chain within a given habitat (Lamberti et al., 1989). As primary producers within a lake, algae ultimately support all other aquatic life. Water depth and movement, surrounding terrestrial vegetation, herbivory, climatic conditions, and littoral zone water chemistry will regulate the type of algae able to colonize substrates such as rocks and plants. (Round, 1965). Light and temperature play a definitive role in algal colonization but it has been difficult to separate the effects of these two factors (Whitford, 1959).

A lentic environment contains algae in three different life forms: benthos, periphyton, and phytoplankton. Benthos refers to algae growing on the bottom substrate. Periphytic algae attach to vegetation and rocks within the littoral zone and phytoplankton float in the water column.

This study examined algal colonization within the littoral zones of two lakes. The littoral zone can be defined as the region of a lake extending from the water's edge to the maximum depth of rooted vegetation. A large percentage of algae in the littoral zone is represented by periphyton, mostly desmids and diatoms (Lee, 1989).

The littoral algal community can be classified into three different types of algae. First, some algae are macroscopic and are found in the bottom substrate (eg. Nitella). Second, Spirogyra and Mougeotia are non-motile microscopic algae often found at the surface of the sediment. The third type of littoral zone algae are motile microscopic algae such as diatoms, desmids, flagellates, and filamentous and thalloid cyanophytes which can be found on the sediment surface. (Round, 1965).

In an experimental study, Lamberti et al. (1989) found that at all irradiances tested, algal assemblages in laboratory streams were colonized by diatoms during the first nineteen days of exposure. Robinson and Dickerson (1987) stated that an ecological community initially is not complex, and after a mature state has been reached it will not remain static. Succession in algal assemblages is often determined by seasonal productivity and species composition (Whitford, 1959). One explanation for algal succession is that one species makes a habitat more suitable for another (Robinson and Dickerson, 1987).

The objective of this experiment was to answer fundamental questions concerning intra- and inter-lake algal colonization patterns. First, is there a difference between algal colonization and chlorophyll a in two areas of the same lake? Second, what differences in algal colonization and chlorophyll a can be attributed to different lake habitats? Third, what factors may be responsible for the

similarities and differences in algal colonization patterns and chlorophyll a between and within a lake?

METHODS AND MATERIALS

The colonization patterns of benthic algae and littoral zone planktonic algae in lakes were determined by using clay tiles (15cm x 15cm) as artificial substrates. The tiles were soaked in lake water for seven days before being used to eliminate any processing chemicals or residue that may have been present. In a pilot study in Big Sulphur Creek, Lamberti and Resh (1983) found that grazer colonization and algal growth on tiles was comparable to that on natural stream rocks.

An eight-week study was conducted in two lakes (Morris Lake and Bay Lake) at the University of Notre Dame Environmental Research Center, Gogebic County, Michigan. Bay Lake has a surface area of 60 ha. and a littoral zone macrophyte community dominated by Nuphar. Morris Lake is smaller than Bay Lake and has a surface area of 4.9 ha. The littoral zone of this lake has more extensive algal and macrophyte growth than Bay Lake. Massive beds of Nitella as well as Nuphar were present. Morris Lake has a higher pH than Bay Lake, as well as a much greater alkalinity and lower secchi disk reading (Tables 2,3).

Two benthic control plots were established at two sites in the littoral zone of the two study lakes. A plot was

constructed by placing twelve tiles on plastic-coated fencing (dimensions of fencing = 100cm x 50cm). The sides of the fencing were folded so the tiles would not be moved by wave action. To further prevent movement of the tiles, metal clips were used to attach tiles to the fencing. Six to eight steel electric fence posts were driven into the lake bottom. The fencing was attached to these posts by electric fence insulators. An elevated experimental plot was constructed by raising the tile and fence arrangement above the lake bottom. Both non-elevated and elevated plots were placed side-by-side so that conditions were as uniform for both plots as possible. Site 1 was located in Bay Lake in an area characterized by an abundance of snag habitats. Tall trees lined the shore. The tall trees may have had some effect on the light levels. Site 1 consisted of the tiles on the lake bottom and the elevated tiles which were 34 cm from the lake bottom. Site 2 was located directly across from site 1 on the other side of that arm of Bay Lake. Site two consisted of the tiles on the lake bottom and the elevated tiles which were 50 cm above the lake bottom. The site two area received a lot of wave action as evidenced by increased siltation of the bottom tiles. Snag habitats were buried deep in the sediments. Site 3 was located in Morris Lake in an area where the shore was lined with short shrubs. Site 3 consisted of the tiles on the lake bottom and the elevated tiles which were 58 cm above the lake bottom. A fish nest was located adjacent to site 3. Site 4 was also located in

Morris Lake but this site was placed close to a stand of tall grass that was growing along the shore line. Site 4 consisted of tiles on the lake bottom and the elevated tiles which were 28 cm above the lake bottom. Three tiles were chosen randomly from each plot every two weeks

Three random tiles were collected biweekly from each plot. Tiles from Bay Lake were collected on 12 June, 25 June and 9 July, 1990. Tiles from Morris Lake were collected on 13 June, 26 June, and 10 July, 1990. Three scrapes with a razor blade were taken from each tile. These scrapes were used to determine (1) algal biomass (dry weight), (2) chlorophyll a concentration, and (3) algal species composition. The dry weight was obtained by allowing the sample to dry for 72 hours prior to weighing. Chlorophyll a was measured using a Turner 112 fluorometer. The chlorophyll a sample was filtered onto a 6F/F glass fiber filter, folded in half, and placed in an empty film canister and frozen for one hour to lyse the algal cells. Following freezing, 25ml of MeOH was added and the sample was refrigerated for 24 hours prior to fluorometric determination (McKay, 1990). For algal identification samples, a 1:10 dilution was made and 0.5% of the final volume of glutaraldehyde was added as a preservative. Algae were identified and counted by making three passes on a Sedgewick-Rafter cell under a compound microscope. Once all data were gathered and recorded, a chi-square analysis on the counts of the four major algal groups was performed

using MINITAB. This test was used to determine if there were differences in algal species composition in the various habitats. Using SYSTAT, chlorophyll a readings were analyzed by two-way analysis of variance using treatment and time as the independent variables.

RESULTS

I. Algal colonization on elevated plots.

Two weeks after the artificial substrates were placed into the lakes, all tiles were dominated by chrysophytes (Figures 1-8). The null hypothesis that there was no significant interaction between time and algal counts for the elevated tiles at site 1 (Figure 1) could be rejected ($\chi^2 = 205.3$, $df = 6$, $p < 0.005$). Between weeks 2 and 4, there was an increase in Chlorophyta, a noted decline in Chrysophyta counts, and an overall increase in Cyanophyta. Dinobryon was the dominant chrysophyte during all three sampling periods.

Figure 2 represents the algal colonization for the elevated tiles at site 2. There was a significant (chi-square = 397.29, $df=6$, $p < 0.005$) association between algal counts and time. A large increase in Chlorophyta from the first sampling period to the second likely contributed to the chi-square value. Two other factors influencing the chi-square value were the increase in Cyanophyta over the six week study period and a decrease in Chrysophyta between

the second and third sampling periods. Dinobryon was the dominant Chrysophyta during all three time periods.

The null hypothesis that there was no significant interaction between time and algal counts for the elevated tiles at site 3 in Morris Lake (Figure 3) can be rejected (chi-square = 198.32, df=8, $p < 0.005$). An increase in Cyanophyta during the study period was observed. Chrysophyta decreased between the 14th and 28th day but increased again by the 42nd day. Chlorophyta steadily increased in numbers over the six week period. It should be noted that Pyrrophyta was also present at all three times on this plot. Fragilaria and Tabellaria were the dominant chrysophyte genera for the first two weeks. However, by the end of the sixth week Frustulia had become the dominant chrysophyte.

For the elevated tiles at site 4 in Morris Lake (Figure 4), the null hypothesis that there was no significant interaction between time and algal counts was rejected (chi-square = 203.65, df=6, $p < 0.005$). Chlorophyta and Cyanophyta showed dramatic increases between 14 and 28 days. Fragilaria was the dominant chrysophyte at this site.

Within Bay Lake, Chlorophyta had almost identical colonization patterns at sites 1 and 2 for the elevated tiles (Figures 1 and 2) characterized by increasing and then slightly decreasing numbers. In both sites at Morris Lake, Chlorophyta increased over the six week period. Figures 3 and 4 illustrate that the chrysophyte population followed the same colonization patterns at both sites in the

lake. Cyanophyta increased during the study period on all four of the elevated plots.

II. Algal colonization on bottom plots.

Figure 5 presents algal colonization data in Bay Lake for the non-elevated tiles at site 1. The null hypothesis that there was no significant interaction between time and algal counts was rejected (Chi-square = 75.91, $df = 4$, $p < 0.005$). At this site, Chlorophyta showed a gradual increase over the study period. Chrysophyta decreased in number between 14 and 28 days and then showed an increase after 42 days. Dinobryon was the dominant chrysophyte for all three sampling periods.

Figure 6 presents algal colonization data in Bay Lake for the bottom tiles at site 2. With a chi-square value of 76.23 ($df=6$, $p < 0.005$) the null hypothesis that there was no significant interaction between time and algal counts was rejected. At this site, Chlorophyta showed a slight increase and then a decrease in numbers, while Chrysophyta decreased in numbers between 14 and 28 days. Dinobryon was the dominant chrysophyte for the first 14 days. By day 42, Tabellaria and Dinobryon were the co-dominant chrysophytes.

In Morris Lake at site 3 (figure 7) the null hypothesis that there was no significant interaction between time and algal counts was rejected (chi-square = 145.52, $df=20$, $p < 0.005$). Chlorophyta had a growth pattern similar to the growth pattern that was observed in Bay Lake on the bottom

tiles at site 3 (Figure 6). However, Chrysophyta remained relatively constant over all times. Fragilaria was the dominant Chrysophyte for all three sampling periods.

The null hypothesis that there was no significant interaction between time and algal counts was also rejected for site 8 (chi-square = 843.57, df=16, p 0.005). Synedra dominated for the first 14 days, but after 42 days Frustulia and Fragilaria became dominant.

The only similar pattern seen for the bottom plots in both lakes was the initial increase and later decrease of Chlorophyta except at site 1 in Bay Lake. One notable comparison between the elevated and non-elevated plots is that the Chlorophyta are present in lower numbers on non-elevated plots.

III. Chlorophyll a readings.

Table 1 presents the ANOVA results for the chlorophyll a readings. There was a significant difference (p=0.005) for time at site 1 in Bay Lake. There was no significant interaction (p=.486) between treatment and time. Figure 9 illustrates chlorophyll a readings for this site. At the bottom plot, the chlorophyll a reading was 0.03ug/cm² for days 14 and 28 and 0.25ug/cm² at day 42. The chlorophyll a readings increased over time from 0.03 ug/cm² to 0.42ug/cm² at the elevated plot.

Site 2 in Bay Lake showed significant changes in chlorophyll a for both treatment and time (p=0.000), as well

as a significant interaction between treatment and time ($p=0.000$; Table 1). Chlorophyll a at all three time periods of the non-elevated plot remained at about 0.03 ug/cm^2 (Figure 10). On the elevated plot the chlorophyll a reading varied from 0.03 ug/cm^2 at day 14 to 0.6 ug/cm^2 at day 42.

Treatment ($p=0.010$), time ($p=0.023$), and the interaction between treatment and time ($p=0.010$) all had a significant effect on chlorophyll a at site 3 in Morris Lake (Table 1, Figure 11). For site 4 in Morris Lake, the only significant effect was for time ($p=0.014$; Table 1; Figure 12).

DISCUSSION

There are several questions which were addressed in this study. First, does algal colonization differ between two different areas of a lake? Second, what effect do different factors have on algal colonization? Finally, what factors may be responsible for the similarities and differences between and within lakes?

Experimental conditions

It should be noted that this experiment began as an investigation of grazer effect on benthic algae within the littoral zone of a lake. However, insect densities were insufficient for statistical analysis.

Chrysophytes dominated all sites in both lakes over the entire six week period. According to Whitford (1959), Chrysophyta are somewhat indifferent to light. However, he does suggest that they may respond to high light intensities if other conditions are ideal. One possible explanation for the dominance of chrysophytes in these lakes may be that, in general, diatoms are considered to be more abundant in northern latitude lakes (Whitford, 1959).

In Bay Lake, Dinobryon dominated both elevated plots during the first four weeks. However, Fragilaria was the dominant chrysophyte in Morris Lake. A possible explanation for the difference in dominant algae could be that biological and chemical factors interact within a lake. This interaction may influence what algal species will colonize (Hutchinson 1944, Robinson and Dickerson 1987, Connell and Statyer 1977). Bay lake is considered to be a meso-eutrophic lake while Morris Lake is eutrophic. Also, Morris Lake had a large bed of Nitella in the littoral zone. Bay Lake had scattered beds of Nuphar in the areas being sampled. It is suggested that the physical and chemical environment may be influencing whether Dinobryon or Fragilaria will dominate.

Cyanophyta increased over the six week period on the elevated plots in both lakes but not on the bottom plots. Cyanophyta may be responding to higher temperatures in the water column (Whitford, 1959).

Chlorophyta counts on the elevated plots were almost twice as high as those on the bottom plots. Green algae have

been found to prefer high light levels (Whitford, 1959). A possible explanation for this may be grazing by invertebrates, but this would have to be investigated further. Lamberti and Resh (1983) showed that grazed periphyton contained a well-developed diatom layer. In contrast, the ungrazed periphyton changed from diatoms to filamentous green algae.

The chlorophyll a levels on the elevated tiles at all four sites increased during the 42 day period. At sites 1 and 4, the non-elevated tiles showed an increase in chlorophyll a as well. A significant interaction between treatment and time occurred at sites 2 and 3. At site 2, silt was observed to have accumulated on the non-elevated tiles. This silt may have caused some shading, preventing light to reach the benthic algae. A possible explanation for the interaction between treatment and time at site 3 may be possible shading from the extensive growth of Nuphar which grew over the non-elevated tiles at this site.

In Morris Lake, the non-elevated tiles at both sites 3 and 4 showed an interesting pattern (Figures 11, 12). From day 14 to day 28, the chlorophyll a increased. From day 28 to day 42 the chlorophyll a decreased. It is possible that grazers may have an influence on benthic algae chlorophyll a levels but this will have to be further investigated at another time.

As a future extension to this experiment, it is important to examine the effect grazers have on benthic

algae to see if grazers have a significant effect on algal succession. Such a study should place benthic tiles close to the shore so that sediment and insects are not disturbed. In collecting tiles, it may be best to snorkel and use a net to prohibit loss of insects. An Ekman grab sample should be taken at each site on sampling days to get a representation of the insects present within the sediments throughout the study period.

In the future, it would be best to work with one lake at a time until more information has been obtained. More than three tiles should be sampled from each site during each sampling period to yield more reliable statistical results. Several sampling areas should be established in the lake so that results can be compared. Furthermore, a future study needs to be longer than six weeks. It would be interesting to follow the algal succession patterns from the beginning to the end of the summer.

ACKNOWLEDGMENTS

I thank Dr. Jensen and Dr. Berg for ideas and advice concerning this study. This research was supported by an endowment given to the University of Notre Dame by Mr. and Mrs. Hank.

Literature Cited

- Connell, J., and R. Statyer. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. *American Naturalist* 111: 1119-1144.
- Fritsch, F. 1931. Some aspects of the ecology of fresh-water algae. *J.Ecol.* 19:233-272.
- Grover, J. 1988. Dynamics of competition in a variable environment: experiments with two diatom species. *Ecology* 69:408-17.
- Hawkins, C., and J. Furnish. 1987. Are snails important competitors in stream ecosystems? *Oikos* 49:209-220.
- Hutchinson, G. 1944. Limnological studies in Connecticut. VII. Examination of the supposed relationship between phytoplankton periodicity and chemical changes in lake waters. *Ecology* 25:3-26.
- Lamberti, G., S. Gregory, L. Ashkenas, A. Steinman, and C. McIntire. 1989. Productive capacity of periphyton as a determinant of plant-herbivore interactions in streams. *Ecology* 70:1840-56.
- Lamberti, G., and V. Resh. 1983. Stream periphyton and insect herbivores: An experimental study of grazing by a caddisfly population. *Ecology* 64:1124-1135.
- Lee, R. 1989. *Phycology*. Second edition. Cambridge University Press. Cambridge, England.
- McKay, N. 1990. Chlorophyll-a analysis. In P. Soranno, ed. *Methods of the cascading trophic interactions project*. Center for Limnology, Madison, Wisconsin.
- Peterson, C., and K. Hoagland, and R. Stevenson. 1990. Timing of wave disturbance and the resistance and recovery of a freshwater epilithic microalgal community. *J.North Am. Benthol. Soc.* 9(1):54-67.
- Robinson, J., and J. Dickerson, Jr. 1987. Does invasion sequence affect community structure? *Ecology* 68:587-595.
- Round, F. 1965. *The biology of the algae*. University of Bristol. St.Martin's Press, New York.
- Strom, K. 1924. Studies in the ecology and geographical distribution of fresh-water algae and plankton. *Rev. Algol.* 1:127-155.

- Taafe, C. 1990. A chemical analysis of three adjacent lakes with contrasting fish populations. U.N.D.E.R.C. Project Report.
- U.N.D.E.R.C. 1990. Guide to U.N.D.E.R.C. University of Notre Dame Environmental Research Center, Notre Dame, IN.
- Whitford, L. 1959. Ecological distribution of fresh-water algae. In C. Tryon, Jr., and R. Hartman, eds. The ecology of algae. University of Pittsburgh. Edward Brothers, Inc. Ann Arbor, Michigan.

Figure Legends

Fig. 1. Abundance of different periphyton taxa collected from elevated tiles at site 1, Bay Lake on 12 June, 25 June, and 9 July, 1990.

Fig. 2. Abundance of different periphyton taxa collected from elevated tiles at site 2, Bay Lake on 12 June, 25 June, and 9 July, 1990.

Fig. 3. Abundance of different periphyton taxa collected from elevated tiles at site 3, Morris Lake on 13 June, 26 June, and 10 July, 1990.

Fig. 4. Abundance of different periphyton taxa collected from elevated tiles at site 4, Morris Lake on 13 June, 26 June, and 10 July, 1990.

Fig. 5. Abundance of different periphyton taxa collected from non-elevated tiles at site 1, Bay Lake on 12 June, 25 June, and 9 July, 1990.

Fig. 6. Abundance of different periphyton taxa collected from non-elevated tiles at site 2, Bay Lake on 12 June, 25 June, and 9 July, 1990.

Fig. 7. Abundance of different periphyton taxa collected from non-elevated tiles at site 3, Morris Lake on 13 June, 26 June, and 10 July, 1990.

Fig. 8. Abundance of different periphyton taxa collected from non-elevated tiles at site 4, Morris Lake on 13 June, 26 June, and 10 July, 1990.

Fig. 9. Chlorophyll a ($\mu\text{g}/\text{cm}^2$) for site 1, Bay Lake collected on 12 June, 25 June, and 9 July, 1990. Bars represent \pm one standard error.

Fig. 10. Chlorophyll a ($\mu\text{g}/\text{cm}^2$) for site 2, Bay Lake measured on 12 June, 25 June, and 9 July, 1990. Bars represent \pm one standard error.

Fig. 11. Chlorophyll a ($\mu\text{g}/\text{cm}^2$) for site 3, Morris Lake measured on 13 June, 26 June, and 10 July, 1990. Bars represent \pm one standard error.

Fig. 12. Chlorophyll a ($\mu\text{g}/\text{cm}^2$) readings for site 1, Morris Lake measured on 13 June, 26 June, and 10 July, 1990. Bars represent \pm one standard error.

Figure 1.

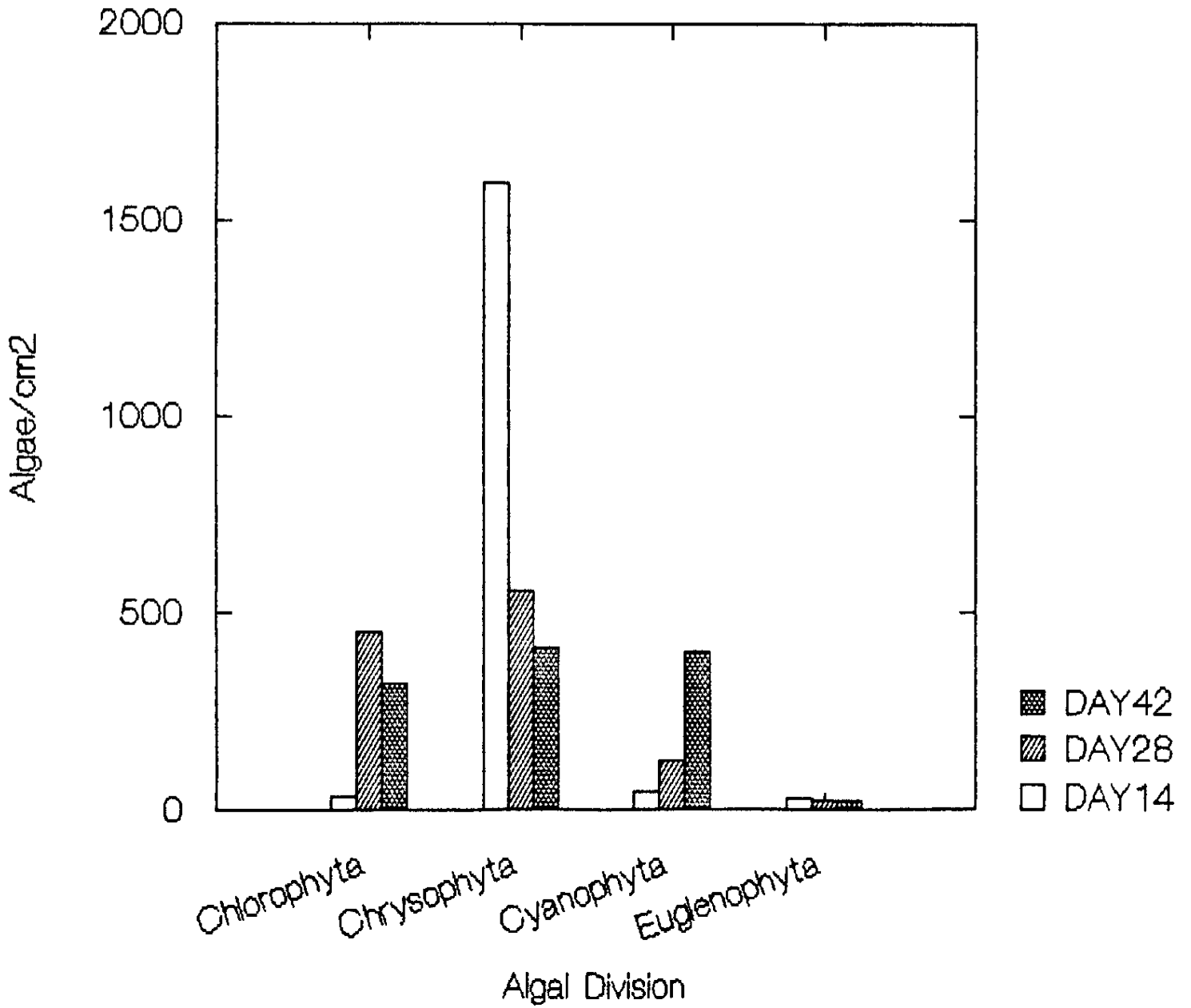


Figure 2.

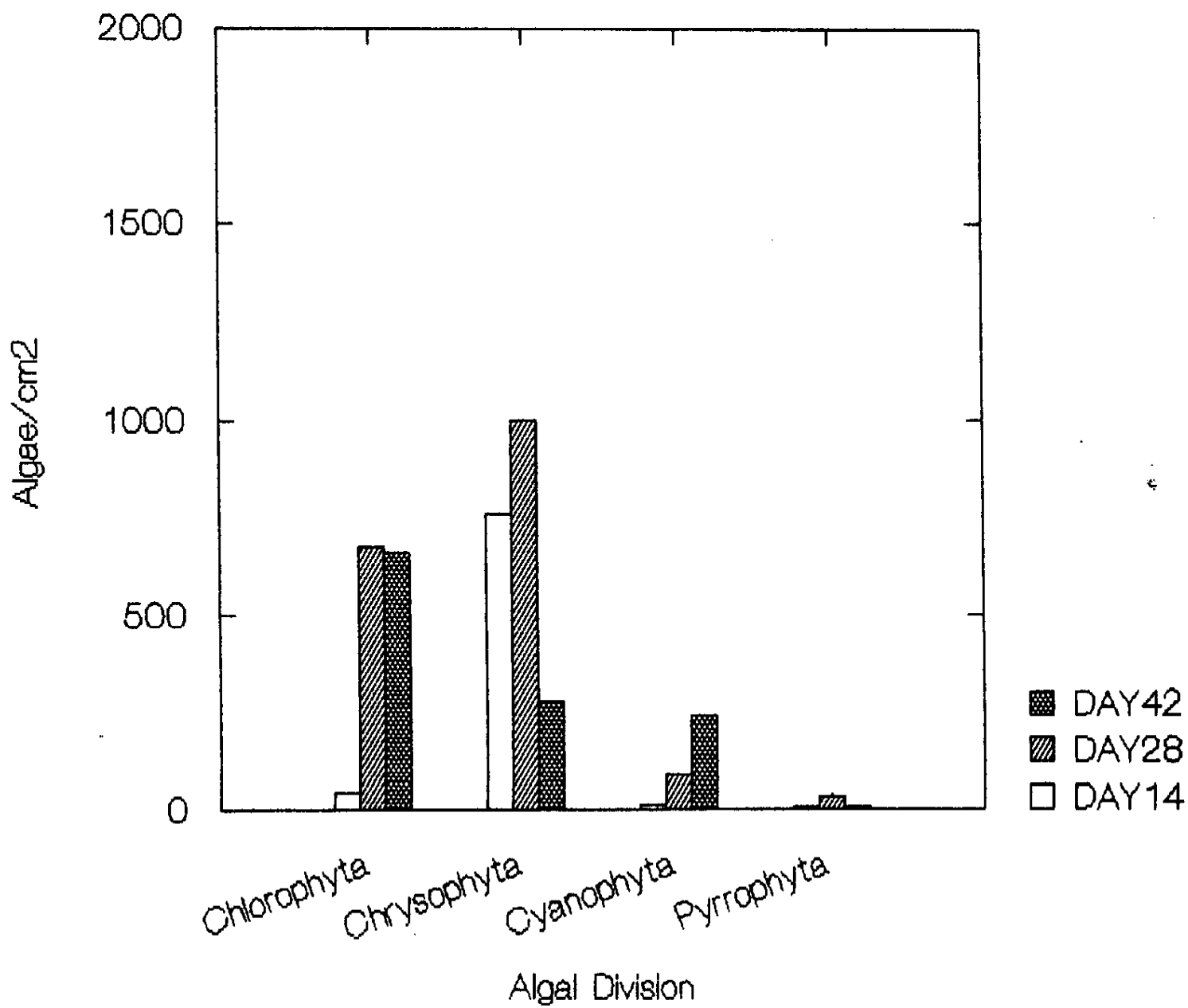


Figure 3.

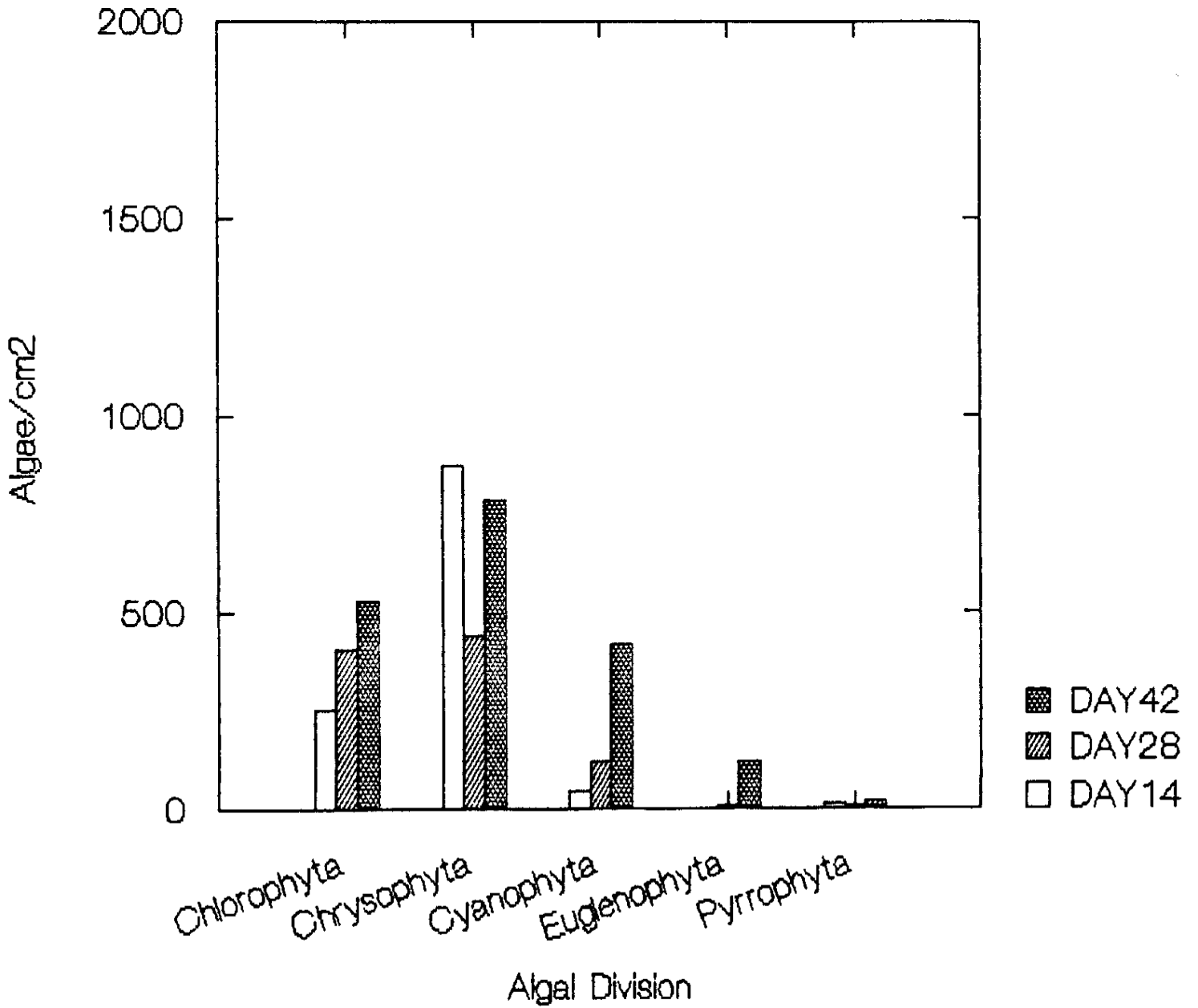


Figure 4.

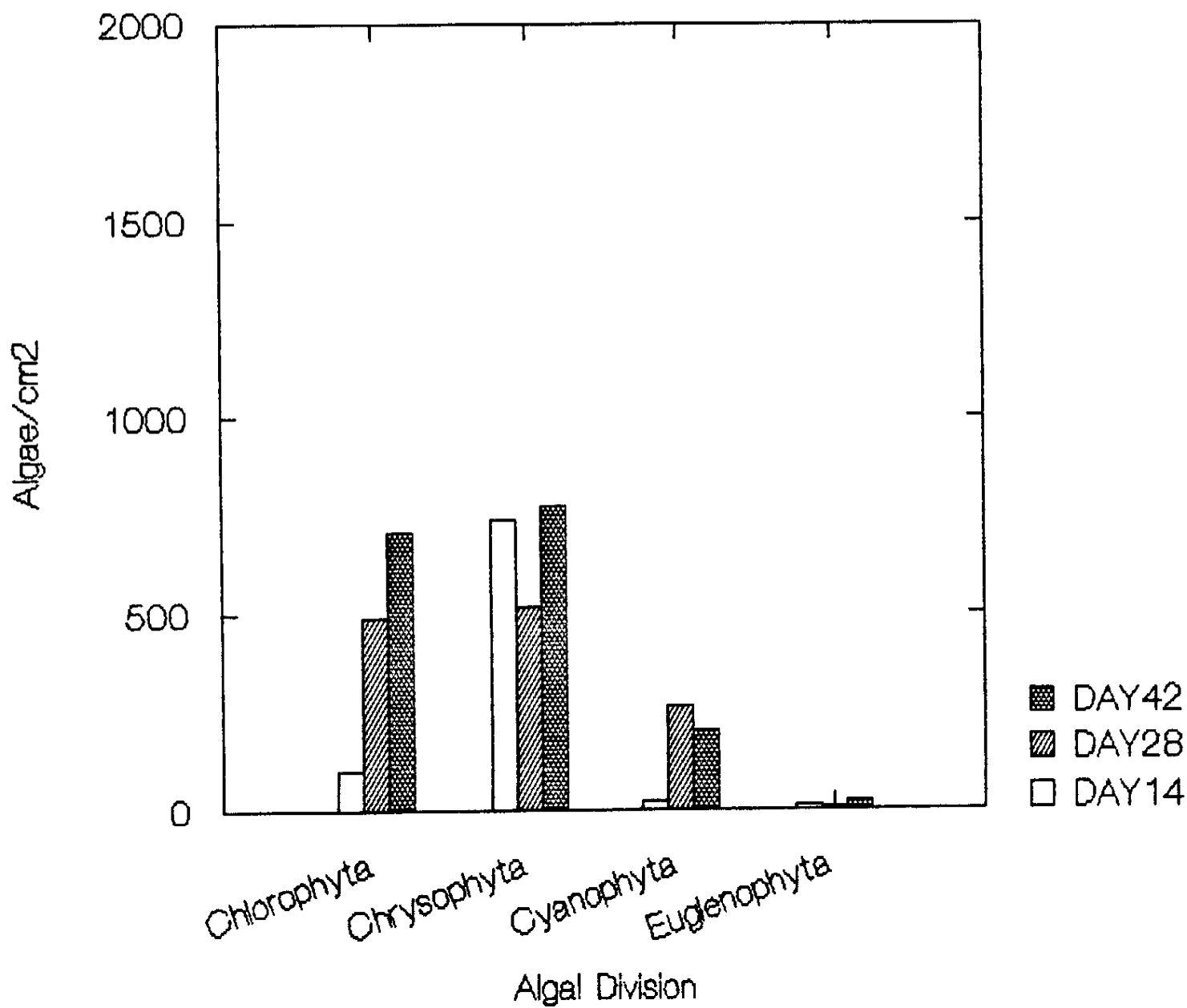


Figure 5.

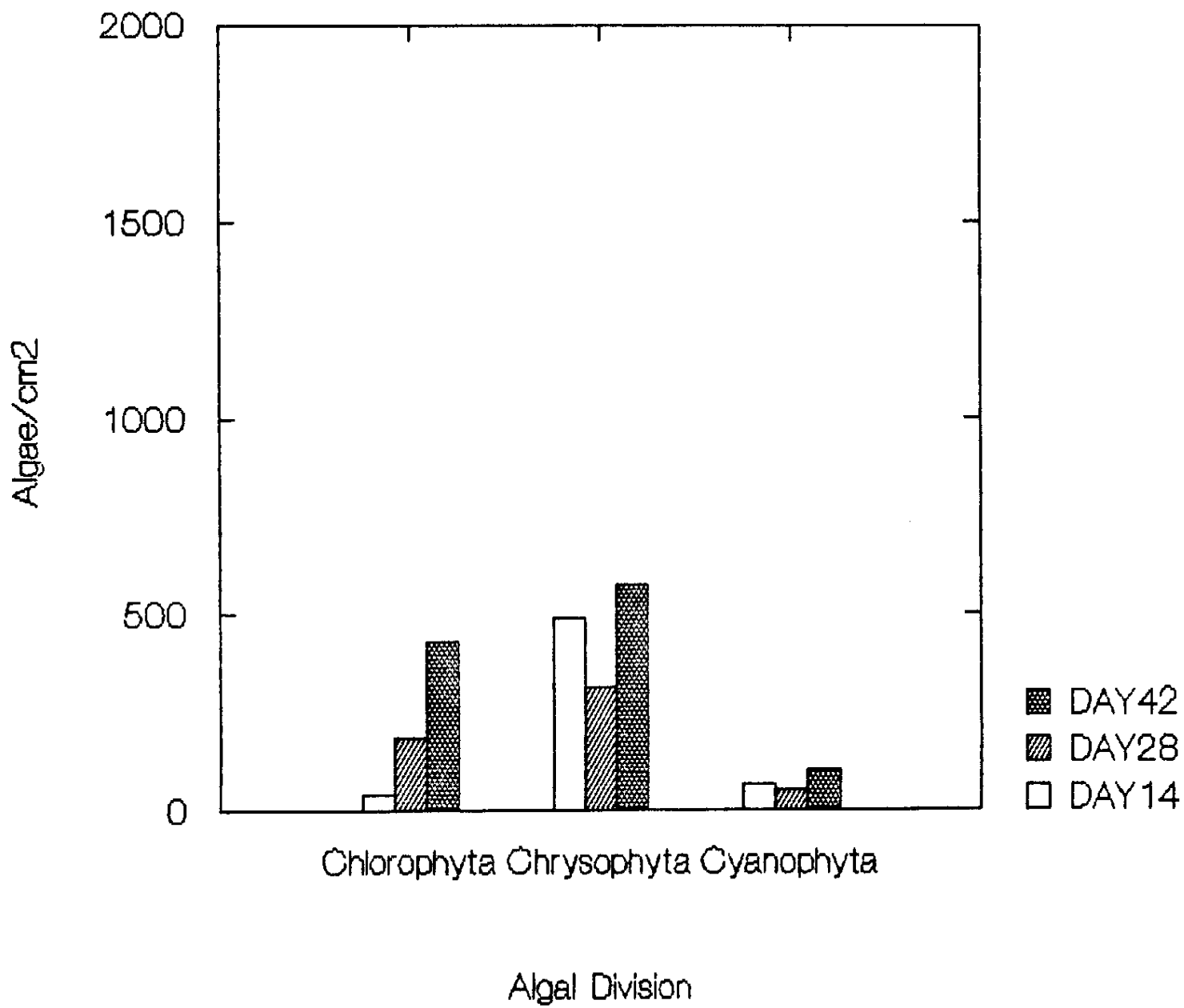


Figure 6.

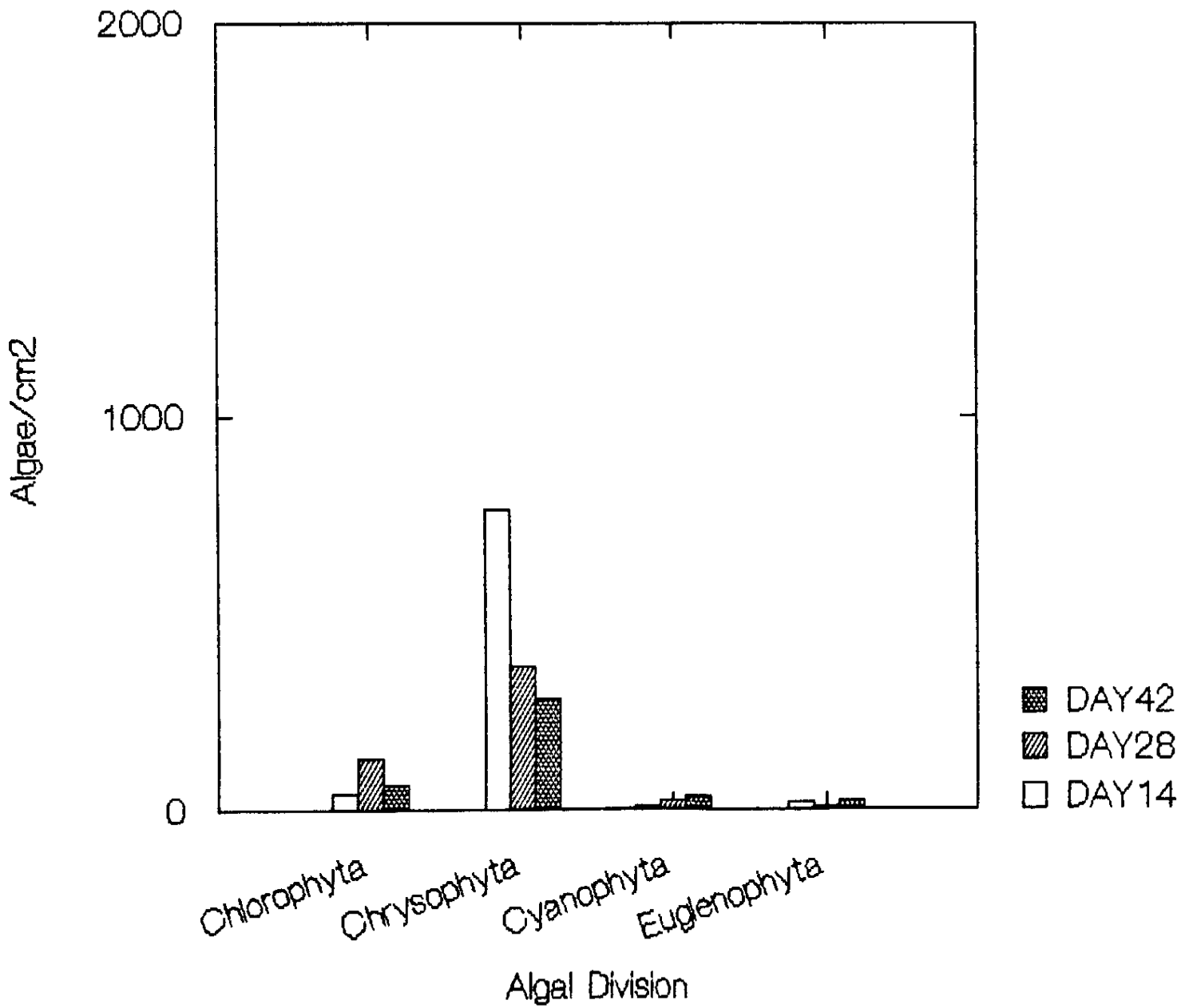


Figure 7.

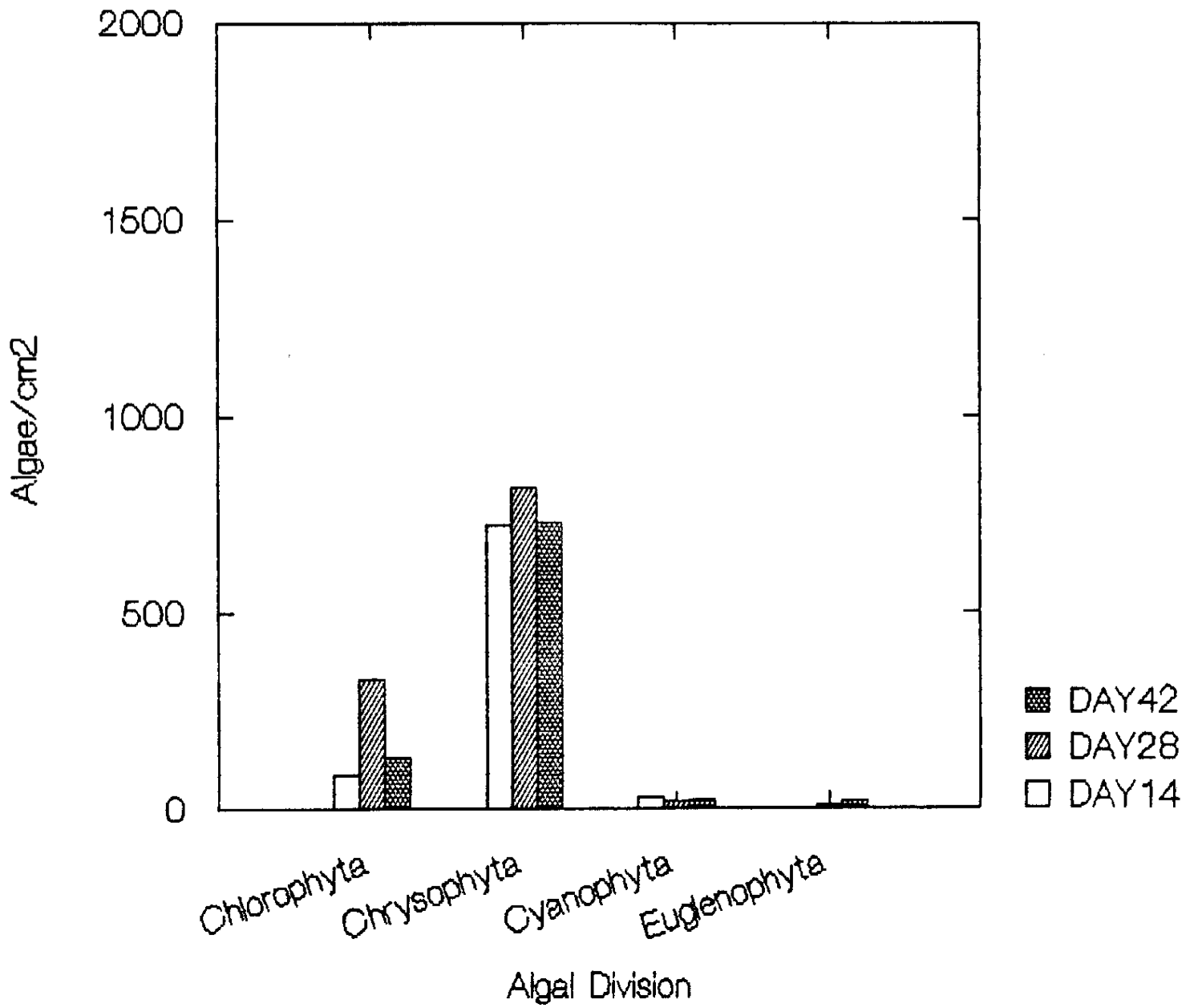
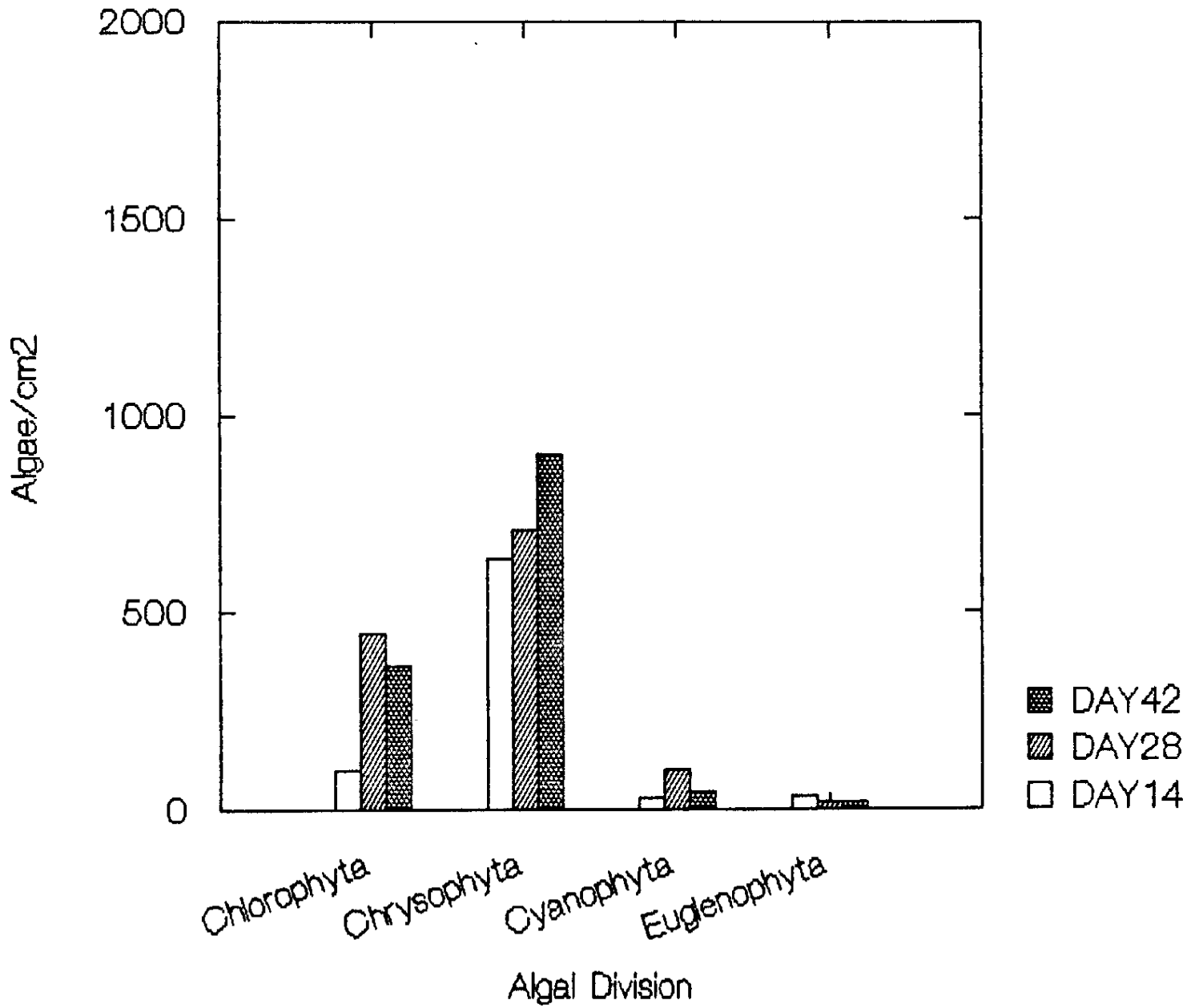
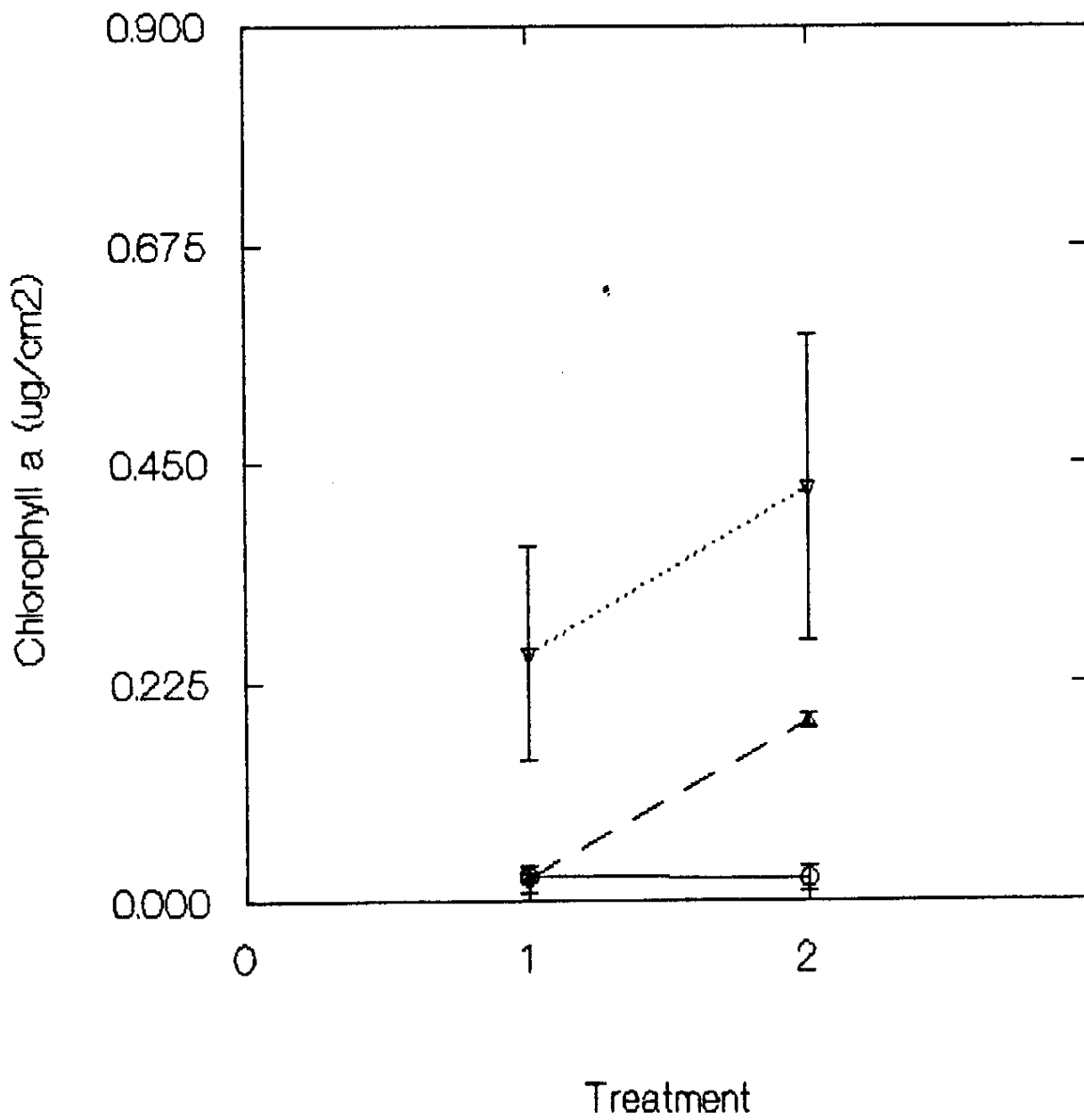


Figure 8.



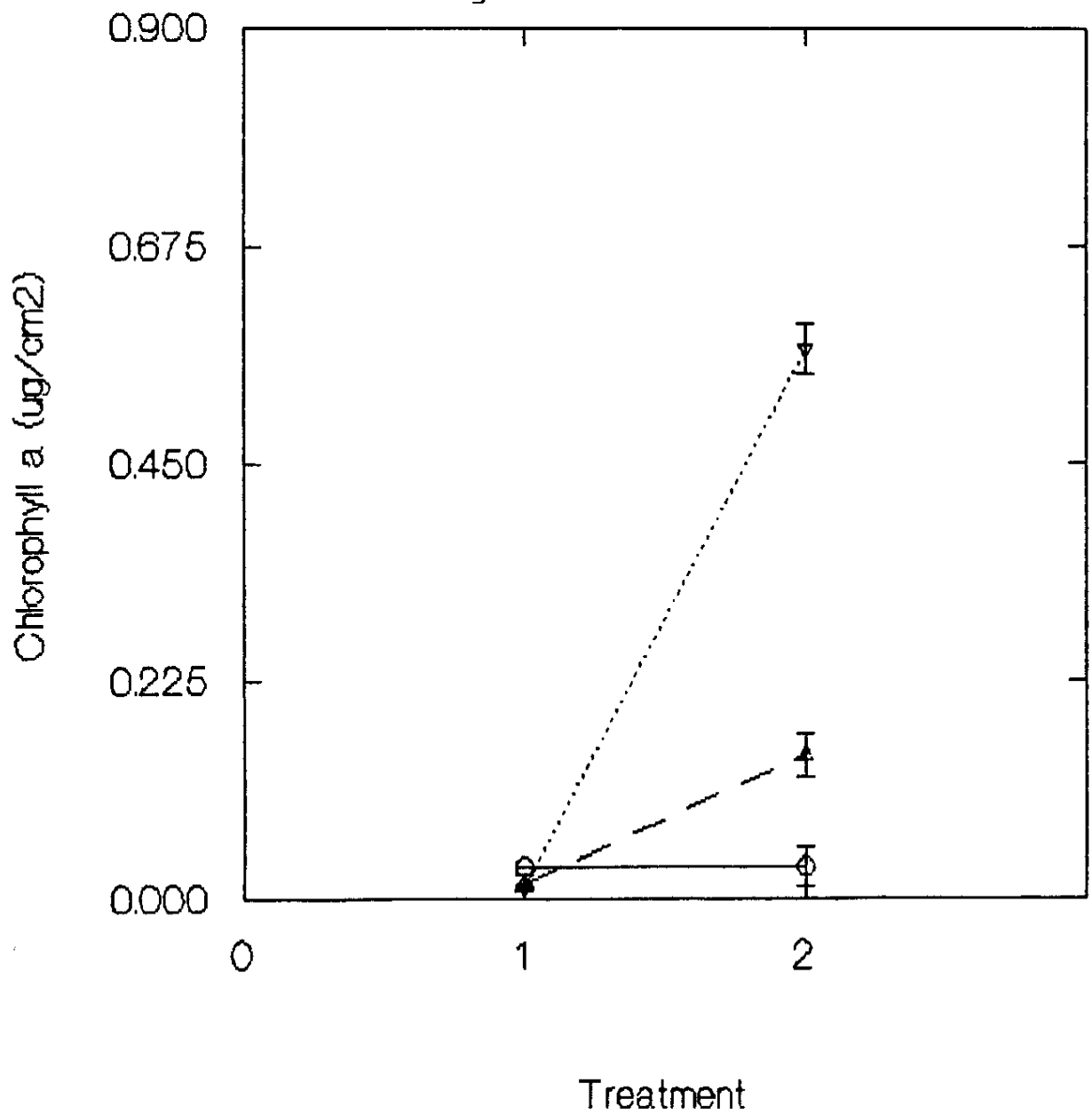
1 = non-elevated tiles 0 = 14 days
2 = elevated tiles \blacktriangle = 28 days
 \blacktriangledown = 42 days

Figure 9.



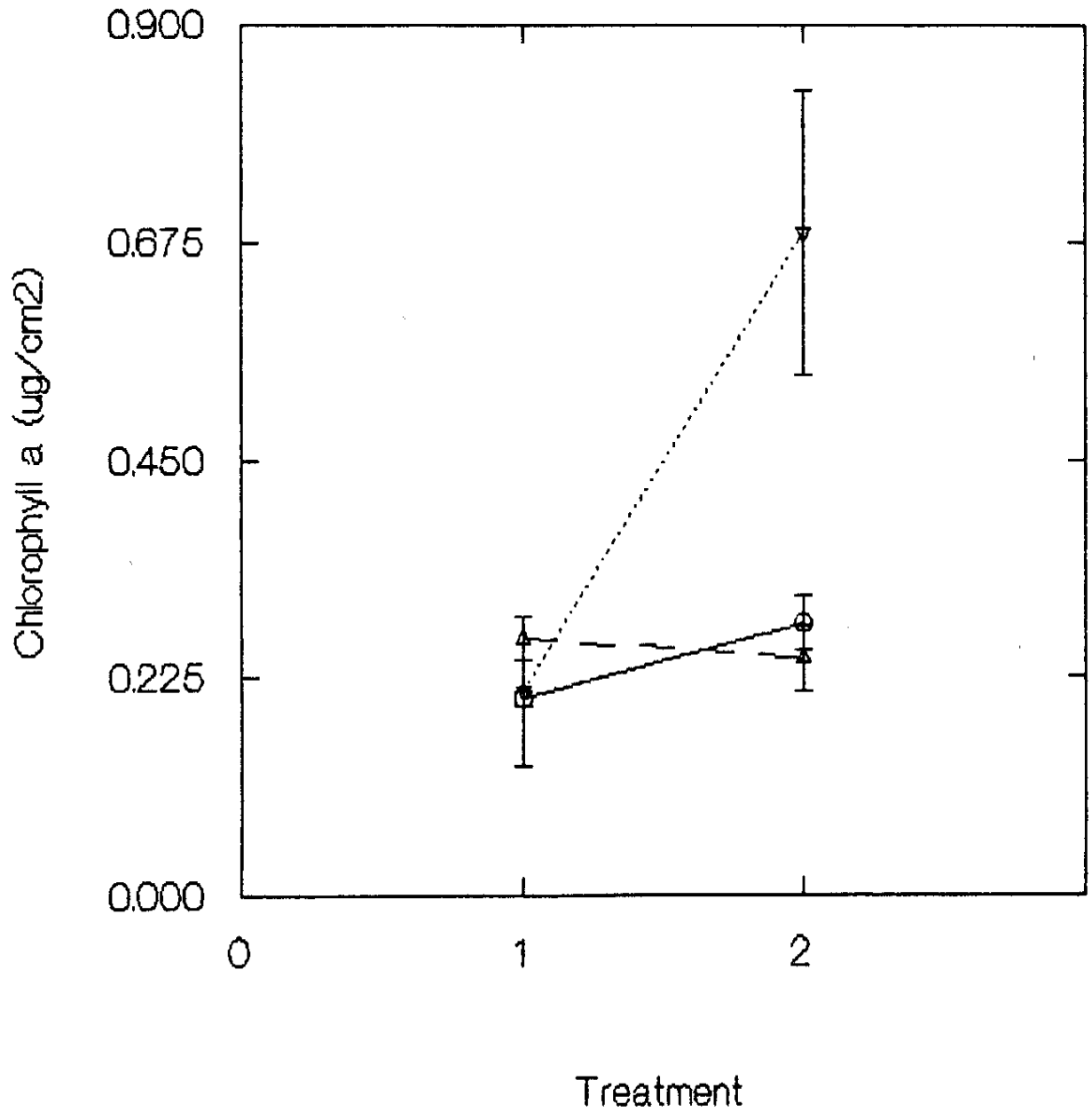
1 = non-elevated tiles 0 = 14 days
2 = elevated tiles Δ = 28 days
 ∇ = 42 days

Figure 10.



1 = non-elevated tiles 0 = 14 days
2 = elevated tiles Δ = 28 days
 ∇ = 42 days

Figure 11.



1 = non-elevated tiles 0 = 14 days
2 = elevated tiles Δ = 28 days
 ∇ = 42 days

Figure 12.

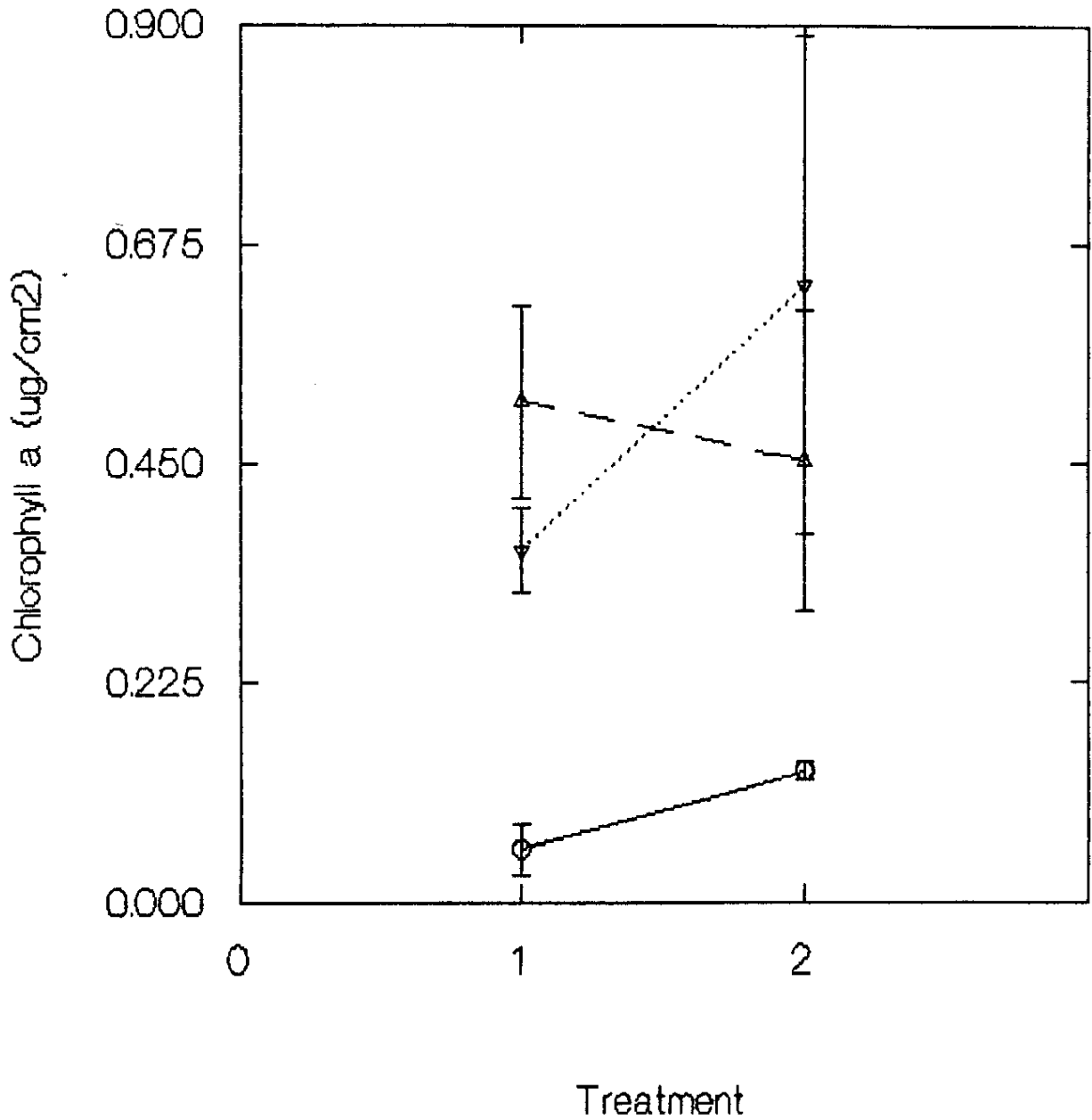


Table 1. Chlorophyll 'a' ANOVA results.

(status = treatment)

Bay Lake, Site 1.
ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATUS	0.055	1	0.055	2.954	0.111
TIME	0.324	2	0.162	8.727	0.005
STATUS* TIME	0.028	2	0.014	0.766	0.486
ERROR	0.223	12	0.019		

Bay Lake, Site 2.
ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATUS	0.238	1	0.238	273.876	0.000
TIME	0.225	2	0.113	129.723	0.000
STATUS* TIME	0.254	2	0.127	146.044	0.000
ERROR	0.010	12	0.001		

Morris Lake, Site 1.
ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATUS	0.141	1	0.141	9.276	0.010
TIME	0.159	2	0.080	5.236	0.023
STATUS* TIME	0.208	2	0.104	6.846	0.010
ERROR	0.182	12	0.015		

Morris Lake, Site 2.
ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
STATUS	0.042	1	0.042	0.822	0.382
TIME	0.629	2	0.315	6.163	0.014
STATUS* TIME	0.085	2	0.042	0.828	0.461
ERROR	0.612	12	0.051		

Table 2. Bay Lake water chemistry (U.N.D.E.R.C. 1990).

Alkalinity (mg/L).....5.0

Color

 Apparent.....28.75

 True.....35.00

Specific Conductance (umhos/cm).....22.2

pH.....5.8

Secchi disk (m)3.75

Temperature (°C) 15.3

Table 3. Morris Lake water chemistry (Taafe 1990,
U.N.D.E.R.C. 1990).

Alkalinity (mg/L).....45

Color

 Apparent.....90

 True.....80

Specific Conductance (umhos/cm).....95

pH.....7.2

Secchi disk (m).....1.75

Temperature (°C).....15

