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ALGAE CONTROL IN FISH PONDS THROUGH CHEMICAL CONTROL OF AVAILABLE NUTRIENTS

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ALGAE CONTROL IN FISH PONDS THROUGH CHEMICAL CONTROL OF AVAILABLE NUTRIENTS

By

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ABSTRACT

Laboratory and pond tests were conducted to evaluate aluminum sulfate and the chelating agents Versene and Versenol 120 for limiting the availability of phosphorus and iron and thereby reducing the growth of algae in fish ponds. Aluminum sulfate rapidly removed substantial amounts of phosphorus without obvious harm to young walleyes or invertebrates. The response of algae populations to reduced phosphorus levels was variable. The chelating agents reduced iron concentrations in water but were ineffective in reducing algal growth.

INTRODUCTION

Excessive production of blue-green algae is often a problem in Minnesota fish rearing ponds. Growths occasionally become dense enough to cause critical oxygen levels at night or during periods of cloudy weather. There are algicides available which will temporarily control blue-green algae blooms but sustained control without repeated application is difficult to achieve.

Algae control through limitation of critical growth elements has been used successfully in lakes. Since phosphorus in lake water is usually present in the smallest amount in relation to the needs of an algal population, most work has been directed at control of this element. The phosphorus level in a Swedish Lake was reduced by the application of aluminum sulfate (Jernelov 1970). Aluminum sulfate was applied to a small lake in Wisconsin with the result that total phosphorus concentrations and algal production decreased, water transparency increased and oxygen levels improved especially during winter time (Peterson et al, 1973). The use of metal salts to precipitate phosphorus in wastewater has also received considerable attention.

In 1961 two ponds at the Minnesota Division of Game and Fish Area Fisheries Headquarters at Waterville, Minnesota were treated with the chelating agent Versenol 120[1/] in an attempt to increase pond productivity. Decreased productivity resulted. The pond water remained extremely clear and production of rooted vegetation, algae, zooplankton, and bottom fauna declined. It was speculated that excessive chelation of iron had occurred and lowered the availability to algae to the point of growth limitation.

[1/] Trisodium salt of N-hydroxyethylene diamine triacetic acid, Dow Chemicals Co.

The successful use of aluminum sulfate on lakes and the response of the Waterville Ponds to Versenol applications suggested potential techniques for reducing critical plant nutrients and controlling algae blooms in fish ponds. Laboratory and pond tests were conducted at the Waterville Fisheries Headquarters to evaluate chelating agents and aluminum sulfate for this purpose.

DESCRIPTION OF PONDS

The ponds used in this study are part of a series of ten one-acre ponds located in LeSueur County near the town of Waterville, Minnesota. Each pond is approximately 250 feet long and 170 feet wide with a maximum depth of 7 feet and an average depth of 4.8 feet. Bank and bottom soils are a mixture of sand and clay. Each pond has one concrete control structure with an inlet-outlet valve and dam boards. The control structures are connected by a single inlet-outlet line which is used for both filling and draining. Water for the ponds is pumped from Lake Tetonka the surface of which is 23 feet below the maximum pond water level. All ten ponds are on the same elevation.

Lake Tetonka has a surface area of 1,336 acres and contains hard water of high chemical fertility. During midsummer, surface water usually has a total alkalinity (expressed as $CaCO_3$) of about 135 mg/l, a range in total phosphorous concentrations of .1 to .2 mg/l and a range in total nitrogen concentrations of 1.5 to 2.0 mg/l. Copper sulfate applications are commonly made in Lake Tetonka during the summer to control nuisance blooms of blue-green algae.

METHODS AND MATERIALS

Laboratory Experiments

Laboratory tests were conducted in 1969 to determine the effectiveness of Versene[2] for making the supply of available iron critical for algal growth.

A plastic cylindrical tank 100 inches high and 6 inches in diameter equipped with drain cocks at one foot intervals was filled with pond water filtered through a No. 6 mesh silk tow net. It was submerged in the pond in an attempt to promote an algae bloom within. After two days the water at one foot intervals was tested for total phosphorus, soluble phosphorus, and iron. At the end of two weeks, the water was strained through the same tow net and the algae preserved in formalin. The tube was refilled with strained water and treated with 17 parts of the powdered chelating agent Versene for every 1.0 ppm of total iron in the water. The procedures used in the control were repeated.

During 1970 Versene and Versenol 120 were tested in 19.4 liter aquariums filled with lake water. Four tests were made in the aquariums with Versene

[2] Na_4EDTA - Tetrasodium salt of ethylenediaminetetraacetic acid, Dow Chemical Co.

powder and four with Versenol 120. Versene treatments were made to give concentrations of 5, 7, 14, and 52 mg/l and Versenol 120 treatments 10, 30, 30, and 60 mg/l. Following treatment the water was analyzed for iron content and counts of *Scenedesmus* cells were made irregularly.

Laboratory tests were also conducted during 1970 with aluminum potassium sulfate ($AlK(SO_4)_2 \cdot 12H_2O$) to determine the effectiveness of aluminum in reducing phosphorus levels and controlling the growth of the green alga *Scenedesmus* in 19.4 liter aquariums, 600 ml beakers and one gallon jars. Five experiments were conducted. In experiment 1, two 19.4 liter aquariums were filled with lake water. The water in one aquarium was treated with alum to give a concentration of 2.9 mg aluminum/l and the other was used as a control. The level of soluble phosphorus in both tanks was determined before treatment and subsequently on days 1, 2, 3, 4, 7, and 11.

In experiment 2, before placing water in two 19.4 liter aquariums it was contaminated with potassium phosphate to increase the phosphorus content. The water in one aquarium was treated as in experiment 1 and the other was used as a control. The level of soluble phosphorus in both tanks was determined before treatment and subsequently on days 1, 2, 3, 4, 7, 11, and 28.

In experiment 3, three lots of water with different soluble phosphorus levels were prepared: (1) natural lake water with a soluble phosphorus level of .225 mg/l (2) lake water contaminated with potassium phosphate to give a soluble phosphorus concentration of 0.363 mg/l (3) distilled water contaminated with potassium phosphate to give a soluble phosphorus concentration of 0.480 mg/l. Half liter samples from each lot were treated with 2.9, 5.7, and 11.4 mg Al/l. A half liter sample from lot 1 was used as a control. Subsequent soluble phosphorous analyses were made on days 1 and 2.

In experiment 4, half liter samples of lake water with a soluble phosphorus content of 0.230 mg/l were treated with 0.3, 0.6, 1.4, and 2.9 mg al/l, Subsequent soluble phosphorus analyses were made on days 1 and 3.

In experiment 5, three-liter samples of lake water with a soluble phosphorus content of 0.180 mg/l were treated with 0.3, 0.6, 1.1, 1.7, 2.3, and 2.9 mg Al/l. Two three liter samples were used as controls. Subsequent soluble phosphorus analyses were made on days 1, 2, 3, and 4.

Soluble phosphorus was determined by use of the molybdate-stannous chloride method described by Dobie and Moyle (1962). In all tests the alum was thoroughly mixed with the water.

<u>Pond Experiments</u>

In the spring of 1970 a pond was divided in half from the middle of the control structure to the opposite side by a barrier of polyethylene sheeting. After the pond was filled, the water was treated with copper sulfate to eliminate algae present in the water which was pumped from Lake Tetonka. To encòurage a bloom in the pond 50 pounds each of 33.5-0-0 and 0-46-0 commercial fertilizer were applied to each side of the pond. The next day Versenol 120 was applied to one side of the pond to give a concentration of 7 mg/l.

Analyses for iron content and algal abundance on both sides of the pond were made before and after treatment.

Pond experiments with aluminum sulfate were conducted during the summers of 1971, 1972, and 1973. Each year a pond was divided with a barrier of polyethylene sheeting and one side was experimental while the other side was the control. The same pond was used in 1971 and 1972 but in 1973 a different pond was selected.

To discourage growth of rooted vegetation, 20 percent 2, 4-D granules were distributed on the bottom of the ponds before they were filled and to increase the phosphate content of the water and encourage development of blue-green algae, commercial fertilizer was applied two to four days before the alum applications were made.

Ground aluminum sulfate ($Al_2(SO_4)_3 .14 H_2O$) was slurried and dispersed on one side of the ponds from a boat by siphoning to the propellor wash of the outboard motor. Details of the treatments are presented in Table 1.

Analytical methods for soluble phosphorus, total phosphorus, and total alkalinity were as described by Dobie and Moyle (ibid.). The pH was measured with Beckman Model 72 and pocket pH meters. Analyses were made on water from the surface and bottom but because there were no large or consistent differences only the surface analyses are presented.

Bottom fauna was sampled with a 6 inch square Peterson dredge and samples consisted of 10 grabs made diagonally across each side of the ponds. Samples were hand picked and the organisms enumerated by taxa and wet volumes determined by water displacement.

Microcrustacea were sampled with surface tows of No. 6 bolting cloth around the periphery of each side of the ponds. Counts were made on one ml. aliquots with a Sedgwick-Rafter cell.

Before the alum application in 1971 walleye fry were stocked on both sides of the pond at a rate of 20,000 per acre.

Table 1. Summary of aluminum sulfate pond treatments.

	1971	1972	1973
Pond Number	5	5	4
Experimental Side	South	North	North
Treatment Date	May 27	June 6	June 7
Application Rate:			
lb. aluminum sulfate/acre	1,200	600	800
mg. aluminum/l	8.4	4.2	5.6
Cost of Chemical per Acre	$66	$33	$44
Water Temperature - Degrees F.	58	76	72
Fish Present	Walleye	None	None

RESULTS

1969-Versene in Plastic Cylinder

The experiment was unsuccessful because all attempts to create an algae bloom in the plastic cylinder failed. Chemical analyses revealed no discernable changes in water chemistry.

1969-Versene and Versenol in Laboratory Aquariums

Although both Versene powder and Versenol 120 reduced the amount of iron present in the water, heavy blooms of *Scenedesmus* still developed in the aquariums. In some experiments the treated water turned green more rapidly than the nontreated water and had higher *Scenedesmus* counts at the end of the test.

Laboratory Experiment 1 With Alum

Two days after treatment soluble phosphorus in the treated tank had declined 66 percent from its initial level while in the control it had increased slightly (Figure 1). By the 3rd day the soluble phosphorus level in the control tank had started to decline and continued to decline through the 11th day. This decline in the control was coincident with the development of a *Scenedesmus* bloom which was first apparent on the 3rd day. By the 7th day the water in the control was quite green and opaque while the treated water was transparent with no apparent green color. There was no apparent change in the appearance of either tank through the 11th day when the test was terminated.

Laboratory Experiment 2 With Alum

On the 2nd day the soluble phosphorus level in the treated water had declined 73 percent from its initial level while in the control it had declined less than 10 percent (Figure 1). The water in both tanks remained clear through the 7th day. By the 11th day the water in both tanks was still clear, however, the bottom of the treated tank was green and the water turned pale green upon being stirred. By the 14th day the water in the control tank was pale green and by the 18th day was quite green and opaque while the treated water was only slightly green and still transparent. There was no apparent change in the appearance of the control by the 28th day, however, the soluble phorphorus had dropped to the same level as that in the treated tank. Although the treated water was not yet as green as the control it was becoming progressively darker. However, this began occurrring after the water had been stirred repeatedly.

Whenever the water was disturbed, soluble phosphorus levels rose sharply in the treated water but there was no appreciable change in the controls. Soluble phosphorus levels immediately before and after the water was stirred are shown in Table 2. Phosphorus in the treated water rapidly settled out again after being stirred on the 3rd day of experiment 1. The following day the soluble phosphorus level had dropped to 0.064 mg/l and was still at that level on the 7th day. This however, was considerably higher than the level before stirring and accounted for the rise of the curve in Figure 1.

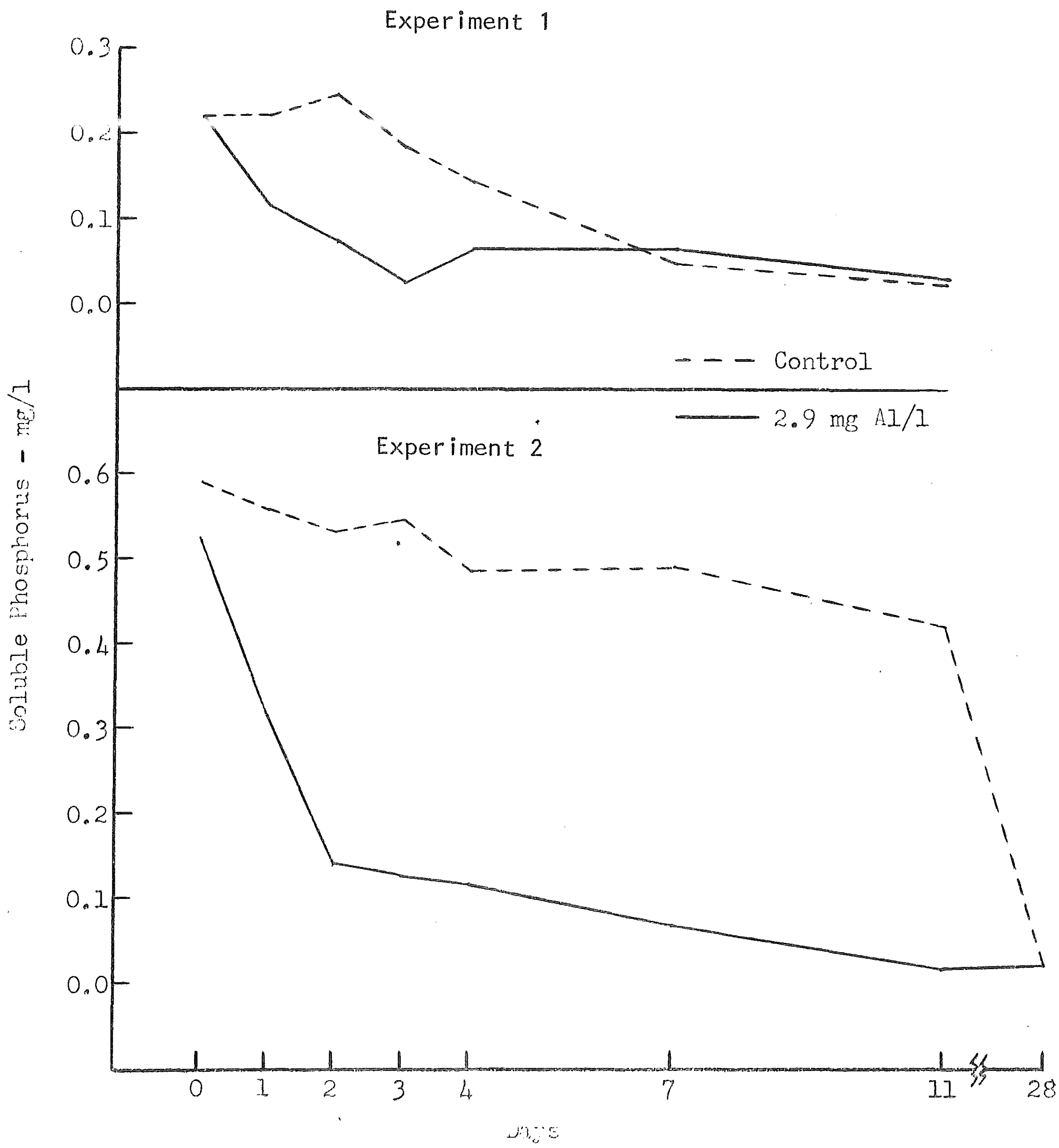

Figure 1.- Soluble phosphorus levels in aquaria following application of aluminum potassium sulfate.

Table 2. Effect of stirring on soluble phosphorus levels in 19.4 liter aquariums.

		Soluble Phosphorus Level mg/l	
		Control Tank	Treated Tank
Experiment 1			
	Day 3		
	Before stirring	0.185	0.025
	After stirring	0.185	0.290
	Day 11		
	Before stirring	0.025	0.029
	After stirring	0.029	0.192
Experiment 2			
	Day 28		
	Before stirring	0.020	0.020
	After stirring	0.029	0.154

Laboratory Experiments 3-5 With Alum

The results of experiments 3-5 in lake water (combined and presented in Figure 2) indicate the optimum aluminum dosage in lake water to lie within the range of 2.9 and 5.7 mg/l. Over 5.7 mg/l was excessive.

In the lake water experiments there was rapid floc formation following the addition of the alum but the addition of alum to distilled water with potassiums phosphate added in experiment 3 produced no visible floc and resulted in little or no phosphate reduction.

Pond Experiments

1970-Versenol 120

The effect of Versenol 120 on development of a blue-green algae bloom could not be evaluated because a bloom did not occur on either side of pond 5. Instead, the *Aphanizomenon* initially present soon disappeared and dense mats of filamentous algae developed on both sides of the pond.

Before treatment the iron content was 0.1 mg/l on both sides of the pond. Within a few days after treatment it had declined to less than 0.05 mg/l on the north side and remained there throughout the month following while on the south side it ranged from 0.1 to 0.2 mg/l. This reduction of iron on the north side did not appear to inhibit growth of filamentous algae.

1971, 1972, and 1973-Aluminum Sulfate

Floc Formation

The method of application appeared to mix the chemical quite well from surface to bottom and a good aluminum hydroxide floc was formed within minutes at all application rates. Most of the floc had settled by the following day

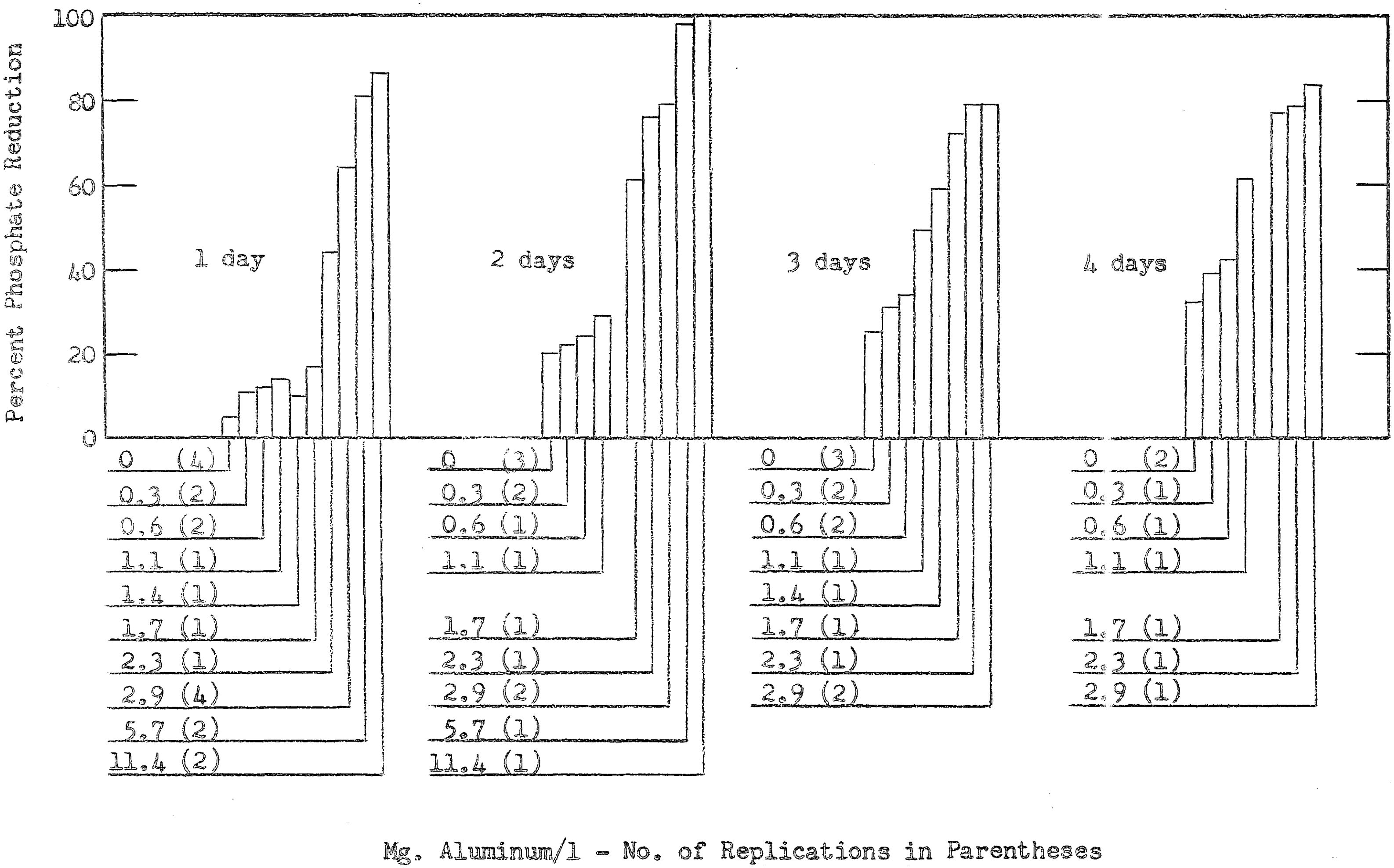

Figure 2. Average percentage reduction of soluble phosphorus in lake water in jar tests with varying concentrations of aluminum.

but wind action kept some in suspension as long as 3 days. Within a week the floc had dissipated and was no longer visible on the bottom.

The treatments were always followed by a temporary clearing of the water and a substantial loss of color, also temporary.

Phosphorus

In all three years there was a rapid drop in the phosphorus concentrations of the treated water following the alum application and in two of the years a small rise in July or August (Figures 3 and 4). However, in 1972 it subsequently rose to a level higher than at the time of treatment.

Initial phosphorus concentrations in the ponds were always quite low which necessitated the addition of fertilizer to raise them prior to the alum applications. Only in 1971 did the control give a desired response when there was a continual decline of the phosphorus level into August followed by a rapid return to the initial level. This seemed to be influenced by the development of a dense algal bloom which peaked in mid-July and had nearly disappeared by mid-August. In 1972 and 1973 the phosphorus concentrations of the controls declined quite rapidly and within a month had dropped to the levels of the experimental sides of the ponds. These declines could not be attributed to phytoplankton activity. In 1973 there was a sharp rise of phosphorus in the control in August followed by the development of a very dense algal bloom.

Total Alkalinity

As expected the alum applications were always followed by a decline in total alkalinity of the treated water (Figure 5). In 1971 the total alkalinity of the control did not change appreciably throughout the summer but the following two years it declined more gradually than on the experimental side but was at or near the same level in July.

pH

The pH of the treated water was generally lower than in the controls throughout all three summers (Figure 6). In 1971 the pH differences seemed to be influenced by phytoplankton activity, however, in 1972 and 1973 there were no obvious relationships.

Blue-green Algae

In 1971 the control developed a dense bloom of *Aphanizomenon* which peaked in mid-July then declined rapidly and nearly disappeared in August while very little appeared on the experimental side of the pond.

In September *Anabaena* bloomed on both sides of the pond. It appeared about a week earlier on the experimental side and had become quite dense by the time the pond was drained in mid-September at which time the control still had only a mild bloom.

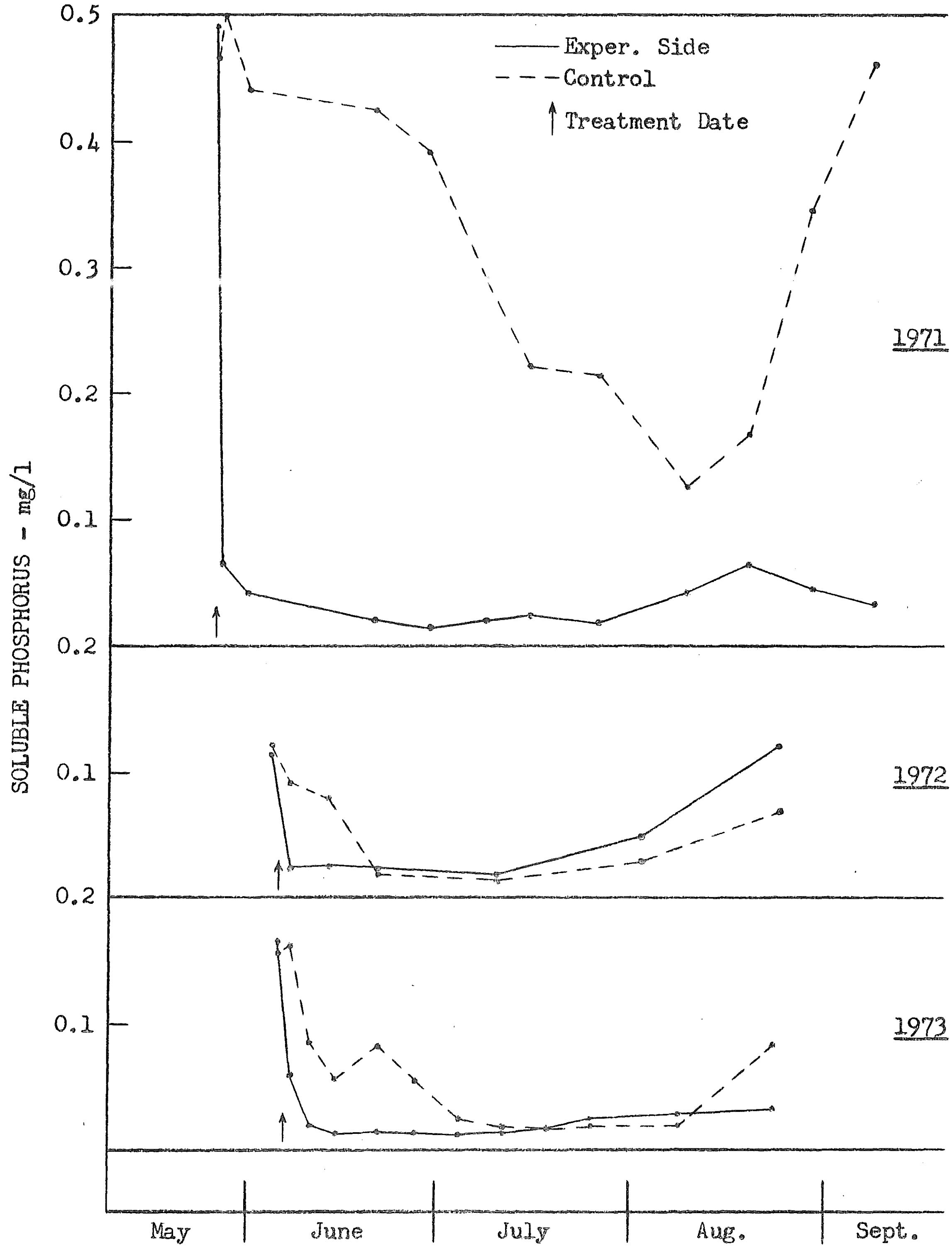

Figure 3.- Soluble phosphorus at the pond surface.

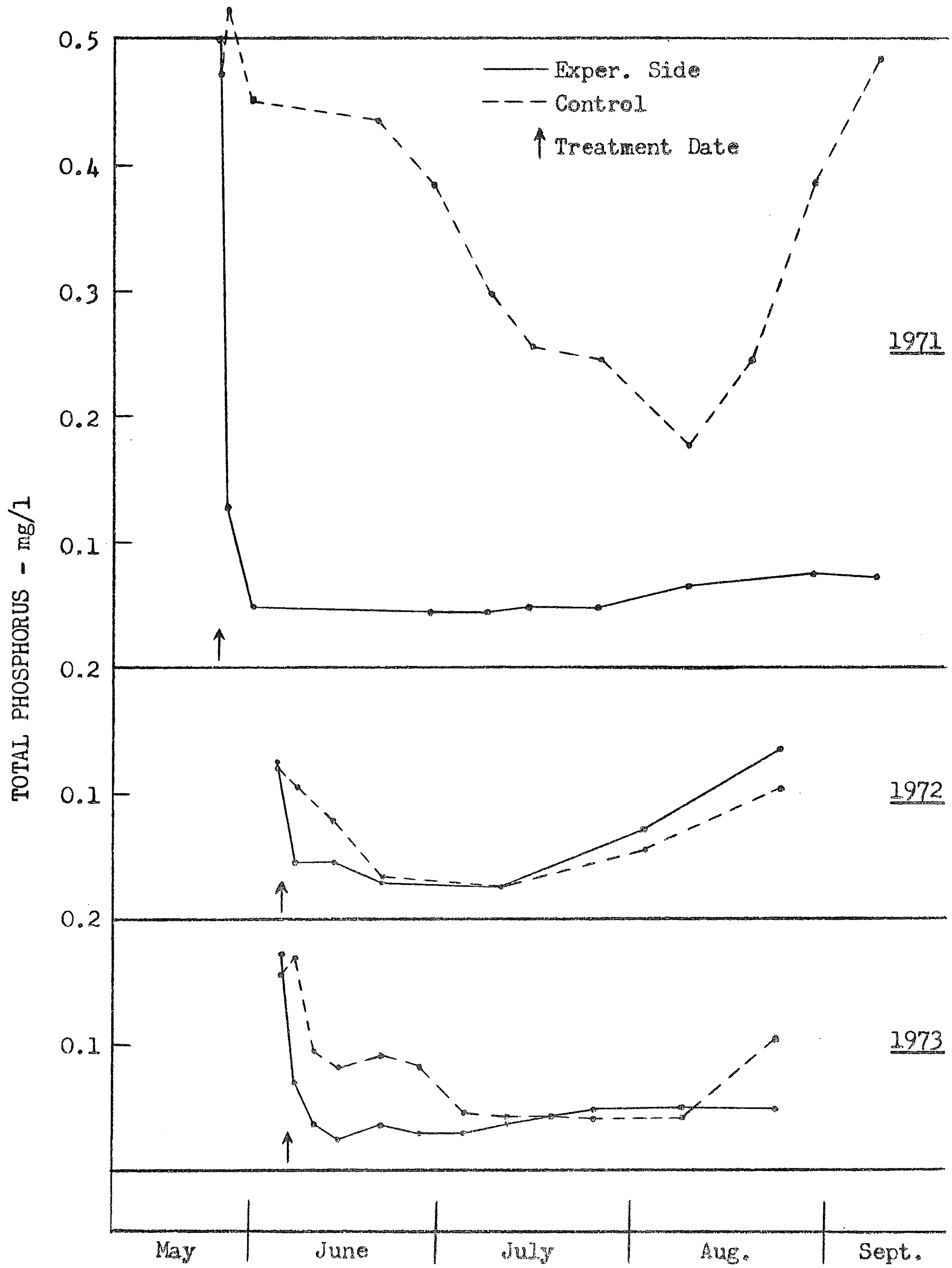

Figure 4.- Total phosphorus at the pond surface.

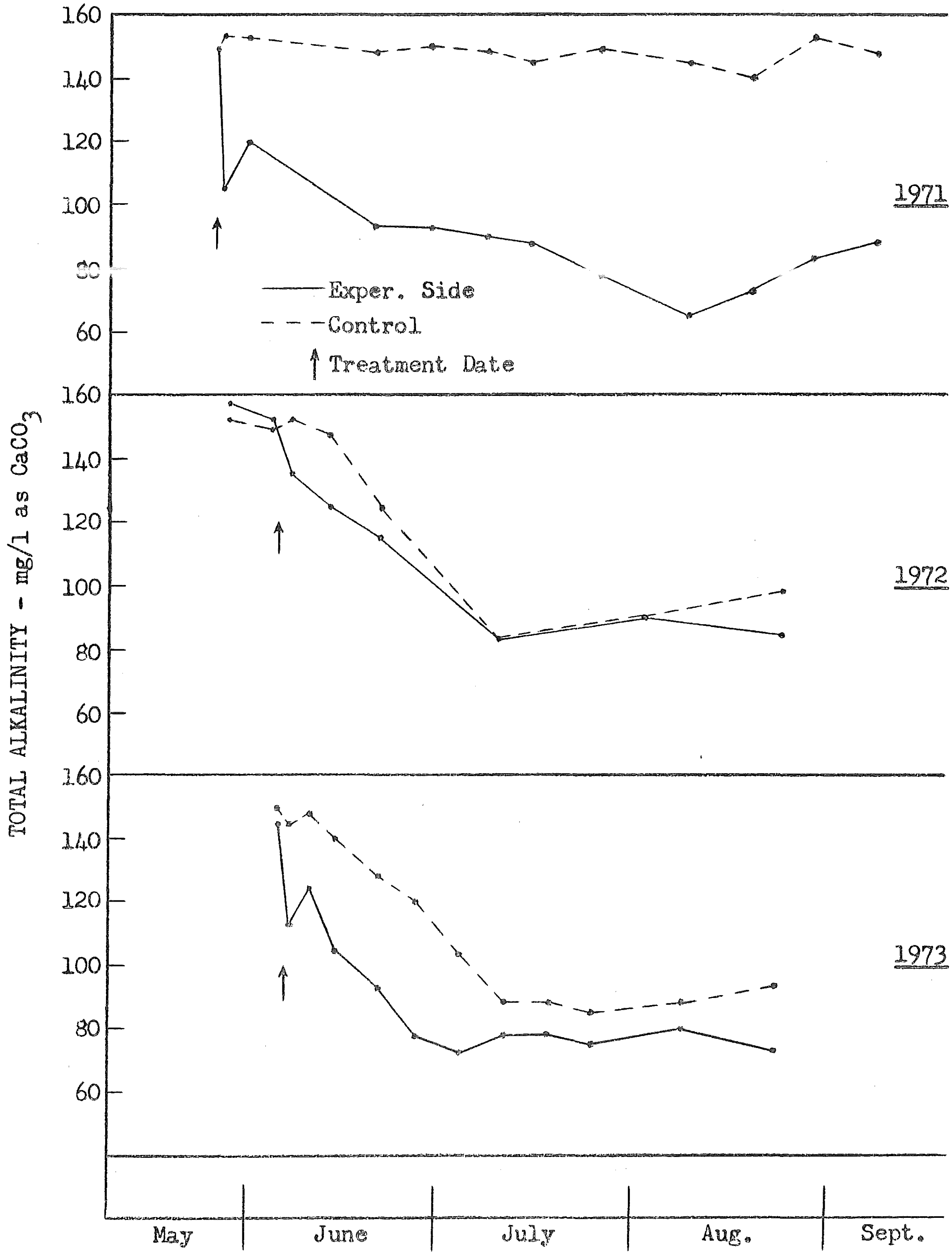

Figure 5.- Total alkalinity at the pond surface.

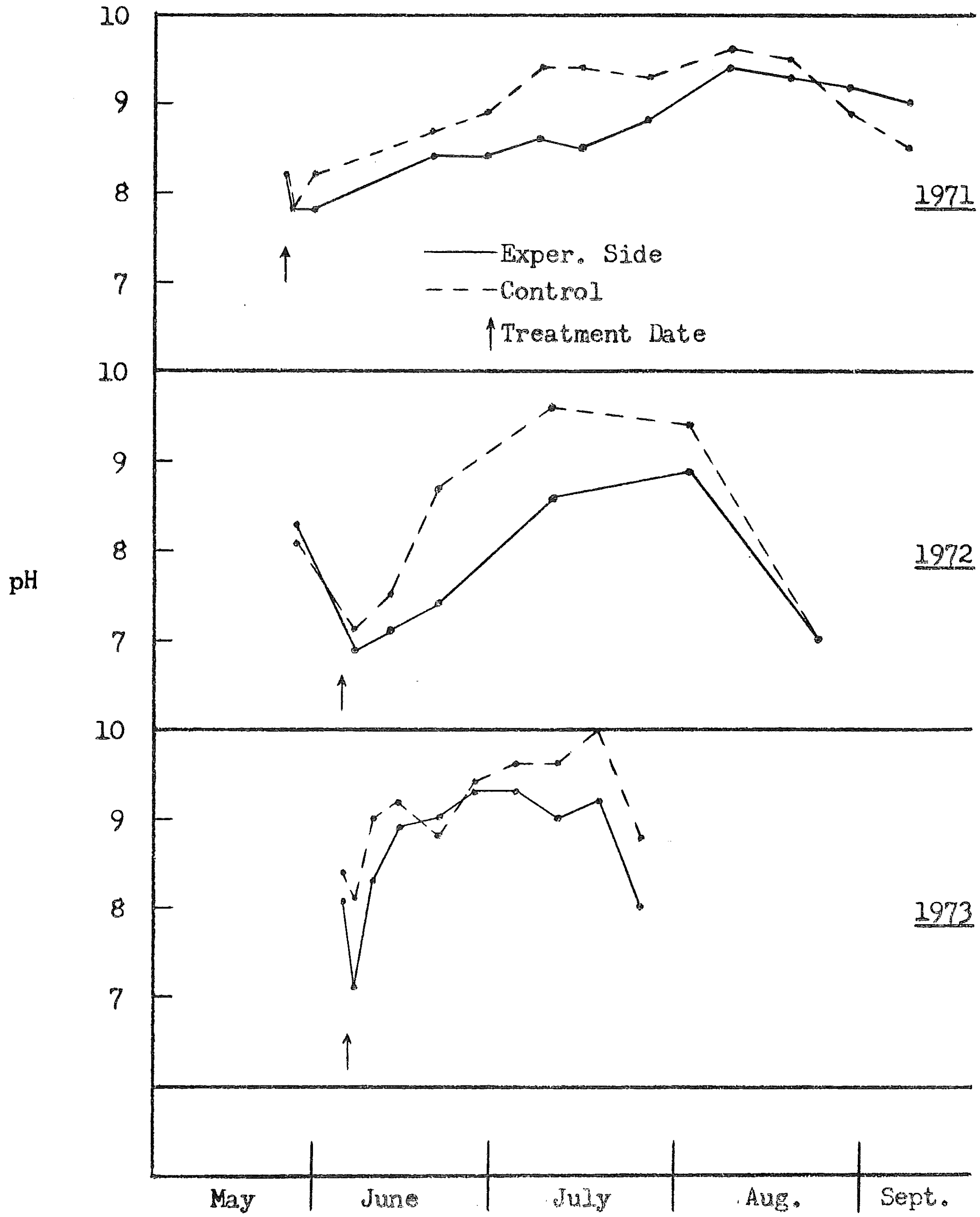

Figure 6.- pH at the pond surface.

In 1972 the experimental side of the pond developed a very mild bloom of *Aphanizomenon* in July which persisted for five to six weeks. No phytoplankton bloomed in the control the entire summer.

In 1973 a small amount of *Aphanizomenon* was visible on both sides of the pond at the time of treatment. Following treatment it became somewhat more dense on both sides then, in mid-July, nearly disappeared in the control while a mild bloom persisted on the experimental side the entire summer.

In September the control developed a very dense bloom of *Anacystis*.

Other Vegetation

In 1971 a dense growth of filamentous algae (primarily *Cladophora*) developed on the experimental side of the pond soon after the alum treatment then declined rapidly and had nearly disappeared by July. Filamentous algae also developed in the control (but were not as dense as on the experimental side in June) and persisted the entire summer.

Chara, bushy pondweed (*Najas flexilis*), and sago pondweed (*Potamogeton pectinatus*) became quite dense on both sides of the pond but were most dense on the experimental side.

In 1972 *Cladophora* was again most dense on the experimental side immediately following treatment but was not as dense as in 1971. Within two weeks *Hydrodictyon* appeared in the control and before the end of June covered half the surface, then gradually declined and had nearly disappeared before the end of July. On the experimental side *Hydrodictyon* could be detected only by microscopic examination. By the latter part of August the control had little filamentous algae of any kind while the experimental side still had some *Cladophora* around the edge and small mats scattered over the surface clinging to pondweed.

Again *Chara* and the two pondweeds were most dense on the experimental side of the pond.

In 1973 *Cladophora* became quite dense around the edge on both sides of the pond before the alum was applied. Most was removed by hand but it again became quite dense on both sides following treatment. In July it declined immensely and was about gone on both sides in August. At no time during the summer did it appear to favor one side or the other.

Little pondweed was apparent on either side until July. From mid-July through much of August it seemded to be most dense in the control after which it appeared to decline in the control followed by an *Anacystis* bloom in September. The pond was drained on September 20 and pondweed (bushy and sago) was much more dense on the experimental side. *Chara* was not present on either side.

Impact on Walleye and Invertebrates

Several young walleyes still in the pelagic stage were seen swimming through the chemical as it was being applied in 1971 and none were noted to show distress. The fingerling harvest in September from the experimental side was 1.6 times that from the control in numbers and pounds.

Although, on the average, standing crops of chironomids favored the controls over the three years there were many inconsistencies (Tables 3-5). The most notable differences occurrred in 1971. This was the year that walleye fingerlings were present and most abundant on the experimental side of the pond and possibly accounted for some of the difference noted in chironomid abundance. Chironomid production on one side of a pond which was divided in 1973 in connection with another study was notably higher than on the opposite side and considering the wide variation exhibited within a single untreated pond it would be impossible to attribute the inconsistent differences exhibited here in chironomid abundance to the aluminum sulfate applications.

Oligochaetes were generally more abundant in the controls in 1971 and 1972 but again there were inconsistencies. They appeared in only a single sample in 1973. Amphipods, when present, were generally more abundant on the experimental side and Muscidae pupae favored one side one year and the other side the next year. The organisms grouped in the "Other" columns occurred only sporadically and did not favor either side.

No microcrustacean consistently favored either side of the ponds over the three years (Tables 6-8). Here too, the aforementioned untreated pond exhibited wide variation in production between the two sides of the pond.

In conclusion, there was no evidence that the aluminum sulfate applications had an adverse effect, directly or indirectly, on walleye or invertebrates.

DISCUSSION

Attempts to control algae growth through use of the chelating agents Versene and Versenol 120 failed. Iron concentrations were reduced in laboratory aquariums and in an experimental pond but this did not appear to inhibit the growth of algae. The levels of available iron were probably not lowered to the point of growth limitation. Aluminum sulfate rapidly precipitated substantial amounts of phosphorus without obvious harm to young walleyes or invertebrates.

In a shallow body of water with a high phosphorus content aluminum sulfate will greatly reduce the level of this critical plant nutrient throughout the body of water if application methods are such that the chemical is rapidly and thoroughly mixed with the water.

Jar tests in the laboratory indicated the optimum aluminum concentration for satisfactory phosphorus reduction in lake water to lie within the range of 2.9 to 5.7 mg/l if the chemical was mixed well with the water. Over 5.7 mg/l was excessive. In 1972 the pond application of 600 pounds of aluminum sulfate per acre (4.2 mg Al/l) affected a good initial phosphate reduction, however, it

Table 3.- Standing crops (no. organisms per m^2/cc per 100 m^2) of bottom fauna in pond 5, 1971

		Chironomidae	Amphipoda	Oligochaeta	Other[1]
June	22	22/ 13 168/103[2]	9/ 4 -	- 47/13	13/ 4 13/ 9
July	6	4/ 4 52/ 39	- 9/ 4	9/ 4 9/tr[3]	- 13/13
	19	- 4/ 2	4/ 2 -	13/ 4 -	4/ 2 13/ 9
	29	9/ 11 9/ 4	26/ 6 13/ 2	17/ 9 22/ 9	17/ 9 13/ 2
Aug.	2	9/ 11 52/ 47	52/15 4/ 2	4/tr 9/ 4	26/ 9 9/ 6
	16	- 82/108	112/30 95/22	- 17/ 9	4/ 4 86/34
	24	9/ 1 9/ 4	112/22 39/ 6	- 13/ 6	9/ 1 35/21
	30	4/ 1 52/ 30	168/17 262/47	9/ 2 47/19	8/ 5 4/ 2
Sept.	9	- 56/ 39	237/26 189/34	- 17/ 4	4/ 4 8/18
	13	9/ 2 86/103	361/47 198/26	- 4/ 2	8/ 6 8/11

1/ Muscidae Pupae, *Caenis*, Hydrophilidae, Zygoptera, *Chaoborus*, Tabanidae, Ceratopogonidae, Dytiscidae, Lepidoptera, and Hirudinea

2/ Experimental Side
Control

3/ Less than 0.5

Table 4.- Standing crops (no. organisms per m^2/cc per 100 m^2) of bottom fauna in pond 5, 1972

	Chiro-nomidae	Amphi-poda	Oligo-chaeta	Muscidae Pupae	Other 1/
June 6*	26/ 4 2/	-	-	-	-
	30/13	-	4/ 2	-	4/ 2
12	43/ 9	-	4/ 2	-	13/ 6
	30/13	-	4/ 9	4/ 4	-
20	-	4/ 2	4/ 4	47/ 82	4/ 4
	103/39	-	-	-	-
26	9/ 9	-	-	56/151	4/ 4
	103/43	-	9/13	9/ 9	4/ 2
July 7	26/30	-	-	116/237	4/ 4
	43/17	-	9/22	-	26/35
18	30/22	9/ 9	-	52/108	-
	52/43	4/ 4	4/ 4	-	-
25	13/ 4	-	13/ 4	43/ 95	9/ 4
	9/ 4	9/ 4	-	-	17/ 9
31	4/ 4	30/ 9	-	47/116	40/22
	-	-	4/ 4	-	-
Aug. 8	108/52	13/ 4	4/ 4	26/ 34	-
	22/ 4	9/ 4	-	-	43/13
22	39/39	-	-	60/129	-
	9/ 4	4/ 4	17/ 9	-	4/17
28	4/ 4	52/ 9	4/ 4	47/112	8/ 4
	86/52	-	4/ 4	-	-

1/ Caenis, Zygoptera, Hydrophilidae, Tabanidae, Ceratopogonidae, Anisoptera, Lepidoptera, Dolichopodidae, and Hirudinea

2/ Experimental Side
Control

* Before Treatment

Table 5.- Standing crops (no. organisms per m^2/cc per 100 m^2) of bottom fauna in pond 4, 1973

	Chironomidae	Muscidae Pupae	Other[1]
May 25*	34/ 9[2] -	26/ 30 133/314	12/ 20 17/ 16
June 1*	- -	17/ 22 90/163	- -
6*	22/ tr[3] 17/ 4	17/ 39 112/249	4/ 9 8/ 33
11	116/ 18 155/ 31	22/ 47 43/ 97	4/ 2 4/ 9
25	275/239 434/237	39/ 86 95/185	8/ 6 13/ 37
July 3	129/168 353/331	47/ 82 151/344	4/ 2 -
10	202/314 232/243	56/ 97 133/301	- -
25	155/103 73/ 61	90/202 56/103	- 4/151
Aug. 8	65/ 30 189/ 56	56/123 47/ 99	4/ 2 9/ 24
23	43/ 43 215/106	22/ 34 159/314	8/ 5 13/ 8

1/ Tabanidae, Stratiomyiidae, *Callibaetis*, Anisoptera, Zygoptera, Ceratopogonidae, Haliplidae, *Caenis*, Dolichopodidae, Dytiscidae, Lepidoptera, and Oligochaeta

2/ Experimental Side
Control

3/ Less than 0.5

* Before Treatment

Table 6.- Standing crops (no. organisms per m towed) of microcrustacea at the surface of pond 5, 1971

	Daphnia		Diaptomus		Cyclops		Ceriodaphnia		Other 1/	
	Exp.	Control	Exp.	Control	Exp.	Control	Exp.	Control	Exp.	Control
May 24*	831 2/	922	107 3/	351	526	549	-	38	290	351
	145	61	8	8						
June 9	91	943	115	432	72	45	-	-	4	68
	107	273	-	68						
21	14	130	135	218	22	26	12	5	2	-
	10	63	8	12						
July 5	7	318	109	182	274	45	42	145	1	-
	-	6	38	34						
19	-	36	76	326	182	155	31	1,332	1	32
	-	24	1	16						
29	1	-	290	307	124	91	103	3,091	-	-
	-	-	1	45						
Aug. 2	-	-	239	305	93	185	178	1,200	5	36
	-	-	-	71						
16	-	-	743	389	82	373	432	782	-	-
	-	-	-	5						
25	-	-	105	145	52	359	451	995	-	18
	-	-	-	5						
30	-	-	87	188	50	295	244	1,006	1	28
	-	-	-	-						
Sept. 9	-	-	93	173	38	432	501	964	-	14
	-	-	-	-						
13	-	-	37	41	7	368	445	1,549	-	20
	-	5	-	-						

1/ *Bosmina*, *Chydorus*, Ostracoda, *Alonella*, and *Simocephalus*

2/ < 1.5 mm
> 1.5 mm

3/ < 1.0 mm
> 1.0 mm

* Before Treatment

Table 7.- Standing crops (no. organisms per m towed) of microcrustacea at the surface of pond 5, 1972

	Daphnia		Diaptomus		Cyclops		Ceriodaphnia		Other 1/	
	Exp.	Control	Exp.	Control	Exp.	Control	Exp.	Control	Exp.	Control
June 5*	1,229 45	2,179 2/ 40	350 20	538 3/ -	54	13	-	-	-	-
12	191 13	355 32	239 9	274 27	31	27	-	-	-	-
20	114 375	284 909	432 114	1,023 199	57	85	-	-	-	-
July 11	114 2	24 -	242 85	833 45	90	3	13	3	2	-
18	176 -	128 -	206 51	385 131	99	12	6	-	-	-
24	104 3	235 -	107 48	296 69	24	10	10	-	24	-
31	139 9	216 -	348 27	368 25	45	-	-	-	5	-
Aug. 7	116 18	386 -	200 18	191 68	25	-	-	-	9	-
21	102 -	464 -	719 41	116 177	17	-	3	14	7	7
29	82 15	1,568 250	516 118	477 159	20	-	77	68	15	68

1/ Ostracoda, _Alonella_, _Chydorus_, _Bosmina_, and _Simocephalus_

2/ < 1.5 mm
> 1.5 mm

3/ < 1.0 mm
> 1.0 mm

* Before Treatment

Table 8.- Standing crops (no. organisms per m towed) of microcrustacea at the surface of pond 4, 1973

	Daphnia		Diaptomus		Cyclops		Ceriodaphnia		Other 1/	
	Exp.	Control	Exp.	Control	Exp.	Control	Exp.	Control	Exp.	Control
May 25*	85 2/	98	102 3/	80	102	127	6	7	6	7
	142	45	6	11						
June 1*	1,955	1,886	375	250	125	114	-	23	11	102
	11	91	91	34						
6*	707	571	349	239	17	34	-	-	-	9
	94	85	68	34						
11	114	155	132	131	2	12	2	-	23	12
	16	24	23	48						
22	-	152	297	520	14	30	-	-	9	25
	-	9	53	61						
July 3	16	43	432	284	39	16	36	2	2	57
	-	-	11	66						
9	89	23	665	307	10	23	181	7	-	27
	-	-	58	36						
23	68	323	968	627	7	9	443	145	7	9
	7	14	82	64						
Aug. 7	82	25	884	69	3	2	28	10	-	11
	3	-	31	8						
20	85	131	577	233	3	9	17	17	6	37
	3	-	63	105						
30	30	31	661	92	2	3	-	15	5	10
	-	-	34	19						

1/ Ostracoda, *Chydorus*, *Bosmina*, *Diaphanosoma*, *Leptodora*, *Simocephalus*, and *Alonella*

2/ $<$ 1.5 mm
$>$ 1.5 mm

3/ $<$ 1.0 mm
$>$ 1.0 mm

* Before Treatment

is not known if the later increase to a higher level than at the time of treatment could have been avoided with a heavier application of alum.

In deeper waters where the chemical cannot be initially mixed throughout the entire depth a heavier concentration of aluminum sulfate should be well mixed near the surface in a manner similar to that done in a deep Wisconsin lake (Peterson et al., 1973).

Application should be made in spring before the nuisance algae have had a chance to progress far in development as they have the ability to store phosphorus within the cell in much larger amounts than that needed to supply their immediate metabolic demands. Perhaps the mild blooms of *Aphanizomenon* in 1972 and 1973 could have been avoided if the alum applications had been made earlier.

Although the rate of floculation increases as water temperature increases, satisfactory phosphorus removal was attained in laboratory tests at initial temperatures near 40 degrees F. A temperature of 58 degrees F. at the time of the 1971 pond application did not seem to seriously affect the efficiency of the chemical. However, the application rate was probably excessive.

Following an alum application an accelerated growth of benthic vegetation might be expected due to increased light penetration and possibly increased availability of precipitated phosphorus to these plants.

LITERATURE CITED

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