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EFFECTS OF CALCIUM MAGNESIUM ACETATE, A ROAD DEICER, ON THE LENTIC ENVIRONMENT IN INTERIOR ALASKA

INTERIM REPORT

by

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INTRODUCTION

The application of chloride deicing salts to roadways has increased dramatically in recent years due to public demand for safer winter driving conditions. Unfortunately, these salts create adverse effects such as corrosion of vehicles and bridge structures. More recently, adverse environmental effects have been attributed to road salt applications. Judd (1976) noted lake stratification from salt-laden runoff, and Huling and Holocher (1972) found contaminated groundwater supplies. Evidence has accumulated regarding salt's detrimental effects on aquatic communities. Nuisance bluegreen algal blooms and ion exchange with toxic mercury in the sediments are some examples (Horner, 1984).

Calcium magnesium acetate (CMA) was identified as a viable alternative to sodium and calcium chloride salts, and field and lab tests were performed to determine its level of performance. Preliminary findings indicate that CMA is less corrosive than chloride salts on metallic highway structures and automobiles, and less detrimental on aquatic communities (Chollar, 1983; Winters, 1984). The significance of an environmentally safer road deicer for Alaska is great. Due to the longer winter, the number of deicer applications is significantly greater than in the contiguous United States. However, with spring runoff being the major melt event in interior Alaska, a high dilution factor into lotic systems would occur, thereby minimizing the direct effects of the deicer on streams. A major concern for Alaska is the accumulation of the deicer into small roadside ponds via snowmelt. The purpose of this study was to examine the effects of CMA entering the aquatic ecosystem of small ponds and compare with similar control ponds. Our preliminary study was designed to determine:

1. presence of calcium, magnesium, sodium and potassium concentrations within the water column and sediments to monitor the divalent-to-monovalent cation ratio;

2. standing crop of vascular plants to estimate productivity;

3. algae colonization onto artificial substrates; and

4. the amount of dissolved oxygen available and produced by the ecosystem.

Three ponds received an amount of CMA that significantly elevated the calcium concentrations, and three ponds, matched chemically and morphometrically, remained untreated to serve as controls. Data collection was conducted from May through September 1984. Throughout this sampling period, elevations of calcium levels and alkalinity were noted, although associated detrimental effects were not detected. Significant changes of dissolved oxygen levels did not occur and chlorophyll a concentrations increased primarily with time. Future investigation is necessary to determine any long-term detrimental effects.

Sampling of sediments was not conducted the first field season due to the unavailability of necessary equipment and personnel. This study was designed to consider the environmental effects of CMA on the aquatic ecosystem within interior Alaska. Studies regarding its manufacture (Economides and Ostermann, 1982) and corrosion effects (Venkatesh and Kutterer, 1985) have been investigated separately. This study will serve as a preliminary guide for continued study another year.

STUDY SITE DESCRIPTION

We studied six ponds near Delta Junction, approximately 160 km (100 mi) southeast of Fairbanks, at latitude 63°52'N and longitude 145°50'W. The ponds lie between the Delta River and Richardson Highway on the Fort Greely Military Reservation (Figure 1). The surface morphology of the area contains depositional and erosional topography; it lies on a terminal moraine formed during Donnelly glaciation correlative to Wisconsinan glaciation, approximately 20,000 years ago (Pewe, 1975). The area is dotted with kettle lakes and thaw ponds. Some of the lakes contain 3-5 m of fine sediments and peat. The surrounding soils contain sand and gravel with interbedded silt layers and areas of discontinuous permafrost can be found from the moraine south of Fort Greely to the

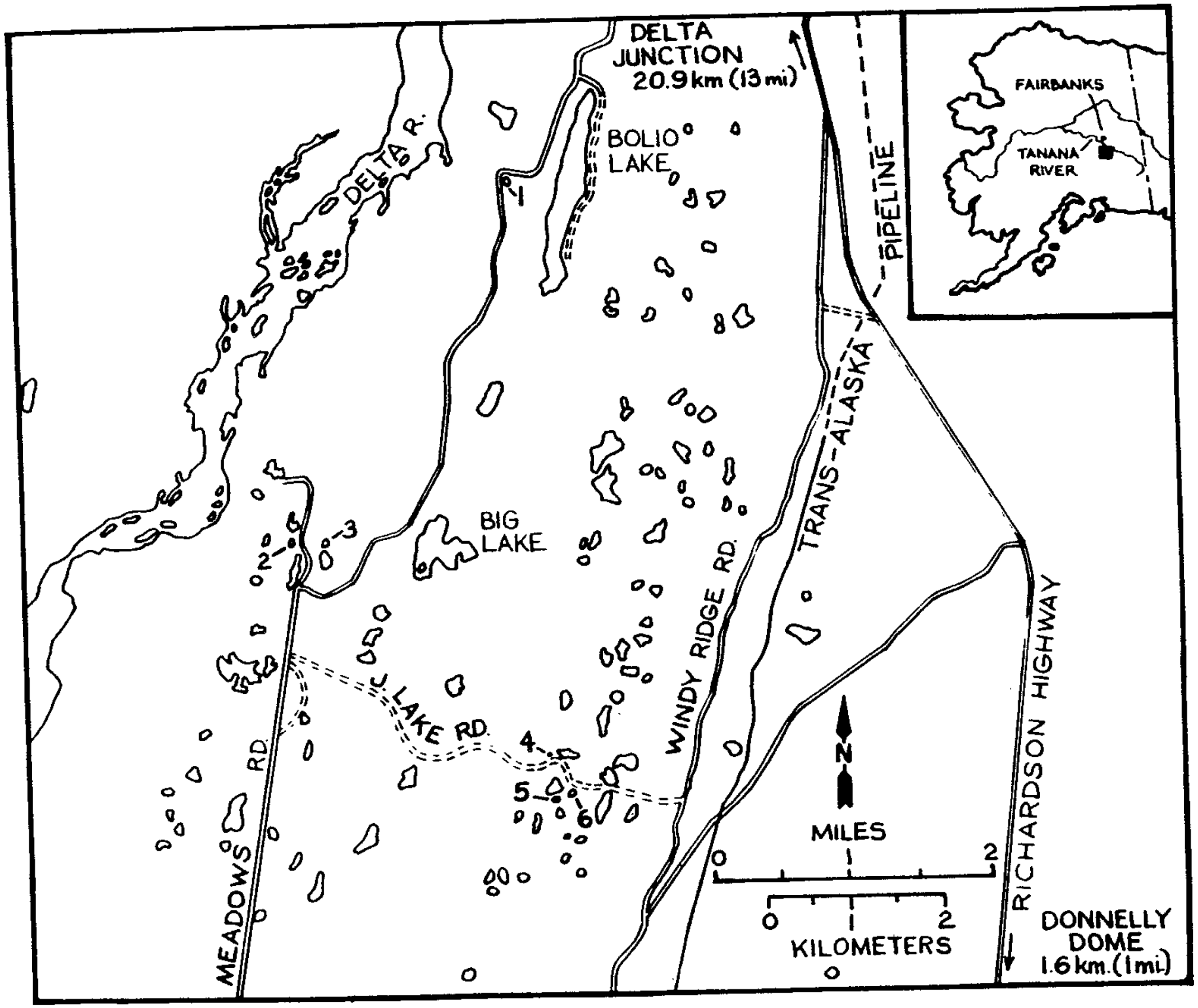

Figure 1. Inset map of Alaska showing Delta Junction and a detailed map of sampling ponds on Fort Greely Military Reservation. (Ponds 2, 3 and 6 are treated; 1, 4 and 5 are controls.)

Tanana River 19.2 km (12 mi) north of Fort Greely (Pewe and Reger, 1983).

The surrounding terrestrial vegetation consists of mixed evergreen-deciduous scrub and shrub vegetation. Pond No. 4 off Meadows Road is located in a bog where its surrounding vegetation is primarily cottongrass tussocks (*Eriophorum vaginatum*) and sedges (*Carex* spp.). Stands of black spruce (*Picea mariana*), alder (*Alnus tenuifolis*), and willow (*Salix alaxensis*, *Salix arbusculoides*) are found throughout the study area as are various lichens and moss species.

Aquatic vegetation included sedges, reeds, dwarf buttercup, moss, water lily and grasses. Aquatics identified were of the genera *Equisetum*, *Utricularia*, *Rannunculus* and *Polygenom*. The ponds on the northwest area of the reservation nearest the Delta River are surrounded by dead trees burned in a fire that went through the reservation in the spring of 1981.

We selected this study area because: (1) the ponds are readily accessible by road; (2) the area does not receive a substantial influx of local traffic; (3) no fishes are present in any of the selected ponds; and (4) the ponds are relatively close to one another providing more efficient sampling.

The Delta Junction area has a high frequency of strong winds compared to other interior regions of Alaska, especially during the winter. From 20 years of data, the Federal Aviation Administration reports a near wind velocity of 9.3 miles per hour (4.2 meters per second) compared to 5 miles per hour (2.2 meters per second) in Fairbanks (Pewe and Reger, 1983). Calm occurs only 13 percent of the time. With such strong winds, the ponds treated with CMA should be thoroughly mixed within a couple of days.

On July 27, 1984, three ponds (numbers 2, 3 and 6) were treated with approximately 200 gallons of CMA. A submersible pump was used to transfer the CMA from 55 gallon plastic drums to the ponds.

On August 16, 1984, two ponds (number 2 and 6) were treated with an additional 200 gallons of CMA as the calcium level was not significantly elevated by the previous applications.

SAMPLING METHODS

Physical and Chemical Measurements

Physical factors such as air and water temperatures were measured at each sampling site. Surface water temperature readings were made with hand-held pocket thermometers. Supplementary information regarding daily air temperatures, precipitation and wind speeds for the various sites have been provided by the Fort Greely meteorological team.

Chemical factors of pH, alkalinity and dissolved oxygen (DO) were measured on site. Measurements of pH were made using a HACH digital pH meter. Alkalinity was measured as mg/l as $CaCO_3$ via Gran Plot titrations (Stumm and Morgan, 1970). The alkalinity of a water is its quantitative capacity for negative ions of the salts of weak acids to react with a strong acid to a designated pH (APHA, 1980). In low alkalinity waters, end point recognition must be fairly precise to decrease relative error. The Gran Plot titration method is based on the principle that added increments of mineral acid linearly increase hydrogen ion concentration (Stumm and Morgan, 1970).

Dissolved oxygen measurements were made via the Winkler Method, a titrimetric procedure based on the oxidizing property of dissolved oxygen (APHA, 1980). A dissolved oxygen meter was also used in this study, calibrated with the Winkler Method. This membrane electrode procedure is based upon the rate of diffusion of molecular oxygen across a membrane. Replicate samples were collected in 300 ml glass-stoppered biochemical oxygen demand (BOD) bottles, and DO was determined immediately. The titrant used was phenylarsenine oxide standardized against an iodate-iodide standard by HACH Chemical Company.

Total Chlorophyll *a*

Artificial substrate samplers for periphyton were suspended throughout the water column at three depths within two stations of each pond. Three replicates at corresponding depths in matched ponds were submersed for colonization for a total of six weeks. Samples were removed at two-week intervals and fixed with magnesium carbonate solution to reduce acidification during transport. The periphyton were scraped and filtered in the lab (Gelman glass fiber type A-E, 0.45 μm) and frozen for subsequent analysis. Cells were ruptured by grinding the filter in a tissue homogenizer, and the total chlorophyll a was extracted using a 90% acetone solution. Total chlorophyll a was measured with a spectrophotometer (Wetzel and Likens, 1979) or a fluorometer, dependent upon the amount of chlorophyll a present. The fluorometer was calibrated against the spectrophotometer according to Jeffrey and Humphrey (1975). Once the pigment concentration in the extract was determined, the amount of chlorophyll per unit surface area was calculated (APHA, 1980).

$$\text{Chl } \underline{a} \text{ (mg/m}^2\text{)} = \frac{\text{Ca x volume extract, l}}{\text{substrate area, m}^2}$$

where Ca = 11.6X (adsorption at 665 nm).

RESULTS

A chemical analysis of the calcium magnesium acetate solution (Table 1) shows calcium as the dominant ion (96.2% of the total concentration, excluding acetate) and magnesium a minor constituent (.037% total concentration). The solution should thus be considered a calcium acetate (CA) rather than calcium magnesium acetate (CMA) mixture.

Physical/Chemical Factors

The maximum and minimum ranges for pH, total alkalinity (mg/L as $CaCO_3$), dissolved oxygen (mg/L) and water temperature (°C) are listed for each pond in Tables 2 through 7. All data collected are contained in Appendices A and B. In pair one, pH fluctuated throughout the summer; the highest readings were obtained during August, and were probably caused by intense plant production. Total alkalinity values rose steadily; the control pond increased approximately 3.3 times and

TABLE 1. Chemical analysis of calcium acetate solution.

Parameter	mg/L	Standard deviation
Acetate ion	399,000*	---
Arsenic	0.607	0.069
Cadmium	0.159	0.001
Calcium	67,800	640
Chloride	2,100	---
Chromium	0.440	0.002
Lead	0.287	0.038
Magnesium	21.3	0.100
Mercury	0.002	---
Nickel	3.99	0.090
Phosphorous	200	100
Selenium	1.60	0.310
Sodium	14.0	0.300
Sulfate-S	304	---

* By calculation, if all the calcium is combined with the acetate.

Analysis done by Northern Testing Laboratories, Inc.

TABLE 2. Minimum and maximum values of physical/chemical characteristics for Pond Three. (Treated: Pair One)

Characteristic Measured	June	July	August	September
pH	6.73- 7.08	6.23- 7.58	5.90- 8.10	
Total alkalinity (mg/l as $CaCO_3$)	20.79-44.73	36.05-52.28	61.56-97.11	94.95-99.90
Dissolved oxygen (mg/l)		6.80-11.00	8.80-10.10	
Water temperature (°C)	12-19	9-23	6-19	7-8

TABLE 3. Minimum and maximum values of physical/chemical characteristics for Pond Five. (Control: Pair One)

Characteristic Measured	June	July	August	September
pH	6.79- 7.33	6.43- 7.36	6.80- 7.40	
Total alkalinity (mg/l as $CaCO_3$)	16.54-27.09	30.26-96.60	35.14-62.53	48.98-54.60
Dissolved oxygen (mg/l)	9.45*	8.25-11.30	8.70- 9.60	9.50-10.20
Water temperature (°C)	15-22	15-20	10-16	7-8

* No replication

TABLE 4. Minimum and maximum values of physical/chemical characteristics for Pond One. (Control: Pair Two)

Characteristic measured	May	June	July	August	September
pH	5.85- 5.90	5.75- 6.63	6.30- 7.15	5.90- 8.10	
Total alkalinity (mg/l as $CaCO_3$)		4.10-37.80	44.70-104.24	42.61-46.91	48.38-52.73
Dissolved oxygen (mg/l)			5.77- 8.37	9.00*	7.73*
Water temperature (°C)	13-15	16-22	14-23	7-16	

TABLE 5. Minimum and maximum values of physical/chemical characteristics for Pond Six. (Treated: Pair Two)

Characteristic measured	May	June	July	August	September
pH	6.60- 7.40	6.42- 6.79	6.38- 7.55	6.98- 7.80	6.57- 6.87
Total alkalinity (mg/l as $CaCO_3$)		8.85-27.92	20.40- 47.12	68.40-85.20	74.62-78.82
Dissolved oxygen (mg/l)		7.00- 8.39	9.00*	7.80- 9.00	6.50- 9.27
Water temperature (°C)	15-17	15-22	12-20	7-16	8

* No replication.

TABLE 6. Minimum and maximum values of physical/chemical characteristics for Pond Two. (Treated: Pair Three)

Characteristic measured	June	July	August	September	October
pH	6.66- 6.95	6.64- 7.54	7.02- 7.80	7.10	
Total alkalinity (mg/l as $CaCO_3$)	17.20-34.40	53.67-83.93	116.99-120.20		191.10-204.83
Dissolved oxygen (mg/l)		5.97- 8.77	6.60- 7.70	5.77	
Water temperature (°C)	15-21	13-24	6-19	10	

TABLE 7. Minimum and maximum values of physical/chemical characteristics for Pond Four. (Control: Pair Three)

Characteristic measured	June	July	August	September	October
pH	6.59- 6.84	6.83- 7.30	6.85- 8.60	6.70- 6.99	
Total alkalinity (mg/l as $CaCO_3$)	35.28-52.29	54.37-88.37	74.48-94.07	94.50-100.80	
Dissolved oxygen (mg/l)		7.07*	9.60-10.60	9.50- 10.70	
Water temperature (°C)	14-19	12-22	6-17	6-8	

* No replication.

the treated pond 4.8 times its original value. The final value for the treated pond was 1.8 times higher than the control. Dissolved oxygen values did not show any significant differences between the two, and the water temperature readings fluctuated throughout the season in both ponds.

In pair two, pH readings varied with the highest values again obtained during the month of August. Total alkalinity increased 12.9 times its initial value in the control and 8.9 times in the treated pond. Dissolved oxygen and water temperature varied throughout the summer.

Pair three shows the highest pH values during August, decreasing in September. Total alkalinity increases 11.9 times in the treated and 2.8 times in the control pond. Dissolved oxygen values are higher in the control and the water temperature fluctuates similarly in both.

Cation Presence

Water samples were analyzed for calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}) concentrations via atomic absorption spectrophotometry. Samples taken at three different depths (Appendix C) exhibited no significant difference in concentration, therefore all reported values are mean concentrations over depth (Table 8).

Calcium concentrations within the treated ponds showed a dramatic increase after July 31, 1984. The ponds were treated by the addition of 200 gallons of calcium acetate on July 29, 1984. The largest difference in calcium level, 14 mg/L occurs within Pair 1 on August 28 (Figure 2). In the treated pond, the mean concentration increases from 4.00 mg/L in June to 22.2 mg/L in late August for a mean seasonal value of 16.84 mg/L. In the control, calcium increased from 4.00 mg/L in early June to its maximum 9.8 mg/L in late September with a mean seasonal value of 8.53 mg/L.

Pair two shows a steady increase in calcium within the treated pond beginning August 5, 1984, approximately one week after addition of 200 gallons of calcium acetate (Figure 3). A second inflection point can be detected on August 22 as the calcium level continues its gradual increase. The point represents a week after the second addition of 200

TABLE 8. Mean concentration of cations within pairs, n = 33.

	Cation	Seasonal mean conc'n (mg/L)	Standard deviation	Minimum & Maximum
PAIR ONE				
Treated	Calcium	16.84	5.72	4.00 - 24.2
	Magnesium	4.78	1.07	2.80 - 7.3
	Sodium	1.13	0.36	0.52 - 2.0
	Potassium	1.40	0.48	0.55 - 2.8
Control	Calcium	8.53	2.21	4.00 - 11.7
	Magnesium	3.19	0.90	1.10 - 4.70
	Sodium	1.13	0.63	0.18 - 3.40
	Potassium	2.12	1.09	0.36 - 6.90
PAIR TWO				
Treated	Calcium	13.66	6.93	2.3 - 22.2
	Magnesium	2.23	1.34	0.68 - 8.8
	Sodium	0.52	0.20	0.15 - 1.3
	Potassium	2.03	0.56	0.19 - 2.9
Control	Calcium	10.69	3.60	4.8 - 23.4
	Magnesium	4.74	1.16	1.9 - 6.2
	Sodium	0.68	0.40	0.21 - 2.7
	Potassium	1.38	0.56	0.91 - 4.00
PAIR THREE				
Treated	Calcium	22.16	6.73	7.2 - 29.3
	Magnesium	6.90	1.77	2.5 - 8.8
	Sodium	1.37	0.50	0.78 - 3.0
	Potassium	1.68	0.75	0.70 - 2.6
Control	Calcium	20.40	5.43	8.8 - 28.8
	Magnesium	6.93	1.72	2.1 - 8.8
	Sodium	1.38	0.37	0.48 - 2.6
	Potassium	0.67	0.83	0.09 - 3.9

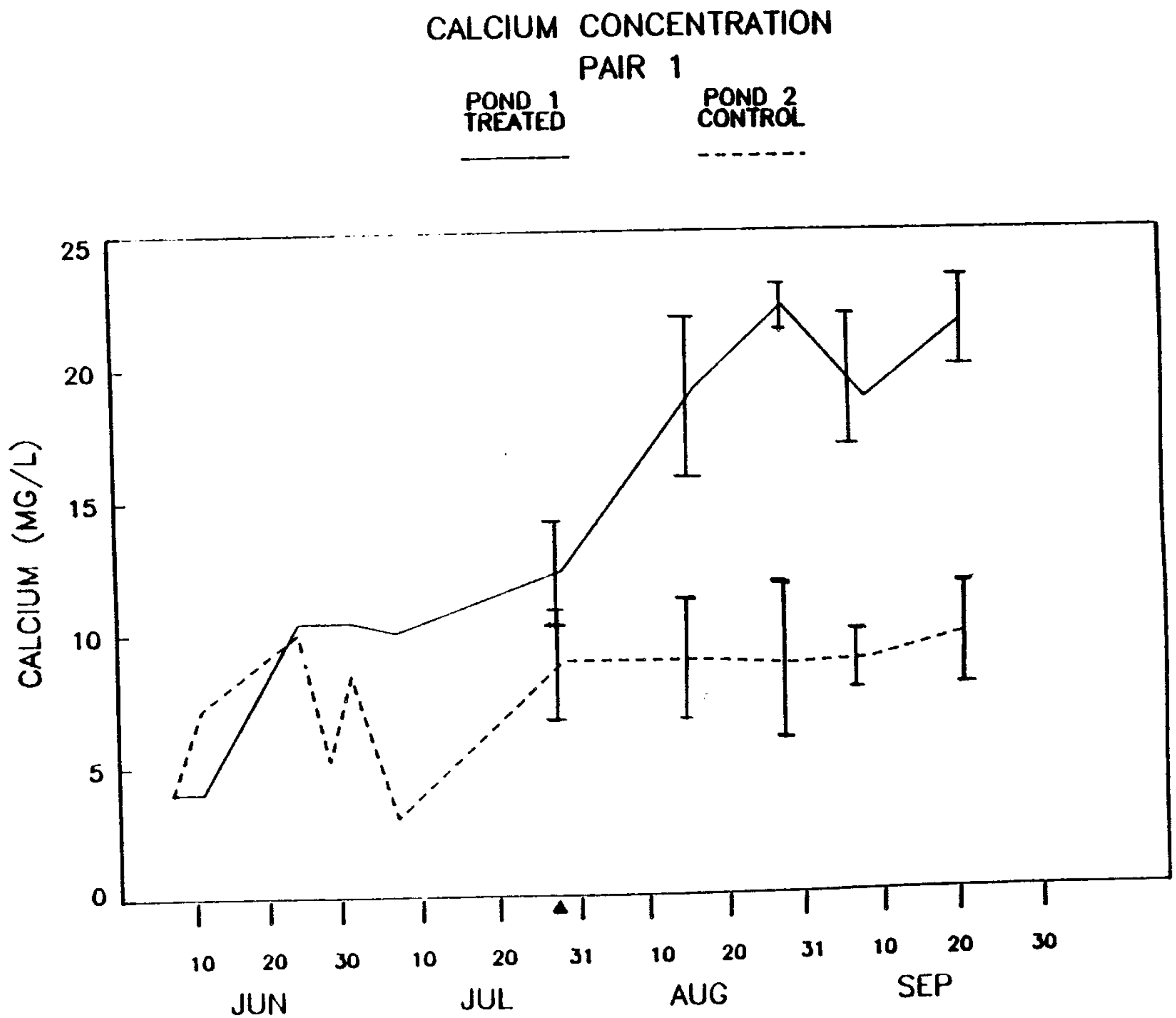

Figure 2. Mean calcium concentrations for Pair One.

▲: CMA addition

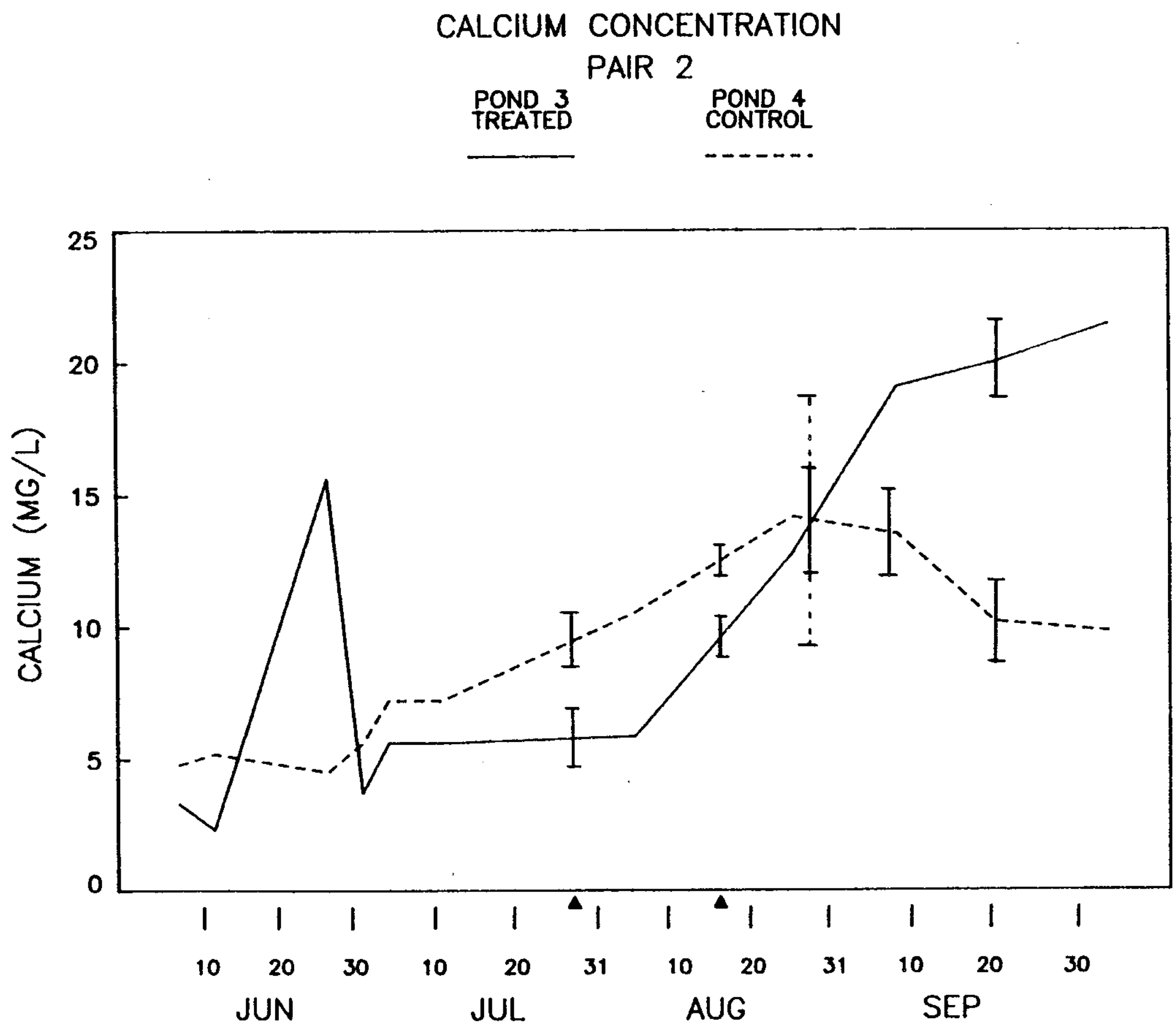

Figure 3. Mean calcium concentrations for Pair Two.

▲: CMA addition

gallons of CA. The calcium level increases from 2.3 mg/L in early June to a maximum 21.4 mg/L in late September. The control pond has higher calcium concentration from early July until late August. Its minimum concentration was 4.8 mg/L in early June and its maximum concentration 13.5 mg/L in late August, decreasing to 9.8 mg/L by late September.

Pair three does not show significant differences in calcium levels until early September. The treated pond had a calcium level of approximately 26 mg/L, increasing to 28.5 mg/L in early September (Figure 4). The control pond decreased from 23 mg/L to 19 mg/L in the same period of time. Samples from the treated pond were not obtained in late September.

Total Chlorophyll *a*

A multivariate analysis of variance (MANOVA) was designed by Dr. Dana Thomas to test the variability of the chlorophyll data within and between paired ponds. The test determined no difference in chlorophyll *a* with depth or station between treated and control ponds. Date, or length of time for colonization was found to be a significant source of variance. Tables 9 through 14 present mean chlorophyll *a* values and their standard deviations for the three sampling periods (Tables 13 and 14 have only two sampling dates because the samples in the treated pond were not recovered). Figures 5 through 7 present chlorophyll *a* within the two stations of each pond.

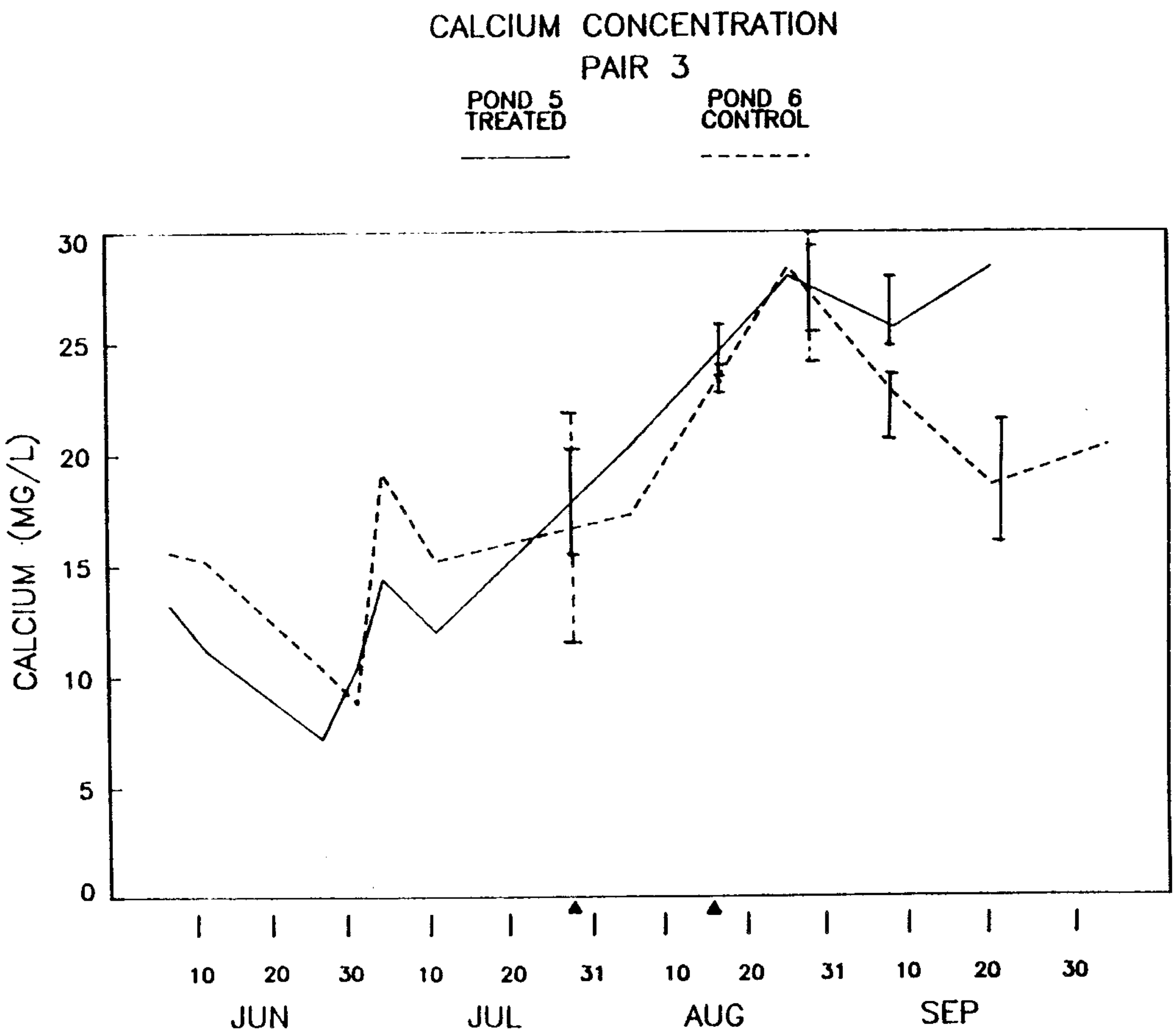

Figure 4. Mean calcium concentrations for Pair Three.

▲: CMA addition

TABLE 9. Mean chlorophyll *a* colonization - Pond Five.
(Control: Pair One)

	Chlorophyll a (mg/m^2)					
	VIII/26/84		IX/6/84		IX/21/84	
	Mean two week	Standard deviation	Mean four week	Standard deviation	Mean six week	Standard deviation
Depth (m)						
Station I:						
0.25	.048	.009	.108	.055	.459	.303
0.50	.060	.015	.151	.130	.645	.491
0.75	.094**		.140	.068	.541	.340
Station II:						
0.50	.062	.008	.343	.161	.415	.001
1.00	.068**		.478	.143	.616	.186
1.50	.058	.013	.276	.187	1.10	0.56

TABLE 10. Mean chlorophyll *a* colonization - Pond Three.
(Treated: Pair One)

	Chlorophyll a (mg/m^2)				
	VIII/26/84		IX/6/84		IX/21/84
	Mean two week	Standard deviation	Mean four week	Standard deviation	Mean six week
Depth (m)					
Station I:					
0.25	1.53	1.93	2.72	1.74	4.33**
0.50	1.21	0.814	2.38	0.47	1.13**
0.75	***		1.96		1.99**
Station II:					
0.50	2.01	.594	2.62	1.35	***
1.00	0.344	.26	4.88		***
1.50	0.728	.09	.658	.364	***

*** Samples not recovered.
** No replication.

TABLE 11. Mean chlorophyll a colonization - Pond Six. (Treated: Pair Two)

	Chlorophyll a (mg/m²)					
	VIII/26/84		IX/5/84		IX/22/84	
	Mean two week	Standard deviation	Mean four week	Standard deviation	Mean six week	Standard deviation
Depth (m)						
Station I:						
0.25	.144**		.544	.224	1.34	1.17
0.50	.186	.016	1.09	.338	1.96	0.449
0.75	.293	.064	.792	.072	1.89	0.353
Station II:						
0.50	.152**		.864	.632	1.59	0.396
1.00	.252	.028	.761	.089	2.74	1.37
1.50	.297**		1.01	.558	1.69	0.382

TABLE 12. Mean chlorophyll a colonization - Pond One. (Control: Pair Two)

	Chlorophyll a (mg/m²)					
	VIII/26/84		IX/5/84		IX/22/84	
	Mean two week	Standard deviation	Mean four week	Standard deviation	Mean six week	Standard deviation
Depth (m)						
Station I:						
0.25	.469	.373	.610	.419	1.02	.105
0.50	.416	.156	1.40	.198	.349	.236
0.75	.526**		.821	.765	.663	.027
Station II:						
0.50	.364	.098	.806	.168	.806	.168
1.00	.478	.305	1.07	.969	1.37	.996
1.50	.382	.028	.468	.232	.468	.232

** No replication.

TABLE 13. Mean chlorophyll a colonization - Pond Four. (Control: Pair Three)

	Chlorophyll a (mg/m^2)			
	VIII/26/84		IX/5/84	
	Mean two week	Standard deviation	Mean four week	Standard deviation
Depth (m)				
Station I:				
0.20	2.18	.658	1.62	.728
0.40	1.40		2.61	1.52
0.60	3.54**	.064	7.36	1.70
Station II:				
0.25	1.47	.244	2.18	2.43
0.50	2.24	.134	2.42	.771
0.75	2.83	.792	1.39	.681

TABLE 14. Mean chlorophyll a colonization - Pond Two. (Treated: Pair Three)

	Chlorophyll a (mg/m^2)			
	VIII/26/84		IX/5/84	
	Mean two week	Standard deviation	Mean four week	Standard deviation
Depth (m)				
Station I:				
0.20	1.04	.518	1.45	.911
0.40	1.02	.327	2.14	.908
0.60	2.04	1.20	3.65	2.30
Station II:				
0.25	0.635	.071	1.52	.170
0.50	0.818	.172	1.51	.552
0.75	2.36	1.39	2.94	3.07

** No replication.

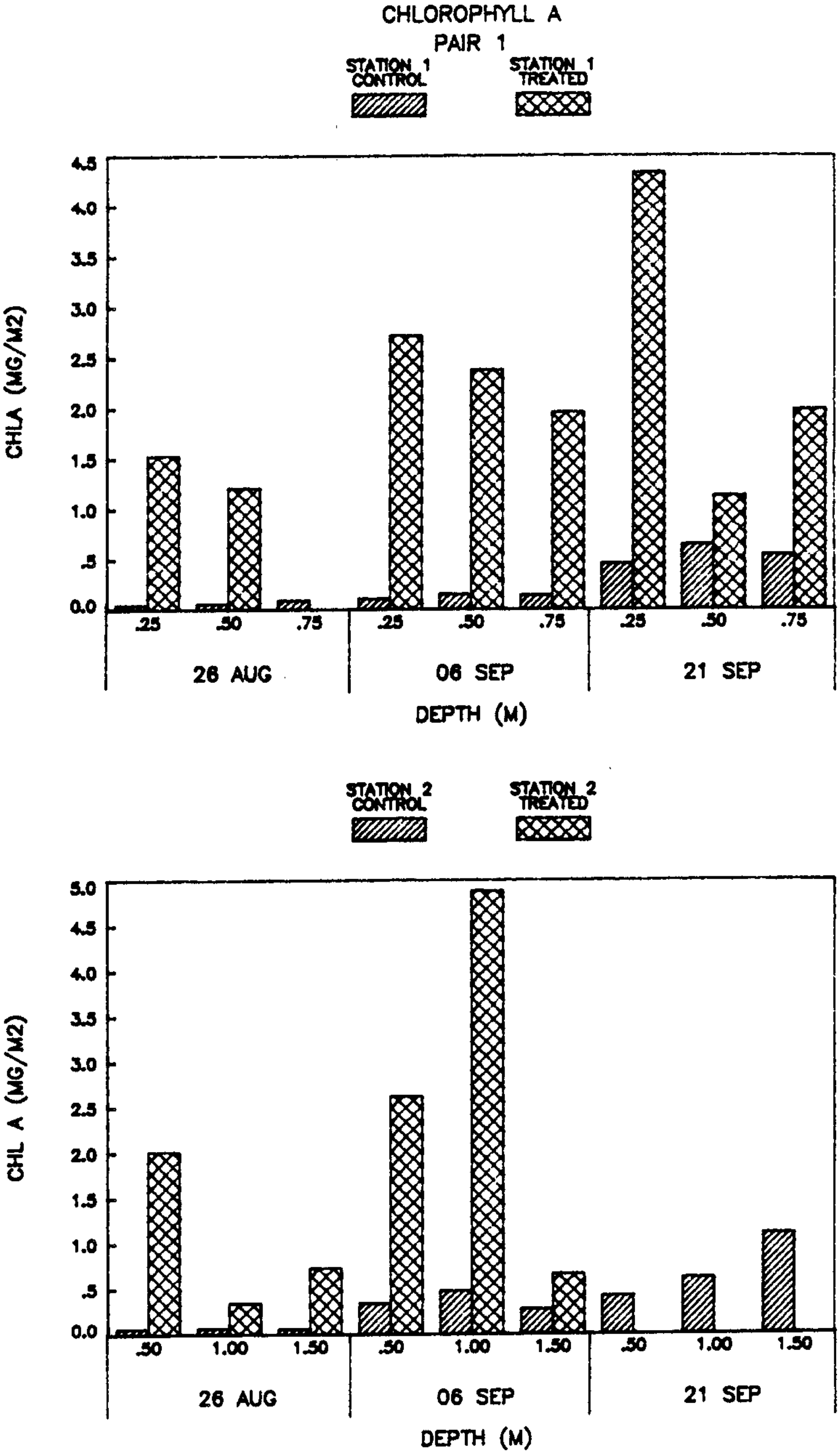

Figure 5. Mean concentration of chlorophyll a for Pair One. Station 1 = shallow. Station 2 = deep.

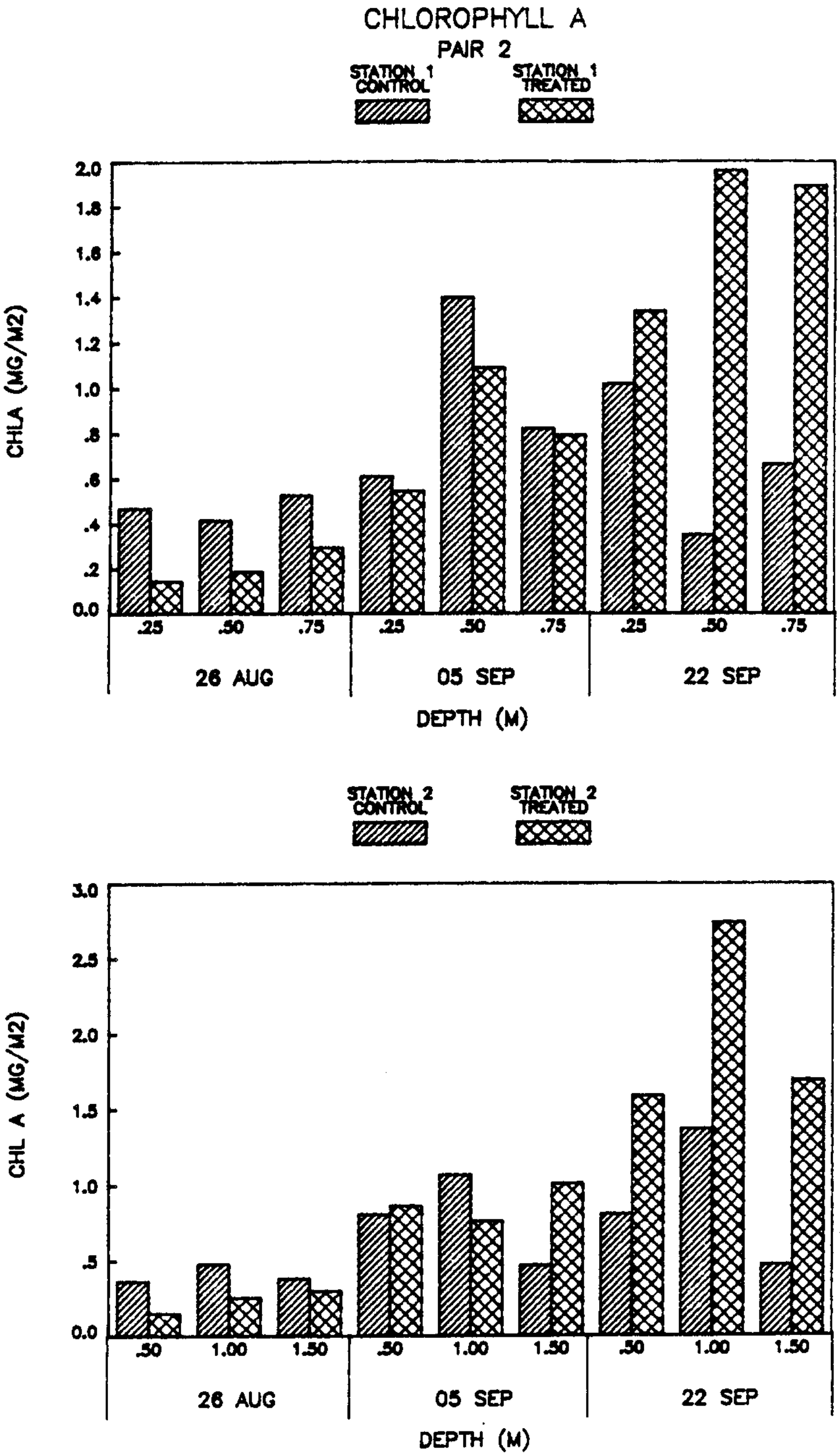

Figure 6. Mean concentration of chlorophyll *a* for Pair Two. Station 1 = shallow. Station 2 = deep.

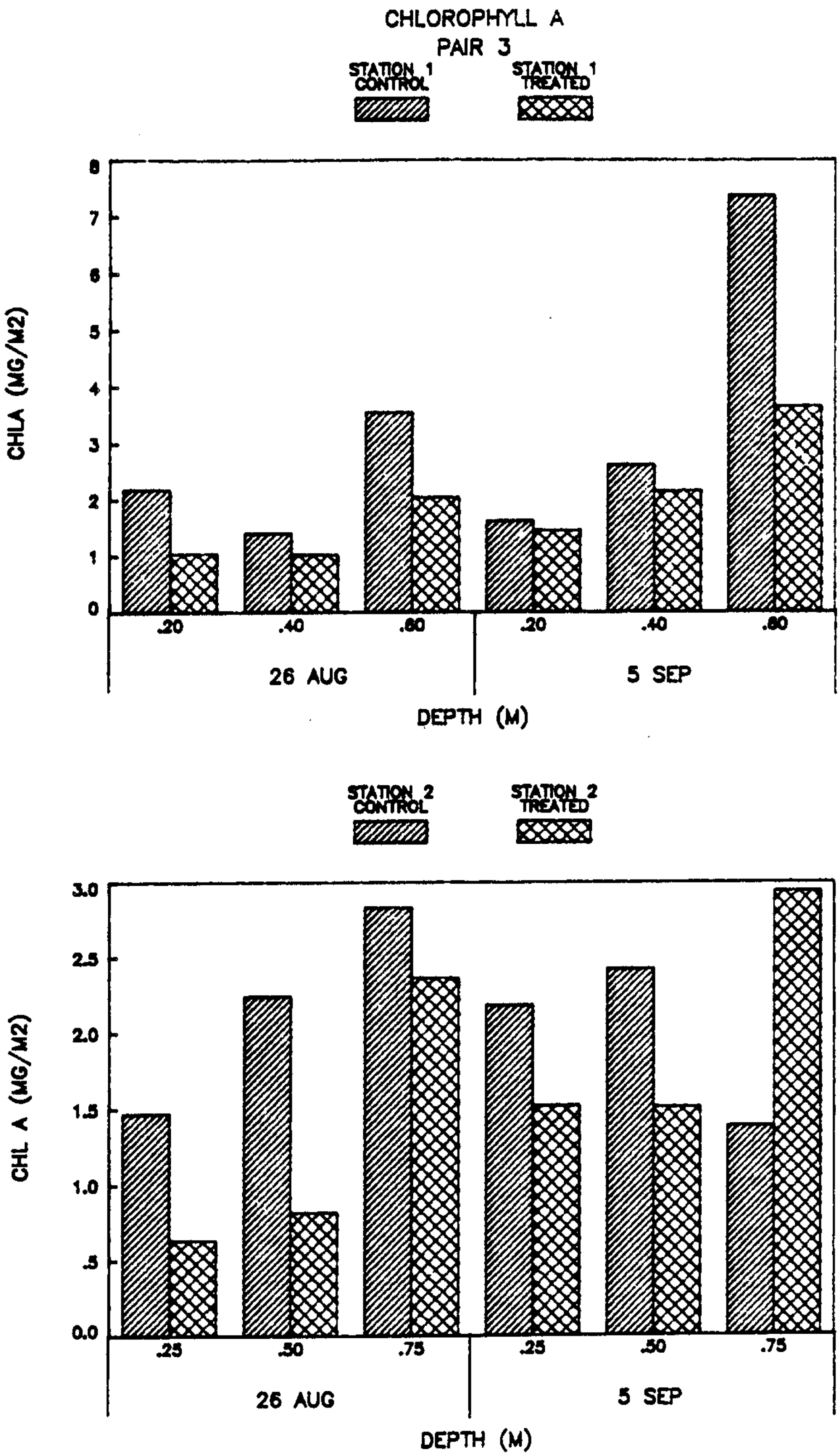

Figure 7. Mean concentration of chlorophyll a for Pair Three. Station 1 = shallow. Station 2 = deep.

DISCUSSION

The most significant differences between the control and treated ponds are shown in the level of calcium present. The addition of calcium acetate elevated the levels substantially and the calcium concentrations were continually increasing as of the last sampling dates (Figures 2, 3 and 4). The initial cation levels from May were low. This could be due to the presence of meltwater from snow runoff at that time. The ponds freeze to the bottom in winter so that the initial water is primarily due to runoff.

Samples taken at different depths and locations within the ponds did not show enough variation to warrant this sampling procedure in the continuation study. The ponds are shallow and the existence of high winds is sufficient to mix them thoroughly, prventing any stratification effects.

Dissolved oxygen levels did not vary greatly throughout the summer, however, more tests should have been done to accurately monitor any noticeable changes. A diurnal dissolved oxygen run should be made at least monthly within each pond to get a representative oxygen profile available to the algae and bacteria.

Algae growth was not significantly inhibited nor enhanced within the treated as compared to the control ponds. The maximum accumulation of periphyton occurred after six weeks. A longer incubation time is necessary to determine if the maximum accumulation would have occurred later. A six week incubation period is usually the accepted maxima because sloughing of cells occurs after that time (Welch, 1980). The disadvantages in using artificial substrata are: (1) the species that might normally occur within the pond are not necessarily selected; and (2) the accumulation rate could not be related to productivity per se because growth is starting from a bare area in contrast to what would normally be occurring as standing crop. Advantages of using artificial substrata are: (1) they represent a known area on which organisms at each station have an equal chance for attachment and growth; (2) a precise, comparable "rate of growth" or "rate of accumulation" can be determined; (3) they facilitate data collection; and (4) they can be a sensitive index of water quality and effects are integrated over time.

In the continuation of the CMA study we will also focus on the effects on the bacterial populations within the water column of the ponds. Background information will be obtained from the collection of phytoplankton and benthic algae for chlorophyll a estimates and supportive physical/chemical measurements will be taken. Laboratory studies will be done to determine the rate of uptake of the acetate molecule by the bacterial populations. The rate of consumption of the acetate by the bacteria is important in understanding the significance of adding such a food source to an ecosystem. A direct count method using a fluorescent dye and epifluorescence microscope will be done to count aquatic bacteria (Hobbie et al., 1977).

IMPLEMENTATION

This environmental assessment project is a portion of a larger program concerned with the production and utilization of calcium magnesium acetate (CMA) as a road deicer. The results of this project, and its successor project, will provide the information necessary to file an environmental impact statement should the Department of Transportation and Public Facilities decide to proceed with a full-scale demonstration of CMA.

Larry Sweet
Project Manager
DOT&PF

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APPENDIX A. Physical/chemical characteristics.

Date	Air Temp (°C)	Water	Time	pH	DO (mg/L)	Cloud cover (%)
			PAIR ONE			
			CONTROL			
7 June	25	15	1815	7.23		25.00
14 June	16	16	1600	6.79		100.00
21 June	20	22	1815			
22 June	15	20	2030	7.30	9.45	25.00
28 June	19	20	1900	7.33		
1 July	16	15	40		8.25	
1 July	24	20	1300		10.35	25.00
6 July	18	18	1630	7.02		25.00
7 July	13	17	1830	6.43		
13 July	12		2200		11.30	
14 July	12	18	1430	7.01	9.36	75.00
29 July*	12	13	1545	7.36		100.00
2 August	19	13	5			
3 August	24	16	1145			50.00
19 August**	15	12	1330	7.40	8.70	75.00
25 August	10	10	1530	6.80	9.60	
30 August	6	7	1615	7.14		100.00
6 Sept	13	8	1050		10.20	25.00
21 Sept	15	7	1550	6.98	9.50	25.00
			TREATED			
7 June	19	17	2030			
14 June	12	15	1820	6.96		100.00
22 June	15	17	2050	6.73		25.00
28 June	17	21	1615	7.08		100.00
1 July	23	23	1510			25.00
6 July	18	14	1300	6.23	6.80	100.00
7 July	13	18	1510	7.28		100.00
13 July	9	19	20	6.60		50.00
13 July	9		100		8.61	
13 July	15	14	1000	7.35	9.59	
13 July	18	16	1630	7.58	11.00	75.00
14 July	13	16	1700	6.99		100.00
29 July	20	14	1255	7.01		50.00
2 August	20	16	2005	5.90		
3 August	24	19	1310			50.00
17 August	19	16	1700		9.74	75.00
19 August	12	12	1020	7.80	8.80	100.00
26 August	2	8	930	8.10	10.10	
30 August	6	6	1515	7.02		100.00

APPENDIX A (Continued).

Date	Air Temp (°C)	Water	Time	pH	DO (mg/L)	Cloud cover (%)
			PAIR TWO			
			CONTROL			
15 May	20	13				100.00
21 May	19	15	11.45	5.90		25.00
25 May	7	14	1325	5.85		100.00
7 June	19	16	2100			100.00
14 June	12		18.40	6.03		100.00
23 June	16	19	40	5.75		25.00
28 June	20	22	1400	6.63		25.00
1 July	26	23	1540			25.00
6 July	18	20	17.30	7.15		100.00
7 July	15	18	1305	7.13		100.00
12 July	11	20	2200	6.30	7.07	
13 July	14	14	900	7.04	5.77	
13 July	12	16	1520	7.15	8.37	
14 July	13	16	1710	6.61		
29 July	20	14	1055	6.60		25.00
2 August	20	16	2005	5.90		
26 August	6	7	1445	6.77		100.00
30 August	6	7	1445	6.77		100.00
6 Sept	14	10	1400	6.45	7.73	25.00
			TREATED			
21 May	17	15	1445	6.60		75.00
25 May	25	17	1430	7.40		25.00
14 June	16	15	1600	6.79		100.00
21 June	24	22	1535		8.39	
22 June	18	22	1700	6.43	7.00	
30 June	16	14	2355		7.40	
1 July	24	20	1430			25.00
6 July	18	18	1630	7.02		25.00
7 July	13	17	1930	6.38		
13 July			2330	7.55	9.00	
13 July	12	17	1500	6.50	9.00	75.00
29 July	12	12	1610	7.20		100.00
2 August	19	13	20			
3 August	24	16	1115			50.00
19 August	15	13	1220	7.80	7.80	75.00
25 August	11	10	945	7.80	9.00	
30 August	6	7	1630	6.98		100.00
6 Sept	13	8	1100	6.85	6.50	25.00
22 Sept	12	8	1430	6.57	9.27	25.00

APPENDIX A (Continued).

Date	Air Temp (°C)	Water	Time	pH	DO (mg/L)	Cloud cover (%)
			PAIR THREE			
			CONTROL			
21 May	18	14	1325	6.60		75.00
7 June	16	15	1945			
14 June	12	14	1710	6.73		100.00
22 June	15		2040	6.59		
28 June	14	19	1730	6.84		
1 July	24	22				25.00
6 July	18	15	1604	7.12		25.00
7 July	13	15	1700	7.13		25.00
13 July	12	13	35	7.30	7.07	
29 July	12	12	1440	6.83		25.00
2 August	19	13	2330			
3 August	24	17	1220			50.00
17 August	15	16	1920		10.60	75.00
19 August	15	15	1435	8.60	9.60	75.00
25 August	10				10.30	
30 August	6	6	1550	6.85		100.00
6 Sept	13	8	1220	6.70	9.50	25.00
21 Sept	7	6	1825	6.99	10.70	25.00
			TREATED			
7 June	19	17	2035			
14 June	12	15	1810	6.78		100.00
23 June	15	16	10	6.66		25.00
28 June	17	21	1650	6.95		
1 July	23	24	1455			25.00
6 July	18	19	1525		5.97	100.00
7 July	13	17	1600	7.17		100.00
13 July	9	18	230	6.85	7.52	50.00
13 July	15	13	1100	7.31	8.77	
13 July	18	15	1700	7.54	8.66	
14 July	13	17	1700	6.93		100.00
29 July	20	15	1155	6.64		25.00
2 August	20	15	2050			
3 August	24	19	1335			50.00
17 August	19	16	1845		7.70	75.00
19 August	12	12	1020	7.80	6.60	75.00
26 August	2		1045	7.20		
30 August	6	6	1515	7.02		100.00
6 Sept	13	10	1335	7.10	5.77	25.00

APPENDIX B. Gran titration alkalinities

Julian date	Pair	Pond	Station	Depth (m)	pH	Alkalinity (mg/L as $CaCO_3$)
158	1	Treated	1	0.40	6.79	20.79
173	1	Treated	1	0.40	6.73	44.73
188	1	Treated	1	0.40	7.28	36.05
197	1	Treated	1	0.40	7.12	44.55
210*	1	Treated	1	0.25	6.91	48.83
210	1	Treated	1	0.50	7.01	52.28
242*	1	Treated	2	0.20	7.10	97.11
242	1	Treated	2	0.40	7.20	96.64
242	1	Treated	2	0.60	6.91	95.72
264	1	Treated	1	0.20	7.08	99.90
264	1	Treated	1	0.40	7.36	95.03
264	1	Treated	1	0.60	7.22	95.48
264	1	Treated	2	0.20	7.03	96.08
264	1	Treated	2	0.40	7.51	94.95
264	1	Treated	2	0.60	7.08	98.48
158	1	Control	1	0.40	7.23	27.09
173	1	Control	1	0.40	7.30	16.54
188	1	Control	1	0.40	6.43	30.26
197	1	Control	1	0.40	7.42	44.25
210	1	Control	1	0.25	7.11	82.58
210	1	Control	1	0.50	7.15	96.60
242	1	Control	2	0.20	6.68	54.60
242	1	Control	2	0.40	6.90	53.70
242	1	Control	2	0.60	6.89	55.88
264	1	Control	1	0.20	6.30	51.90
264	1	Control	1	0.40	6.50	54.60
264	1	Control	1	0.60	6.82	52.80
264	1	Control	2	0.20	6.34	51.38
264	1	Control	2	0.40	6.49	53.18
264	1	Control	2	0.60	6.35	48.98

* CMA additions

APPENDIX B (Continued)

Julian date	Pair	Pond	Station	Depth (m)	pH	Alkalinity (mg/L as $CaCO_3$)
158	2	Treated	1	0.40	6.96	27.92
173	2	Treated	1	0.40	6.45	8.85
188	2	Treated	1	0.40	6.38	20.40
194	2	Treated	1	0.40	6.79	42.38
210*	2	Treated	1	0.25	6.54	26.70
210	2	Treated	1	0.50	7.41	29.85
242*	2	Treated	2	0.20	6.78	85.20
242	2	Treated	2	0.40	7.01	83.65
242	2	Treated	2	0.60	7.08	84.92
265	2	Treated	1	0.40	6.88	78.37
265	2	Treated	1	0.40	7.17	78.37
265	2	Treated	1	0.60	7.44	78.82
265	2	Treated	2	0.20	6.88	74.62
265	2	Treated	2	0.40	7.27	77.93
265	2	Treated	2	0.60	6.80	78.15
158	2	Control	1	0.40	6.23	4.10
173	2	Control	1	0.40	5.75	37.80
188	2	Control	1	0.40	7.13	32.86
194	2	Control	1	0.40	6.84	42.83
210	2	Control	1	0.25	6.60	44.70
210	2	Control	1	0.50	7.15	104.24
242	2	Control	2	0.20	6.80	42.61
242	2	Control	2	0.40	6.61	42.62
242	2	Control	2	0.60	6.63	46.91
265	2	Control	1	0.20	6.26	51.53
265	2	Control	1	0.40	7.28	50.63
265	2	Control	1	0.60	6.38	48.38
265	2	Control	2	0.20	6.88	51.90
265	2	Control	2	0.20	7.10	51.30
265	2	Control	2	0.20	7.22	52.73

* CMA additions

APPENDIX B (Continued)

Julian date	Pair	Pond	Station	Depth (m)	pH	Alkalinity (mg/L as $CaCO_3$)
158	3	Treated	1	0.40	6.78	34.40
173	3	Treated	1	0.40	6.66	17.20
188	3	Treated	1	0.40	7.17	53.67
194	3	Treated	1	0.40	7.10	68.63
210*	3	Treated	1	0.25	6.92	76.50
210	3	Treated	1	0.50	7.08	83.93
242*	3	Treated	1	0.20	7.10	120.20
242	3	Treated	1	0.40	7.02	116.99
242	3	Treated	1	0.60	6.80	119.55
285	3	Treated	1	0.20	7.31	191.10
285	3	Treated	1	0.40	7.18	204.83
285	3	Treated	1	0.60	7.16	203.10
158	3	Control	1	0.40	6.90	52.29
173	3	Control	1	0.40	6.59	35.28
188	3	Control	1	0.40	7.13	54.37
194	3	Control	1	0.40	6.82	86.25
210	3	Control	1	0.25	6.91	88.37
210	3	Control	1	0.50	6.91	76.88
242	3	Control	1	0.20	6.71	74.48
242	3	Control	1	0.40	6.72	94.07
242	3	Control	1	0.60	6.78	90.10
264	3	Control	1	0.20	6.99	104.10
264	3	Control	1	0.40	7.35	103.65
264	3	Control	1	0.60	6.95	110.48
264	3	Control	2	0.20	6.35	94.50
264	3	Control	2	0.40	6.90	96.60
264	3	Control	2	0.60	6.95	100.80

* CMA additions

APPENDIX C. Concentration of metals.

Julian Date	Station	Depth (m)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)
			PAIR ONE			
			TREATED			
158	1	0.40	4.00	2.80	0.96	1.6
162	1	0.40	4.00	3.00	0.99	2.8
175	1	0.40	10.4	3.80	1.2	1.7
179	1	0.40	10.4	3.80	1.2	1.7
183	1	0.40	10.4	3.60	1.6	1.8
188	1	0.40	10.0	3.90	1.9	2.3
210*	1	0.20	12.8	4.3	0.68	0.94
210	1	0.40	12.8	4.3	0.70	0.98
210	1	0.60	14.4	5.3	0.82	1.1
210	2	0.20	10.4	3.2	0.68	0.83
210	2	0.40	11.2	3.2	0.62	0.85
210	2	0.60	12.0	4.0	0.77	0.80
228*	1	0.20	20.0	5.6	1.1	1.2
228	1	0.40	17.6	4.6	0.83	0.88
228	1	0.60	14.4	3.4	0.52	0.55
228	2	0.20	18.4	5.4	1.1	1.2
228	2	0.40	23.2	4.3	1.1	1.8
228	2	0.60	20.8	5.8	1.1	1.3
240	1	0.20	21.3	5.3	1.0	1.3
240	1	0.40	22.6	4.9	0.81	0.95
240	1	0.60	22.6	5.5	1.2	1.4
240	2	0.20	22.6	5.6	1.4	1.4
240	2	0.40	21.3	5.3	1.2	1.4
240	2	0.60	22.6	5.4	1.2	1.5
251	1	0.20	20.0	5.1	1.1	1.5
251	1	0.40	20.0	7.3	1.4	2.4
251	1	0.60	16.0	4.4	0.94	1.2
264	1	0.20	20.8	5.9	1.3	1.2
264	1	0.40	21.3	5.9	1.5	1.3
264	1	0.60	20.1	5.7	1.6	1.5
264	2	0.20	21.2	5.6	1.5	1.5
264	2	0.40	21.8	6.1	1.4	1.4
264	2	0.60	24.2	5.6	2.0	1.9

* CMA additions

APPENDIX C (Continued)

			PAIR ONE			
Julian Date	Station	Depth (m)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)
			CONTROL			
158	1	0.40	4.00	2.70	3.40	2.20
162	1	0.40	7.20	1.80	0.39	1.30
175	1	0.40	10.00	3.60	3.10	6.90
179	1	0.40	5.20	2.10	0.81	2.10
183	1	0.40	8.40	3.10	1.40	2.90
188	1	0.40	3.00	1.20	0.18	0.36
210	1	0.20	10.00	3.60	1.20	1.50
210	1	0.40	9.6	3.6	1.0	2.2
210	1	0.60	10.00	3.60	1.10	2.20
210	2	0.20	5.6	2.0	0.68	1.1
210	2	0.40	8.8	3.2	1.1	2.1
210	2	0.60	9.2	3.6	1.1	1.4
228	1	0.20	8.8	3.0	0.84	1.7
228	1	0.40	5.6	1.9	0.42	0.73
228	1	0.60	10.4	3.2	0.88	1.9
228	2	0.20	10.4	3.6	1.2	2.5
228	2	0.40	9.2	4.7	0.81	1.6
228	2	0.60	8.8	2.7	0.76	1.4
240	1	0.20	4.7	1.1	0.66	0.68
240	1	0.40	11.3	3.7	1.2	2.3
240	1	0.60	9.2	3.3	0.65	1.2
240	2	0.20	6.3	2.0	0.72	1.5
240	2	0.40	10.5	3.8	1.3	2.6
240	2	0.60	10.1	3.7	1.2	2.6
251	1	0.20	7.8	3.3	1.2	2.6
251	1	0.40	9.8	3.7	1.2	2.4
251	1	0.60	8.9	4.4	1.2	2.4
264	1	0.20	10.4	3.9	1.6	2.6
264	1	0.40	6.9	3.9	1.1	2.6
264	1	0.60	11.7	4.4	1.2	2.3
264	2	0.20	9.2	3.2	1.2	2.6
264	2	0.40	10.9	3.7	1.2	2.6
264	2	0.60	9.6	4.0	1.4	2.9

APPENDIX C (Continued)

Julian Date	Station	Depth (m)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)
			PAIR TWO			
			TREATED			
158	1	0.40	3.3	0.92	0.15	1.4
162	1	0.40	2.3	0.68	0.24	2.4
175	1	0.40	15.6	1.0	0.69	2.9
179	1	0.40	3.7	1.3	0.77	2.2
183	1	0.40	5.6	1.4	0.53	2.3
188	1	0.40	5.6	1.8	0.45	2.4
210*	1	0.20	6.0	1.6	0.39	1.9
210	1	0.40	6.4	1.6	0.39	2.2
210	1	0.60	6.4	1.6	0.45	1.7
210	2	0.20	5.6	1.6	0.24	1.4
210	2	0.40	3.9	0.80	0.15	0.70
210	2	0.60	6.8	2.0	0.49	1.6
228*	1	0.20	13.2	2.2	0.52	2.3
228	1	0.40	10.8	1.8	0.38	1.7
228	1	0.60	12.4	2.2	0.60	2.3
228	2	0.20	13.6	2.3	0.65	2.4
228	2	0.40	13.2	2.2	0.58	2.2
228	2	0.60	13.2	8.8	1.3	0.19
240	1	0.20	16.0	1.6	0.38	1.4
240	1	0.40	18.6	2.3	0.52	2.2
240	1	0.60	21.3	2.3	0.53	2.4
240	2	0.20	20.0	2.4	0.54	2.2
240	2	0.40	18.6	2.3	0.46	2.0
240	2	0.60	20.0	2.3	0.53	2.1
251	1	0.20	20.0	2.7	0.62	2.4
251	1	0.40	20.0	2.5	0.62	2.0
251	1	0.60	20.0	2.4	0.54	2.0
264	1	0.20	22.2	2.7	0.54	2.0
264	1	0.40	23.0	2.9	0.52	2.1
264	1	0.60	22.1	2.9	0.56	2.1
264	2	0.20	21.3	2.5	0.58	2.2
264	2	0.40	20.9	2.7	0.68	2.4
264	2	0.60	19.2	3.3	0.60	3.2

* CMA additions

APPENDIX C (Continued)

Julian Date	Station	Depth (m)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)
			PAIR TWO			
			CONTROL			
158	1	0.40	4.8	2.0	0.21	0.91
162	1	0.40	5.2	2.0	0.38	1.20
175	1	0.40	4.5	1.9	0.69	1.50
179	1	0.40	5.6	2.9	0.57	1.40
183	1	0.40	7.2	3.2	0.55	1.30
188	1	0.40	7.2	3.3	0.44	1.00
210	1	0.20	9.6	4.8	0.44	0.97
210	1	0.40	9.6	5.0	0.42	1.10
210	1	0.60	12.0	5.6	0.48	0.96
210	2	0.20	11.2	5.5	0.36	1.10
210	2	0.40	9.6	5.4	0.36	0.94
210	2	0.60	11.2	5.6	0.59	1.00
228	1	0.20	14.4	5.9	0.68	1.30
228	1	0.40	14.4	6.1	0.65	1.30
228	1	0.60	14.4	5.8	0.64	1.30
228	2	0.20	13.6	5.8	0.67	1.30
228	2	0.40	13.6	5.6	0.68	1.40
228	2	0.60	14.4	6.2	0.64	1.30
240	1	0.20	11.3	4.9	2.7	2.10
240	1	0.40	11.6	5.0	0.69	1.20
240	1	0.60	11.3	5.2	0.67	1.20
240	2	0.20	23.4	5.2	0.68	1.30
240	2	0.40	11.2	5.0	1.10	2.20
240	2	0.60	12.2	5.2	0.68	1.20
251	1	0.20	11.4	5.2	0.80	1.90
251	1	0.40	10.5	4.9	0.80	4.00
251	1	0.60	8.6	4.8	0.68	1.50
264	1	0.20	7.2	4.8	0.66	1.30
264	1	0.40	10.4	4.8	0.70	1.30
264	1	0.60	10.5	4.8	0.64	1.40
264	2	0.20	10.0	4.5	0.66	1.20
264	2	0.40	10.5	4.8	0.78	1.40
264	2	0.60	10.2	4.7	0.60	1.10

APPENDIX C (Continued)

Julian Date	Station	Depth (m)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)
			PAIR THREE			
			TREATED			
158	1	0.40	13.2	4.5	2.3	0.70
162	1	0.40	11.2	3.7	0.88	1.3
175	1	0.40	7.2	2.5	3.0	4.8
179	1	0.40	10.4	3.5	0.78	1.3
183	1	0.40	14.4	5.0	1.2	1.8
188	1	0.40	12.0	3.8	0.87	1.4
210*	1	0.20	17.6	6.9	0.99	1.3
210	1	0.40	20.8	7.2	1.0	1.4
210	1	0.60	21.6	6.4	1.1	1.4
210	2	0.20	19.2	7.4	0.43	0.78
210	2	0.40	20.0	7.2	1.2	1.4
210	2	0.60	23.2	8.0	1.4	1.3
228*	1	0.20	27.2	8.0	1.5	1.6
228	1	0.40	27.2	7.8	1.5	1.7
228	1	0.60	28.8	8.0	1.5	1.7
228	2	0.20	28.8	8.0	1.5	1.6
228	2	0.40	28.0	8.0	1.5	1.8
228	2	0.60	28.0	8.0	1.5	1.7
240	1	0.20	26.6	8.0	1.6	1.8
240	1	0.40	26.6	8.0	1.6	1.8
240	1	0.60	26.6	8.1	1.6	1.8
240	2	0.20	23.9	8.2	1.2	1.3
240	2	0.40	26.6	8.8	1.1	1.4
240	2	0.60	23.9	7.6	0.90	1.1
251	1	0.20	29.3	7.8	1.6	2.2
251	1	0.40	26.6	8.0	1.6	2.6
251	1	0.60	29.3	8.0	1.7	2.4

* CMA additions

APPENDIX C (Continued)

Julian Date	Station	Depth (m)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)
			PAIR THREE			
			CONTROL			
158	1	0.40	15.6	7.6	1.0	1.3
162	1	0.40	15.2	3.8	1.6	0.84
175	1	0.40	10.4	3.7	2.6	3.9
179	1	0.40	8.8	2.8	0.48	0.21
183	1	0.40	19.2	6.9	1.4	0.57
188	1	0.40	15.2	5.6	1.2	0.09
210	1	0.20	20.8	7.9	0.98	0.32
210	1	0.40	19.2	8.0	1.1	0.23
210	1	0.60	18.4	7.2	1.0	0.23
210	2	0.20	18.4	7.2	0.68	0.26
210	2	0.40	18.4	7.9	1.2	3.1
210	2	0.60	8.8	2.1	1.3	0.89
228	1	0.20	28.8	8.8	1.4	0.42
228	1	0.40	28.0	8.0	1.4	1.7
228	1	0.60	28.0	8.0	1.3	0.14
228	2	0.20	28.8	8.8	1.4	0.25
228	2	0.40	28.8	8.8	1.3	0.26
228	2	0.60	28.0	8.0	1.4	0.34
240	1	0.20	23.9	8.0	1.4	0.32
240	1	0.40	23.9	7.8	1.5	0.50
240	1	0.60	23.9	8.0	1.4	0.29
240	2	0.20	17.8	7.8	1.4	0.30
240	2	0.40	22.6	8.1	1.4	0.26
240	2	0.60	23.9	8.0	1.5	0.33
251	1	0.20	13.6	5.3	1.5	1.2
251	1	0.40	17.3	7.3	2.2	10.6
251	1	0.60	20.0	7.4	1.4	0.90
264	1	0.20	22.3	7.4	1.3	0.52
264	1	0.40	23.9	7.4	1.5	0.28
264	1	0.60	19.6	4.7	1.5	0.48
264	2	0.20	18.4	6.8	1.6	0.42
264	2	0.40	18.9	6.8	1.5	0.40
264	2	0.60	19.3	6.9	1.6	0.32

APPENDIX D. Chlorophyll *a*.

Julian date	Station	PAIR ONE Depth (m)	Sample	Chl *a* (mg/m^2)
		TREATED		
238	1	0.25	1	.166
		0.25	2	2.89
		0.50	1	0.90
		0.50	2	.729
	2	0.50	1	2.43
		0.50	2	1.59
		1.00	1	.158
		1.00	2	.531
		1.50	1	.666
		1.50	2	.789
249	1	0.25	1	1.06
		0.25	2	2.56
		0.25	3	4.54
		0.50	1	1.87
		0.50	2	2.78
		0.50	3	2.50
		0.75	1	1.84
		0.75	2	2.96
		0.75	3	1.08
	2	0.50	1	1.07
		0.50	2	3.54
		0.50	3	3.26
		1.00	1	4.88
		1.50	1	0.400
		1.50	2	0.915
264	1	0.25	1	4.33
		0.50	1	1.13
		0.75	1	1.99
	2			
264 Artificial substrate #2	1	0.25	1	2.50
		0.25	2	2.98
		0.25	3	.951
		0.50	1	3.84
		0.50	2	3.92
		0.50	3	1.86

APPENDIX D (Continued)

Julian date	Station	PAIR ONE Depth (m)	Sample	Chl $\underline{a}$ (mg/m^2)
		TREATED		
	2	0.50	1	1.18
		1.00	1	2.79
		1.00	2	5.49
		1.00	3	2.99
		1.00	4	3.42
		1.00	5	1.98
		1.00	6	4.00
		1.50	1	1.29
		1.50	2	.422
		1.50	3	.135
		1.50	4	.167

APPENDIX D (Continued)

Julian date	Station	PAIR ONE Depth (m)	Sample	Chl a (mg/m^2)
		CONTROL		
238	1	0.25	1	.041
		0.25	2	.055
		0.50	1	.076
		0.50	2	.046
		0.50	3	.059
		0.75	1	.094
	2	0.50	1	.062
		0.50	2	.054
		0.50	3	.070
		1.00	1	.068
		1.50	1	.044
		1.50	2	.069
		1.50	3	.062
249	1	0.25	1	.056
		0.25	2	.101
		0.25	3	.166
		0.50	1	.116
		0.50	2	.042
		0.50	3	.295
		0.75	1	.124
		0.75	2	.082
		0.75	3	.215
	2	0.50	1	.162
		0.50	2	.471
		0.50	3	.396
		1.00	1	.526
		1.00	2	.591
		1.00	3	.317
		1.50	1	.248
		1.50	2	.475
		1.50	3	.104
264	1	0.25	1	.792
		0.25	2	.385
		0.25	3	.200
		0.50	1	1.18
		0.50	2	.540
		0.50	3	.214
		0.75	1	.882
		0.75	2	.538
		0.75	3	.202

APPENDIX D (Continued)

Julian date	Station	PAIR ONE Depth (m)	Sample	Chl a (mg/m^2)
		CONTROL		
	2	0.50	1	.414
		0.50	2	.416
		1.00	1	.744
		1.00	2	.702
		1.00	3	.402
		1.50	1	.651
		1.50	2	1.73
		1.50	3	.918
264 Artificial substrate #2	1	0.25	1	.342
		0.25	2	.325
		0.25	3	.379
		0.25	4	.229
		0.50	1	.575
		0.50	2	.514
		0.50	3	.775
		0.50	4	.454
	2	0.50	1	.458
		0.50	2	.354
		0.50	3	.555
		0.50	4	1.55
		0.50	5	.752
		1.00	1	.181
		1.00	2	.161
		1.00	3	.474
		1.00	4	.082
		1.00	5	.128

APPENDIX D (Continued)

PAIR TWO

Julian date	Station	Depth (m)	Sample	Chl a (mg/m^2)
		TREATED		
238	1	0.25	1	.144
		0.50	1	.198
		0.50	2	.175
		0.75	1	.338
		0.75	2	.248
	2	0.50	1	.152
		1.00	1	.272
		1.00	2	.232
		1.50	1	.297
248	1	0.25	1	.702
		0.25	2	.385
		0.50	1	.997
		0.50	2	.801
		0.50	3	1.46
		0.75	1	.861
		0.75	2	.797
		0.75	3	.718
	2	0.50	1	.443
		0.50	2	.558
		0.50	3	1.59
		1.00	1	.864
		1.00	2	.702
		1.00	3	.718
		1.50	1	.819
		1.50	2	.576
		1.50	3	1.64
265	1	0.25	1	2.69
		0.25	2	.792
		0.25	3	.542
		0.50	1	2.48
		0.50	2	1.67
		0.50	3	1.74
		0.75	1	1.72
		0.75	2	1.66
		0.75	3	2.30

APPENDIX D (Continued)

Julian date	Station	PAIR TWO Depth (m)	Sample	Chl a (mg/m^2)
		TREATED		
	2	0.50	1	2.05
		0.50	2	1.35
		0.50	3	1.38
		1.00	1	4.32
		1.00	2	2.12
		1.00	3	1.79
		1.50	1	1.96
		1.50	2	1.42

APPENDIX D (Continued)

Julian date	Station	PAIR THREE Depth (m)	Sample	Chl a (mg/m^2)
		CONTROL		
238	1	0.25	1	.576
		0.25	2	.117
		0.25	3	.715
		0.50	1	.527
		0.50	2	.306
		0.75	1	.526
	2	0.50	1	.407
		0.50	2	.432
		0.50	3	.252
		1.00	1	.830
		1.00	2	.299
		1.00	3	.304
		1.50	1	.410
		1.50	2	.382
		1.50	3	.353
248	1	0.25	1	.906
		0.25	2	.313
		0.50	1	1.26
		0.50	2	1.54
		0.75	1	.461
		0.75	2	1.70
		0.75	3	.302
	2	0.50	1	.912
		0.50	2	.612
		0.50	3	.894
		1.00	1	.585
		1.00	2	2.19
		1.00	3	.446
		1.50	1	.585
		1.50	2	.618
		1.50	3	.201
265	1	0.25	1	.941
		0.25	2	1.09
		0.50	1	.516
		0.50	2	.182
		0.75	1	.644
		0.75	2	.682

APPENDIX D (Continued)

Julian date	Station	Depth (m)	Sample	Chl a (mg/m^2)
		PAIR THREE		
		CONTROL		
	2	0.50	1	.912
		0.50	2	.612
		0.50	3	.894
		1.00	1	1.67
		1.00	2	2.19
		1.00	3	.264
		1.50	1	.585
		1.50	2	.618
		1.50	3	.201

APPENDIX D (Continued)

Julian date	Station	PAIR THREE Depth (m)	Sample	Chl a (mg/m^2)
		TREATED		
238	1	0.20	1	.497
		0.20	2	1.09
		0.20	3	1.53
		0.40	1	.686
		0.40	2	1.03
		0.40	3	1.34
		0.60	1	.695
		0.60	2	3.03
		0.60	3	2.38
	2	0.25	1	.685
		0.25	2	.585
		0.50	1	.940
		0.50	2	.697
		0.75	1	3.35
		0.75	2	1.38
248	1	0.20	1	.876
		0.20	2	.972
		0.20	3	2.50
		0.40	1	1.19
		0.40	2	3.00
		0.40	3	2.22
		0.60	1	2.12
		0.60	2	2.54
		0.60	3	6.30
	2	0.25	1	1.53
		0.25	2	1.35
		0.25	3	1.69
		0.50	1	1.90
		0.50	2	1.12
		0.75	1	6.48
		0.75	2	1.37
		0.75	3	.979

APPENDIX D (Continued)

PAIR THREE

Julian date	Station	Depth (m)	Sample	Chl a (mg/m^2)
		CONTROL		
238	1	0.20	1	1.71
		0.20	2	2.64
		0.40	1	1.36
		0.40	2	1.45
		0.60	1	3.54
	2	0.25	1	1.65
		0.25	2	1.56
		0.25	3	1.19
		0.50	1	2.14
		0.50	2	2.33
		0.75	1	3.39
		0.75	2	2.27
248	1	0.20	1	.792
		0.20	2	1.89
		0.20	3	2.17
		0.40	1	3.63
		0.40	2	3.33
		0.40	3	.861
		0.60	1	9.24
		0.60	2	5.94
		0.60	3	6.90
	2	0.25	1	1.18
		0.25	2	.412
		0.25	3	4.95
		0.50	1	2.97
		0.50	2	1.88
		0.75	1	1.08
		0.75	2	2.17
		0.75	3	.918