INVESTIGATIONS IN FISH CONTROL

3. Minimum Lethal Levels of Toxaphene as a Piscicide in North Dakota Lakes

4. Effects of Toxaphene on Plankton and Aquatic Invertebrates in North Dakota Lakes

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INVESTIGATIONS IN FISH CONTROL

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NOTE

Toxaphene has never been registered for use as a piscicide. The Bureau of Sport Fisheries and Wildlife has discontinued management use of toxaphene at least until completion of definitive studies on detoxification in relation to water quality, residual toxicities, and short-term effects of its use on aquatic organisms. These six papers on toxaphene and its effects are published as contributions to an understanding of the chemical and its use in fish management.

INVESTIGATIONS IN FISH CONTROL

3. Minimum Lethal Levels of Toxaphene as a Piscicide in North Dakota Lakes

By Dale L. Henegar
Chief, Fish Management Division
North Dakota Game and Fish Department

U.S. DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
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CONTENTS

MINIMUM LETHAL LEVELS OF TOXAPHENE AS A PISCICIDE IN NORTH DAKOTA LAKES

By Dale L. Henegar, Chief, Fish Management Division
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Abstract.--To determine minimum levels of toxaphene lethal to fishes in prairie lakes and reservoirs, 16 North Dakota lakes, ranging from 6.3 to 915 acres, were treated in 1959 and 1960 with concentrations of toxaphene ranging from 0.005 to 0.035 p.p.m. Physical and chemical studies were made of each area, hydrological maps were prepared, and test netting was carried out before and after treatment; application methods and equipment were according to North Dakota Game and Fish Department regulations. Mortality after treatment varied from incomplete, involving only young-of-the-year fish, to complete. A marked selective mortality pattern was noted: smaller fish succumbed at lower dosages; as the concentrations were increased, larger fish were killed. Duration of toxicity did not appear excessive--five of the seven lakes in which mortality was complete were successfully restocked within 7 months after treatment.

Toxaphene (chlorated camphene) has not been widely used as a piscicide for local field application because minimum lethal concentrations in the field have not been determined. Considerable information has been gained from laboratory bioassay studies (Surber, 1948; Doudoroff et al., 1953; Hooper and Grzenda, 1957; Henderson et al., 1959), but the concentrations indicated by such studies are not necessarily correct for field use. Prevost (1960) pointed out that results of controlled laboratory experiments do not always yield dosages giving similar results in the field, where there are a number of variables, both known and unknown, over which the field worker has little or no control.

Gebhards (1960) in his review lists 14 Western States and 6 Canadian Provinces that have used toxaphene in fish-control programs in various formulations at concentrations ranging from a low of 0.003 parts per million (p.p.m.) to a high of 0.61 p.p.m. Inconsistencies were emphasized in the review by the side variations in results. Fifteen of the reports said an average concentration of 0.185 p.p.m. failed to kill all fishes in treated areas, while 23 reports mention that an average concentration of 0.139 p.p.m. caused complete mortality. Stringer and McMynn (1958) reported complete kills at from 0.010 p.p.m. to 0.036 p.p.m.

In North Dakota, mortality of fish was complete when toxaphene was applied at a concentration of 0.070 p.p.m., which was not considered the minimum lethal level (Henegar, 1958). It was to determine the desirable minimum concentration for management use in North Dakota that this study was initiated.

Sixteen lakes were chosen for treatment during 1959 and 1960. All were test netted to determine existing populations of fish both before and after treatment. Physical and chemical characteristics were studied to establish criteria. Application of the toxaphene followed procedures commonly used by the North Dakota Game and Fish Department.

This publication is based on a thesis submitted to the Graduate Faculty, Department of Agriculture, South Dakota State College of Agriculture and Mechanic Arts, in partial fulfillment of the requirements for the degree of Master of Science, June 1961.

For lakes with physical and chemical characteristics of those in the Great Plains, recommended concentrations range from 0.025 to 0.030 p.p.m. as indicated in table 1. Concentrations used on the project areas ranged from 0.005 to 0.035 p.p.m.

TABLE 1.--Recommended concentration of toxaphene for various types of lakes.

[William Cooper & Nephews, Chicago, Ill., 1958]

Concentration of toxaphene	Lake type
25-30 p.p.b.[1].....	Unstratified, shallow, hard-water lakes of low transparency and high productivity.
15-20 p.p.b.......	Unstratified, soft-water lakes of moderate or high transparency.
10-20 p.p.b.......	Stratified lakes of moderate depth (mean depth less than 20 feet) and moderate to low transparency.
7.5-10 p.p.b......	Stratified lakes of great depth (mean depth greater than 20 feet), high transparency, and low productivity.

[1] One report indicates that a concentration of 50-100 p.p.b. should be used in highly turbid waters containing suspended clay (Secchi disk reading less than 1 foot).

I wish to express my appreciation to Marvin O. Allum, Assistant Professor of Zoology, for his suggestions, interest, and constructive criticism during this study. I also wish to thank Dr. Donald Progulske, Assistant Professor of Zoology, for his advice and suggestions on preparation of the manuscript. I am obliged to all the members of the Fishery Division of the North Dakota Game and Fish Department who generously contributed time and suggestions on the field work.

CHARACTERISTICS OF TOXAPHENE

Toxaphene is one of the group of toxicants known as cyclodione insecticides, which also includes aldrin, dieldrin, chlordane, heptachlor, endrin, and isodrin. Toxaphene is not as well characterized chemically as the others, and the precise nature of the compounds in the mixture of isomers is not known (Negherbon, 1959). Most frequently encountered formulations are 10- to 20-percent dusts, 40-percent wettable powders, and emulsifiable concentrates of 4, 6, and 8 pounds per gallon.

The commercial product used in the study was Agricultural Cooper-Tox No. 6 (toxaphene emulsifiable concentrate) manufactured by William Cooper & Nephews, Chicago, Ill. The formulation contained 6 pounds of technical toxaphene per gallon.

Toxaphene remains toxic for extended periods of time following application as a piscicide. Ten Michigan lakes treated in 1949 and 1950 detoxified in from 8 to 33 months. Other Michigan lakes detoxified in from 2 to 10 months after being treated at a concentration of 0.010 p.p.m. (Hooper and Grzenda, 1957). Stringer and McMynn (1960) reported that several British Columbia lakes remained toxic for over 2 years after treatment. Application at 1.00 p.p.m. (2.7 lbs. per acre-foot) gave concentrations of from 0.40 to 0.50 p.p.m. toxaphene.

Application rates do not appear to be important to the duration of toxicity when applied within the median tolerance limits of fishes. Mayhew (1959) stated that the period of toxicity is more related to chemical and physical characteristics of treated lakes than to the concentration of toxaphene.

The factors which influence detoxification are dilution, water temperature, water circulation, oxygen levels, turbidity, alkalinity, types of substrate, microorganisms, and ratio of water to bottom interface (Hemphill, 1954; Hooper and Grzenda, 1957; Rose, 1958; Henegar, 1958; Prevost, 1960).

Detoxification takes place very slowly when ice cover is present and more rapidly when water temperatures are high and conditions are favorable for the growth of plankton and other microorganisms.

METHOD OF APPLICATION

Toxaphene has been applied in various ways, the method usually depending on the formulation. The wettable powder has been applied by aircraft and by placing it in burlap bags and then towing in the wake of an outboard motor (Henegar, 1953). The emulsifiable liquid has been applied by aircraft, but most commonly by distributing premixed solutions with powder sprayers mounted in boats. One method is the metering of desired amounts into the wake of a moving outboard-powered boat (Stringer and McMynn, 1960), but unless this is carefully controlled the toxaphene solution may settle to the bottom in a comparatively undiluted state.

In this study, a pumping system used by the North Dakota Game and Fish Department was employed (fig. 1). It consists of a 55-gallon drum connected to a motor-driven centrifugal pump with two outlet pipes terminating in common garden-type nozzles extending behind the boat transom on each side. During use, the nozzles are in contact with the surface of the lake to minimize airborne spray from coming in contact with the boat operator.

The toxaphene was premixed in the barrel at a maximum ratio of 1 gallon to 5 gallons of water so that a minimum of 55 gallons of liquid was available for spraying on each lake. During application the spray boat, powered by an 18-horsepower outboard motor, was operated at full throttle. This allowed for a maximum coverage of 200 acres an hour. On smaller lakes adjustment of the nozzles reduced application time to as little as 30 minutes.

The spray unit was left intact in the boat after each project, when the boat was loaded onto a boat trailer. This reduced the time necessary to ready equipment for each treatment.

Figure 1.--Spray boat used in application of toxaphene on project lakes.

Areas for treatment were determined from prepared hydrographic maps of each lake. Lakes over 100 acres in size were subsectioned, and each subsection was treated as a separate unit.

CHARACTERISTICS OF THE LAKES

For study I selected 16 lakes, varying in size from 6.3 to 915 acres, in widely scattered areas of North Dakota. Seven are impoundments, and nine are natural. Maximum depths ranged from 8 to 26 feet, and volume from 79 to 8,254 acre-feet (table 2). At the time of treatment, none of the lakes were chemically or thermally stratified.

Water samples were taken from all lakes, and field analyses were made to determine chemical characteristics of the water (table 2). Concurrently, 1-gallon samples of water were forwarded to the North Dakota Health Department to check the accuracy of the field analyses. The variation in results between field and laboratory analyses was not significant.

With one exception, all the lakes had extensive growths of aquatic vegetation extending from shore outward to a depth of 8 feet. Potamogeton spp. and Myriophyllum spp. were particularly abundant, with Polygonum spp. and Sagittaria spp. prevailing less frequently. In all the lakes, primary bottom composition was silt, mud, clay, and organic material. Areas of sand, gravel, and rubble were of minor importance and were restricted to the natural lakes.

TABLE 2.--Physical and chemical characteristics of project lakes

Lake	Size	Maximum depth	Volume	pH	Alkalinity		Hardness	Total dissolved solids
					Phenol-phthalein	Methyl orange		
	Acres	Feet	Acre-feet		P.p.m.	P.p.m.	P.p.m.	P.p.m.
Odland Lake	103.3	19	712.9	8.2	120	180	171	414
Brush Lake	160.2	23	1,526.7	8.5	40	460	476	290
Long Lake	290.8	23	2,390.6	8.3	40	220	308	307
Gumms Lake	173.6	8	853.7	9.0	84	442	821	816
North Lake Metigoshe	670.8	22	7,588.5	8.8	20	210	205	317
South Lake Metigoshe	915.0	22	8,254.4	8.7	30	240	238	326
Red Willow Lake	129.9	26	1,272.8	8.0	24	178	239	364
Frettum Lake	95.2	22	511.7	8.3	54	496	444	281
North Lake Tobiason	50.3	14	472.8	8.6	44	282	359	779
Bowbells Mine Lake	6.3	21	78.9	9.9	0	800	2,385	4,100
Glen Ullin Reservoir	12.3	18	144.4	8.0	60	420	136	418
South Lake Tobiason	40.1	10	286.9	8.5	106	460	547	1,452
Nieuwsma Lake	80.8	23	651.2	7.9	0	140	136	415
Cat Coulee Lake	8.0	17	87.4	8.8	30	130	170	328
Wolf Butte Lake	17.3	14	137.5	9.4	100	260	114	940
Jund Lake	18.5	14	162.9	8.0	20	80	51	306

TEST NETTING

Qualitative sampling of fish populations in all lakes was carried out before and after treatment (table 3). Three types of gear were used. gill nets, small-mesh seines, and small-mesh frame nets.

The gill nets were experimental nylon nets, 250 by 6 feet, composed of 50-foot sections of increasing mesh size: 3/4, 1, 1-1/4, 1-1/2, and 2 inches. Total netting effort for each lake varied according to size: a greater number of sets were made in larger lakes. The nets were fished in diurnal and nocturnal periods to lend validity to the results. Although this type of gear is subject to considerable error, estimates of fish populations may be made from the data. During the project period all lakes were gill-netted a total of 2,304 hours, representing 96 individual sets.

Shoreline seining with a 100- by 6-foot, 1/4-inch-mesh, nylon bag seine was done where vegetation was not too dense. Data so gathered were of limited value owing to

TABLE 3.--Fishes in project lakes.

Rainbow trout, Salmo gairdneri Richardson.
Northern pike, Esox lucius Linnaeus.
Carp, Cyprinus carpio Linnaeus.
Golden shiner, Notemigonus crysoleucas (Mitchill).
Bluntnose minnow, Pimephales notatus (Rafinesque).
White sucker, Catostomus commersoni (Lacepede).
Black bullhead, Ictalurus melas (Rafinesque).
Brown bullhead, Ictalurus nebulosus (LeSueur).
Orangespotted sunfish, Lepomis humilis (Girard).
Bluegill, Lepomis macrochirus Rafinesque.
White crappie, Pomoxis annularis Rafinesque.
Black crappie, Pomoxis nigromaculatus (LeSueur).
Yellow perch, Perca flavescens (Mitchill).
Walleye, Stizostedion vitreum vitreum (Mitchill).

inconsistent results. Altogether, 71 drags were made in project lakes, representing a coverage of 35,500 square feet.

Small-mesh frame nets produced valid data on populations of fishes inhabiting the littoral zone. These nets were originally designed to sample young-of-the-year northern pike in heavily vegetated areas. The front frame of each net was 3 feet high and 4 feet wide (fig. 2); the net was 15 feet long and had round wooden hoops behind the front rectangular frame. The webbing was 1/4-inch nylon dyed a dark brown. The single tunnel used the string type of construction rather than open orifice, and the net retained the trapped fishes very satisfactorily. The single, 50-foot lead from the front frame was of the same material as the body of the net. In use, the frame nets were placed at right angles to the shoreline. A net of this type can be placed in position by one man, and sets are made without using a boat. Representative catches were made in all types of habitat. The frame nets were fished a total of 3,704 hours during the project period.

Figure 2.--Small-mesh frame net used to sample fishes in the littoral zone.

RESULTS

ODLAND LAKE

Odland Lake was treated on August 12, 1960, with toxaphene at a concentration of 0.005 p.p.m. No effects of the toxaphene were observed for 10 hours following application; after this period, distressed young-of-the-year yellow perch and black bullheads were noted in the shallow bays and backwaters. Within 36 hours many of these small fishes were either lying dead on the bottom or washed ashore. Evident mortality ceased 48 hours after application. In the observation period only seven larger fish were noticeably affected. The small fish decomposed rapidly, and after 7 days evidence of their mortality disappeared.

The lake was test-netted 48 days after treatment. Net frequencies (table 5) were not significantly changed from those arrived at before the toxaphene was used. In this lake the net frequencies did not show the true population

TABLE 4.--Concentrations of toxaphene applied and fish mortality in project lakes

Lake	Concentration (p.p.m.)	Mortality
Odland Lake	0.005	Incomplete
Brush Lake	0.010	Incomplete
Long Lake	0.010	Incomplete
Gumms Lake	0.010	Incomplete
North Lake Metigoshe	0.015	Incomplete
South Lake Metigoshe	0.015	Incomplete
Red Willow Lake	0.015	Incomplete
Frettum Lake	0.020	Incomplete
North Lake Tobiason	0.020	Incomplete
Bowbells Mine Lake	0.025	Complete
Glenn Ullin Reservoir	0.025	Complete
South Lake Tobiason	0.025	Complete
Nieuwsma Lake	0.025	Complete
Cat Coulee Lake	0.030	Complete
Wolf Butte Lake	0.030	Complete
Jund Lake	0.035	Complete

TABLE 5.--Changes in test-netting frequencies following application of toxaphene in project lakes

[Frequencies are computed as fish per hour per net both for frame and gill nets. Seining data not used]

	Concentration (p.p.m.)	Frequency		Reduction (Percent)
		Before treatment	After treatment	
Odland Lake	0.005	6.91	6.94	None
Brush Lake	0.010	6.88	1.34	80.5
Long Lake	0.010	10.38	1.59	84.6
Gumms Lake	0.010	34.46	7.96	76.9
North Lake Metigoshe	0.015	8.46	1.07	87.3
South Lake Metigoshe	0.015	6.46	1.11	83.2
Red Willow Lake	0.015	10.20	2.50	75.4
Frettum Lake	0.020	6.36	.32	94.9
North Tobiason Lake	0.020	12.91	.33	97.4
Bowbells Mine Lake	0.025	.95	0.00	100.0
Glen Ullin Reservoir	0.025	6.91	0.00	100.0
South Lake Tobiason	0.025	7.29	0.00	100.0
Nieuwsma Lake	0.025	5.89	0.00	100.0
Cat Coulee Lake	0.030	4.06	0.00	100.0
Wolf Butte Lake	0.030	15.08	0.00	100.0
Jund Lake	0.035	3.62	0.00	100.0

structure. Young-of-the-year fishes taken during pretreatment test netting (table 6) were absent from the data. Average sizes of larger fishes remained relatively stable, reflecting insignificant mortality.

BRUSH LAKE

Brush Lake was treated on October 5, 1959, with toxaphene at a concentration of 0.010 p.p.m. Application preceded lake freeze-up by only 2 days. During the 2 days that observations could be made, no affected fish were found. The following spring (157 days after treatment) thousands of partly decomposed yellow perch (2.1 to 6.1 inches) were washed on shore. Seventeen walleyes (9.8 to 12.3 inches) and five northern pike (10.1 to 13.1 inches) were recorded. Further observations for 5 days after breakup did not reveal additional current mortality.

Ninety-six hours of posttreatment test netting starting on April 22, 1960, disclosed only a partial mortality among the fishes. It was evident from the results (table 7) that although mortality was heavy among the young-of-the-year and older yellow perch (2.1 to 5.9 inches), little difference in the abundance of the larger fishes could be found. Total test netting frequency was reduced by 80.5 percent (table 5).

On May 27, 1960, Brush Lake was stocked with 29,000 northern pike fingerlings (2,000/lb.). On June 26, 1960, it was stocked with 48,000 walleye fingerlings (1,600/lb.) and on August 1, 1960, with 200,000 bluntnose minnows (1,000/lb.).

TABLE 6.--Odland Lake test netting data before and after treatment with 0.005 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (134 hours):			
Black bullhead	418	4.0 - 11.6	5.8
Do	405	young-of-year	--
Yellow perch	44	3.4 - 6.5	5.5
Golden shiner	27	5.1 - 6.5	6.1
Northern pike	17	16.0 - 28.3	21.7
White sucker	9	9.0 - 18.5	13.6
White crappie	3	7.5 - 8.5	8.0
Orangespotted sunfish	2	5.5 - 5.6	5.5
After treatment (152 hours):			
Black bullhead	904	5.0 - 10.5	5.7
Do	0	young-of-year	--
Northern pike	59	15.0 - 29.0	21.8
Yellow perch	48	3.5 - 12.5	5.8
White crappie	19	5.5 - 9.0	7.3
Golden shiner	17	6.0 - 7.1	6.5
Orangespotted sunfish	11	5.5 - 6.0	5.6
White sucker	1	16.7	17.7

TABLE 7.--Brush Lake test netting data before and after treatment with 0.0 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (144 hours):			
Yellow perch	908	2.6 - 13.7	4.1
Do	894	young-of-year	--
Walleye	49	9.7 - 17.7	15.6
Northern pike	32	10.3 - 27.2	20.3
White sucker	4	10.1 - 10.5	10.3
After treatment (96 hours):			
Yellow perch	57	6.0 - 12.8	7.2
Do	0	young-of-year	--
Northern pike	56	17.6 - 30.2	22.4
Walleye	39	15.8 - 18.1	16.1
White sucker	7	10.8 - 11.1	10.9

Additional test netting of the lake in September proved good survival and growth of al stocked fishes. This test netting also substantiated results from the posttreatment survey.

LONG LAKE

Long Lake was treated on July 17, 1960, wi toxaphene at a concentration of 0.010 p.p.m. Mortality during the first 3 hours after application was light and was restricted to young-of-the-year yellow perch. At the end of 5 hours, yearling and 2-year-old yellow perch were in distress. Twenty hours later yellow perch up to 5.1 inches were either moribund or dead in all sections of the lake. At this tim distressed and dying young-of-the-year north- ern pike were found. Deaths continued until 72 hours after treatment, when the last affected fish were observed. During the apparent peric of toxicity only two dead 10-inch walleyes and no northern pike larger than young-of-the-yea were observed. No dead white suckers could b located.

On August 18, approximately 1 month after treatment, Long Lake was stocked with 160,00 (360/lb.) bluntnose minnows. Periodic observa- tions for 10 days after stocking indicated no mortality of these fishes.

During posttreatment test netting begun on October 25, the stocked minnows were frequently taken in the small-mesh frame nets. Yields of these small-mesh frame nets (table denoted that the toxaphene had either severely reduced or eliminated yellow perch less than 5.5 inches in length. Partial reduction of young-of-the-year northern pike was evident.

TABLE 8.--Long Lake test netting before and after treatment with 0.010 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (250 hours):			
Yellow perch	1,240	2.6 - 6.8	3.8
Do	1,017	young-of-year	--
Northern pike	6	26.0 - 31.3	28.2
Do	327	young-of-year	--
Walleye	3	10.0 - 10.3	10.1
After treatment (250 hours):			
Yellow perch	263	5.6 - 6.8	6.5
Do	0	young-of-year	--
Northern pike	5	25.1 - 32.1	28.6
Do	114	young-of-year	--
Walleye	3	10.3 - 10.6	10.4
White sucker	3	17.3 - 17.6	17.5

Total net frequency on all fishes was reduced by 84.6 percent (table 5). No measurable changes were found in the populations of adult northern pike, walleyes, or white suckers (table 8).

GUMMS LAKE

Gumms Lake was treated on August 8, 1959, with toxaphene at a concentration of 0.015 p.p.m. At time of treatment the lake contained the largest yellow perch population of all project lakes (table 9). One hour after application, small affected yellow perch were seen over most of the surface of the lake. After 3 hours many yellow perch (2.4 to 6.6 inches) were either distressed or dead. This condition was maintained for 26 hours, after which the incidence started a rapid decline. The last moribund fish was located 71 hours after treatment, and by this time thousands of yellow perch lined the shore and were floating on the lake. During the period of mortality no yellow perch larger than 7 inches were seen.

Test netting on September 14, 1958, revealed an incomplete kill. No yellow perch smaller than 5.5 inches were taken, but the abundance of larger yellow perch remained unchanged (table 9). Average size of fishes taken during this posttreatment netting increased from 5.3 to 7.8 inches (table 9). Total net frequency indicated a gross reduction of 87.3 percent (table 5).

Plans for additional test netting of this lake in 1960 were abandoned after winter-kill conditions during the winter of 1959-60.

TABLE 9.--Gumms Lake test netting before and after treatment with 0.010 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (28 hours):			
Yellow perch	964	3.1 - 10.2	5.3
After treatment (28 hours):			
Yellow perch	223	7.0 - 10.3	7.8

NORTH LAKE METIGOSHE

North Lake Metigoshe was treated on September 13, 1960, with toxaphene at a concentration of 0.015 p.p.m. It was the second largest lake in the project and contained the most desirable fish population. Because of its size, it was treated in segments, and each was sprayed as a separate unit. Application was completed in 6 hours.

Reaction of the fishes to the toxaphene was slow because of low water temperature of 43 F., but by the end of 14 hours following completion of treatment surfacing of small fishes was noted. Young-of-the-year yellow perch and black bullheads were affected first, followed by larger perch (2.0 to 3.2 inches) and bullheads (2.2 to 5.8 inches) after 20 hours. Thirty-six hours later, numbers of dead and affected perch and bullheads were blown to the north shore by a strong southerly wind that prevailed for 10 hours. Frequency of distressed fishes was highest after 72 hours, after which there was a rapid decline. All activity had ceased at the end of 12 days.

Observations of gross mortality after 96 hours disclosed countless yellow perch ranging from young-of-the-year to 5.1 inches in length, 181 northern pike (11.9 to 18.4 inches), and 17 walleyes (14.2 to 15.2 inches). No mortality of white suckers was noted. Observers checking the bays and shallow water failed to find any living bullheads or yellow perch.

Posttreatment netting was delayed to 3 days before freeze-up (October 24). Observations made on the lake during the period of toxicity were confirmed by the results of the test netting (table 10). The toxaphene had failed to kill all fishes in the lake (fig. 3). Yellow perch

TABLE 10.--North Lake Metigoshe test netting data before and after treatment with 0.015 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (322 hours):			
Yellow perch	1,305	2.4 - 10.1	4.1
Do	626	young-of-year	--
Black bullhead	416	2.1 - 11.1	4.8
Do	1,438	young-of-year	--
Walleye	46	13.0 - 25.3	17.6
Northern pike	27	12.0 - 24.8	16.1
Bluntnose minnow	17	--	--
White sucker	9	17.7 - 23.0	19.9
After treatment (322 hours):			
Yellow perch	49	4.3 - 9.6	6.8
Do	0	young-of-year	--
Black bullhead	246	6.1 - 10.2	7.6
Do	0	young-of-year	--
Walleye	39	19.1 - 26.2	22.8
Northern pike	15	13.3 - 24.7	19.3
White sucker	8	17.6 - 24.0	19.8

Figure 3.--Fish taken in gill net from North Lake Metigoshe after treatment with 0.015 p.p.m. toxaphene.

from young-of-the-year to 4.0 inches and black bullheads from young-of-the-year to 5.8 inches were absent from the nets. The average sizes of yellow perch and black bullheads increased from 4.1 inches to 6.8 inches and 4.8 inches to 7.6 inches respectively (table 10). Average sizes of northern pike, walleyes, and white suckers stayed approximately the same. Reduction in total test net frequency was 87.3 percent (table 5).

SOUTH LAKE METIGOSHE

South Lake Metigoshe was treated on July 7, 1960, with toxaphene at a concentration of 0.015 p.p.m. It was the largest lake in the project and for convenience was divided into segments for treatment. Application of the toxaphene was completed in 7 hours.

High water temperature (75° F.) at time of treatment caused the toxaphene to act rapidly on the fishes. One hour after starting application small yellow perch and black bullheads were surfacing. Frequency of distress increased rapidly, and at the end of 2 hours moribund and dead fishes were seen in treated areas (fig. 4). Rate of death increased in all parts of the lake for another 48 hours and then began a rapid decrease. Ninety-six hours later

Figure 4.--Moribund and dead young-of-the-year yellow perch taken at South Lake Metigoshe 4 hours after treatment with 0.015 p.p.m. of toxaphene.

major activity had stopped. Ten days later a discontinuation of activity was obvious.

Five to 7 days after treatment, "float-up" took place as thousands of decomposing fish floated into shore. This caused a public-relations problem of some magnitude with the 491 cabin owners on the lake and emphasized the value of fall treatment. Mortality estimates made at the time were of questionable value because fishes were picked up and disposed of as soon as they came to shore. It seemed, however, that while many smaller fishes had succumbed, the larger fishes were unaffected.

Posttreatment test netting (table 11) from September 17 to 20 proved the kill was incomplete. Young-of-the-year yellow perch, black bullheads, and northern pike were severely reduced. The only area containing any of these fishes was close to the entrance from North Lake Metigoshe. It is probable that they migrated into the area from this entrance following detoxification.

Yellow perch (2.4 to 4.0 inches) and black bullheads (2.1 to 4.2 inches) were absent from the population samples taken after treatment. Frequencies and average sizes of the northern pike, walleyes, and white suckers in the posttreatment population were relatively the same as before treatment. Total test netting frequency was reduced by 83.2 percent (table 5).

After the presence of walleyes and northern pike was established by the posttreatment netting, some sport fishing took place. A small number of both fishes were taken until fishing was halted by freeze-up.

TABLE 11.--South Lake Metigoshe test netting data before and after treatment with 0.015 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (333 hours):			
Yellow perch	2,984	2.4 - 9.5	4.0
Do	2,024	young-of-year	--
Black bullhead	737	2.1 - 9.7	6.7
Do	814	young-of-year	--
Northern pike	18	10.7 - 21.7	18.1
Do	142	young-of-year	6.1
Walleye	19	7.5 - 25.5	18.3
Bluntnose minnow	2	--	--
After treatment (290 hours):			
Yellow perch	104	4.1 - 9.4	9.3
Do	17	young-of-year	--
Black bullhead	520	4.2 - 9.6	7.9
Do	26	young-of-year	--
Northern pike	19	14.1 - 22.3	20.1
Do	28	young-of-year	9.1
Walleye	22	12.1 - 24.2	18.6

RED WILLOW LAKE

Red Willow Lake was treated on July 17, 1959, with toxaphene at a concentration of 0.020 p.p.m. During application the water temperature was 72° F., and action of the toxicant was rapid. Small yellow perch and black bullheads surfaced 1 hour after spraying was begun. Surfacing movements became more rapid and then waned at the end of 72 hours. Many yellow perch (3.1 to 6.8 inches) and black bullheads (3.2 to 5.6 inches) were discovered in the vegetation and along the shore. Observations also disclosed 73 dead northern pike (12.4 to 17.6 inches) and only 2 dead white suckers (17.2 inches).

Test netting of the lake on October 13, 1959, (table 12) disclosed an incomplete kill of the fish population. The reduction of yellow perch was of consequence, but the black bullheads retained their original abundance. Average length of the yellow perch increased from 5.3 to 6.9 inches, while the average length of the black bullheads increased only from 6.8 to 6.9 inches. Frequencies of larger fishes failed to display a positive reduction. Total net frequency was lowered by 75.4 percent (table 5).

FRETTUM LAKE

Frettum Lake was treated on July 19, 1959, with toxaphene at a concentration of 0.020 p.p.m. Pretreatment test netting of this lake

TABLE 12.--Red Willow Lake test netting data before and after treatment with 0.015 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (48 hours):			
Yellow perch	351	3.7 - 7.1	5.3
Black bullhead	120	3.8 - 9.0	6.8
Northern pike	12	13.0 - 27.5	19.9
White sucker	7	14.0 - 18.5	17.4
After treatment (48 hours):			
Yellow perch	5	6.6 - 7.2	6.9
Black bullhead	103	3.9 - 8.2	6.9
Northern pike	13	9.0 - 16.7	14.7
White sucker	2	14.9 - 15.0	14.9

revealed a dense population of yellow perch except for young-of-the-year. In only 3 hours after application, numerous fishes were either dead or distressed. After 96 hours further movement could not be found. This initial high mortality of the perch suggested the possibility of a complete kill. Posttreatment test netting on October 21, 1959, proved this assumption to be incorrect. Although smaller yellow perch (4.0 to 6.4 inches) were absent from the test nets, larger yellow perch were taken (table 13). The average length of the yellow perch increased from 5.3 to 7.3 inches, and percent reduction of total netting frequency was 94.9 (table 5).

TABLE 13.--Frettum Lake test netting data before and after treatment with 0.020 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (120 hours):			
Yellow perch	429	4.1 - 14.0	5.3
Do	335	young-of-year	--
After treatment (116 hours):			
Yellow perch	38	6.5 - 14.1	7.3
Do	0	young-of-year	--

NORTH LAKE TOBIASON

North Lake Tobiason was treated on August 6, 1959, with toxaphene at a concentration of 0.020 p.p.m. Reaction of fishes to the toxaphene began 1 hour after spraying was started, and after 4 hours yellow perch and brown bullheads were surfacing over the entire lake. This activity gained in intensity for another 68 hours and then dwindled to nothing after 72 hours. When apparent toxicity ceased, examination of the dead fish revealed many dead yellow perch and brown bullheads but only five dead northern pike (19.2 to 20.5 inches).

This lake was not test netted until 10 months after treatment (June 7, 1960), and results ascertained that only a partial kill had taken place. Brown bullheads were absent from the test nets. No yellow perch were taken in the samples, and the only fishes surviving were larger northern pike and white suckers (table 14). The percent reduction in total net frequency was 97.4 (table 5).

TABLE 14.--North Lake Tobiason test netting data before and after treatment with 0.020 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (48 hours):			
Yellow perch	446	3.1 - 7.2	5.3
Brown bullhead	160	4.2 - 10.2	7.8
Northern pike	5	19.1 - 26.2	23.7
White sucker	6	16.4 - 19.0	17.2
White crappie	4	4.3 - 4.5	4.4
After treatment (48 hours):			
Yellow perch	0	--	--
White sucker	8	16.5 - 19.0	17.3
Northern pike	7	21.0 - 26.1	24.2

BOWBELLS MINE LAKE

Bowbells Mine Lake was treated on August 28, 1959, with toxaphene at a concentration of 0.025 p.p.m. The lake, which was the smallest of the series involved, manifested extremes in water chemistry (table 2). The origin of the lake is seepage of ground water into an abandoned lignite-coal strip mine. The toxicant acted more slowly on the fishes than in any other project lake, and 6 hours elapsed before the first distressed yellow perch were visible. The frequency of kill increased gradually for 96 hours after which it dropped off rapidly, and at the end of 10 days a cessation of activity was noted.

Posttreatment test netting (table 15) was not carried out until May 9, 1960, at which time no fish were taken. The lake was then restocked on September 21, 1960, with 2,200 rainbow trout (2.8/lb.). Test netting in November 1960 disclosed good survival and additional growth of the trout.

GLEN ULLIN RESERVOIR

Glen Ullin Reservoir was treated on July 23, 1959, with toxaphene at a concentration of 0.025 p.p.m. Fishes reacted rapidly to the toxicant, and within 4 hours after spraying was begun distressed fish were in evidence in all areas of the lake. After 17 hours, mortality of white crappie and yellow perch appeared complete. No carp or white suckers were observed until 14 hours after treatment, but all had apparently died after 35 hours. Continued observations for 7 days disclosed no further mortality. Two days of posttreatment test netting on September 26, 1959, and May 17, 1960, did not yield any live fish (table 16). The

TABLE 15.--Bowbells Mine Lake test netting data before and after treatment with 0.025 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (24 hours):			
Yellow perch	17	5.1 - 8.3	7.2
White sucker	6	12.2 - 17.1	14.2
After treatment (48 hours):			
No fish taken	--	--	--

TABLE 16.--Glen Ullin Reservoir test netting data before and after treatment with 0.025 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (24 hours):			
White crappie	160	3.1 - 5.0	4.5
Yellow perch	3	4.7 - 5.2	5.0
Carp	2	13.1 - 13.4	13.25
White sucker	1	13.0	13.0
After treatment (48 hours):			
No fish taken	--	--	--

lake was then restocked with 5,000 fingerling largemouth bass, 572 adult white crappies, 90,000 bluntnose minnows, and 7,500 fingerling bluegills. Subsequent test netting in November 1960 indicated good survival and growth of these fishes.

SOUTH LAKE TOBIASON

South Lake Tobiason was treated on August 7, 1959, with toxaphene at a concentration of 0.025 p.p.m. Six hours after treatment, large numbers of distressed or dead black bullheads were found around the shore or floating on the surface. Forty-eight hours later no further mortality was apparent.

Posttreatment test netting on October 9, 1959, and April 12, 1960, failed to take any live fishes (table 17).

NIEUWSMA LAKE

Nieuwsma Lake had been treated in 1957 with emulsifiable rotenone at a concentration of 1.00 p.p.m. The treatment was unsuccessful in killing all of the black bullheads. Plantings of northern pike and bluegills in 1958 were of limited value. Retreatment of the lake with a concentration of 0.025 p.p.m. of toxaphene was

TABLE 17.--South Lake Tobiason test netting before and after treatment with 0.025 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (24 hours):			
Black bullhead	172	5.5 - 6.9	6.2
Northern pike	2	12.0	12.0
Yellow perch	1	6.2	6.2
After treatment (96 hours):			
No fish taken	--	--	--

carried out on June 7, 1960. Five hours after beginning the application, large numbers of black bullheads could be seen at the surface. Mortality continued for 120 hours and then dwindled until after 145 hours no further movement was observed.

On October 2, 1960, posttreatment test netting failed to produce any live fish from the lake (table 18).

CAT COULEE LAKE

Cat Coulee Lake had been previously treated twice (1.00 p.p.m. and 2.00 p.p.m. of emulsifiable rotenone) to eradicate a population of black bullheads. Both applications were unsuccessful. On July 15, 1959, the lake was retreated with toxaphene at a concentration of 0.030 p.p.m. Within 5 hours of starting the application, distressed black bullheads were to be found in all areas of the lake. The few rainbow trout in the lake succumbed quickly, and the last moribund bullhead was observed 96 hours later.

No fish were caught in test netting (table 19) on May 4, 1960. The lake was restocked on September 23, 1960, with 4,600 rainbow trout (600/lb.).

WOLF BUTTE LAKE

In 1957 Wolf Butte Lake was treated with 1.00 p.p.m. of emulsifiable rotenone to remove a population of bullheads and green sunfish. The application was unsuccessful. Rainbow trout that had been stocked into the area after treatment furnished angling for one season, and

TABLE 18.--Nieuwsma Lake test netting before and after treatment with 0.025 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (48 hours):			
Black bullhead....................	771	2.3 - 7.1	5.5
Northern pike.....................	12	11.1 - 16.3	14.8
After treatment (72 hours):			
No fish taken.....................	--	--	--

TABLE 19.--Cat Coulee Lake test netting data before and after treatment with 0.030 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (48 hours):			
Black bullhead....................	194	3.1 - 6.2	4.1
Rainbow trout.....................	5	9.0 - 12.3	9.7
After treatment (48 hours):			
No fish taken.....................	--	--	--

the green sunfish and bullheads quickly regained their original abundance. After this the trout fishing began a rapid decline.

The lake was retreated on July 9, 1960, with toxaphene at a concentration of 0.030 p.p.m. The fish reacted slowly to the toxaphene, and it was not until 21 hours after treatment that any activity was noted. Surfacing of distressed and dying fishes continued for 7 days, and then no further activity was observed.

Posttreatment test netting carried out on September 8, 1960, indicated all fish had succumbed (table 20).

JUND LAKE

Jund Lake was treated on June 9, 1960, with toxaphene at a concentration of 0.035 p.p.m. Action of the toxicant was rapid, and within 2 hours many dead small bullheads were in evidence. Activity increased for 24 hours and then declined at a rapid rate. After 72 hours no additional mortality was found.

On October 5, 1960, the lake was test netted, and negative results indicated complete mortality (table 21).

TABLE 20.--Wolf Butte Lake test netting data before and after treatment with 0.030 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (72 hours):			
Green sunfish.....................	1,003	1.8 - 5.3	4.0
Black bullhead....................	68	4.2 - 8.1	7.1
Rainbow trout.....................	18	10.2 - 15.2	13.1
After treatment (72 hours):			
No fish taken.....................	--	--	--

TABLE 21.--Jund Lake test netting data before and after treatment with 0.035 p.p.m. toxaphene

[Combined data from all types of netting gear]

Species	Number	Length (inches)	
		Range	Average
Before treatment (48 hours):			
Black bullhead....................	163	3.1 - 5.9	4.8
Rainbow trout.....................	1	15.7	15.7
After treatment (48 hours):			
No fish taken.....................	--	--	--

DISCUSSION AND CONCLUSIONS

The mortality pattern following application of various concentrations of toxaphene was consistent, and a marked size selectivity was exhibited. As concentration rates were increased, the extent of mortality of larger fishes increased until the minimum lethal level (when all fishes succumbed) was reached. From results on the 16 project lakes it appears that the minimum lethal concentration for treatment of most North Dakota lakes is 0.025 p.p.m. of toxaphene. Concentrations progressively less than this induce mortality only on progressively smaller fishes.

The use of sublethal dosages of toxaphene for partial population removal is indicated. In all lakes treated below lethal concentrations, smaller fishes were removed leaving the larger fishes relatively unharmed. In lakes without rough fish populations this removal of small, undesirable fishes could have beneficial effects on the resulting fishery. The need for further research along this line is pointed out.

Present methods of applying toxaphene are satisfactory, for during the project period no difficulty was experienced. Observed mortality patterns indicate advantages to spending more than the minimum time necessary for application. This would be of greater importance if toxaphene were being used for partial population removal. More thorough distribution of the toxaphene would give more homogeneous immediate concentration, negating the problem of mortality among the desirable larger fishes from high initial unmixed concentrations. It is also conceivable that in larger lakes (500 acres or more), under conditions of rapid detoxification, the concentration of toxaphene could be lowered to less than the minimum lethal level before complete mixing.

No marked correlation between water chemistry and rate of reaction of fishes to toxaphene was noted. It did appear that in highly alkaline waters the toxicant acted somewhat slower, but inasmuch as all lakes were alkaline in nature this was not definite. Temperature was the factor determining the rate of reaction: the lower the temperature of the water the slower the reaction of the fishes to the toxaphene. Results from Brush Lake prove that toxaphene will detoxify even while the lake is under ice cover.

Actual detoxification rates were not studied during the project period. It must be assumed that in lakes where kills were incomplete the initial concentration was below minimum lethal level or detoxification at these low dosages is more rapid than heretofore believed.

Five of the seven lakes in which mortality was complete were restocked within 7 months of treatment, and good survival and growth has been noted among the stocked fishes.

In all lakes, increase in transparency was evident following application of the toxaphene. This could have been related to the removal of fishes that kept materials in suspension. In some cases, however, it was more probable that the increase in transparency was due to limited flocculation caused by the toxaphene or its solvents.

No ill effects were felt by personnel working with the toxaphene. It appears that if toxaphene is judiciously handled, there is little danger in its use. It was found advantageous, however, to direct the spray downward to reduce airborne spray which is irritating to the eyes.

SUMMARY

During the summers of 1959 and 1960, 16 North Dakota lakes ranging from 6.3 to 915 acres were treated with toxaphene to remove populations of fishes. Objective of the study was to determine the minimum lethal concentration of toxaphene necessary for lake eradication projects.

Concentrations of toxaphene used on the lakes varied from 0.005 p.p.m. to 0.035 p.p.m. Incomplete mortality of fishes resulted in lakes at concentrations less than 0.025 p.p.m. At concentrations of 0.025 p.p.m. to 0.035 p.p.m. complete mortality was indicated, subject to the validity of test netting results.

Duration of toxicity of the toxaphene was not excessive. Five of the seven lakes in which kills were complete were successfully restocked within 7 months after treatment.

Results indicate that the North Dakota Game and Fish Department can use toxaphene at concentrations of 0.025 p.p.m. to 0.035 p.p.m. with reasonable assurance of killing all fishes in the treated lakes.

All lakes displayed a definite mortality pattern; the small fishes were the first to die, and the largest fishes were last. At the lowest project dosage of 0.005 p.p.m. only young-of-the-year were affected. The use of toxaphene as a size selective piscicide is strongly suggested.

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INVESTIGATIONS IN FISH CONTROL

4. Effects of Toxaphene on Plankton and Aquatic Invertebrates in North Dakota Lakes

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Montana Department of Fish and Game

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CONTENTS

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

By Robert G. Needham, Fishery Biologist
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Abstract.--Effects of low concentrations of toxaphene on plankton and larger invertebrates were studied in four North Dakota lakes (a fifth lake, untreated, was a control). Brachionus, Keratella, Trichocerca, Asplanchna, Polyarthra, Conochiloides, Daphnia, Ceriodaphnia, Bosmina, and Cyclops were dominant zooplankters; none exhibited marked reduction after treatment at 5 to 34 p.p.b. Most phytoplankter populations showed no obvious changes after treatment, except Aphanizomenon, which increased in all lakes. The posttreatment increase in South Lake Metigoshe was especially noticeable, since there was no increase in untreated North Lake Metigoshe. Several of the plant-inhabiting and bottom fauna decreased slightly after 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 larger invertebrates, Hirudinea, Hydracarina, and Gastropoda were the most tolerant, followed in order by Trichoptera, Odonata, Hemiptera, Ephemeroptera, Amphipoda, and Coleoptera.

Use of toxicants in fishery 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 some such effects: Hooper and Grzenda, 1957, in Michigan; Hoffman and Olive, 1961, and Cushing and Olive, 1957, in Colorado; and Stringer and McMynn, 1958, in British Columbia.

The object of this study was to determine the effects of toxaphene at low 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, which various concentrations of toxaphene were used. Investigations were carried out in four lakes--a natural lake in the north-central part of the State and three impoundments in the southwest. A fifth lake, untreated, was a control. The study extended from June through September of both 1960 and 1961.

Dr. C. J. D. Brown directed the study; Dale L. Henegar, Chief of Fisheries, North Dakota Game and Fish Department, suggested the problem; I am indebted also to Dr. John C. Wright and Dr. G. W. Prescott for help in identifying plankton, to Dr. George F. Edmunds, Jr., for help in identifying aquatic insects, to Donald C. Warnick for help in field work, and to my wife Avis for help in analysing samples. Chemical analyses were made by the State Laboratories. The fish studies were by the North Dakota Fish and Game Department, which also provided financial aid under Dingell-Johnson Projects F-2-R 7 and 9. The National Wildlife Federation granted a fellowship for the last year of the study.

This publication is based on a thesis submitted to the Graduate Faculty, Montana State College, in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management, March 1962.

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 containing 6 pounds of technical toxaphene per gallon. Before application the toxaphene was diluted to 10 to 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 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 in total enumeration of all organisms in 1 cc., with the exception of a few abundant phytoplankters, which were counted by the differential method, employing 20 to 80 fields within a 1-cc. sample.

Plant-inhabiting organisms were collected with a metal device that I designed. This had an opening of 1 square foot and a height of 30 inches. Openings (4 by 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 2 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 8 to 16 in 1960 and from 3 to 5 in 1961.

Bottom organisms were taken with an Ekman dredge at depths ranging from 4 to 10 feet. Either 3 or 4 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.

TABLE 1.--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]

Sampling dates	Temperature (^{o}F)		Secchi disk (feet)	Total solids	Total hardness	pH	Total alkalinity	Chlorides	Sulfates	Iron
	Surface	Bottom								
Wolfe Butte Reservoir (treated Aug. 8, 1960):										
Aug. 5, 1960	71.4	68.2	4.9	904	114	9.4	408	none	280	1.5
Aug. 16, 1960	68.6	68.2	4.2	1,025	114	9.1	463	none	348	1.1
Sept. 7, 1960	64.0	63.7	7.9	--	--	--	--	--	--	--
Aug. 9, 1961	71.0	70.0	4.3	678	84	9.2	336	trace	164	1.0
Raleigh Reservoir (treated Aug. 4, 1960):										
Aug. 4, 1960	72.1	70.5	3.2	266	184	8.4	153	none	86	1.0
Aug 15, 1960	71.7	68.8	4.7	336	196	8.7	143	none	96	0.5
Sept. 6, 1960	68.0	67.6	8.7	--	--	--	--	--	--	--
Aug. 8, 1961	71.0	68.2	11.0	380	180	9.8	200	28	143	0.5
South Lake Metigoshe (treated July 17, 1960):										
July 14, 1960	71.8	68.5	7.9	270	228	8.8	224	none	27	0.2
July 21, 1960	72.0	68.4	8.4	279	222	8.5	214	none	53	0.3
Aug. 26, 1960	64.6	62.3	8.3	--	--	--	--	--	--	--
Sept. 15, 1960	60.2	59.1	6.4	--	--	--	--	--	--	--
July 19, 1961	68.5	66.8	10.0	299	208	9.4	216	28	44	0.8
North Lake Metigoshe (untreated control):										
July 14, 1960	71.8	66.8	8.5	281	232	8.6	224	none	33	0.9
July 21, 1960	72.3	68.0	8.8	282	226	8.2	214	none	53	0.2
Aug. 26, 1960	64.9	61.9	6.4	--	--	--	--	--	--	--
Odland Reservoir (treated Aug. 11, 1960):										
Aug. 10, 1960	69.1	66.1	2.2	414	184	8.2	187	none	165	0.2
Aug. 16, 1960	68.0	65.8	1.8	510	202	8.2	195	none	186	0.8
Sept. 8, 1960	65.0	64.0	3.1	--	--	--	--	--	--	--
Aug. 8, 1961	71.2	68.0	2.1	574	208	8.5	196	trace	259	0.5

WOLF BUTTE RESERVOIR

DESCRIPTION

Wolf Butte Reservoir, in southwestern North Dakota, has a surface area of 24 acres and a maximum depth of 9 feet. It has no permanent inlet or outlet, 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 p.p.b. on August 8, 1960, in an attempt to eradicate the fish population. This impoundment was heavily populated with green sunfish (Lepomis cyanellus) black bullheads (Ictalurus melas), and a few large rainbow trout (Salmo gairdneri). Many green sunfish and black bullheads were found dead and dying after treatment. The reservoir was test-netted 1 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 near the center of the reservoir. Collections were made 3 days before treatment, and after treatment at 8 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 first.

Comparison in numbers per liter was made between pretreatment and posttreatment collections. Rotifers were represented by nine genera, Keratella and Asplanchna being the

TABLE 2.--Number of plankters per liter in Wolf Butte Reservoir before and after toxaphene treatment at 35 parts per billion.

[Treated Aug. 8, 1960]

Organism	Before Aug. 5, 1960	After		
		Aug. 16, 1960	Sept. 7, 1960	Aug. 9, 1961
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[1]......	106	26	10	73
Pandorina.....	3	15	--	--
Oedogonium....	3	4	--	--
Cladophora....	--	--	--	[2] 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
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	--

[1] Includes nauplii of both Diaptomus and Cyclops.
[2] Less than 1 per liter.

most numerous. Keratella changed from 91 before treatment to 15 at 1 week, 2 at 1 month, and only 1 at 1 year after treatment. Asplanchna increased from 73 before treatment to 106 at 1 week after treatment, but none were present in collections at 1 month or 1 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 1 week, then increased to 129 at 1 month after treatment. Bosmina exhibited the reverse effect, and both were less abundant at 1 year after treatment. Copepoda were represented by Diaptomus, Cyclops, and undetermined nauplii. Six Diaptomus were taken before treatment, but none were found at 1 week or 1 month after treatment and only 2 at 1 year.

Cyclops decreased from 46 in the pretreatment collection to 3 at 1 week after treatment, but increased to 11 at 1 month. Nauplii decreased from 106 before treatment to 26 and 10 at 1 week and 1 month after treatment. Cyclops and nauplii were relatively abundant the following year.

There were 16 genera of Chlorophyta, 8 of Chrysophyta, and 1 of Pyrrophyta 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 at 1 week after treatment, then decreased to 149,306 at 1 month. Aphanizomenon increased from 7,377 before treatment to 54,716 at 1 month after treatment. Polycystis, Coelospharium, and Anabaena decreased after treatment. Polycystis was abundant at 1 year, but Coelospharium and Anabaena did not reappear 1 year after 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 1 week and 1 month after treatment, but were more abundant at 1 year. Tendipes decreased from 44 before treatment to 9 at 1 week after treatment, while 48 were taken at 1 month and 25 at 1 year after treatment. Gastropoda (Physa and Gyraulus) increased from 771 before treatment to 1,107 at 1 week, 1,366 at 1 month, and 1,558 at 1 year after treatment.

TABLE 3.--Number of plant-inhabiting organisms and bottom fauna in Wolf Butte Reservoir before and after toxaphene treatment at 35 parts per billion.

[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. tr = less than 1 per pound or per square foot]

Organism	Before Aug. 5, 1960		After Aug. 16, 1960		Sept. 7, 1960		Aug. 9, 1961	
	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

Numerical comparisons of the seven dominant genera revealed no marked changes before and after treatment. Reductions of Ephemeroptera and Odonata in the first two posttreatment collections may be significant but could 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 6 before treatment to less than 1 at 1 week, 44 at 1 month, and less than 1 at 1 year after treatment. The large number at 1 month after treatment resulted from a collection that contained considerable vegetation. Tendipes decreased from 28 before treatment to 12 and 9 at 1 week and 1 month after treatment but increased to 25 at 1 year. A comparison of the number of bottom organisms before and after treatment revealed no marked changes.

RALEIGH RESERVOIR

DESCRIPTION

Raleigh Reservoir, in southwestern North Dakota, 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 3 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 p.p.b. 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 p.p.b. on September 26, 1960.

Fish.--Before 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, and 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 netted again 1 week after the first treatment, but with only two experimental gill nets set for 24 hours. These contained 10 white suckers and 5 black bullheads. Test-netting was discontinued since drought had lowered water levels to a point where restocking was impracticable.

Plankton.--Four collections were made at one station near the center of the reservoir. Collections were made 1 day before the first treatment and at 11, 33, and 371 days after the first treatment; a second treatment was made 53 days after the first, and the fourth collection was 318 days after this treatment. Quantities of plankters in pretreatment and posttreatment collections are shown in table 4. Rotifers were represented by 15 genera, but only Brachionus and Asplanchna were abundant. Brachionus decreased from 114 before treatment to 108 at 11 days and 15 at 33 days after treatment. Asplanchna varied from 24 before treatment to 194 at 11 days and 16 at 33 days after treatment. Only 3 Brachionus and 1 Asplanchna were

TABLE 4.--Number of plankton per liter in Raleigh Reservoir before and after treatment at 25 parts per billion.

[Treated Aug. 4, and Sept. 26, 1960]

Organism	Before Aug. 3, 1960	After		
		Aug. 15, 1960	Sept. 6, 1960	Aug. 10, 1961[1]
Brachionus...	114	108	15	3
Keratella....	13	11	9	7
Platyias.....	[2] 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[3].....	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	--
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

[1] After the second treatment at 90 p.p.b.
[2] Less than 1 per liter.
[3] Includes nauplii of both Diaptomus and Cyclops.

taken 371 days after treatment. All rotifers were very scarce at this time, and 6 of the original genera were not found.

Cladocera was the most abundant zooplankter. *Daphnia*, *Ceriodaphnia*, and *Bosmina* were present in large numbers. *Daphnia* varied from 65 before treatment to 173 at 11 days, 57 at 33 days, and only 9 at 371 days after treatment. *Ceriodaphnia* increased from 44 before treatment to 156 at 11 days, then decreased to 100 at 33 days, and only 1 was taken at 371 days after treatment. *Bosmina* decreased from 314 before treatment to 283 at 11 days and 50 at 33 days after treatment and disappeared by 371 days. A few *Chydorus* were found in the pretreatment and early posttreatment collections, but did not occur in the collection 371 days after treatment. Copepoda were represented by the young and adults of *Diaptomus* and *Cyclops*. *Diaptomus* changed from 10 before treatment to 1 at 11 days and 1 at 33 days, but none at 371 days after treatment. There were 120 *Cyclops* before treatment while collections after treatment showed 9 at 11 days, 41 at 33 days, and 8 at 371 days. Nauplii decreased from 190 before treatment to 85 at 11 days, 19 at 33 days, and 7 at 371 days after treatment.

The Chlorophyta were 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. *Spirogyra* was the most abundant of the Chlorophyta in the collection 371 days after treatment, but was scarce in the pretreatment and early posttreatment collections. The Chrysophyta contained 9 genera and the Pyrrophyta 1. These were infrequently encountered, and no comparisons were made. The Cyanophyta were represented by 8 genera. *Synechocystis*, *Polycystis*, *Coelospharium*, *Aphanizomenon*, and *Nodularia* were the dominant organisms. *Synechocystis* and *Polycystis* decreased in the first two posttreatment collections but were abundant at 371 days after treatment. *Coelospharium* and *Aphanizomenon* increased after treatment but were scarce at 371 days after treatment. *Nodularia* varied from 77 before treatment to 3,663 at 11 days, 21 at 33 days, and 3 at 371 days after treatment.

Changes after the first treatment (25 p.p.b.) are probably the result of normal population fluctuations. At 371 days after treatment water levels had dropped 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 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 before treatment to 313 at 1[illegible] days, 569 at 33 days, and 334 at 371 days after treatment. Hydrachnidae decreased from 45 before treatment to 27 at 11 days, 22 at 33 days, and 14 at 371 days after treatment. *Callibaetis*, *Caenis*, *Ischnura*, and *Tendipes* were markedly reduced in the first two posttreatment collections, but all except *Caenis* were abundant at 371 days after treatment. *Sigara* decreased from 39 before treatment to less than 1 at 11 days after treatment, and none were taken afte[illegible]

TABLE 5.--Numbers of plant inhabiting organisms and bottom fauna in Raleigh Reservoir before and after toxaphene treatment at 25 parts per billion.

[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 Aug. 3, 1960		After Aug. 15, 1960		After Sept. 6, 1960		After Aug. 10, 1961[1]	
	Plant	Bottom	Plant	Bottom	Plant	Bottom	Plant	Bottom
Oligochaeta...	--	4	--	8	--	11	--	28
Hirudinea.....	[2] 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	--	--

[1] After the second treatment at 90 p.p.b.
[2] Less than one per pound or square foot.

this time. There were 1,163 Gyraulus before treatment, 1,695 at 11 days, 398 at 33 days, and 38 at 371 days after 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; all but Caenis, however, were abundant 371 days after treatment. Stringer and McMynn (1958) reported that Ephemeroptera were killed at 30 p.p.b. 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 reduction of Gyraulus at 371 days after treatment may be related to lowered water levels, since other workers (Hooper and Grzenda, 1957; and Stringer and McMynn, 1958) found Gastropoda to be unaffected by toxaphene at 100 p.p.b.

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 4 before treatment to 28 at 371 days after treatment. Cushing and Olive (1957) found an increase in Oligochaeta after treatment with 100 p.p.b. toxaphene. Ephemeroptera decreased from 7 before treatment to less than 1 at 11 days, and none were taken in succeeding collections. Tendipes decreased from 27 before treatment to 2 at 11 days and 6 at 33 days after treatment, then increased to 71 at 371 days after treatment.

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

SOUTH LAKE METIGOSHE

DESCRIPTION

South Lake Metigoshe is a glacial lake 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. Water levels fluctuate slightly owing 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 p.p.b. on July 17, 1960, in an attempt to reduce the number of yellow perch (Perca flavescens) and black bullheads. This was supplemented by 5 p.p.b. 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 1 week before, 1 week after, and again 11 months after treatment; the netting efforts were 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 before treatment to 36 at 1 week and none at 11 months after treatment. Young-of-the-year were reduced from 610 before treatment to 6 at 1 week and none at 1 year after treatment. Young-of-the-year black bullheads decreased from 240 before treatment to 9 at 1 week and none at 11 months after treatment. Young-of-the-year northern pike (Exos lucius) decreased from 40 before treatment to 10 at 1 week and none at 11 months after treatment. Netting at 1 week after 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 after treatment, and bullheads and northern pike were greatly reduced. The paucity of all species taken at 11 months after 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 2 days before treatment and at 4, 40, 60, and 367 days after treatment. The pretreatment and the first two posttreatment 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 is adjacent to South Lake Metigoshe and is connected by a channel approximately 30 feet wide; 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.

TABLE 6.--Number of plankton per liter in South and North Lake Metigoshe before and after toxaphene treatment at 15 parts per billion

[South Lake Metigoshe treated July 17, 1960]

Organism	Before, July 15, 1960		After-					
			July 21, 1960		Aug. 26, 1960		Sept. 15, 1960, South	July 19, 1961, South
	South	North	South	North	South	North		
Brachionus	--	2	1	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[2]	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	--	--	--	--	--
Cosmarium	1	tr	1	tr	--	3	1	tr
Staurastrum	15	16	17	8	60	23	106	67
Desmidium	3	4	4	1	2	3	1	1
Botryococcus	--	1	--	2	2	tr	2	2
Dinobryon	7	98	1	11	--	tr	--	--
Melosira	11	73	5	40	568	1,040	462	3
Diatoma	1	1	--	1	--	--	1	1
Fragilaria	144	235	71	45	871	50	71	3,078
Synedra	42	51	60	13	304	62	581	6,803
Asterionella	1	1	1	tr	tr	1	1	tr
Navicula	13	1	22	1	25	29	3	6
Pinnularia	4	1	16	1	5	8	1	1
Frustulia	1	--	1	--	1	1	--	--
Gyrosigma	tr	--	tr	--	--	1	tr	tr
Pleurosigma	tr	tr	--	--	1	tr	tr	tr
Gomphonema	2	9	9	6	39	9	61	61
Cymbella	4	1	18	1	10	2	1	1
Nitzschia	2	2	19	4	7	3	3	12
Cymatopleura	--	--	--	--	--	tr	1	--
Camplyodiscus	2	tr	1	tr	3	1	1	tr
Glenodinium	tr	1	1	2	--	1	--	--
Ceratium	52	42	71	61	190	300	260	948
Polycystis	87	396	73	330	155	1,057	218	462
Merismopedia	--	--	--	tr	--	--	--	1
Coelospharium	7	132	9	238	150	2,510	470	207
Phormidium	3	--	4	--	1	--	tr	--
Lyngbya	13	24	21	27	2,312	2,932	81	39
Anabaena	7,794	3,540	1,982	1,915	130,515	4,716	127,470	1,222
Aphanizomenon	2,642	5,773	1,096	1,836	69,617	4,742	98,018	53
Nodularia	3	2	14	4	6,869	4	5,019	39
Gloeotrichia	3	1	3	1	2	--	1	1

[1] Represents less than one per liter.
[2] Includes nauplii of Diaptomus and Cyclops.

Rotifers were represented by 15 genera. Trichocerca and Conochiloides were the most abundant. Trichocerca decreased from 234 before treatment to 31 at 40 days, 3 at 60 days, and 3 at 367 days after treatment. Conochiloides decreased from 182 before treatment to 160 at 1 days, 1 at 40 days, none at 60 days, and less than 1 at 367 days after treatment. Asplanchna decreased from 28 before treatment to 1 at 40 days, none at 60 days, and 20 at 367 days after treatment. Hexarthra decreased from 11 before treatment to none at 40 days, none at 60 days, and less than 1 at 367 days after treatment. Keratella, Polyarthra, and Filinia remained almost constant. There were six genera of Cladocera; Daphnia, Ceriodaphnia, and Bosmina were the most abundant. Daphnia increased from 1 before treatment to 41 at 367 days after treatment; Ceriodaphnia remained nearly constant, but was less abundant at 367 days after treatment; Bosmina decreased from 110 before treatment to 8 at 40 days and 1 at 367 days after 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, 2 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 after treatment and, with the exception of Melosira, were more abundant at 367 days after treatment. Cyanophyta were the most abundant phytoplanters. Polycystis, Coelospharium, Lyngbya, Anabaena, Aphanizomenon, and Nodularia were abundant. Polycystis and Coelospharium increased slightly after treatment, whereas Anabaena, Lyngbya, Aphanizomenon, and Nodularia exhibited large posttreatment increases (table 6).

Comparisons of zooplankters before and after treatment revealed no marked changes. Posttreatment 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 posttreatment 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. Collections were made 1 day before treatment, and at 5, 45, 59, and 367 days after treatment. The pretreatment and the first two posttreatment 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, p. 12). There were 28 genera of organisms taken; Gammarus, Tendipes, Physa, and Gyraulus were the most abundant. A comparison of pretreatment and posttreatment collections revealed no marked changes in the number of any organism.

Bottom fauna.--No pretreatment samples were obtained, but two posttreatment samples were taken, which consisted of 3 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 after treatment.

ODLAND RESERVOIR

DESCRIPTION

Odland Reservoir, in southwestern North Dakota, 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.--Number of plant-inhabiting organisms and bottom fauna in South and North Lake Metigoshe before and after toxaphene treatment at 15 parts per billion.

[Plant inhabiting organisms expressed as the number per pound of plants and bottom fauna as number per square foot of bottom. South Lake Metigoshe treated July 17, 1960]

Organism	Before, July 16, 1960		After					
			July 22, 1960		Aug. 31, 1960		Sept. 16, 1960, South	July 18, 1961, South
	South	North	South	North	South	North		
Hirudinea	1	[1] tr	tr	tr	1	tr	1	2
Amphipoda:								
Gammarus	639	198	406	186	177	130	295	424
Hydracarina:								
Hydrachnidae	11	4	5	4	1	1	1	1
Ephemeroptera:								
Callibaetis	2	tr	--	tr	--	1	tr	6
Caenis	1	3	2	2	--	2	--	--
Odonata:								
Sympetrum	tr	--	--	--	--	--	--	--
Anax	tr	tr	--	tr	--	--	--	1
Aeschna	--	--	--	--	--	tr	--	1
Ischnura	tr	tr	tr	1	tr	7	tr	2
Hemiptera:								
Plea	tr	1	tr	tr	tr	2	tr	7
Notonecta	--	tr	--	--	--	--	--	3
Buenoa	tr	--	--	--	--	--	tr	--
Sigara	tr	tr	tr	tr	tr	--	tr	6
Trichoptera:								
Psychomyia	1	1	--	1	--	tr	--	tr
Oecetis	1	1	tr	1	--	tr	--	--
Triaenodes	3	1	tr	tr	--	--	--	tr
Phryganea	tr	tr	tr	tr	--	tr	--	--
Coleoptera:								
Copelatus	2	2	1	3	tr	3	1	11
Haliplus	1	2	tr	2	tr	2	tr	2
Hydrocanthus	--	tr	--	--	tr	--	tr	2
Gyrinus	--	--	tr	--	--	tr	--	--
Diptera:								
Chaoborus	tr	--	1	--	--	--	--	--
Tendipes	9	5	3	6	11	3	2	1
Probezzia	tr	1	tr	tr	tr	--	--	--
Gastropoda:								
Physa	24	28	21	27	31	19	29	66
Lymnaea	--	tr	--	tr	--	--	tr	--
Gyraulus	47	56	24	44	51	105	86	10
Valvata	--	tr	tr	--	tr	--	tr	--

[1] Represents less than 1 per pound.

TREATMENT

Fish.--Toxaphene was applied at 5 p.p.b. 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 orange-spotted 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 few were found dead and large numbers were taken in posttreatment test nettings.

Plankton.--Four collections were made at each of two stations. These were made 1 day before treatment, and at 7, 28, and 362 days after treatment. The kinds and number of plankters per liter are given for each collection (table 8). There were 10 genera of Rotifera taken; Brachionus, Keratella, Polyarthra, and Conochiloides were the most abundant and remained nearly constant before and after treatment. Cladocera were the most abundant zooplankters with Daphnia, Ceriodaphnia, and Bosmina being most common. There were 22 Daphnia before treatment, 68 at 7 days, 40 at 28 days and 3 at 362 days after treatment. Ceriodaphnia varied from 31 before treatment to 66 at 7 days, 37 at 28 days, and only 1 at 362 days after treatment. Bosmina decreased from 459 before treatment to 24 at 28 days and 66 at 362 days after treatment. Copepoda were represented by adults and nauplii of Diaptomus and Cyclops. Cyclops decreased from 71 before treatment to 16 at 28 days after treatment, and nauplii decreased from 129 before treatment to 36 at 28 days after treatment, but both were again abundant at 362 days after treatment. Fourteen genera of Chlorophyta, 12 of Chrysophyta, 1 of Pyrrophyta, and 5 of Cyanophyta were found. Melosira, Ceratium, Polycystis, and Aphanizomenon were the dominant organisms of these groups. These increased at 7 days and 28 days after treatment. Approximately the same numbers were found in posttreatment collections at 362 days as were found before treatment. Numerical comparisons of pretreatment and posttreatment collections showed no marked changes.

TABLE 8.--Number of plankton per liter in Odland Reservoir before and after toxaphene treatment at 5 parts per billion.

[Treated Aug. 11, 1960]

Organism	Before, Aug. 10, 1960	After		
		Aug. 18, 1960	Sept. 8, 1960	Aug. 8, 1961
Brachionus...	--	10	26	12
Keratella....	3	7	71	33
Trichocerca..	--	1	1	--
Asplanchna...	5	3	6	4
Polyarthra...	7	61	55	229
Synchaeta....	1	2	17	4
Filinia......	--	1	11	1
Trochoephaera	1	1	7	4
Hexarthra....	[1] tr	tr	--	tr
Conochiloides	--	tr	63	tr
Daphnia......	22	68	40	3
Simocephalus.	--	--	tr	--
Ceriodaphnia.	31	66	37	1
Bosmina......	459	333	24	66
Chydorus.....	--	--	2	--
Diaptomus....	1	1	1	--
Cyclops......	71	26	16	34
Nauplii [2]....	129	61	36	115
Oedogonium...	--	1	--	--
Rhizoclonium.	--	--	3	--
Microactinium	--	1	--	tr
Pediastrum...	4	3	10	12
Hydrodicton..	--	tr	--	--
Oocystis.....	tr	1	2	--
Closteriopsis	10	5	1	2
Tetraedon....	tr	1	1	--
Scenedesmus..	5	3	7	1
Mougeotia....	--	--	1	--
Spirogyra....	--	tr	1	--
Closterium...	tr	--	1	1
Cosmarium....	1	2	tr	--
Staurastrum..	3	2	6	1
Desmidium....	3	8	16	2
Botryococcus.	--	--	1	--
Dinobryon....	--	--	11	--
Melosira.....	6	55	33	131
Diatoma......	2	2	1	16
Synedra......	tr	1	1	4
Asterionella.	1	1	6	tr
Navicula.....	tr	1	1	--
Pleurosigma..	--	tr	--	--
Cymbella.....	1	tr	--	--
Nitzschia....	6	15	3	1
Cymatopleura.	tr	tr	--	tr
Ceratium.....	391	542	3,302	1,123
Polycystis...	6	9	130	3
Lyngbya......	1	1	3	--
Anabaena.....	1	5	3	5
Aphanizomenon	14	287	5,812	4
Nodularia....	tr	1	8	--

[1] Represents less than one per liter.
[2] Includes nauplii of both Diaptomus and Cyclops.

TABLE 9.--Number of plant-inhabiting organisms and bottom fauna in Odland Reservoir before and after toxaphene treatment at 5 parts per billion.

[Plant-inhabiting organisms expressed as number per pound of plants and bottom fauna as number per square foot of bottom. Treated August 11, 1960]

Organism	Before, Aug. 10, 1960		After					
			Aug. 18, 1960		Sept. 8, 1960		Aug. 8, 1961	
	Plant	Bottom	Plant	Bottom	Plant	Bottom	Plant	Bottom
Oligochaeta...	--	2	--	1	--	[1] tr	--	2
Hirudinea.....	tr	--	tr	--	--	1	2	--
Amphipoda:								
Gammarus.....	195	1	294	2	303	6	76	tr
Hydracarina:								
Hydrachnidae.	53	--	34	--	4	--	17	--
Ephemeroptera:								
Caenis.......	21	2	11	tr	5	--	11	tr
Odonata:								
Sympetrum....	1	--	tr	--	--	--	--	--
Aeschna......	tr	tr	tr	--	--	--	2	--
Ischnura.....	5	1	4	tr	13	1	11	--
Hemiptera:								
Notonecta....	tr	--	1	--	2	--	--	--
Sigara.......	tr	--	tr	--	1	--	--	--
Trichoptera:								
Hydroptila...	--	1	--	--	--	--	--	--
Psychomyia...	tr	--	--	--	--	--	--	--
Phryganea....	tr	--	--	--	--	--	--	--
Coleoptera:								
Haliplus.....	6	--	1	--	1	--	tr	--
Hydroporus...	tr	--	tr	--	2	--	--	--
Diptera:								
Tendipes.....	37	18	6	8	4	2	14	8
Probezzia....	--	--	tr	--	--	tr	--	tr
Chrysops.....	--	tr	--	1	--	tr	--	--
Gastropoda:								
Physa........	32	3	52	9	23	1	89	2
Gyraulus.....	1,301	7	964	11	721	17	320	2
Valvata......	48	11	52	17	149	78	7	23
Pelecypoda:								
Pisidium.....	--	9	--	11	--	15	--	32

[1] Less than 1 per pound or square foot.

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, Physa, 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 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 that could be attributed to toxaphene treatment.

EXPERIMENTS

Six Rotifera, two Cladocera, and two Copepoda were tested at six toxaphene concentrations ranging from 50 to 1,000 p.p.b., to determine their tolerance levels. All tests were conducted in battery jars, each containing 8 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 p.p.m., total alkalinity of 341 p.p.m., and pH of 8.4. Before 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 were then 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. To avoid collecting the dead and affected plankters the jars were tilted and 200 cc. were left 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).

Larger invertebrates were tested to determine the concentration at which 100 percent survived for 24 hours and 100 percent were killed (table 11). These tests were carried out in galvanized tanks, each 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 to 20 organisms were used to calculate percent survival and mortality. Controls were maintained for 2 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 1 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 because of inadequate washing, since these minnows were found to have low tolerance levels (Hooper and Grzenda, 1957). The lowest concentration used in the experiments was 10 p.p.b., 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 p.p.b., cladocerans (Daphnia pulex and Boxmina) at 250 p.p.b., and copepods at 100 p.p.b. (table 10). All genera in each group exhibited similar tolerance levels. Four trials employing 10 organisms each were conducted with Daphnia magna at six concentrations. No effects were obvious at 50 to 400 p.p.b., however retarded movements were observed at 1,000 p.p.b., and movements had nearly ceased at 1,500 p.p.b. Prevost (1960) reported a median

TABLE 10.--Comparison in number of zooplankters per cc. in 25-cc. concentrates from treated and control jars.

Organism and trial	50 p.p.b.		100 p.p.b.		250 p.p.b.		500 p.p.b.		750 p.p.b.		1,000 p.p.b.	
	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated
Polyarthra:												
Trial 1	1	1	5	4	5	6	0	2	1	0	2	1
Trial 2	4	6	0	1	0	2	69	23	14	1	0	0
Trial 3	7	4	7	2	1	4	10	0	10	0	2	1
Hexarthra:												
Trial 1	4	5	5	5	5	2	0	0	4	1	0	0
Trial 2	111	133	14	6	10	10	8	0	111	2	4	1
Trial 3	3	4	3	2	4	1	7	1	7	0	20	1
Filinia:												
Trial 1	19	26	14	35	14	14	22	11	19	1	3	0
Trial 2	6	5	4	3	22	8	17	9	6	1	4	0
Trial 3	7	6	7	2	3	10	12	3	12	1	2	0
Keratella:												
Trial 1	0	1	9	9	9	4	2	0	0	0	16	1
Trial 2	1	1	35	11	2	1	23	14	1	0	35	1
Trial 3	105	51	105	41	1	1	12	3	12	1	18	2
Asplanchna:												
Trial 1	8	10	18	14	18	22	8	3	8	0	7	0
Trial 2	12	7	14	13	8	9	98	48	12	0	1	0
Trial 3	11	9	10	12	13	21	1	0	1	2	7	2
Brachionus:												
Trial 1	122	136	296	252	296	278	144	102	122	10	80	6
Trial 2	58	68	72	85	144	148	351	191	58	11	79	24
Trial 3	27	24	27	18	281	363	94	88	88	23	84	11
Daphnia:												
Trial 1	24	21	10	8	10	3	11	7	24	1	6	0
Trial 2	11	16	1	2	11	10	8	1	11	0	7	0
Trial 3	5	5	5	7	36	8	7	0	7	0	28	0
Bosmina:												
Trial 1	34	43	75	79	79	13	29	4	34	0	37	8
Trial 2	76	93	6	7	29	5	68	2	76	4	16	4
Trial 3	19	27	19	17	69	33	88	4	88	4	202	8
Diaptomus:												
Trial 1	140	116	25	16	15	3	183	8	140	1	166	0
Trial 2	23	27	23	9	183	5	21	0	33	0	23	1
Trial 3	52	36	52	3	50	2	122	0	122	0	32	0
Cyclops:												
Trial 1	20	12	14	6	5	2	12	0	20	1	28	0
Trial 2	4	6	5	6	12	1	58	3	14	0	14	0
Trial 3	10	14	10	8	10	0	27	1	27	0	85	0
Nauplii:[1]												
Trial 1	53	49	63	40	63	15	46	11	53	2	48	0
Trial 2	80	71	48	31	46	26	89	12	80	2	80	1
Trial 3	50	58	50	46	59	29	73	19	73	7	152	9

[1] Represents both Diaptomus and Cyclops.

TABLE 11.--Percent survival of several aquatic invertebrates after 24 hours' exposure to toxaphene concentrations

Organism and toxaphene concentration	Percent alive
Hirudinea (2 trials):	
1,000 p.p.b.	100
Amphipoda:	
Gammarus (14 trials):	
100 p.p.b.	100
200 p.p.b.	39
300 p.p.b.	21
500 p.p.b.	0
Hydracarina (4 trials):	
1,000 p.p.b.	100
Ephemeroptera:	
Callibaetis (14 trials):	
150 p.p.b.	100
300 p.p.b.	71
400 p.p.b.	13
500 p.p.b.	0
Odonata:	
Aeschna (17 trials):	
200 p.p.b.	100
275 p.p.b.	84
350 p.p.b.	40
450 p.p.b.	0
Lestes (21 trials):	
450 p.p.b.	100
500 p.p.b.	81
600 p.p.b.	33
850 p.p.b.	0
Hemiptera:	
Notonecta (18 trials):	
275 p.p.b.	100
300 p.p.b.	71
400 p.p.b.	39
600 p.p.b.	0
Sigara (19 trials):	
50 p.p.b.	100
75 p.p.b.	60
100 p.p.b.	25
150 p.p.b.	0
Trichoptera:	
Limnephilus (12 trials):	
500 p.p.b.	100
550 p.p.b.	49
600 p.p.b.	20
650 p.p.b.	0
Coleoptera:	
Haliplus (22 trials):	
10 p.p.b.	100
40 p.p.b.	45
50 p.p.b.	11
75 p.p.b.	0
Hydroporus (18 trials):	
60 p.p.b.	100
100 p.p.b.	63
300 p.p.b.	35
450 p.p.b.	0
Dytiscus (Larvae) (9 trials):	
15 p.p.b.	100
50 p.p.b.	76
60 p.p.b.	58
75 p.p.b.	0
Gyrinus (16 trials):	
65 p.p.b.	100
100 p.p.b.	78
150 p.p.b.	60
185 p.p.b.	0
Gastropoda:	
Lymnaea (4 trials):	
700 p.p.b.	100

tolerance limit (TL_m) of 0.037 p.p.m. for cladocerans, and Hooper and Grzenda (1957) found Daphnia magna to have a TL_m of 1.5 p.p.m. at 55^o 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 relation (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 10 degrees. Hooper and Grzenda (1957) found mortality in fathead minnows increased approximately threefold by raising the temperature from 50^o F. to 75^o 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 posttreatment changes were not severely reduced, therefore no obvious effects could definitely be attributed to toxaphene treatment. Extensive fish removal can evidently be accomplished without seriously affecting the plankton, but large reductions in these organisms occur at 100 p.p.b. (Wollitz, 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 invertegrates. Hooper and Fukano (1960) reported bottom fauna to be nearly as abundant in two Michigan lakes after treatment (10 p.p.b.) as before, but Stringer and McMynn (1958) found that Amphipoda was eliminated at 10 p.p.b. and Ephemeroptera at 30 p.p.b. Severe reductions in many of these organisms may be expected at higher concentrations. Odonata, Ephemeroptera, Tendipedidae, and Chaoborus, were eliminated with 100 p.p.b. toxaphene (Hooper and Grzenda, 1957; and Cushing and Olive, 1957). Unionidae, Sphaeridae, Gastropoda, Oligochaeta, and Hirudinea appear to be more resistant (Hooper and Grzenda, 1957); 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. It should be recognized that lower tolerance levels probably exist under field conditions which involve longer exposure periods.

SUMMARY

Effects of different toxaphene concentrations on plankton and other aquatic invertebrates were studied under natural and controlled conditions. Five North Dakota lakes were included in the study, which extended from June through September of 1960 and 1961. Physical and chemical data are presented for each lake.

Polyarthra, Keratella, Asplanchna, Conochiloides, Brachionus, Trichocera, Daphnia, Bosmina, Ceriodaphnia, and Cyclops were the dominant zooplankters. No marked reductions were observed after treatment with 5 to 35 p.p.b., but a marked reduction of many plankters followed the second treatment (90 p.p.b.) in Raleigh Reservoir. The Cyanophyta were the most abundant phytoplankters in all lakes. Aphanizomenon increased in all lakes after treatment, but other phytoplankters exhibited no consistent changes. Chlorophyta, Chrysophyta, and Pyrrophyta contributed little to phytoplankton abundance.

The most abundant plant-inhabiting organisms and bottom fauna exhibited no marked changes after treatment. Gammarus, Physa, Gyraulus remained almost constant, while Callibaetis, Caenis, Ischnura, and Tendipes decreased slightly but were again numerous 1 year after treatment.

Tests on several species of zooplankters showed Rotifera to be the most tolerant, followed by Cladocera and Copepoda. Reductions were in Rotifera at 500 p.p.b., in Cladocera at 250 p.p.b., and in Copepoda at 100 p.p.b. Experiments with the larger invertegrates showed Hirudinea, Hydracarina, and Gastropoda to be the most resistant to toxaphene, followed in order by Trichoptera, Odonata, Hemiptera, Ephemeroptera, Amphipoda, and Coleoptera. Survival among the larger invertegrates at intermediate concentrations between 100-percent survival and 100-percent mortality revealed an approximate straight-line relation. Genera within each group exhibited dissimilar tolerance levels.

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INVESTIGATIONS IN FISH CONTROL

5. Growth Rates of Yellow Perch in Two North Dakota Lakes After Population Reduction with Toxaphene

By Donald C. Warnick, Fishery Biologist

U.S. DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
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GROWTH RATES OF YELLOW PERCH IN TWO NORTH DAKOTA LAKES AFTER POPULATION REDUCTION WITH TOXAPHENE

By Donald C. Warnick, Fishery Biologist

Abstract.--Growth rates of yellow perch that survived a toxaphene treatment in Brush and Long Lakes in North Dakota were calculated by the scale method for the 1960 and 1961 growing seasons. Brush Lake fish exhibited greatly increased growth rates for both growing seasons following the treatment. Increased growth rates were not evident for Long Lake fish until the 1961 growing season. At the end of the first full growing season after treatment the surviving yellow perch exceeded what may be considered to be the minimum harvestable size of 7 inches. The approximate concentration of toxaphene for reducing the density of fish populations is believed to be 25 percent of the rate determined for fish eradication in most North Dakota waters.

Waters overpopulated with desirable species generally produce few harvestable fish, because of slow growth. Bennett (1962) stated that no fish of harvestable size were found in some waters thus affected; Eschmeyer (1936) made a similar observation concerning overcrowded populations of yellow perch (Perca flavescens). For lack of more efficient remedial measures the use of piscicides has been recommended to reduce the numbers of the problem species.

Relatively low concentrations of toxaphene (chlorinated camphene) in two North Dakota lakes substantially reduced the density of the yellow perch populations; the effect on other fish species was less obvious. The results reported (Henegar, 1965) were incidental to the determination of the minimum toxaphene concentration necessary for fish control in that State. My study was started in 1960 to determine the growth rates of the yellow perch surviving in Brush and Long Lakes, and thus gain information concerning the suitability of toxaphene for reducing the numbers of fish in overpopulated waters. The scale method was employed to calculate growth rates of Brush Lake fish for the 1960 and 1961 growing seasons. Posttreatment growth rates of Long Lake fish were determined for part of the 1960 growing season and for all of the 1961 season.

Several authors reporting on the use of rotenone to thin overcrowded populations or to restore balance among fish species considered the results favorable. Beckman (1941) noted that the growth rates of fish surviving the treatment of half of Booth Lake, Mich., were too great to be accounted for by normal variation. Substantially increased harvests, apparently the results of accelerated growth rates of remaining fishes, were reported by Swingle, Prather, and Lawrence (1953) following treatment of some Alabama ponds. Hooper and Crance (1960) stated that the use of rotenone was an effective and economical way to restore balance in certain fish populations. The use of toxaphene was recommended by several authors including Hemphill (1954) who first used the chemical for fish eradication.

This publication is based on a thesis submitted to the Graduate Faculty, Department of Entomology-Zoology, South Dakota State College of Agriculture and Mechanic Arts, in partial fulfillment of the requirements for the degree of Master of Science, June 1963.

Cost of fish eradication with toxaphene is approximately 15 percent of the cost with rotenone. With recommended concentrations and methods for thinning overcrowded fish populations with these chemicals, toxaphene is even more economical. Definite information about this use of the poison and the subsequent results is conspicuously absent.

Unfavorable results from the early use of toxaphene for fish eradication were not uncommon and tended to delay the acceptance of the piscicide for use in fishery management (Prevost, 1960). Consequences of a serious nature were the failure of the poison to kill all fish; the extended toxicity of some treated waters; and the reduction or elimination of many aquatic organisms. Hooper and Grzenda (1955) first suggested that such results were due to confusion concerning lethal concentrations and the belief was substantiated by the accumulation of additional evidence (Stringer and McMynn, 1960). Increased proficiency in using the chemical for fish eradication led to its acceptance for that purpose as indicated by Gebhards' 1960 review of past and proposed use in western states.

Toxaphene concentrations used for fish eradication reportedly reduce or eliminate many fish-food and food-chain species, some of which do not reappear in quantity for extended periods (Stringer and McMynn, 1958). Relatively little is known concerning the effects of the lesser toxaphene application rates recommended for reducing the density of overcrowded fish populations. A paucity of fish-food organisms in the North Dakota lakes--even for a comparatively short period after toxaphene application--would affect growth rates of the surviving fish as indicated by scale analysis.

I am obliged to Dale L. Henegar, Chief of Fisheries, North Dakota Game and Fish Department, who brought to my attention the opportunity for this investigation, and to the fishery personnel who assisted with the field work. I wish to thank Marvin O. Allum, Associate Professor of Zoology, for his counsel during the study, and the other faculty members and fellow graduate students of South Dakota State College for their interest and assistance.

THE STUDY LAKES

The minimum concentration of toxaphene required for fish eradication is determined on the basis of the physical and chemical characteristics of the water for which treatment is proposed in addition to certain biological conditions, and this is assumed to be true with regard to application rates for reducing the density of fish in overpopulated waters. Some physical and chemical characteristics of Brush Lake and Long Lake are presented in table 1. The following history is pertinent to the study of the posttreatment growth rates and is based on material presented by Henegar in 1961 (Henegar, 1966).

Both lakes were treated with toxaphene to produce concentrations of approximately 0.010 parts per million (p.p.m.) using an emulsifiable concentrate containing 6 pounds of the active ingredient per gallon. Brush Lake was treated on October 5, 1959, and Long Lake on July 17, 1960. The method of application was that commonly used by the North Dakota Game and Fish Department, and similar to that described by Stringer and McMynn (1958).

Dilution of the waters by rainfall or by runoff was inconsequential after toxaphene treatment, because of unusual drought. Water levels receded somewhat during the course of the study. Rooted aquatic vegetation was along portions of the shoreline and in several small shallow areas of Long Lake at the time of treatment, but was nearly absent from Brush Lake because of the late-season treatment date.

Apparently, all young-of-the-year yellow perch were eliminated from both lakes.

TABLE 1.--Physical and chemical characteristics of the lakes

Item	Brush Lake	Long Lake
Location (North Dakota)	McLean County	Bottineau County
General area of State	Central	North Central
Origin of lakes	Glacial	Glacial
Bottom type	Silt-loam	Silt-loam
Surface acres	160	291
Acre feet	1,527	2,391
Maximum depth (feet)	23-24	23-24
Average depth (feet)	9.5	8.2
pH[1]	8.5	8.3
Phenolphthalein alkalinity (p.p.m.)[1]	40	40
Methyl orange alkalinity (p.p.m.)[1]	460	220
Hardness (p.p.m.)[1]	476	308
Total dissolved solids (p.p.m.)[1]	290	307

[1] Condition on date of application.

Observations established deaths of some young-of-the-year northern pike (Esox lucius) in Long Lake, but posttreatment netting disclosed they were not eliminated. The effect of the poison on adult fish of several species in both lakes was less evident than the effect on yellow perch, the dominant species.

Excluding the young-of-the-year, yellow perch density was reduced approximately 91 percent in Brush Lake and 79 percent in Long Lake. The figures are derived from the results of test-netting just before and several months after poisoning. Netting results also indicated that a greater percentage of the smaller yellow perch (less than 140 millimeters) was eliminated than of the larger fish. Observation of Long Lake for several days after toxaphene application tended to substantiate the netting results.

Populations of fathead minnows (Pimephales promelas) were established in the lakes after treatment. Brush Lake was stocked on May 27, 1960, and Long Lake on August 18, 1960. Introduction of minnows after toxaphene treatment is a general practice of the North Dakota Game and Fish Department.

AGE AND GROWTH

Varied evidence has been presented in support of the validity of the scale method for the determination of the age and growth of fishes (Lee, 1920; Van Oosten, 1929). Similar evidence indicates that the method is valid for determining the age and growth rates of yellow perch. Joeris (1957) indicated that additional evidence on the validity of the annulus world accumulate from the further study of Green Bay (Lake Michigan) perch. Jobes, as early as 1934, assumed the validity of the method for yellow perch. The North Dakota study was based on the assumption that the method is valid.

Scale samples of yellow perch from the study lakes were obtained from specimens netted before and after the poisoning, from poisoned fish, and from winterkilled specimens.

It was apparent during analysis of the scale samples from Long Lake, July 12-17, 1960, that distinction of age classes would be difficult. Determination of the age composition for this group was dependent on the identification of all annuli for each scale sample. For many samples it could not be established whether the 1960 annulus had been formed. The samples from smaller fish (80-120 millimeters) generally evidenced annulus formation and some subsequent growth, but the 1960 annulus was apparently unformed on some of the scales of larger fish. Because of relatively little scale growth the previous season, it could not be determined whether the annulus was recently formed and the later scale growth was of the 1960 growing season, or the annulus was unformed and the scale growth of the previous year was represented. An error of 1 year would be introduced by the wrong choice.

A similar difficulty was noted by Joeris (1957) during analysis of yellow perch scales. Beckman (1943) reported that the time of annulus formation may vary notably among species and within age groups of the same species. Annulus formation probably would have occurred before the July collection date with more favorable growth conditions.

Even without this difficulty, determination of age classes would have been somewhat subjective. Annuli were not distinct, and markings assumed to be false annuli were common. Consequently the age classes and specific growth rates of fish before treatment are not included.

Posttreatment scale samples from both lakes were obtained after the interruption of growth for the 1961 season and before 1962 growth was begun. An annulus was assumed at the scale margin although none was evident. All discernible increase in scale growth of the Long Lake fish was included between the margin and the annulus of the previous year. The scale growth of Long Lake fish during the 1960 season after poisoning was not distinguishable from previous scale growth. Growth increments for the 1961 growing season are presented in table 2. Errors other than mechanical are unlikely because of the distinctive scale growth and the absence of false annuli during that period.

TABLE 2.--Calculated growth increments of yellow perch from Long Lake for the 1961 growing season

[In millimeters]

Number of fish	Total length at capture		Calculated growth increment	
	Range	Average	Range	Average
17[1]	103-132	115	--	--
1	--	178	--	82
5	201-210	205	58-101	75
1	--	219	--	59
21	221-230	227	59-120	74
32	231-240	235	45-116	75
28	241-250	247	56-106	79
12	251-260	253	75-116	83
7	261-270	265	54-99	78

[1] Young-of-the-year in 1961.

Scale samples were not obtained from Brush Lake fish until 2 years after treatment. Accelerated scale growth was obvious between the scale margin and annuli of the 2 previous years. The calculated growth rates for the corresponding periods are contained in table 3. As in the scales of Long Lake fish, growth before poisoning was obscured by the presence of numerous false annuli.

When an annulus of the year previous to those located for the preparation of tables 2 and 3 was obvious, as it was on some scales, a direct comparison of scale growth before and after poisoning was made. On this basis the post-treatment growth during the first year was approximately six times greater than for the previous year.

Table 4 shows the relation of fish length to subsequent growth--both calculated. The fact that greater length increments were recorded for smaller fish lends validity to the scale method as applied here.

A change in the size composition of Long Lake fish is evident in table 5. The numbers of fish in the last column represent a subsample of winterkilled specimens in addition to several obtained by qualitative test-netting. The numbers of fish in the other columns represent test-netting results at the times indicated. Excluding the 17 young-of-the-year of 1961, the lengths of fish listed in the last column are approximately 75 to 100 millimeters greater than the lengths of fish listed in the previous column. Despite the time interval, only one growing season, 1961, is represented. The calculated average growth increment for the period was 82 millimeters.

TABLE 3.--Calculated growth increments of yellow perch from Brush Lake for the 1960 and 1961 growing seasons

[In millimeters]

Number of fish	Total length at capture	Average 1960 increment	Average 1961 increment
6[1]	175-200	95	98
0	201-225	--	--
7	226-250	89	45
15	251-275	95	51
8	276-300	100	57

[1] Young-of-the-year in 1960.

TABLE 4.--Relation of fish lengths to subsequent growth increments (both calculated) for yellow perch from Long Lake

[In millimeters]

Number of fish	Calculated length, May 1961	Growth increment 1961	
		Range	Average
17[1]	103-132	103-132	115
2	91-100	82-121	101
2	101-110	101-119	110
1	111-120	--	--
0	121-130	--	--
8	131-140	64-116	92
15	141-150	61-104	85
27	151-160	58-96	76
29	161-170	59-101	76
12	171-180	67-89	75
8	181-190	45-82	67
1	191-200	--	66
1	201-210	--	54

[1] Young-of-the-year in 1961; lengths are measured total lengths.

TABLE 5.--Toxaphene-effected change in the yellow perch population of Long Lake based on measured total lengths of fish taken during the study

Length range	Number of fish		
	Before treatment (July 1960)	After treatment	
		October 1960	May 1962
45-65 mm.	1,010	0	0
66-100 mm.	527	0	0
101-125 mm.	312	0	[1] 17
126-150 mm.	198	152	0
151-175 mm.	196	243	0
176-200 mm.	7	0	1
201-225 mm.	0	0	12
226-250 mm.	0	0	75
251-275 mm.	0	0	19
Total	2,250	395	124

[1] Young-of-the-year in 1961.

DISCUSSION

The yellow perch is a popular species in recreational fisheries, especially for winter fishing, but fish shorter than a total length of 7 inches or approximately 175 millimeters are not often sought and removed by fishermen. If this length is considered the minimum harvestable size, the growth rates recorded for the yellow perch from the North Dakota lakes are significant with respect to the short time required for the improvement of recreational fisheries. All yellow perch surviving similar treatment rates could be expected to exceed the minimum desirable size during the subsequent growing season, and young-of-the-year after only two growing seasons.

Young-of-the-year yellow perch commonly reach harvestable size in three or more growing seasons except in overpopulated waters where growth is restricted. Growth rates of surviving fish were exceptionally rapid during the growing season following treatment--1960 for Brush Lake and 1961 for Long Lake--when compared with growth rates of yellow perch in other areas. Similar growth increments have not been recorded even for more southern latitudes with longer growing seasons (Carlander, 1953).

On the basis of this study, better recreational fishing can be provided at low cost in some lakes and small impoundments overpopulated with yellow perch. Improved angling was assumed in the North Dakota lakes since more fish of harvestable size were produced, but the determination of increased harvests would be conclusive. Comparable results might also be expected following the thinning of other commonly overpopulated species inasmuch as my study was opportunistic, not a deliberate selection of species.

Low toxaphene concentrations in North Dakota lakes have been observed to eliminate small fish of many species including the bullhead (Ictalurus melas), reported by Kallman, Cope, and Navarre (1962) to be somewhat resistant to the toxicant. The policy in North Dakota of introducing minnows in waters after treatment with toxaphene is based on this observation.

An assumed absence of prey fish may explain the continued slow growth of yellow perch in Long Lake during the 1960 growing season, after the mid-July application of toxaphene. The May 27, 1960, introduction of 180,000 fathead minnows in Brush Lake evidently assured the presence of significant numbers for the same growing season and no unusual period of slow growth was apparent from scale analysis. The reduction or elimination of prey fish by the mid-July poisoning and the August 18, 1960, stocking of 200,000 fathead minnows, leaves doubt whether significant numbers were present in Long Lake until the 1961 growing season when growth rates of yellow perch were greatly accelerated. A need for more conclusive information concerning the relation of prey species to growth rates is indicated.

Assuming need for the introduction of prey species, a definite advantage is apparent for the fall treatment of waters since stocking can be accomplished early in the subsequent growing season. Treatment in April or May is probably more advantageous than during the growing season, but conditions then are not favorable for rapid detoxification, and stocking of prey species might have to be delayed.

The toxaphene treatment rate which allowed the survival of yellow perch in the North Dakota lakes was approximately one-third of the determined rate for fish eradication in most waters of that State. A belief that the reductions were excessive can be temporized since the possibility that an optimum number of fish survived in either lake is unlikely, and greater growth rates could hardly be expected. Test-netting of both lakes and observation after a partial winterkill of Long Lake in 1962 substantiates the belief. Concentrations approximating 0.008 p.p.m. (one-fourth of the minimum lethal rate) probably would have allowed the survival of more fish without significantly reducing growth rate.

On the basis of a recent report by Kallman, Cope, and Navarre (1962), the presence of relatively large quantities of vegetation at the time of treatment could affect the outcome, especially in consideration of the low toxaphene concentrations required for the thinning of fish populations. It was indicated that high concentrations of toxaphene are accumulated by certain vegetative species in a relatively short time, thus essentially removing the chemical from the water--at least temporarily--and the further disposition of the chemical was unknown. Therefore, more consistent results might be obtained, with regard to the degree of reduction, by treatment during the absence of most aquatic vegetation.

The appropriate reduction for any population necessarily depends on a variety of conditions, some unknown. The difficulty of determining the magnitude of fish populations, particularly after treatment, seriously affects an evaluation of the results. Additional information concerning the use of toxaphene for reducing the density of fish populations is needed for its greatest usefulness.

SUMMARY AND CONCLUSIONS

Yellow perch populations in two North Dakota lakes were substantially reduced by low toxaphene concentrations. Growth rates of surviving fish were determined by the scale method for 2 years after treatment. Greatly increased growth rates were evident for both growing seasons following the fall treatment of Brush Lake. Increased growth rates were not evident for Long Lake fish after the July 17, 1960, treatment until the 1961 growing season. All yellow perch surviving the poisoning exceeded what may be considered to be the minimum harvestable size during the first full growing season after treatment. Comparable results can be expected from similar and perhaps lesser reductions with toxaphene.

Further use of toxaphene is recommended for reducing the density of yellow perch populations and thus improving certain recreational fisheries. Other species might be similarly managed. Reduction or elimination of prey species was believed to explain the continued slow growth of Long Lake fish for approximately 2 months after toxaphene application. Fall treatment is apparently the most timely, especially with regard to assuring the presence of significant numbers of prey species during the growing season. Numerous conditions affect the concentration of toxaphene needed for fish eradication, and the approximate concentration for reducing the density of fish populations is believed to be 25 percent of that rate.

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INVESTIGATIONS IN FISH CONTROL

6. Mortality of Some Species of Fish to Toxaphene at Three Temperatures

By Mahmoud Ahmed Mahdi, Fishery Biologist

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MORTALITY OF SOME SPECIES OF FISH TO TOXAPHENE AT THREE TEMPERATURES

By Mahmoud Ahmed Mahdi, Fishery Biologist

Abstract.--Lethal concentrations of toxaphene were determined for the stoneroller, golden shiner, goldfish, black bullhead, and bluntnose minnow in water at 53° F., 63° F., and 73° F.; rainbow trout were tested at 53° F. The TL_m and LD_{50} were obtained by graphic methods. For comparison a normit method was used with the bluntnose minnow data; all three methods gave similar results for the bluntnose minnow. In most experiments, concentrations of toxaphene needed to cause 50 percent mortality decreased as the temperature increased from 53° F. to 63° F. and to 73° F. The 96-hour TL_m values were below 0.1 p.p.m. of toxaphene in all species tested. Goldfish were the most tolerant, with the other species showing so similar a sensitivity that they could not be effectively ranked by these data.

Toxaphene (chlorinated camphene) is used widely as an insecticide on farm crops and as a poison to control fish populations (Henderson et al., 1959; Fukano and Hooper, 1958). Toxaphene is highly toxic, especially to man, and is never recommended for household use (it can be absorbed through the skin). For mammals, toxaphene is one of the more toxic of the chlorinated hydrocarbon insecticides (Cohen et al., 1960, p. 1552). Negherbon (1959) lists it as being more toxic to fish than DDT or rotenone. Toxaphene is nonvolatile, yellow to amber in color, and has an aromatic, pinelike smell. It is insoluble in water but soluble in organic solvents (Henderson et al., 1959). The emulsion used in this investigation was milky white.

This study was an attempt to determine the concentrations of toxaphene that will kill certain species of fish. Three temperatures were used, to ascertain the role temperature plays in the toxicity of toxaphene.

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I am indebted to Dr. Kenneth D. Carlander for his help in interpreting the data and in putting this work in its final form. I am obliged also to T. Hoage, Dr. V. Gooch, J. Reynolds, and C. Caillouet for their advice on interpretation of the data, and to Charles Walker of the Fish Control Laboratory, La Crosse, Wis., who supervised the experiments.

METHODS

These experiments were carried out at the Fish Control Laboratory of the Bureau of Sport Fisheries and Wildlife at La Crosse, Wis. The fish were provided by the Laboratory and from various sources, including hatcheries. The following species were tested:

1. Rainbow trout, Salmo gairdneri.
2. Stoneroller, Campostoma anomalum.
3. Goldfish, Carassius auratus.
4. Golden shiner, Notemigonus crysoleucas.
5. Bluntnose minnow, Pimephales notatus.
6. Black bullhead, Ictalurus melas.

Before starting an experiment the fish were examined thoroughly to make sure that there were no signs of disease. They were left in large holding tanks and fed regularly until 2 days before the start of the experiment. To keep to a minimum waste products that might affect toxicity, they were not fed during the experiments.

WATER

Deionized water was reconstituted by adding a mixture of 0.45 grams of calcium sulphate, 0.45 grams of manganous sulphate, 0.72 grams of sodium bicarbonate, and 0.03 grams of potassium chloride, giving 1.65 grams of a powdered mixture for every 15 liters of water. This reconstituted water has the following characteristics:

pH	7.9
Carbon dioxide	1.0 p.p.m.
Total alkalinity	36.0 p.p.m.
Total hardness	72.0 p.p.m.
Calcium hardness	26.0 p.p.m.
Manganese	0.075 p.p.m.
Sulphate ion	37.5 p.p.m.
Chloride ion	6.86 p.p.m.
Ammonia nitrogen	0.05 p.p.m.
Total ion	0.00 p.p.m.

The reconstituted water was aerated for 24 hours and was then transferred into glass jars of two sizes, large ones containing 15 liters of water and small ones of 1 gallon each. Each sized jar was large enough to hold the required volume of water at a point somewhat below the rim. The large jars were placed in concrete tanks about 30 inches deep and 3 feet wide, where they were allowed to rest in the water. Eighteen jars were used in each experiment, including three for controls and three each for five different concentrations. Sometimes additional jars were used to permit more than five concentrations in an experiment. The small jars were put in aluminum troughs 1 foot deep; four small jars were used for the control and 15 for each concentration.

Circulating water pumps were used to mix water in tanks and aluminum troughs to ensure an even temperature. Elevated temperatures were maintained with electric water heaters and thermostats. A small thermogrph recorded the temperature of the water, and these records indicated good temperature control.

TRANSFER OF FISH

Hand nets that were used to take fish out of the tanks were kept in an antiseptic solution ([illegible] milliliters of Roccal to 25,000 milliliters of water) when not in use. The fish were transferred into a bucket of water mixed with acriflavine (concentration not critically determined). Douglas and Irwin (1962) found that Terramycin and acriflavine in small amounts were successful in combating fin or tail rot. The fish were not overcrowded, but to ensure an abundance of oxygen, air was run into the bucket. During the transfer, any fish which fell to the floor were not used in the experiment.

After making sure that the water temperature in the jars was adjusted, the fish were weighed and placed in the jars to be acclimatized for another 24 hours. To ensure that the fish were not overcrowded, they were introduced according to the loading capacity of each species by weight, making sure that the weight of fish should not exceed the safe range. In the case of the lowest temperature used, 53° F., the safe range of the loading capacity of each jar for different species of fish had been determined by the staff of the Fish Control Laboratory. Experiments were run to determine the safe loading capacity at 73° F. of several species of fish (table 1). From these data it is clear that up to 2 grams of goldfish per liter of water can be used safely for a period of 96 hours. For the golden shiner and the stoneroller, up to 1 gram of fish per liter of water can safely be used for 96 hours. Two grams of golden shiner per liter of water can be used, but not for more than 72 hours, whereas the same loading capacity is not advisable for the sonteroller even for the first 24 hours.

The largemouth bass can stand up to 2 grams of fish per liter of water only for the first 24 hours. If bass are to be used for more than 24 hours, one-fourth gram of fish per liter of water could only be used for not more than 48 hours. Otherwise less loading should be tried.

No loading capacity tests were run at 63° F., but loading capacities exceeding those found at 73° F. were not used.

TABLE 1.--Percentage mortality of four species of fish, and dissolved oxygen in parts per million, at different loading capacities at 73° F.

Fish and time	At a load per liter of water of--							
	0.25 gram of fish		0.5 gram of fish		1.0 gram of fish		2.0 grams of fish	
	Fish killed	Oxygen	Fish killed	Oxygen	Fish killed	Oxygen	Fish killed	Oxygen
	Percent	P.p.m.	Percent	P.p.m.	Percent	P.p.m.	Percent	P.p.m.
Stoneroller:								
24 hours	0	--	0	--	0	--	38	--
48 hours	0	3.5	0	3.5	0	1.6	38	1.6
72 hours	0	2.6	0	2.6	0	1.4	38	1.3
96 hours	0	2.8	0	2.7	0	1.5	50	1.3
Goldfish:								
24 hours	--	--	0	--	0	--	0	--
48 hours	--	--	0	2.9	0	1.4	0	0.9
72 hours	--	--	0	1.7	0	1.0	0	0.8
96 hours	--	--	0	2.0	0	1.6	0	0.8
Golden shiner:								
24 hours	0	--	0	--	0	--	0	--
48 hours	0	5.3	0	3.8	0	1.9	7	1.6
72 hours	0	3.9	0	2.7	0	3.1	7	1.5
96 hours	0	3.5	0	3.1	0	3.7	15	1.5
Largemouth bass:								
24 hours	0	--	0	--	8	--	4	--
48 hours	0	5.3	33	4.3	31	2.2	22	0.9
72 hours	25	4.1	33	2.5	31	1.6	26	0.8
96 hours	25	3.7	33	2.5	31	2.0	26	1.3

INTRODUCTION OF TOXAPHENE

Toxaphene solution was prepared fresh from commercial stock each time it was to be introduced into the jars. The commercial stock was a solution of 4 pounds per gallon. Two milliliters of the commercial stock were transferred to a 1-liter flask, and deionized water was added to make 1 liter of solution. When 1 milliliter of this solution was added to 1 liter of water it gave approximately 1 part per million of the toxicant. The toxaphene concentration was calculated according to this and introduced into the different jars as required. When very dilute solutions were required, the stock solution was further diluted by taking 100 mililiters of it and adding 1 liter of deionized water, making a new stock solution (0.0001 toxaphene) of which 1 milliliter in 1 liter of water gave 0.1 p.p.m.

In the introduction of the toxicant, 1-milliliter, 2-milliliter, and 5-milliliter pipettes were used. To avoid suction of the toxicant and to speed the introduction of the toxaphene into the jars, the stock solution was put in a long cylinder and the pipette filled by capillary action. When the level of the solution in the cylinder went down, more was added from the original solution. A glass rod was used to ensure mixing of the toxicant. The concentration of each jar was noted by marking with a wax pencil on the logs of wood supporting the big jars or on the aluminum tank near each small jar.

OBSERVATIONS

Observations were recorded each 24 hours after the toxaphene was introduced. Readings were taken for 96 hours, showing the number of dead fish in each jar. Oxygen was tested each day from the day of introduction of toxaphene to the last day of the experiment. Samples for oxygen determination were taken from the controls and not always from the same jar each day. This does not show exactly the oxygen situation in all the jars. There is a greater chance for more oxygen in the jars that lost larger numbers of fish (died and removed) than jars with most of the fish still alive.

Unless a fish was completely dead, it was recorded as alive. Some fish, bluntnose minnows for example, rested at the bottom of the container with their backs down and appeared to be dead. The fish in such cases were touched with a glass rod; if they did not show signs of movement, they were recorded as dead. Dead fish were removed only once a day. Each day the dead fish were collected and burned. At the end of the experiment all treated fish, including those still alive, were disposed of in the same way.

ANALYSIS

From the mortality observed, the TL_m (median tolerance limit) values were obtained. The TL_m is "the concentration of the tested material in a suitable diluent (experimental water) at which just 50 percent of the test animals are able to survive for a specified period of exposure" (American Public Health Association, 1960, p. 458).

On semilogarithmic paper, 3 cycles x 70 divisions, concentration of the toxicant was plotted against the mortality observed. Two points only were used, one point showing mortality above 50 percent of the population and the other one below 50 percent. These two points were connected (see fig. 1). From this line the concentration which killed 50 percent of the population was obtained. In this example the 96-hour TL_m for bluntnose minnows at 63^{o} F. was found to be 0.0088 p.p.m. In certain cases where the gap between the two points was big, for instance, goldfish at 63^{o} F., the 72-hour TL_m values were obtained but were considered rough.

Whenever there were sufficient data, the L LD_{50} (the median lethal dose) was evaluated by a graphic method (Wilcoxon and Litchfield, 1949). The does were plotted against the percent mortality on logarithmic-probability paper No. 3228. Tests showing 0 percent or 100 percent mortality were omitted. A straight line was drawn through the points, particularly those showing just less and just more than 50 percent mortality (fig. 2). The expected mortality at each concentration is then read from the straight line and compared with the observed mortality (table 2). These authors stated that if the chi square of the line is, less than the value of chi square given in table 2 for degrees of freedom, the data are not significantly heterogeneous, that is, the line is a good fit.

Since 0.0502 is less than 7.82, the line seems to be a good fit. From this line (fig. 2) the concentration of the toxicant which kills 50 percent of the population was read and the LD_{50} was found to be 0.011 p.p.m.

In cases where there were only two points (above and below 50 percent mortality), LD_{50} values were determined but they could not be checked statistically as the number of degrees of freedom equals 0.

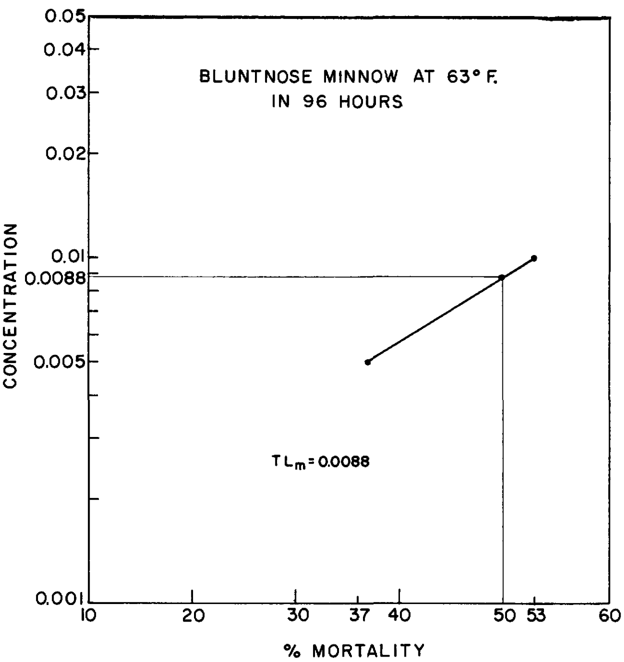

Figure 1.--The 96-hour TL_m for bluntnose minnows at 63° F.

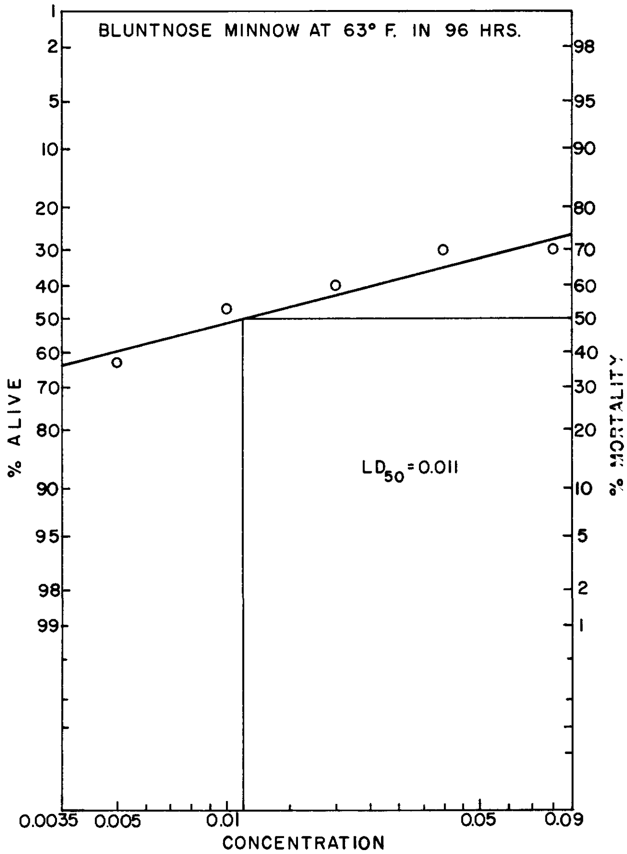

Figure 2.--The 96-hour LD_{50} for bluntnose minnows at 63° F.

TABLE 2.--Chi-square test of the 96-hour LD_{50} for bluntnose minnows at 63° F.

Toxaphene concentration	Percentage mortality		Difference	Contribution to chi square
	Observed	Expected		
0.005 p.p.m.......	37	40	3	0.0036
0.01 p.p.m.......	53	59	4	0.0060
0.02 p.p.m.......	60	57	3	0.0035
0.04 p.p.m.......	70	65	5	0.0100
0.08 p.p.m.......	70	72	2	0.0020
All.............	--	--	--	0.0251

For the bluntnose minnows a third method of analysis was also used, the minimum normit chi square method (Berkson, 1955). The LD_{50} is 0.0092 p.p.m. which is quite close to the TL_m and graphic LD_{50} values.

RESULTS

The three methods of analyzing the data gave very similar results in most cases when applied to the bluntnose minnow (table 3). At 24 hours at 53° F. none of the concentrations gave over 22 percent mortality, and therefore the TL_m and LD_{50} values must be very approximate. At 63° F. the mortality was spread over a wide range of concentrations with lower mortality sometimes appearing in higher concentrations. With such variation in the experimental data it can be expected that the estimates of the concentration at which 50 percent die is subject to considerable variation. Yet the three methods give quite comparable estimates except for the 48-hour period. At 73° F. the 48-hour TL_m and normit LD_{50} values do not agree very well. This results from the use of only two points in each case, and the two points used were not the same.

The normit method was used only with the bluntnose minnow. In several situations with other species the graphic LD_{50} method could not be used because mortality rates both above and below 50 percent, but not 0 or 100 percent, were not available. In all other cases the TL_m and LD_{50} values were quite similar.

TABLE 3.--TL_m and LD_{50} values for bluntnose minnows at three temperatures.

Temperature and time	TL_m	LD_{50}	
		Graphic	Normit
At 53° F:			
24 hours................................	>4.0	--	11.58
48 hours................................	0.86	0.86	0.93
72 hours................................	0.15	--	0.118
96 hours................................	0.03	0.03	0.038
At 63° F:			
24 hours................................	0.2	0.15	0.1849
48 hours................................	0.035	0.088	0.04609
72 hours................................	0.014	0.016	0.01805
96 hours................................	0.0088	0.011	0.0092
At 73° F:			
24 hours................................	0.015	0.016	0.0124
48 hours................................	0.0084	--	0.0043
72 hours................................	0.0065	0.0088	0.0071
96 hours................................	0.0063	0.007	0.0066

Berkson (1950) used eight different methods for the estimation of the LD_{50} and found that all gave about the same results. Since the three methods used here gave close results in most cases, only the TL_m data are discussed table 4).

CHANGE WITH TIME

It can be anticipated that fish can survive higher concentrations of a toxicant for short periods of time than they can for longer periods. As expected, in most of the tests (table 4) the TL_m values decreased with time; in some cases the TL_m remained constant, for instance the 72-hour and 96-hour TL_m of the golden shiner at 73° F. and of the goldfish at 53° F. and 63° F., and the 48-hour, 72-hour, and 96-hour TL_m of the goldfish at 73° F. Henderson and Tarzwell (1957) stated that experience with a variety of industrial effluents has shown major difference in 24- and 48-hour TL_m values, although there was little or no difference in the 48- and 96-hour values, except for an occasional effluent which produced fish mortality over the longer period.

Pickering et al (1962) when examining the acute and chronic or accumulative toxicity of Delnav to fathead minnows, found that TL_m

TABLE 4.--Median tolerance limits (TL_m) to toxaphene for six species of fishes at three temperatures.

Species and temperature	Concentration in p.p.m. for--			
	24 hrs.	48 hrs.	72 hrs.	96 hrs.
Rainbow trout:				
At 53° F......................	0.03	0.0145	0.0111	0.0084
Stonerollers:				
At 53° F......................	0.062	0.027	0.027	0.014
Do........................	0.028	0.0086	0.008	0.0066
At 63° F......................	0.054	0.044	0.035	0.032
At 73° F......................	0.009	0.0078	<0.005	<0.005
Goldfish:				
At 53° F......................	0.27	0.115	0.094	0.094
At 63° F......................	0.086	0.035	0.028	0.028
At 73° F......................	0.054	0.05	0.05	0.05
Golden shiner:				
At 53° F......................	0.0125	--	--	--
At 63° F......................	0.027	0.007	0.0062	<0.005
At 73° F......................	0.0134	0.0066	0.006	0.006
Bluntnose minnow:				
At 53° F......................	>4.0	0.86	0.15	0.03
At 63° F......................	0.2	0.035	0.014	0.0088
At 73° F......................	0.015	0.0084	0.0065	0.0063
Black bullhead:				
At 53° F......................	>0.048	>0.048	0.034	0.025
At 63° F......................	0.015	0.0043	0.0042	0.0027
At 73° F......................	0.012	0.0042	0.003	0.0018

values decreased (toxicity increased) rapidly for the first 5 days and less rapidly for the next 10 days. They did not notice any further decreases in TL_m values during the additional 15 days of exposure.

CHANGE WITH TEMPERATURE

With increase in temperature the rate of metabolism is higher and the toxicant is expected to be more effective. This was very clear in the case of the black bullhead and the bluntnose minnow which showed rapid decrease in TL_m with increase in temperature. The goldfish showed rapid decrease in TL_m with increase in temperature from 53^o F. to 63^o F. At 73^o F. the 24-hour TL_m went down and then kept constant at the 48-hour, 72-hour, and 96-hour TL_m values higher than those at 63^o F.

The golden shiner and the sonteroller showed decrease in TL_m with change in temperature from 63^o F. to 73^o F. When temperature was changed from 53^o F. to 63^o F., the 24-hour TL_m of the golden shiner was higher at 63^o F. than at 53^o F. The 24-hour TL_m of the stoneroller at 53^o F. was higher in one test when compared with the TL_m at 63^o F. and lower in the other. Both experiments of stoneroller at 53^o F. were lower in 48-hour, 72-hour, and 96-hour TL_ms than the equivalent TL_m at 63^o F. These variations in results indicate tests which should be repeated.

SPECIES COMPARISONS

Toxaphene was highly toxic to fish with 96-hour TL_m values below 0.1 p.p.m. in all the tested cases. Henderson et al. (1959) gave TL_ms of four species of fish to toxaphene (table 5). Their results for the fathead minnow are very similar to ours for bluntnose minnows (table 4). The TL_m values for goldfish are somewhat different, but the TL_m values for goldfish at 73^o F. (table 4) have already been questioned. When they used BHC insecticide at 77^o F. they found the 24-, 48-, and 96-hour TL_m for the fathead to be 22, 16, 15 p.p.m. respectively and for the goldfish 26, 21, and 15 p.p.m.

TABLE 5.--Median tolerance limits (TL_m) to toxaphene at 77^0 F. for four species of fish.

[From Henderson et al., 1959, p. 27]

Fish	Toxaphene, reference standard, 100-percent active in acetone, diluted in--	TL_m (p.p.m.) at--		
		24 hrs.	48 hrs.	96 hrs.
Fatheads..	Soft water......................	0.013	0.0075	0.0075
Do......	Hard water......................	.016	.0075	.0051
Bluegills.	Soft water......................	.0075	.0038	.0035
Goldfish..	....do..........................	.0082	.0068	.0056
Guppies...	....do..........................	.042	.024	.020

When comparing the action of toxaphene in a period of 24 hours, the bluntnose minnow at 53^o F. seemed to be the most tolerant of all the tested species. These fish settle on their backs and remain in a half-dead state thus tolerating high doses of the toxicant. The goldfish ranked second, followed by the stoneroller, black bullhead, rainbow trout, and golden shiner. At 63^o F. the black bullhead was more sensitive than the golden shiner, whereas the others ranked the same as at 53^o F. (no data on the rainbow trout). At 73^o F. the goldfish showed higher TL_m than the bluntnose minnow, followed by the golden shiner, the black bullhead, and the stoneroller.

In comparison of the 96-hour TL_m at 53^o F., the goldfish was the most tolerant, followed by the bluntnose minnow, black bullhead, and stoneroller, with the rainbow trout as the most sensitive (no data on the golden shiner). At 63^o F. the stoneroller was the most tolerant, leaving the goldfish in the second rank, followed by the bluntnose minnow, black bullhead, and golden shiner. At 73^o F. the goldfish appeared to be the most tolerant, followed by the bluntnose minnow, golden shiner, black bullhead, and stoneroller.

In general, it seemed that the goldfish was the most tolerant of the tested fish to toxaphene, realizing that the bluntnose minnow at 53^o F. showed higher TL_m in the first 72 hours.

This apparent high tolerance of the bluntnose minnow in the first 3 days was due to the fact that they remained on their backs, but still half alive, for some time after being affected. If the half-dead fish had been considered dead, the TL_m values would probably have been lower than those of the goldfish, which died quicker. The other species seem to be about equally sensitive to toxaphene and cannot be readily ranked.

OXYGEN

Aeration of the water was not consistent enough for the experiments to be comparable with respect to dissolved oxygen. Dissolved oxygen recorded at the beginning of the experiments (24 hours after the fish were put in the jars) varied from 5.9 to 8.0 p.p.m. at the 53° F., from 4.8 to 6.2 at 63° F., and from 3.2 to 6.0 p.p.m. at 73° F. More consistent results might have been secured if all experiments had been started with dissolved oxygen near saturation.

In four experiments (stoneroller at 73° F., bullhead at 73° F., and bluntnose minnow at 53° F. and at 73° F.), the recorded dissolved oxygen increased at least 1 p.p.m. sometime during the experiment, a situation which is difficult to explain.

The dissolved oxygen was below 3 p.p.m. at the end of the first 24 hours in the goldfish experiments at 53° F. and 73° F., the two experiments with the highest loading capacity, 2 grams per liter. It was also below this level for the stoneroller at 63° F. and for all 73° F. experiments except the bluntnose minnow. While minimal oxygen requirements of fish are subject to many factors such as temperature and carbon dioxide content, the dissolved oxygen, if at the recorded values, was probably low enough to seriously affect the experimental fish. The Aquatic Life Advisory Committee of the Ohio River Valley Water Sanitation Commission states (1955, p. 327):

> The dissolved oxygen content of warm water fish habitats shall be not less than 5 p.p.m. during at least 16 hr. of any 24-hour. period. It may be less than 5 p.p.m. for a period not to exceed 8 hr. within any 24-hr. period, but at no time shall the oxygen content be less than 3 p.p.m. To sustain a coarse fish population the dissolved oxygen concentration may be less than 5 p.p.m. for a period of not more than 8 hr. out of any 24-hr. period, but at no time shall the concentration be below 2 p.p.m.

Rounsefell and Everhart (1953) mentioned that the 5 p.p.m. oxygen tolerance limit is too high and listed minimum oxygen requirements as low as 0.38 p.p.m. for largemouth bass, 0.2-0.3 p.p.m. for black bullhead, and below 0.2 p.p.m. for golden shiner.

The fact that no fish died in the controls indicates that oxygen deficiency in itself was not a direct cause of mortality.

SUMMARY

Experiments were run at the Fish Control Laboratory, Bureau of Sport Fishery and Wildlife, La Crosse, Wis., in the summer of 1962, to determine the mortality of the stoneroller, golden shiner, goldfish, black bullhead, and bluntnose minnow to toxaphene in water at 53° F., 63° F., and 73° F. A sixth species, rainbow trout, was tested at 53° F. only.

At the start of testing, all fish were in good health and showed no disease or abnormalities; fish were not fed during the experiments. Deionized water was reconstituted to give a standard water with specified characteristics. Air was run in the reconstituted water for 24 hours before the start of an experiment. A reliable temperature control device was used to ensure constant temperature. Fish were introduced into jars to acclimatize for 24 hours before treatment with various concentrations of toxaphene. Mortality of fish was recorded every 24 hours for 4 days. Untreated controls were used in each experiment.

TL_m and LD_{50} were obtained by graphic methods to get the concentrations which will kill 50 percent of the population. A normit method was used with the bluntnose minnow data only for comparison. The three methods gave similar results. In most experiments, concentrations of toxaphene needed to cause 50 percent mortality decreased as the length of exposure increased from 24 to 96 hours, and decreased as temperature increased from 53° F. to 63° F. and to 73° F. Dissolved oxygen did not show consistent results and was below 3 p.p.m. in several tests. At 96 hours the TL_m values were below 0.1 p.p.m. of toxaphene in all species, indicating that fish are quite sensitive to toxaphene.

In general, goldfish was the most tolerant of the species tested with the other species showing similar enough sensitivity that they cannot

be effectively ranked with these data. Bluntnose minnows remained half dead much longer than other species, and thus the TL_m values for the first 3 days at least may be somewhat high. Running experiments for longer periods of time is suggested. Narrower ranges of concentrations with several intermediate concentrations can be used in further tests now that the general range has been determined.

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INVESTIGATIONS IN FISH CONTROL

7. Treatment of East Bay, Alger County, Michigan with Toxaphene for Control of Sea Lampreys

By William E. Gaylord, Biological Field Station, Ludington, Mich.
and Bernard R. Smith, Biological Field Station, Marquette, Mich.
Bureau of Commercial Fisheries

U.S. DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
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FOREWORD

Application of toxaphene to East Bay had the approval of the Michigan Department of Conservation and of local inhabitants who were advised on the project in public hearings. The Bureau of Commercial Fisheries and the Great Lakes Fishery Commission, after this single experiment, abandoned the use of toxaphene in the program for control of the sea lamprey. It is believed that certain of the observations in East Bay are of sufficient interest to warrant publication of this report. This study was part of a program conducted by the Bureau of Commercial Fisheries under contract with the Great Lakes Fishery Commission.

TREATMENT OF EAST BAY, ALGER COUNTY, MICHIGAN, WITH TOXAPHENE FOR CONTROL OF SEA LAMPREYS

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Abstract.--An experiment was conducted to determine whether toxaphene can be used to eradicate lake-dwelling sea lampreys and to determine its effect on fish populations. In East Bay, a 78-acre lake on the Sucker River, Alger County, Mich., an estimated concentration of 100 parts per billion was maintained for 14 days. The sea lamprey larvae were more resistant to toxaphene than were the fish, but a complete kill was indicated. One year after treatment, sea lampreys were absent from the lake, while the fish population had recovered.

The Bureau of Commercial Fisheries' program for control of the sea lamprey (Petromyzon marinus) in the Great Lakes has progressed rapidly with the development of lamprey larvicides (Applegate et al., 1961). Success of chemical control depends on treatment of all populations of ammocetes in the streams and lakes tributary to the Great Lakes.

The selective lampricide now being used has proved successful in streams and rivers, but its relatively high cost prohibits use in the larger estuarine bodies and lakes in river systems. In many of these a general toxicant can be used without permanent damage to fish populations. Several chemicals are readily available at nominal cost.

Toxaphene (chlorinated camphene) has been used widely as an agricultural insecticide; it has been used to some extent as a fish toxicant, but no reference could be found to its effect on lampreys. Hooper and Grzenda (1957) stated that 0.05 p.p.m. of emulsified toxaphene is sufficient for fish eradication. They also demonstrated that the substrate influences the rate of detoxification of the material. Hooper and Fukano (1960) observed a slowdown in fish mortality with falling temperatures, particularly at values below 50° F.

An experiment to test the feasibility of using a commercial formulation of toxaphene was planned for 1961. The site selected was East Bay, a small lake in the lower end of the Sucker River, 2 miles east of Grand Marais, Alger County, Mich. The Sucker River had been treated with selective larvicide in 1958 and 1959. The toxaphene formulation used was Cooper-Tox No. 6 (toxaphene emulsifiable concentrate).

STUDY AREA

East Bay is a 78-acre lake formed by low, shifting sand dunes on the shore of Lake Superior (fig. 1). The margin of the lake has a narrow, shallow-water shelf beyond which water depth drops abruptly to 20-30 feet. The bottom is primarily sand; some limited areas have bottoms of soft mud and silt. The Sucker River flows into the southeast end of East Bay. The outlet is on the west side into West Bay, which is connected directly to Lake Superior. The inflow averages approximately 85 c.f.s., but it varied from 80 to 200 c.f.s. during the treatment period.

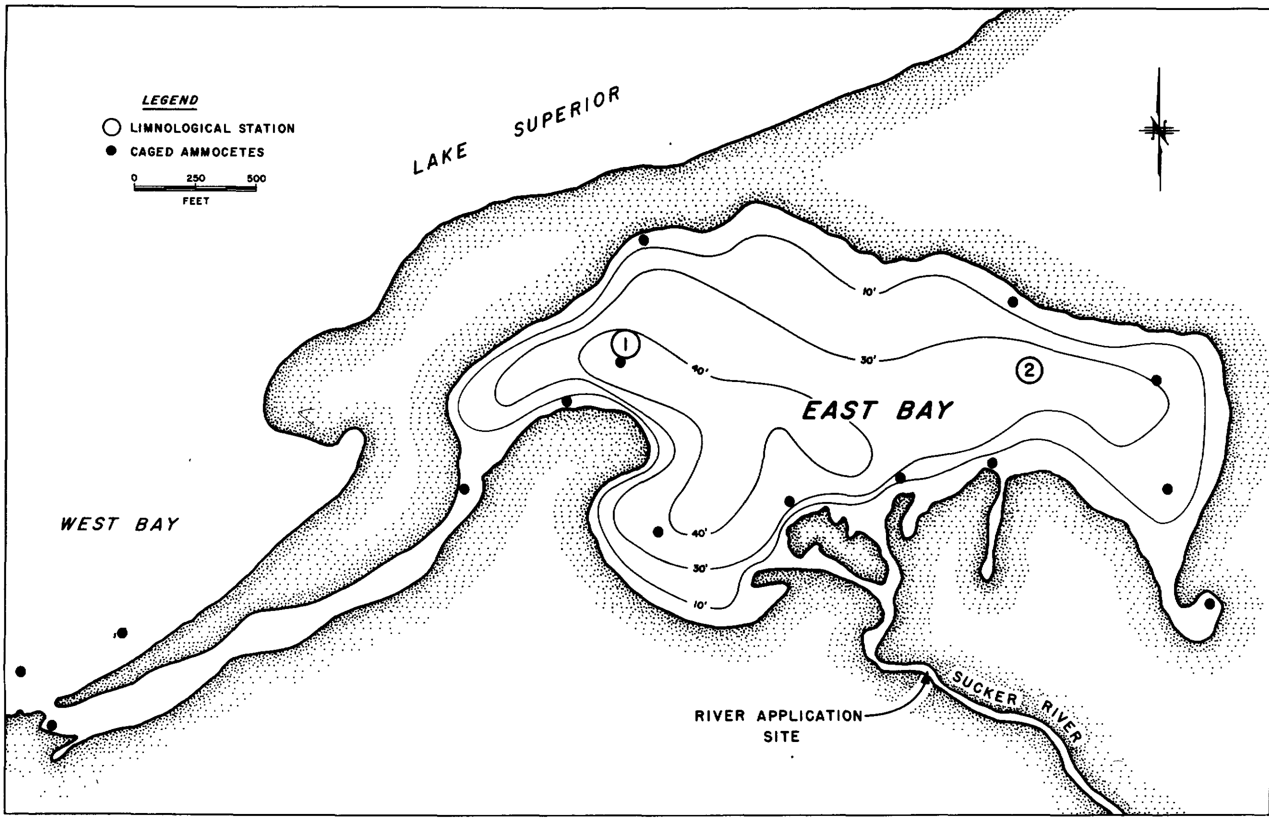

Figure 1.--Map of East Bay showing location of ammocete cages, limnological stations, and the application site in the Sucker River.

East Bay was not stratified thermally in the fall of 1961. Water temperatures varied from a maximum of 49° F. to a minimum of 42° F.; the difference between the surface and the bottom was nil to 2.5° F. (table 1).

Dissolved oxygen remained high (8.9 to 10.2 p.p.m.) during the period of observation. The hydrogen-ion concentration varied from pH 7.5 near the bottom to 9.5 near the surface.

PRETREATMENT SURVEYS

Pretreatment surveys with electric shockers had demonstrated the presence of sea lamprey ammocetes in large numbers in East Bay. The greatest concentrations were on the alluvial fan formed by the Sucker River. The size of the population was estimated at 96,000 individuals (Wagner and Stauffer, 1962). Ammocetes were found also in the connecting channel between East and West Bays and in West Bay in the immediate area of the mouth of the channel.

A riffle fyke net fished in the channel between East Bay and West Bay from March 15 to October 24, 1961, captured 278 sea lampreys (9 transformed individuals and 269 larvae) and 220 American brook lamprey larvae. These data supported the view that a large population remained in the lake, although the Sucker River had been successfully treated with selective larvicide in 1959.

TABLE 1.--Water temperatures (°F.) in East Bay, October-November 1961

Depth	October 4, at station--		October 25, at station--		November 1, at station--		November 6, at station--	
	1	2	1	2	1	2	1	2
Surface....	49.0	49.4	45.0	45.0	43.0	43.0	42.0	42.0
10 feet..	48.2	48.8	--	--	--	--	--	--
20 feet..	47.2	48.2	--	--	--	--	--	--
30 feet..	46.5	47.0	--	--	--	--	--	--
Bottom[1]....	46.5	47.0	45.0	45.0	43.0	43.0	42.0	42.0

[1] 39 feet at station 1, 34 feet at station 2.

Tows, totaling 43 minutes trawling time, with an electric beam trawl at several stations in East Bay in August 1961 captured 52 sea lampreys and 44 American brook lampreys. September 20-22, 151 minutes of trawling in West Bay yielded 16 sea lampreys and 14 brook lamprey larvae. All were captured near the mouth of the channel connecting the two bays.

The fish population was sampled immediately before the treatment by sets of gill nets at 7 locations. Each set included four 125-foot nets with 25-foot sections of 1-1/2-, 2-, 2-1/2-, 3-, and 4-inch mesh (extended measure). The catch in 7 nights of fishing was 27 rainbow trout, 8 northern pike, 41 white suckers, 47 yellow perch (all less than 6 inches long), and a few individuals of 6 other species, to bring the total to 141 fish (table 2).

TABLE 2.--Number of fish, by species, taken from East Bay before and after poisoning with toxaphene

Species	Before treatment (October 5-11, 1961)		After treatment (October 23-25, 1962)	
	Total number	Number per 1,000 feet of net	Total number	Number per 1,000 feet of net
Rainbow trout:				
12 inches and over	24	6.9	4	2.7
Less than 12 inches	3	0.9	34	22.7
White sucker:				
9 inches and over	30	8.6	11	7.3
Less than 9 inches	11	3.1	9	6.0
Northern pike	8	2.3	2	1.3
Round whitefish	6	1.7	1	0.7
Yellow perch	47	13.4	3	2.0
Walleye	1	0.3	0	0.0
Alewife	5	1.4	0	0.0
Burbot	2	0.6	0	0.0
Rock bass	3	0.9	0	0.0
Brook trout	1	0.3	0	0.0
Brown trout	0	0.0	1	0.7
Smelt	0	0.0	2	1.3
Brown bullhead	0	0.0	1	0.7
Total	141	40.3	68	45.3

BIOASSAYS WITH TOXAPHENE

Bioassays were conducted, at the Bureau's Hammond Bay Biological Station, of various concentrations of toxaphene to test the effect of the material on lamprey larvae. The laboratory tests indicated that, to be killed in a reasonable time (15 to 20 days), ammocetes should be exposed to a concentration of at least 80 p.p.b. (table 3). Because lack of time prohibited more extensive study, a concentration of 100 p.p.b. was chosen for the treatment.

TABLE 3.--Results of bioassays with toxaphene on lamprey ammocetes, October 1961

[Temperature, 58°-66° F.]

Size of test container	Concentration of toxaphene	Exposure time	Mortality
	P.p.b.	Days	Percent
200 gallons	50	17	4
20 gallons	40	19	10
20 gallons	80	16	100
20 gallons	120	9	40
20 gallons	120	12	100

APPLICATION OF CHEMICALS

The Sucker River was re-treated with the selective larvicide 3-trifluoromethyl-4-nitrophenol (TFM), October 19-22, 1961, to prevent immediate recontamination of East Bay by young lampreys from upstream.

Treatment of East Bay with toxaphene began on October 24. Eighty-five gallons of this toxicant, the amount needed to give a concentration of 100 p.p.b. through the entire volume, were distributed systematically over the surface of the lake. Simultaneously, toxaphene was added (by means of a portable fuel-pump feeder--Anderson, 1962) into the river above East Bay at a rate to produce 100 p.p.b. in the water entering East Bay. This pump operated continuously for 14 days.

Eleven days after the distribution of toxaphene began, 5 more gallons were applied to the surface of a small backwater at the southeast end of the lake and to the shoreline on the east end of the lake. A few ammocetes had been observed swimming in those areas the previous day.

Before treatment, 10 lamprey larvae were placed in each of 15 cages (11 cages in East Bay, 2 in the connecting channel to West Bay, and 2 in West Bay near the mouth of the channel--fig. 1). The condition of these larvae and the number dead were recorded at intervals from October 22 until November 26, when cold weather forced termination of observation.

Equipment was not available for quantitative determination of toxaphene during this experiment. Assuredly, it would have been advantageous to know the toxaphene concentration at different intervals after application. The work of others would seem to indicate that concentrations reached may have been considerably less than those desired (Kallman, Cope, and Navarre, 1962).

IMMEDIATE EFFECTS OF THE TOXICANT

Small fish were observed surfacing and dying the day after treatment began. Mortality of fish increased daily, reached a peak during the third and fourth days, and ended shortly after. The area was kept under observation during the treatments, and estimates were recorded of the number and species of dead fish. These estimates were biased by recovery of fish by fishermen. Approximately 50 to 80 large rainbow trout (more than 12 inches long) and 25 northern pike were the only game fish of appreciable size observed. Yellow perch were killed in large numbers (3,000 to 4,000), but almost none were over 6 inches long. Several hundred white suckers, several thousand minnows, and a few small rainbow trout, round whitefish, walleye, burbot, and rock bass were seen.

The first dead larval lampreys were seen on the fourth day after treatment began. Their numbers were small in relation to the estimated size of the population.

Ammocetes were slow to emerge from the mud in the bottom of the test cages. Only a few individuals in each container in East Bay had appeared by the end of 4 days. All specimens had emerged by the sixth day and approximately one-third were dead. Most of the remainder were near death.

After emergence from the bottom, some larval lampreys swam aimlessly for a short time, but most lay contorted on the bottom and gave only an occasional twitch. They remained in this condition to the end of the daily observations. Many lampreys gave indications of hemorrhage around the gills, sides, and anus. All ammocetes showed loss of pigmentation.

Daily observations of the caged lampreys were continued for 14 days. During this period, 6 cages were lost in storms. Of the original 90 specimens in the remaining 9 cages, all in 4 cages were dead and 33 in 5 cages were alive at the end of 14 days. Observations were terminated at the end of 36 days of exposure. Two ammocetes were then still alive.

POSTTREATMENT SURVEYS

A riffle fyke net, fished in the connecting channel between East and West Bays after the treatment until November 30, captured no lamprey ammocetes. It was reset in the same location March 15 and fished without interruption until November 26, 1962. During this period, only 1 American brook lamprey ammocete was taken.

The electric beam trawl was dragged in East Bay in May and August 1962, for a total towing time of 113 minutes. No lampreys were taken. Trawling in West Bay near the mouth of the channel in 1962 yielded 7 ammocetes (5 sea lampreys and 2 American brook lampreys) in 79 minutes.

It is evident from these data that toxaphene brought about nearly complete eradication of ammocetes in East Bay. The two test animals that were still alive 36 days after treatment indicated that mortality may not have been complete, but it is probable that larvae not dead at the end of the treatment period had received a lethal dose and subsequently died.

The fish population was sampled again 1 year after the experiment to determine the extent of recovery from the toxaphene. Nets fished 1 night at each of three 1961 locations captured 68 fish, including 4 rainbow trout over 12 inches, 2 northern pike, and 20 white suckers (table 2). The population of yellow perch was sharply lower than a year earlier, but the number of immature rainbow trout had increased.

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INVESTIGATIONS IN FISH CONTROL

8. Effects of Toxaphene on Fishes and Bottom Fauna of Big Kitoi Creek, Afognak Island, Alaska

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EFFECTS OF TOXAPHENE ON FISHES AND BOTTOM FAUNA OF BIG KITOI CREEK, AFOGNAK ISLAND, ALASKA

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Abstract.--Big Kitoi Creek, on Afognak Island, Alaska, was treated with toxaphene in July 1961 to remove sculpins predaceous on pink salmon fry. Dispersion and penetration of toxaphene into the streambed were determined, as well as time required for detoxification. The population of sculpins in the creek before treatment was estimated at 30,000, of which 82 percent were in the size range considered predaceous on pink salmon fry. Extent of predation was determined by examination of stomachs of 180 sculpins. Considering the rate of predation, it was estimated that, of 847,500 ± 418,600 fry in the gravel 3 months before treatment, 12 percent may have been eaten by sculpins before the fry migrated to salt water. Bottom fauna decreased in numbers and weight after the toxaphene treatment: insects were completely eradicated; some other invertebrate groups were not completely eliminated. Posttreatment recruitment of bottom fauna began later in the summer; a year later the pretreatment levels of biomass had not yet been reached. Species composition of bottom fauna a year after treatment differed somewhat from that before treatment. Assuming that, if the creek had not been treated, 30,000 sculpins would have been present in the spring of 1962, then the treatment possibly saved approximately 135,000 pink salmon fry in 1962.

Pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*) deposit their eggs in the gravel of coastal streams in Alaska from July to October. Eggs incubate through the winter, and fry migrate into salt water the following spring. During downstream migration, fry of both species are from 26 to 36 millimeters long and are subject to predation both in streams and in estuaries.

Since pink and chum salmon go to sea almost immediately after they emerge from streambed gravels, they usually are not dependent on a food supply while in fresh water. Coho salmon (*O. kisutch*), on the other hand, remain in fresh water for 1 or 2 years before going to sea; hence, the food supply may sometimes limit their survival.

The coastrange sculpin (*Cottus aleuticus*) is one of the chief predators on salmon fry in fresh-water streams. Because there were large numbers of *C. aleuticus* as well as an annual run of several thousand pink salmon in Big Kitoi Creek, a study was carried out in 1961 and 1962 to determine (1) the extent of predation by sculpins on pink salmon fry, (2) the effects of toxaphene on the sculpins, and (3) the effects of toxaphene on the bottom fauna.

If predation by sculpins was significant, eradication of the sculpin population would relieve downstream migrant pink salmon fry of this cause of mortality. If the bottom fauna was at the same time eradicated, and the rate of

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recovery was slow, production of resident fish such as coho salmon and trout would be limited.

Predation by sculpins probably depends on the species of sculpin and availability of salmon fry. Bailey (1952) reported that food studies on Cottus bairdi by Ricker (1934), Koster (1937), and Dineen (1951) indicated that this species was not a serious game fish predator. Bailey's study of Cottus bairdi in Montana agreed with these findings. On the other hand, Robertson (1949) reported that sculpins (species not mentioned) exacted the greatest toll of sockeye salmon fry migrating from tributary streams into Port John Lake in British Columbia. One sculpin, 4-1/2 inches long, contained 38 fry, and the average was 13 fry per sculpin. Pritchard (1936) determined that the average consumption of salmon fry by sculpins in McClinton Creek in British Columbia for 1931 and 1933 respectively was 0.8 and 1.5 fry per sculpin. Hunter (1959) determined that in Hooknose Creek, Port John, British Columbia, C. aleuticus and C. asper fed almost exclusively on pink and chum salmon fry during downstream migration. Hunter calculated that numbers of pink and chum fry consumed by sculpins alone (1948 to 1957) ranged from 73,868 in 1950 to 276,833 in 1948. Hikata and Nagasawa (1960) reported that of 442 C. nozawae stomachs examined in Memu Stream, Tokachi River system, 5.4 percent contained salmon fry. Patten (1962) reported on predation upon coho salmon fry by C. perplexus and C. rhotheus. Hence, where fresh-water sculpins have access to salmon fry, they can be serious predators. In years when few pink salmon fry are produced in a stream a greater proportion would be eaten, perhaps enough to keep a low spawning run depressed (Neave, 1953).

STUDY AREA

Big Kitoi Creek originates at the outlet of Big Kitoi Lake, a 356-acre lake on Afognak Island, Alaska (fig. 1). The creek flows approximately 2,000 feet before it enters salt water; only the lower half of the stream is accessible to anadromous fishes, because two falls prevent passage. Average gradient of the stream below the falls is 2.3 percent, and the streambed consists of rocks up to 18 inches in diameter. At least 80 percent of the particles comprising the streambed are larger than 3 millimeters. The stream averages 20 feet in width and is from 1 to 3 feet deep during normal water conditions.

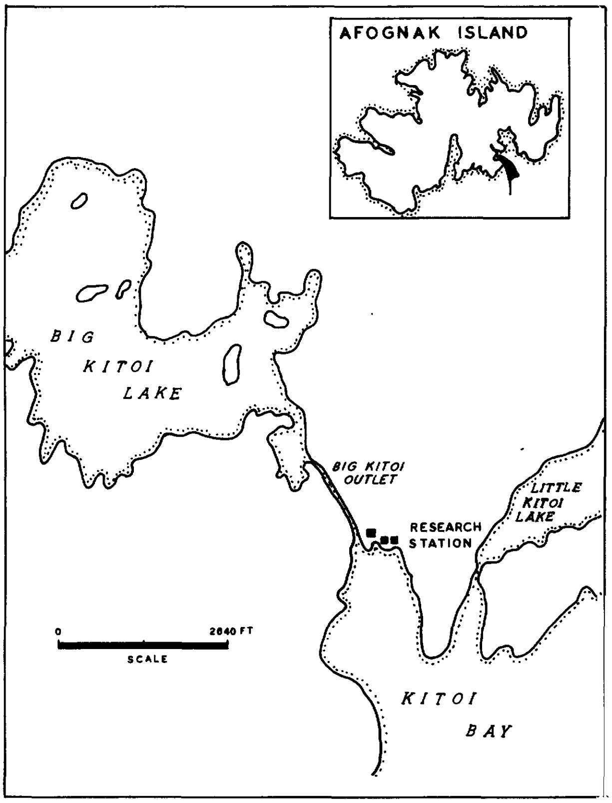

Figure 1.--Location of study area, Afognak Island, Alaska.

The stream was marked off in 100-foot sections for sampling, with section I at the mouth and section 10 ending immediately below the first falls. Only 700 feet proved to be usable for the bottom fauna study (sections 3 through 9), since the lower two sections were saline and section 10 was too swift. Section 3 was flooded at each high tide; tidal influences were also observed in section 4, and at extremely high tides in section 5. Above section 5, the stream narrowed and was swifter than in the lower sections.

In addition to sculpins and pink salmon, other fishes in Big Kitoi Creek in varying numbers and at intervals were Dolly

Varden (Salvelinus malma), threespine stickleback (Gasterosteus aculeatus), coho salmon, rainbow trout (Salmo gairdneri), and to a much lesser extent sockeye salmon (O. nerka), crescent gunnel (Pholis laeta), and smelt (Osmeridae).

METHODS

FISH

The population of sculpins in Big Kitoi Creek before poisoning was estimated in two ways: (1) By flushing random 4-square-foot areas with an air-water jet directed into the streambed (McNeil, 1960) and dislodging sculpins into a collecting net, and (2) by tag and recovery. In the latter case 255 sculpins were collected with a 110-volt a.c. electroshocker, tagged, and released back into the creek.

To evaluate the seriousness of predation in Big Kitoi Creek, rate of digesting was first studied by placing 37 sculpins in a glass aquarium, starving them for 24 hours (Darnell and Meierotto, 1962), then furnishing them with an abundance of pink salmon fry for a short time. Stomachs from sculpins taken in the creek were examined, and condition of pink salmon fry compared with the laboratory specimens.

Extent of predation was studied by collecting 180 sculpins with an electroshocker on May 10, 11, and 12, 1961, and examining stomachs. During this period, downstream pink salmon fry migration was at its peak.

BOTTOM FAUNA

Bottom organisms were sampled periodically before and after toxaphene treatment by means of a Surber square-foot bottom sampler. Three samples were taken in each section once a month. The sampling sites were selected by use of a table of random numbers at the beginning of the study, and subsequent samples were taken adjacent to the initial sampling sites so that the same type of substrate was sampled each month in each section. These samples were preserved in formal-alcohol for future analysis. Preservative was composed of equal parts by volume of 70-percent ethyl alcohol and 5-percent formalin. Each sample was then sorted, the organisms were identified, and the number in each group was recorded. Later, the total fauna of each square-foot sample was blotted for 1 minute and immediately weighed on an analytical balance. Shells of live mollusks were included in the weights; empty shells and cases of Trichoptera larvae were not included. Weights were recorded to the nearest milligram. These data were later transferred to punchcards for tabulation.

APPLICATION OF TOXAPHENE

The stream was treated with toxaphene (Agricultural Cooper-Tox No. 6) on July 5 and 6, 1961. At this time all pink salmon fry had migrated to sea, and returning pink salmon adults had not yet entered the creek.

Two 5-gallon cans of toxaphene were placed at the top of a 12-foot falls, immediately above Section 10, and were siphoned directly into the creek through a rubber tube and metered with an adjustable clamp. The rate of flow was determined by means of a graduated cylinder and stopwatch. Concentrations were calculated on the basis of amount of toxaphene mixed with known discharge (13.1 c.f.s.). Toxaphene was applied for 18.5 hours, with an average concentration of 1.5 p.p.m.

Immediately after treatment, all visible dead fish were counted in sections 3, 4, and 5. Some rocks were turned over and the streambed examined, because many sculpins remained under rocks after they had died.

Heavy concentrations of toxaphene caused water in the stream to turn a milky color. Although it appeared that thorough mixing was achieved, fluorescein dye was inserted at the treatment point to make mixing easier to observe. Observations of dye showed complete mixing from the falls to tidewater, even in small pools and backwater eddies.

To determine the extent of penetration of toxicant into streambed gravels, plastic standpipes were placed 7 or 8 inches deep at six cross-sectional stations. Vaux (1962) and Sheridan (1962) describe the interchange between surface stream water and water in the gravel of the streambed. Based on these findings alone, we can assume penetration of toxicant into the gravel. In corroboration of the assumption, after dye was released upstream its presence was detected in samples of water withdrawn from the standpipes. Therefore, as assumed, diluted toxicant penetrated to a depth of at least 7 inches into the streambed.

Toxicity of stream water was evaluated by placing live fish (sculpins and salmonids from a nearby stream) in small wire-screen minnow traps up and down the stream and observing effects at periodic intervals during and after treatment.

RESULTS

FISH

Of the 255 sculpins tagged, 13 were recovered in a sample of 2,000 sculpins collected after poisoning. The population estimate by this method is then approximately 40,000 sculpins in the creek below the falls before poisoning. At approximately the same time 95-percent confidence limits for the population determined by hydraulic displacement were 37,957 ± 9,265. We feel that, based on the above population estimates, 30,000 sculpins is a reasonable estimate of the total number of sculpins in the stream. Of these 30,000, 82 percent fall in the size range 5.0 cm. to 11.9 cm. (based on a sample of 597 sculpins measured after treatment).

Sculpins maintained in the aquarium for determination of rate of digestion of pink salmon fry were reluctant to feed in captivity, but enough did eat so that when sacrificed at periodic intervals after feeding, condition of consumed fry could be determined. Seven hours after consumption, pink salmon fry were readily detectable as such. After 20 hours, fry were mostly a digested mass, almost unrecognizable as fish. This means that pink salmon fry (recognizable as such) found in sculpin stomachs in the morning were most likely eaten the preceding night.

Of 180 sculpins collected before poisoning, 25 contained an average of 2.1 fry, or an overall average of 0.14 fry per sculpin. The smallest sculpin (total length) which contained fry was 2.7 cm. and the largest was 8.7 cm. We think that this example of consumption of a fry by a predator no larger than the prey was an isolate instance. Therefore, in the following calculations of extent of predation, this one instance i disregarded.

Using a method similar to that of Hunter (1959), we multiplied 30 days (duration of mos intense pink salmon fry migration) × number o sculpins capable of consuming fry (24,600) × rate of predation (0.14) and found that 103,320 pink salmon fry were possibly consumed by sculpins during the 1961 spring migration. Pre viously we estimated 847,500 ± 418,600 fry in the gravel in March; hence, 12 percent of the mean estimated number of pink salmon fry ma have been eaten by sculpins.

In addition to sculpins, other fish were observed dead as follows: Dolly Vardens, 43; rainbow trout, 3; coho fingerlings, 74; and gunnels, 6.

BOTTOM FAUNA

Bottom organisms decreased in number and weight after toxaphene treatment in July 1961 (tables 1 and 2). Before treatment, the specie composition of Big Kitoi Creek bottom fauna changed rapidly as the influence of salt water decreased, or as areas further upstream were considered. The various species of midges (Tendipedidae), for example, made up a much larger part of the bottom fauna upstream than in sections 3 and 4 where tidewater influence were pronounced. Conversely, the brackish-water-inhabiting forms such as the amphipod and isopods decreased in relative abundance

TABLE 1.--Number and weight of organisms per square foot before and after poisoning

Section	Before poisoning (Spring 1961)		After poisoning			
			Summer 1961		Spring 1962	
	Number	Weight (grams)	Number	Weight (grams)	Number	Weight (grams)
3.............	336.0	1.383	94.6	0.414	156.9	0.206
4.............	115.5	0.310	50.0	0.069	62.3	0.082
5.............	134.6	0.142	77.8	0.287	33.7	0.057
6.............	71.5	0.167	45.6	0.045	108.3	0.187
7.............	--	--	33.0	0.121	134.2	0.251
8.............	--	--	--	--	115.6	0.186
9.............	--	--	7.8	0.016	66.2	0.345
Mean.........	164.4	0.501	50.7	0.136	96.8	0.188

TABLE 2.--Analysis of variance for difference in number and weight of organisms per square foot before and after treatment

[July to September]

	Degrees of freedom	Sum of squares	Mean square	F
Mean number of organisms per square foot:				
Between treatment......	1	144,327	144,327	15.6**
Within treatment.......	60	554,134	9,236	
Total................	61	698,461		
Mean weight of organisms per square foot:				
Between treatment......	1	8,783	8,783	48.0**
Within treatment.......	58	10,614	0.183	
Total................	59	19,397		

**Significant at 1 percent level.

with a similar transition to a completely freshwater environment. Midges were the most important group throughout the stream; the crustaceans (Amphipoda and Isopoda) were also relatively abundant, although primarily in the intertidal sections.

Treatment of the stream with toxaphene had several effects on the bottom fauna. The insect groups succumbed completely and more rapidly than other invertebrates, such as clams and snails, which were the last groups to be affected and which were never completely eliminated. Although the July sampling showed a complete lack of live insects, the insects began to reinvade the stream later in the summer. Emergence of adult insects contributed to this elimination of insects in the July sampling, as evidenced by a few shed larval cases and pupal skins; however, most of the insects were killed before emergence. Amphipods and isopods in the intertidal sections were eventually completely eradicated, although these two groups were still present in the July sampling, indicating that they were more resistant. The upstream sections became barren of bottom fauna before the lower and intertidal sections.

DETOXIFICATION AND RECOVERY OF CREEK

Fish.--Bioassay with coho and sockeye smolts, threespine stickleback, and sculpins showed that the stream became nontoxic after 21 days. In addition, Dolly Vardens moved into the stream from salt water early in August and remained throughout the salmon spawning run.

Final evidence that Big Kitoi Creek became free from toxicant in a short time was the success of pink salmon spawning in the stream after treatment. Pinks deposited eggs from August 25 until early October, 1961; hence, spawning first occurred 50 days after treatment. Sampling of eggs in the streambed in November 1961 revealed a very high survival, and subsequent sampling of preemergent fry in March 1962 gave a mean estimate of 1,124,000 fry, or 44 percent egg-to-fry survival.

Bottom fauna.--When initial recruitment of organisms began later in the summer, the upstream sections were the first to show an influx. This is probably due to the drifting in of organisms from the lake and stream above the falls area (Waters, 1961). The partially eradicated mollusk populations were the first to show a marked increase after treatment, and the insect groups were slowest to appear in quantity. One year later the pretreatment levels of biomass, in terms of weight and number of organisms per square foot of streambed, had not been reached. The species composition of the bottom fauna almost 1 year after treatment was somewhat different from that before treatment. The noninsect forms, including annelids, were the dominant forms throughout the study area, although the tendipedids were still the most numerous insect form. In the intertidal sections, annelid worms were abundant while the previously numerous amphipods and isopods were absent. The annelids were becoming reestablished in the most saline environment and were gradually expanding to the less saline areas. The mollusks (Gastropods, Pelecypoda), which were never completely eradicated, became established in greater magnitude after treatment but occupied the same general area as before treatment.

DISCUSSION

Results of treating Big Kitoi Creek with toxaphene show that this was an economical (cost of toxaphene for Big Kitoi Creek was $28) and effective way to control predation on salmon fry in this stream.

Although the method described in this report lends itself to eradication of undesirable fish in streams, it cannot be used where there are resident populations of trout and/or salmon which should be maintained. Both the desirable fish and their food supply would be eradicated. On the other hand, there are streams in Alaska which support only pink and chum salmon and these streams are ideal for treatment. For example Noerenberg (1960) reported that in Prince William Sound pink and chum salmon comprise 90 percent of the run, sockeye salmon 10 percent. Coho salmon are of little importance and no known spawning runs of chinook salmon (O. tshawytscha) or steelhead trout (Salmo gairdneri) exist.

Assuming that 30,000 sculpins would have been present in Big Kitoi Creek in the spring of 1962 if treatment had not occurred, it is possible that 12 percent, or approximately 135,000 pink salmon fry, were saved in 1962 by the treatment.

SUMMARY

Part of Big Kitoi Creek, on Afognak Island, Alaska, was treated with toxaphene to determine (1) the extent of predation by sculpins on pink salmon fry in the stream, (2) the effects of toxaphene on the sculpins, and (3) the effects of toxaphene on the bottom fauna.

The estimated population of sculpins before treatment was 30,000. Approximately 100,000 pink salmon fry could have been taken by sculpins in 1961. Treatment with toxaphene eliminated sculpins and other fishes in a 1,000-foot section of the stream. Sculpins were not observed up to 1 year later.

Insects were eliminated, and populations of other invertebrate forms were greatly reduced. Recruitment of bottom organisms began shortly after treatment, but 1 year after treatment the pretreatment levels of bottom fauna biomass had not been reached. In general, the various groups of organisms were reestablished in the same areas they inhabited before treatment; in a few cases major groups have been replaced by different forms which were less well represented before treatment.

In this case we feel that the treatment of Big Kitoi Creek with toxaphene was an economical and effective means of reducing predation on pink salmon fry.

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