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The Use of Multiple Inversion and Clean-Flo Lake Cleanser in Controlling Aquatic Plants

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ABSTRACT

Prior to the use of Clean-Flo Lake Cleanser ($CaSO_4$:$AL_2(SO_4)_3$:H_3BO_3), in three Minnesota lakes the water was preconditioned to remove carbon dioxide and bottom acids. This was accomplished by a Multiple Inversion of the lake. This process was found effective in controlling the macrophytes.

INTRODUCTION

Bottom water of natural lakes often contains high levels of hydrogen sulfide and carbon dioxide which cause the pH to be generally lower than 7. High levels of ammonia, as well as carbon dioxide in the bottom water serve as aquatic plant nutrients.

In most lakes a continuous process of phosphorus removal occurs as natural calcium in the water combines with phosphorus to form tri-calcium phosphate and many other phosphate salts of calcium. As these salts precipitate to the bottom, they are redissolved by carbon dioxide, and by mildly acidic bottom water. Phosphorus is then recycled for aquatic plant assimilation (5).

Once each spring and again each fall in northern lakes, and at random periods as cold fronts move through during the winter season in southern lakes, the surface water cools and turnover occurs. At this time, density of the surface water becomes greater than subsurface water, and a natural inversion of the lakes takes place. This inversion increases oxygen at the sediment-water interface, simultaneously bringing ammonia, hydrogen sulfide and carbon dioxide in the bottom water to the surface to be oxidized or exhausted to the atmosphere.

Oxygen enrichment and removal of carbon dioxide from the bottom water produces a decline in anaerobic activity at the sediment-water interface due to oxygen toxicity and removal of carbon dioxide, as a food source for the anaerobes. Bottom acids are reduced and the calcium phosphates remain on the bottom in the precipitated form (3, 7, 9).

The oxygen is soon depleted by benthic organisms, and carbon dioxide and hydrogen sulfide are constantly released by subsurface fermentation of organic carbon. After the initial inversion, prior conditions soon reappear, with low pH, high acidity, and high carbon dioxide levels.

Therefore, to maintain a favorable environment to hold phosphate precipitates, it is highly desirable to continuously invert the lake water.

Such a condition is achieved by use of a Multiple Inversion system which continuously floats bottom water to the surface by introducing microscopic bubbles into the bottom water from diffusers supplied with compressed air. A Multiple Inversion system produced by Clean-Flo Laboratories, Inc. is capable of moving 1,363,000 liters of water from the bottom to the surface per hour per horsepower.

Iron and manganese are oxidized. Ammonia is oxidized to nitrite under aerobic conditions. Nitrobacter further oxidizes nitrite to nitrate. At the low oxygen sediment-water interface, Pseudomonas, while obligately aerobic, is capable of anaerobic respiration in the presence of nitrates. Nitrate then serves as the final electron acceptor as Pseudomonas convert nitrate and organic carbons to water and to nitrogen gas and carbon dioxide, which are exhausted by the wind. Reduction of nutrients using Multiple Inversion and Clean-Flo Lake Cleanser is best documented by Kaleel et al[1] or Bateman (1).

Phosphate then is removed by natural calcium precipitation. But since the calcium available in the water is in the carbonate form, it is normally a slow process. To accelerate the phosphate removal, a soluble calcium compound is added to the water.[2]

The purpose of this study was to monitor the effects of Multiple Inversion and Clean-Flo Lake Cleanser upon the aquatic plant community in three Minnesota lakes.

METHODS AND MATERIALS

Each lake received Multiple Inversion for at least six months prior to the addition of Lake Cleanser. Observations supervised by the Minnesota Department of Natural Resources were conducted over a period of four months; testing every two weeks began on June 24, 1974.

Crystal Lake. Crystal Lake (29.5 ha) is located in Robbinsdale, Minnesota. Its maximum depth is 10.7 m.

Until 1948, Crystal Lake had a surface area of 109.3 ha. It was heavily silted and dredging operations inadvertently punctured the lake bottom down to porous gravel. The lake drained to its present size, and at the beginning of this study, was being maintained by a 3.79 cubic m/min pump connected to a 107-m-deep well. Water from the aquafer is high in phosphate, iron, carbon dioxide, and ammonia. The pump was operated 24 hours per day throughout the spring, summer and fall of each year. Six storm sewers drain into Crystal Lake from a 518 ha section of north Minneapolis and from the local Robbinsdale area. In the spring, these sewers bring in large quantities of silt and organic material. The lake has no surface outflow. Littoral submergent plants flourished.

Crystal Lake was once considered excellent for fishing, but by 1976 contained only a few bullheads (*Ictalurus melas* R.) and goldfish (*Carassins auratus*). Bottom water was high in ammonia, carbon dioxide, phosphates, hydrogen sulfide, and BOD. No dissolved oxygen was present at depth over 3 m.

On November 22, 1973, three 0.33-hp and three 0.5-hp Multiple Inversion systems were installed.

On June 26 and June 27, 1974, 10 mg/l calcium compound was added to the water. This amounted to 8,278 kg of the compound.

Edina Pond. Edina Pond (2.4 ha) serves as a storm sewer reservoir for a 648 ha area of the City of Edina, Minnesota. The lake has an average depth of 1.0 m, and a maximum depth of 2.0 m.

During an average rainstorm, 0.6 cm to 1.3 cm of rainfall flushes the pond forcing its contents into an interconnected lake. By the early spring of 1973, as in previous years, a dense growth of coontail (*Cerataphyllum demersum* L.) and western waterweed (*Elodea nuttalli* Planch.) had grown to the bottom of the ice which covers the pond during the winter. In the past, the City of Edina each year would spread granules of 2,4-Dichloro-phenoxy-acetic acid (2,4-D) on the ice just before break-up, but growth was only temporarily checked. Clean-Flo's sole purpose in treating this lake was to examine whether or not application of the calcium compound would have any lasting effect upon plant growth in a periodically flushed impoundment.

Otto Pond. 150 m from the test pond, Otto is almost identical in its use and configuration, and was selected to serve as a control for both Crystal Lake and Edina Pond. Otto Pond, however, serves as a watershed of about 0.01 times the area of the Edina Swimming Pool Pond watershed area, and therefore is not affected to any significant extent by rains.

A 0.5-hp Multiple Inversion system was installed in Edina Pond on August 13, 1973. On June 28, 1974, a second application of 30 mg/l calcium compound was made.

Peavey Lake. Located in Wayzata, Minnesota, Peavey Lake has a surface area of 2.6 ha, is 27.4 m deep and is connected to 6444 ha Lake Minnetonka by a channel approximately 3 m wide, 3 m deep, and 100 m long. For several decades, it served as a sewage settling pond for the City of Wayzata. In 1970, sewage was diverted from Peavey Lake to a metropolitan pipeline and taken to another facility for further treatment.

Peavey Lake commonly in summer contained a dense

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[1] Kaleel, R. T. and A. E. Gabor, Lake Weston Restorative Evaluation, Orange County Pollution Control Department, February, 1978.

[2] Clean-Flo Lake Cleanser is a registered product of Clean-Flo Laboratories, Inc., EPA registration number 33436-1 U. S. Patent Pending.

infestation of filamentous algae (unspeciated), and coontail. A strong sewage odor was present. There was at least 1.5 m of unconsolidated organic ooze throughout the bottom of the lake.

Because of the size of Lake Minnetonka, it was felt that a small pond connected to the lake should be used as a control, as well as the region of Lake Minnetonka near the Peavey Lake Channel. Such a site was located 1.6 km from Peavey Lake at the Wayzata Boat Lagoon (0.5 ha, 2 m deep) which is also connected by a channel.

Multiple Inversion was initiated at Peavey Lake on May 10, 1973, when a 0.5-hp system was installed. The diffuser was placed 46 m from shore, at a depth of 3.0 m. On June 3, a second 0.5-hp unit was installed near the center of the lake at a depth of 26 m. The calcium compound was added on July 10, 1973, but phosphorus, while reduced 65%, remained too high to control plant growth. Because it would take a year for the multiple inversion to condition the water properly, herbicide was added three times during 1973 for aesthetic purposes. The aquatic plant tests began on July 4, 1974. On July 11, 1974, 10 mg/l of the calcium compound was added to the lake.

To sample the lakes for aquatic plants, four rake casts oriented 90 degrees apart were made at each test site. Plants recovered in the rake are speciated, and a discrete recovery value is assigned each species found at each test site.

The parameter described by Jessen and Lound (6) and used in this study to measure macrophyte abundance is density rating, which is the number of times at a single sampling site in which a given species is recovered.

Density ratings have discrete values from 0 to 4, but 5 is assigned if a given plant species fills the teeth of the rake in all four casts at a given site. If the plant species is brown and obviously dying as it lay on the bottom, a value of −1 is added to the density rating. If a species is recovered in a uniformly dead and disintegrating form, it is not included.

Intitial density ratings, T_0 for the control lakes often varied appreciably from T_0 values for the treatment lakes. Usual linear adjustments of the data cannot be made, and a standard analysis of variance is therefore not possible.

The data can be sucessfully analyzed, however, using the Randomization Test for Two Independent Samples, as described by Conover (2). This test does not assume normality. The critical assumptions are that the different species of plants grow independently of one another, and that they are randomly distributed among sites. These assumptions appear to be valid in this experiment. In addition, there was nothing peculiar to any given test site in a given lake which would have prevented any of the species sampled in that lake from appearing at that test site.

In this study, the p-value is the probability of finding the observed value or higher values in the control lake if the calcium compound has no effect. The natural log of the p-value multiplied by negative two (−2) approximates a chi-square statistic with two degrees of freedom (4). These chi-square values and their degrees of freedom can be added directly to provide an overall chi-square statistic for each species of plant in each group, and to give a total chi-square value for all test species in a given test group. The null hypothesis tested is:

> If treatment sites are compared to control sites that have the same plant density ratings at the beginning of the experiment, the total population of plants sampled will have density ratings that are randomly distributed among those test sites at the end of the experiment.

The null hypothesis is rejected for large values of chi-square, which generate small alpha values. An alpha-level of 0.05 is used to determine significance in this study.

If the null hypothesis is accepted (i.e. alpha level > 0.05), it can be concluded that the Multiple Inversion and calcium compound had no significant effect on the treatment lakes. If, however, the null hypothesis is rejected, it can be concluded that the compound did significantly control aquatic weeds in the treatment lakes.

Data was analyzed in two ways. First, only those sites having the same initial density ratings were compared. This enabled only 32% of the test sites to be analyzed, however. To examine the data more completely, all sites having initial density ratings of 0, 1, and 2 were pooled together, as were all sites with initial values of 3, 4, and 5. This enabled 60% of the data to be included in the analysis.

RESULTS AND DISCUSSION

Five species or groups of aquatic plants were compared in Group I, while seven are compared in Group II. Plants analyzed in each lake are shown in Table 1.

Sites were selected which theoretically would reflect the

TABLE 1. AQUATIC PLANTS FOUND IN THE TEST LAKES AND CONTROLS.

Group I	Test Lakes	Controls
Filamentous algae (unspeciated)	Crystal, Edina	Otto
Berchtold's pondweed (*Potamogeton Berchtoldi* spp.)	Crystal, Edina	Otto
Flatstem pondweed (*P. zosteriformis* spp.)	Crystal	Otto
Coontail (*Ceratophyllum demersum* L.)	Edina	Otto
Western waterweed (*Elodea nutalli* Planch.)	Edina	Otto
Group II		
Filamentous algae (unspeciated)	Peavey	Wayzata, Minnetonka
Berchtold's pondweed (*Potamogeton Berchtoldi* spp.)	Peavey	Minnetonka
Flatstem pondweed (*P. zosteriformis* spp.)	Peavey	Wayzata, Minnetonka
Coontail (*Ceratophyllum demersum* L.)	Peavey	Wayzata, Minnetonka
Love grass (*Eragrostis* spp.)	Peavey	Wayzata, Minnetonka
Naiad (*Naias* spp.)	Peavey	Wayzata, Minnetonka
Narrowleaf pondweed (*Potamogeton* spp.)	Peavey	Wayzata, Minnetonka

TABLE 2. NUMBER OF SAMPLING SITES SELECTED FOR TESTING AQUATIC PLANT RESPONSE TO CLEAN-FLO LAKE CLEANSER AND MULTIPLE INVERSION.

Treatment Lakes		Control Lakes	
Name	Test Sites	Name	Test Sites
Crystal	9	Otto	3
Edina	5	Wayzata	3
Peavey	4	Minnetonka	2

Table 3. Results of a statistical analysis of unpooled density ratings for Group I plants (Crystal and Edina, using Otto as a control).

Plant	Probability that calcium compound had no effect
Filamentous algae	.250
Berchtold's pondweed	.22
Flatstem pondweed	.167
Coontail	.05
Western waterweed	.14
Total	.025

Table 4. Results of a statistical analysis of unpooled density ratings for Group II plants (Peavey Lake, using Wayzata and Minnetonka as controls).

Plant	Probability that calcium compound had no effect
Filamentous algae	.14
Berchtold's pondweed	.342
Flatstem pondweed	.009
Coontail	.033
Love grass	.214
Naiad	.024
Narrowleaf pondweed	.13
Total	< .001

Table 5. Results of a statistical analysis of pooled density ratings for Group I plants.

Plant	Probability that calcium compound had no effect
Filamentous algae	.125
Berchtold's pondweed	.04
Flatstem pondweed	.004
Coontail	.009
Western waterweed	.025
Total	<< .005

Table 6. Results of a statistical analysis of pooled density ratings for Group II plants.

Plant	Probability that calcium compound had no effect
Filamentous algae	.04
Berchtold's pondweed	.342
Flatstem pondweed	.004
Coontail	.004
Love grass	.112
Naiad	.004
Narrowleaf pondweed	.036
Total	<< .001

overall condition of a particular lake. Test sites were allocated among the test lakes as shown in Table 2.

Table 3 gives results of the analysis of unpooled density ratings for unpooled Crystal-Edina-Otto (Group I) experiment. With a p-value of 0.025, the null hypothesis is rejected (plants definitely controlled).

Table 4 provides unpooled results from the Peavey-Wayzata-Minnetonka (Group II) experiment. The p-value is less than 0.001, and the null hypothesis is strongly rejected.

Tables 5 and 6 give results for density rating which have been pooled to avoid a large loss of data. The p-value in the Group I experiment is less than 0.005. In the Group II experiment, it is very much less than 0.001. In either case, the null hypothesis is very strongly rejected.

Although the Crystal Lake/Edina Pond experiment was adversely affected by the flushing of Edina Pond during rainstorms, it can be seen that the null hypothesis was rejected or strongly rejected in every case. A conservative conclusion based on these results would be that Clean-Flo Lake Cleanser has a very high efficacy for reducing plant growth in natural, non-flowing waters which have been continuously inverted.

These conclusions apply to the aquatic plant community as a whole. Control over individual species is statistically significant in a majority of cases, but the results are not always uniform. In order to obtain a graphical representation of cumulative percent control (Figures 1-7), a recovery index for each plant species in each test lake was compared with the recovery index of the control lakes. Recovery index is a measure of each species recovered on each date, and is obtained by multiplying the average density rating for the plant by the percentage of test sites in which the plant species occurred. Each post-treatment value is progressively added to a general summation of the indices, and the mean value is calculated by dividing the number of test dates included in the summation.

Control of filamentous algae was lost in Edina Pond (Figure 1) after heavy June rains, when the pond was completely flushed with storm water runoff. Edina Pond had least response to the treatment (Figures 1, 2, and 4).

In Crystal Lake, filamentous algae completely disap-

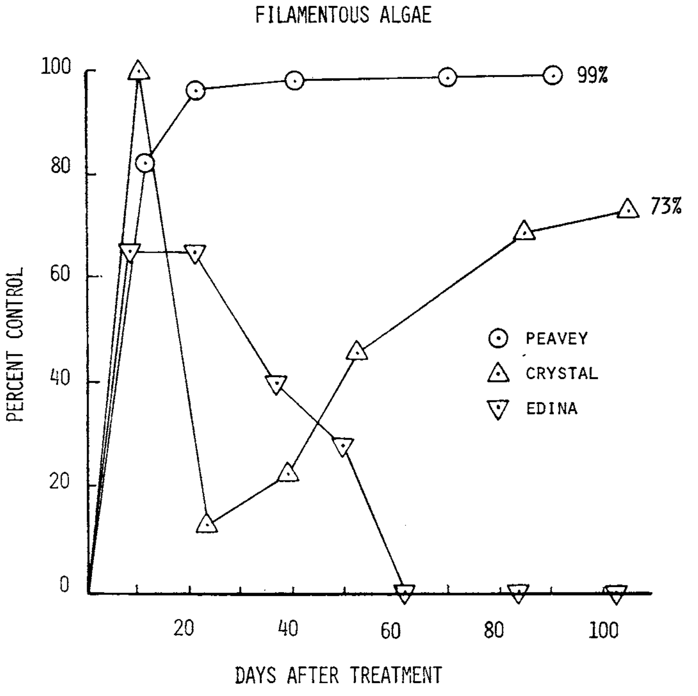

Figure 1. Cumulative mean control of filamentous algae in test lakes compared to growth or decline in control lakes. Lake Cleanser added to Crystal Lake 6/26 and 27; Peavey Lake 7/11; and Edina Pond 6/28.

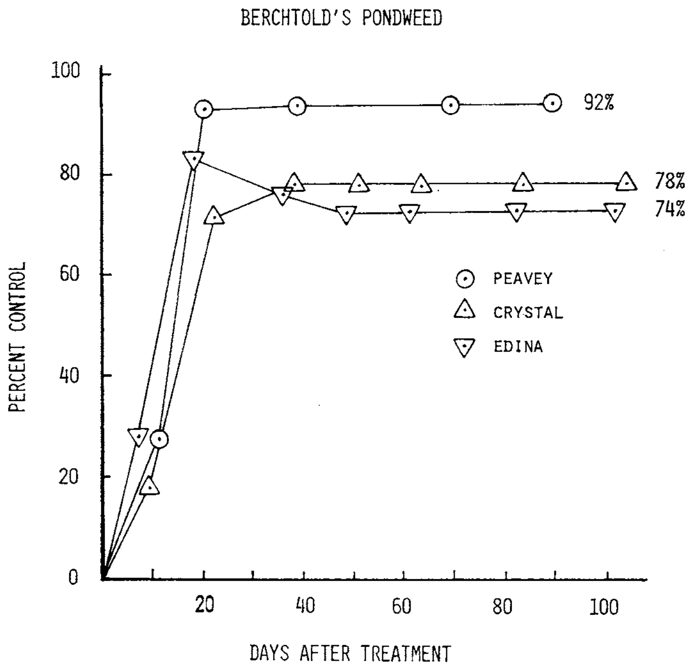

Figure 2. Cumulative mean control of Berchtold's pondweed in the test lakes compared to growth or decline in control lakes.

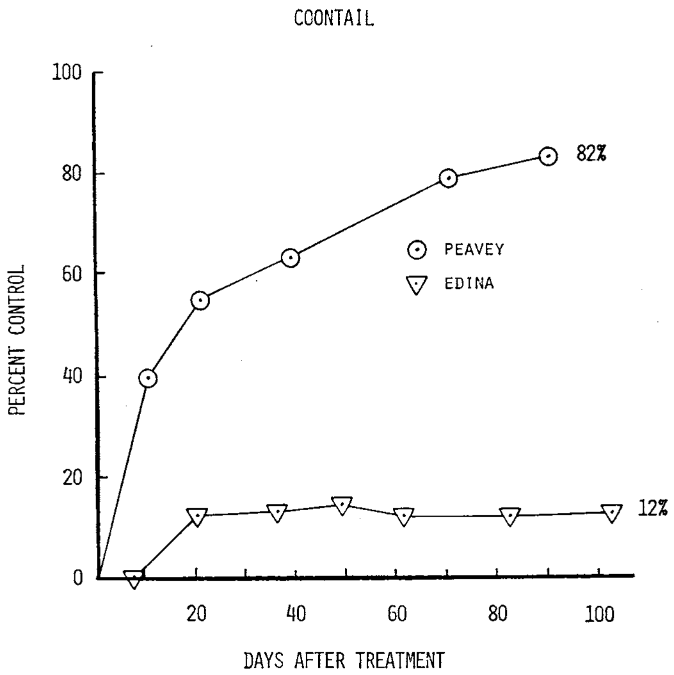

Figure 4. Cumulative mean control of coontail in Peavey Lake and Edina Pond.

peared after treatment (100% control), but temporary regrowth occurred after the rains, followed by another decline. Flatstem pondweed (Figure 3) declined a maximum of 79% in Crystal Lake (56% cumulative mean control), but then recovered completely after the June rains. Berchtold's pondweed ended the season with 78% mean cumulative control compared to the control lake (Figure 2).

Peavey Lake, which was treated after the rains, had an immediate 99% decline in filamentous algae after treatment, compared to the controls. This control was maintained throughout the test period. Similar response occurred with the other macrophytes.

While storm water influent may account for most of this variance, it is our belief that environmental differences from lake to lake and the particular plant's versatility in extracting nutrients from that particular environment will determine the immediate plant response to our process.

While this study tests the response of only eight plant

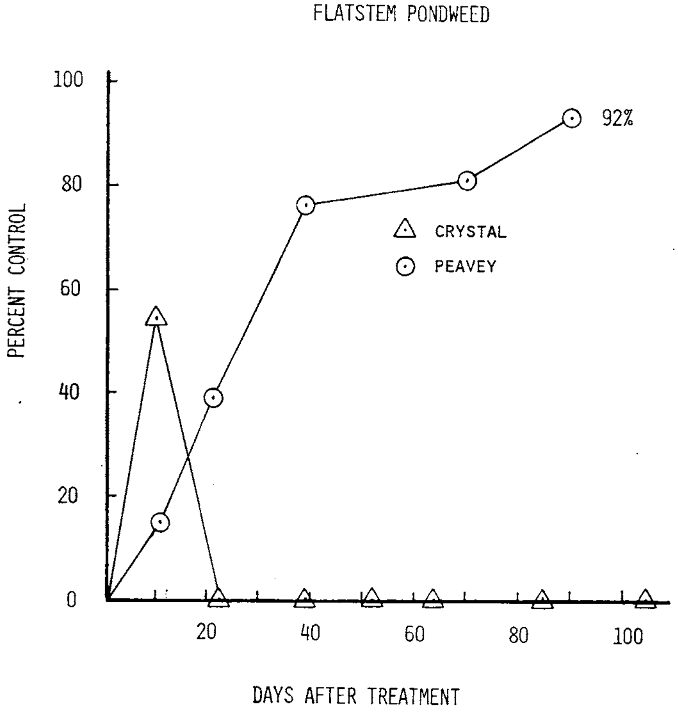

Figure 3. Cumulative mean control of Flatstem pondweed in Crystal and Peavey Lakes.

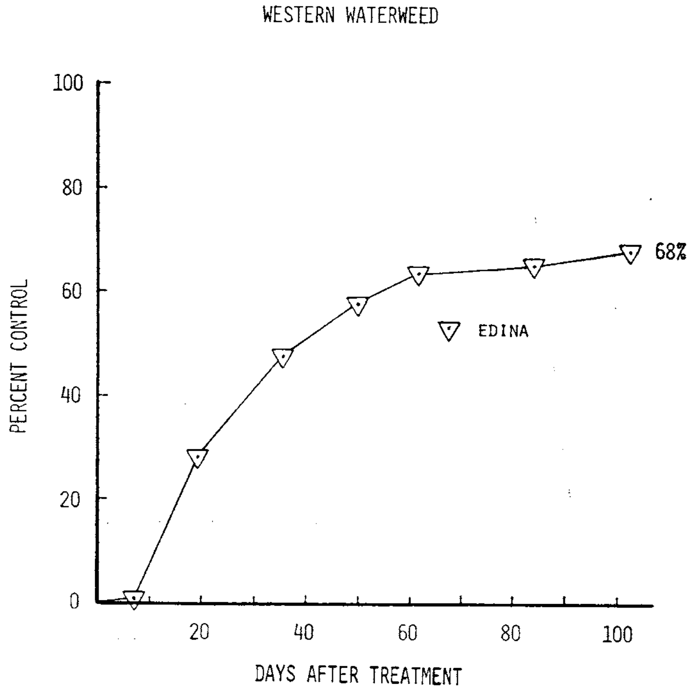

Figure 5. Cumulative mean control of Western waterweed in Edina Pond.

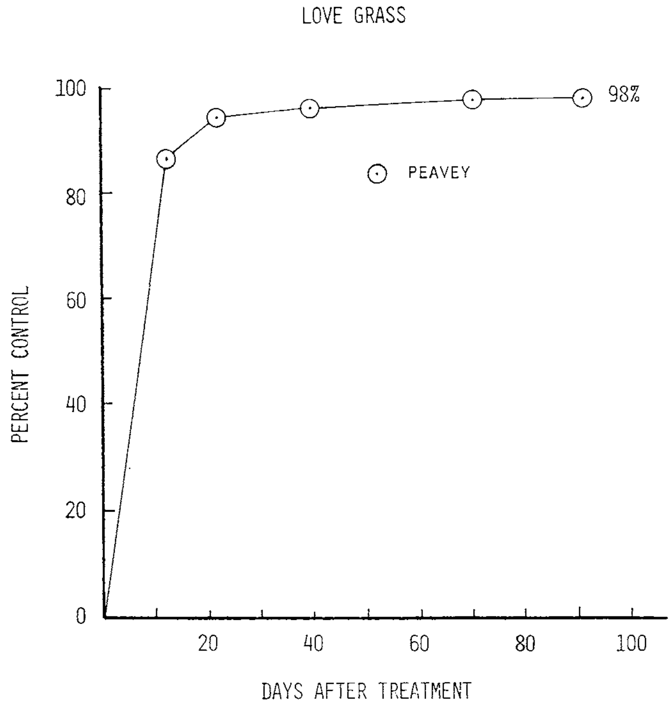

Figure 6. Cumulative mean control of Love grass in Peavey Lake.

species to the process, treatment of several other lakes has produced similar results on these same species and on duckweed (*Lemna minor* L.), Canadian waterweed (*Elodea canadensis* G.), Southern naiad (*Najas quadalupensis*), Eurasian watermilfoil (*Myriophyllum spicatum* L.), Muskgrass (*Chara* sp.), Curlyleaf pondweed (*Potamogeton crispus* L.), Sago pondweed (*Potamogeton pectinatus* L.), and control ranging from limited to 100% on hydrilla (*Hydrilla verticillata* Royle) (8).

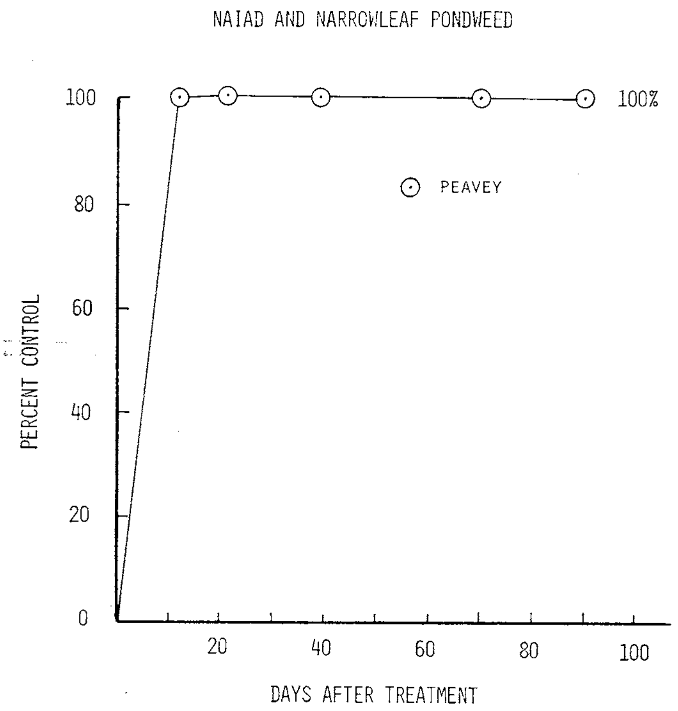

Figure 7. Cumulative mean control of Naiad and Narrowleaf pondweed in Peavey Lake. Both plants had an immediate 100% decline.

We have concluded that over a longer period of time, there is a high probability that any submergent plant will respond to nutrient reduction. If plant reduction is only 12%, however, as it is in coontail in Edina Pond (Fig. 4), this would be considered a failure from an aesthetic viewpoint, although statistically, coontail was affected by the treatment.

It is significant to note that after repeated treatment in the year following this study, flatstem pondweed and filamentous algae were controlled 90-100% in Crystal Lake, and Coontail, Berchtold's pondweed, western waterweed, and filamentous algae were controlled 90-100% in Edina Pond, even though these plants recovered somewhat after heavy rain in the present study.

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