



Effects of toxaphene upon plankton and aquatic invertebrates in North Dakota lakes
by Robert G Needham

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

© Copyright by Robert G Needham (1962)

Abstract:

The effects of low toxaphene concentrations on plankton and larger invertebrates were studied in five North Dakota lakes. *Brachionus*, *Keratella*, *Trichocerca*, *Asplanthna*, *Polvarthra*, *Conochiloides*, *Daphnia*, *Ceriodaphnia*, *Bosmina*, and *Cyclops*, were the dominant zooplankters. None of these exhibited marked reductions after treatment at 5 to 35 ppb.

Most phytoplankter populations showed no obvious changes after treatment, except *Aphanizomenon* which increased in all lakes. The post-treatment increase in South Lake Metigoshe was especially noticeable, since it did not increase in North Lake Metigoshe, which was untreated. Several of the plant inhabiting and bottom fauna decreased slightly post-treatment, but this did not appear to be the result of toxaphene treatment. Tolerance levels for several zooplankters and other aquatic invertebrates were observed in controlled experiments. Rotifera was the most tolerant group, followed in order by Cladocera and Copepoda. Among the larger invertebrates tested, Hirudinea, Hydracarina, and Gastropoda, were the most tolerant, followed in decreasing order by Trichoptera, Odonata, Hemiptera, Ephemeroptera, Amphipoda, and Coleoptera.

EFFECTS OF TOXAPHENE UPON PLANKTON
AND AQUATIC INVERTEBRATES IN NORTH DAKOTA LAKES

by

Robert G. Needham

A THESIS

Submitted to the Graduate Faculty

in

partial fulfillment of the requirements

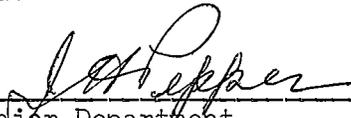
for the degree of

Master of Science in Fish and Wildlife Management

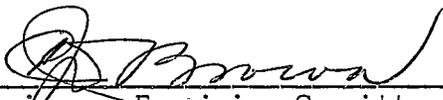
at

Montana State College

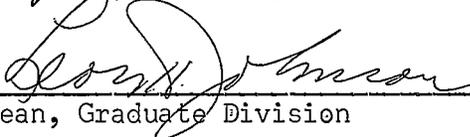
Approved:



Head, Major Department



Chairman, Examining Committee



Dean, Graduate Division

Bozeman, Montana
March, 1962

TABLE OF CONTENTS

	Page
Abstract	4
Introduction	5
Methods	6
Wolf Butte Reservoir	8
Fish	9
Plankton	9
Plant Inhabiting Organisms	12
Bottom Fauna	13
Raleigh Reservoir	15
Fish	15
Plankton	16
Plant Inhabiting Organisms	20
Bottom Fauna	21
South Lake Metigoshe	21
Fish	23
Plankton	24
Plant Inhabiting Organisms	27
Bottom Fauna	28
Odland Reservoir	28
Fish	30
Plankton	30
Plant Inhabiting Organisms	32
Bottom Fauna	32
Experiments	34
Results	36
Discussion	38
Summary	39
Literature Cited	41

ABSTRACT

The effects of low toxaphene concentrations on plankton and larger invertebrates were studied in five North Dakota lakes. Brachionus, Keratella, Trichocerca, Asplandhna, Polyarthra, Conochiloides, Daphnia, Ceriodaphnia, Bosmina, and Cyclops, were the dominant zooplankters. None of these exhibited marked reductions after treatment at 5 to 35 ppb. Most phytoplankter populations showed no obvious changes after treatment, except Aphanizomenon which increased in all lakes. The post-treatment increase in South Lake Metigoshe was especially noticeable, since it did not increase in North Lake Metigoshe, which was untreated. Several of the plant inhabiting and bottom fauna decreased slightly post-treatment, but this did not appear to be the result of toxaphene treatment. Tolerance levels for several zooplankters and other aquatic invertebrates were observed in controlled experiments. Rotifera was the most tolerant group, followed in order by Cladocera and Copepoda. Among the larger invertebrates tested, Hirudinea, Hydracarina, and Gastropoda, were the most tolerant, followed in decreasing order by Trichoptera, Odonata, Hemiptera, Ephemeroptera, Amphipoda, and Coleoptera.

INTRODUCTION

The use of toxicants in fisheries management has provided considerable information concerning the effects of various poisons on fish. Much less is known of the effects on the fish-food organisms. Several workers have reported the effects of toxaphene on fish-food organisms: included are Hooper and Grzenda, 1955, in Michigan; Hoffman and Olive, 1961; and Cushing and Olive, 1957, in Colorado; Stringer and McMynn, 1958, in British Columbia.

The objective of the present study was to determine the effects of low toxaphene concentrations on the plankton and certain other aquatic organisms under natural and controlled conditions. This was made possible by the rough-fish removal program in North Dakota, during which various concentrations of toxaphene were used.

The investigation included five lakes. Two were natural lakes located in the north central part of the state and three were impoundments located in the southwest. The period of study extended from June through September of both 1960-61.

Acknowledgments

The writer extends sincere appreciation to Dr. C. J. D. Brown for directing the study and for help in preparing the manuscript. Dale L. Henegar, Chief of Fisheries, North Dakota State Game and Fish Department suggested the problem and gave helpful advice. Thanks are also due: Dr. John C. Wright and Dr. G. W. Prescott for assistance in identification of plankton; Dr. George F. Edmunds, Jr. for assistance in identification of

aquatic insects; Donald C. Warnick for help with field work; my wife Avis, for aid in the analysis of samples. Chemical analyses were made by the State Laboratories. The fish studies were by North Dakota Fish and Game Department who also provided financial aid under Dingell-Johnson Projects F-2-R-7,9. The National Wildlife Federation granted a fellowship for the last year of the study.

METHODS

Surface water temperatures were obtained with a pocket thermometer and depth temperatures with a reversing thermometer. Secchi disk readings were taken at all stations in conjunction with each collection series.

The toxaphene used was an emulsified concentrate marketed under the trade name Cooper-Tox. It contained six pounds of technical toxaphene per gallon. Prior to application the toxaphene was diluted 10-15 times with water to facilitate uniform distribution. It was applied to the water surface by spraying from a boat.

Water samples were collected before and after toxaphene treatment in 1960, and once in 1961. A summary of the physical and chemical data is presented in Table 1.

Plankton samples were secured with a pump at 1.5 and 7.5 feet respectively at all stations. All samples were taken while the boat was moving in order to avoid resampling the same water. Each sample contained 40 gallons of water and two samples constituted a collection. Each sample was concentrated to 200 cc with a No. 20 silk plankton net. Plankton counts consisted of total enumeration of all organisms in one cc,

Table 1. A summary of physical and chemical data before and after toxaphene treatment for two lakes and three reservoirs in North Dakota. (All chemical data except pH are expressed as parts per million; bottom temperatures were taken at depths of 9-12 feet).

Lake and date treated	Sampling dates	Temperature (°F)		Secchi disk (feet)	Total solids	Total hardness	pH	Total alkalinity	Chlorides	Sulfates	Iron
		Surface	Bottom								
Wolf	8/5/60	71.4	68.2	4.9	904	114	9.4	408	none	280	1.5
Butte	8/16/60	68.6	68.2	4.2	1,025	114	9.1	463	none	348	1.1
Reservoir	9/7/60	64.0	63.7	7.9							
	8/8/60	71.0	70.0	4.3	678	84	9.2	336	trace	164	1.0
	8/4/60	72.1	70.5	3.2	266	184	8.4	153	none	86	1.0
Raleigh	8/15/60	71.7	68.8	4.7	336	196	8.7	143	none	96	0.5
Reservoir	9/6/60	68.0	67.6	8.7							
	8/4/60	71.0	68.2	11.0	380	180	9.8	200	28	143	0.5
	7/14/60	71.8	68.5	7.9	270	228	8.8	224	none	27	0.2
South	7/21/60	72.0	68.4	8.4	279	222	8.5	214	none	53	0.3
Metigoshe	8/26/60	64.6	62.3	8.3							
	7/17/60	60.2	59.1	6.4							
	7/19/61	68.5	66.8	10.0	299	208	9.4	216	28	44	0.8
	7/14/60	71.8	66.8	8.5	281	232	8.6	224	none	33	0.9
North	7/21/60	72.3	68.0	8.8	282	226	8.2	214	none	53	0.2
Metigoshe	8/26/60	64.9	61.9	6.4							
	8/10/60	69.1	66.1	2.2	414	184	8.2	187	none	165	0.2
Odland	8/16/60	68.0	65.8	1.8	510	202	8.2	195	none	186	0.8
Reservoir	9/8/60	65.0	64.1	3.1							
	8/11/60	71.2	68.8	2.1	574	208	8.5	196	trace	259	0.5

with the exception of a few abundant phytoplankters, which were counted by the differential method, employing 20-80 fields within a one cc sample.

Plant inhabiting organisms were collected with a metal device designed by the writer. This had an opening of one square foot and a height of 30 inches. Openings (4 x 6 inches) were cut on two sides to allow for drainage. These were covered by screen having 30 meshes per inch. A sliding plate was installed at the bottom to sever the plants near their roots. Samples were limited to water depths of two feet or less, since this device had to be operated manually. Approximately 4.5 pounds (drained weight, 2-3 minutes) of plants were taken per sample in 1960. In 1961 this was reduced to approximately 12 ounces, since analyses showed this to be adequate. The number of square feet of bottom covered in each sample varied from eight to 16 in 1960, and three to five in 1961.

Bottom organisms were taken with an Ekman dredge at depths ranging from 4-10 feet. Either three or four square feet were sampled at each station. Organisms from both plant and bottom samples were concentrated with a screen having 30 meshes per inch.

Plant inhabiting organisms and bottom fauna were sampled at the same stations, which were approximately 50 feet in diameter. These stations had both abundant vegetation and open water.

WOLF BUTTE RESERVOIR

Description

Wolf Butte Reservoir, located in southwestern North Dakota, has a

surface area of 24 acres and a maximum depth of 9 feet. No permanent inlets or outlets are present and water is supplied mainly by runoff. The bottom is muck. No marked thermal stratification was present. The area surrounding the reservoir is primarily rangeland. Aquatic vegetation was very abundant at all depths less than 4 feet. Potamogeton pectinatus, P. richardsoni, and Myriophyllum exalbescens, were the dominant plants. A heavy mat of filamentous algae (Rhizoclonium) accompanied these plants at the water surface.

Treatment

Fish: Toxaphene was applied at 35 ppb on August 8, 1960, in an attempt to eradicate the entire fish population. This impoundment was heavily populated with green sunfish (Lepomis cyanellus), black bullheads (Ictalurus melas), and a few large rainbow trout (Salmo gairdneri). A large number of green sunfish and black bullheads was found dead and dying after treatment. The reservoir was test-netted one week after eradication and again the following spring. Two 125-foot experimental gill nets were set for 24 hours and no fish of any species were taken. The reservoir was test-netted again in August of 1961, when one 125-foot gill net and one frame net were set for 24 hours. The nets contained approximately 475 black bullheads and 83 trout. Many young-of-the-year green sunfish were also observed. A trapping program later in the fall revealed several adult green sunfish.

Plankton: Four collections of plankton were made at one station located near the center of the reservoir. Collections were made three

days prior to treatment, and after treatment at eight days, 30 days, and 366 days. The kinds and numbers of plankton are given for each collection in Table 2. These are arranged in a phylogenetic order with the zooplankters listed first.

A comparison in numbers per liter was made between pre- and post-treatment collections. Rotifers were represented by nine genera, Keratella and Asplanchna being the most numerous. Keratella changed from 91 before treatment to 15 at one week, two at one month, and only one at one year post-treatment. Asplanchna increased from 73 prior to treatment to 106 one week after treatment, but none were present in collections at one month or one year after treatment. Other rotifers were too scarce for comparisons.

Cladocerans were the most abundant zooplankters with Daphnia and Bosmina appearing in large numbers. Daphnia decreased from 244 before treatment to 18 at one week, then increased to 129 one month after treatment. Bosmina exhibited the reverse effect and both were less abundant at one year post-treatment. Copepoda was represented by Diaptomus, Cyclops, and undetermined nauplii. Six Diaptomus were taken prior to treatment, but none were found at one week or one month post-treatment and only two at one year. Cyclops decreased from 46 in the pre-treatment collection to three one week post-treatment, but increased to 11 by one month. Nauplii decreased from 106 pre-treatment to 26 and ten at one week and one month respectively post-treatment. Cyclops and nauplii were relatively abundant the following year.

Table 2. Number of plankters per liter in Wolf Butte Reservoir before and after toxaphene treatment at 35 ppb. (Treated Aug. 8, 1960).

Organism	Before 8/5/60	After 8/16/60	After 9/7/60	After 8/9/61
<u>Brachionus</u>	1	4	--	3
<u>Keratella</u>	91	15	2	1
<u>Lecane</u>	--	--	--	1
<u>Trichocerca</u>	1	--	--	--
<u>Chromogaster</u>	1	2	1	--
<u>Asplanchna</u>	73	106	--	--
<u>Polyarthra</u>	7	13	1	2
<u>Filinia</u>	1	1	--	1
<u>Hexarthra</u>	3	21	3	--
<u>Daphnia</u>	244	18	129	28
<u>Simocephalus</u>	--	--	1	--
<u>Ceriodaphnia</u>	4	9	18	--
<u>Bosmina</u>	98	130	18	25
<u>Chydorus</u>	1	--	--	--
<u>Diaptomus</u>	6	--	--	2
<u>Cyclops</u>	46	3	11	13
*Nauplii	106	26	10	73
<u>Pandorina</u>	3	15	--	--
<u>Oedogonium</u>	3	4	--	--
<u>Cladophora</u>	--	--	--	tr
<u>Rhizoclonium</u>	4	1	8	1
<u>Pediastrum</u>	12	5	3	61
<u>Coelastrum</u>	--	--	--	3
<u>Oocystis</u>	1	3	--	--
<u>Closteriopsis</u>	1	4	--	tr
<u>Tetraedon</u>	--	1	--	--
<u>Scenedesmus</u>	7	14	7	--
<u>Mougeotia</u>	--	--	1	--
<u>Spirogyra</u>	1	1	52	--
<u>Closterium</u>	1	4	1	tr
<u>Cosmarium</u>	4	1	2	--
<u>Staurastrum</u>	3	3	--	--
<u>Desmidium</u>	65	84	7	tr
<u>Botryococcus</u>	--	3	2	7
<u>Diatoma</u>	2	1	1	2
<u>Navicula</u>	5	6	--	--
<u>Pinnularia</u>	1	--	--	--
<u>Pleurosigma</u>	--	--	1	--
<u>Cymbella</u>	1	tr	--	--
<u>Nitzschia</u>	11	9	4	tr
<u>Campliodiscus</u>	1	--	--	--
<u>Ceratium</u>	5	2	--	11
<u>Synechocystis</u>	90,067	589,405	149,306	82,563

Table 2, continued.

Organism	Before 8/5/60	After 8/16/60	After 9/7/60	After 8/9/61
<u>Polycystis</u>	242	131	2	110
<u>Merismopedia</u>	--	--	1	--
<u>Coelospharium</u>	50	28	1	--
<u>Lynqbya</u>	8	2	9	--
<u>Anabaena</u>	61	58	1	--
<u>Aphanizomenon</u>	7,377	33,157	54,716	138
<u>Nodularia</u>	--	12	1	--

* Includes nauplii of both Diaptomus and Cyclops.
Tr Represents less than one per liter.

There were 16 genera of Chlorophyta, eight of Chrysophyta, and one of Pyrrophyta, represented in the collections. None exhibited numerical changes which could be attributed to toxaphene treatment. Eight genera of Cyanophyta were present and these were the most numerous algae.

Synechocystis and Aphanizomenon were the most abundant genera. Synechocystis increased from 90,067 before treatment to 589,405 one week after treatment, then decreased to 149,306 at one month. Aphanizomenon increased from 7,377 pre-treatment to 54,716 at one month after treatment. Polycystis, Coelospharium, and Anabaena, decreased after treatment. Polycystis was abundant at one year, but Coelospharium and Anabaena did not reappear one year post-treatment.

Most of the changes before and after treatment were small and could well be the result of normal fluctuations in the population or the result of sampling techniques. A few of these changes may have resulted from the toxaphene, but none were obvious.

Plant Inhabiting Organisms: Aquatic plant inhabiting organisms were

collected at two stations on the same dates plankton was sampled. The numbers of organisms per pound of vegetation for the four collections is presented in Table 3. Nineteen genera were represented, but only seven were numerous. Gammarus varied throughout the study, but remained abundant. Callibaetis, Caenis, and Ischnura decreased at one week and one month post-treatment, but were more abundant at one year post-treatment. Tendipes decreased from 44 pre-treatment to nine at one week while 48 and 25 were taken at one month and one year, respectively, post-treatment. Gastropoda (Physa and Gyraulus) increased from 771 before treatment to 1107 at one week, 1366 at one month, and 1558 at one year post-treatment.

Numerical comparisons of the seven dominant genera revealed no marked changes before and after treatment. Reductions of Ephemeroptera and Odonata in the first two post-treatment collections may be significant; however, this could also have resulted from an emergence.

Bottom Fauna: These organisms were collected at the same stations as those used for plant inhabiting organisms. Each collection consisted of 3 square feet of bottom. The number of organisms per square foot of bottom is given for each collection (Table 3). Thirteen genera were taken, but only Gammarus and Tendipes were abundant. Gammarus fluctuated from six before treatment to less than one at one week, 44 at one month, and less than one at one year after treatment. The large number at one month post-treatment resulted from a collection which contained considerable vegetation. Tendipes decreased from 28 before treat-

Table 3. Numbers of plant inhabiting organisms and bottom fauna in Wolf Butte Reservoir before and after toxaphene treatment at 35 ppb. (Plant inhabiting organisms are expressed as the number per pound of plants and bottom fauna as the number per square foot of bottom. Treated Aug. 8, 1960).

Organism	Before 8/5/60		After 8/16/60		After 9/7/60		After 8/9/61	
	Plant	Bottom	Plant	Bottom	Plant	Bottom	Plant	Bottom
Oligochaeta	--	tr	--	tr	--	tr	--	3
Hirudinea	--	--	tr	--	--	--	--	--
Amphipoda								
<u>Gammarus</u>	63	6	172	tr	73	44	265	tr
Hydracarina								
Hydachnidae	5	--	tr	--	2	--	23	--
Ephemeroptera								
<u>Callibaetis</u>	5	1	tr	--	--	--	124	tr
<u>Caenis</u>	6	3	1	tr	--	tr	16	tr
Odonata								
<u>Sympetrum</u>	tr	--	tr	tr	--	--	3	--
<u>Aeschna</u>	--	--	tr	--	--	--	--	--
<u>Ischnura</u>	40	5	10	1	--	4	56	tr
Hemiptera								
<u>Plea</u>	--	--	tr	--	--	--	--	--
<u>Notonecta</u>	1	--	--	--	3	--	10	--
<u>Sigara</u>	3	--	--	--	tr	--	2	--
Coleoptera								
<u>Halipus</u>	2	--	tr	--	--	--	1	--
<u>Copelatus</u>	tr	--	--	--	tr	--	2	--
<u>Hydroporus</u>	--	--	--	--	1	--	tr	--
Trichoptera								
<u>Hydroptila</u>	--	1	--	tr	--	--	--	--
Diptera								
<u>Tendipes</u>	44	28	9	12	48	9	25	25
<u>Probezzia</u>	tr	3	--	2	--	--	--	--
<u>Chrysops</u>	--	1	--	1	--	--	--	--
Gastropoda								
<u>Physa</u>	123	2	325	1	156	3	886	6
<u>Gyraulus</u>	648	tr	782	1	1,210	9	672	1
Pelecypoda								
<u>Pisidium</u>	--	3	--	1	--	8	--	4

Tr Represents less than one per pound or square foot.

ment to 12 and nine at one week and one month, respectively, after treatment; but increased to 25 at one year. A comparison of the number of bottom organisms before and after treatment revealed no marked changes.

RALEIGH RESERVOIR

Description

Raleigh Reservoir is located in southwestern North Dakota. It has a surface area of 15 acres, and a maximum depth of 18 feet. There are no permanent inlets or outlets and the water is supplied mainly by runoff. The bottom is muck, covered by silt in some areas. No marked thermal stratification was present. The surrounding area is almost entirely rangeland. Aquatic vegetation was very abundant at all depths less than three feet. Potamogeton pectinatus, P. richardsoni, Myriophyllum exalbescens, and Ceratophyllum demersum were the dominant plants. Large amounts of filamentous algae (Rhizoclonium) accompanied these plants in most areas.

Treatment

Toxaphene was applied at 25 ppb on August 4, 1960, in an attempt to remove the entire fish population. A complete kill was not achieved and a second treatment was made at 90 ppb on September 26, 1960.

Fish: Prior to treatment, two 125-foot experimental gill nets and four frame nets were set for 24 hours. The frame nets contained several thousand golden shiners (Notemigonus crysoleucas), approximately 5,000

green sunfish, 1,200 white crappies (Pomoxis annularis) and black crappies (Pomoxis nigromaculatus). The two experimental gill nets captured 13 white suckers (Catostomus commersoni), 11 black bullheads, and a few golden shiners, green sunfish, and crappies. Large numbers of the four most numerous species were found dead and dying after treatment. The reservoir was again netted one week after the first treatment, but with only two experimental gill nets set for 24 hours. These contained ten white suckers and five black bullheads. No further test-netting was done, since drought had lowered water levels severely restocking was no longer considered.

Plankton: Four collections were made at one station located near the center of the reservoir. A collection was made one day prior to the first treatment and those after the first treatment were at 11 days, 33 days, and 371 days. However a second treatment was made 53 days after the first, and one collection was made at 318 days following this treatment. The number of plankters was compared for pre- and post-treatment collections (Table 4). Rotifers were represented by 15 genera, but only Brachionus and Asplanchna were abundant. Brachionus decreased from 114 pre-treatment to 108 at 11 days and 15 at 33 days post-treatment. Asplanchna varied from 24 pre-treatment to 194 at 11 days and 16 at 33 days post-treatment. Only three Brachionus and one Asplanchna were taken 371 days after treatment. All rotifers were very scarce at this time and six of the original genera were not found.

Cladocera was the most abundant zooplankter. Daphnia, Ceriodaphnia,

Table 4. Number of plankton per liter in Raleigh Reservoir before and after treatment at 25 ppb. (Treated Aug. 4, and Sept. 26, 1960).

Organism	Before 8/3/60	After 8/15/60	After 9/6/60	** After 8/10/61
<u>Brachionus</u>	114	108	15	3
<u>Keratella</u>	13	11	9	7
<u>Platyias</u>	tr	17	1	--
<u>Lecane</u>	tr	2	--	--
<u>Monostyla</u>	1	1	--	5
<u>Trichocerca</u>	5	--	--	tr
<u>Chromogaster</u>	1	3	--	1
<u>Asplanchna</u>	24	194	16	1
<u>Polyarthra</u>	3	15	7	1
<u>Synchaeta</u>	1	11	13	--
<u>Filinia</u>	tr	1	--	tr
<u>Testudinella</u>	1	--	tr	--
<u>Trochosphaera</u>	tr	--	1	--
<u>Hexarthra</u>	2	--	--	--
<u>Conochiloides</u>	3	11	--	--
<u>Daphnia</u>	65	173	57	9
<u>Ceriodaphnia</u>	44	156	100	1
<u>Bosmina</u>	314	283	50	--
<u>Chydorus</u>	4	17	1	--
<u>Diaptomus</u>	10	1	1	--
<u>Cyclops</u>	120	9	41	8
*Nauplii	190	85	19	7
<u>Elakothrix</u>	--	--	1	--
<u>Microspora</u>	--	1	3	--
<u>Oedogonium</u>	9	3	1	--
<u>Rhizoclonium</u>	7	5	3	1
<u>Golenkinia</u>	--	3	--	--
<u>Pediastrum</u>	151	462	3	3
<u>Coelastrum</u>	7	594	--	--
<u>Oocystis</u>	69	75	2	--
<u>Chodatella</u>	4	15	--	--
<u>Closteriopsis</u>	18	462	1	--
<u>Tetraedon</u>	11	89	--	--
<u>Scenedesmus</u>	727	3,038	133	1
<u>Crucigenia</u>	17	264	4	--
<u>Tetrastrum</u>	--	3	--	--
<u>Mougeotia</u>	--	1	1	--
<u>Zygnema</u>	1	--	--	--
<u>Spirogyra</u>	2	4	19	107
<u>Closterium</u>	--	--	2	tr
<u>Cosmarium</u>	20	4	5	1
<u>Staurostrum</u>	4	9	--	--
<u>Desmidiium</u>	925	1,189	4	--

Table 4, continued.

Organism	Before 8/3/60	After 8/15/60	After 9/6/60	** After 8/10/61
<u>Botryococcus</u>	5	8	7	--
<u>Melosira</u>	4	9	--	2
<u>Diatoma</u>	8	--	3	1
<u>Synedra</u>	4	3	--	3
<u>Navicula</u>	6	1	1	--
<u>Pinnularia</u>	1	--	1	--
<u>Frustulia</u>	--	tr	1	--
<u>Gyrosigma</u>	--	tr	--	--
<u>Pleurosigma</u>	tr	--	--	--
<u>Gomphonema</u>	tr	1	--	--
<u>Cymbella</u>	4	4	1	--
<u>Nitzschia</u>	8	14	7	8
<u>Cymatopleura</u>	2	1	--	--
<u>Campylodiscus</u>	2	--	--	--
<u>Ceratium</u>	24	7	4	5
<u>Synechocystis</u>	54,161	6,275	2,312	601,057
<u>Polycystis</u>	2,906	859	38	99
<u>Merismopedia</u>	9	7	1	--
<u>Coelospharium</u>	2	25	94	4
<u>Lynghya</u>	10	1	8	1
<u>Anabaena</u>	5	4	16	2
<u>Aphanizomenon</u>	6	190	81,902	tr
<u>Nodularia</u>	77	3,633	21	3

Tr Represents less than one per liter.

* Includes nauplii of both Diaptomus and Cyclops.

** After the second treatment at 90 ppb.

and Bosmina were present in large numbers. Daphnia varied from 65 pre-treatment to 173 at 11 days, 57 at 33 days, and only nine at 371 days post-treatment. Ceriodaphnia increased from 44 pre-treatment to 156 at 11 days, then decreased to 100 at 33 days, and only one was taken at 371 days post-treatment. Bosmina decreased from 314 before treatment to 283 at 11 days, 50 at 33 days, and disappeared by 371 days post-treatment. A few Chydorus were found in the pre- and early post-treatment collections, but did not occur in the collection 371 days post-treatment. Copepoda was

represented by the young and adults of Diaptomus and Cyclops. Diaptomus changed from ten before treatment to one at 11 days and one at 33 days, but none at 371 days post-treatment. There were 120 Cyclops before treatment while collections after treatment showed nine at 11 days, 41 at 33 days, and eight at 371 days. Nauplii decreased from 190 pre-treatment to 85 at 11 days, 19 at 33 days, and seven at 371 days post-treatment.

Chlorophyta was represented by 21 genera. Pediastrum, Coelastrum, Glosteriopsis, Tetraedon, Scenedesmus, Crucigenia, and Desmidium were the most abundant. All of these increased in the collection 11 days after treatment, but were greatly reduced at 33 days and 371 days post-treatment. Spirogyra was the most abundant Chlorophyta in the collection 371 days after treatment, but was scarce in the pre- and early post-treatment collections. Chrysophyta contained nine genera and Pyrrophyta one. These were infrequently encountered and no comparisons were made. Cyanophyta was represented by eight genera. Synechocystis, Polycystis, Coelospharium, Aphanizomenon, and Nodularia were the dominant organisms. Synechocystis and Polycystis decreased in the first two post-treatment collections, but were abundant at 371 days post-treatment. Coelospharium and Aphanizomenon increased after treatment, but were scarce at 371 days post-treatment. Nodularia varied from 77 pre-treatment to 3,663 at 11 days, 21 at 33 days, and three at 371 days post-treatment.

Changes after the first treatment (25 ppb) are probably the result of normal population fluctuations. At 371 days post-treatment water

levels had declined approximately 6 feet, the water was clear, and aquatic vegetation had increased. The severe reduction in nearly all plankters at this time may have been due to the drop in water levels and/or the possible consequent increased toxaphene concentration.

Plant Inhabiting Organisms: Collections were made at two stations on the same dates plankton was collected. The number of organisms per pound of vegetation is presented for each collection (Table 5). Nineteen genera were taken, but only eight were abundant. Gammarus increased from 31 pre-treatment to 313 at 11 days, 569 at 33 days, and 334 at 371 days post-treatment. Hydrachnidae decreased from 45 pre-treatment to 27 at 11 days, 22 at 33 days, and 14 at 371 days post-treatment. Callibaetis, Caenis, Ischnura, and Tendipes were markedly reduced in the first two post-treatment collections, but all except Caenis were abundant at 371 days post-treatment. Sigara decreased from 39 before treatment to less than one at 11 days after treatment, and none were taken after this time. There were 1163 Gyraulus pre-treatment, 1695 at 11 days, 398 at 33 days and 38 at 371 days post-treatment.

Several changes were noted following treatment, some of which may be the result of the toxaphene. Reductions of Callibaetis, Caenis, Ischnura, and Tendipes may be significant, however all but Caenis were abundant 371 days post-treatment. Stringer and McMynn (1958) reported that Ephemeroptera were killed at 30 ppb toxaphene. The disappearance of Sigara after treatment appears to be the result of the toxaphene since they exhibited low tolerance levels in the controlled experiments (Table 11). The re-

duction of Gyraulus at 371 days post-treatment may be related to lowered water levels, since other workers (Hooper and Grzenda, 1955; and Stringer and McMynn, 1958) found Gastropoda to be unaffected by toxaphene at 100 ppb.

Bottom Fauna: Four collections were made at two stations on the same dates plant inhabiting organisms were collected. The number per square foot of bottom is given for each collection (Table 5). Eleven genera were taken, but most of these were too scarce for comparisons. Oligochaeta increased throughout the study from four pre-treatment to 28 at 371 days post-treatment. Cushing and Olive (1957) found an increase in Oligochaeta after treatment with 100 ppb toxaphene. Ephemeroptera decreased from seven before treatment to less than one at 11 days, and none were taken in succeeding collections. Tendipes decreased from 27 pre-treatment to 2 at 11 days, 6 at 33 days, then increased to 71 at 371 days post-treatment.

The reductions of Ephemeroptera and Tendipes may be significant. Stringer and McMynn (1958) reported that Ephemeroptera were killed at 30 ppb toxaphene, and Cushing and Olive found that a concentration of 100 ppb eliminated Tendipedidae.

SOUTH LAKE METIGOSHE

Description

South Lake Metigoshe is a glacial lake located in the Turtle Mountains in north central North Dakota. It has an area of 915 surface acres and an average depth of 9 feet. Water is supplied mainly by runoff,

Table 5. Numbers of plant inhabiting organisms and bottom fauna in Raleigh Reservoir before and after toxaphene treatment at 25 ppb. (Plant inhabiting organisms are expressed as the number per pound of plants and bottom fauna as the number per square foot of bottom. Treated Aug. 4, and Sept. 26; 1960).

Organism	Before 8/3/60		After 8/15/60		After 9/6/60		* After 8/10/61	
	Plant	Bottom	Plant	Bottom	Plant	Bottom	Plant	Bottom
Oligochaeta	--	4	--	8	--	11	--	28
Hirudinea	tr	--	tr	--	--	--	5	--
Amphipoda								
<u>Gammarus</u>	31	4	313	tr	569	3	334	1
Hydracarina								
Hydrachnidae	45	--	27	--	22	--	14	--
Ephemeroptera								
<u>Callibaetis</u>	66	1	9	tr	tr	--	60	--
<u>Caenis</u>	185	6	10	tr	6	--	3	--
Odonata								
<u>Sympetrum</u>	--	--	1	--	tr	--	17	--
<u>Anax</u>	--	--	--	--	--	--	1	--
<u>Aeschna</u>	tr	--	tr	--	--	--	1	--
<u>Ischnura</u>	109	2	21	1	8	--	134	--
Hemiptera								
<u>Notonecta</u>	2	--	tr	--	tr	--	5	--
<u>Sigara</u>	39	2	tr	--	--	--	--	--
Coleoptera								
<u>Copelatus</u>	--	--	tr	--	--	--	--	--
<u>Hydroporus</u>	2	--	7	--	6	--	8	--
Diptera								
<u>Chaoborus</u>	--	1	--	--	--	--	--	--
<u>Tendipes</u>	12	27	tr	2	1	6	52	71
<u>Probezzia</u>	tr	--	tr	--	--	--	--	--
<u>Chrysops</u>	--	--	tr	--	--	tr	--	--
Gastropoda								
<u>Physa</u>	5	--	13	--	6	--	22	--
<u>Gyraulus</u>	1,163	tr	1,695	4	398	2	38	--
Pelecypoda								
<u>Pisidium</u>	--	tr	--	4	--	7	--	--

Tr Represents less than one per pound or square foot.

* After the second treatment at 90 ppb.

Water levels fluctuate slightly due to releases from an upstream reservoir. The major bottom materials are peat and muck. No marked thermal stratification was present. Trees border most of the shoreline. Aquatic vegetation was common and was exceptionally abundant in the bays. Scirpus sp. occupied several large areas near shore. Myriophyllum exalbescens and Ceratophyllum demersum were present at most depths less than 15 feet. Other dominant plants were Potamogeton natans, P. pectinatus, P. richardsoni, P. zosteriformis, Najas flexilis, Sagittaria latifolia, Eleocharis palustris, and Polygonum amphibium.

Treatment

Toxaphene was applied at 10 ppb on July 17, 1960 in an attempt to reduce the number of yellow perch (Perca flavescens) and black bullheads. This was supplemented by 5 ppb on July 19.

Fish: Several 250-foot experimental gill nets and frame nets (0.5 inch and 0.25 inch mesh) were set at selected stations one week before, one week after, and again 11 months after treatment. The netting effort at each time was 333, 290, and 120 hours respectively. The fish taken are expressed as the number per 100-net-hours. Adult yellow perch were reduced from 900 pre-treatment to 36 at one week and none at 11 months post-treatment. Young-of-the-year were reduced from 610 pre-treatment to six at one week and none at one year post-treatment. Young-of-the-year black bullheads decreased from 240 pre-treatment to nine at one week and none at 11 months post-treatment. Young-of-the-year northern pike (Esox lucius) decreased from 40 pre-treatment to ten at one week and none at 11 months

post-treatment. Netting at one week post-treatment did not show a reduction in adult black bullhead, northern pike, and walleye (Stizostedion vitreum), but several were found dead along shore at this time. No walleye were taken at 11 months post-treatment and bullheads and northern pike were greatly reduced. The low number of all species taken at 11 months post-treatment may have been due to the residual effects of the toxaphene.

Plankton: Five collections were made at four stations on South Lake Metigoshe. These were made two days prior to treatment and after treatment at 4, 40, 60, and 367 days. The pre- and first two post-treatment collections at South Lake Metigoshe are compared with those made at four stations on North Lake Metigoshe, which was sampled on the same dates. North Lake Metigoshe lies adjacent to South Lake Metigoshe and is connected by a channel approximately 30 feet wide, but it was not treated until later in the fall and could therefore be used as a control. The number of plankton per liter for all collections in both lakes is given in Table 6.

Rotifers were represented by 15 genera. Trichocerca and Conochiloides were the most abundant. Trichocerca decreased from 234 pre-treatment to 31 at 40 days, three at 60 days, and three at 367 days post-treatment. Conochiloides decreased from 182 pre-treatment to 160 at four days, one at 40 days, none at 60 days, and less than one at 367 days post-treatment. Asplanchna decreased from 28 before treatment to one at 40 days, none at 60 days, and 20 at 367 days post-treatment. Hexarthra decreased from 11 pre-treatment to none at 40 days, none at 60 days, and less than one at

Table 6. Number of plankton per liter in South and North Lake Metigoshe before and after toxaphene treatment at 15 ppb. (South Lake Metigoshe treated July 17, 1960).

Organism	Before 7/15/60		After 7/21/60		After 8/26/60		After 9/15/60	After 7/19/61
	S.L.	N.L.	S.L.	N.L.	S.L.	N.L.	S.L.	S.L.
<u>Brachionus</u>	--	2	1	1	tr	--	1	--
<u>Keratella</u>	35	28	48	22	1	25	11	12
<u>Lecane</u>	tr	--	--	--	1	tr	--	tr
<u>Monostyla</u>	3	--	2	--	9	2	1	2
<u>Trichocerca</u>	234	111	83	86	31	5	3	3
<u>Ascomorpha</u>	1	3	5	4	4	tr	tr	1
<u>Chromogaster</u>	tr	2	tr	2	3	--	tr	1
<u>Asplanchna</u>	28	3	24	6	1	12	--	20
<u>Polyarthra</u>	4	27	35	34	42	32	28	16
<u>Synchaeta</u>	17	1	19	3	10	2	1	tr
<u>Filinia</u>	3	3	25	2	7	2	2	3
<u>Testudinella</u>	--	--	--	tr	--	--	--	tr
<u>Hexarthra</u>	11	1	15	2	--	1	--	tr
<u>Conochiloides</u>	182	14	160	34	1	10	--	tr
<u>Stephanoceros</u>	--	--	--	--	--	tr	--	--
<u>Daphnia</u>	1	9	1	2	9	5	16	41
<u>Simocephalus</u>	1	--	2	--	1	1	tr	tr
<u>Ceriodaphnia</u>	37	99	67	37	40	18	7	1
<u>Bosmina</u>	110	67	119	35	8	18	8	1
<u>Graptolebris</u>	--	--	--	--	4	--	--	--
<u>Chydorus</u>	10	1	2	tr	20	3	19	5
<u>Diaptomus</u>	1	12	tr	13	tr	5	--	2
<u>Cyclops</u>	17	17	4	17	13	9	22	44
* <u>Nauplii</u>	29	83	17	76	28	37	11	67
<u>Pandorina</u>	1	tr	1	1	5	5	5	5
<u>Volvox</u>	tr	tr	1	1	15	1	1	--
<u>Apicystis</u>	--	--	--	--	--	--	--	tr
<u>Oedogonium</u>	--	1	tr	tr	3	--	tr	--
<u>Rhizoclonium</u>	tr	tr	tr	tr	--	--	--	--
<u>Pediastrum</u>	4	17	2	7	7	38	6	6
<u>Coelastrum</u>	tr	tr	tr	tr	--	--	1	--
<u>Oocystis</u>	1	1	1	1	1	tr	--	2
<u>Chodatella</u>	--	tr	tr	--	--	--	--	tr
<u>Closteriopsis</u>	1	2	1	2	2	tr	1	5
<u>Kirchneriella</u>	--	tr	--	--	--	--	--	--
<u>Tetraedon</u>	--	--	tr	--	--	--	--	--
<u>Scenedesmus</u>	tr	1	1	1	1	2	tr	1
<u>Crucigenia</u>	tr	tr	8	--	1	--	1	1
<u>Mougeotia</u>	--	--	--	--	--	--	tr	tr
<u>Spirogyra</u>	tr	1	tr	--	1	--	tr	tr
<u>Closterium</u>	tr	--	tr	--	--	--	--	--

Table 6, continued.

Organism	Before 7/15/60		After 7/21/60		After 8/26/60		After 9/15/60	After 7/19/61
	S.L.	N.L.	S.L.	N.L.	S.L.	N.L.	S.L.	S.L.
<u>Cosmarium</u>	1	tr	1	tr	--	3	1	tr
<u>Staurastrum</u>	15	16	17	8	60	23	106	67
<u>Desmidium</u>	3	4	4	1	2	3	1	1
<u>Botryococcus</u>	--	1	--	2	2	tr	2	2
<u>Dinobryon</u>	7	98	1	11	--	tr	--	--
<u>Melosira</u>	11	73	5	40	568	1,040	462	3
<u>Diatoma</u>	1	1	--	1	--	--	1	1
<u>Fragilaria</u>	144	235	71	45	871	50	71	3,078
<u>Synedra</u>	42	51	60	13	304	62	581	6,803
<u>Asterionella</u>	1	1	1	tr	tr	1	1	tr
<u>Navicula</u>	13	1	22	1	25	29	3	6
<u>Pinnularia</u>	4	1	16	1	5	8	1	1
<u>Frustulia</u>	1	--	1	--	1	1	--	--
<u>Gyrosigma</u>	tr	--	tr	--	--	1	tr	tr
<u>Pleurosigma</u>	tr	tr	--	--	1	tr	tr	tr
<u>Gomphonema</u>	2	9	9	6	39	9	61	61
<u>Cymbella</u>	4	1	18	1	10	2	1	1
<u>Nitzschia</u>	2	2	19	4	7	3	3	12
<u>Cymatopleura</u>	--	--	--	--	--	tr	1	--
<u>Camplyodiscus</u>	2	tr	1	tr	3	1	1	tr
<u>Glenodinium</u>	tr	1	1	2	--	1	--	--
<u>Ceratium</u>	52	42	71	61	190	300	260	948
<u>Polycystis</u>	87	396	73	330	155	1,057	218	462
<u>Merismopedia</u>	--	--	--	tr	--	--	--	1
<u>Coelospharium</u>	7	132	9	238	150	2,510	470	207
<u>Phormidium</u>	3	--	4	--	1	--	tr	--
<u>Lynxbya</u>	13	24	21	27	2,312	2,932	81	39
<u>Anabaena</u>	7,794	3,540	1,982	1,915	130,515	4,716	127,470	1,222
<u>Aphanizomenon</u>	2,642	5,773	1,096	1,836	69,617	4,742	98,018	53
<u>Nodularia</u>	3	2	14	4	6,869	4	5,019	39
<u>Gloeotrichia</u>	3	1	3	1	2	--	1	1

Tr Represents less than one per liter.

* Includes nauplii of Diaptomus and Cyclops.

367 days post-treatment. Keratella, Polyarthra, and Filinia remained almost constant. There were six genera of Cladocera with Daphnia, Ceriodaphnia, and Bosmina, being the most abundant. Daphnia increased from one pre-treatment to 41 at 367 days post-treatment, and Ceriodaphnia remained

nearly constant, but was less abundant at 367 days post-treatment. Bosmina decreased from 110 pre-treatment to eight at 40 days, and one at 367 days post-treatment. Copepoda was an abundant group, represented by Diaptomus, Cyclops, and their nauplii, which remained nearly constant during the study.

There were 20 genera of Chlorophyta, two of Pyrrophyta, and 17 of Chrysophyta. Staurastrum, Ceratium, Melosira, Fragilaria, and Synedra were the dominant organisms in these groups. After treatment these increased at 40 days post-treatment and with the exception of Melosira, were more abundant at 367 days post-treatment. Cyanophyta was the most abundant phytoplankter. Polycystis, Coelospharium, Lynobya, Anabaena, Aphanizomenon, and Nodularia were abundant. Polycystis and Coelospharium increased slightly after treatment, whereas Anabaena, Lynobya, Aphanizomenon, and Nodularia exhibited large post-treatment increases (Table 6).

Comparisons of zooplankters before and after treatment revealed no marked changes. Post-treatment decreases in South Lake Metigoshe were not significant, because comparisons with untreated North Lake Metigoshe revealed similar decreases in most instances during the same period. Most of the dominant phytoplankters remained almost constant or increased following treatment. The large post-treatment increase exhibited by Anabaena, Aphanizomenon, and Nodularia may be the result of treatment, since they did not increase significantly in North Lake Metigoshe.

Plant Inhabiting Organisms: Four stations were established on South Lake Metigoshe and five collections were made at each of these. Col-

lections were made one day before treatment and after treatment at 5, 45, 59, and 367 days. The pre- and first two post-treatment collections at South Lake Metigoshe are compared with three collections made at four stations on North Lake Metigoshe, which were not treated until later in the fall. The number of organisms per pound of plants is given for both South and North Lake Metigoshe (Table 7). There were 28 genera of organisms taken. Gammarus, Tendipes, Physa, and Gyraulus were the most abundant. A comparison of pre- and post-treatment collections revealed no marked changes in the number of any organism.

Bottom Fauna: No pre-treatment samples were obtained, but two post-treatment samples were taken, which consisted of three square feet each. Tendipes was the dominant organism; but a few Gammarus, Chaoborus, and Oligochaeta were also present. Nine Tendipes per square foot were taken at 60 days and 31 at 367 days post-treatment.

ODLAND RESERVOIR

Description

Odland Reservoir is located in southwestern North Dakota and has a surface area of 100 acres and a maximum depth of 16 feet. There are no permanent inlets or outlets and the water is supplied mainly by runoff. The major bottom material is muck. No marked thermal stratification was present. Aquatic vegetation was abundant in all shallow areas. Potamogeton pectinatus, P. richardsoni, Scirpus sp., Myriophyllum exalbescens, and Chara sp. were the dominant plants.

Table 7. Numbers of plant inhabiting organisms and bottom fauna in South Lake Metigoshe before and after toxaphene treatment at 15 ppb. (Plant inhabiting organisms are expressed as the number per pound of plants and bottom fauna as the number per square foot of bottom. (Treated July 17, 1960).

Organism	Pre-treatment				Post-treatment					
	7/16/60		7/22/60		8/31/60		9/16/60		7/18/61	
	S.L.	N.L.	S.L.	N.L.	S.L.	N.L.	S.L.	N.L.	S.L.	N.L.
Hirudinea	1	tr	tr	tr	1	tr	1		2	
Amphipoda										
<u>Gammarus</u>	639	198	406	186	177	130	295		424	
Hydracarina										
Hydrachnidae	11	4	5	4	1	1	1		1	
Ephemeroptera										
<u>Callibaetis</u>	2	tr	--	tr	--	1	tr		6	
<u>Caenis</u>	1	3	2	2	--	2	--		--	
Odonata										
<u>Sympetrum</u>	tr	--	--	--	--	--	--		--	
<u>Anax</u>	tr	tr	--	tr	--	--	--		1	
<u>Aeschna</u>	--	--	--	--	--	tr	--		1	
<u>Ischnura</u>	tr	tr	tr	1	tr	7	tr		2	
Hemiptera										
<u>Plea</u>	tr	1	tr	tr	tr	2	tr		7	
<u>Notonecta</u>	--	tr	--	--	--	--	--		3	
<u>Buena</u>	tr	--	--	--	--	--	tr		--	
<u>Sigara</u>	tr	tr	tr	tr	tr	--	tr		6	
Trichoptera										
<u>Psychomyia</u>	1	1	--	1	--	tr	--		tr	
<u>Oecetis</u>	1	1	tr	1	--	tr	--		--	
<u>Trienodes</u>	3	1	tr	tr	--	--	--		tr	
<u>Phryganea</u>	tr	tr	tr	tr	--	tr	--		--	
Coleoptera										
<u>Copelatus</u>	2	2	1	3	tr	3	1		11	
<u>Halipus</u>	1	2	tr	2	tr	2	tr		2	
<u>Hydrocanthus</u>	--	tr	--	--	tr	--	tr		2	
<u>Gyrinus</u>	--	--	tr	--	--	tr	--		--	
Diptera										
<u>Chaoborus</u>	tr	--	1	--	--	--	--		--	
<u>Tendipes</u>	9	5	3	6	11	3	2		1	
<u>Probezzia</u>	tr	1	tr	tr	tr	--	--		--	
Gastropoda										
<u>Physa</u>	24	28	21	27	31	19	29		66	
<u>Lymnaea</u>	--	tr	--	tr	--	--	tr		--	
<u>Gyraulus</u>	47	56	24	44	51	105	86		10	
<u>Valvata</u>	--	tr	tr	--	tr	--	tr		--	

Tr Represents less than one per pound.

Treatment

Fish: Toxaphene was applied at 5 ppb on August 11, 1960, to reduce young-of-the-year black bullheads and yellow perch. Large numbers of these fish and several young of the year northern pike, white crappie, and orangespotted sunfish (Lepomis humilis) were found dead along shore the day after treatment. Adults of these species were not significantly reduced by treatment, since only a small number was found dead, and large numbers were taken in post-treatment test-nettings.

Plankton: Four collections were made at each of two stations. These were made one day prior to treatment and after treatment at 7, 28, and 362 days. The kinds and number of plankters per liter are given for each collection (Table 8). There were ten genera of Rotifera taken. Brachionus, Keratella, Polyarthra, and Conochiloides were the most abundant and remained nearly constant before and after treatment. Cladocera was the most abundant zooplankter with Daphnia, Ceriodaphnia, and Bosmina being most common. There were 22 Daphnia pre-treatment, 68 at seven days, 40 at 28 days and three at 362 days post-treatment. Ceriodaphnia varied from 31 pre-treatment to 66 at seven days, 37 at 28 days, and only one at 362 days post-treatment. Bosmina decreased from 459 before treatment to 24 at 28 days, and 66 at 362 days post-treatment. Copepoda was represented by adults and nauplii of Diaptomus and Cyclops. Cyclops decreased from 71 pre-treatment to 16 at 28 days post-treatment and nauplii decreased from 129 pre-treatment to 36 at 28 days post-treatment, but both were again abundant at 362 days post-treatment.

Table 8. Number of plankton per liter in Odland Reservoir before and after toxaphene treatment at 5 ppb. (Treated Aug. 11, 1960).

Organism	Before 8/10/60	After 8/18/60	After 9/8/60	After 8/8/61
<u>Brachionus</u>	--	10	26	12
<u>Keratella</u>	3	7	71	33
<u>Trichocerca</u>	--	1	1	--
<u>Asplanchna</u>	5	3	6	4
<u>Polyarthra</u>	7	61	55	229
<u>Synchaeta</u>	1	2	17	4
<u>Filinia</u>	--	1	11	1
<u>Trochosphaera</u>	1	1	7	4
<u>Hexarthra</u>	tr	tr	--	tr
<u>Conochiloides</u>	--	tr	63	tr
<u>Daphnia</u>	22	68	40	3
<u>Simocephalus</u>	--	--	tr	--
<u>Ceriodaphnia</u>	31	66	37	1
<u>Bosmina</u>	459	333	24	66
<u>Chydorus</u>	--	--	2	--
<u>Diaptomus</u>	1	1	1	--
<u>Cyclops</u>	71	26	16	34
* <u>Nauplii</u>	129	61	36	115
<u>Oedogonium</u>	--	1	--	--
<u>Rhizoclonium</u>	--	--	3	--
<u>Microactinium</u>	--	1	--	tr
<u>Pediastrum</u>	4	3	10	12
<u>Hydrodictyon</u>	--	tr	--	--
<u>Oocystis</u>	tr	1	2	--
<u>Closteriopsis</u>	10	5	1	2
<u>Tetraedon</u>	tr	1	1	--
<u>Scenedesmus</u>	5	3	7	1
<u>Mougeotia</u>	--	--	1	--
<u>Spirogyra</u>	--	tr	1	--
<u>Closterium</u>	tr	--	1	1
<u>Cosmarium</u>	1	2	tr	--
<u>Staurastrum</u>	3	2	6	1
<u>Desmidium</u>	3	8	16	2
<u>Botryococcus</u>	--	--	1	--
<u>Dinobryon</u>	--	--	11	--
<u>Melosira</u>	6	55	33	131
<u>Diatoma</u>	2	2	1	16
<u>Synedra</u>	tr	1	1	4
<u>Asterionella</u>	1	1	6	tr
<u>Navicula</u>	tr	1	1	--
<u>Pleurosigma</u>	--	tr	--	--
<u>Cymbella</u>	1	tr	--	--
<u>Nitzschia</u>	6	15	3	1

Table 8, continued.

Organism	Before 8/10/60	After 8/18/60	After 9/8/60	After 8/8/61
<u>Cymatopleura</u>	tr	tr	--	tr
<u>Ceratium</u>	391	542	3,302	1,123
<u>Polycystis</u>	6	9	130	3
<u>Lynqbya</u>	1	1	3	--
<u>Anabaena</u>	1	5	3	5
<u>Aphanizomenon</u>	14	287	5,812	4
<u>Nodularia</u>	tr	1	8	--

Tr Represents less than one per liter.

* Includes nauplii of both Diaptomus and Cyclops.

Fourteen genera of Chlorophyta, 12 of Chrysophyta, one of Pyrrophyta, and five of Cyanophyta were found. Melosira, Ceratium, Polycystis, and Aphanizomenon, were the dominant organisms of these groups. After treatment these increased at seven days and 28 days post-treatment. Approximately the same numbers were found in post-treatment collections at 362 days as were found pre-treatment. Numerical comparisons of pre- and post-treatment collections showed no marked changes.

Plant Inhabiting Organisms: Four collections were made at two stations on the same dates plankton were collected. The number of organisms per pound of plants is given for each collection (Table 9). Nineteen genera were taken with Gammarus, Hydrachnidae, Caenis, Ischnura, Tendipes, Physsa, Gyraulus, and Valvata being the most abundant. Caenis and Tendipes decreased slightly after treatment, probably a normal population fluctuation rather than a result of the toxaphene treatment. All other organisms remained nearly constant.

Bottom Fauna: Four collections were made at the same stations on the

Table 9. Numbers of plant inhabiting organisms and bottom fauna in Odland Reservoir before and after toxaphene treatment at 5 ppb. (Plant inhabiting organisms are expressed as the number per pound of plants and bottom fauna as the number per square foot of bottom. Treated August 11, 1960).

Organism	Before 8/10/60		After 8/18/60		After 9/8/60		After 8/8/61	
	Plant	Bottom	Plant	Bottom	Plant	Bottom	Plant	Bottom
Oligochaeta	--	2	--	1	--	tr	--	2
Hirudinea	tr	--	tr	--	--	1	2	--
Amphipoda								
<u>Gammarus</u>	195	1	294	2	303	6	76	tr
Hydracarina								
Hydrachnidae	53	--	34	--	4	--	17	--
Ephemeroptera								
<u>Caenis</u>	21	2	11	tr	5	--	11	tr
Odonata								
<u>Sympetrum</u>	1	--	tr	--	--	--	--	--
<u>Aeschna</u>	tr	tr	tr	--	--	--	2	--
<u>Ischnura</u>	5	1	4	tr	13	1	11	--
Hemiptera								
<u>Notonecta</u>	tr	--	1	--	2	--	--	--
<u>Sigara</u>	tr	--	tr	--	1	--	--	--
Trichoptera								
<u>Hydroptila</u>	--	1	--	--	--	--	--	--
<u>Psychomyia</u>	tr	--	--	--	--	--	--	--
<u>Phryganea</u>	tr	--	--	--	--	--	--	--
Coleoptera								
<u>Halipus</u>	6	--	1	--	1	--	tr	--
<u>Hydroporus</u>	tr	--	tr	--	2	--	--	--
Diptera								
<u>Tendipes</u>	37	18	6	8	4	2	14	8
<u>Probezzia</u>	--	--	tr	--	--	tr	--	tr
<u>Chrysops</u>	--	tr	--	1	--	tr	--	--
Gastropoda								
<u>Physa</u>	32	3	52	9	23	1	89	2
<u>Gyraulus</u>	1,301	7	964	11	721	17	320	2
<u>Valvata</u>	48	11	52	17	149	78	7	23
Pelecypoda								
<u>Pisidium</u>	--	9	--	11	--	15	--	32

Tr Represents less than one per pound or square foot.

same dates plant inhabiting organisms were collected. Each sample contained 4 square feet of bottom. The number of organisms per square foot of

bottom is given for each collection (Table 9); Fourteen genera were taken; but only Tendipes, Physa, Gyraulus, Valvata, and Pisidium were abundant. None of these exhibited marked numerical changes which could be attributed to toxaphene treatment.

EXPERIMENTS

Six Rotifera, two Cladocera, and two Copepoda were tested at six toxaphene concentrations ranging from 50 to 1000 ppb, to determine their tolerance levels. All tests were conducted in battery jars containing eight liters of filtered lake water, taken at the site where the organisms were collected. The water had an average temperature of 68° F, a dissolved oxygen content of 9.8 ppm, total alkalinity of 341 ppm, and pH of 8.4. Prior to each experiment the jars were washed with steel wool soap pads and rinsed. All organisms were collected by pumping lake water through a No. 20 plankton net and placed in the jars. The toxaphene was diluted with water and applied to the water surface with moderate mixing, and after 24 hours the plankters were removed by siphoning into a No. 20 plankton net and concentrated to 25 cc. All organisms in 2 cc of this sample were counted. In order to avoid collecting the dead and affected plankters the jars were tilted and 200 cc was left remaining in the bottom after drainage. Three trials were conducted at each concentration and the number of organisms counted was compared with untreated controls, which were maintained for all experiments (Table 10).

Experiments with larger invertebrates were conducted in an attempt to determine the concentration at which 100 percent survived for 24 hours

Table 10. A comparison in the number of zooplankters per cc in the 25 cc concentrates from the treated and control jars.

Organism.	Trial No.	50 ppb		100 ppb		250 ppb		500 ppb		750 ppb		1000 ppb	
		Cont.	Tox.	Cont.	Tox.	Cont.	Tox.	Cont.	Tox.	Cont.	Tox.	Cont.	Tox.
<u>Polyarthra</u>	I	1	1	5	4	5	6	0	2	1	0	2	1
	II	4	6	0	1	0	2	69	23	14	1	0	0
	III	7	4	7	2	1	4	10	0	10	0	2	1
<u>Hexarthra</u>	I	4	5	5	5	5	2	0	0	4	1	0	0
	II	111	133	14	6	10	10	8	0	111	2	4	1
	III	3	4	3	2	4	1	7	1	7	0	20	1
<u>Filinia</u>	I	19	26	14	35	14	14	22	11	19	1	3	0
	II	6	5	4	3	22	8	17	9	6	1	4	0
	III	7	6	7	2	3	10	12	3	12	1	2	0
<u>Keratella</u>	I	0	1	9	9	9	4	2	0	0	0	16	1
	II	1	1	35	11	2	1	23	14	1	0	35	1
	III	105	51	105	41	1	1	12	3	12	1	18	2
<u>Asplanchna</u>	I	8	10	18	14	18	22	8	3	8	0	7	0
	II	12	7	14	13	8	9	98	48	12	0	1	0
	III	11	9	10	12	13	21	1	0	1	2	7	2
<u>Brachionus</u>	I	122	136	296	252	296	278	144	102	122	10	80	6
	II	58	68	72	85	144	148	351	191	58	11	79	24
	III	27	24	27	18	281	363	94	88	88	23	84	11
<u>Daphnia</u>	I	24	21	10	8	10	3	11	7	24	1	6	0
	II	11	16	1	2	11	10	8	1	11	0	7	0
	III	5	5	5	7	36	8	7	0	7	0	28	0
<u>Bosmina</u>	I	34	43	75	79	79	13	29	4	34	0	37	8
	II	76	93	6	7	29	5	68	2	76	4	16	4
	III	19	27	19	17	69	33	88	4	88	4	202	8
<u>Diaptomus</u>	I	140	116	25	16	15	3	183	8	140	1	166	0
	II	23	27	23	9	183	5	21	0	33	0	23	1
	III	52	36	52	3	50	2	122	0	122	0	32	0
<u>Cyclops</u>	I	20	12	14	6	5	2	12	0	20	1	28	0
	II	4	6	5	6	12	1	58	3	14	0	14	0
	III	10	14	10	8	10	0	27	1	27	0	85	0
*Nauplii	I	53	49	63	40	63	15	46	11	53	2	48	0
	II	80	71	48	31	46	26	89	12	80	2	80	1
	III	50	58	50	46	59	29	73	19	73	7	152	9

* Represents both Diaptomus and Cyclops.

and 100 percent were killed (Table 11). These were carried out in galvanized tanks containing 20 gallons of lake water at 71° F. The water used, toxaphene application, and cleaning method were the same as for zooplankters. In most cases 10-20 organisms were used to calculate percent survival and mortality. Controls were maintained for two weeks, then discontinued and survival was assumed to be 100 percent, with the exception of Gammarus which showed 91 percent survival.

Fathead minnows (Pimephales promelas) approximately one inch in length were placed in all containers after washing, for 48 hours at 10-day intervals. This was done to determine whether large amounts of toxaphene were accumulating due to inadequate washing, since these minnows were found to have low tolerance levels (Hooper and Grzenda, 1955). The lowest concentration used in the experiments was 10 ppb, which produced 100 percent mortality among the test fish while all experimental organisms survived. No fathead minnows died in the washed tanks and it was assumed that the procedure was adequate.

Results

Marked reductions of rotifers were first observed at 500 ppb, cladocerans (Daphnia pulex and Bosmina) at 250 ppb, and copepods at 100 ppb (Table 10). All genera in each group exhibited similar tolerance levels. Four trials employing ten organisms each, were conducted with Daphnia magna at six concentrations. No effects were obvious at 50 to 400 ppb, however retarded movements were observed at 1000 ppb, and movements had nearly ceased at 1500 ppb. Prevost (1960) reported a median

Table 11. Tolerance levels and percent survival for several aquatic invertebrates at various toxaphene concentrations.

Organism	No. trials	Percent alive	Tox. conc. (ppb)	Organism	No. trials	Percent alive	Tox. conc. (ppb)
Hirudinea	2	100	1000	Hemiptera (cont'd.)		100	50
Amphipoda		100	100	<u>Sigara</u>	19	60	75
<u>Gammarus</u>	14	39	200			25	100
		21	300			0	150
		0	500	Trichoptera		100	500
Hydracarina	4	100	1000	<u>Limnephilus</u>	12	49	550
Ephemeroptera		100	150			20	600
<u>Callibaetis</u>	14	71	300			0	650
		13	400	Coleoptera		100	10
		0	500	<u>Halipus</u>	22	45	40
Odonata		100	200			11	50
<u>Aeschna</u>	17	84	275			0	75
		40	350	<u>Hydroporus</u>	18	100	60
		0	450			63	100
<u>Lestes</u>	21	100	450			35	300
		81	500			0	450
		33	600	<u>Dytiscus</u>	9	100	15
		0	850	(Larvae)		76	50
Hemiptera		100	275			58	60
<u>Notonecta</u>	18	71	300			0	75
		39	400	<u>Gyrinus</u>	16	100	65
		0	600			78	100
						60	150
						0	185
				Gastropoda			
				<u>Lymnaea</u>	4	100	700

tolerance limit (T.L.M.) of 0.037 ppm for cladocerans and Hooper and Grzenda (1955) found Daphnia magna to have a T.L.M. of 1.5 ppm at 55° F.

Tolerance levels (100 percent survival) for the larger invertebrates are listed in decreasing order as follows: Hirudinea, Hydracarina, Gastropoda, Trichoptera, Odonata, Hemiptera, Ephemeroptera, Amphipoda, Coleoptera (Table 11). Survival at concentrations between 100 percent survival and 100 percent mortality showed an approximate straight line relationship (Table 11). Genera within each group did not exhibit similar tolerance levels. This was evidenced among members of Odonata, Hemiptera, and Coleoptera. Lowered temperatures produced marked increases in tolerance levels. In Lestes tolerance increased approximately 35 percent by lowering the temperature ten degrees. Hooper and Grzenda (1955) found mortality in fathead minnows increased approximately three-fold by raising the temperature from 50° F to 75° F. Many of the findings are similar to those of Prevost (1960), however comparisons are difficult since he provided no temperature data.

DISCUSSION

Populations of plankton show many large variations throughout the year (Pennak, 1949; and Rawson, 1956). In the present study, the populations of organisms which could best illustrate post-treatment changes were not severely reduced, therefore no obvious effects could definitely be attributed to toxaphene treatment. Extensive fish removal can obviously be accomplished without seriously affecting the plankton, but large reductions in these organisms occur at 100 ppb (Wellitz, 1958; and Hoffman

and Olive, 1961). However, they reappear while the water is still toxic to fish (Tanner and Hayes, 1955), and begin repopulating before detoxification will permit fish survival.

No marked reductions were observed among most of the larger invertebrates. Hooper and Fukano (1960) reported bottom fauna to be nearly as abundant in two Michigan lakes after treatment (10 ppb) as before, however Stringer and McMynn (1958) found that Amphipoda was eliminated at 10 ppb and Ephemeroptera at 30 ppb. Severe reductions in many of these organisms may be expected at higher concentrations. Odonata, Ephemeroptera, Tendipedidae, and Chaoborus, were eliminated with 100 ppb toxaphene (Hooper and Grzenda, 1955; and Cushing and Olive, 1957). Unionidae, Sphaeriidae, Gastropoda, Oligochaeta, and Hirudinea appear to be more resistant (Hooper and Grzenda, 1955; and Stringer and McMynn, 1958).

Field observations were supplemented by controlled experiments, since most organisms tested were not reduced at concentrations used for fish removal. However, it should be recognized that lower tolerance levels probably exist under field conditions which involve longer exposure periods.

SUMMARY

1. The effects of different toxaphene concentrations on the plankton and other aquatic invertebrates was studied under natural and controlled conditions. Five North Dakota lakes were included in the study, which extended from June through September of both 1960-61.

2. A summary of physical and chemical data is presented for each lake.

3. Polyarthra, Keratella, Asplanchna, Conochiloides, Brachionus, Trichocerca, Daphnia, Bosmina, Ceriodaphnia, and Cyclops were the dominant zooplankters. No marked reductions were observed after treatment with 5 to 35 ppb, however a marked reduction of many plankters followed the second treatment (90-ppb) in Raleigh Reservoir.

4. Cyanophyta was the most abundant phytoplankter in all lakes. Aphanizomenon increased in all lakes post-treatment, but other phytoplankters exhibited no consistent changes. Chlorophyta, Chrysophyta, and Pyrrophyta contributed little to phytoplankton abundance.

5. The most abundant plant inhabiting organisms and bottom fauna exhibited no marked changes post-treatment. Gammarus, Physa, Gyraulus remained almost constant while Callibaetis, Caenis, Ischnura, and Tendipes decreased slightly after treatment, but were again numerous one year after treatment.

6. Controlled experiments conducted on several species of zooplankters showed Rotifera to be the most tolerant, followed in order by Cladocera and Copepoda. Noticeable reductions occurred in Rotifera at 500 ppb, Cladocera at 250 ppb, and Copepoda at 100 ppb.

7. Experiments with the larger invertebrates showed Hirudinea, Hydra-carina, and Gastropoda to be the most resistant to toxaphene, followed in order by Trichoptera, Odonata, Hemiptera, Ephemeroptera, Amphipoda, and Coleoptera.

8. Survival among the larger invertebrates at intermediate concentrations between 100 percent survival and 100 percent mortality revealed an

approximate straight line relationship. Genera within each group exhibited dissimilar tolerance levels.

LITERATURE CITED

- Cushing, C. E. and J. R. Olive. 1957. Effects of toxaphene and rotenone upon the macroscopic bottom fauna of two northern Colorado reservoirs. *Trans. Am. Fish. Soc.*, 86:294-301.
- Hoffman, D. A. and J. R. Olive. 1961. The effects of rotenone and toxaphene upon plankton of two Colorado reservoirs. *Limnol. Oceanogr.*, 6:219-222.
- Hooper, F. F. and K. G. Fukano. 1960. Summary of experimental lake treatments with toxaphene 1954-1958. *Inst. for Fish. Res., Mich. Dept. Conser.*, 17 pp. (Manuscript).
- Hooper, F. F. and A. R. Grzenda. 1955. The use of toxaphene as a fish poison. *Trans. Am. Fish. Soc.*, 85:180-190.
- Pennak, R. W. 1949. Annual limnological cycles in some Colorado reservoir lakes. *Ecol. Monog.*, 19:233-267.
1953. *Fresh-water invertebrates of the United States*. New York, The Ronald Press Co., 769 pp.
- Prevost, G. 1960. Use of fish toxicants in the Province of Quebec. *Canadian Fish Cult.*, 28:13-35.
- Rawson, D. S. 1956. The net plankton of Great Slave Lake. *J. Fish. Res. Bd. Canada*, 13:56-127.
- Stringer, G. E. and R. G. McMynn. 1958. Experiments with toxaphene as a fish poison. *Canadian Fish Cult.*, 23:39-47.
- Tanner, H. A. and M. L. Hayes. 1955. Evaluation of toxaphene as a fish poison. *Colo. Coop. Fishery Res. Unit Quart. Rept.*, 1:31-39.
- Ward, H. B. and G. C. Whipple. 1959. *Fresh-water biology*. John Wiley & Sons, Inc., 1248 pp.
- Wollitz, R. E. 1958. The effects of certain commercial toxicants on the limnology of three cold water ponds near Three Forks, Montana. M.S. thesis, Montana State College, 63 pp.

