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

Abstract:
The effects of low toxaphene concentrations on plankton and larger invertebrates were studied in five North Dakota lakes. Brachionus. Keratella, Trichocerca, Asplandhna, 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.

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TABLE OF CONTENTS

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.

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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) Surface	Temperature (°F) Bottom	Secchi disk (feet)	Total solids	Total hardness	pH	Total alkalinity	Chlorides	Sulfates	Iron
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	8/9/61	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	8/10/61	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	9/15/60	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	8/8/61	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
Brachionus	1	4	--	3
Keratella	91	15	2	1
Lecane	--	--	--	1
Trichocerca	1	--	--	--
Chromogaster	1	2	1	--
Asplanchna	73	106	--	--
Polyarthra	7	13	1	2
Filinia	1	1	--	1
Hexarthra	3	21	3	--
Daphnia	244	18	129	28
Simocephalus	--	--	1	--
Ceriodaphnia	4	9	18	--
Bosmina	98	130	18	25
Chydorus	1	--	--	--
Diaptomus	6	--	--	2
Cyclops	46	3	11	13
*Nauplii	106	26	10	73
Pandorina	3	15	--	--
Oedogonium	3	4	--	--
Cladophora	--	--	--	tr
Rhizoclonium	4	1	8	1
Pediastrum	12	5	3	61
Coelastrum	--	--	--	3
Oocystis	1	3	--	--
Closteriopsis	1	4	--	tr
Tetraedon	--	1	--	--
Scenedesmus	7	14	7	--
Mougeotia	--	--	1	--
Spirogyra	1	1	52	--
Closterium	1	4	1	tr
Cosmarium	4	1	2	--
Staurastrum	3	3	--	--
Desmidium	65	84	7	tr
Botryococcus	--	3	2	7
Diatoma	2	1	1	2
Navicula	5	6	--	--
Pinnularia	1	--	--	--
Pleurosigma	--	--	1	--
Cymbella	1	tr	--	--
Nitzschia	11	9	4	tr
Camplyodiscus	1	--	--	--
Ceratium	5	2	--	11
Synechocystis	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
Polycystis	242	131	2	110
Merismopedia	--	--	1	--
Coelospharium	50	28	1	--
Lyngbya	8	2	9	--
Anabaena	61	58	1	--
Aphanizomenon	7,377	33,157	54,716	138
Nodularia	--	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								
Gammarus	63	6	172	tr	73	44	265	tr
Hydracarina								
Hydachnidae	5	--	tr	--	2	--	23	--
Ephemeroptera								
Callibaetis	5	1	tr	--	--	--	124	tr
Caenis	6	3	1	tr	--	tr	16	tr
Odonata								
Sympetrum	tr	--	tr	tr	--	--	3	--
Aeschna	--	--	tr	--	--	--	--	--
Ischnura	40	5	10	1	--	4	56	tr
Hemiptera								
Plea	--	--	tr	--	--	--	--	--
Notonecta	1	--	--	--	3	--	10	--
Sigara	3	--	--	--	tr	--	2	--
Coleoptera								
Haliplus	2	--	tr	--	--	--	1	--
Copelatus	tr	--	--	--	tr	--	2	--
Hydroporus	--	--	--	--	1	--	tr	--
Trichoptera								
Hydroptila	--	1	--	tr	--	--	--	--
Diptera								
Tendipes	44	28	9	12	48	9	25	25
Probezzia	tr	3	--	2	--	--	--	--
Chrysops	--	1	--	1	--	--	--	--
Gastropoda								
Physa	123	2	325	1	156	3	886	6
Gyraulus	648	tr	782	1	1,210	9	672	1
Pelecypoda								
Pisidium	--	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
Brachionus	114	108	15	3
Keratella	13	11	9	7
Platyias	tr	17	1	--
Lecane	tr	2	--	--
Monostyla	1	1	--	5
Trichocerca	5	--	--	tr
Chromogaster	1	3	--	1
Asplanchna	24	194	16	1
Polyarthra	3	15	7	1
Synchaeta	1	11	13	--
Filinia	tr	1	--	tr
Testudinella	1	--	tr	--
Trochosphaera	tr	--	1	--
Hexarthra	2	--	--	--
Conochiloides	3	11	--	--
Daphnia	65	173	57	9
Ceriodaphnia	44	156	100	1
Bosmina	314	283	50	--
Chydorus	4	17	1	--
Diaptomus	10	1	1	--
Cyclops	120	9	41	8
*Nauplii	190	85	19	7
Elakothrix	--	--	1	--
Microspora	--	1	3	--
Oedogonium	9	3	1	--
Rhizoclonium	7	5	3	1
Golenkinia	--	3	--	--
Pediastrum	151	462	3	3
Coelastrum	7	594	--	--
Oocystis	69	75	2	--
Chodatella	4	15	--	--
Closteriopsis	18	462	1	--
Tetraedon	11	89	--	--
Scenedesmus	727	3,038	133	1
Crucigenia	17	264	4	--
Tetrastrum	--	3	--	--
Mougeotia	--	1	1	--
Zygnema	1	--	--	--
Spirogyra	2	4	19	107
Closterium	--	--	2	tr
Cosmarium	20	4	5	1
Staurastrum	4	9	--	--
Desmidium	925	1,189	4	--

Table 4, continued.

Organism	Before 8/3/60	After 8/15/60	After 9/6/60	** After 8/10/61
Botryococcus	5	8	7	--
Melosira	4	9	--	2
Diatoma	8	--	3	1
Synedra	4	3	--	3
Navicula	6	1	1	--
Pinnularia	1	--	1	--
Frustulia	--	tr	1	--
Gyrosigma	--	tr	--	--
Pleurosigma	tr	--	--	--
Gomphonema	tr	1	--	--
Cymbella	4	4	1	--
Nitzschia	8	14	7	8
Cymatopleura	2	1	--	--
Camplyodiscus	2	--	--	--
Ceratium	24	7	4	5
Synechocystis	54,161	6,275	2,312	601,057
Polycystis	2,906	859	38	99
Merismopedia	9	7	1	--
Coelospharium	2	25	94	4
Lyngbya	10	1	8	1
Anabaena	5	4	16	2
Aphanizomenon	6	190	81,902	tr
Nodularia	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, Closteriopsis, 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, Coelosphærium, 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. Coelosphærium 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								
Gammarus	31	4	313	tr	569	3	334	1
Hydracarina								
Hydrachnidae	45	--	27	--	22	--	14	--
Ephemeroptera								
Callibaetis	66	1	9	tr	tr	--	60	--
Caenis	185	6	10	tr	6	--	3	--
Odonata								
Sympetrum	--	--	1	--	tr	--	17	--
Anax	--	--	--	--	--	--	1	--
Aeschna	tr	--	tr	--	--	--	1	--
Ischnura	109	2	21	1	8	--	134	--
Hemiptera								
Notonecta	2	--	tr	--	tr	--	5	--
Sigara	39	2	tr	--	--	--	--	--
Coleoptera								
Copelatus	--	--	tr	--	--	--	--	--
Hydroporus	2	--	7	--	6	--	8	--
Diptera								
Chaoborus	--	1	--	--	--	--	--	--
Tendipes	12	27	tr	2	1	6	52	71
Probezzia	tr	--	tr	--	--	--	--	--
Chrysops	--	--	tr	--	--	tr	--	--
Gastropoda								
Physa	5	--	13	--	6	--	22	--
Gyraulus	1,163	tr	1,695	4	398	2	38	--
Pelecypoda								
Pisidium	--	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 S.L.	Before 7/15/60 N.L.	After 7/21/60 S.L.	After 7/21/60 N.L.	After 8/26/60 S.L.	After 8/26/60 N.L.	After 9/15/60 S.L.	After 7/19/61 S.L.
Brachionus	--	2	1	1	tr	--	1	--
Keratella	35	28	48	22	1	25	11	12
Lecane	tr	--	--	--	1	tr	--	tr
Monostyla	3	--	2	--	9	2	1	2
Trichocerca	234	111	83	86	31	5	3	3
Ascomorpha	1	3	5	4	4	tr	tr	1
Chromogaster	tr	2	tr	2	3	--	tr	1
Asplanchna	28	3	24	6	1	12	--	20
Polyarthra	4	27	35	34	42	32	28	16
Synchaeta	17	1	19	3	10	2	1	tr
Filinia	3	3	25	2	7	2	2	3
Testudinella	--	--	--	tr	--	--	--	tr
Hexarthra	11	1	15	2	--	1	--	tr
Conochiloides	182	14	160	34	1	10	--	tr
Stephanoceros	--	--	--	--	--	tr	--	--
Daphnia	1	9	1	2	9	5	16	41
Simocephalus	1	--	2	--	1	1	tr	tr
Ceriodaphnia	37	99	67	37	40	18	7	1
Bosmina	110	67	119	35	8	18	8	1
Graptolebris	--	--	--	--	4	--	--	--
Chydorus	10	1	2	tr	20	3	19	5
Diaptomus	1	12	tr	13	tr	5	--	2
Cyclops	17	17	4	17	13	9	22	44
*Nauplii	29	83	17	76	28	37	11	67
Pandorina	1	tr	1	1	5	5	5	5
Volvox	tr	tr	1	1	15	1	1	--
Apiocystis	--	--	--	--	--	--	--	tr
Oedogonium	--	1	tr	tr	3	--	tr	--
Rhizoclonium	tr	tr	tr	tr	--	--	--	--
Pediastrum	4	17	2	7	7	38	6	6
Coelastrum	tr	tr	tr	tr	--	--	1	--
Oocystis	1	1	1	1	1	tr	--	2
Chodatella	--	tr	tr	--	--	--	--	tr
Closteriopsis	1	2	1	2	2	tr	1	5
Kirchneriella	--	tr	--	--	--	--	--	--
Tetraedon	--	--	tr	--	--	--	--	--
Scenedesmus	tr	1	1	1	1	2	tr	1
Crucigenia	tr	tr	8	--	1	--	1	1
Mougeotia	--	--	--	--	--	--	tr	tr
Spirogyra	tr	1	tr	--	1	--	tr	tr
Closterium	tr	--	tr	--	--	--	--	--