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Determination of Minimum Lethal Level of Toxaphene As A Piscicide in Lakes of North Dakota

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

BY

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Toxaphene as a piscicide for localized field application has not been widely used because minimum lethal concentrations have not been determined in the field. There is, however, considerable information gained from laboratory bio-assay studies (Surber, 1948; Duodoroff, et al. 1953; Hooper and Grzenda, 1955; Henderson, et al. 1959). Concentrations indicated by such studies are not necessarily correct for field use. Prevost (1960) pointed out that results from controlled laboratory experiments do not always yield dosages exhibiting similar results in the field where a number of variables, both known and unknown, exist over which the field worker has little or no control.

Gebhards (1960) in a review of toxaphene as a fish toxicant lists 14 western states and 6 Canadian provinces that have used toxaphene in fish control programs. Toxaphene was used 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. Complete kills were variable in their occurrence within this range. Inconsistencies were emphasized in the review by the wide variations in results. An average concentration of 0.135 p.p.m. from 15 reports failed to kill all fishes in treated areas but an average concentration of 0.139 p.p.m.

from 23 reports induced complete mortalities. Stringer and McMynn (1958), however, reported complete kills at from 0.010 p.p.m. to 0.036 p.p.m.

In North Dakota complete fish population mortality occurred when toxaphene was applied at a concentration of 0.070 p.p.m. (Henegar, 1958) which was not considered as the minimum lethal level. 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 lakes were test netted to determine existing populations of fishes 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.

In lakes displaying similar physical and chemical characteristics to those in the Great Plains area, recommended concentrations range from 0.025 to 0.030 p.p.m. as indicated in Table I. Concentrations used on the project areas ranged from 0.005 to 0.035 p.p.m.

TABLE I. RECOMMENDED CONCENTRATION OF TOXAPHENE FOR VARIOUS TYPES OF LAKES

(William Cooper & Nephews, Chicago, Illinois)
1958

Concentration (Parts per billion Toxaphene)	Lake Type
25-30*	Unstratified, shallow hard water lakes of low transparency and high productivity.
15-20	Unstratified soft-water lakes of moderate or high transparency.
10-20	Stratified lakes of moderate depth (mean depth less than 20 feet) and moderate to low transparency.
7.5-10	Stratified lakes of great depth (mean depth greater than 20 feet), high transparency and low productivity.

*One report indicates that a concentration of 50-100 p.p.b. should be used in highly turbid waters containing suspended clay (secchi disc reading less than one foot).

MATERIALS AND METHODS

Characteristics of Toxaphene

Toxaphene is a member of the group of toxicants known as cyclodiene insecticides which also includes aldrin, dieldrin, chlordane, heptachlor, endrin and isodrin. Toxaphene is not well characterized chemically as are the other cyclodiene insecticides and the precise nature of the compounds present in the mixture of isomers is not known (Negherbon, 1959).

Toxaphene is a yellow to amber, waxy solid emitting an aromatic, pine-like odor. While virtually insoluble in water it is readily soluble in a wide range of organic solvents and oils. Most frequently encountered formulations are in the form of 10%-20% dusts, 40% wettable powders, and emulsifiable concentrates of four, six and eight pounds per gallon.

The commercial product used during the study was Cooper-Tox No. 6 manufactured by William Cooper and Nephews, Chicago, Illinois. The formulation contained six pounds of technical toxaphene per gallon.

Duration of Toxicity

Toxaphene is known to remain toxic for extended periods of time following application as a piscicide.

Ten Michigan lakes treated with Fish-Tox* 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, 1955). Stringer and McMynn (1958) after treating several British Columbia lakes with Fish-Tox reported them remaining in a toxic state for over two years. Fish-Tox applied at the recommended dosages of 1.00 p.p.m. (2.7 lbs./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.

Factors influencing detoxification are: dilution, water temperature, water circulation, oxygen levels, turbidity, alkalinity, types of substrate, micro-organisms, and ratio of water to bottom interface (Hemphill, 1954; Hooper and Grzenda, 1955; Rose, 1957; Honegar, 1958 and Prevost, 1960).

Detoxification takes place very slowly when ice

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*A commercial fish toxicant containing toxaphene. Distributed by Standard Supply, Wenatchee, Washington.

cover is present and most rapidly when water temperatures are high and conditions are favorable for the growth of plankton and other micro-organisms. "Unstratified lakes should detoxify in one month or less when water temperatures are above 70° F. Deep, cold, trout lakes may require four or more months to detoxify. Circulation of water through the lake basin enhances detoxification" (Anonymous, 1958, p. 5).

METHOD OF APPLICATION

Depending on the formulation, toxaphene has been applied in various ways. The wettable powder has been applied by aircraft and by placing in burlap bags and then towing in the wake of an outboard motor (Henegar, 1953). The emulsifiable liquid has been applied by aircraft (McCarraher and Dean, 1959), but most commonly by distributing premixed solutions with power sprayers mounted in boats. One currently accepted 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 might settle to the bottom in a comparatively undiluted state.

During this study a pumping system used by the North Dakota Game and Fish Department was employed (Figure 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 one gallon to five gallons of water so that a minimum of 55 gallons of liquid was available for spraying on each lake. During application the spray boat

Figure 1. Spray Boat Used in Application of Toxaphene on Project Lakes

powered by an 18 h.p. outboard motor, was operated at full throttle. This allowed for a maximum coverage of 200 acres per 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 and then loaded onto a boat trailer. This reduced the time necessary to ready equipment for each treatment.

Areas for treatment were determined from prepared hydrographic maps of each lake (Figure 2). Lakes over 100 acres in size were subsectioned and each subsection was treated as a separate unit. Even though Cooper-Tox maintains toxicity for a long period of time and elaborate application methods are not required, over-simplification of application is to be avoided. It is possible that reported cases of toxaphene failing to completely eradicate populations of fishes may be due to inadequate mixing of the toxicant in the treated area.

Physical and Chemical Characteristics of Lakes

Sixteen lakes varying in size from 6.3 to 915 acres were chosen for study from widely scattered areas of North Dakota. Seven were impoundments and nine were of natural origin. Maximum depths ranged from 3 to 26 feet and volume from 78.9 to 9254 acre feet (Table II). At

NORTH METIGOSHE and LAKE Mc DONALD

BOTTINEAU COUNTY NORTH DAKOTA

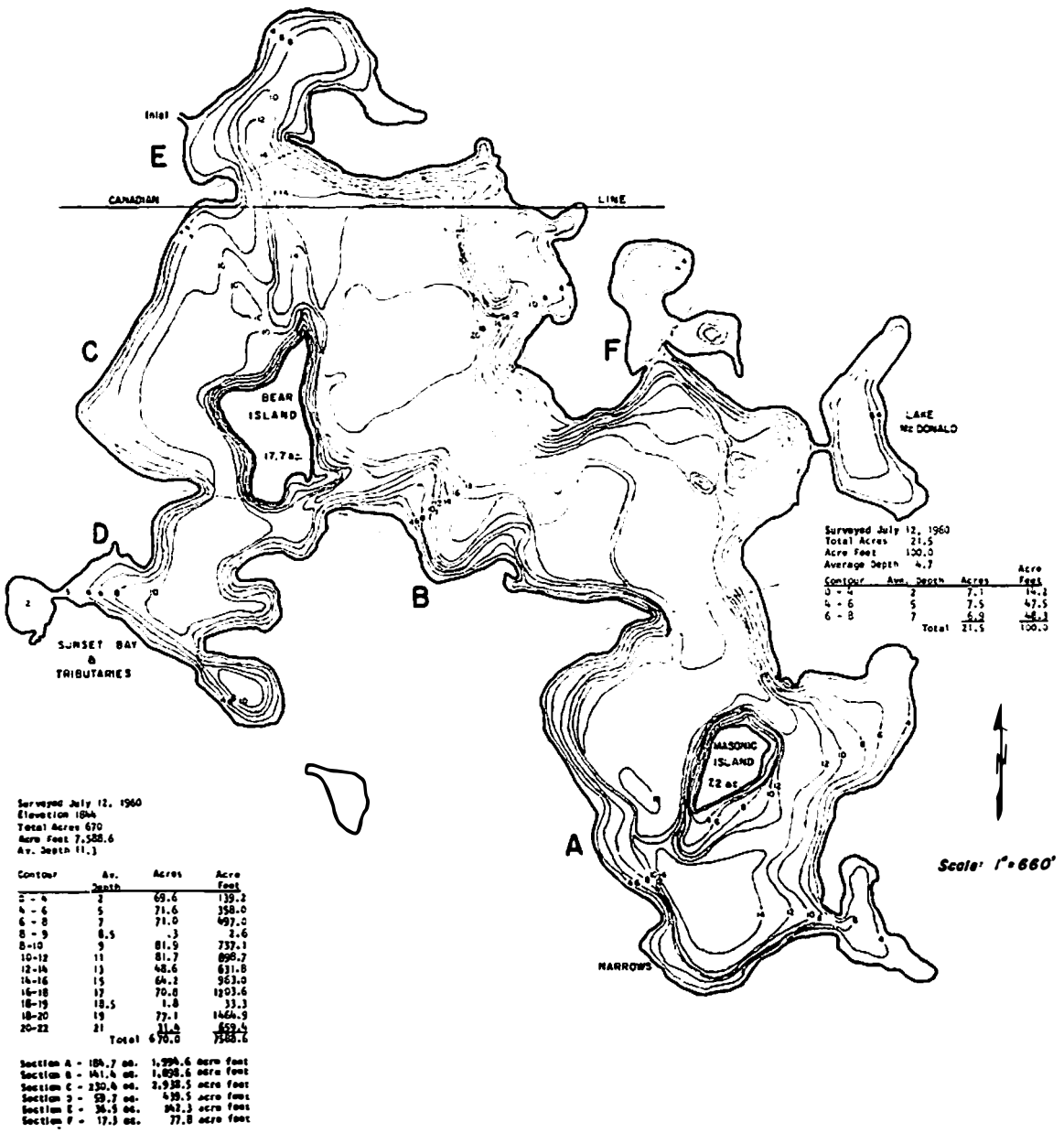

Figure 2. Photograph of Typical Hydrographic Map Used for all Lakes in Project

TABLE II. PHYSICAL CHARACTERISTICS OF PROJECT LAKES

Lake Number	Size (acres)	Maximum Depth (feet)	Volume (acre-feet)
1.	103.3	19	712.9
2.	160.2	23	1526.7
3.	290.8	23	2390.6
4.	173.6	8	853.7
5.	670.8	22	7588.5
6.	915.0	22	8254.4
7.	129.9	26	1272.8
8.	95.2	22	511.7
9.	50.3	14	472.3
10.	6.3	21	78.9
11.	12.3	18	144.4
12.	40.1	10	236.9
13.	80.8	23	651.2
14.	8.0	17	87.4
15.	17.3	14	137.5
16.	18.5	14	162.9

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. Concurrently one-gallon samples of water were forwarded to the North Dakota Health Department laboratory to ascertain the accuracy of the field analyses. The variation in results between the field and laboratory analyses was not significant.

Alkalinity (phenolphthalein) ranged from 0.0 to 120 p.p.m., pH from 7.9 to 9.9, alkalinity (methyl orange) from 80 to 800 p.p.m., hardness as calcium carbonate 51 to 2385 p.p.m. and total dissolved solids from 231 to 4100 p.p.m. (Table III).

With one exception, all lakes had extensive growths of aquatic vegetation extending from shore outward to eight feet in depth. Potamogeton spp. and Myriophyllum spp. were particularly abundant with Polygonum spp. and Sagittaria spp. prevailing less frequently.

In all lakes of the study primary bottom composition was silt, mud, clay and organic material. Areas of sand, gravel and rubble were of minor importance and restricted to the natural lakes.

TABLE III. CHEMICAL CHARACTERISTICS OF PROJECT LAKES

Number	pH	Ph-th (p.p.m.)	Methyl Orange (p.p.m.)	Hardness (p.p.m.)	Total Dissolved Solids (p.p.m.)
1.	8.2	120	180	171	414
2.	8.5	40	460	476	290
3.	8.3	40	220	308	307
4.	9.0	84	442	821	816
5.	8.8	20	210	205	317
6.	8.7	30	240	238	326
7.	8.0	24	178	239	364
8.	8.3	54	496	444	281
9.	8.6	44	282	359	779
10.	9.9	0	800	2385	4100
11.	8.0	60	420	136	418
12.	8.5	106	460	547	1452
13.	7.9	0	140	136	415
14.	8.8	30	130	170	328
15.	9.4	100	260	114	940
16.	8.0	20	80	51	306

Test Netting

Qualitative sampling of fish populations in all lakes was carried out before and after treatment. Procedures were those normally used by the North Dakota Game and Fish Department. Three types of gear were utilized: gill nets, small mesh seines and small mesh frame nets.

Gill Netting

The gill nets were 250 feet X 6 feet standardized experimental nylon nets composed of 50 foot sections of increasing mesh size. Mesh sizes were 3/4-, 1-, 1 1/4-, 1 1/2-, and 2 inch. Total netting effort for each lake varied according to the size: in larger lakes a greater number of sets were made. The nets were fished both during diurnal and nocturnal periods to lend validity to the results. Although this type of gear is subject to considerable error, fish population estimates may be made from the data. During the project period all lakes were gill netted a total of 2304 hours representing 96 individual gill net sets.

Shoreline Seining

Shoreline seining with a 100 foot X 6 foot, one quarter inch mesh nylon bag seine was carried out where vegetation was not too dense. Data so gathered was of limited value due to inconsistent results. A total of 71

drags was made in project lakes representing a coverage of 35,500 square feet.

Small Mesh Frame Nets

Small mesh frame nets produced valid data on populations of fishes inhabiting the littoral zone. These nets were originally designed to sample young-of-year northern pike* in heavily vegetated areas. The front frames of the nets were three feet high and four feet wide (Figure 3). The net was 15 feet long and had round wooden hoops behind the front rectangular frames. The webbing was 1/4 inch nylon dyed a dark brown in color. The single tunnel used the string type 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 3704 hours during the project period.

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*See Appendix A for scientific names of fishes encountered in study.

Figure 3. Photograph of Small Mesh Frame Net Used During Project to Sample Fishes in the Littoral Zone

RESULTS

Lake Odland

Lake Odland (Table IV) was treated at a concentration of 0.005 p.p.m. of toxaphene on August 12, 1960. No effects of the toxaphene were observed for 10 hours following application. After this period, however, distressed young-of-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 effected. The small fish decomposed rapidly and after seven days evidence of their mortality disappeared.

The lake was test netted 48 days after treatment. Net frequencies (Table V) were not significantly changed from those arrived at before the toxaphene was used. In this lake the net frequencies did not represent the true population structure. Young-of-year fishes taken during pretreatment test netting (Table VI) were absent from the data. Average sizes of larger fishes remained relatively stable reflecting insignificant mortality.

TABLE IV. LAKES TREATED; CONCENTRATIONS OF TOXAPHENE APPLIED AND EXTENT OF FISH MORTALITY

	Lake Name	Concentration (p.p.m.)	Mortality
1.	Lake Odland	0.005	Incomplete
2.	Brush Lake	0.010	Incomplete
3.	Long Lake	0.010	Incomplete
4.	Gumms Lake	0.010	Incomplete
5.	North Lake Metigoshe	0.015	Incomplete
6.	South Lake Metigoshe	0.015	Incomplete
7.	Red Willow Lake	0.015	Incomplete
8.	Frettum Lake	0.020	Incomplete
9.	North Tobiason Lake	0.020	Incomplete
10.	Bowbells Mine Lake	0.025	Complete
11.	Glen Ullin Lake	0.025	Complete
12.	South Tobiason Lake	0.025	Complete
13.	Nieuwsma Lake	0.025	Complete
14.	Cat Coulee Lake	0.030	Complete
15.	Wolf Butte Lake	0.030	Complete
16.	Jund Dam	0.035	Complete

TABLE V. CHANGES IN TEST NETTING FREQUENCIES FOLLOWING APPLICATION OF TOXAPHENE*

Lake Number	Concentration (p.p.m.)	Frequency		Reduction (%)
		Pretreatment	Post-treatment	
1.	0.005	6.91	6.94	None
2.	0.010	6.88	1.34	80.5
3.	0.010	10.38	1.59	84.6
4.	0.010	34.46	7.96	76.9
5.	0.015	8.46	1.07	87.3
6.	0.015	6.46	1.11	83.2
7.	0.015	10.20	2.50	75.4
8.	0.020	6.36	.32	94.9
9.	0.020	12.91	.33	97.4
10.	0.025	.95	0.00	100.0
11.	0.025	6.91	0.00	100.0
12.	0.025	7.29	0.00	100.0
13.	0.025	5.89	0.00	100.0
14.	0.030	4.06	0.00	100.0
15.	0.030	15.98	0.00	100.0
16	0.035	3.62	0.00	100.0

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

TABLE VI. LAKE ODLAND TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.005 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (134 hours)			
418	Black bullheads	4.0 - 11.6	5.8
405	Black bullheads	Young-of-year	
44	Yellow perch	3.4 - 6.5	5.5
27	Golden shiners	5.1 - 6.5	6.1
17	Northern pike	16.0 - 28.3	21.7
9	Black suckers	9.0 - 18.5	13.6
3	White crappies	7.5 - 8.5	8.0
2	O-Spotted sunfish	5.5 - 5.6	5.5
Post-treatment (152 hours)			
904	Black bullheads	5.0 - 10.5	5.7
0	Black bullheads	Young-of-year	
59	Northern pike	15.0 - 29.0	21.8
48	Yellow perch	3.5 - 12.5	5.8
19	White crappies	5.5 - 9.0	7.3
17	Golden shiners	6.0 - 7.1	6.5
11	O-Spotted sunfish	5.5 - 6.0	5.6
1	Black sucker	16.7	17.7

*Combined data from all types of netting gear.

Brush Lake

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

Ninety-six hours of post-treatment test netting starting on April 22, 1960 disclosed only a partial mortality among the fishes. It was evident from the results (Table VII) that while heavy mortality had taken place among the young-of-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 per cent (Table V).

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 43,000 walleye fingerlings (1600/lb.) and on August 1, 1960 with 200,000 blunt-nose minnows (1,000/lb.).

TABLE VII. BRUSH LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.010 P.P.M. TOXAPHENE

Total Fishes*	Species	Length	
		Range (Inches)	Average (Inches)
Pretreatment (144 hours)			
903	Yellow perch	2.6 - 13.7	4.1
894	Yellow perch	Young-of-year	
49	Walleye	9.7 - 17.7	15.6
32	Northern pike	10.3 - 27.2	20.3
4	Black sucker	10.1 - 10.5	10.3
Post-treatment (96 hours)			
57	Yellow perch	6.0 - 12.8	7.2
0	Yellow perch	Young-of-year	
56	Northern pike	17.6 - 30.2	22.4
39	Walleye	15.8 - 18.1	16.1
7	Black sucker	10.8 - 11.1	10.9

*Combined data from all types of netting gear.

Additional test netting of the lake in September proved good survival and growth of all stocked fishes. This test netting also substantiated results from the post-treatment survey.

Long Lake

Long Lake (Table IV) was treated on July 17, 1960 at a concentration of 0.010 p.p.m. of toxaphene. Mortality during the first three hours after application was light and was restricted to young-of-year yellow perch. At the end of five hours, yearling and two-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 time distressed and dying young-of-year northern pike were found. Death continued for 72 hours after treatment when the last affected fish were observed. During the apparent period of toxicity only two dead walleyes (10.1 to 10.2 inches) and no northern pike larger than young-of-year were observed. No dead black suckers could be located.

On August 18, approximately one month after treatment, Long Lake was stocked with 160,000 (360/lb.) bluntnose minnows. Periodic observations for 10 days after stocking indicated no mortality of these fishes.

During post-treatment test netting begun on

TABLE VIII. LONG LAKE TEST NETTING BEFORE AND AFTER TREATMENT WITH 0.010 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (250 hours)			
1240	Yellow perch	2.6 - 6.8	3.8
1017	Yellow perch	Young-of-year	
6	Northern pike	26.0 - 31.3	28.2
327	Northern pike	Young-of-year	
3	Walleye	10.0 - 10.3	10.1
Post-treatment (250 hours)			
263	Yellow perch	5.6 - 6.8	6.5
0	Yellow perch	Young-of-year	
5	Northern pike	25.1 - 32.1	28.6
114	Northern pike	Young-of-year	
3	Walleye	10.3 - 10.6	10.4
3	Black sucker	17.3 - 17.6	17.5

*Combined data from all types of netting gear.

October 25 the stocked minnows were frequently taken in the small mesh frame nets. Yields of these small mesh frame nets (Table VIII) denoted that the toxaphene had either severely reduced or eliminated yellow perch less than 5.5 inches in length. Partial reduction of young-of-year northern pike was evident. Total net frequency on all fishes was reduced by 84.6 per cent (Table V). No measurable changes were found in the populations of adult northern pike, walleyes or black suckers (Table VIII).

Gumms Lake

Gumms Lake (Table IV) was treated at a concentration of 0.015 p.p.m. of toxaphene on August 8, 1959. At time of treatment the lake contained the largest yellow perch population of all project lakes (Table IX). One hour following application small affected yellow perch were seen over most of the surface of the lake. After three 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 7.0 inches were seen.

TABLE IX. GUNNS LAKE TEST NETTING BEFORE AND AFTER TREATMENT WITH 0.010 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (28 hours)			
964	Yellow perch	3.1 - 10.2	5.3
Post-treatment (28 hours)			
223	Yellow perch	7.0 - 10.3	7.8

*Combined data from all types of netting gear.

Test netting on September 14, 1959 revealed an incomplete kill. No yellow perch smaller than 5.5 inches were taken but the abundance of larger yellow perch remained unchanged (Table IX). Average size of fishes taken during this post-treatment netting increased from 5.3 to 7.8 inches (Table IX). Total net frequency indicated a gross reduction of 87.3 per cent (Table V).

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

North Lake Metigoshe

North Lake Metigoshe (Table IV) was treated at a concentration of 0.015 p.p.m. of toxaphene on September 13, 1960. It was the second largest lake in the project and contained the most desirable fish population (Figure 4). Because of its size, it was treated in segments and each was sprayed as a separate unit. Six hours after starting the application it was completed.

Reaction of the fishes to the toxaphene was slow due to 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-year yellow perch and black bullheads were affected first succeeded by larger perch (2.0 to 3.2 inches) and bullheads (2.2 to 5.8

TABLE X. NORTH LAKE METIGOSHE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.015 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (322 hours)			
1305	Yellow perch	2.4 - 10.1	4.1
626	Yellow perch	Young-of-year	
416	Black bullheads	2.1 - 11.1	4.8
1438	Black bullheads	Young-of-year	
46	Walleye	13.0 - 25.3	17.6
27	Northern pike	12.0 - 24.8	16.1
17	Bluntnose minnows		
9	Black suckers	17.7 - 23.0	19.9
Post-treatment (322 hours)			
49	Yellow perch	4.3 - 9.6	6.8
0	Yellow perch	Young-of-year	
246	Black bullheads	6.1 - 10.2	7.6
0	Black bullheads	Young-of-year	
39	Walleye	19.1 - 26.2	22.8
15	Northern pike	13.3 - 24.7	19.3
8	Black suckers	17.6 - 24.0	19.8

*Combined data from all types of netting gear.

Figure 4. Photograph of Fish Taken by Gill Netting in North Lake Metigoshe Previous to Treatment With Toxaphene

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 a rapid decline occurred. 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-year to 5.1 inches in length, 181 northern pike 11.9 to 18.4 inches), 17 walleyes (14.2 to 15.2 inches) but no black suckers were killed. Observers checking the bays and shallow water failed to find any living schools of small bullheads or yellow perch.

Post-treatment netting was delayed to three days prior to freeze-up (October 24). Observations made on the lake during the period of toxicity were confirmed by the results of the test netting (Table X). The toxaphene had failed to kill all fishes in the lake (Figure 5). Yellow perch from young-of-year to 4.0 inches and black bullheads from young-of-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 X). Average sizes of northern pike, walleyes and black suckers stayed approximately the same. Reduction in

Figure 5. Photograph of Fish Taken in Gill Net From North Lake Metigoshe Following Treatment With 0.015 p.p.m. Toxaphene

total test net frequency was 87.3 percent (Table V).

South Lake Metigoshe

South Lake Metigoshe (Table IV) was treated on July 7, 1960 at a concentration of 0.015 p.p.m. toxaphene. It was the largest lake in the project and for convenience was divided into segments for treatment. Application of the toxaphene was completed in seven 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 two hours moribund and dead fishes were seen in treated areas (Figure 6). Rate of death increased in all parts of the lake for another 48 hours and then began a rapid decrease. Ninety-six hours later major activity had stopped. Ten days later a discontinuation of activity was obvious.

Five to seven days after treatment "float-up" took place as thousands of decomposing, and consequently repugnant fishes floated into shore. This caused a public relations problem of some magnitude with the 491 cabin owners on the lake and emphasized one value of fall treatment. Mortality estimates made at the time were of questionable value due to the fishes being picked up and

TABLE XI. SOUTH LAKE MESTIGOSHE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.015 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (333 hours)			
2984	Yellow perch	2.4 - 9.5	4.0
2024	Yellow perch	Young-of-year	
737	Black bullheads	2.1 - 9.7	6.7
814	Black bullheads	Young-of-year	
18	Northern pike	10.7 - 21.7	18.1
142	Northern pike	Young-of-year	6.1
19	Walleye	7.5 - 25.5	18.3
2	Bluntnose minnow		
Post-treatment (290 hours)			
104	Yellow perch	4.1 - 9.4	9.3
17	Yellow perch	Young-of-year	
520	Black bullheads	4.2 - 9.6	7.9
26	Black bullheads	Young-of-year	
19	Northern pike	14.1 - 22.3	20.1
28	Northern pike	Young-of-year	9.1
22	Walleye	12.1 - 24.2	18.6

*Combined data from all types of netting gear.

Figure 6. Photograph of Moribund and Dead Young-of-year Yellow Perch Taken at South Lake Metigoshe Four Hours After Treatment with 0.015 p.p.m. of Toxaphene

disposed of as soon as they came to shore. It seemed, however, that while many smaller fishes had succumbed, the larger fishes were unaffected.

Post-treatment test netting (Table XI) from September 17 to 20 proved the kill was incomplete. Young-of-year yellow perch, black bullheads and northern pike were severely reduced. The only area containing any of these fishes was in close proximity 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 black suckers in the post-treatment population were relatively the same as before treatment. Total test netting frequency was reduced by 83.2 per cent (Table V).

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

Red Willow Lake

Red Willow Lake (Table IV) was treated on July 17, 1959 at a concentration of 0.020 p.p.m. toxaphene.

TABLE XII. RED WILLOW LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.015 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (48 hours)			
351	Yellow perch	3.7 - 7.1	5.3
120	Black bullhead	3.8 - 9.0	6.8
12	Northern pike	13.0 - 27.5	19.9
7	Black sucker	14.0 - 18.5	17.4
Post-treatment (48 hours)			
5	Yellow perch	6.6 - 7.2	6.9
103	Black bullheads	3.9 - 8.2	6.9
13	Northern pike	9.0 - 16.7	14.7
2	Black sucker	14.9 - 15.0	14.9

*Combined data from all types of netting gear.

During application the water temperature was 72° F. and action of the toxicant was rapid. Small yellow perch and black bullheads surfaced one hour after initiation of spraying. 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 two dead black suckers (17.2 inches).

Test netting of the lake on October 13, 1959 (Table XII) divulged the occurence of 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 per cent (Table V).

Frettum Lake

Frettum Lake (Table IV) was treated on July 19, 1959 at a concentration of 0.020 p.p.m. of toxaphene. Pretreatment test netting of this lake revealed a dense population of yellow perch except for young-of-year. In

TABLE XIII. FRETTUM LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.020 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (120 hours)			
429	Yellow perch	4.1 - 14.0	5.3
335	Yellow perch	Young-of-year	
Post-treatment (116 hours)			
38	Yellow perch	6.5 - 14.1	7.3
0	Yellow perch	Young-of-year	

*Combined data from all types of netting gear.

only three hours after application numerous fishes were either dead or distressed. After 96 hours further movement could not be found. This initial high rate of mortality of the perch suggested the possibility of a complete kill. Post-treatment 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 XIII). The average length of the yellow perch increased from 5.3 to 7.3 inches and percentile reduction of total netting frequency was 94.9 (Table V).

North Tobiason Lake

North Tobiason Lake (Table IV) was treated on August 6, 1959 at a concentration of 0.020 p.p.m. toxaphene. Reaction of fishes to the toxaphene began one hour after spraying was started and after four 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 ten months

TABLE XIV. NORTH TOBIASON LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.020 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (48 hours)			
446	Yellow perch	3.1 - 7.2	5.3
160	Brown bullheads	4.2 - 10.2	7.8
5	Northern pike	19.1 - 26.2	23.7
6	Black sucker	16.4 - 19.0	17.2
4	White crappie	4.3 - 4.5	4.4
Post-treatment (48 hours)			
0	Yellow perch		
8	Black sucker	16.5 - 19.0	17.3
7	Northern pike	21.0 - 26.1	24.2

*Combined data from all types of netting gear.

after treatment (June 7, 1960) and results ascertained that only a partial kill had taken place. An observation was that the brown bullheads were absent from the test nets. This was the only brown bullhead population encountered in any of the project lakes. No yellow perch were taken in the samples and the only fishes surviving were larger northern pike and black suckers (Table XIV). The percentage reduction in total net frequency was 97.4 (Table V).

Bowbells Mine Lake

Bowbells Mine Lake (Table IV) was treated with toxaphene on August 28, 1959 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 III). 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 six 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 experienced.

Post-treatment test netting (Table XV) was not carried out until May 9, 1960 at which time no fish were

TABLE XV. BOWDELLS MINE LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.025 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (24 hours)			
17	Yellow perch	5.1 - 8.3	7.2
6	Black suckers	12.2 - 17.1	14.2
Post-treatment (48 hours)			
No fish taken			

*Combined data from all types of netting gear.

taken. The lake was then restocked on September 21, 1960 with 2200 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 (Table IV) 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 four hours after spraying was begun they were in evidence in all areas of the lake. After 17 hours mortality of white crappie and yellow perch appeared complete. No carp or black suckers were observed until 14 hours after treatment but all had apparently died after 35 hours. Continued observations for seven days disclosed no further mortality. Two days of post-treatment test netting on September 26, 1959 and May 17, 1960 did not yield any live fish (Table XVI). The lake was then restocked with 5,000 fingerling large-mouth black 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 (Table IV) was treated on

TABLE XVI. GLEN ULLIN LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.025 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (24 hours)			
160	White crappie	3.1 - 5.0	4.5
3	Yellow perch	4.7 - 5.2	5.0
2	Carp	13.1 - 13.4	13.25
1	Black sucker	13.0	13.0
Post-treatment (48 hours)			
No fish taken			

*Combined data from all types of netting gear.

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

Post-treatment test netting on October 9, 1959 and April 12, 1960 failed to take any live fishes (Table XVII).

Nieuwsma Lake

Nieuwsma Lake (Table IV) 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 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 post-treatment test netting failed to produce any live fish from the lake. (Table XVIII).

TABLE XVII. SOUTH TOBIASON LAKE TEST NETTING BEFORE AND AFTER TREATMENT WITH 0.025 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (24 hours)			
172	Black bullheads	5.5 - 6.9	6.2
2	Northern pike	12.0	12.0
1	Yellow perch	6.2	6.2
Post-treatment (96 hours)			
No fish taken			

*Combined data from all types of netting gear.

TABLE XVIII. NIEUWSNA LAKE TEST NETTING BEFORE AND AFTER TREATMENT WITH 0.025 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (48 hours)			
271	Black bullheads	2.3 - 7.1	5.5
12	Northern pike	11.1 - 16.3	14.8
Post-treatment (72 hours)			
No fish taken			

*Combined data from all types of netting gear.

Cat Coulee Lake

Cat Coulee Lake had been previously treated twice (1.00 p.p.m. and 2.00 p.p.m. emulsifiable rotenone) to eradicate a population of black bullheads. Both applications were unsuccessful. On July 15, 1959 the lake (Table IV) was retreated with toxaphene at a concentration of 0.030 p.p.m. Within five hours of starting 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 XIX) on May 4, 1960. The lake was then restocked on September 23, 1960 with 4,600 rainbow trout (600/lb.) and will open to fishing in 1961.

Wolf Butte Lake

In 1957 Wolf Butte Lake was treated with 1.00 p.p.m. 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 the green sunfish and bullheads quickly regained their original abundance. After this the trout fishing began a rapid decline.

TABLE XIX. CAT COULEE LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.030 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (48 hours)			
194	Black bullheads	3.1 - 6.2	4.1
5	Rainbow trout	9.0 - 12.3	9.7
Post-treatment (48 hours)			
No fish taken			

*Combined data from all types of netting gear.

TABLE XX. WOLF BUTTE LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.030 P.P.M. TOXAPHENE

Total Fishes*	Species	Length Range (Inches)	Length Average (Inches)
Pretreatment (72 hours)			
1003	Green sunfish	1.8 - 5.3	4.0
68	Black bullheads	4.2 - 8.1	7.1
18	Rainbow trout	10.2 - 15.2	13.1
Post-treatment (72 hours)			
No fish taken			

*Combined data from all types of netting gear.

The lake was retreated on July 9, 1960 with toxaphene at a concentration of 0.030 p.p.m. (Table IV). 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 seven days and then no further activity was observed.

Post-treatment test netting carried out on September 8, 1960 indicated all fish had succumbed (Table XX).

Jund Lake

Jund Lake (Table IV) was treated on June 9, 1960 at a concentration of 0.035 p.p.m. of toxaphene. Action of the toxicant was rapid and within two 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 had ensued (Table XXI).

TABLE XXI. JUND LAKE TEST NETTING DATA BEFORE AND AFTER TREATMENT WITH 0.035 P.P.M. TOXAPHENE

Total Fishes*	Species	Length	
		Range (Inches)	Average (Inches)
Pretreatment (48 hours)			
163	Black bullheads	3.1 - 5.9	4.8
1	Rainbow trout	15.7	15.7
Post-treatment (48 hours)			
No fish taken			

*Combined data from all types of netting gear.

DISCUSSION AND CONCLUSIONS

The mortality pattern following application of various concentrations of toxaphene was consistent and a marked size selectivity was exhibited. As concentration ratos 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 on progressively smaller fishes.

The use of sub-lethal 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 homogenous immediate concentrations 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 that the concentration of toxaphene could be lowered to less than the minimum lethal level prior to 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. In lakes where incomplete kills occurred it must be assumed that either the initial concentration was below minimum lethal level or that detoxification at these low dosages is more rapid than

previously believed.

Five of the seven lakes sustaining complete mortalities were restocked within seven 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, little danger is present 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 mortalities 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 mortalities were indicated subject to the validity of test netting results.

Duration of toxicity of the toxaphene was not excessive. Five of the seven lakes exhibiting complete kills were successfully restocked within seven 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-year were effected. The use of toxaphene as a size selective piscicide is strongly suggested.

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APPENDIX

APPENDIX A. COMMON AND SCIENTIFIC NAMES OF FISHES FOUND IN PROJECT LAKES

Common name	Scientific name
Northern pike	Esox lucius Linnaeus
Walleye	Stizostedion vitreum (Mitchell)
Yellow perch	Perca flavescens (Mitchell)
Black bullhead	Ictalurus melas (Rafinesque)
Brown bullhead	Ictalurus nebulosus (LeSueur)
Black sucker	Catostomus commersonii (Lacepede)
Orangespot sunfish	Lepomis humilis (Girard)
Bluegill	Lepomis macrochirus Rafinesque
White crappie	Pomoxis annularis (Rafinesque)
Black crappie	Pomoxis nigromaculatus (LeSueur)
Rainbow trout	Salmo gairdneri Gibbons
Bluntnose minnow	Hyborhynchus notatus (Rafinesque)
Carp	Cyprinus carpio Linnaeus
Golden shiner	Notemigonus crysoleucas (Rafinesque)