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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The effects of certain commercial toxicants on the physical, chemical and biological properties of three cold water ponds were studied. The East Pond was treated with toxaphene, the Middle Pond with Chem-Fish Special, Pro-Noxfish and toxaphene and the West Pond with Pro-Noxfish.

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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TABLE OF CONTENTS

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

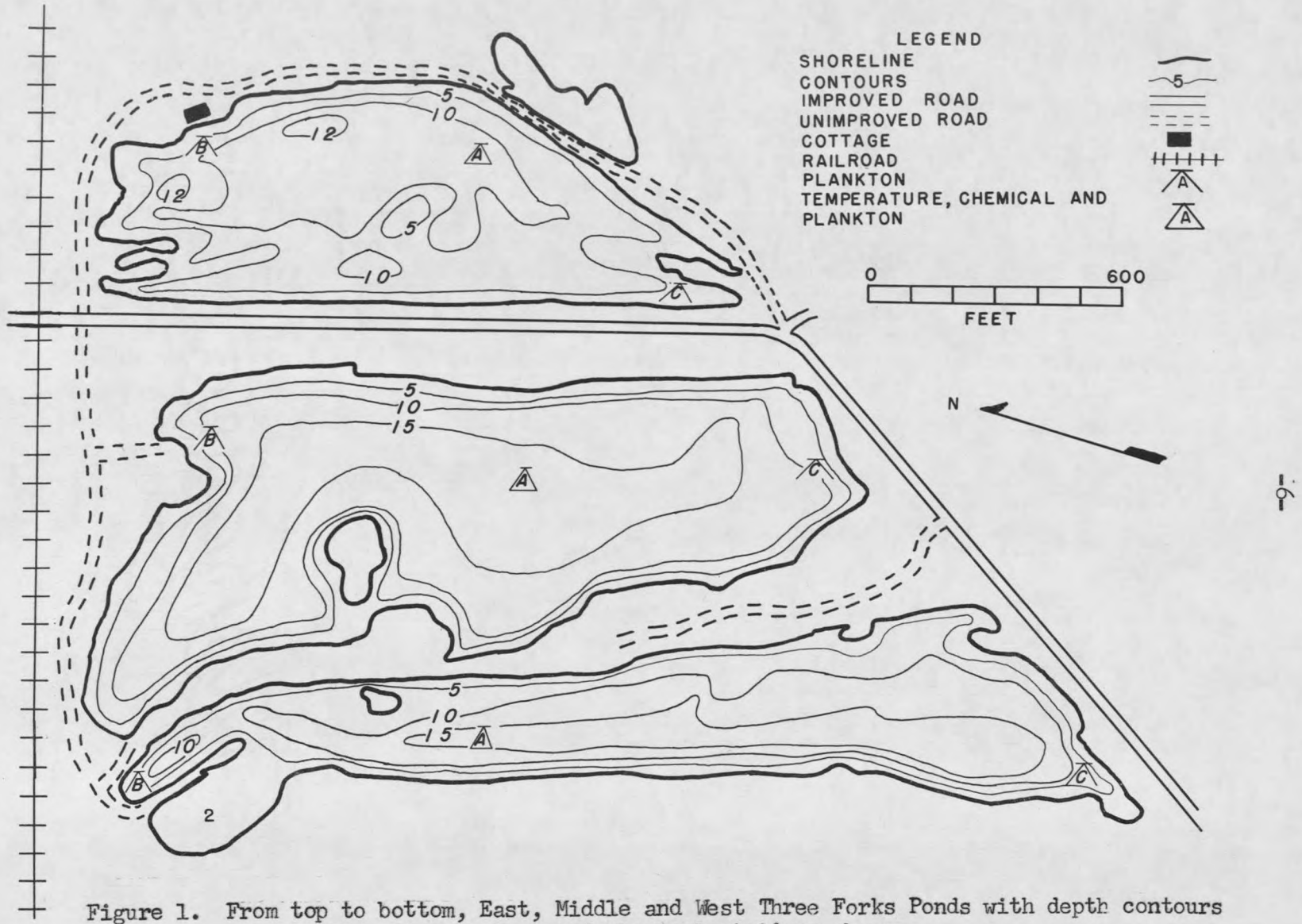

Figure 1. From top to bottom, East, Middle and West Three Forks Ponds with depth contours and plankton, temperature and chemical stations shown.

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-

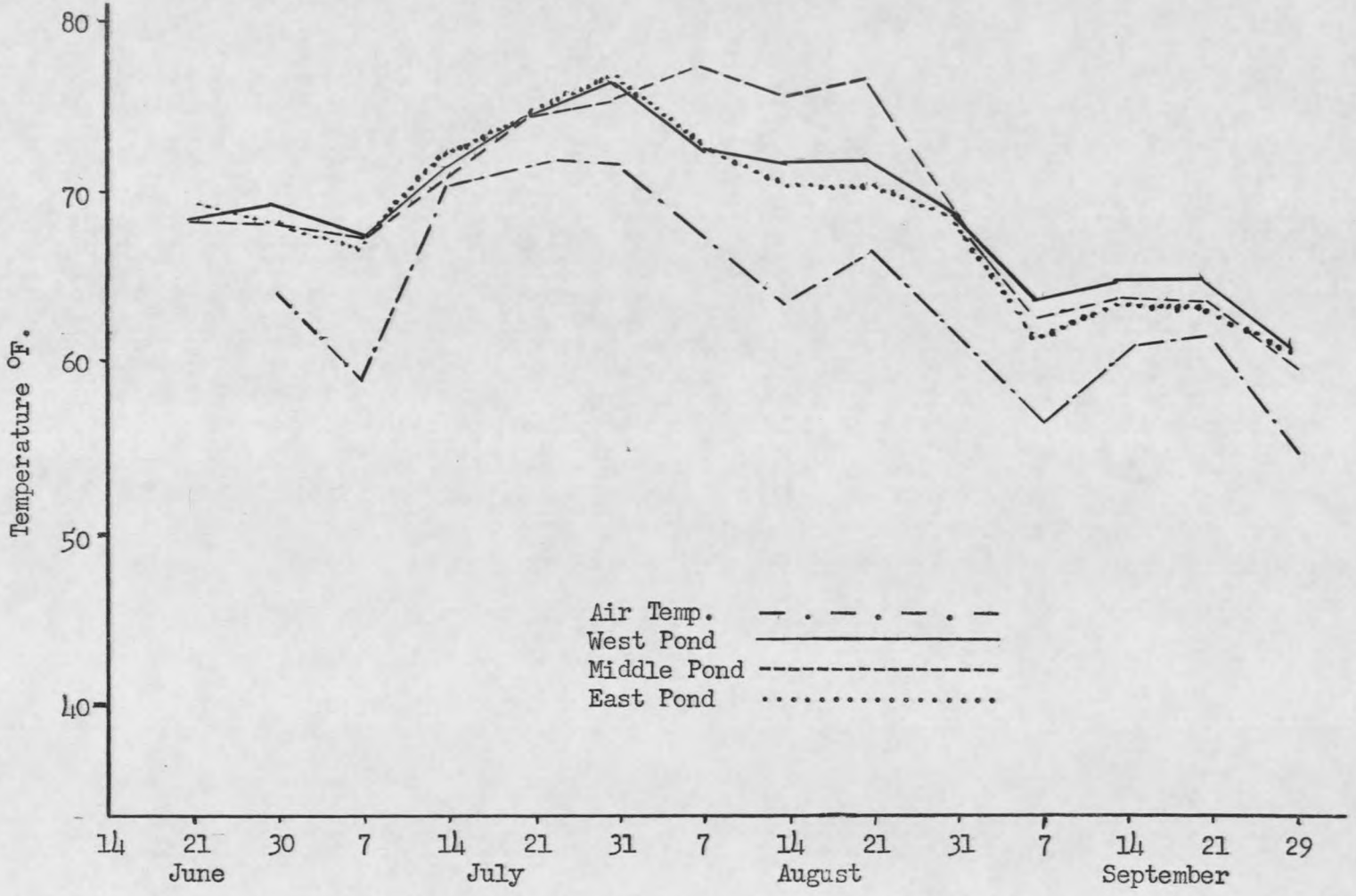

Figure 2. Average monthly air temperatures and surface water temperatures for the East, Middle and West Three Forks Ponds, for the period June to October, 1956.

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.

	Before											
	1956								1957			
Organism	April	May	June	July	Aug.	Sept.	Oct.	Dec.	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).

	Before			After							
	1957			1958							
Organism	May	June	July	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.

	Before											
	1956							1957				
Organism	April	May	June	July	Aug.	Sept.	Oct.	Dec.	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	1	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-

ment (July 16, 1957) and did not reappear in collections until September 20, when Bosmina and Cyclops were found. At this time the water was still toxic to trout. Tanner and Hayes (1955) reported that zooplankton reappeared while the water was still toxic to fish. Hooper and Grzenda (1955) found that the 24-hour TLm of Daphnia was 75 times greater than that of the bluntnose minnow (Pimephales promelas).

On September 20, 1957, advanced stages of Cyclops reappeared but nauplii did not reappear in collections until November 4. Pennak (1953) reported that Cyclops may form "cysts" or "cocoons" under adverse environmental conditions when in the copepodid stage and cites as an example an abundance of cysts on lake bottoms in midsummer possibly in response to anaerobic conditions. Presence of advanced stages of Cyclops prior to the appearance of nauplii may be another indication of the formation of such cysts.

Ostracoda disappeared after treatment and did not reappear before termination of this study. Protozoa were greatly reduced following treatment but did not completely disappear until August 15. They were not found following this date. Rotifers were greatly reduced but not completely eliminated. Brachionus was found immediately after treatment and through September 7, 1957 when it disappeared and was not encountered afterwards. Polyarthra and Keratella disappeared after treatment, but reappeared in the collection on August 15, 1957.

Bottom Organisms

Before Treatment. Tendipedidae and Tubificidae were the most abund-

ant organisms prior to treatment. They were present in approximately equal numbers but Tendipedidae constituted a larger volume (Table V). During the period June 25 to September 19, 1956, the numbers of individuals in both families remained nearly constant but were noticeably reduced in the May and July collections of 1957. Other organisms occasionally encountered were: Hemiptera - Notonecta; Gastropoda - Gyraulus and Physa; Coleoptera - Haliplus; Ephemeroptera - Tricorythodes; Trichoptera - Phryganea.

After Treatment. Neither Tendipedidae nor Tubificidae exhibited any noticeable reduction following treatment. Tendipedidae increased slightly and remained nearly constant in number throughout the remainder of the study. This is not in accord with the findings of other investigators. Hooper and Grzenda (1955) reported that a large portion of the benthos was killed within one month following treatment in two Michigan lakes. Cushing and Olive (1956) reported that no living Tendipedidae larvae were present in collections three days following treatment. Failure of Tendipedidae to die in our ponds may have resulted from inflowing springs in the bottoms. Tubificidae were taken in approximately the same number seven days after treatment as three days prior to treatment. They increased greatly in abundance 34 days (August 19, 1957) after treatment. An increase in abundance of Tubificidae after treatment with toxaphene was reported by Cushing and Olive (1956).

Plant Inhabiting Organisms

Before Treatment. Gastropoda was the most numerous group of organ-

Table V. Number and volume (cc) of bottom organisms per square foot in the East, Middle and West Ponds before and after treatment.

East Pond					Middle Pond					West Pond				
	Tendipedidae		Tubificidae			Tendipedidae		Tubificidae			Tendipedidae		Tubificidae	
Date	No.	Vol.	No.	Vol.	Date	No.	Vol.	No.	Vol.	Date	No.	Vol.	No.	Vol.
Before														
6/25/56	50	T*	61	0.07	6/21/56	54	0.33	206	0.16	6/20/56	60	0.09	20	T
7/23/56	82	0.2	17	T	7/19/56	143	0.99	145	0.14					
8/17/56	80	0.3	66	0.07	8/15/56	103	0.53	264	0.26	8/13/56	102	1.25	244	0.24
9/19/56	84	0.7	132	0.07	9/9/56	79	0.99	330	0.33	9/14/56	77	0.59	0	0.0
5/10/57	12	**	0	0.0	5/18/57	55	**	24	**	5/20/57	62	**	0	0.0
7/13/57	14	0.1	10	T	7/12/57	82	0.46	132	0.13	7/12/57	91	0.26	1037	1.45
7/16/57	toxaphene				7/17/57	Chem-Fish Special				7/18/57	Pro-Noxfish			
After														
7/23/57	7	0.2	14	T	7/23/57	70	0.33	53	0.06	7/23/57	28	0.19	297	0.30
8/19/57	39	0.7	132	0.80	8/19/57	206	1.20	594	0.59	8/19/57	193	1.58	858	0.86
					9/17/57	Pro-Noxfish								
					10/17/57	toxaphene								
After														
12/19/57	23	0.2	396	2.40	11/15/57	26	0.20	201	1.20	11/15/57	175	1.09	858	0.86
3/28/58	31	0.3	330	2.80	3/28/58	5	0.07	1089	2.18	3/28/58	238	1.12	0	0.0

* Less than 0.05 cc.

** Organisms partially decomposed, volumes not determined.

isms encountered, while Gyraulus and Lymnaea were the most abundant genera (Table VI). Gyraulus reached maximum abundance in August, 1956 and minimum in July, 1957. Lymnaea was most abundant in October, 1956 and least abundant in May, 1957. Physa was most numerous in August but reached its greatest volume in October, 1956. It was absent from collections in May but reappeared in July, 1957, just prior to treatment.

Ischnura (Odonata) was most numerous but of minimum volume in August and September, 1956, when large numbers of young individuals were present. Its maximum volume was encountered in July, 1957, when a relatively small number of sub-imagos was present.

Naididae (Oligochaeta) was present only in August and September, 1956 with maximum numbers occurring in the latter month. Tendipedidae (Diptera) was very abundant in 1956 but was not found in 1957 samples. Odonata and Gastropoda were the only groups of organisms present on July 13, 1957, three days prior to treatment.

After Treatment. A reduced number of gastropods was found in samples eight days following treatment. After July 24, all genera of this group increased and on March 24, 1958, their combined total volume exceeded that for any time prior to treatment. Odonata did not appear in any samples taken following treatment. The absence of Oligochaeta, Amphipoda, Diptera, Coleoptera, Ephemeroptera and Trichoptera in collections taken after treatment is not significant since they were not present in the sample taken immediately prior to treatment.

Table VI. Number and volume (cc) of plant inhabiting organisms per kilogram of submerged aquatic vegetation in the East Pond before and after treatment with toxaphene.

	Before										After							
	8/3/56		9/3/56		10/27/56		5/20/57		7/13/57		7/24/57		8/23/57		12/9/57		3/28/57	
Organism	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Amphipoda																		
Hyallela	9	T*	68	T														
Coleoptera																		
Stenelmis	5	T	5	T	12	T	239	**										
Diptera																		
Tendipedidae	515	0.3	309	T														
Ephemeroptera																		
Baetis			5	T														
Tricorythodes	42	T	42	T														
Gastropoda																		
Gyraulus	543	0.9	450	0.5	256	0.3	123	**	33	0.2	17	T	64	T			60	0.5
Lymnaea	56	T	10	T	232	0.9	65	**	83	T	21	T	61	0.8			154	0.3
Physa	61	T	37	T	42	0.3	0	0.0	25	T	8	T	1107	1.1			97	3.9
Odonata																		
Ischnura	285	0.7	283	0.5	125	0.4	136	**	58	1.4								
Oligochaeta																		
Naididae	47	T	3143	0.5														
Trichoptera																		
Oecetis	5	T	-															
Phryganea			16	T														

* T indicates trace.

** Organisms starting to decompose and volumes not determined.

Middle Pond

Description

The Middle Pond is 23 years old, dredging having been completed in 1935. It has a surface area of 20.3 acres, a volume of approximately 183 acre feet, a maximum depth of 18 feet and mean depth of nine feet. The height of the shore varies from one to about 15 feet above the surface of the water and is generally over six feet in height. The bottom is quite regular in spite of dredging and is composed of a large amount of muck and smaller amounts of sand and coarse gravel. The surface water fluctuated 13 inches in 1956 and 23 inches in 1957.

The predominant shore vegetation is Kentucky bluegrass. Emergent aquatic vegetation included great bullrush and cattail which occur along about 90 per cent of the shoreline. Submerged vegetation is found over most of the bottom and consists largely of stonewort, sago pondweed, water milfoil and small amounts of white-water crowfoot (Ranunculus circinatus).

The only known fish introduction (2,440 five-inch rainbow trout) occurred in May, 1941. No trout of any species was found during this study. The fish found included largemouth black bass, black crappie, yellow perch, white sucker, carp and northern brown bullhead (Ameiurus nebulosus). Centrarchids and yellow perch were presumed to have been introduced as unrecorded state plants or as unofficial transplants from the East Pond. Carp, white sucker and northern brown bullhead may have been introduced by bait fishermen.

Fish Eradication

This pond was treated with three different commercial toxicants, although plans called for the use of Chem-Fish Special only. Live fish were found after treatment with Chem-Fish Special and Pro-Noxfish, thus requiring a third treatment (toxaphene) for a complete kill.

First Treatment. On July 17, 1957, Chem-Fish Special was used at a concentration of approximately 0.7 ppm. This toxicant contained 5.5 per cent rotenone, 11 per cent other cube extractives and 83.5 per cent inert ingredients. Application began at 7:30 a.m. and was completed at 10:00 a.m.

Distress resulting from rotenone, i.e. increased movement of fish including lunges from the water in an apparent effort to gulp air, were observed within 15 minutes after the start of application. Fifteen minutes later, a large number of bluegills were observed lying on their sides near death, at the surface of the water.

In order to determine effective penetration, fish were suspended in wire cages at depths as follows: five feet - two bluegills, one largemouth black bass, one white sucker; ten feet - five bluegills, one largemouth black bass, one white sucker; 19 feet - two bluegills, one white sucker. One of the bluegills in the cage at five feet was found dead one hour after the start of application and 15 minutes later the other had died. Two hours after the start of application, all fish in the cage at ten feet and one bluegill and one white sucker in the cage at 19 feet were found dead. These were the last fish to die in any of the cages. The sucker in the cage at five feet was lying on its back four hours after the start of

application but appeared normal 20 hours later. This fish remained alive for 20 days after treatment (time of the last observation).

Six hours after the start of application and on other occasions prior to the second treatment, small numbers of centrarchids were observed swimming among the vegetation. It appeared that the toxicant did not penetrate vegetative areas in sufficient concentrations to kill all fish.

One and one-half days (60 man-hours) were spent in recovering dead fish. Only those fish which came to the surface during that time and those in shallow water (less than three feet in depth) were recovered. Bluegills were the most abundant species found followed in order by yellow perch, black crappie and largemouth black bass (Table I). The numerical relationship of these fish in the above order was 53:32:2:1 and their weight relationship was 11:7:1:2. Numbers of carp, white suckers and northern brown bullheads are not included in the table since only a few individuals of these species were killed and consequently recovered.

Second Treatment. On September 17, 1957, this pond was treated with Pro-Noxfish at a concentration of approximately 0.95 ppm. This toxicant is known to contain 2.5 per cent rotenone, 2.5 per cent sulfoxide and other cube extractives. Bluegills, black crappies, largemouth black bass, white suckers and northern brown bullheads were killed by this treatment. No centrarchids were observed dying after the day of application and no suckers were observed to die after the second day but northern brown bullheads continued to die for three days following treatment.

Six days after treatment (September 23), five brown trout were

placed in cages and suspended in the pond. Five days later, these fish had died and the pond was considered still toxic to trout. On October 11, trout were again suspended in the pond. These were still living six days later and the pond was considered non-toxic to trout.

Observations and fishing effort, i.e. three 48-hour gill net sets, showed no living centrarchids but numerous live white suckers and northern brown bullheads were found.

Third Treatment. Since northern brown bullheads and white suckers survived the two previous treatments, the pond was treated with toxaphene. The concentration used was approximately 0.17 ppm. Three weeks following treatment, four 48-hour and two 72-hour gill net sets revealed no living fish. This pond was last tested on May 31, 1958 and found to be still toxic to trout (7.5 months). Hemphill (1953) reported that alkaline waters treated with toxaphene in Arizona were safely restocked with rainbow trout four weeks following treatment. Tanner and Hayes (1955) on the other hand reported that an alkaline lake treated with this chemical in Colorado remained toxic for at least seven months.

Physical and Chemical Characteristics

Before Treatment. During the summer and fall of 1956, the limit of visibility (secchi disc) averaged 6.2 feet and was lowest in the fall. During the spring and summer of 1957 it averaged 8.8 feet. Turbidity was not determined during 1956 but was generally less than 7.0 ppm SiO_2 in 1957. The turbidity immediately prior to treatment was 3.8 ppm.

During the summer of 1956, oxygen concentrations and phenolpthalein

alkalinity were higher and methyl orange alkalinity lower in surface water than at the 15-foot depth (Table VII). Stratification also occurred to a lesser extent during the winter. Oxygen saturation values during 1956 were usually less than 100 per cent. Methyl orange alkalinity averaged near 200 ppm and the pH range was 8.2-8.8. No phenolpthalein alkalinity was found during the spring of 1956 and the winter of 1956-7.

Inorganic nitrogen and phosphates were present in the following amounts: June 20, 1956 - nitrogen, 0.07 ppm and phosphate 0.20 ppm; November 7, 1956 - nitrogen, 0.21 and phosphate, 0.00; March 24, 1957 - nitrogen, 0.10 and phosphate, 0.06.

After Treatment. Following treatment with Chem-Fish Special, the limit of visibility increased markedly. The average after treatment was 14.3 feet as compared with 8.8 feet before. No change was observed following treatment with Pro-Noxfish. However, after treatment with toxaphene a secchi disc was visible at the bottom. The average turbidities, ppm SiO_2, were as follows: Chem-Fish Special - 1.75; Pro-Noxfish - 2.35; toxaphene - 0.85. No important change was observed in inorganic nitrogen or phosphates following treatment with Chem-Fish Special. Determinations on August 19, 1957 showed nitrates to be 0.08 ppm and phosphate 0.06 ppm.

Phytoplankton

Before Treatment. Chrysophyta was the predominant group of algae (Table VIII). Dinobryon was the most numerous representative being found during most of the open water period. It peaked in August and again in October, 1956. Diatoms were also present during most of the open water

Table VII. Range of physical and chemical properties of the Middle Pond before and after treatment.

	Depth (feet)	Before						After		
		Spring	Summer	Fall	Winter	Spring	Summer	Summer	Fall	Winter
Oxygen per cent saturation	0	58-131	62-97	86-107	47-78	84-127	99-125	103-112	89-126	100-105
	15	-	12-75	76-88	36-64	83-128	66-96	64-99	89-115	79-107
Phenolpthalein alkalinity (ppm)	0	0-6	7-15	0-16	0	8-12	16-24	0-23	25-30	21-32
	15	0	0-4	0-20	0	1-15	5-10	18-20	22-30	10-32
Methyl Orange alkalinity (ppm)	0	207-226	191-217	180-202	205-241	195-210	186-188	151-185	182-190	185-200
	15	-	160-235	192-200	205-245	195-215	196-200	176-193	182-195	185-205
pH	0	8.2-8.8	8.5-8.8	8.0-8.7	7.8-8.5	8.2-9.0	7.0-8.7	8.2-8.8	8.2-8.8	8.2-8.8
	15	-	-	-	7.3-8.0	7.2-8.6	8.1-8.6	8.2-8.7	8.2-8.8	8.3-8.9
Turbidity (ppm SiO_2)	0	-	-	-	-	1.9-12.0	1.9-2.5	1.3-2.2	1.4-2.6	0.5-1.0
	15	-	-	-	-	2.6-6.0	2.5-4.3	1.5-2.2	1.6-3.9	0.7-1.2
Secchi disc (feet)			5-9	5-6	-	5-10	8-11	10-18	10-16	18

	6/20/56	11/7/56	3/28/57	8/19/57
NO_3	0.07	0.21	0.10	0.08
PO_4	0.20	0.0	0.06	0.06

Table VIII. Number of phytoplankters per liter of water in the Middle Pond before and after treatment.

	Before												
	1956								1957				
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.
Chlorophyta													
Closterium				8	54	8		28					8
Closteriopsis					36								
Cosmarium				8	35	8							
Gloeocystis				4									
Pediastrum						8							
Scenedesmus				2									
Staurastrum					8	8						12	
Mougeotia	84	26			123	104							
Oedogonium					16	8							
Spirogyra		3	78										
Zygnema	97	1,944	10	69	390	329	39						
Unidentified	171	50	39		54		8						
Chrysophyta													
Chrysophyceae													
Dinobryon	45	47	151	419	3,494	216	33,425	1,618					8
Bacillariophyceae													
Coscinodiscaceae	52		28										
Cymbellaceae	230	35	58	138	182	208	42	8				341	
Fragilariaceae	4,521	542	132	56	264	292	121		52			5,083	87
Gomphonemataceae	33			104									
Naviculaceae	2,073	318	391	143	156	141	117					1,729	8
Surirellaceae						11	26						
Pyrrophyta													
Ceratium	5	38	2,691	3,119	355	364	33						
Peridinium				8	8	8				26			
Cyanophyta													
Cylindrospermum				52	43		26						
Nodularia		33	13										
Oscillatoria	5	32	8	35	35								

Table VIII (Continued).

	Before 1957			After 1958							
	May	June	July	Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	March	April
Chlorophyta											
Closterium				8							
Gloeocystis						8	69				
Staurastrum		8									
Mougeotia	8	48	35	17						16	156
Oedogonium		8	8	8	17						
Spirogyra		4	8								52
Zygnema		74	69		104						
Unidentified		4	35		4						
Chrysophyta											
Chrysophyceae											
Dinobryon	100	4	8	8	17						52
Bacillariophyceae											
Coscinodiscaceae				4							34
Cymbellaceae	26	78	476	251	524	31					16
Fragilariaceae	82	152	130	199	945	962	98	26		43	52
Naviculaceae	22	43	199	152	200	4					
Surirellaceae				8							
Pyrrophyta											
Ceratium	35	451	2,739	555	334	48					
Peridinium	43	30	35		17						16
Cyanophyta											
Nodularia		8	16	43							
Oscillatoria		4		34							

period and reached their greatest abundance in April, 1956 and March, 1957.

The next most abundant group was Pyrrophyta with Ceratium being predominant. It was present from April through November, 1956 and May through October, 1957. Chlorophyta, represented largely by filamentous algae, was most abundant in May, 1956. Cyanophyta was rarely encountered.

The abundance of phytoplankton varied considerably between the three sampling stations. Individuals were most abundant in the more protected area (Sta. C). Peaks of abundance occurred in the spring, summer and fall. Those occurring in the spring resulted from increased numbers of Fragilariaceae and Naviculaceae; in the summer from Dinobryon and Ceratium; in the fall from Ceratium. Phytoplankton was not encountered in samples taken during February, 1957.

After Treatment. Little qualitative change occurred in most phytoplankton following treatment with Chem-Fish Special. Ceratium was absent from the sample taken 14 days following treatment but was present in the sample obtained 29 days after treatment. Brown and Ball (1943), Smith (1939-40) and Hooper (1948) reported little effect on most groups of phytoplankton from the use of derris. In this study most groups exhibited reductions following treatment with Pro-Noxfish and toxaphene but these are not significant since similar reductions occurred during the same period of 1956.

Zooplankton

Before Treatment. Rotifers were predominant with Keratella the most abundant representative (Table IX). The latter was present in all

Table IX. Number of zooplankters per liter of water in the Middle Pond before and after treatment.

	Before												
	1956									1957			
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Cladocera													
Bosmina	13	21	14	4	16	2	7	7	17	12	4	6	32
Ceriodaphnia	T*	T	12	13	T		T						
Chydorus	6	3	T	3	8	10							
Daphnia			2	3	T	T	T						
Diaphanosoma			T	8	15	T							
Copepoda													
Cyclops	32	34	16	40	62	37	8	7	37	45	18	17	7
Diaptomus				T									
nauplii	37	50	55	72	98	38	40	71	41	16	3	3	74
Rotatoria													
Asplanchna	159	22	2	9	12	2		63	12	1			1
Filinia	18	10	T										
Keratella	583	788	2	10	16	13	15	194	65	80	73	29	54
Lecane	6	1	T	T	T	T							
Lepadella												T	T
Notholca	5	4	T			T	T			1			
Pedalia		1	3	3	11	1							
Pompholyx ?		T	30	3									
Polyarthra	31	24	29	11	57	68	77	73	3		2	6	34
Trichocerca			T	1	9	6	T						
Testudinella ?		T	2	T	13	4							
Protozoa													
Diffulgia	2	2	4	T	T	9	8	236	75	1		7	T
Ostracoda	T	T	T	T	5	4						T	

* Less than one per liter.

Table IX (Continued).

	Before			After							
	1957			1958							
	May	June	July	Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	March	April
Cladocera											
Bosmina	47	63	11	1	16						
Ceriodaphnia		T*	4	19	3						
Chydorus		1	5	T	T						
Daphnia			1	T							
Copepoda											
Cyclops	18	22	33	12	7	2				T	
nauplii	39	46	96	53	66	4					
Rotatoria											
Asplanchna	T		T	1	2				1	4	
Keratella	58	85	107	13	12					T	T
Lecane				4	T	T					
Lepadella	T	T									
Notholca					T				8		1
Polyarthra	54	84	114	58	98			1	20	29	34
Testudinella ?			T		70						
Protozoa											
Diffulgia	T	1	2	3	10	T					T
Ostracoda			3	T	T						

* Less than one per liter.

samples but was most numerous in April, May and November, 1956 and November, 1957. Asplanchna and Polyarthra were present in most samples. The former reached peak abundance in April, 1956 and the latter in October, 1956 and July, 1957. Notholca and Filinia were most abundant in the spring while Testudinella, Trichocerca and Pompholyx were most numerous in the summer. The latter two were present only in 1956.

Cyclops was the predominant copepod, being present in all samples. Largest numbers occurred in August, 1956 and January and July, 1957. Bosmina was the only cladoceran present in all samples and was most numerous in June, 1957. Ceriodaphnia and Chydorus were present in the spring and summer while Daphnia and Diaphanosoma were present only in the summer. In 1957, Diaphanosoma was absent and Daphnia was scarce.

Noticeable variations in abundance of zooplankton occurred between the three sampling stations. Cladocera and Rotatoria were most abundant at station A, while the number of Copepoda was about the same at all stations.

Two zooplankton pulses were observed in 1956. The larger occurred during the period April 14 to May 1 and resulted from increased numbers of Keratella and Asplanchna. The smaller occurred in November and resulted from large numbers of Keratella and Diffulgia. A pulse was also observed in July, 1957 which resulted from eruptions of Keratella and Polyarthra. Other organisms rarely encountered were: Rotatoria - Brachionus, Euchlanis, Lecane, Lepadella and Synchaeta; Copepoda - Diaptomus; Protozoa - Centropyxis.

After Treatment. Fourteen days following treatment with Chem-Fish

Special, Bosmina, Cyclops, Keratella and Polyarthra were much reduced. Twenty-nine days after treatment, Bosmina had returned to its former abundance and the other organisms showed an increase. Brown and Ball (1943), Smith (1939-40) and Hooper (1948) reported sharp reductions in Cladocera and Copepoda and with variable results in the Rotatoria following treatment with derris.

After treatment with Pro-Noxfish, Cladocera disappeared and was absent from all later collections. Copepoda, Protozoa and Rotatoria were greatly reduced. Of the latter group, Asplanchna, Keratella, Polyarthra and Testudinella were absent in samples prior to treatment with toxaphene. Eighteen days after treatment with toxaphene no zooplankton was found in samples. The first sign of recovery by organisms was observed 85 days (January 10, 1958) following treatment when a single individual of Polyarthra was found. Keratella and Cyclops first reappeared in collections 158 days (March 24) following treatment and Diffulgia, 175 days (April 11).

Bottom Organisms

Before Treatment. Tendipedidae and Tubificidae were the most abundant organisms (Table V). Tendipedidae fluctuated slightly prior to treatment with Chem-Fish Special but was most numerous in July, 1956 and least numerous in May, 1957. Tubificidae increased slightly from June 21 to September 9, 1956. It was most abundant in September, 1956 and least abundant in May, 1957. Chaoborus was rarely found in collections.

After Treatment. The number of Tendipedidae and Tubificidae showed a decrease six days after treatment with Chem-Fish Special. About twice as

many individuals of these families were present 37 days after treatment as immediately prior to it.

No information on the effects of Pro-Noxfish on bottom organisms was secured since no collections were taken following treatment. Collections taken 29 days following treatment with toxaphene show an 80 per cent reduction in Tendipedidae and after 162 days (March 28, 1958), there was an additional 15 per cent reduction. Although Tendipedidae suffered large reductions after treatment with toxaphene, Tubificidae were approximately twice as abundant.

Plant Inhabiting Organisms

Before Treatment. Gastropoda was the predominant group of organisms with Physa as its most abundant representative followed by Gyraulus and Lymnaea (Table X). Abundance of all three organisms was greatest in August, 1956. Physa and Lymnaea were least abundant in May and Gyraulus in July, 1957. Ischnura (Odonata) was most numerous in August, 1956 and least numerous in July, 1957. Tricorythodes (Ephemeroptera) was usually scarce, except during May, 1957. Other organisms rarely encountered included: Oligochaeta - Naididae; Diptera - Tendipedidae; Odonata - Erythemis and Gomphidae; Trichoptera - Agraylea and Phryganea.

After Treatment. The abundance of plant inhabiting organisms observed after treatment as compared to before treatment was as follows: Tricorythodes was less numerous; Ischnura showed little change in abundance; Gyraulus and Lymnaea were approximately 10 times more numerous; Physa was about twice as abundant. While Hyallela and Tendipedidae were

Table X. Number and volume (cc) of plant inhabiting organisms per kilogram of submerged vegetation in the Middle Pond before and after treatment.

	Before											
	7/7/56		8/1/56		8/30/56		9/26/56		10/27/56		5/20/57	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Amphipoda												
Hyallela	124	T	10	T	105	T	143	T			9	**
Coleoptera												
Haliplus					10	T	5	T	5	T		
Diptera												
Tendipedidae	426	T	136	T	130	T	14	T				
Ephemeroptera												
Tricorythodes	71	0.24	21	T	45	T	38	T			431	**
Gastropoda												
Gyraulus	43	T	215	0.52	600	0.50	488	0.33	21	T	78	**
Lymnaea			613	1.83	165	T	119	T	94	T	27	**
Physa	143	0.48	120	4.19	365	3.00	349	1.43	37	T	41	**
Odonata												
Erythemis							5	T				
Gomphidae			5	T								
Ischnura	43	0.71	89	T	650	0.50	315	0.48	73	T	165	**
Trichoptera												
Agraylea					15	T						
Phryganea			16	T	10	T	43	0.48				
Oligochaetes												
Naididae	71	T			930	T						

** Organisms partially decomposed, volumes not determined.

Table X (Continued).

	Before		After							
	7/13/57		7/24/57		8/23/57		12/9/57		3/28/57	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Amphipoda										
Hyallela			26	T						
Diptera										
Tendipedidae			65	T						
Ephemeroptera										
Tricorythodes	53	T	7	T						
Gastropoda										
Gyraulus	53	T	543	T	411	0.41	127	T	118	0.51
Lymnaea	95	T	925	0.65	62	0.40	196	T		
Physa	374	T	628	1.29	946	2.49	127	2.31	133	4.60
Odonata										
Erythemis					4	T				
Ischnura	30	T	32	T	46	T				

not present in collections obtained four days prior to treatment, they were present in those taken seven days after. Gomphidae, Agraylea, Phryganea and Naididae were absent seven days after treatment but this is not significant since they were not present in collections immediately prior to treatment.

No collections were taken following treatment with Pro-Noxfish and before treatment with toxaphene.

After treatment with toxaphene, the Gastropoda was the only group present in collections. Fifty-three days following treatment, Gyraulus was reduced about 75 per cent and Physa about 90 per cent but Lymnaea increased approximately 30 per cent. Numbers of Gyraulus and Physa remained about equal and Lymnaea was absent in collections taken 162 days following treatment. Ischnura and Erythemis, while present before treatment with Pro-Noxfish, were absent following treatment with toxaphene.

West Pond

Description.

The West Pond has been periodically dredged for gravel since 1936. The last substantial dredging was in 1955. The pond now has a surface area of 12.8 acres, a volume of approximately 132 acre-feet, a maximum depth of 19 feet and mean depth of ten feet. The shore level is generally less than one foot above the water surface but rises to a maximum height of ten feet on the south end. The pond bottom is quite regular in spite of dredging operations and is covered almost entirely with fibrous peat. The surface water fluctuated 13.6 inches in 1956 and 18 inches in 1957.

The predominant shore vegetation on the east side is cottonwood and Kentucky bluegrass and on the west side sweet clover (Melilotus alba) and Russian thistle (Salsola kali). Emergent aquatic vegetation is found only around the east shore and consists of great bullrush and cattail. Submerged aquatic vegetation consists largely of stonewort with small amounts of sago pondweed.

No records of fish introductions are available and it is presumed that the existing fish population resulted from unofficial transplants from the Middle and East Ponds. The species of fish present were bluegill, largemouth black bass and yellow perch.

Fish Eradication

On July 18, 1957, the West Pond was treated with a commercial toxicant (Pro-Noxfish). The concentration used was approximately 0.7 ppm. Application began at 7:15 a.m. and terminated at 9:45 a.m.

Distress resulting from rotenone was first observed ten minutes after the start of application. Ten minutes later fish were found near death lying on their sides at the surface.

Effective depth penetration of the toxicant was determined by suspending wire cages containing healthy fish at various depths in the pond. Fish were suspended as follows: five-foot depth, two bluegills and one white sucker; 10-foot depth, one bluegill, one largemouth black bass, one white sucker; 19-foot depth, one white sucker. Two bluegills in the cage at the five-foot depth were dead 13 hours (8:00 p.m.) after the start of application. All fish in cages at greater depths appeared healthy at that

time. No more observations were made until 23 hours after treatment began (6:15 a.m. the following morning), at which time, all fish, except the sucker at the 10-foot depth, were dead. This sucker was near death but did not die until 1:00 p.m. the same date.

The length of time the water remained toxic to trout was determined in the same manner as for the East Pond. Tests made 17 days following treatment showed the water to be non-toxic. At that time, observations and fishing effort, i.e. six 24-hour and three 48-hour gill net sets, failed to show any live fish.

One and one-half days (23 man-hours) were spent in recovering dead fish. An attempt was made to recover all fish which came to the surface and those lying on the bottom of the pond in shallow water (depth less than three feet). Those which remained on the bottom in deep water and those which surfaced later were not recovered. Weights and length measurements were made.

Yellow perch was the most abundant species present (Table I). Largemouth black bass was second in total weight but least numerous while bluegill weighed the least but was second most numerous. The ratio of yellow perch to bluegills to largemouth black bass was approximately 8:2:1 and the weight relationship was 4:1:6. The average total length of yellow perch was greater than the same species from either of the other ponds. This probably resulted from the smaller population in the West Pond.

Physical and Chemical Characteristics

During the entire study period, a secchi disc was visible on the

bottom and turbidities were generally less than five ppm SiO_2 (Table XI).

Only slight chemical variations occurred between surface water and that at the 15-foot depth during periods of open water. Oxygen saturation usually exceeded 100 per cent during the spring and early summer but was lower in late summer and fall. Methyl orange alkalinity was usually above 200 ppm, except during the summer, and the pH ranged from 7.5 to 8.5.

During the winter of 1956 some chemical stratification occurred in the West Pond. Water at a depth of 15 feet contained a lower concentration of oxygen, lower pH and higher methyl orange alkalinity than water immediately below the ice. During the winter of 1957, stratification was less pronounced with slightly lower pH and higher methyl orange alkalinity at the 15-foot depth. The less pronounced stratification in 1957 may have been due to greater transparency of the ice which permitted more primary production.

Following treatment, no change in physical or chamical properties was observed.

Phytoplankton

Before Treatment. Chrysophyta was the most dominant group of algae followed in order by Pyrrophyta, Chlorophyta and Cyanophyta (Table XII). Of the first named group, Dinobryon was most numerous. It peaked during August, 1956 and again in October, 1957. Diatoms were scarce during most of the period but were numerous from April through June, 1956 and in March, 1957. Of the Pyrrophyta, Peridinum was present in the majority of samples.

Table XI. Ranges of physical and chemical properties of the West Pond before and after treatment.

		Before						After		
	Depth (feet)	Spring	Summer	Fall	Winter	Spring	Summer	Summer	Winter	Spring
Oxygen per cent saturation	0	66-160	62-89	60-101	63-83	95-150	117-132	90-112	87-118	100-121
	15	-	55-82	44-101	12-64	95-139	98-130	80-95	87-117	89-130
Phenolpthalein alkalinity (ppm)	0	0	0-5	0	0	0-10	0	0	0	0
	15	0	0-6	0	0	0-12	0	0	0	0
Methyl Orange alkalinity (ppm)	0	172-220	147-205	212-232	235-282	182-205	107-160	161-191	194-215	160-247
	15	180-220	142-205	202-240	250-330	182-242	125-172	165-181	194-220	230-280
pH	0	-	8.0-8.5	7.5-8.5	7.6-8.3	8.0-8.2	7.8-8.3	7.5-7.9	7.5-8.1	7.3-8.5
	15	-	-	-	7.0-7.4	8.0-8.2	7.6-8.1	7.5-8.0	7.8-8.1	7.2-8.2
Turbidity (ppm SiO_2)	0	-	-	-	-	2.4-5.0	1.4-2.5	1.3	1.0-1.3	0.5-1.0
	15	-	-	-	-	1.2-12.0	1.0-1.3	0.9-1.4	1.1-1.4	0.5-1.0
Secchi disc (feet)		19	19	19	-	19	19	19	19	19
			6/20/56	11/7/56	3/24/57			8/19/57		
NO_3			0.20	0.17	0.07			0.02		
PO_4			0.05	1.00	0.03			0.02		

Table XII. Number of phytoplankters per liter of water in the West Pond before and after treatment.

	Before											
	1956							1957				
	April	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Chlorophyta												
Closteriopsis		3	9	11								
Closterium					10							
Cosmarium					2							
Gloeocystis				2	4	78						
Pleurotaenium				2								
Scenedesmus			2									
Mougeotia	794	316	61								251	8
Oedogonium			2									
Spirogyra	1,129	598	416	50	45							17
Zygnema	1,389	26		9	9		26					17
Unidentified				6								
Chrysophyta												
Chrysophyceae												
Dinobryon	140	2,365	614	7,568	126	474	459				710	69
Bacillariophyceae												
Coscinodiscaceae	17	52										
Cymbellaceae	453	32	48	2	95	8	4					12
Fragilariaceae	3,476	786	6	10	8	48	9				252	52
Gomphonemataceae					8							
Naviculaceae	211	86	106		87	87		26			217	104
Pyrrophyta												
Ceratium		314	396	277	37							
Peridinium	4	47	61		43	22	26	182	156	26	6	26
Cyanophyta												
Cylindrospermum			2		8							
Nodularia			2									
Oscillatoria		6										

Table XII (Continued).

	Before			After							
	1957			1958							
	May	June	July	Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	March	April
Chlorophyta											
Closteriopsis			8								
Gloeocystis	69	8			56	243	147				
Mougeotia	43	4	199	22							367
Oedogonium			8		34						8
Spirogyra	35		17	8	568	4				52	126
Zygnema		4									
Unidentified			8								17
Chrysophyta											
Chrysophyceae											
Dinobryon	867	1,053	2,669	282	2,920	6,305	52				8
Bacillariophyceae											
Cymbellaceae		17	17	13		82				8	
Fragilariaceae		4	8		8	84				156	94
Gomphonemataceae						8				17	
Naviculaceae	139	13	104	13	13	52				30	17
Pyrrophyta											
Ceratium	8		61	65	17	4					
Peridinium	234	156	52	82					52		
Cyanophyta											
Oscillatoria		8		26							

It was most numerous in December, 1956 and January, May and June, 1957. Ceratium was present from June through September, 1956, with peaks in June, July and August. It was also present from May through October, 1957. Chlorophyta was usually scarce, except from April through July, 1956, when large amounts of filamentous algae were present. Representatives of the Cyanophyta were rare.

There was considerable variation in abundance of phytoplankton between the three sampling stations. Station C, located in the most protected area (also known to contain springs) had the greatest number of individuals. Phytoplankton blooms, resulting primarily from Dinobryon, occurred in August, 1956 and in October, 1957.

After Treatment. Treatment with Pro-Noxfish appeared to have little effect on most groups of phytoplankton. Dinobryon decreased following treatment (August 1, 1957) and was absent from samples taken August 15. By September 7, it had reached its former abundance. Brown and Bali (1943) report that Dinobryon increased following rotenone treatment in Third Sister Lake, Michigan.

Zooplankton.

Before Treatment. The predominant group of zooplankton present was Rotatoria (Table XIII). Keratella was the predominant genus in most samples and became abundant in November, 1956 and June, 1957. Polyarthra was present in nearly all samples but was never abundant. Asplanchna and Pedalia were most numerous in summer.

Copepoda and Cladocera were about equally abundant and were repre-

Table XIII. Number of zooplankters per liter of water in the West Pond before and after treatment.

	Before											
	1956						1957					
	April	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
Cladocera												
Bosmina			13	27	3	8	T	9	2	11	14	19
Ceriodaphnia		T*	7	15	21	5						
Chydorus	26	6	6	T	32	3	1		1	1	T	T
Daphnia	1	3	T									
Scapholebris		20	4	3								
Copepoda												
Cyclops	4	5	18	4	17	19	7	26	57	26	13	33
Diaptomus	T	1	5	4	4	2	T	3				
nauplii	19	48	70	57	36	25	14	15	6		42	55
Rotatoria												
Asplanchna		2	3	23	3	2						1
Keratella	6	96	25	2	3	24	332	122	112	49	18	26
Lecane	1			T			T					
Lepadella				T								
Notholca	7	T				T					T	T
Pedalia		T	20	6	T							
Platyias		T	T	T	T							
Polyarthra	T	6	19	6	11	9	1					
Protozoa												
Diffulgia	4	1	T	T	1							1
Ostracoda	1	T	2	T	2	T						

* Less than one organism per liter.

Table XIII (Continued).

	Before			After							
	1957			1958							
	May	June	July	Aug.	Sept.	Oct.	Nov.	Jan.	Feb.	March	April
Cladocera											
Bosmina	15	12	21								
Ceriodaphnia		T	2	1	11	T					
Chydorus		2	2	2	6	7	T	1	2		
Daphnia					2	2		1	2	T	T
Scapholebris			2	T	3						
Copepoda											
Cyclops	35	19	14	3	5	4	1	32	17	T	T
nauplii	74	37	21	15	22	15	6	6	26	1	T
Rotatoria											
Asplanchna			T	3	8	T	T			T	T
Brachionus		T		T							
Keratella	125	134	41	32	11	4	2	10			
Lecane				T	T						
Notholca	T	T				T		T			
Polyarthra	2	3	26	72	15	2	10		2		
Protozoa											
Diffulgia	T	2	T	3	T	T					
Ostracoda		1	T	T							

sented in all samples. Cyclops was the predominant copepod and reached its peak in January and May, 1957. A small number of Diaptomus was present from April through December, 1956.

Bosmina was the most abundant cladoceran being present in all samples prior to treatment while Chydorus was slightly less abundant. Ceriodaphnia and Scapholebris appeared in summer and early fall. The former was most numerous in September and the latter in June, 1956.

Protozoa and Ostracoda were present from April through October, 1956 but were never abundant. Other organisms occasionally encountered were: Rotatoria - Brachionus, Monostyla, Notholca, Pompholyx, Platyias, and Lepadella; Protozoa - Centropyxis.

A noticeable difference in abundance occurred at the three stations during the study. Station A, located in a deep water area, had the greatest number of individuals except in November, 1956, when station C had a greater number of Keratella. Scapholebris was found only at stations B and C. Daphnia was most abundant at station A and was rarely found at stations B and C and Chydorus, while present at all stations, was most numerous at station C.

Zooplankton in this pond exhibited less variation in abundance than in the other ponds. The only pulses observed occurred in November, 1956 and June, 1957 resulting from increased numbers of Keratella.

After Treatment. Treatment with Pro-Noxfish had little apparent effect on most groups of zooplankton. Bosmina was the only organism which exhibited adverse effects. It was present in collections taken on July 13 (five days prior to treatment) but was absent from all later samples. The

absence of Diaptomus, Brachionus, Monostyla, Notholca, Pompholyx, Platyias, Lepadella and Centropyxis after treatment is not considered significant since they were not present immediately prior to treatment. Brown and Ball (1943), Smith (1939, 1940), and Hooper (1948) reported sharp reductions in Cladocera and Copepoda. The five per cent concentration of rotenone in derris used in the above studies was twice that found in Pro-Noxfish and this may account for the higher mortality of microcrustaceans.

Bottom Organisms

Before Treatment. Tendipedidae and Tubificidae were the predominant organisms. The number of Tendipedidae fluctuated little but their volume was greatest in August, 1956 (Table V). Tubificidae increased over the period June to September, 1956. In 1957, they were absent in May but reached maximum abundance in the July collection. Procambarus (Decapoda) and Agraylea (Trichoptera) were encountered rarely.

After Treatment. Seven days following treatment (July 23, 1957), a large reduction in Tendipedidae and Tubificidae was observed. Thirty-two days following treatment (August 19), and in most later collections, Tendipedidae were approximately twice as abundant as in previous collections and Tubificidae were more numerous than in previous collections, except for July 12, 1957. Tubificidae were absent from the May, 1957 and March, 1958 collections. Brown and Ball (1943), Smith (1939 and 1940) and Hooper (1948) report little effect on most bottom organisms by rotenone. Hespercorixa (Hemiptera) was found in collections taken August 19, 1957 and Chaoborus, Baetis, Ephemera, Tricorythodes and Ishnura in collections

taken March 28, 1958. These were not found prior to treatment.

Plant Inhabiting Organisms

Before Treatment. Hyallela was the predominant organism followed in order by Tricorythodes, Tendipedidae, Ischnura, Hydroporus and Procambarus (Table XIV). These organisms were present in nearly all samples and exhibited peaks of abundance as follows: Hyallela and Tricorythodes in August and September, 1956; Ischnura in September, 1956; Tendipedidae in May, 1957. Hydroporus and Procambarus were numerous in all months. Procambarus was the least numerous, but its volume usually exceeded the others. Lymnaea, Physa, Agraylea, Polycentropis and Haliplus were scarce.

After Treatment. The different kinds of organisms exhibited varied effects from the treatment with Pro-Noxfish. Procambarus, Tricorythodes and Ischnura appeared to be uneffected, being approximately as abundant after treatment as before. Ischnura increased after July and reached maximum abundance in March, 1958. Tricorythodes was most numerous in August, 1957 and then decreased sharply, being least numerous in December. This decrease is not thought to have been the result of the toxicant, since toxicity tests revealed the water to be non-toxic to trout by August 5. Physa, while scarce prior to treatment, appeared in all after treatment collections, except on August 27. Leonard (1938) reported no signs of distress by several kinds of insects, snails and crustaceans which were exposed to a rotenone concentration of one ppm for 96 hours.

Hyallela and Tendipedidae were the only organisms that exhibited a noticeable reduction. The former was much less numerous in the collection

Table XIV. Number and volume (cc) of plant inhabiting organisms per kilogram of submerged vegetation in the West Pond before and after treatment.

	Before									
	7/5/56		7/30/56		8/27/56		9/24/56		10/27/56	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Amphipoda										
Hyallela	1,182	0.71	710	0.47	1,332	1.69	1,595	1.60	220	0.16
Coleoptera										
Haliplus	3	T*	10	T	13	T	9	T		
Hydroporus	11	T	10	T	13	T	4	T	14	T
Decapoda										
Procambarus	53	11.35	7	1.67	4	2.11	9	7.79	14	T
Diptera										
Tendipedidae	74	T	223	0.33	220	0.42	78	T	179	3.43
Ephemeroptera										
Baetis			3	T	4	T	14	T	7	T
Tricorythodes	21	T	37	T	2,166	0.42	2,012	0.92	571	T
Gastropoda										
Lymnaea	3	T								
Physa	96	1.41	3	T			4	T		
Odonata										
Ischnura	21	T	27	T	220	1.26	389	0.32	96	1.37
Trichoptera										
Agraylea	11	T	23	T	63	T	110	T		
Polycentropis			7	T	76	T	119	1.38	37	T

* Less than 0.05 cc.

Table XIV (Continued).

	Before				After							
	5/20/57		7/13/57		7/24/57		8/27/57		12/9/57		3/28/57	
	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.
Amphipoda												
Hyallela	281	**	185	0.30	77	0.13	188	0.92	376	0.85	737	1.65
Coleoptera												
Hydroporus			13	T			18	T	13	T	66	0.55
Decapoda												
Procambarus			4	0.43	5	0.51	9	9.16	10	T	22	20.62
Diptera												
Tendipedidae	571	**	418	0.22					30	T	302	0.55
Ephemeroptera												
Baetis	7	**							142	0.68	49	0.55
Tricorythodes	632	**	39	T	31	T	229	T	29	T	55	T
Gastropoda												
Gyraulus					5	T					5	T
Lymnaea			4	T							16	T
Physa					10	T			3	T	5	1.01
Hemiptera												
Notonecta									2	0.68		
Vermicorixa									3	T		
Odonata												
Ischnura	96	**	39	T	25	T	169	0.34	254	1.01	412	9.90
Trichoptera												
Agraylea									7	T		

** Organisms partially decomposed, no volumes determined.

obtained six days after treatment than before. Forty days after, it had recovered to its former abundance and in March, 1958 reached maximum abundance. While Tendipedidae was present in samples immediately prior to treatment, it was not found following treatment until December, 1957. Hydroporus was absent from the sample taken immediately after treatment but appeared in its former abundance after 40 days. It occurred in such small numbers prior to treatment that its absence may have been the result of sampling error. Absence of Agraylea, Polycentropis, Haliplus and Baetis is insignificant since these organisms were not present immediately prior to treatment. With the exception of Polycentropis, all were present in collections taken in December, 1957. Notonecta and Hesperocorixa were not found prior to treatment and were in only one collection following (December 9, 1957).

SUMMARY

1. The effects of the commercial toxicants, Pro-Noxfish, Chem-Fish Special and toxaphene on the physical, chemical and biological properties of three cold water ponds were studied during the period April 14, 1956 to April 11, 1958.

2. The East Pond was treated with toxaphene at a concentration of 0.13 ppm. The Middle Pond was treated with the following toxicants and concentrations: Chem-Fish Special - 0.7 ppm; Pro-Noxfish - 0.95 ppm; toxaphene - 0.15 ppm. The West Pond was treated with Pro-Noxfish at a concentration of 0.7 ppm.

3. Live fish were suspended at various depths in the ponds to test

the toxicity of the water. The first fish died in the East Pond five hours after the start of application of toxaphene and the last fish died 14-24 hours after. After application of Chem-Fish Special, the first fish died in one hour and the last fish to die did so within the next hour. In the West Pond the first fish died 13 hours after start of application of Pro-Noxfish and the last 30 hours after.

4. Duration of toxicity to fish was as follows: East Pond, less than five months; West Pond, less than two weeks. Not all fish died in the Middle Pond from treatment with Chem-Fish Special and Pro-Noxfish. After application of toxaphene, the pond has remained toxic up to the present time (June 4, 1958).

5. The numerical ratio for yellow perch, bluegills, largemouth black bass, black crappie, carp, suckers recovered from the East Pond was 135: 119:17:14:13:1. The ratio of bluegills, yellow perch, black crappie, largemouth black bass from the Middle Pond was 53:32:2:1. The ratio of yellow perch, bluegills, largemouth black bass was 13:8:1.

6. Following treatment, a secchi disc was visible on the bottom of each pond.

7. The predominant algae in all ponds were Dinobryon and Ceratium, each of which were reduced following treatment in the East Pond. Ceratium was reduced following treatment with Chem-Fish Special in the Middle Pond and Dinobryon in the West Pond.

8. Keratella, Polyarthra, Bosmina, Chydorus and Cyclops were the dominant zooplankters present in all ponds. All Cladocera and Copepoda were absent following treatment in the East Pond. In the Middle Pond,

Keratella, Polyarthra and Cyclops were greatly reduced after treatment with Chem-Fish Special. Copepods and rotifers were reduced following treatment with Pro-Noxfish and Cladocera disappeared. All zooplankton organisms disappeared after treatment with toxaphene. In the West Pond, only Bosmina was reduced following treatment.

9. In the East Pond, Tendipedidae showed no effect following treatment and Tubificidae increased. Tendipedidae was reduced and Tubificidae increased after treatment in the Middle Pond. Tubificidae and Tendipedidae increased following treatment in the West Pond.

10. All plant inhabiting organisms, except the Gastropoda, disappeared following treatment in the East Pond and Middle Pond. In the West Pond, Hyallela and Tendipedidae were reduced after treatment while other organisms appeared uneffected.

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