The effects of certain commercial toxicants on the limnology of three cold water ponds near Three Forks, Montana
by Robert E Wollitz

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

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Time of death of test fish varied with the different toxicants. The numerical ratio of fish recovered was determined. Following treatment in the East and Middle Ponds,light penetration increased markedly. Dinobryon and Ceratium were the only phytoplankters which showed a reduction following the treatments. Treatment with the toxicants had varied effects on zooplankton. Bottom organisms were effected as follows: Tendipedidae exhibited little effect following treatment in the East Pond, decreased in the Middle Pond and increased in the West Pond; Tubificidae increased in all ponds. All plant inhabiting organisms except the Gastropoda, dis-' appeared following treatment in the East and Middle Ponds. In the West Pond, Hyallela and Tendipedidae were reduced after treatment while other organisms appeared uneffected.

THE EFFECTS OF CERTAIN COMMERCIAL TOXICANTS ON THE LIMNOLOGY OF THREE COLD WATER PONDS NEAR THREE FORKS, MONTANA

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ABSTRACT

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INTRODUCTION

During recent years, fish toxicants have become increasingly important in fisheries management. While some information is available concerning their effects on different species of fish, little has been reported regarding their effects on fish food organisms. A study was undertaken to determine important changes in the physical, chemical and biological characteristics resulting from commercial toxicants.

This investigation was conducted from April, 1956 to April 11, 1958 on three adjacent gravel-pit ponds, which are located 1.5 miles east of Three Forks, Montana. The project consisted of three phases: first, the determination of physical, chemical and biological characteristics of the ponds prior to the application of toxicants; second, the application of the toxicants and observations on their immediate effects on fish and fish-food organisms; third, the determination of changes in the physical, chemical and biological characteristics of the ponds following treatment.

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Montana State College Agricultural Experiment Station and the Montana Fish and Game Department.

METHODS

Physical and Chemical

Maximum-minimum air temperatures and surface water temperatures in each pond were secured daily, except Sundays. Surface temperatures were taken with a pocket thermometer and depth temperatures with a reversing thermometer. Turbidities were determined with a Hellige turbidimeter. Visibility (Secchi disc) and water fluctuations were determined at regular intervals.

The following chemical analyses were made at the time plankton samples were taken: dissolved oxygen, pH, phenolphthalein alkalinity and methyl orange alkalinity. Oxygen saturation was determined from a nomogram for giving values at different temperatures and altitudes (Rawson, 1944). Phosphate and inorganic nitrogen analyses were made by the Chemistry Department, Montana State College.

Plankton.

Plankton samples were obtained with a 1.2 liter Kemmerer water sampler. Each sample was concentrated to 20 ml by means of a No. 25 silk bolting cloth plankton net and then preserved with Lugol's solution. Nine sampling areas were established (Fig. 1): one was located near each end (Stas. B, C) and the other (Sta. A) in the middle of each pond. A sample of 19.2 liters of water was taken from each station B and C. Samples from

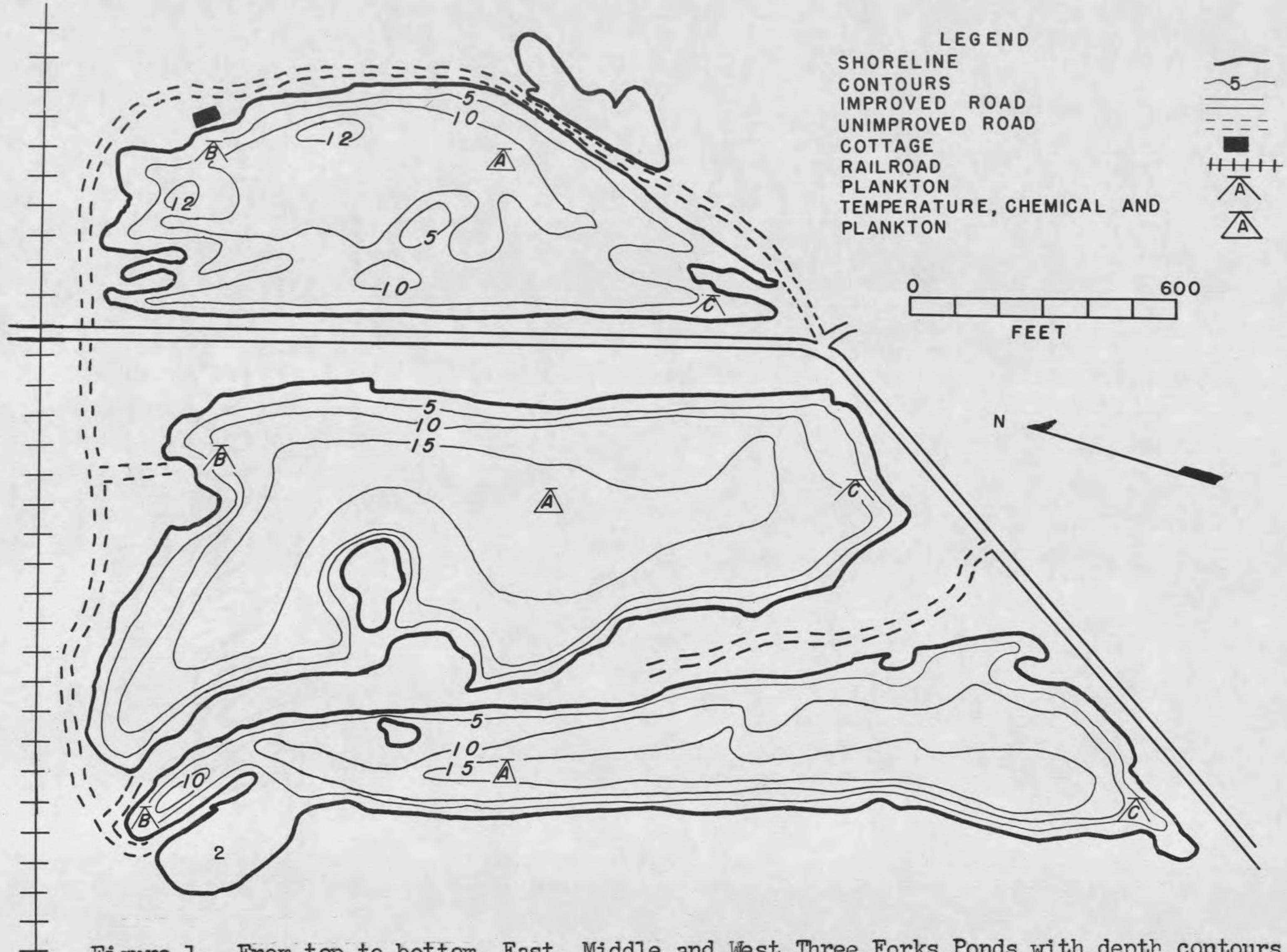

Figure 1. From top to bottom, East, Middle and West Three Forks Ponds with depth contours and plankton, temperature and chemical stations shown.

station A combined plankton from equal volumes of water (total 76.8 liters) obtained from the surface, 5-, 10-, and 15-foot depths in the Middle Pond and West Pond from April-September, 1956. During the same period a combined sample (total 38.4 liters) was taken at the surface and five feet from the East Pond. After September, samples were secured from the surface and the bottom (7-9 ft.) in the East Pond and the total sample was reduced to 19.2 liters at station A in all ponds. Samples were taken approximately every two weeks at all stations during periods of open water. During the winter, monthly samples were secured immediately under the ice and confined to station A. The overall sampling period extended from April 17, 1956 to April 11, 1958 with the following exceptions: no samples were obtained May 1-June 2, 1956 in any of the ponds; no station A samples were taken in the East Pond on June 2 and 29, 1956 and no samples were taken in the East Pond October 9, 1956-December 13, 1957 or in any of the ponds November 4, 1957-January 10, 1958.

Numerical plankton counts were made on one milliliter of concentrate placed in a Sedgwick-Rafter cell. Plankton organisms were identified to genus, with the exception of diatoms which were identified to family only. Zooplankton counts were made by the survey method and phytoplankton by the differential method. For phytoplankton, 10-40 fields were counted, the number depending on the density of plankters as determined by inspection. Identification of phytoplankton followed Smith (1950) and zooplankton followed Pennak (1953).

Bottom Samples.

Bottom samples (1.5 sq. ft.) were taken with an Eckman dredge. Bottom materials were washed through a sieve with openings approximately 0.5 X 0.5 mm and the organisms sorted from the remaining material. Organisms were identified to family and their volumes determined by water displacement. All samples were taken at depths of 10-15 feet.

During the summer of 1956, four samples were secured from the East Pond, four from the Middle Pond and three from the West Pond. Five samples were obtained from each pond in 1957 and one from each in March, 1958. Two of the 1957 samples were taken prior to the application of toxicants and the remaining samples were taken after.

Samples of Plant-Inhabiting Organisms

A metal cylinder (21 inches long and 6 inches in diameter) was used to obtain samples of plant inhabiting organisms at depths of 12-24 inches. The sampler was first placed over the vegetation which was then loosened from the bottom. A small piece of screen (18 mesh per inch) placed over the bottom of the cylinder prevented organisms from escaping. The whole unit was lifted from the water and its contents placed in a large pan. Approximately one-half pound of vegetation (damp weight after 15-20 minutes of draining) was taken for each sample. Organisms were removed from the vegetation and identified to family or genus and their volumes determined by water displacement.

Vegetation samples were taken as follows: 1956, four in the West Pond, four in the Middle Pond and three in the East Pond; 1957, two prior to the application of toxicants and three following. One sample was also taken in each pond March, 1958.

Application of Toxicants.

All toxicants were applied from a boat by means of a portable, gasoline-powered pump. The effective penetration of toxicants and period of toxicity were determined by the death of healthy fish placed in wire cages at various depths. Extensive gill-netting was carried out to determine the completeness of kill.

RESULTS

The three study ponds, which are all dredged pits lying adjacent to each other, receive their water supply mainly from seepage and springs. They have no inlets or outlets. Frequent winds and the shallowness of the ponds does not permit marked thermal stratification during the summer. Average weekly surface water temperatures of all ponds were similar and closely approximated air temperatures during the summer of 1956 (Fig. 2). Ice cover formed on all ponds between November 3-10, 1956 and between November 15-18, 1957. The ice disappeared between March 22-April 3, 1956, between March 24-30, 1957 and on March 24, 1958. Snowfall was light during the winter and no prolonged snow cover on pond ice was observed.

East Pond

Description

The East Pond has not been dredged since 1940 but the exact time is not known. It has a surface area of 12.9 acres and a volume of approxi-

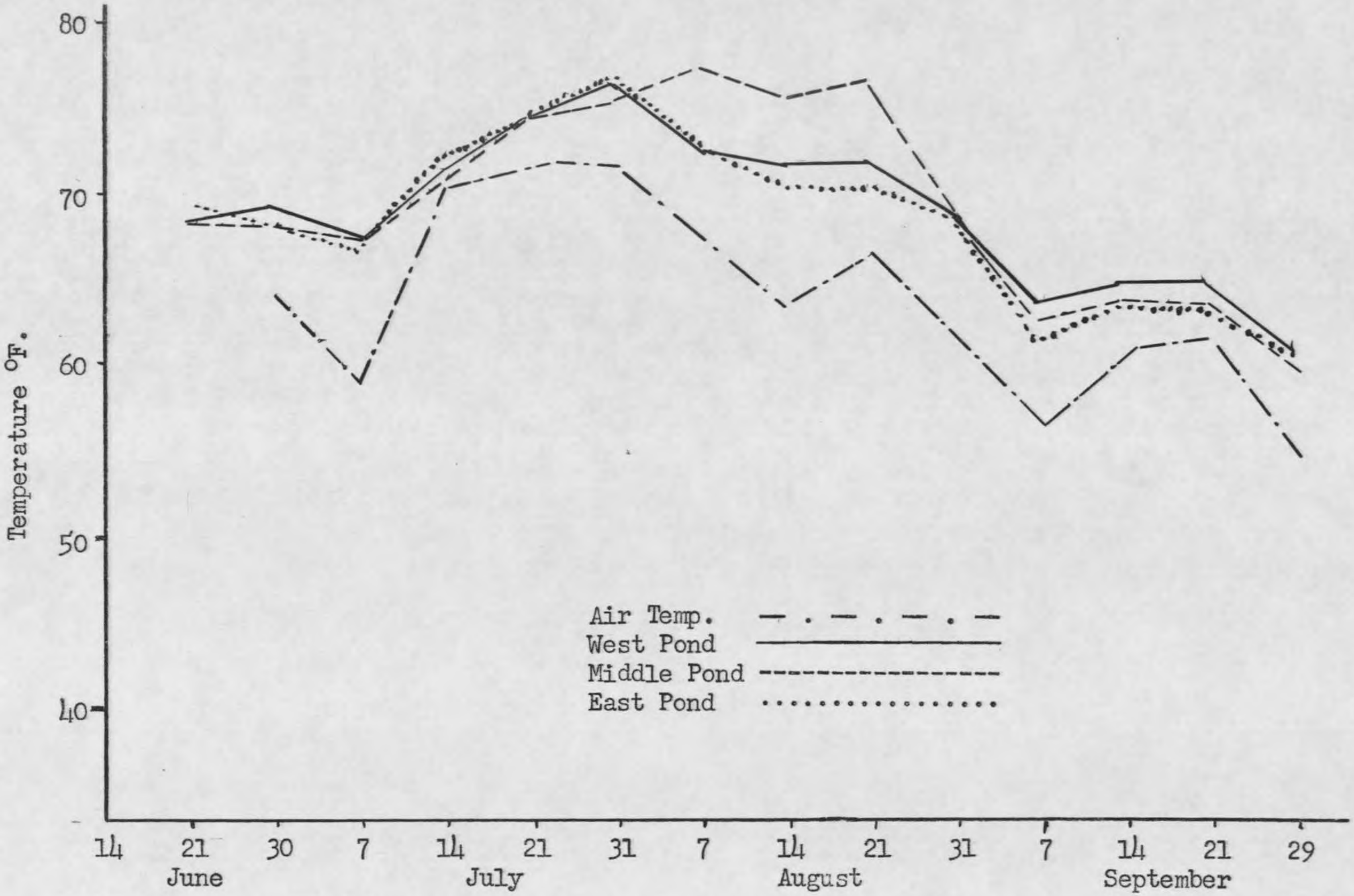

Figure 2. Average monthly air temperatures and surface water temperatures for the East, Middle and West Three Forks Ponds, for the period June to October, 1956.

mately 100 acre feet, a maximum depth of 12 feet and a mean depth of 7.9 feet. The shore is generally less than two feet above the surface of the water but rises to a maximum of 10 feet in a few places. The pond bottom is extremely irregular due to dredging and is covered with about equal areas of coarse gravel and muck. The surface water fluctuated 14 inches in 1956 and 19 inches in 1957.

The important shore vegetation included willow (Salix sp.), and Kentucky bluegrass (Poa pratensis). Emergent aquatic vegetation occupied approximately 40 per cent of the shoreline and consisted of great bullrush (Scirpus validus) and cattail (Typha latifolia). Submerged vegetation included dense growths of stonewort (Chara sp.), water milfoil (Myrophyllum exalbescens) and lesser amounts of widgeon grass (Ruppia maritima) and sago pondweed (Potamogeton pectinatus).

The earliest known fish introduction consisted of 8,000 four-inch largemouth black bass (Micropterus salmoides) which were planted in November, 1938. Another 1,000 largemouth black bass were stocked in November, 1944. Black crappies (Pomoxis nigro-maculatus), bluegills (Lepomis machrochirus), yellow perch (Perca flavescens), carp (Cyprinus carpio), longnose sucker (Catostomus catostomus), white sucker (Catostomus commersoni) and golden shiner (Notemigonus crysoleucas) were also present but no records of introductions were found. It is surmised that the black crappies and bluegills were introduced with the largemouth black bass as forage fish and that the others were introduced by private individuals or bait fishermen.

Fish Eradication

On July 16, 1957, an emulsifiable solution containing 60 per cent toxaphene was applied to the East Pond. The concentration used was approximately 0.13 ppm. Application began at 6:15 a.m. and was completed at 9:00 a.m.

The first signs of distress in fish were observed 45 minutes after the start of application when small fish were observed jumping. At the end of one and one-half hours, fish were observed swimming erratically near the surface of the water and appeared unable to go below. A few minutes later some fish were lying at the surface, near death. Small fingerling largemouth black bass and bluegills were the first to die. Fish over five inches in total length (all lengths are from the tip of the snout to the distal end of the caudal fin) were first observed dying two hours and 40 minutes after the start of application.

One sucker and two bluegills were placed in each of two wire mesh ($\frac{1}{2}$ in.) cages. One cage was suspended at the five foot depth and the other at 10 feet, to determine the effective rate of toxicant penetration. A sucker in the cage at 10 feet died five hours after the start of application and a bluegill 5.5 hours. One of the bluegills in the cage at five feet died seven hours following the start of application and the other at 8.5 hours. The remaining bluegill in the cage at 10 feet and the sucker in the cage at five feet were still alive 14 hours (8:00 p.m.) after the first poison was applied. No observations were made between 8:00 p.m. and 6:00 a.m. the following morning, at which time the remaining fish were dead.

Observations and fishing effort (six 48-hour gill net sets) revealed no living fish present one month following poisoning and it was assumed that a complete kill had been obtained. Immediately following the chemical treatment snails were the only aquatic invertebrates observed. After August 1, 1957, a considerable number of living Notonectidae and frogs were observed in the pond.

Toxicity of water to fish was tested by suspending cages containing brown trout (Salmo trutta) and rainbow trout (Salmo gairdneri) at various places in the pond. The toxicity of the water declined gradually as demonstrated by the length of time it took to kill trout. The length of time that test fish lived was as follows: August, two days; September, seven days; October, 14 days. By November, 1957, the water was considered non-toxic, since test fish introduced at that time lived for over two months.

Three days (68 man-hours) were spent in recovering dead fish. An attempt was made to recover all fish which came to the surface during this time. Those which remained on the bottom and those which surfaced later were not recovered. All fish of each species were counted and bulk-weighed. Individual total lengths were recorded for a sample of each species (Table I).

Food fish, consisting of bluegills, yellow perch, largemouth black bass and black crappies, made up 94 per cent of the total number recovered and 33 per cent of the total weight while carp, longnose suckers and white suckers made up about six per cent of the total number and 66 per cent of the total weight. No carp less than seven inches in length were recovered

Table I. Numbers, lengths (inches) and weights (pounds) of fish recovered from ponds.

Fish Species	Pond	Total No.	Total Wt.	Per cent Total No.	Per cent Total Wt.	No. Measured	Per cent Measured	Length Range	Av. Length
Bluegill	East	1,667	138	38	14	170	10.0	1.2-6.8	4.0
	Middle	20,745	558	59	51	32	0.1	1.3-7.3	4.1
	West	636	24	11	4	27	4.0	1.7-6.7	3.6
Black Crappie	East	195	24	5	2	24	12.0	2.2-8.2	6.0
	Middle	810	50	2	5	29	3.0	3.1-7.8	5.5
	West	*							
Largemouth Black Bass	East	241	97	6	6	97	40.0	1.0-16.2	5.0
	Middle	391	117	1	11	78	20.0	1.0-16.1	7.9
	West	363	142	6	26	62	17.0	0.9-16.2	6.2
Yellow Perch	East	1,889	110	45	11	25	1.0	3.0-6.8	5.0
	Middle	12,694	361	37	33	22	0.2	1.9-7.3	4.2
	West	4,931	540	83	69	45	0.9	1.9-11.2	7.7
Carp	East	188	612	44	63	45	23.0	7.2-26.0	18.0
	Middle								
	West	*							
White Sucker	East	6	9	1	1				
	Middle								
	West	*							
Longnose Sucker	East	8	20	1	2				
	Middle								
	West	*							

* Not present in pond.

(Table I), indicating that this species was not reproducing successfully. The average length of largemouth black bass was five inches, however, 32 per cent were over six inches and 20 per cent were over 10 inches. The approximate numerical ratio of yellow perch, bluegill, black crappie, carp, suckers was 135:119:17:14:13:1 and the approximate weight ratio was 4:5:3:1:21:1.

Physical, Chemical Characteristics

Before Treatment. Limit of visibility was usually less than five feet and turbidities averaged 8.2 ppm SiO_2.

No chemical stratification occurred in this pond. Oxygen saturation was usually less than 100 per cent and was lowest in winter (Table II). Phenolpthalein alkalinity ranged from 0.0 to 18.0 ppm, being absent during the spring of 1956 and the winter of 1956-7. Methyl orange alkalinity ranged from 163 to 245 ppm being highest in winter. The pH ranged from 8.2 to 8.6 in the spring and summer, 1956, 7.4 to 8.0 in the winter and 7.5 to 8.6 in the spring and summer, 1957.

Nitrates ranged from 0.07 ppm to 0.13 ppm and phosphates from 0.0 to 0.45 ppm, being absent in the fall, 1956.

After Treatment. A marked change occurred in most physical and chemical properties following treatment. Visibility extended to the bottom. Turbidities decreased to less than 3.0 ppm SiO_2 immediately following treatment and by the winter of 1957-8 had decreased to less than 1.0 ppm. This decrease in turbidity probably resulted from the removal of rough fish, which have a tendency to stir up the bottom. Similar

Table II. Ranges of physical and chemical properties of the East Pond before and after treatment.

	Before						After		
	Spring	Summer	Fall	Winter	Spring	Summer	Summer	Fall	Winter
Dissolved oxygen per cent saturation	46-118	61-105	92-108	43-87	78-126	79-114	105-163	101-164	120-141
Phenolpthalein alkalinity (ppm)	0	5-18	7-15	0	0-5	0-8	17-40	41-54	10-48
Methyl orange alkalinity (ppm)	190-212	163-181	167-195	205-245	192-215	192-217	126-151	121-130	110-132
pH	8.2-8.3	8.3-8.5	8.2-8.6	7.4-8.0	7.5-8.3	7.5-8.6	8.2-9.3	8.9-9.5	9.2-9.6
Turbidity ($ppm\ SiO_2$)					4.9-14.0	2.6-15.0	1.3-2.6	1.2-2.6	0.6-1.7
Secchi disc (ft.)		3-5	3	*	3-4	3-4	B**	B	B
		6/20/56	11/8/56	3/24/56			8/19/57		
NO_3 (ppm)		0.13	0.15	0.07			0.03		
PO_4 (ppm)		0.45	0.0	0.03			0.09		

* Ice cover, no readings taken.

** Bottom of pond, 12 feet.

decreases following removal of rough fish were reported by Ricker and Gottschalk (1940); Weier and Starr (1950); Tanner and Hayes (1955).

There was a decided change in most chemical properties associated with the increase in visibility and decrease in turbidity. Dissolved oxygen was greater than 100 per cent saturation at all times; phenolpthalein alkalinity and pH increased; methyl orange alkalinity decreased. No change was observed in nitrates or phosphates.

On January 10 and February 12, 1958, oxygen saturation values of 121 and 145 per cent, respectively, were found beneath the ice cover. On these dates the ice was very transparent making the bottom visible over most of the pond. Submerged vegetation remained green during the period of ice cover.

Phytoplankton

Before Treatment. Semi-monthly plankton counts from all stations were combined and averaged. In counting phytoplankton, individual colonies, filaments and cells were considered as one unit.

Chrysophyta was the most dominant group of algae encountered (Table III). Diatoms were present in nearly all samples. Peaks of abundance were encountered in April, July and October, 1956 and in May and September, 1957. Dinobryon was present from late spring to late fall and was the most abundant alga found prior to treatment. Pyrrophyta was the next most abundant group with Ceratium being the most numerous representative. The groups Chlorophyta and Cyanophyta were represented by several genera but contributed little to the overall abundance of phytoplankton. Station C,

Table III. Average number of phytoplankters per liter of water combined from stations A, B and C in the East Pond.

Organism	Before 1956 April	May	June	July	Aug.	Sept.	Oct.	Dec.	1957 Jan.	Feb.	March	April
Chlorophyta												
Closterium												13
Cosmarium			1	13								9
Gloeocystis				52								
Pediastrum			1			9						
Scenedesmus			26	4		65						
Staurastrum			1			9						
Mougeotia		9										
Oedogonium		4										
Zygnema		4		1	13	9						
Unidentified	245	199	6	4	35	121	69					
Chrysophyta												
Chrysophyceae												
Dinobryon		17	3,102	442	416	5,222	260					
Bacillariophyceae												
Coscinodiscaceae	87					39					52	113
Cymbellaceae	19	13	19	404	100	208	269	208			104	78
Fragilariaceae	704	299	61	24	9	195	269	104	104	0	624	433
Gomphonemataceae				35	9		17					9
Naviculaceae	271	139	136	559	161	347	1,031	156	208	0	364	676
Surirellaceae	17							52			52	4
Unidentified												
Pyrrophyta												
Ceratium	4	100	181	2,369	2,747	1,010						
Peridinium					87	13		104				
Cyanophyta												
Oscillatoria		4	13	22								
Cylindrospermum			1	919	69	4						
Nodularia					104							
Calothrix				87								

Table III (Continued).

Organism	Before 1957 May	June	July	After 1958 Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	March	April
Chlorophyta											
Cosmarium		295		9	78						
Gloeocystis	9				4	30	295		104		52
Pediastrum	9		65		9				26		
Scenedesmus	65		35								
Staurastrum					9						
Mougeotia				22	17	13					
Oedogonium			9								
Spirogyra			39	39	26	17			78	35	52
Zygnema			9	9					26		
Unidentified	13		35		167						
Chrysophyta											
Chrysophyceae											
Dinobryon	4,758	108	22,282	17	17	4	26				9
Bacillariophyceae											
Coscinodiscaceae	17				13						
Cymbellaceae	130	9	43	17	919	13		26	26		39
Fragilariceae	1,365	13		56	121	403			130	138	78
Gomphonemataceae						17		104			
Naviculaceae	489	4	295	230	364	13				130	
Surirellaceae	17	17	39								
Unidentified						21					
Pyrrophyta											
Ceratium	30	26	563	9							
Peridinium	9	182	65							17	9
Cyanophyta											
Cylindrospermum			9		9						
Nodularia				13							
Oscillatoria	9			9	9	9					
Spirulina					4						

at the more protected end of the pond, had the greatest number of individuals of all groups except Dinobryon which was most abundant at Station A.

Phytoplankton blooms were encountered in the spring, summer and fall of each year but varied in seasonal magnitude. In 1956, maximum abundance occurred in September and the minimum in April. In 1957, the maximum was in July and the minimum in September.

After Treatment. Treatment with toxaphene (July 16, 1957) appeared to have little effect on most phytoplankters although Dinobryon was reduced and Ceratium was entirely absent after treatment. Ceratium reappeared in the collection on March 24, 1958.

Zooplankton

Before Treatment. Zooplankton was present on all sampling dates prior to treatment (Table IV). Rotatoria and Copepoda were the most frequently encountered groups with the genera Keratella, Polyarthra and Cyclops present in all samples. A few genera of Rotatoria and Copepoda appeared seasonally. Brachionus was present during the entire period of open water. Lepadella and Notholca appeared during the spring and Lecane and Diaptomus were present in the summer and fall. While cladocerans were present on most occasions, they did not occur as frequently as rotifers and copepods. Chydorus was present in samples prior to treatment except during February, April, May and June, 1957. Bosmina occurred infrequently from April, 1956 through January, 1957 and was found in all

Table IV. Average number of zooplankters per liter combined from stations A, B and C in the East Pond.

Organism	Before 1956 April	May	June	July	Aug.	Sept.	Oct.	Dec.	1957 Jan.	Feb.	March	April
Cladocera												
Bosmina		T*	T					4		2	1	2
Ceriodaphnia			5	26	43	20						
Chydorus	19	78	7	3	113	14	6	1	2		3	
Diaphanosoma		T	1	2	2	T						
Copepoda												
Cyclops	12	46	10	15	49	41	14	5	5	58	35	23
Diaptomus			T	4	16	15						
nauplii**	142	91	30	136	438	43	30	24	19	182	55	152
Rotatoria												
Asplanchna	8	2	T	17	43	50	23			T	4	
Brachionus	9	9	1	18	64	4						
Keratella	14	24	4	191	36	79	21	68	16	9	9	1
Lecane				T	4	T	T					
Lepadella	T	T	T									
Notholca	6	9					1		2	1		1
Polyarthra	2	4	38	42	38	131	18	17	6	112	36	31
Protozoa	2	1	3	8	T	T	3	7			6	T
Ostracoda		T	T	4	11	22	7					

* T indicates organisms that were present in numbers less than one per liter.
**nauplii includes larval forms of both Cyclops and Diaptomus.

Table IV (Continued)

	Before			After							
	1957			1958							
Organism	May	June	July	Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	March	April
Cladocera											
Bosmina	T	94	38		T*	2	T	3			
Ceriodaphnia		26	60								
Chydorus			5								
Diaphanosoma			5								
Copepoda											
Cyclops	52	113	62		5	5	1			2	3
Diaptomus		T									
nauplii**	403	39	69				2	2	3	5	14
Rotatoria											
Asplanchna	1	T		1	1	8	13	2	3	10	6
Brachionus	1	1	35	16	1						
Keratella	35	38	66	T	T	2	11	2	1	2	6
Lecane				4	6	1					
Lepadella										2	13
Nothulca											1
Polyarthra	20	50	85	2	21	10	93		5	11	14
Protozoa	539	53	130	6							
Ostracoda			4								

* T indicates organisms that were present in numbers less than one per liter.
** nauplii includes larval forms of both Cyclops and Diaptomus.

samples from February until the treatment date. Ceriodaphnia and Diaphanosoma were found only from June to October, 1956 and in June and July, 1957. Protozoa was scarce during 1956 but very abundant from May through July 14, 1957. Ostracoda was scarce in all samples. Other organisms rarely encountered were: Cladocera - Alona, Daphnia, Eurycercus, Scapholebris; Rotatoria - Euchlanis, Platyias, Filinia, Trichocerca; Protozoa - Centropyxis.

Considerable variation occurred in the number of organisms taken at the three sampling stations. Station C, located at the more protected end of the pond generally yielded a greater number than either stations A or B which were more affected by wave action. The largest variations occurred during pulses. On May 6, 1956, numbers of Chydorus varied from two organisms per liter at station A to 222 at station C and on August 25, from seven per liter at station B to 234 at station C. The number of nauplii ranged from 140 per liter at station A to 1968 at station C on August 10 and Keratella ranged from 10 per liter at station C to 867 at station B on July 14. On May 1, 1957, nauplii numbers ranged from 43 per liter at station B to 1400 at station C.

Zooplankton abundance in this pond did not follow any regular pattern during the period April 17, 1956 to July 16, 1957. In 1956, the only pronounced zooplankton pulse appeared in August and resulted from an increase in the common genera. In 1957, prior to treatment, only one pulse was observed. This occurred in May and resulted from eruptions of nauplii and Diffulgia.

After Treatment. All Cladocera and Copepoda disappeared after treat-