A POPULATION STUDY OF THE FISHES OF WINTERGREEN LAKE, KALAMAZOO COUNTY, MICHIGAN: WITH NOTES ON MOVEMENT AND EFFECT OF NETTING ON CONDITION

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Carlos de la Mesa Fetterolf, Jr.

1952

This is to certify that the

thesis entitled

"A population study of the fishes of Wintergreen Lake, Kalamazoo County, Michigan: With notes on movement and effect of trap netting on condition."

presented by

Carlos Fetterolf

has been accepted towards fulfillment
of the requirements for

M.S. degree in Zoology

Peter I. Tack
Major professor

Date March 11, 1952.

A POPULATION STUDY OF THE FISHES OF WINTERGREEN LAKE, KALAMAZOO COUNTY, MICHIGAN: WITH NOTES ON MOVEMENT AND EFFECT OF NETTING ON CONDITION

By

CARLOS de la MESA FETTEROLF, JR.

A THESIS

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Zoology

1952

THESIS

411/52
(9)

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

ACKNOWLEDGEMENTS

The author is grateful to Dr. Peter I. Tack for his guidance and enthusiasm throughout this study. Much of the statistical analysis was suggested and supervised by Dr. Don W. Hayne, who gave generously of his time and energy. However, the author accepts full responsibility for any errors of calculation or in method of application. Appreciation is extended to Dr. Robert C. Ball for the use of his extensive library. The cooperation and assistance of Dr. Arthur E. Staebler, director of the Kellogg Bird Sanctuary, in the field work was invaluable. Dr. Gerald W. Prescott supervised the laboratory analysis of plankton and the identification of higher aquatic plants. I am also indebted to him and Dr. Ball for their critical reading of this manuscript. The Michigan Institute for Fisheries Research and the Fish Division of the Michigan Conservation Department supplied ready access to their unpublished reports on Wintergreen Lake. Thanks are due Dr. Gerald P. Cooper for permission to use material from one of his papers which is in press.

The summer field work with the large trap nets could not have been accomplished without the assistance of the following: Ralph Morrill, Dean Williams, Raymond Sharpe, Winifred Ford, Richard Hansen, David Stafford, Alfred Brower, and Aelred Geis.

Allan Hirsch aided the author in the spring plankton observations and with the capture and release of the first 800 fish. His cooperation, as well as that of other student colleagues, is sincerely appreciated.

Acknowledgement is due Miss Norma Lorraine Baughan who assisted in the laboratory and field tabulation of data and with some of the typing of the manuscript.

A POPULATION STUDY OF THE FISHES OF WINTERGREEN LAKE,

KALAMAZOO COUNTY, MICHIGAN: WITH NOTES ON MOVEMENT

AND EFFECT OF NETTING ON CONDITION

By

CARLOS de la MESA FETTEROLF, JR.

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan

State College of Agriculture and Applied Science

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Zoology

Year 1952

Approved Peter I. Tack

fo

of

mi

fi

th

f

p

(

t

Carlos M. Fetterolf, Jr.

ABSTRACT

A POPULATION STUDY OF THE FISHES OF WINTERGREEN LAKE, KALAMAZOO COUNTY, MICHIGAN: WITH NOTES ON MOVEMENT AND EFFECT OF NETTING ON CONDITION

A forty-acre, shallow, warm water lake, heavily fertilized by waterfowl droppings, has a standing crop of approximately 265 pounds per acre of common bluegills, largemouth bass, common sunfish, yellow perch, common bluegill X common sunfish hybrids, yellow bullheads, and bowfin. Only fish which an angler would consider of "desirable size" are included in this productivity figure. When yellow bullheads and bowfin are excluded from the total, the lake has a heavier standing crop per acre of game and pan fish than any natural lake listed by Rounsefell (1946) or Carlander (1950). Fishing has been restricted for over 20 years and the exploitation rate is low, approximately 5.4 percent by angling in 1952.

Fish were captured by angling and trap netting. Mortality of fish in the nets prompted a comparison of the condition factor of fish removed from the nets with fish captured by angling. A _t_ test showed that the fish removed from the trap nets had a significantly lower K factor than fish captured by angling.

Populations were estimated by the mark and recapture method, using the formulae of Schnabel (1938) and Schumacher and Eschmeyer (1943). Confidence limits were applied to the former method and limits of one standard error to the latter. A discussion of the sources of error is included.

The lake was divided into quarters by imaginary lines and all fish

capt
appr
quar
leas
fift
angl
the
com
(31
mar
cap
had
oth

th
re
th
ra
ca

l
A
r

captured in each quarter received a distinctive mark by removal of the appropriate fin. Fish captured by angling were released in their home quarter, while those captured by netting were released at a central release point at the intersection of the dividing lines. Two hundred and fifty-eight regional markings on largemouth bass originally captured by angling were reobserved. Of these, 110 (42.6 percent) were reobserved in the quarter of their original capture. Twenty-two regional markings on common bluegills originally captured by netting were reobserved. Seven (31.8 percent) of these had returned to the quarter of their original marking. Forty-five regional markings on yellow bullheads originally captured by netting were reobserved. Thirteen (28.9 percent) of these had returned to the region of their original capture. Recaptures of other species were insufficient to yield satisfactory movement patterns.

A statistical analysis of the movements of largemouth bass indicated that their redistribution from either the central release station or a regional release station was not random. Statistical tests suggested that largemouth bass exhibited a homing tendency. The hypothesis of random redistribution of common bluegills and yellow bullheads from the central release station is statistically acceptable by the Chi^2 test.

Results from two similar investigations of fish movements (Cooper, 1951) were compared statistically with data from Wintergreen Lake. Analysis showed that the possibility of similar behavior patterns with respect to redistribution after release was likely.

Length-frequency distributions showed that 49.8 percent of the la

pe

le

le

largemouth bass were between 8.7 and 10.6 inches total length and 69.3 percent of the common bluegills were between 7.6 and 8.6 inches total length. The possibility that these fish exhibit rapid growth to these lengths and then undergo a sudden decrease of growth rate is discussed.

INTRODUCTION

Much of the present work in the widely expanding field of fresh-water fishery biology deals with population studies and interrelationships of predator and prey fishes. A lake is considered to be in "balance" when it supports a large population of game and pan fish which are growing at an average rate. Achievement of this "balanced" situation is one of the aims of fisheries management.

In an effort to achieve a desirable "balance" between predator and prey members of a game and pan fish population, artificial fertilization of lakes and ponds has been carried out in many areas.

Wintergreen Lake, where this investigation was performed, appears to be an example of an unusual lake which produces fast-growing game and pan fish, which has a heavy standing crop of large sized fish, and over the last twenty years has received large quantities of nutrients in the droppings of thousands of waterfowl.

Since this lake, to a certain degree, represents the conditions which would be achieved by continued artificial fertilization, it offers opportunities to evaluate the results which might be accomplished by this type of management.

Objectives of this study were to determine:

(1) Total adult fish population.

(2) Interrelationships of predator and prey species.

(3) Movement and degree of territorialism of fish in the lake.

(4) Effect of netting on condition factor of fish.

(5) Composition of length-frequency distributions of fish.

HISTORY OF WINTERGREEN LAKE

The late Mr. W. K. Kellogg of the W. K. Kellogg Cereal Co., Battle Creek, Michigan, purchased the 500 acre farm that surrounds Wintergreen Lake in 1926. His primary interest was to establish a sanctuary for waterfowl. In 1929 he turned the farm and sanctuary over to Michigan State College for agricultural experimentation and scientific investigations. The Kellogg Company, in cooperation with the college, still operates a feed research unit on the farm.

Before Mr. Kellogg purchased the lake, inhabitants of the vicinity exploited it more heavily than it has been in the past twenty years. The college has allowed ice fishing by permit for many years, but summer fishing has been very light in comparison with fishing pressure on similar lakes of the region. Local fishermen state that before the public access was denied, Wintergreen Lake had been a favorite fishing spot that always yielded fish of a larger average size than surrounding lakes did. A few of these people confided that gill nets had been used in the lake five or six nights each spring for a number of years before the sale to Mr. Kellogg. This practice continued, although on a reduced scale, after the lake had been turned over to the college. These poachers have not been active since the close of World War II.

The lake has been the object of several fisheries investigations during the past twenty years. Dr. John Greeley, now of the New York State Conservation Department, was the first investigator. He tagged bass with an opercle clip in 1931, but his tags pulled lose and the experiment was a failure. Dr. Miles D. Pirnie became director of the sanctuary in 1931 and cooperated with the Institute for Fisheries Research of the Michigan Conservation Department in investigations which resulted in six unpublished reports dealing with Wintergreen Lake (Report numbers 280, 289, 365, 366, 366A, and 790). Information from these papers will be incorporated at appropriate points in this thesis.

DESCRIPTION OF WINTERGREEN LAKE

Physical

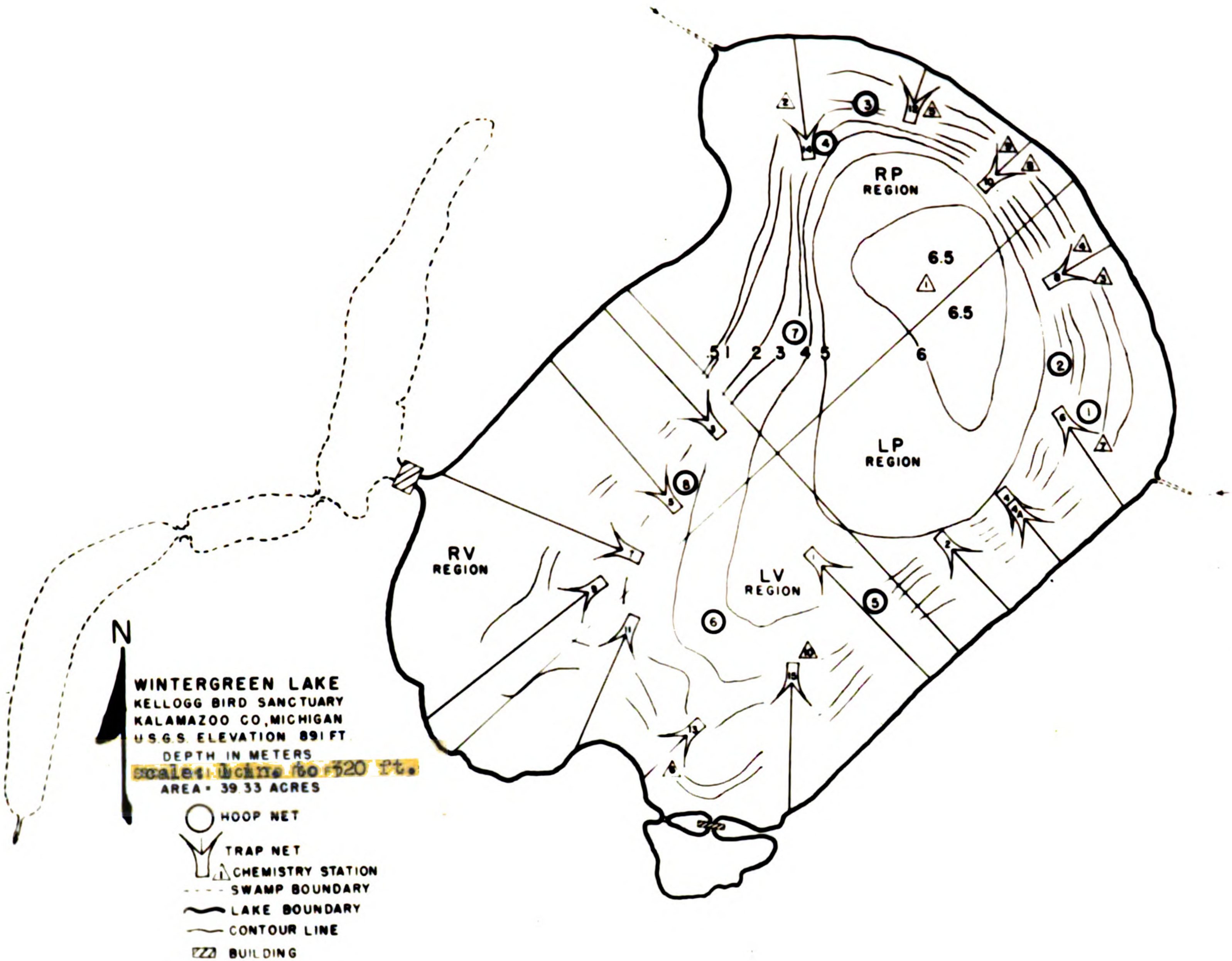
Wintergreen Lake (Tier 1 south, Range 9 west, Section 8) is located on the W. K. Kellogg Bird Sanctuary of Michigan State College in Ross Township, Kalamazoo County, Michigan. The lake has an area of 39.33 acres, according to measurements taken from a topographical survey of the sanctuary prepared by engineers of the landscape architectural firm of T. Glenn Phillips, Detroit, Michigan in 1937. Depth contour lines were added by F. Earl Lyman about 1935, while he was a graduate student at Michigan State College.

Measurements of these contour lines show that the lake has a mean depth of 7.56 feet and a volume of 297.16 acre feet. Maximum depth is 6.5 meters or 21.33 feet. Drainage area is 530 acres. There are no permanent feeder streams. The two streams indicated in Figure 1 are intermittent. At the south end of the adjoining swamp area there is an outlet which empties into Gull Lake, a half mile distant. Presumably, springs located on the north and northeast shore keep the lake at a fairly constant level.

Wintergreen Lake lies in the Kalamazoo-Mississinawa moranic system outwash plain. This plain is characterized by numerous lakes in the morainic basins and in the pits in the outwash plain. (Geologic history from I. D. Scott, 1920.) Wintergreen Lake is one of many small pit lakes in the vicinity.

Figure 1. Wintergreen Lake, Kellogg Bird Sanctuary, Hickory Corners, Michigan.

This map shows the lines dividing the lake into quarters. All netting, chemistry, and plankton collection stations are shown.


RP
REGION
LP
REGION
LV
REGION
RV
REGION
6.5
6.5
6
.5
1
2
3
4
5
N
WINTERGREEN LAKE
KELLOGG BIRD SANCTUARY
KALAMAZOO CO, MICHIGAN
U.S.G.S. ELEVATION 891 FT
DEPTH IN METERS
scale: 1 in. to 320 ft.
AREA = 39.33 ACRES
HOOP NET
TRAP NET
CHEMISTRY STATION
SWAMP BOUNDARY
LAKE BOUNDARY
CONTOUR LINE
BUILDING

Bottom Type

Bottom deposits are variable. The south and west shore is pulpy peat to a depth of three feet, where marl becomes intermixed with it. Marl is predominant to a depth of about twelve feet in all other parts of the lake except the east and northeast shore. These shores are exposed to wave and wind action and are sandy to a depth of 2.5 feet where marl again becomes predominant. Beyond the twelve-foot depth the bottom is of a fine organic ooze.

Aquatic Vegetation

Chara is dominant in the shallow areas of the lake. As the depth increases, two species of Potamogeton become abundant: Sago pondweed, *Potamogeton pectinatus*, and leafy pondweed, *Potamogeton foliosus*. Coontail, *Ceratophyllum demersum*, and bushy pondweed, *Najas flexilis*, combine with the potamogetons to give a dense weed bed extending to about the four meter contour. Beds of spatterdock, *Nuphar advena*, occur along the shore in the southwestern half of the lake. There are two patches in the northeastern half; one in the eastern corner and another in the northwestern corner. White water lily, *Nymphaea* (*Castalia* of authors) *odorata*, is limited to the lagoon area at the southern tip. The shoreline vegetation consists predominately of two species: Swamp loosestrife or water willow, *Decodon verticillatus* var. *laevigatus*, and button bush, *Cephalanthus occidentalis*.

Natural Fertilization

Many recently published fisheries articles and much of the present fisheries research work deal with enrichment of lakes by addition of fertilizer. This lake is perhaps one of the richest in the country from the standpoint of the nutrients added by natural fertilization. Each fall from 6,000 to 10,000 Canadian geese use the sanctuary as a stopping over place on their southward migration. An equal number of ducks are also present at this time and a flock of about 70 swans, geese, and ducks use the lake the year around. The extent to which the tremendous amount of natural fertilizer in their droppings improves the environment for fish production is unknown. The luxuriant higher aquatic plant growth has been described above. The bottom fauna is rich in quantity and utilized by the pan fish as food (Funk, 1942). On numerous occasions during calm days, black terns visit the lake and feed on emerging midges near the water surface.

Plankton and Algae

The plankton and other algal growths are very abundant and deserve mention. An algal study was made by taking algal collections on the lake one day a week from April 6 to May 28, 1951. Sampling was done with a Kemmerer water sampler at two stations. One station was permanent, in the deepest part of the lake, where six samples were taken weekly; two each at the surface, three meters, and five meters. Two surface samples were taken from the shore against which the waves broke. One of each pair of samples was settled with mercuric chloride whereas the other was centrifuged. Resulting concentrates were treated as suggested by G. W. Martin, Iowa State College, in an unpublished manuscript. Numbers of organisms were obtained by the following formula - Average number of organisms per field x number of fields in area of cover slip x number of drops per cc. x 1000 all divided by concentration factor equals number of organisms per liter. This method was used for the microplankton. The macroplankton was counted by use of a low-power binocular microscope and the number obtained was discrete. Dr. Gerald W. Prescott, Michigan State College Botany Department, supervised the laboratory analysis and served as an advisor to the investigators.

At the peak of the spring bloom on April 6, 1951 the average number of algal and protozoan organisms per liter of lake water was 70 million. The Secchi disk reading averaged 0.8 meters while water temperature was 43 degrees F. with pH of 7.5 and methyl orange alkalinity of 176. One month later on May 6, the average number of organisms per liter had dropped to 350,000. The Secchi disk could be seen resting on the lake bottom in 6.5 meters of water. Water temperature was 62 degrees F., pH 7.3, and methyl orange alkalinity averaged 162. On April 6 the samples were made up of <u>Schroederia</u> and <u>Cyclotella</u> in a two to one ratio, with <u>Euglenoids</u>, <u>Synedra</u>, <u>Navicula</u>, <u>Chlamydomonas</u>, and ciliated protozoans being incidental. On May 6 there was no one species that was dominant. The samples contained <u>Cyclotella</u>, <u>Schroederia</u>, <u>Euglenoids</u>, ciliated protozoans, <u>Chroococcus</u>, <u>Scenedesmus</u>, <u>Synedra</u>, <u>Asterionella</u>, and <u>Navicula</u> in equal numbers. Unidentified green and blue green algal cells were present occasionally.

The population of macroplankton, Cladocera, Ostracods, Copepods, and Rotifera, varied from a low of 11 per liter on April 6 to a high of 97 per liter on May 6. On this latter date, while the water was exceptionally clear, the Cladocerans were in layers so thick that they presented the appearance of a false sandy bottom to the eye. They were not taken abundantly in the samples after that date through May 28 when sampling was discontinued.

The filamentous algae showed a similar cycle. They were almost non-existent until May 6. They reached their peak of abundance in the following month. Their bloom was concurrent with the rapid growth of the potamogetons. Conditions for both algae and larger vegetation must have been good coincidentally, for each newly developed higher plant would have a growth of algae on it. Many of these algae became planktonic as high winds stirred the water and broke many filaments loose from the bottom and from the potamogetons during the week of May 6 - 12.

Nostoc balls were present on the lake bottom during the spring and summer. All of the above information on plankton and algae came from an unpublished report by Fetterolf and Hirsch (1951).

The next observations on the lake were in the latter part of June at the onset of a dense Microcystis bloom which remained during the entire summer.

Limnology

Temperatures and some chemical information were recorded concurrently with the plankton study. A diurnal chemical analysis was taken on September 4 and 5, 1951. Results are presented in Tables I and II.

TABLE I

WEEKLY CHEMISTRY OF WINTERGREEN LAKE, APRIL 6 - MAY 28, 1951

Date	Station see map	Time	Weather	Temp. Air	Temp. H_2O	Depth[1] meters	pH	MOA	Secchi
April 6	1	1210	.2 clouds	53	43	Surf.	7.5	176	.8 m.
			SE wind		43	3	7.5	178	
			0-5 mph		43	5	7.5	178	
	2	1330		53	44	Surf.	7.5	175	
April 13	1	1300	Sleet	36	46	Surf.	7.4	168	.85 m.
			SW wind		46	3	7.4	175	
			20-25 mph		46	5	7.4	172	
	3	1500			46	Surf.	7.4	176	
April 21	1	1500	Lt. rain	55	47	Surf.	7.3	164	1.15 m.
			NE wind		47	3	7.3	165	
			20 mph		44	5	7.4	172	
April 22	4	1000	Overcast	50	47.5	Surf.	7.3	172	
			SW wind						
			15 mph						
April 27	1	1745	.1 clouds	63	56	Surf.	7.4	166	4.2 m.
			SSW wind		52.5	3	7.4	171	
			0-10 mph		50.5	5	7.4	170	
	5	1815			58	Surf.	7.4	164	
May 6	1	1200	.2 clouds	56	62	Surf.	7.3	159	6.5 m.
			N wind		58	3	7.3	164	on
			10-15 mph		49	5	7.3	171	bottom
	6	1345			62	Surf.	7.3	154	
May 12	1	1615	.2 clouds	67	59	Surf.	7.4	153	6.5 m.
			W wind		55	3	7.4	159	on
			5-10 mph		53	5	7.4	158	bottom
	7	1745			62.5	Surf.	7.4	154	
May 20	1	1100	.1 clouds	80	73.5	Surf.	7.4	120	4.6 m.
			SW wind		67	3	7.4	134	strong
			0-10 mph		59	5	7.4	160	winds
	8	1230			76	Surf.	7.4	118	prior
									36 hrs.
May 28	1	0900	Overcast	54	64	Surf.	7.4	112	5.2 m.
			SE wind		64	3	7.4	110	
			10 mph		60	5	7.4	120	
	9	1020			62	Surf.	7.4	110	

[1] The depth of the lake at station number 1 was 6.5 meters and 1 meter at stations number 2 - 9.

TABLE II

A DIURNAL CHEMISTRY OF WINTERGREEN LAKE

Date	Station see map	Time	Weather	Temp. Air	Temp. H_2O	Depth[1] meters	O_2 ppm	CO_2 ppm
Sept. 4	10	1300	Clear	81	70	Surf.	7.1	0
			SE wind		72.5	1		
			0-5 mph		70	2		
						2.5	6.8	0
					69	3		
	1	1400	Clear	80	73.5	Surf.	7.2	0
			S wind		72	1		
			0-5 mph		70	2	7.3	0
					69.5	3	6.3	0
					69	4	3.1	1
					65	5	0.0	26
					59	6	0.0	68
	10	1715	Clear	72	75	Surf.	7.6	0
			NE wind		73	1		
			0-5 mph		70	2		
						2.5	7.9	0
					69	3		
	1	1815	Clear	70	74	Surf.	7.8	0
			NE wind		72	1		
			0-3 mph		70.5	2	8.1	0
					70	3	4.7	0
					69	4	2.7	1
					65	5	0.0	9
					59	6	0.0	88
	10	2100	Clear	59	73	Surf.	7.6	0
			E wind		72.5	1		
			0-3 mph		71	2		
						2.5	7.1	0
					70.5	3		
	1	2215	Clear	59	72	Surf.	7.9	0
			No wind		71.5	1		
					70.5	2	7.5	0
					69.5	3	6.4	0
					68.5	4	4.8	0
					65.5	5	1.8	9
					59.5	6	0.0	72
Sept. 5	10	0100	Clear	53	72	Surf.	7.7	0
			No wind		72	1		
					70	2		
						2.5	7.5	0
					70	3		
	1	0200	Clear	53	71	Surf.	7.9	0
			No wind		71	1		
					70	2	7.3	0
					69.5	3	6.3	0
					69.5	4	0.7	10
					64.5	5	0.7	20
					59.0	6	0.0	81

[1] The depth of the lake at station number 1 was 6.4 meters and 3 meters at station number 10.

On May 24 a trapnet was set in 15 feet of water and allowed to fish for 3 days. Upon raising the net, all fish were in excellent condition and the net yielded one of the largest catches of fish of the season. The next trapnet set was on July 2 in water 10 feet deep. The net was raised 2 days later and the entire catch was dead. Since the time of the previous set the lake had stratified thermally and chemically. It is believed that fish entered the trap when the water at that depth contained enough oxygen to sustain life, at least for a brief time. After becoming trapped the fish may have died because the dissolved oxygen content was too low to sustain life over an extended period or because of lowered oxygen content during the night when photosynthesis ceased. Rate of decomposition of decaying matter would be increased by warmer temperatures, thus adding to decomposition products in the deeper water.

To test the hypothesis that there was less dissolved oxygen present during darkness than during daylight at the same depth an immediate diurnal chemical analysis should have been made. The chemical reagents to perform these tests were lacking and they were not procured until August. The latter part of August was cool and the mortality rate of fish in the nets was lower than usual. It was desired to have a warm period to make chemical tests, as stratification, both thermal and chemical, would be more clearly defined. The writer was unable to make the chemical analysis until September 4 and 5, see Table II.

At 0200, September 5, there were 6.3 parts per million of dissolved oxygen present at 3 meters (9.8 feet) and 0.7 parts per million of dissolved oxygen present at 4 meters (13.1 feet). This latter amount was much less than the amount found at that depth earlier in the diurnal cycle. Apparently the assumption that the same layer of water contained less oxygen during the night than during the day was correct. Whether this condition existed in July is unknown. However, it is believed that this condition would have been accentuated during the warmer month of July.

Birge's definition of a thermocline (1904, as cited by Welch, 1935) states that the upper limit of the thermocline begins where the temperature drop is 1 degree C. or more per meter. Table II shows that the thermocline begins at a depth of 4 meters. It is regretted that further temperature and chemical tests were not taken during warm periods, for a person swimming could easily detect temperature changes with his feet. It is possible that chemical stratification accompanied the thermocline to this high level, although there is no proof. This stratification could be the cause of the mortality of fish in the nets, when they were forced to remain there for extended periods.

Fish Fauna

A list of the fishes found in the lake in May 1935 appears in an unpublished report of the Michigan Conservation Department, Institute for Fisheries Research (Cooper, 1935b). All but two of the species present at that time were found in 1951. There have been three additions to the list compiled in 1935. All scientific and common names are from Hubbs and Lagler (1949).

SCIENTIFIC NAME	COMMON NAME
Amia calva Linnaeus.	Bowfin or dogfish
Erimyzon sucetta kennerlii (Girard).	Western lake chubsucker
Notropis heterodon (Cope).	Blackchin shiner
Notropis heterolepis heterolepis Eigenmann and Eigenmann.	Northern blacknose shiner
Notropis cornutus chrysocephalus (Rafinesque).	Central common shiner[1]
Notemigonus crysoleucas auratus (Rafinesque).	Western golden shiner
Hyborhynchus notatus (Rafinesque).	Bluntnose minnow
Ameiurus natalis natalis (LeSueur).	Northern yellow bullhead
Esox vermiculatus LeSueur.	Mud pickerel[2]
Perca flavescens (Mitchill).	Yellow perch
Poecilichthys exilis (Girard).	Iowa darter[3]
Micropterus salmoides (Lacepede).	Largemouth bass
Lepomis cyanellus Rafinesque.	Green sunfish[4]
Lepomis gibbosus (Linnaeus).	Pumpkinseed or common sunfish
Lepomis macrochirus macrochirus Rafinesque.	Common bluegill
L. cyanellus X L. macrochirus	Green sunfish X bluegill[5]
L. gibbosus X L. macrochirus	Common sunfish X bluegill

[1] Listed in 1935. Believed to have been introduced by bait fishermen. The fish probably did not reproduce in the lake. None were found in 1951.

[2] Not listed in 1935. In 1951 this fish was common in the shallow outlet area of the lake.

[3] Listed in 1935 as rare. Not found in 1951, but probably present.

[4, 5] Not listed in 1935. A green sunfish X common bluegill hybrid was tagged by Shetter and Whitlock in 1936. Dr. A. E. Staebler, present director of the sanctuary, reports catching the green sunfish in 1950. The fish is probably present, but rare.

MARKING PROCEDURE

Although a study of the population was the primary purpose of this investigation, information on movement of fish within the lake was gathered with a minimum of additional work. Stakes were placed at four points on shore so that imaginary lines drawn between opposite pairs would divide the lake approximately into quarters. See Figure 1. Quarters were symbolized as Right Pectoral, Left Pectoral, Right Ventral, and Left Ventral Regions to correspond to the fin clipped from fish caught in each area. These regional titles will be abbreviated to RP, LP, RV, and LV throughout the remainder of this paper. Respective acreages of the regions were as follows: RP, 10.30; LP, 10.06; RV, 8.80; and LV, 10.17.

Fish caught by angling in a given region were marked by removal of the appropriate fin and an additional cut of one half of the soft dorsal fin. If the fish was captured in a trap or hoop net, the regional mark was applied, but no dorsal cut was made. If a fish marked as caught by angling was recaptured by angling in a different region, a new regional mark was added; fish recaptured in the same region had the whole soft dorsal removed; if recaptured a third time, one half of the spiny dorsal was cut. If a fish originally caught by angling was recaptured by netting, one half of the anal fin was cut. When a fish first caught by nets was recaptured by angling, both one half dorsal and one half anal cuts were made, and the appropriate regional mark added.

Marking of fish began on April 21, 1951. From this date to May 27 almost all fish marked were caught by hook and line. No record of fish caught per man hour was kept, but the number would be high.

This investigator was usually accompanied by another graduate student in fisheries from the College who acted as data clerk. When fishing was slow, total and standard length, weight, and sometimes scale samples were taken as soon as the fish was caught. The fish were fin-clipped according to the system outlined above and released. When a fish seemed moderately injured, it was not released. When fishing was good, the fish were placed in ten gallon milk cans until about five fish were in the boat which would require about five minutes. Then the fish were measured, weighed, fin-clipped and released.

Fish caught by angling were always released within fifty yards of the place they were caught and always within the quarter boundary. Fish captured by nets were placed in ten gallon milk cans. When the cans were filled to a safe capacity, the boat was moved to the intersection of the dividing lines in the center of the lake and anchored. There data was taken and the fish released as rapidly as possible. Any fish in doubtful condition was not released.

The object of having a central release point was three-fold; to attempt to insure a random redistribution of the fish, to eliminate a concentration of marked fish surrounding the net, and to provide a comparison of movements between fish released at their point of capture and those released at a central station.

This last objective met with limited success due to varying susceptibility of a species to angling and netting. A large number of largemouth bass were captured by angling whereas a small number were taken in the nets. The situation was reversed with the bluegills, pumpkinseeds, and bullheads. Recaptures of other species were made in insufficient numbers to yield any significant data. Consequently, information on fish movement was only adequate on one phase of the comparison test.

METHODS OF CAPTURING FISH

Angling

Spring fishing for largemouth bass was done almost entirely by bait-casting and flyrod with artificial lures from April 21 to the middle of May. From the middle of May to the end of the month, minnows were found to be the most successful bait. During the months of July, August, and September most angling was with plugs and flyrod surface lures.

Large numbers of bass were caught by angling during April and May. All fish became increasingly difficult to catch after June. There was an increase in per unit of fishing effort, but a drop in catch. Occasionally throughout the summer, good catches of panfish resulted from bait fishing with earthworms, small minnows, and catalpa worms.

After the opening of the statewide lake fishing season, Dr. A. E. Staebler, director of the sancturary, gave a limited number of people permission to fish the lake if they agreed to cooperate with the creel census. The lake was ideal for census work, as the only boats were located in a boathouse at the outlet on the east shore. These people were permitted on the lake once or twice during the summer. One man, Mr. Kellogg's chauffeur, was given unlimited fishing privileges.

Whenever possible, the writer checked the fish being removed from the lake for marks. Some anglers were careful in their examinations and results were gratifying. Others did not see as many as three fin-clips from a catch of 40 bluegills. If a large number of marked fish left the lake without my knowledge, the results of the population estimate would be high. The error resulting from anglers' carelessness is not thought to be significant when the overall weaknesses of population estimations are recognized.

The following is a condensation of the rules to which all anglers fishing the lake agreed. Cards and pencils were provided. A large printed picture of a bass was posted with all fins labeled.

> A study to determine the total population of the fish in this lake is underway. In order to iliminate discrepancies in the data it is requested that all persons record the number and species of fish caught. Examine your catch and note if the fish have been fin-clipped in any way. An ideal sample report is filled out below. Remember to state how many fish and what kind were removed from the lake.

Netting

Hoop nets were used a few times during the spring. Their rate of capture was far below the rate of capture by angling. Time spent in setting the nets would have been more profitably spent in angling.

The nets were of the standard type, netting stretched over a series of hoops which were connected by funnels of mesh. There were 6 hoops, tapering from a diameter of 3 feet to 1 foot 8 inches. Wings and body were each 9 feet long. Wings were 3 feet deep. All mesh was 2 inches stretched measure.

During the late spring and throughout the summer, Great Lakes trap nets were used. See Figure 2. A hundred yard lead, 4 feet deep, was attached to the net, but usually most of it was placed on shore and not used. Wings, leader, and hearts were of 2.5 inch stretched mesh and the cars were of 1.5 stretched mesh.

Figure 2. Great Lakes Trap Net.

Description on Page 20.

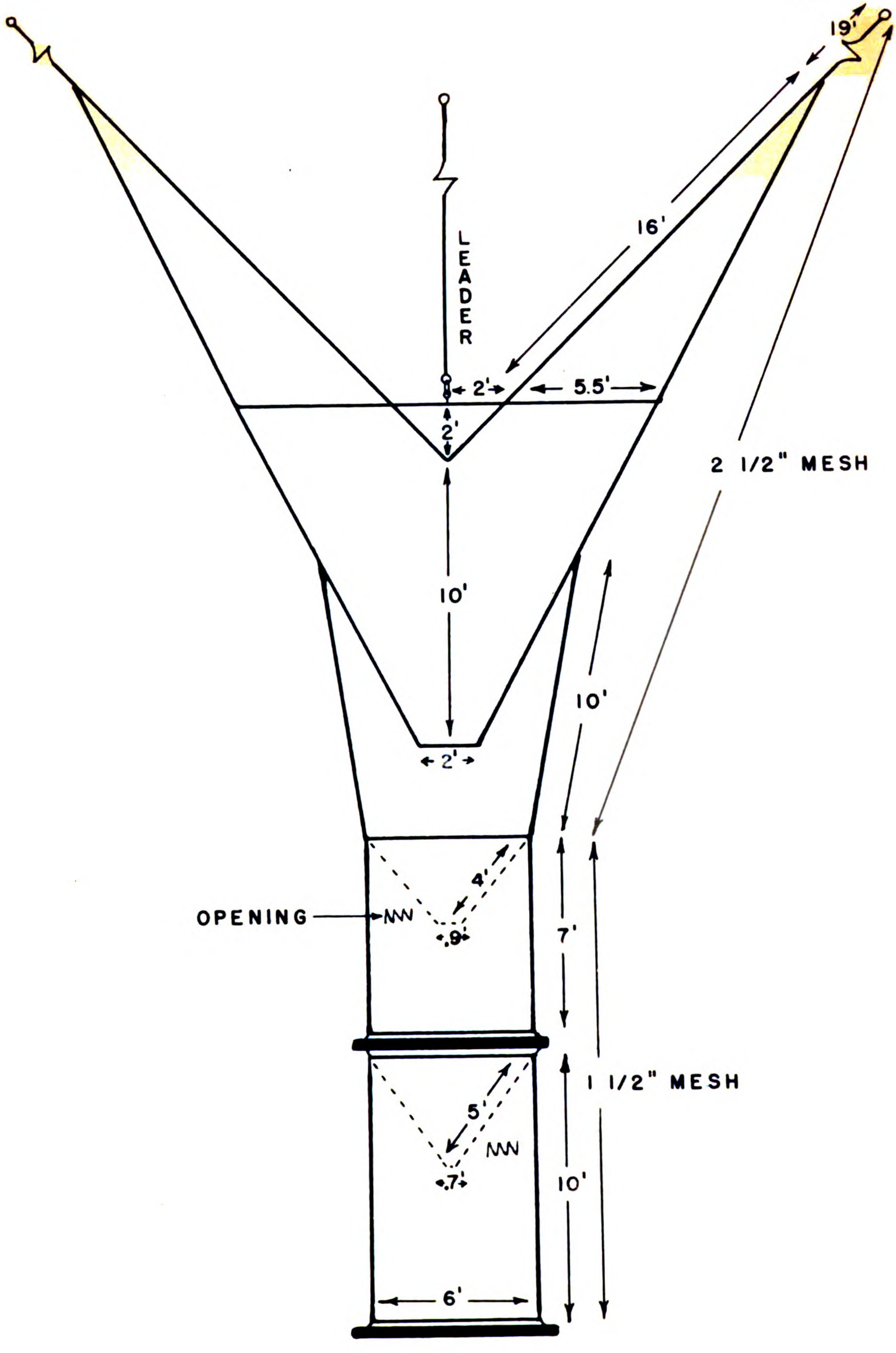

19'
16'
LEADER
2'
5.5'
2'
2 1/2" MESH
10'
10'
2'
4'
OPENING
.9'
7'
1 1/2" MESH
5'
.7'
10'
6'

TABLE III

NETTING RECORD

Date	Set no.	Time in days	No. of lifts	Depth of set	Species[1]	Number caught	Mortality No.	Mortality %
A. Hoop Nets								
April 29	1	1	1	8'	YBH	5	0	0
May 4	2	1	1	10'	YP	1	0	0
May 4-6	3	3	3	5'	BG	3	0	0
					CS	2	0	0
					XB	1	0	0
May 5-6	4	2	2	12'	LMB	1	0	0
					YBH	1	1	100*
May 13	5	2	1	9'	YBH	2	2	100*
	6	2	1	11'	YBH	1	1	100*
					LMB	1	0	0
May 18-19	7	2	2	13'	---	-	-	-
	8	2	2	8'	BG	2	0	0
					CS	2	0	0
B. Trap Nets								
May 24-27	1	2½	1	15'	LMB	11	2	18
					BG	28	0	0
					CS	2	0	0
					XB	1	0	0
					YP	4	0	0
					YBH	20	2**	10
					Amia	12	2**	17
July 2-4	2	2	1	10'	LMB	2	2	100
					BG	2	2	100
					XB	1	1	100
					YP	2	2	100
					YBH	7	7	100
July 1-5	3	4½	2	6'	LMB	3	0	0
					BG	7	1	14
					CS	2	0	0
					YBH	9	0	0
					Amia	1	0	0
July 4-5	4	1	1	9'	LMB	2	1	50
					BG	5	0	0
					CS	5	0	0
					YBH	7	0	0
					Amia	2	2	100***
July 5-10	5	5	2	6'	LMB	8	1	13
					BG	78	5	6
					CS	35	6	17
					XB	21	5	24
					YP	3	3	100
					YBH	17	0	0
					Amia	3	3	100***

NETTING RECORD

Date	Set no.	Time in days	No. of lifts	Depth of set	Species[1]	Number caught	Mortality No.	Mortality %
July 5-10	4A	5	1	7'	LMB	10	0	0
					BG	47	7	14
					CS	12	4	33
					XB	4	0	0
July 10-18	6	7	2	8'	LMB	5	2	40
					BG	53	27	51
					CS	12	4	33
					XB	2	0	0
					YP	1	1	100
					Amia	2	2	100***
July 10-18	7	7	2	7'	LMB	5	0	0
					BG	166	45	27
					CS	55	24	44
					XB	25	9	36
					YBH	9	0	0
					Amia	1	1	100***
July 18-25	8	7	1	10'	LMB	4	2	50
					BG	30	13	43
					CS	22	15	68
					XB	1	0	0
					YP	1	1	100
					YBH	4	0	0
					Amia	1	0	0
July 18-25	9	7	1	$5\frac{1}{2}$'	LMB	1	0	0
					BG	48	4	8
					CS	33	0	0
					XB	9	0	0
					LCS	1	1	100
					Amia	1	0	0
July 25-Aug. 1	10	7	1	7'	LMB	10	4	40
					BG	54	22	41
					CS	43	40	93
					XB	1	1	100
					YP	1	0	0
					YBH	5	0	0
July 25-Aug. 1	11	7	1	5'	LMB	3	0	0
					BG	35	1	3
					CS	24	9	38
					XB	8	1	13
					YP	2	1	50
					YBH	8	1	13
Aug. 1-8	12	7	1	5'	LMB	6	1	17
					BG	7	4	57
					YP	1	0	0
					YBH	8	0	0
					Amia	3	1	33

TABLE III (Cont.)

NETTING RECORD

Date	Set no.	Time in days	No. of lifts	Depth of set	Species[1]	Number caught	Mortality No.	Mortality %
Aug. 1-8****	13	7	1	$5\frac{1}{2}$'	LMB	2	2	100
					YBH	10	0	0
Aug. 8-16*****	14	8	1	6'	BG	7	0	0
					CS	1	0	0
Aug. 8-15	15	7	1	7'	LMB	18	1	6
					BG	113	39	35
					CS	55	27	49
					XB	14	5	36
					YP	5	5	100
					YBH	27	1	4
					Amia	3	3	100

1 Species abbreviations are LMB, largemouth bass; BG, common bluegill; CS, common sunfish or pumpkinseed; XB, common sunfish X common bluegill hybrid; YP, yellow perch; YBH, yellow bullhead; Amia, bowfin; and LCS, western lake chubsucker.

* Removed for stocking experimental ponds of Michigan State College at Lake City, Michigan.

** Placed in exhibition tanks of Kellogg Bird Sanctuary.

*** Killed for stomach analysis.

**** A large rip in the top of the net permitted escape.

***** This net set did not fish correctly.

T

Met
cap

Hoo

Tra

T

Angl

To

Dead f

Gra

I E

* R

** E

C

*** C

TABLE IV

TOTAL MORTALITY AND YIELD FOR SPRING AND SUMMER, 1951, WINTERGREEN LAKE

Method of capture	Species and time of capture[1]	Number caught	Mortality No.	Mortality %	Average weight in grams	Total yield	Pounds per acre
Hoop Net	LMB	2	0	0			
	BG	5	0	0			
	CS	4	0	0			
	XB	1	0	0			
	YP	1	0	0			
	YBH	9	4	44*	521.3	4.6	.12
Total		22	4	18		4.6	.12
Trap Net	LMB	90	18	20	327.4	13.0	.33
	BG	680	170	25	203.4	76.2	1.94
	CS	301	129	43	174.2	49.5	1.26
	XB	87	22	25	176.9	8.6	.22
	YP	20	13	65	150.1	4.3	.11
	YBH	131	11	8**	521.3	12.6	.32
	Amia	29	14	48**	1611.3	49.7	1.26
	LCS	1	1	100	260.0	.6	.02
Total		1339	378***	28***		214.5	5.45
Angling	LMB						
	Before 6-25	1029	27	3	327.4	19.5	.50
	After 6-25	339	142	42		102.5	2.61
	Total	1368	169	12		122.0	3.10
	BG						
	Before 6-25	70	6	9	203.4	2.7	.07
	After 6-25	748	572	76		256.5	6.52
	Total	818	578	71		259.2	6.59
	CS						
	Before 6-25	15	6	40	174.2	2.3	.06
	After 6-25	102	82	80		31.5	.80
	Total	117	88	75		33.8	.86
	XB						
	Before 6-25	1	0	0	176.9		
	After 6-25	23	8	35		3.1	.08
	Total	24	8	33		3.1	.08
	YP						
	Before 6-25	77	5	6	150.1	1.7	.04
	After 6-25	148	120	81		39.7	1.01
	Total	225	125	56		41.4	1.05
	YBH						
	After 6-25	6	6	100	521.3	6.9	.18
	Amia	5	4	80	1611.3	14.2	.36
Total		2563	978	38		480.6	12.22
Dead fish on shore			63			32.1	.82
Grand total		3924	1459	37%		731.8	18.61

1 Explanation of abbreviations found in footnote 1, Table III.

* Removed for stocking experimental ponds at Lake City, Michigan.

** Eight Amia were killed for stomach analysis, two were placed on display, and two bullheads were displayed in the sanctuary aquarium.

*** Corrected for intentional death, would read 366 and 27 percent.

A rowboat was the most suitable craft on the lake for setting and lifting nets. It would have been desirable to release fish from the nets at least twice a week, but the nets were allowed to fish a whole week on numerous occasions. Two men were required to lift the nets, measure and weigh the fish, and move the nets. There were no funds available to employ help. Local high school students and other interested persons supplied the necessary labor. Their reward came in fishing hours on the lake.

COMPARISON OF FISH CAUGHT BY ANGLING AND BY TRAP NETTING

Hansen (1944) observed the rate of escape of fishes from hoop nets. His results showed that common bluegills and largemouth bass exhibited a remarkable facility for escape when left in the nets for a day or more. In one day sets in Maple Lake, Illinois, he used 81 bluegills, of which 32 percent escaped. One day tests at Lake Glendale, Illinois showed 36 percent of 44 bluegills escaped while 37 percent of 16 bass escaped. Fifty-one hour tests in the same lake resulted in 86 percent of 36 bluegills and 20 percent of 51 bass escaping. He writes that fish do not seem to realize they are in traps. They are very calm and do not seem to search for the exit. The fish merely swim in and out of the trap. It would seem that fish trapped in a large enclosure such as the trap nets used in the present study would not become excited at all and would use the net as a shelter.

The above hypothesis does not seem tenable when the mortality rate of trap netted fish in this experiment is considered. See Table IV. Although Hansen states that the fish do not swim wildly about the net in a manner conducive to injury, much of the mortality in trap nets used in this experiment seemed to be caused by physical injury. Visual evidence of tail wear and abrasions about the head were present in many fish. These abrasions gave fungi an opportunity to enter. Although guppies, Lebistes reticulatus, succomb peacefully to oxygen deficiences, (Ball, verbal communication), perhaps the species in these trap nets did not.

Snapping turtles, Chelydra serpentina, and bowfin present in the nets may have caused panic among the trapped fish. Eight bowfin were removed from trap net sets 3, 5, 7, 9, 10, and 11. Two of these turtles were too decomposed to work on, but the other five were examined for stomach contents. All five stomachs were packed with fish. Visual and olfactory clues indicated that the fish eaten had been carrion. There is no proof of this statement and it is possible that the turtles consumed live fish, but it seems more likely they preyed on the dead ones. In all cases the fish remains had never passed the junction of the stomach with the duodenum. The intestines were filled with filamentous algae, molluscs, and other bottom organisms.

It is unknown whether the presence of these predators in the nets had any effect on the entrance of fish into the trap. Aquarium reactions of fish of the size caught in the nets to the bowfin and snapping turtle are indifference. Reactions in the natural environment of the lake may be different.

An effort was made to compare the condition of trapped fish with fish caught by angling. This comparison was not planned and information on the point was collected incidentally to the primary purpose of the experiment, namely population study. Only fish that were judged to be in releasable condition were considered for the test. No data were taken from dead fish or fish with more than a slight fungus infection.

Condition factor for the fish of the two groups was found by the formula: $K = \text{Weight} \times 10^5/\text{Length}^3$. Weight in grams and standard length in millimeters were substituted in the formula. Standard length was used because of worn caudal fin tissue on some of the trapped fish. It has been recognized that the value of K is not constant for an individual fish, species, or a population. However, I believe condition factor is valid when used for comparison purposes between two groups of fish of the same species from the same population, provided the comparison extends over the same period of time.

The _t_ test was used to compare fish removed from trap nets with those captured by angling, following methods presented by Dixon and Massey (1951) for testing the hypothesis that two samples, differing as much as those being examined, might have been drawn from the same population.

It would have been desirable to compare each species over a short period of time, but sampling was not adequate. Bluegills were the only fish adaptable to this periodic comparison. For this species, three time-periods during spring and summer were established, May, July, and August. Measurements were divided into 7 standard length classifications within the range from 10.75 to 21.25 centimeters. Class midpoints were 11.5, 13.0, 14.5, 16.0, 17.5, 19.0, and 20.5 centimeters. Each class limit was .75 centimeters above and below the midpoint. Results are presented in Table V.

This table suggests that largemouth bass, common bluegills, common sunfish, and the common sunfish X common bluegill hybrid may suffer a weight loss while in the nets. All condition factors for largemouth bass, common sunfish, and hybrid sunfish were not utilized in this experiment. When a large quantity of data for an individual species of the same size over a short time-period were available, taken either by angling or netting, but not by both, fish were selected by picking only the second and fifth fish in a series of five. However, all available data for bluegills were used. The _t_ test was applied to all time periods

TABLE V

COMPARISON OF K FACTOR OF FISH CAUGHT BY ANGLING AND BY NETTING

Hypothesis: Condition factor of fish caught by angling has the same condition factor as fish caught by netting.

Species	Time period	Standard length in centimeters	Method of capture	N	Mean of K factors	Observed t value
Largemouth bass	5/25-8/16	All fish	Angling	184	2.226	
			Netting	44	2.180	
				228		2.98**
Common sunfish	5/4-8/16	All fish	Angling	32	5.233	
			Netting	172	5.014	
				204		2.52*
Com'n sunfish X bluegill hybrid	5/4-8/19	All fish	Angling	19	5.684	
			Netting	63	5.316	
				82		3.38**
Common bluegill	5/3-27	13.75-15.25	Angling	12	4.589	
			Netting	11	4.657	
				23		-.34
	5/3-27	15.25-16.75	Angling	35	4.902	
			Netting	17	4.584	
				52		2.55*
	5/3-27	16.75-18.25	Angling	7	5.106	
			Netting	4	4.876	
				11		1.84
	7/3-26	12.25-13.75	Angling	10	4.649	
			Netting	17	4.491	
				27		1.25
	7/3-26	13.75-15.25	Angling	5	4.822	
			Netting	22	4.438	
				27		2.79**
	7/3-26	15.25-16.75	Angling	43	4.852	
			Netting	203	4.480	
				246		8.88**
	7/3-26	16.75-18.25	Angling	20	4.821	
			Netting	79	4.476	
				99		4.45**
	8/1-28	13.75-15.25	Angling	11	4.680	
			Netting	19	4.383	
				30		1.35
	8/1-28	15.25-16.75	Angling	36	4.546	
			Netting	46	4.533	
				82		.01
	8/1-28	16.75-18.25	Angling	29	4.451	
			Netting	61	4.386	
				90		.54
	5/3-8/28	All	Angling	220	4.715	
			Netting	514	4.468	
				734		8.39**

* Significant at the 95 percent level of confidence.

** Significant at the 99 percent level of confidence.

and length groupings in which a minimum of four fish was taken by each of the methods, netting and angling. In only one case, from May 3 to May 27 in the 13.75-15.25 centimeter group, did the mean K factor of trapped fish exceed that of fish taken by angling. These netted fish were captured in hoop net sets of short duration and in one trap net set of 2.5 days. The difference was small and not significant, statistically. There was little opportunity for their condition factor to drop.

When all data are combined for bluegills, irrespective of size or date, then the difference between trapped fish and those taken by angling is highly significant, statistically.

If the mortality which took place was due to oxygen deficiency it seems likely that the fish would have died within a short period. They should not have shown signs of being in the nets a long time. Since the netted fish exhibited such signs as tail wear, abrasions, and a drop in condition factor it seems probable that they had spent at least three days in the trap. The question of whether net mortality was caused by lack of oxygen or length of time in the net is still undecided. It seems apparent that the fish taken in trap net set No. 2 died from a lack of oxygen, but the mortality in other sets probably resulted from a combination of oxygen deficiency, net-caused abrasions, lowered physical vitality, and fungus infections.

MOVEMENT OF FISH

Review of Previous Investigations

Many investigators have performed lake population studies by the mark and recapture system. However, very few have attempted to keep data on horizontal movements of warm water species within the lakes studied. The purpose of most movement studies has been to follow spawning runs or to obtain information on migration and survival of stocked fish. A statistical analysis of these movements has been attempted by even fewer workers. This section of the paper will be devoted to a statistical analysis of horizontal movements of largemouth bass, common bluegills, common sunfish, yellow bullheads, bowfin, yellow perch, and the common sunfish X common bluegill hybrid within Wintergreen Lake.

Ball (1944) divided the shoreline of Third Sister Lake, Michigan into 100 foot sections. All fish tagged in this experiment were released at the point of capture. By this method it was possible to locate the point of capture and release of fish within ten yards. Only fish recaptured fifteen days or more after time of tagging were considered. Area of the lake was approximately ten acres. His results appear below and on the following page.

TABLE VI

SUMMARY OF MOVEMENT OF TAGGED BLUEGILLS IN THIRD SISTER LAKE (BALL, 1944).

Number of fish recaptured	Movement from point of tagging (yards)	Time between tagging and recapture (days)	Percentage of fish recaptured
12	0	15-359	44
4	30	16-343	14.8
2	65	301-404	7.4
4	65-150	37-370	14.8
5	150-plus	20-394	18.5

TABLE VII

SUMMARY OF MOVEMENTS OF BULLHEADS
IN THIRD SISTER LAKE (BALL, 1944)

Number of fish recaptured	Movement from point of tagging (yards)	Time between tagging and recapture (days)	Percentage of fish recaptured
11	0	15-432	39
4	15-30	331-380	14
8	30-100	46-435	28.6
4	100 plus	350-457	14

From these tables it can be seen that about 60 percent of the tagged bluegills were recaptured within 30 yards of the point of original capture. Fifty percent of recaptured bullheads were taken within 30 yards of the point of original tagging and 81 percent within 100 yards. Ball also states that all of the bullheads recaptured more than once were taken at the same location each time, even though intervals between captures were several weeks or months apart. These data seem to indicate a strong territorial tendency of these fish in this small lake.

His information on largemouth bass shows that the 7 individuals recaptured of 56 marked had roved over the entire lake and showed no tendency of having a home range. Four of these fish were retaken more than once, and one was recaptured 4 times. Ball reports that nearly every bullhead and largemouth bass in his nets was gorged with fish. Perhaps the movements of these often recaptured fish were influenced by availability of food in the nets.

Rodeheffer (1941) presented information on movements of northern rock bass, Ambloplites rupestris rupestris (Rafinesque), yellow perch, common sunfish, smallmouth bass, Micropterus dolomieu dolomieu Lacepede, largemouth bass, and northern pike, Esox lucius Linnaeus in Douglas Lake, Michigan. His data were compiled over three summers while he was working on effect of brush shelters in the lake. Over 90 percent of his original captures and recaptures were made by seine in the eastern end of the lake. He released some of his marked fish in unfamiliar territory, but always fairly close to the point of original capture. The great majority of releases occurred at the capture point. He summarized that of all fish marked at several locations and freed in their home territories, none were retaken in distant parts of the lake. He concludes that there was little movement of marked native game fish in the eastern end of Douglas Lake. All brush shelters were at this end of the lake and they may have had an influence in attracting and keeping fish in that sector.

These results are not similar to other investigations. Douglas Lake is a large body of water over 4 miles long. However, this would not seem to limit the wanderings of the fish population. Reference to two of Rodeheffer's previous publications (1939 and 1940) disclose that fish upon which he based his assumptions were over 95 percent young of the year, yearlings, and other fish smaller than those considered in this study. Perhaps the species included in these reports change their territorial habits when they reach maturity. It would be expected that juvenile fish would tend to remain in the location offering the most protection and would not need to forage widely to satisfy their requirements.

Schumacher and Eschmeyer (1942), a statistician and a fisheries biologist, combined their talents in a statistical analysis of movements of largemouth bass, smallmouth bass, and Kentucky bass, *Micropterus punctulatus punctulatus* (Rafinesque), in Norris Reservoir, Tennessee.

Eschmeyer marked and released 662 largemouth bass, 187 smallmouth bass, and 75 Kentucky bass from April 3-May 16, 1940. All captures were by angling along 1 mile of shoreline of Cove Creek, an arm of Norris Reservoir. During the 200 day period following this marking, data were collected from 121 recaptured largemouth bass, 27 smallmouth bass, and 30 Kentucky bass. Summarization of the movements are best explained in the authors' words.

> ".....smallmouth bass travel much less than either largemouth or Kentucky, 90 percent of the smallmouth having been distributed within a distance of two miles from the point of tagging by the 15th day, within 3 miles by the 40th day, and within 3.3 miles by the end of the fishing season. Largemouth bass traveled farthest and most steadily, 90 percent of them having spread over a distance of 4.7 miles by the 15th day, 10.5 miles by the 40th day and 16 miles by the end of the season. The 'spread' of Kentucky bass was, by the end of the season, intermediate between that of the largemouth and smallmouth, 90 percent having spread within a distance of 7.6 miles from the point of tagging."

Manges (1950) presents further results of similar experiments conducted in Norris Reservoir and Cherokee Reservoir from 1946-1949. In Norris Reservoir the average distances, measured in a straight line between points of capture and recapture, covered by 29 largemouth bass for the years 1947, 1948, and 1949 was 4.3 miles; by 11 smallmouth bass was 2.2 miles; and by 5 Kentucky bass in 1949 was 5.8 miles. If Eschmeyer's averages are included, all distances are lowered slightly. The combined results yield the following average distances travelled: 150 largemouth bass, 4.0 miles; 38 smallmouth bass, 1.2; 35 Kentucky bass, 3.6.

Only one second-season recapture was made for these three species and it is not included in the results. Manges' investigations on Cherokee Reservoir for 1947 and 1949 show 11 largemouth bass moved an average of 4.7 miles.

These results on movement of bass are not applicable to any research reported in this paper because the bodies of water are not comparable. Norris Reservoir has a shoreline of over 700 miles while Wintergreen Lake has a total area of 40 acres. It is interesting to note that previous investigations have indicated that largemouth bass exhibit very little territorial tendency and are inclined to be wanderers. Results of study on Wintergreen Lake do not seem to bear this out.

Dr. Gerald P. Cooper in Report No. 1298 of the Michigan Institute for Fisheries Research, in press for Transactions of the American Fisheries Society, Volume 81, 1951, presents data on movement and population in two Michigan lakes. It is with his permission that information presented below is reviewed.

Sugarloaf Lake has a surface area of 180 acres. The lake is uniformly shallow, between 2 and 5 feet deep, with a very small area over 10 feet deep and a maximum depth of 21 feet.

An imaginary line dividing the lake on a north-south axis was established. Similar trap netting patterns were operated in each half. General procedure was to fish several nets on a systematic schedule at numerous stations for four to six weeks. All captured fish were recorded and marked with a regional fin-clip. A single central release station was located over the deepest part of the lake.

There were three netting periods on Sugarloaf Lake: 1948, October

20-November 24; 1949, April 20-May 22; and 1950, April 18-June 1. Over the three periods 12,246 fish were marked. Cooper found homing tendency of the fish to be consistent for both halves of the lake. Fish marked in the west half tended to return to the west half and fish marked in the east half tended to return to the east half in two of the three periods, but in 1948 fish marked in both halves tended to be recaptured in the east half. There were 498 more fish recaptured in their home half than in the opposite half.

For purposes of comparison, these results have been broken down in Table VIII to include only species studied in Wintergreen Lake. All data are totals for three years of study.

TABLE VIII

ANALYSIS OF RECAPTURES OF MARKED FISH IN SUGARLOAF LAKE

Species	Number recaptured	Same half	Opposite half	Preponderance of homing fish
Largemouth bass	54	39	15	24
Common bluegill	1015	603	412	191
Common sunfish	95	79	16	63
Yellow perch	15	7	8	-1
Yellow and brown bullhead	801	442	359	83
Bowfin	83	57	26	31

Dr. Cooper states that the combined preponderance of 18 percent seems inconsequential as a source of bias in his population estimates. He feels that the preponderance may have been only partly an expression of homing to the original netting site and that the extensive netting pattern would compensate for it. He concludes that, ".....Most of the fish redistributed themselves over the lake generally and did not return quickly to a home niche."

Table IX, a Chi^2 test as outlined by Simpson and Roe (1939), which measures differences between theoretical and observed frequencies of occurrence, suggests that Cooper's data indicate that all species listed, with the exception of yellow perch, did not distribute themselves randomly over the lake when released from a central location. The tests shows that there is less than 1 chance in 100 that distribution from the central release station was random. The homing tendency seems well defined as illustrated by Table IX, presented on page 40.

Five hundred and seventy-five acre Fife Lake was the second lake included in Dr. Cooper's report. The lake was divided in half by imaginary lines on a northeast-southwest axis and each half was trap netted with a similar systematic pattern from June 16 to July 19, 1950. Two release stations were established, one in the center of each lake half. Odd and even-numbered netting stations were evenly distributed in the netting pattern. Captured fish were given a mark (fin-clip) distinctive for their half of the lake and for either the odd or even-numbered trap net station where they were caught. All fish were returned to the lake at the release station in their home half. Of 5,641 fish marked in the lake, 309 were recaptured.

Dr. Cooper considers that data for Fife Lake support two conclusions.

(1) Recaptured fish did not show a predominant tendency to be recaptured at their home net site, either odd or even numbered.

TABLE IX

CHI^2 TEST OF REDISTRIBUTION OF MARKED FISH IN SUGARLOAF LAKE

Hypothesis: Redistribution of fish is random from central release.

Species	Recaptured in home half	Recaptured in opposite half	Total recaptures	Observed Chi^2
Largemouth bass	27 / 39	27 / 15	54	10.66**
Common bluegill	507.5 / 603	507.5 / 412	1015	35.94**
Common sunfish	47.5 / 79	47.5 / 16	95	41.78**
Yellow perch	7.5 / 7	7.5 / 8	15	.06
Yellow bullhead and Brown bullhead	400.5 / 442	400.5 / 359	801	8.60**
Bowfin	41.5 / 57	41.5 / 26	83	11.58**
All species[1]	1341 / 1590	1341 / 1092	2682	92.47**

** Significant at the 99 percent level of confidence.
1 Includes other species not shown above.

(2) Fish were recaptured approximately twice as frequently in the same half of the lake where they were originally captured as in the opposite half. Since two release stations were utilized, this preponderance was expected.

He measured average distances in hundredths of a mile between release stations and odd and even-numbered stations in each half and multiplied them by the corresponding figures for percentage of recapture of all species in each type of net set, i.e., east-even, west-odd, etc. This resulted in a migration index he could compare statistically. He concludes that the tendency for fish to be recaptured more frequently in their home half was mostly a function of distance from release station to the recapture netting site, rather than homing instinct.

Wintergreen Lake Results

Methods of marking fish in Wintergreen Lake are outlined in the section on Marking Procedure. Movements of the species will be taken up separately.

Explanation of movement diagrams

The labels of the 4 quarters of the charts correspond to quarters of the lake. Fish captured in any of the regions were marked by clipping the appropriate fin. Numbers appearing outside the quarter, above or below the regional label, indicate the number of markings reobserved from that region. Squares inside the quarters show the number of regional cuts reobserved in their respective home region. For example, in Figure 3a there were 48 RP regional marks reobserved. Of these, 26 were reobserved in their home territory, 6 moved to the LP Region, 7 to the LV Region, and 9 moved to the RV Region. Since there were unequal numbers of recaptures from the various regions, these discrete numbers offer little basis for comparison between the regions.

To enable a comparison to be made, percentages were utilized in the following figures whose numbers are followed by a "b". This permits easier evaluation of movement patterns. For instance, Figure 3b shows that of the 48 RP regional marks reobserved, 54 percent were taken in the same region where they were originally marked, 12.5 percent moved to the LP Region, 15 percent moved to the LV Region, and 19 percent to the RV Region.

The number of marks does not necessarily correspond to the number of fish marked, for some carried two or three marks. If a fish with right ventral and right pectoral fins removed was recaptured in the LP Region, the data were tabulated with two observations; one reading that the fish had been originally marked in the RV Region and had moved to the LP Region, and the second reading that original marking had taken place in the RP Region and movement had been to the LP Region. When a fish bearing both angling and netting marks was recaptured, movement was recorded both for net and angling marked fish. With this methodology in mind, the following charts and tables are presented.

Largemouth bass

More data on migration of this species were collected than for any other. There were 1,101 regional marks made from April through August on released bass. Of these, 317 were made in the RP Region, 197 in the LP, 224 in the RV, and 363 marks were made in the LV Region. Most of these represent angling caught fish, the divisions being 310 caught by angling and 13 by net in the RP Region, 186 and 11 in the LP, 211 and 13 in the RV, and 339 caught by angling and 24 by net in the LV Region.

During the period of early spring angling, most largemouth bass were captured in shoal areas of the RV and LV Regions. After the lake was stratified thermally, greatest angling success was realized in the drop-off area of the RP and LP Regions. This unequal distribution was presumed to enter some bias on results of the Chi^2 test in Table X. To offset this supposed influence, data were split into two periods, April and May, and June, July, and August. Results were surprisingly similar for the two periods, as shown by succeeding tables and figures.

A Chi^2 test, following the same procedure and hypothesis presented in Table X, was applied to data of Figures 4a and 5a. The sum of the Chi squares for 4a was 35.94 and 30.45 for 5a, both highly significant at the 99 percent level of confidence. Thus the hypothesis of complete independence in redistribution is not acceptable. This is expected, for fish were released at the point of capture.

As was the case in Table X, the number of recaptures taken in their home quarters contributed the largest sums to the Chi^2 total. In Figure 4a the RV X RV cell was responsible for 18.47. The other three home

Figure 3a. Actual numbers indicating where regional marks were reobserved. Largemouth bass originally caught by angling, Wintergreen Lake, April - August, 1951.

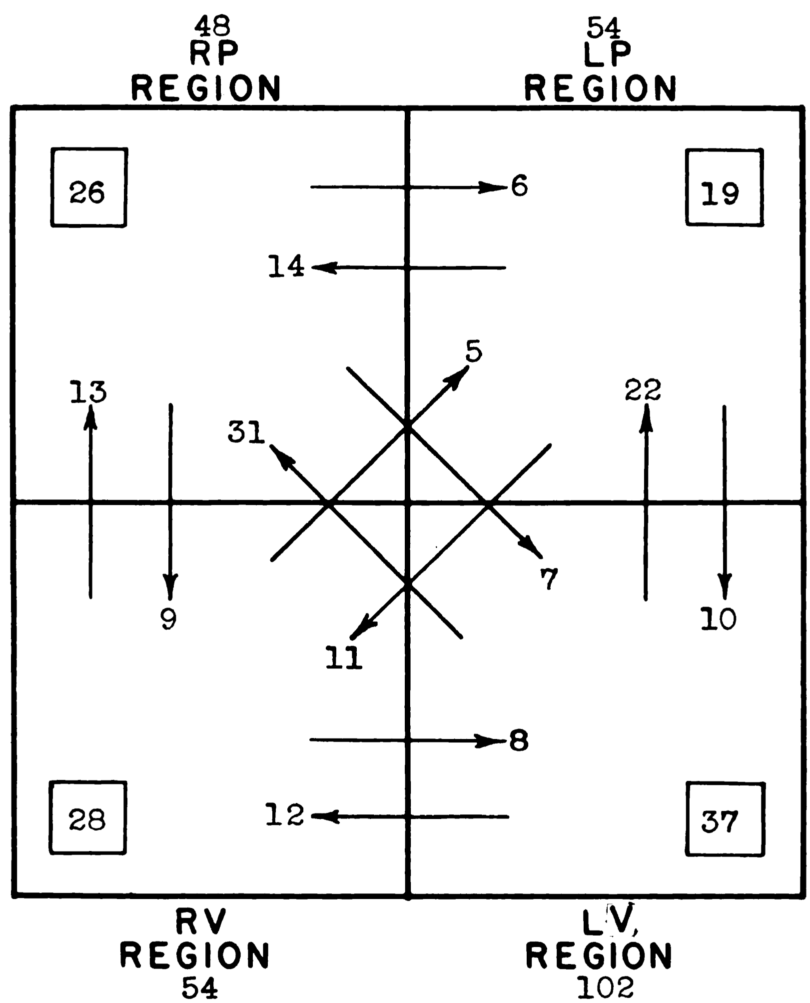

48
RP
REGION
54
LP
REGION
26
19
6
14
5
13
22
31
7
9
10
11
8
12
28
37
RV
REGION
54
LV
REGION
102

Figure 3b. Percentages indicating where regional marks were reobserved. Largemouth bass originally caught by angling, Wintergreen Lake, April - August 1951.

These percentages were derived by multiplying the reciprocal of the actual numbers of reobserved regional marks by the actual numbers indicating movement. This results in percentages that may be compared between regions. The hypothesis necessary to make this supposition is that 100 fish originally captured by angling were recaptured from each region.

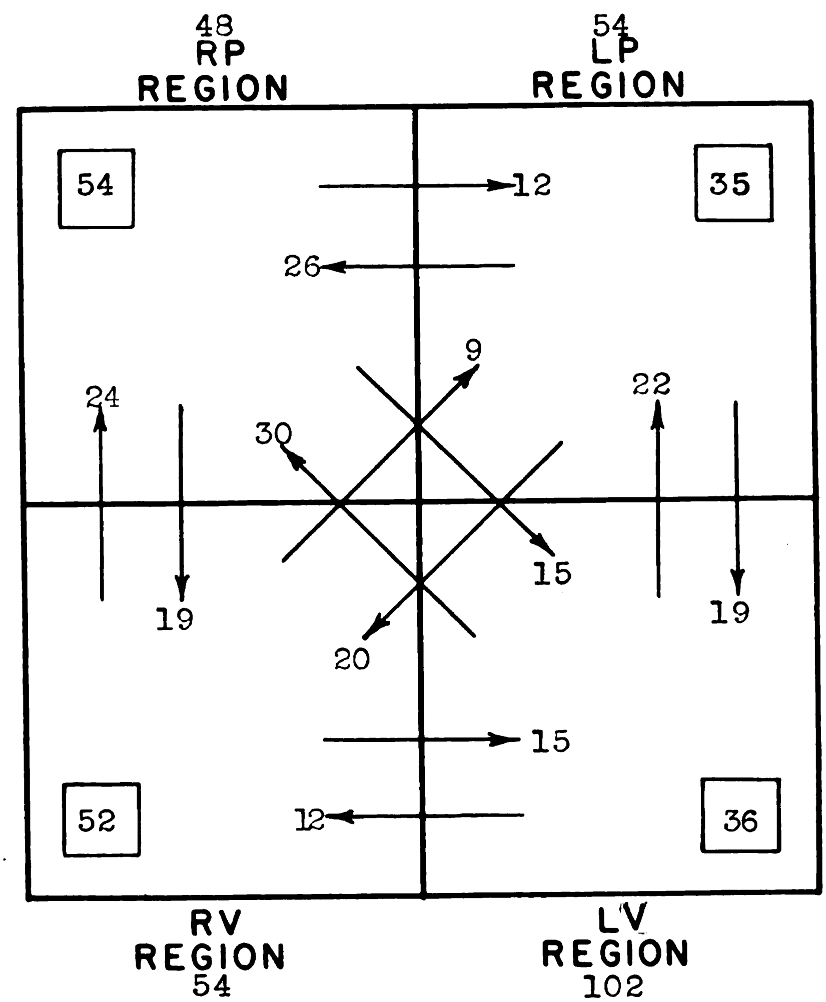

48
RP
REGION
54
LP
REGION
54
12
35
26
9
24
22
30
15
19
19
20
15
52
12
36
RV
REGION
54
LV
REGION
102

TABLE X

CHI^2 TEST FOR INDEPENDENT REDISTRIBUTION OF REGIONAL MARKINGS ON LARGEMOUTH BASS CAUGHT BY ANGLING, APRIL-AUGUST, 1951

Hypothesis: Fish captured by angling and released in their home territory redistributed themselves over the lake with complete independence.

Region Where Recaptured

Region Where Marked	RP	LP	RV	LV	SUM
RP	15.6 / 26	9.7 / 6	11.2 / 9	11.5 / 7	48
LP	17.6 / 14	10.9 / 19	12.6 / 11	13.0 / 10	54
RV	17.6 / 13	10.9 / 5	12.6 / 28	13.0 / 8	54
LV	33.2 / 31	20.6 / 22	23.7 / 12	24.5 / 37	102
SUM	84	52	60	62	258

Theoretical frequencies are entered in the upper left corners of the cells. Observed frequencies are entered in the lower right corners. Method from Simpson and Roe (1939).

Sum of the Chi squares is 55.72. Table value of Chi^2 with 9 degrees of freedom is 21.67 with a 99 percent confidence limit. This table indicates that the bass did not distribute themselves randomly and independently after release in their home region. The hypothesis is rejected.

The sum of the 4 Chi squares for the home regions is 38.15, or an average of 9.54. Average of the other cells is 1.46. This suggests that the territorial tendency was responsible for the large deviation from the expected.

Figure 4a. Actual numbers indicating where regional marks were reobserved. Largemouth bass originally captured by angling, Wintergreen Lake, April and May, 1951.

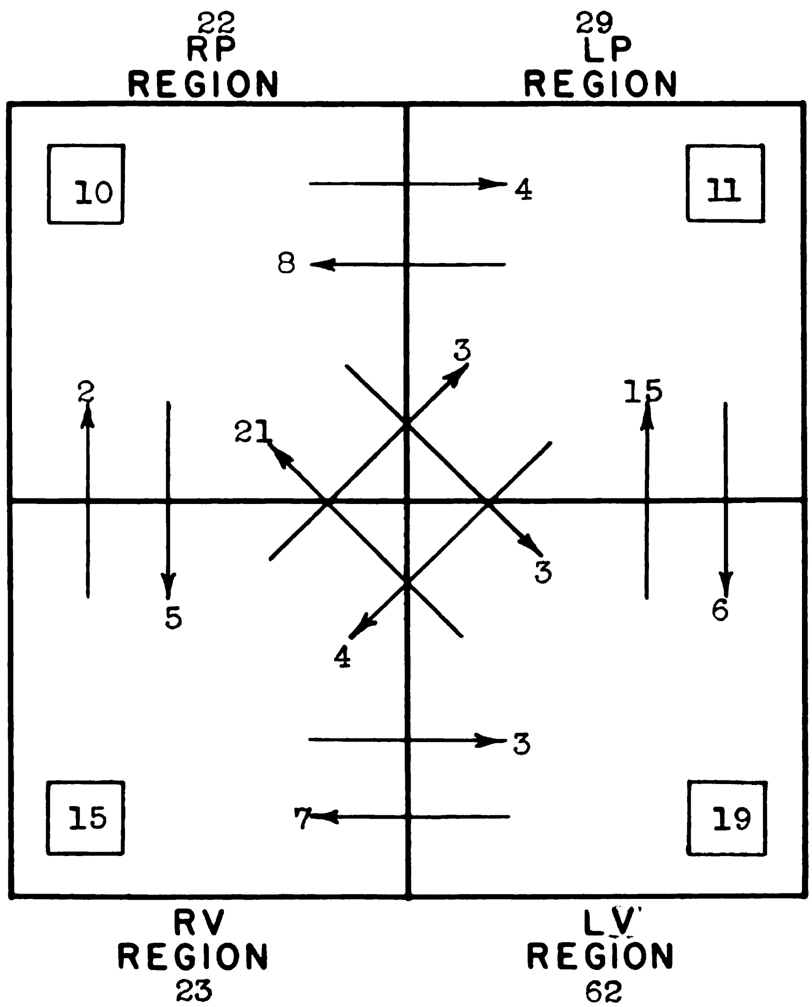

22
RP
REGION
29
LP
REGION
10
11
4
8
3
2
15
21
3
5
6
4
3
15
7
19
RV
REGION
23
LV
REGION
62

Figure 4b. Percentages indicating where regional marks were reobserved. Largemouth bass originally captured by angling, Wintergreen Lake, April and May, 1951.

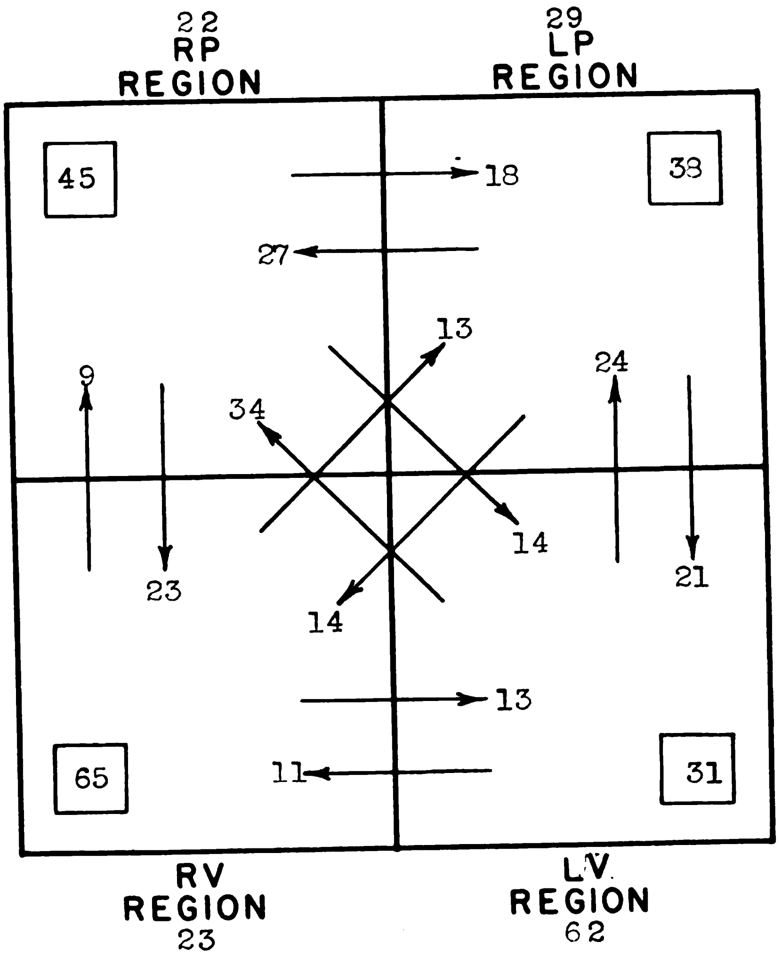

22
RP
REGION
29
LP
REGION
45
38
18
27
13
9
34
24
14
21
23
14
13
65
11
31
RV
REGION
23
LV
REGION
62

Figure 5a. Actual numbers indicating where regional marks were reobserved. Largemouth bass originally captured by angling, Wintergreen Lake, June, July, and August, 1951.

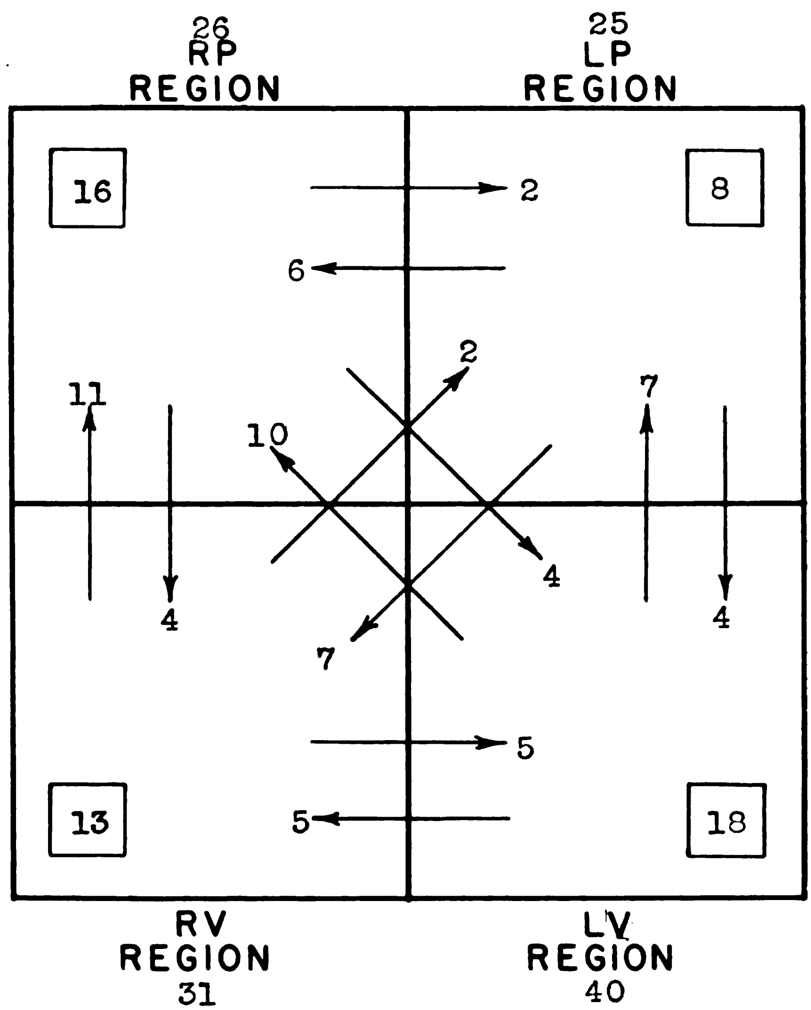
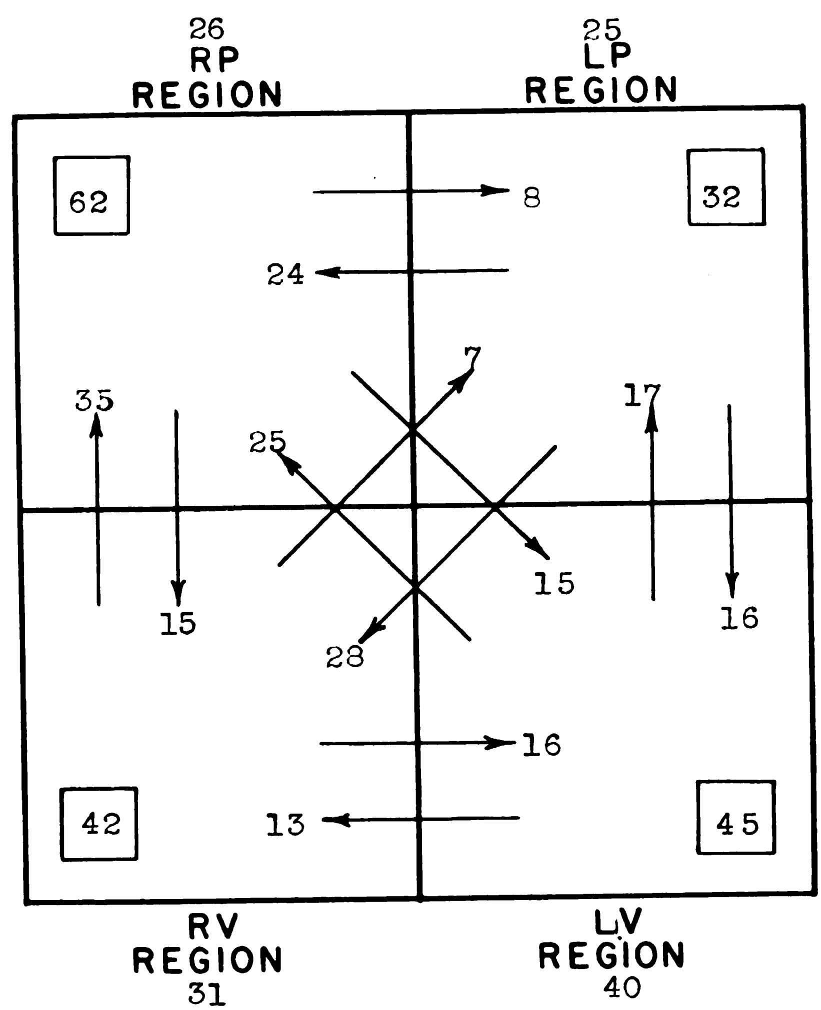

26
RP
REGION
25
LP
REGION
16
8
2
6
2
11
10
7
4
4
4
7
5
5
13
18
RV
REGION
31
LV
REGION
40

Figure 5b. Percentages indicating where regional marks were reobserved. Largemouth bass originally captured by angling, Wintergreen Lake, June, July, and August, 1951.


26
RP
REGION
25
LP
REGION
62
32
8
24
7
35
17
25
15
15
16
28
16
42
13
45
RV
REGION
31
LV
REGION
40

cells averaged 1.91, while all other cells averaged 0.90 per contribution. Data from Figure 5a were in general agreement with that from 4a, except that the RV X RV cell decreased its contribution to a normal level for the home cells, whose average was 4.89. All other cells averaged 0.91.

The preceding information seems to support two conclusions to be drawn from the spring and summer experiment period.

(1) More largemouth bass in Wintergreen Lake were recaptured in regions other than the quarter of their original marking than were recaptured in their home quarter, indicating that some individuals tended to utilize the whole area of the lake. However, a proportionally large percentage of fish were recaptured in their home region. One hundred and ten of 258 regional marks on fish released in their home quarter were reobserved in that same region. This is a percentage of 42.6.

This suggests that many of the largemouth bass have a territorial tendency. Apparently there are at least two behavior patterns present in the species, those that wander and those that prefer to remain in a home niche.

(2) A general trend to move to the drop-off area on the windswept, spring-fed shore also seems evident. After eliminating the numbers of regional markings reobserved in their home quarters, 39.2 percent of the remaining 148 regional markings were found in the RP Region, as opposed to 22.3 percent in the LP, 21.6 in the RV, and 16.9 in the LV Region. The above figures are probably affected by the unequal numbers of recaptures made in each of the four areas.

In order to minimize some of the bias, the hypothesis of reobserving 100 marked fish from each region will be injected again. Proceding under this supposition, the 177 regional markings reobserved in their home quarter are eliminated. This leaves 223 wanderers. Eighty (35.9 percent) of them were reobserved in the RP Region, as opposed to 51 (22.8 percent) in the RV Region, 49 (22.0 percent) in the LV Region, and 43 (19.3 percent) in the LP Region.

There were only 90 largemouth bass taken by trap netting throughout the experiment. Of these, 72 were released at the central release station, bearing a mark for net caught fish. Seven of these were recaptured. This small number is not adequate to draw any conclusions concerning movement or to make any comparisons between the two methods of release for the species. Such information as was gained is presented in Figure 6.

Common bluegills

There were 31 regional marks reobserved on bluegills. Of these, 22 were originally captured by netting and 9 by angling. These numbers are inadequate for drawing any definite conclusions. One general tendency seems common to bluegills released at the central station and in their home territory. They appear to distribute themselves around the lake without showing the predominant homing tendency illustrated by the bass. Perhaps it is mere coincidence because of the small sample, but the hypothesis of random distribution of marked fish released from both station types is statistically acceptable, as illustrated in Table XI. Data are drawn from Figures 7 and 8.

Figure 6. Actual numbers indicating where regional marks were reobserved. Largemouth bass originally captured by netting, Wintergreen Lake, May - August, 1951.

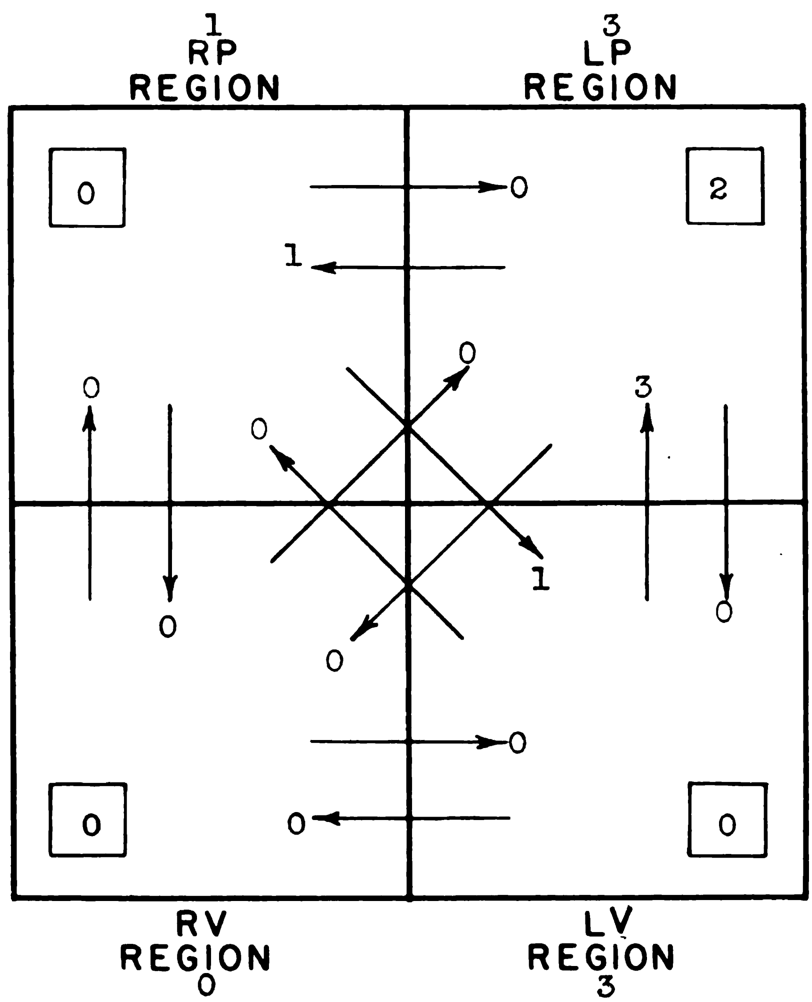

1
RP
REGION
3
LP
REGION
0
2
0
1
0
0
0
3
0
1
0
0
0
0
0
0
0
RV
REGION
0
LV
REGION
3

TABLE XI

CHI^2 CONTINGENCY TEST FOR INDEPENDENT REDISTRIBUTION OF MARKED FISH. COMMON BLUEGILLS CAUGHT BY ANGLING AND NETTING, APRIL - AUGUST, 1951, WINTERGREEN LAKE.

Hypothesis: Released fish distributed themselves over the lake with complete independence.

Method of capture	Type of release	Recaptured: Home quarter	Recaptured: Other quarter	Chi^2 value
Netting	Central	5.5 / 7	16.5 / 15	.55
Angling	Regional	2.25 / 2	6.75 / 7	.04

Both samples fall well within the 95 percent level of confidence, and therefore the hypothesis of distribution of fish with complete independence is acceptable.

Yellow bullheads

Forty-five regional marks were reobserved on bullheads. All of these were originally captured by netting and therefore were released at the central release station. There were no bullheads caught by angling that were marked and released. An examination of Figures 9a and 9b indicates that the LV Region seems to be most attractive to bullheads. Eleven marks from other areas were reobserved there. Apparently this observation is not too extraordinary, for a Chi^2 contingency test patterned after Table XI gives a Chi^2 value of 0.36, which allows acceptance of the hypothesis of complete independence in redistribution. Homing tend-

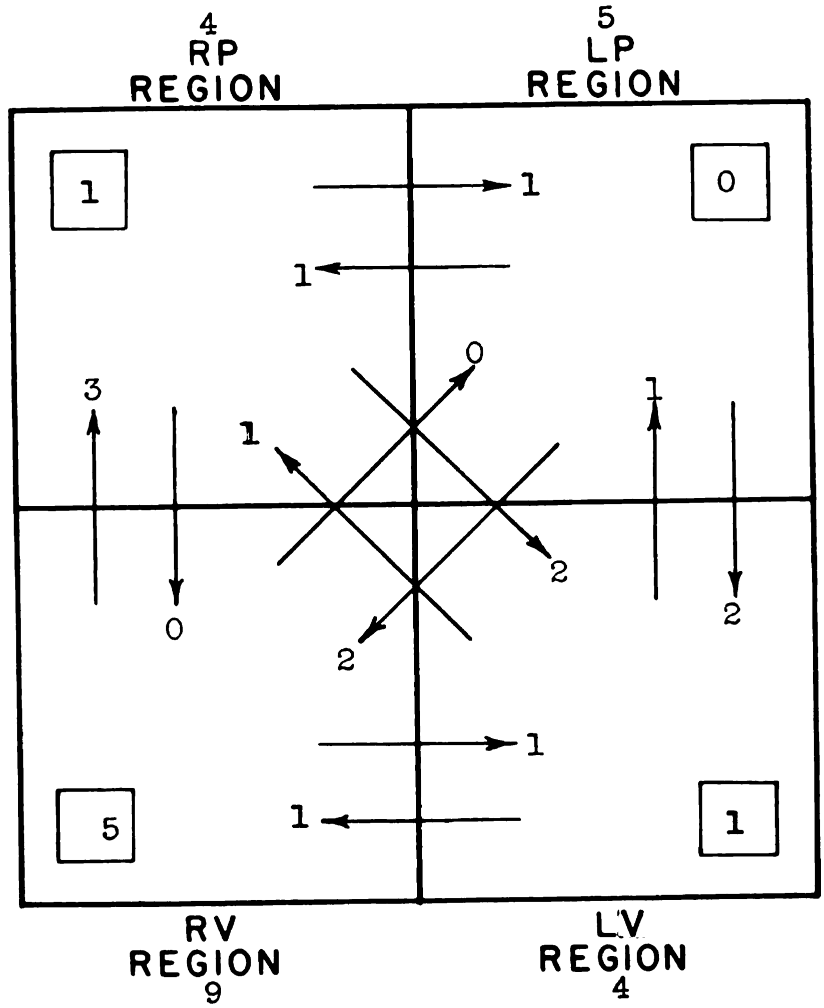
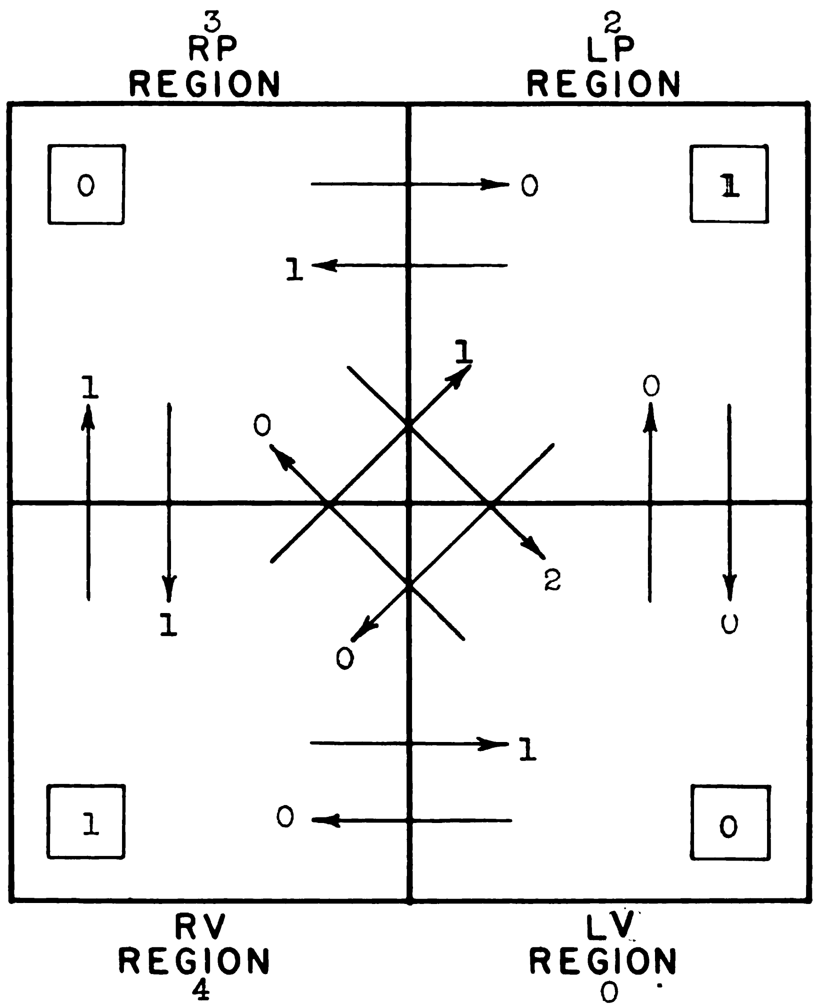

4
RP
REGION
5
LP
REGION
1
0
1
1
3
0
1
1
1
2
2
0
2
2
1
1
5
1
RV
REGION
9
LV
REGION
4

Figure 8. Actual numbers indicating where regional marks were reobserved. Common bluegills originally captured by angling, Wintergreen Lake, April - August, 1951.


3
RP
REGION
2
LP
REGION
0
1
0
1
1
1
0
0
1
0
2
1
0
0
1
0
1
0
RV
REGION
4
LV
REGION
0

ency does not seem prominent for this fish under conditions in this lake.

There were 119 regional marks made and released, of which 45 were reobserved. Besides indicating a low population for this species, this information suggests a high susceptibility to trap netting. Bullheads appeared to be wanderers in the lake. If the fish would ordinarily be a wanderer is not known. Perhaps abnormal behavior was induced by removal from the home niche.

Miscellaneous

The remaining four species were not recaptured in sufficient numbers to indicate any definite movement patterns. The only conclusion that may be stated is that these four species, common sunfish, common sunfish X common bluegill hybrid, yellow perch, and bowfin, tended to roam over the entire lake without exhibiting a homing tendency. In most cases there were more recaptures reported than appear in the following diagrams, but information as to location of capture and regional mark is unknown; therefore, the data are useless to the movement study.

Data on movements of yellow perch and bowfin may be summarized without the use of charts. There were only 2 yellow perch recaptured with a known regional mark. One fish captured by netting in the LP Region was recaptured in the LV Region. One captured by angling in the LP Region was recaptured in the RP Region.

Five regional marks on bowfin were reobserved. Three fish originally netted in the LV Region were recaptured in the following regions, one each in the LP, RP, and RV Regions. One fish netted in the LP

Figure 9a. Actual numbers indicating where regional marks were reobserved. Yellow bullheads originally captured by netting, Wintergreen Lake, April - August, 1951.

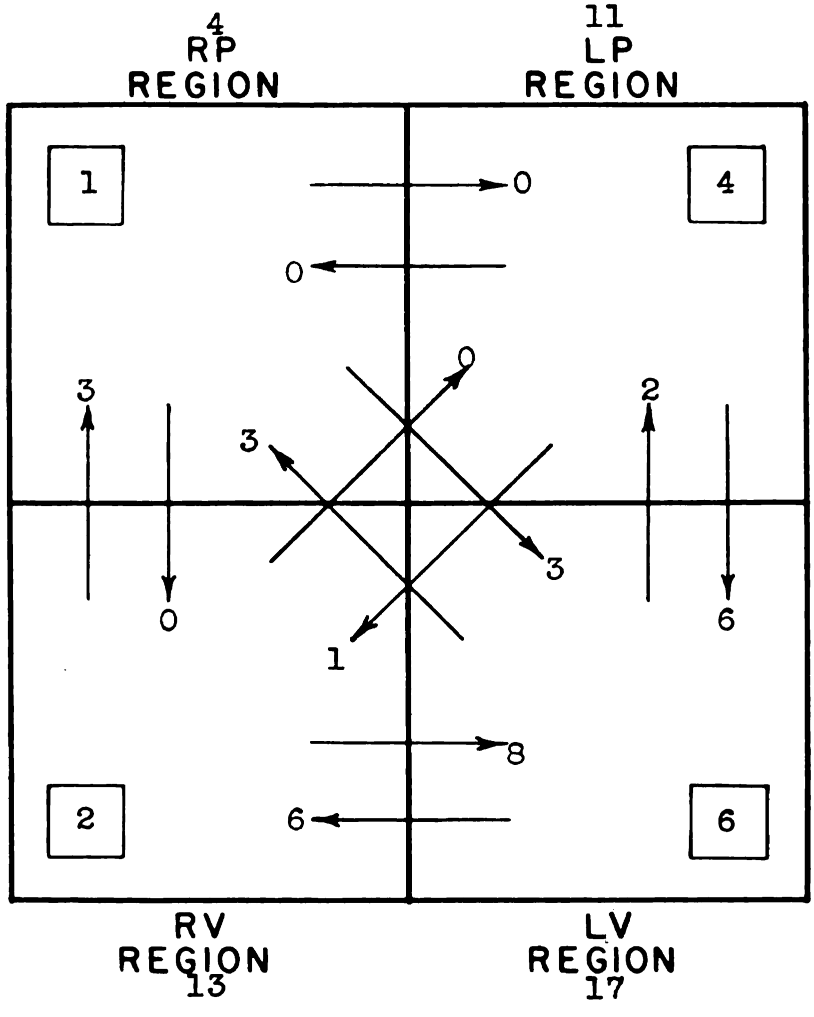
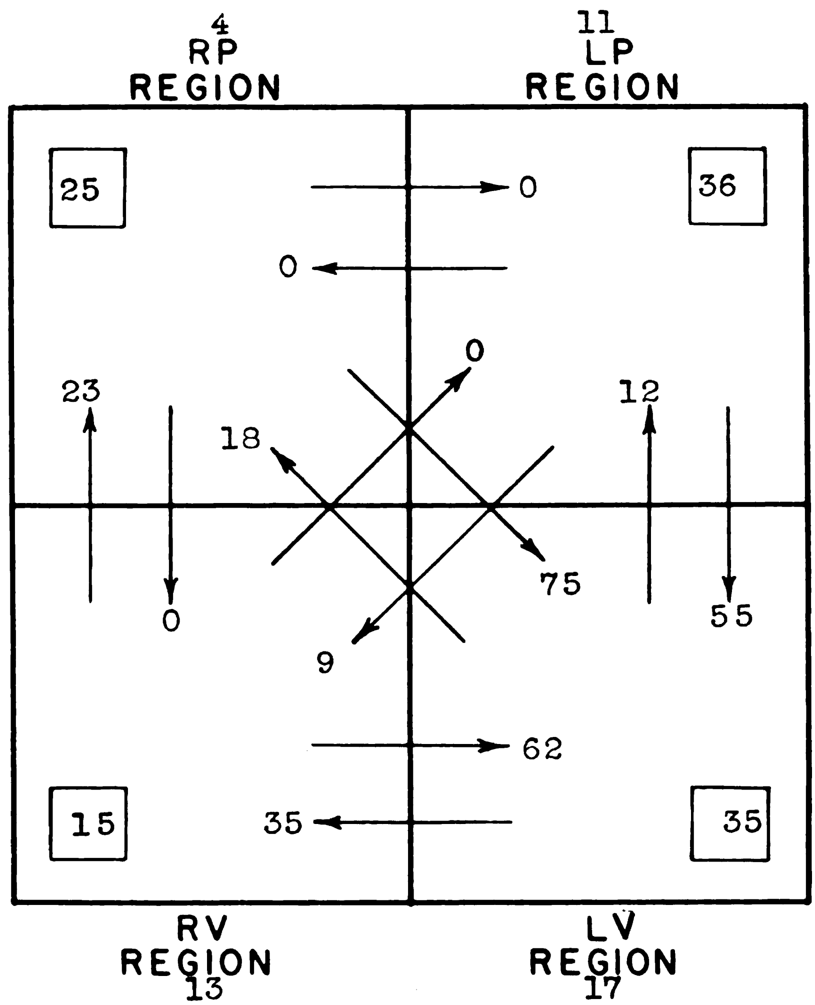

4
RP
REGION
11
LP
REGION
1
4
0
0
0
3
3
2
3
3
0
1
6
8
2
6
6
RV
REGION
13
LV
REGION
17

Figure 95. Percentages indicating where regional marks were reobserved. Yellow bullheads originally captured by netting, Wintergreen Lake, April - August, 1951.


4
RP
REGION
11
LP
REGION
25
36
0
0
0
23
12
18
75
0
55
9
62
15
35
35
RV
REGION
13
LV
REGION
17

Region was reobserved in the RP Region and one bowfin originally captured by angling in the LP Region was recaptured in the RP Region.

In Figures 10 and 11 fish captured by angling and netting are combined. The two are symbolized by an "a" for angling and a "n" for netting.

Comparison of Movements of Fish in Sugarloaf, Fife, and Wintergreen Lakes

Tables XII-XVIII present data comparing Cooper's results from Sugarloaf and Fife Lakes with results of this experiment on Wintergreen Lake. The two sets of data that lend themselves best to comparison are from Sugarloaf and Wintergreen Lakes. Fish in these lakes were captured by trap netting and were released at a central station. Although Wintergreen Lake was divided into quarters by imaginary lines, it was simple to convert movement data to conform with the method employed on Sugarloaf Lake, halving the lake. The quarter system yielded two separate results, for there were two pairs of halves from which to take data, the northeast and southwest and the northwest and southeast. Each pair of halves were compared with Sugarloaf Lake results. Statistical analysis indicated that fish redistributed themselves from the central release station in each lake in a similar manner with respect to which half of the lake they swam to, their home half or opposite half. The hypothesis that samples as divergent as these could have been drawn from the same population is accepted. See Tables XIII and XIV.

Table XV utilizes a formula presented by Snedecor (1950) for derivation of Chi^2 in a fourfold table. The same test may be set up for

Figure 10. Actual numbers indicating where regional marks were reobserved. Common sunfish, Wintergreen Lake, May - August, 1951.

Those originally captured by angling are indicated by "a", those originally captured by netting are indicated by "n".

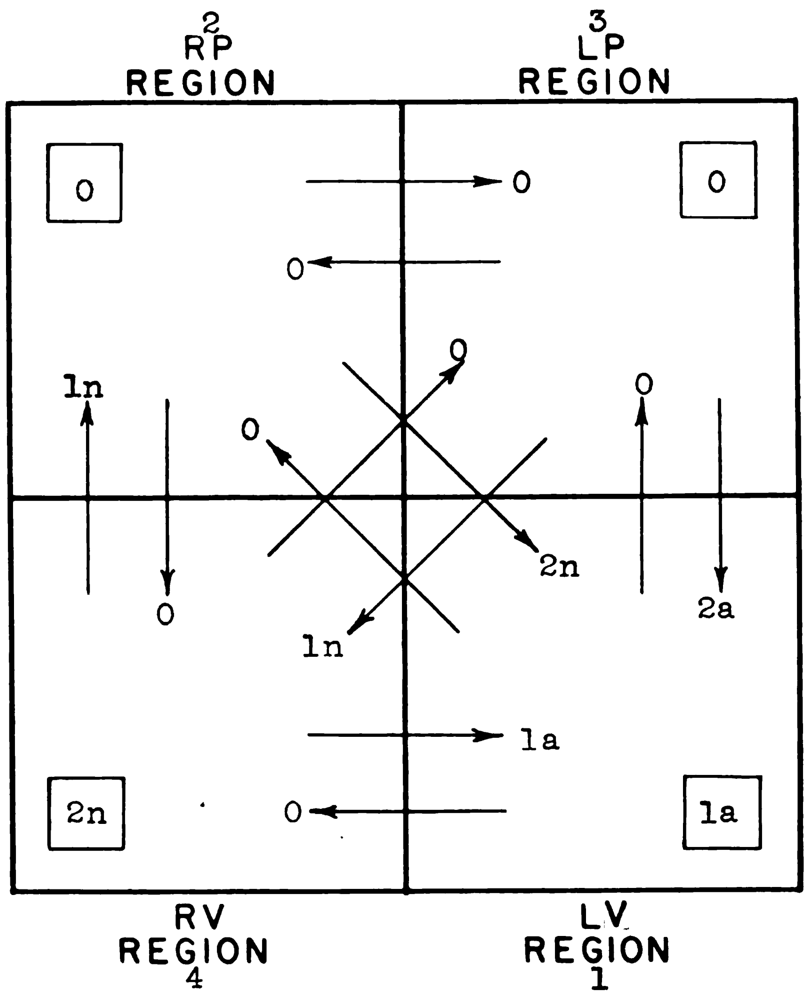
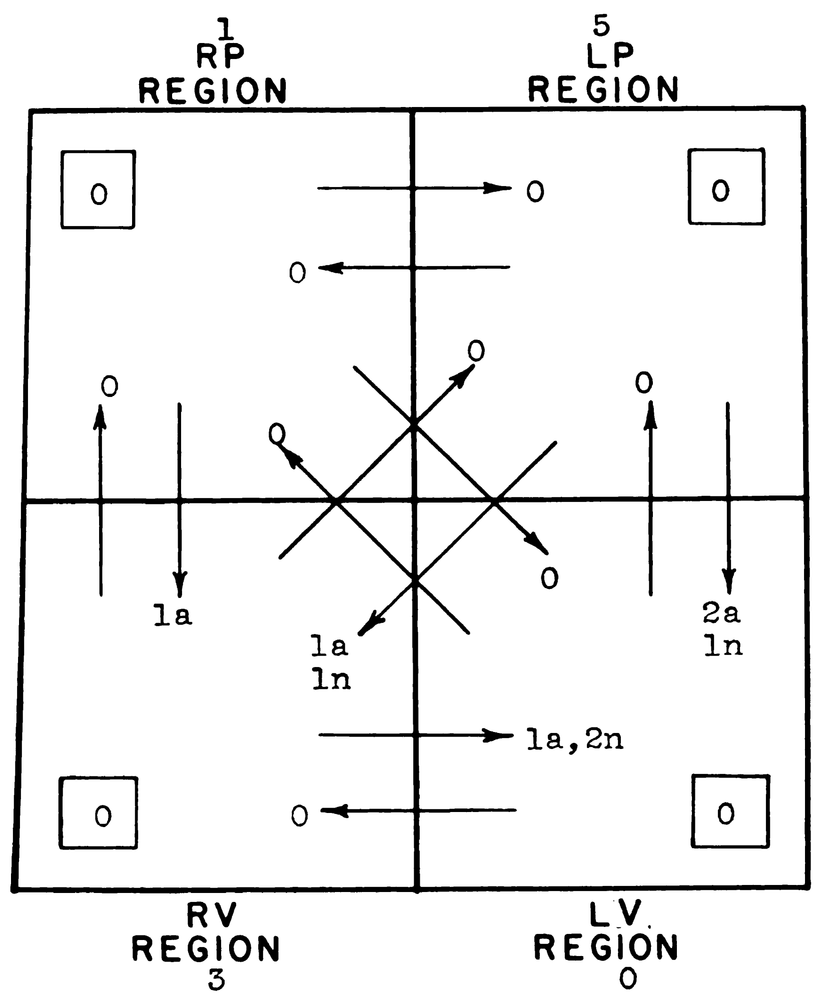

2
RP
REGION
3
LP
REGION
0
0
0
0
0
1n
0
0
2n
0
2a
0
1n
1a
2n
0
1a
RV
REGION
4
LV
REGION
1

Figure 11. Actual numbers indicating where regional marks were reobserved. Common sunfish X common bluegill hybrid, Wintergreen Lake, May - August, 1951.

Those originally captured by angling are indicated by "a", those originally captured by netting are indicated by "n".


1
RP
REGION
5
LP
REGION
0
0
0
0
0
0
0
0
0
1a
1a
1n
0
2a
1n
1a,2n
0
0
0
RV
REGION
3
LV
REGION
0

further comparisons of homing tendencies. The hypothesis of homogeneity presented on page 71 may be accepted when Chi^2 is lower than the table value of 6.63. Results of this test are condensed in Table XIV.

Table XVI, 3 Chi^2 contingency tests of whether redistribution of fish from a central release station is random in Sugarloaf Lake and in Wintergreen Lake, offers results that superficially contradict the indications of Test a and b of Table XIV. In Table XIV, Tests a and b, the data from both Wintergreen and Sugarloaf Lakes are compared and support the hypothesis of similar trends of redistribution. In Table XVI results of redistribution in each of the lakes are compared. These data from Sugarloaf Lake suggest that there is a significant homing tendency displayed by the fish. Statistical analysis of data from Wintergreen Lake is not in agreement with this. The numbers show a preponderance towards a homing tendency, but the sample is not large enough to be significant at the desired level of confidence. When information from both lakes is combined, as in Table XIV, the large number of samples from Sugarloaf Lake is only slightly affected by the small number of samples from Wintergreen Lake.

Fife and Wintergreen Lakes yielded data that could be treated in the same way, although all fish liberated in their home halves in Fife Lake were captured by trap netting, whereas all fish released in their home halves in Wintergreen Lake were caught by angling. Comparisons were not as closely associated as those between Sugarloaf and Wintergreen Lakes. Table XV suggests that the homing tendency of fish in these two lakes varied so much that the fish could not have been drawn from the same population. Perhaps this difference in results was accentuated by different methods of capture or differences in size of lakes; consequently no conclusions may be drawn from the tests. In Table XVII Chi^2 values for the hypothesis of complete independence in redistribution of fish throughout the lake when released in their home halves are significant at the 95 percent level of confidence in all three comparisons. The hypothesis is rejected and homing tendency is illustrated.

The higher percentage (75.7) of homing fish in Fife Lake is to be expected when compared with percentages of homing fish in Wintergreen Lake (57.2 and 62.6). Fife Lake is much larger than Wintergreen (575 acres to 40 acres) and a fish in Fife Lake would have to move a much longer distance to be recaptured in the opposite half. This statement is supported by Cooper's conclusion that the tendency for fish to be recaptured more frequently in their home half was mostly a function of distance from release station to recapture netting site, rather than homing instinct. The figures illustrating movements of Wintergreen Lake fish suggest that in this small circular lake the fish wandered freely about and that their recapture in the home half was not a result of proximity of netting site to release point.

TABLE XII

ANALYSIS OF RECAPTURES OF FISH RELEASED AT THE CENTRAL STATION IN SUGARLOAF AND WINTERGREEN LAKES ACCORDING TO WHETHER RECOVERY WAS IN THE SAME (S) OR OPPOSITE (O) HALF AS WHERE ORIGINALLY MARKED

Species	Lake	Half of lake where marked	Recovery S	Recovery O	Totals S	Totals O
Common bluegill	Sugarloaf	West	280	211		
		East	323	201	603	412
	Wintergreen	NE	3	6		
		SW	8	5	11	11
		NW	9	4		
		SE	4	5	13	9
Common sunfish	Sugarloaf	West	35	5		
		East	46	11	79	16
	Wintergreen	NE	0	3		
		SW	2	1	2	4
		NW	3	2		
		SE	0	1	3	3
Common sunfish X	Wintergreen	NE	0	2		
Common bluegill		SW	2	0	2	2
		NW	0	2		
		SE	1	1	1	3
Largemouth bass	Sugarloaf	West	24	4		
		East	15	11	39	15
	Wintergreen	NE	3	1		
		SW	0	3	3	4
		NW	0	1		
		SE	5	1	5	2
Yellow perch	Sugarloaf	West	2	4		
		East	5	4	7	8
	Wintergreen	NE	0	1		
		SW	0	0	0	1
		NW	0	0		
		SE	1	0	1	0
Bullhead	Sugarloaf	West	292	186		
		East	150	173	442	359
	Wintergreen	NE	5	10		
		SW	22	8	27	18
		NW	6	11		
		SE	18	10	24	21
Bowfin	Sugarloaf	West	30	16		
		East	27	10	57	26
	Wintergreen	NE	1	0		
		SW	1	2	2	2
		NW	1	2		
		SE	0	1	1	3
All species[1]	Sugarloaf	West	661	426	59.5% homing fish	
		East	566	410	1227	836
	Wintergreen	NE	12	23	52.8% homing fish	
		SW	35	19	47	42
		NW	19	22	53.9% homing fish	
		SE	29	19	48	41

[1] All species studied in Sugarloaf Lake are not included.

TABLE XIII

CHI^2 HOMOGENEITY TEST OF REDISTRIBUTION OF MARKED FISH FROM SUGARLOAF AND WINTERGREEN LAKES

Hypothesis: Proportional redistribution of fish took place in a similar manner in each lake.

Lake	Recovery S	Recovery O	Sums	Percent of homing fish
Wintergreen, divided into NE and SW halves	47	42	89	52.8
Sugarloaf	1227	836	2063	59.5
Sums	1274	878	2152	59.2

This test was utilized in a similar fashion for other comparisons. Results of the above test and others are presented on page 80.

TABLE XIV

COMPARISON OF REDISTRIBUTION OF FISH IN SUGARLOAF, FIFE, AND WINTERGREEN LAKES, BY CHI^2 HOMOGENEITY TEST

Hypothesis: Proportional redistribution of fish took place in a similar manner.

Test	Comparitors	Method of capture	Type of release	Observed Chi^2
a.	Wintergreen, divided into NE&SW halves.	Netting	Central	1.57
	Sugarloaf	Netting	Central	
b.	Wintergreen, divided into NW&SE halves.	Netting	Central	1.09
	Sugarloaf	Netting	Central	
c.	Wintergreen, divided into NE&SW halves.	Angling	Home half	22.44**
	Fife	Netting	Home half	
d.	Wintergreen, divided into NW&SE halves.	Angling	Home half	11.79**
	Fife	Netting	Home half	
e.	Wintergreen, divided into NE&SW halves.	Netting	Central	0.00
	Wintergreen, divided into NE&SW halves.	Netting	Central	
f.	Wintergreen, divided into NE&SW halves.	Angling	Home half	1.68
	Wintergreen, divided into NW&SE halves.	Angling	Home half	

** Significant at the 99 percent level of confidence.

TABLE XV

ANALYSIS OF RECAPTURES OF FISH RELEASED IN HOME HALF OF FIFE AND WINTERGREEN LAKES ACCORDING TO WHETHER RECOVERY WAS IN SAME (S) OR OPPOSITE (O) HALF AS WHERE ORIGINALLY MARKED

Species	Lake	Half of lake where marked	Recovery S	Recovery O	Totals S	Totals O
Largemouth bass	Wintergreen	NE	65	37	58.1% homing fish	
		SW	85	71	150	108
		NW	76	26	63.6% homing fish	
		SE	88	68	164	94
Common bluegills	Wintergreen	NE	2	3	4	5
		NW	3	4		
		SE	1	1	4	5
Common sunfish	Wintergreen	NE	0	2		
		SW	2	0	2	2
		NW	0	1		
		SE	3	0	3	1
Common sunfish X Common bluegill	Wintergreen	NE	0	2		
		SW	1	2	1	4
		NW	1	1		
		SE	2	1	3	2
Yellow perch	Wintergreen	NE	1	0		
		SW	0	0	1	0
		NW	0	0		
		SE	0	1	0	1
Bowfin	Wintergreen	NE	1	0		
		SW	0	0	1	0
		NW	0	0		
		SE	0	1	0	1
All species[1]	Wintergreen	NE	69	44	57.2% homing fish	
		SW	90	75	159	119
		NW	80	32	62.6% homing fish	
		SE	94	72	174	104
	Fife	West	128	30	75.7% homing fish	
		East	108	43	228	73

[1] Fife Lake results include species not found in Wintergreen Lake.

TABLE XVI

CHI^2 CONTINGENCY TEST OF RANDOM REDISTRIBUTION OF FISH RELEASED AT A CENTRAL STATION IN SUGARLOAF AND WINTERGREEN LAKES

Hypothesis: Redistribution of fish is random from central release point.

Lake	Recaptured in home half	Recaptured in opposite half	Total recaptures	Observed Chi^2
Sugarloaf	1031.5 / 1227	1031.5 / 836	2063	74.11**
Wintergreen, divided into NE&SW halves	44.5 / 47	44.5 / 42	89	.28
Wintergreen, divided into NW&SE halves	44.5 / 48	44.5 / 41	89	.55

** Significant at the 99 percent level of confidence.

TABLE XVII

CHI^2 CONTINGENCY TEST OF RANDOM REDISTRIBUTION OF FISH RELEASED IN THEIR HOME HALF OF FIFE AND WINTERGREEN LAKES

Hypothesis: Redistribution of fish is completely independent when released in home half of lake.

Lake	Recaptured in home half	Recaptured in opposite half	Total recaptures	Observed Chi^2
Fife	150.5 / 228	150.5 / 73	301	79.82**
Wintergreen, divided into NE&SW halves	139 / 159	139 / 119	278	5.76*
Wintergreen, divided into NW&SE halves	139 / 174	139 / 104	278	17.63**

** Significant at the 99 percent level of confidence.

* Significant at the 95 percent level of confidence.

ESTIMATED FISH POPULATIONS

Method of Estimation

The mark and recapture method of estimating fish populations dates back to the Danish investigator Petersen (1896). Citation from Fredin (1950). The simplest application is to release a stock of marked fish (B) into a body of water, then take a sample catch (A). Ratio of this catch to marked fish caught (C), multiplied by the number of marked fish released, yields an estimate of the population. Formulation: Population = AB/C.

This method of calculation must be modified when the number of marked fish varies throughout the experimental period. As each sample is taken the Petersen index may be set up, but the estimate is subject to very large sampling error. A weighted average estimate is desirable. Schnabel (1938) solves this problem by employing the method of maximum likelihood. She adds the product AB for each sample catch and divides the total by the sum of recoveries. Formulation: Population = Sum(AB)/ Sum (C).

Systematic errors for the mark and recapture method may be introduced from various sources (Ricker, 1942 and 1948). These errors are enumerated below with remarks on their application to the present experiment.

(1) As the marking experiment goes on, more fish are recruited to the available, catchable population. Hence, the fraction of marked fish in the catchable population diminishes. It may be pointed out that natural mortality tends to balance the population number so that the avail-

able population is constant, but it does not keep the marked to unmarked ratio constant. If a limit is imposed on the minimum size of fish in the experiment this produces the problem of deciding during which part of the season the estimate obtained applies most closely.

There was no need for establishing a definite size limit on fish worked with in Wintergreen Lake, as small fish were uncommon. For purposes of this study a classification of "desirable size" was used.

Implications of this term are that the fish would be a desirable size for fishermen to catch and to use as food. Of course this hypothetical concept varies tremendously with individual anglers, but length-frequency tables of fish caught in 1951 (Tables XXIV-XXVI) presented later in this paper show that there were very few bluegills and sunfish caught that were under 6 inches (15.2 cm.), no yellow perch under 7 inches (17.8 cm.), and very few largemouth bass under 9 inches (22.9 cm.). A 9 inch largemouth bass is below the Michigan legal length of 10 inches, but they were considered in this study as "desirable size" fish. These three arbitrarily chosen lengths would seem to place generous limits on the "desirable size" classification.

Data presented by Cooper (1936b) show that the above mentioned species do not reach these "desirable" sizes until the third growing season. After the end of the third season growth slows considerably. The length-frequency tables suggest that fish in their second and third growing seasons are not available to the angler. It is certain that the net mesh employed in 1951 was too large to form a barrier for these fish. Catch methods seem selective for fish above the third year class. It is realized that growth rates for the species involved may have changed during the 15 years elapsed since the time of Cooper's study, but it is suspected that the situation described still exists. See sections on Population Estimates and Length-Frequency Distributions.

Therefore, the fraction of marked fish in the catchable population remains more constant than if a large recruitment was present. The effect of natural mortality is quite indeterminable, but is usually small during a single season marking experiment.

(2) If mortality of marked fish is greater than among unmarked fish another source of error is introduced. If this occurs the number of recaptures will be reduced and population estimates will be too large.

The shoreline of Wintergreen Lake was inspected frequently throughout the experiment. During this time 35 marked fish and 28 unmarked fish were found. Marked fish were subtracted from the total of marked fish in the lake as soon as they were found. There is no way of estimating the number of marked fish that died and did not float to shore. However, the above data show a comparatively even distribution of mortality among marked and unmarked fish. If this same proportion held true throughout the lake the error introduced would be fairly large. It seems likely that most dead fish would float during the heat of summer on a shallow warm water lake. Perhaps this bias towards a higher population estimate is partially balanced by the unknown number of marked fish removed by fishermen who did not recognize the marks.

(3) Marked fish may be rendered more or less vulnerable to capture by the marking procedure. Ricker (1942) found that jaw tagged bluegills were less susceptible to capture by angling than by netting. Another example would be disk tags on salmon which make fish more vulnerable to

gill netting because the disk may catch on the twine. The fin-clip method in this experiment apparently eliminated the varying vulnerability bias. Fin-clipped and unmarked fish taken both by angling and by netting faired equally in display aquariums at the sanctuary. Wounds of clipped fins and abrasions caused by netting healed rapidly.

(4) Loss of marks or tags introduces an error towards increase of population estimation. Regeneration of fins would be the obvious cause of error in this experiment. Ricker (1948) reports that experience in Indiana with largemouth bass, a variety of sunfish, catfish (Ameiurus), and yellow perch, shows that pectoral fins do not regenerate, and that pelvics usually do not. He states that regeneration of these fins, when it occurs, is imperfect. Anal and soft dorsal fins regenerate quickly and almost perfectly. The rapidity of this regeneration of the soft dorsal was obvious during the spring months of experimentation at Wintergreen Lake. However, I do not believe that any fish handled throughout the summer exhibited regeneration that was not recognizable.

A similar source of error is natural absence of fins in wild fish. Although this phenomenon is not rare on salmon (Foerster, 1935), it is uncommon in fresh water fish. The writer observed one occurence of this abnormality in Wintergreen Lake. A bowfin speared in May did not have any right pelvic fin. External examination disclosed no hint that the fin should have been present. Dissection showed the pelvic arch to be degenerate on the right side.

(5) If distribution of marks and fishing effort is not random the population sampled is not representative and therefore neither is the estimation. A discussion of the random sampling and distribution of

marked fish is presented in an earlier section of this paper. It may be said that this error does not enter into computations on this lake.

(6) The inability of fishermen to distinguish the bluegill sunfish, common sunfish, and their hybrid from each other has probably resulted in an indeterminable error. There were not many fish removed from the lake during the experiment that were not checked by a reliable person sure of identification between the two species, but their hybrid was undetermined unless checked by this investigator. Although it seems paradoxical that fishermen do not know what they are catching, this fact was supported by many examples observed this summer.

(7) Another unmeasurable source of error is the possible difference in behavior between marked and unmarked fish. Perhaps effect of capturing and marking produces behavior patterns which render fish more or less vulnerable to methods of recapture.

(8) An obvious source of error would be unreported recaptures. This problem was discussed previously in another part of this paper. It is believed that the error introduced is small in this experiment.

(9) A cause of error which is often suspected, but uncorrected, is the recapture that occurs repeatedly in the nets or on the angler's hook. The easiest way to eliminate this error would be to eliminate the cause, namely the fish. However, that does not seem to be common practice among workers in the field. These repeatedly trapped fish tend to diminish the final population estimate. In this experiment recaptured fish were returned to the lake. Their total effect as a source of error is unknown. Toward the latter part of summer it was more common to catch a marked bass than an unmarked one and a few of these marked fish carried both

net and angling marks from different regions. Many were fish that had been previously captured 2 or 3 times. This suggests that some fish in a population are very susceptible to capture, while others are not vulnerable to angling and netting. This source of error is related to numbers 3 and 7 above, but differs in that it begins to involve the fish's individuality and psychological traits. Perhaps fish, like humans, exhibit a range of wariness varying from those easily fooled to those who are overly cautious. If this is true, then sampling is confined to a part of a population and not the whole, which would result in an estimate below the actual population.

The above 9 sources of possible systematic error indicate the overall weakness of the mark and recapture method of estimating populations. However, this tool of fisheries management is accepted as being accurate enough to yield sufficient information to illustrate the generalities of population and species composition desired by investigators.

Sampling Error of Population Estimates

Calculations of populations by the Schnabel method, and by the Schumacher and Eschmeyer method described below, are based upon one fixed quantity, the number of marked fish present in the lake (B), and two quantities subject to sampling error, number of fish captured and number of recaptures, (A) and (C). The number of recaptures is the smaller of the two and it contributes nearly all sampling error by its variability.

Ricker (1942) states that when the ratio of marked fish to unmarked fish in a lake remains below 0.05 the number of marked fish recovered at each sampling time would constitute a Poisson frequency distribution, if the ratio remained constant and the same total number of fish were caught in each sampling period. If each sampling period is considered individually, the number of marked fish taken may be considered an unique member of a Poisson series. Ricker (1937) has established limits of confidence at the 95 and 99 percent levels for this distribution.

When the ratio of marked fish to unmarked fish in the lake rises above 0.05 the limits established by this method will be too small, (Ricker, 1942). In such a situation he suggests use of fiducial limits for binomial distributions (Clopper and Pearson, 1934). Entrance to their charts necessitates computing the average fraction of marked fish at large. This is easily accomplished by dividing the sum of the recaptures by the sum of the total fish caught in the lake. Formulation: $x/n = \mathrm{Sum}(C)/\mathrm{Sum}(A)$.

The two methods of establishing fiducial limits explained above are utilized in conjunction with the Schnabel method throughout this experiment. All limits are at the 95 percent level.

Schumacher and Eschmeyer (1943) have developed another modification of the Petersen method which considers each sample as a separate estimate from which a more accurate estimate is secured by the method of minimizing squares of residuals.

Formulation: $N = \overset{k}{S}\left[n^2\ (m + u)\right] / \overset{k}{S}\ (nm)$

Where N is the population estimate, m is the number of marked fish recaptured, u is the number of unmarked fish captured, and S indicates summation. These investigators have also established methods for calculating sampling variance and standard error of the estimate.

Formulation for sampling variance of N:

$$s^2 = 1/k\text{-}1\left\{\overset{k}{S}\left[m^2/m + u\right] - 1/N\left[\overset{k}{S}(\hat{N}\hat{M})\right]\right\}$$

Standard error of the estimate is calculated by using the variance measured in the preceding equation.

Formulation of the standard error of the estimate, N, is the square root of: $N^2\left[Ns^2/\overset{k}{S}(nm)\right]$.

Application of above methods are illustrated in Table XVIII.

Both Schnabel's and Schumacher-Eschmeyer's methods are used in the population estimates made on Wintergreen Lake. In all cases confidence limits established for one estimation embraced the estimate of the other method. For final population results, an average of the two estimates was derived and it is on this average that the fish productivity figures for the lake are based.

Use of Formulae

By substituting the hypothetical numbers from Table XVIII into formulae outlined above their use will be clearer.

(1) The Schnabel method of estimating populations.

Formulation: Population = S(AB)/S(C) = 74,104/10 = 7,410

(2) Poisson limits of confidence.

This hypothetical situation fits Ricker's (1942) description of a ratio of marked to unmarked fish below 0.05. In this case it is correct to use his (1937) limits of confidence for a Poisson distribution. Entering the tables with 10, S(C), the lower limit is found to be 4.7 and the upper limit is 18.4 at the 95 percent level of confidence. This means that 95 percent of the time the number of recaptures would be between 4.7 and 18.4. By dividing S(AB) by these limits we establish limits of confidence for the population.

Formulation: Probable limits of population = S(AB)/limits of recaptures.

$\therefore$ 74,104/4.7 = 15,767 and 74,104/18.4 = 4,027.

(3) Binomial limits of confidence.

Ricker (1942) states that binomial limits are not adequate when the ratio of marked to unmarked fish falls below 0.05. The method is outlined here, although its application is not acceptable for the example in Table XVIII. These binomial fiducial limits are used in this paper for population estimates of four species, largemouth bass, yellow bullhead, bowfin, and common sunfish X common bluegill hybrid. The confidence belts used were first published by Clopper and Pearson (1934) and later reprinted by Dixon and Massey (1951), Snedecor (1950), and others.

Formulation: $x/n = S(C)/S(A) = 10/451 = 0.022$.

Possible range of this ratio at the 95 percent level of confidence is estimated at 0.01 to 0.04 from the confidence belts cited above. These ratios multiplied by the total number of fish captured S(A) gives the possible limits of the number of recaptures S(C) as 4.5 and 18.0.

$\therefore$ S(AB)/4.5 = 74,104/4.5 = 16,468 and

S(AB)/18.0 = 74,104/18.0 = 4,117.

(4) The Schumacher and Eschmeyer method of estimating populations.

Formulation: $N = \overset{k}{S}\left[n^2(m + u)\right] / \overset{k}{S}(nm) = 19{,}456{,}916/2{,}480 = 7{,}846.$

TABLE XVIII

TWO METHODS OF ESTIMATING FISH POPULATIONS. HYPOTHETICAL EXAMPLES ARE USED WITH THE ASSUMPTION OF NO MORTALITY

A. Schnabel Method.

Date	A	Number marked and returned	B	AB	S(AB)	S(C)	P	95% Confidence limits
								for 7,410
May 3	126	126	0	0	0	0		by binomial
May 4	88	88	126	10560	10560	2	5280	4,117 to 16,468
May 5	137	133	212	29044	39604	6	6601	by Poisson
May 6	100	96	345	34500	74104	10	7410	4,027-15,767

A is the number of fish caught on any date.
B is the number of marked fish present in the lake on any date.
C is the number of recaptures on any date.
AB is the product of A and B.
P is the population estimate.
S indicates summation.

B. Schumacher and Eschmeyer Method.

Date	n	m	m + u	$n^2(m + u)$	nm	$\frac{m^2}{m + u}$	N	Standard error
May 4	126	2	88	1387088	252	0.045455		+ or -
May 5	212	4	137	6157328	848	0.116788		2,445
May 6	345	4	100	11902500	1380	0.160000		
				19,456,916	2,480	0.322243	7846	5,401-10,291

n is the accumulated number of previously-marked fish.
m is the number of marked fish recaptured.
u is the number of unmarked fish captured.
N is the population estimate.

(5) Sampling variance of N.

Formulation: $s^2 = 1/k\text{-}1 \left\{ \overset{k}{S} \left[m^2/m + u \right] - 1/N \left[\overset{k}{S}(nm) \right] \right\}$

$= \frac{1}{2} \quad 0.322243 - (2480)^2/19{,}456{,}916$

$= \frac{1}{2} \; (0.322243 - 0.316104) = 0.003070$

(6) Standard error of the estimate is the square root of:

$N^2 \left[Ns^2/\overset{k}{S}(nm) \right] = 7846\sqrt{0.003070/0.031610}$

$= 7846\sqrt{0.097121} = + \text{ or } - 2{,}445.$

POPULATION ESTIMATES, STANDING CROP, AND ANNUAL YIELD OF WINTERGREEN LAKE

Table XIX summarizes population estimates by both the Schnabel method and the Schumacher and Eschmeyer method. The average of these methods has been taken as the final estimation. Each species will be discussed below under a separate heading. All ice fishing data from 1948 - 1951 were collected by sanctuary personnel and presented by Dr. A. E. Staebler in the annual reports of the sanctuary.

TABLE XIX

POPULATION ESTIMATES OF "DESIRABLE SIZE" FISH IN WINTERGREEN LAKE. CONFIDENCE LIMITS OF THE SCHNABEL METHOD AT THE 95 PERCENT LEVEL. LIMITS OF ONE STANDARD ERROR ON THE SCHUMACHER AND ESCHMEYER METHOD.

Species	Schnabel	Schumacher and Eschmeyer	Average
Common bluegill*	12,149	13,942	13,046
	9,136 - 16,550	11,918 - 15,966	
Common sunfish*	3,314	3,219	3,267
	1,974 - 6,025	2,564 - 3,874	
Largemouth bass**	2,654	2,578	2,616
	2,420 - 2,818	2,428 - 2,728	
Yellow perch*	2,276	2,150	2,213
	1,198 - 5,122	1,404 - 2,896	
Common sunfish X Common bluegill**	675	748	712
	301 - 1,809	588 - 908	
Yellow bullhead**	166	167	167
	127 - 240	151 - 183	
Bowfin**	46	46	46
	19 - 155	27 - 65	
Totals	21,280	22,850	22,067
	15,183 - 32,750	19,080 - 26,620	

* Confidence limits of Schnabel method by Poisson distribution.
** Confidence limits of Schnabel method by binomial distribution.

TABLE XX

STANDING CROP OF "DESIRABLE SIZE" FISH IN WINTERGREEN LAKE, BASED ON POPULATION ESTIMATES FROM TABLE XIX[1]

Species	Estimated population	Mean length in cm.	Average weight in grams	Mean K factor	Total weight in lbs.	Pounds per acre
Common bluegill	13,046	16.28*	203.4	4.715@	5,850.0	148.7
Largemouth bass	2,616	24.50*	327.4	2.226@	1,888.2	48.1
Common sunfish	3,267	14.93*	174.2	5.233@	1,254.7	31.9
Yellow perch	2,213	19.94*	150.1		732.3	18.6
Common sunfish X Common bluegill	712	14.60*	176.9	5.684@	277.7	7.1
Yellow bullhead	167	32.46x	521.3		191.9	4.9
Bowfin	46	56.90x	1611.3		163.4	4.2
Totals	22,067				10,358.2	263.5

1 There is a slight difference of a few hundredths between mean lengths shown here and those in the length-frequency tables presented later. Figures in this table were back-calculated from the K factor. All fish were not used to determine condition factor of the fish, but as many as possible were used in the length-frequency tables.

* Standard length of fish caught by angling and netting.

@ Calculated from fish caught by angling.

x Total length of bullheads caught by netting and total length of bowfins caught by angling, spearing, and netting.

Common Bluegill

The maximum number of marked bluegills present in the lake was 654. There were 47 recaptures yielding a final population estimate of 13,046. The ratio of marked to unmarked bluegills in the lake was approximately 4.2 percent when 331 marked bluegills were present on July 18. This ratio increased to about 5 percent at the close of the experiment.

Average weight of the bluegills handled was 203.4 grams and mean standard length was 16.28 cm. or 6.4 inches. Mean K factor of fish caught by angling was 4.715. The total weight of bluegills in the lake is estimated to be 5,850 pounds, or 148.7 pounds per acre. These fish composed 56.5 percent of the total poundage.

Trap netting removed 76.2 pounds of bluegills from the lake and angling accounted for 259.2 pounds. Ice fishing during January, February, and March of 1951 resulted in a catch of 4.0 pounds of bluegills. A total of 339.4 pounds, or 8.6 pounds per acre, of bluegills were taken from the lake during a one year period. Rate of exploitation, based on poundage removed divided by estimated total poundage present, is approximately 5.8 percent.

Visual observations indicate that bluegills are the most abundant fish in the lake. During the period from April 27 to April 30 bluegills formed large schools and swam about in the shallow waters over the sandy bottom of the northeast section of the lake. Several thousand bluegills were observed at this time. Their shoreward movements coincided with sunny, warm weather which caused the surface water of the lake to warm from 47 degrees F. to 56 degrees F. in one week. The

Secchi disk reading raised from a little over a meter to 4.2 meters during this same period, thus enabling the investigator to observe the fish clearly. At this time they were not vulnerable to capture by angling. They merely swam slowly about near the surface.

Common Sunfish

On August 16 there were 188 marked common sunfish present in the lake. Throughout the experiment there were 14 recaptures made. When there were 84 marked common sunfish in the lake their ratio to the Schnabel population estimate of that date was 3.1 percent. This ratio increased to approximately 5.6 percent towards the end of the season. Total population estimate is 3,267 fish of desirable size.

Average weight of these fish was 174.2 grams and their mean standard length was 14.93 cm. or 5.9 inches. Mean K factor of fish caught by angling was 5.233. From these data the total weight of common sunfish present was estimated to be 1,254.7 pounds, or 31.9 pounds per acre. This group made up 12.1 percent of the total poundage.

Over the spring and summer period of experimentation 33.8 pounds of common sunfish were removed by angling. Mortality caused by trap netting amounted to 49.5 pounds. Ice fishermen removed 2.7 pounds during the 1951 season. These figures totaled a yield of 86.0 pounds of common sunfish, or 2.2 pounds per acre per year. Approximate rate of exploitation is 6.9 percent.

The population estimates for bluegills and common sunfish yield a ratio of 3.99 bluegills for 1 common sunfish, or 4 : 1. Visual observation during the early spring phenomenon described above did not support this ratio, for there were few common sunfish seen. Later in the spring, when the centrarchids were on their nests, the ratio seemed more appropriate. In late spring and early summer when common sunfish were still nesting and bluegills were finished, this ratio seemed too high. It is interesting to note that the total number of bluegills captured over winter and summer by all methods was 1,512, while the number of common sunfish was 429. This ratio is 3.52 : 1. This is not a reliable ratio of abundance of the two species for their rate of susceptibility to capture by various methods varies tremendously. For example, 491 bluegills and 35 common sunfish were caught during the winter of 1950, giving a ratio of 14.0 : 1, 818 bluegills and 117 common sunfish for summer angling of 1951, giving a ratio of 7.0 : 1, 680 bluegills and 301 common sunfish for the summer trap netting of 1951, giving a ratio of 2.3 : 1, and 9 bluegills and 7 common sunfish for ice fishing of 1951, giving a ratio of 1.3 : 1.

Largemouth Bass

Population estimates indicate that the largemouth bass was the third most abundant game fish in the lake. Nine hundred and forty-two marked bass were present in the lake on August 17. At this time, the ratio of marked bass to unmarked was approximately 35 percent. This ratio remained fairly constant until the final sampling of September 16. At the midpoint of the experiment, when 488 marked bass were in the lake on May 19, the ratio of marked to unmarked was 14 percent.

Starting with April 21, there were 11 days of marking and recapturing bass up to and including May 11. On this date there were 276 marked bass in the lake and a total of 10 recaptures had been made. Sum(AB) was 24,564 and estimated population by the Schnabel method was 5,812. From this time until September 16 the estimated population dropped to the final reading of 2,654. The true population probably lies within those figures, but the point at which to discontinue the Schnabel method calculations is not definite.

During the period that bluegills appeared in the shallow water bass accompanied them. At this time the ratio of marked bass to unmarked was about 4 percent. The soft dorsal marks were fresh and many of the clipped fish were easily observed as they swam slowly about in a lazy manner near the surface. No discernable difference could be noted between actions of marked and unmarked fish. Neither a count of the ratio of marked fish to unmarked was kept, nor a record of the number of bass seen in a full trip around the lake. This is regrettable, for it seems that this would supply an excellent index of population. The most remarkable observation made during this period was that not a single bass was seen whose weight could be estimated at over 3½ pounds. This observation was confirmed during the experiment when some 1,500 largemouth bass were handled (including recaptures and those removed by fishermen) and there were only four bass that weighed 3 pounds or over. The largest was 3 pounds and 7 ounces. Dr. Miles Pirnie stated in a verbal communication that during his tenure as director of the Kellogg Bird Sanctuary, 1931-1948, a bass weighing over three pounds was a great rarity. Dr. Arthur Staebler, sanctuary director since 1948, can

attest to only one bass that weighed more than 3 pounds. The inhabitants of the vicinity relate accounts of bass weighing five pounds and over when the lake was fished publicly, but their memories are probably not clear on this point. However, the possibility that large bass were present at one time may not be overlooked.

The age and growth analysis of these bass is the subject of an incompleted master's thesis by Alfred D. Brower, fisheries graduate student at Michigan State College. Cooper (1935b) gives the following information on the growth rate of largemouth bass in this lake. At the end of the first growing season the bass have reached 4 inches, second - 8.7, third - 11.3, fourth - 11.7, fifth - 12.0, and at the end of the sixth growing season they have reached 12.7 inches. These average figures were derived from 19, 1, 3, 26, 37, and 4 specimens. It is obvious that environmental conditions during the first three growing seasons are excellent for the rapid growth of these bass, but the reason for the sudden cessation of growth is unknown. Perhaps Brower (Ms.) will illuminate this problem.

Further information from Cooper's report indicates that a similar situation existed for bluegills and common sunfish in the lake. His tables show that bluegills reached the following lengths at the end of the indicated growing season: 9 fish, first season, 2.0 inches; 27 fish, third season, 7.5 inches; 4 fish, fourth season, 8.7 inches; 9 fish, fifth season, 8.8 inches; 12 fish, sixth season, 9.4 inches; 8 fish, seventh season, 9.5 inches; and 4 fish, eighth season, 9.4 inches. From the same tables it is found that common sunfish reached the following lengths at the end of the indicated growing season: 48 fish, first season, 2.0 inches; 7 fish, second season, 4.5 inches; 43 fish, third season, 6.9 inches; 9 fish, fourth season, 7.5 inches; 16 fish, fifth season, 8.2 inches; 16 fish, sixth season, 8.2 inches; and 2 fish, seventh season, 8.1 inches. The yellow perch did not exhibit this tendency towards cessation of growth after the first three or four years of life, but continued with normal annual increases.

Mean weight, standard length, and K factor of largemouth bass caught by angling were 327.4 grams, 24.50 cm., or 9.6 inches, and 2.226 respectively. Total weight of desirable size bass was estimated at 1,888.2 pounds, or 48.1 pounds per acre. Their weight composed 18.3 percent of the total poundage of all fish present.

Trap netting removed 13.0 pounds of bass and spring and summer angling accounted for 122.0 pounds. Ice fishing during the first two months of 1951 resulted in a catch of 33 bass which were removed for scale samples. Their approximate weight was 23.8 pounds, based on the average compiled over the 1951 spring and summer months. These figures give a total weight of 158.8 pounds, or 4.0 pounds per acre that were harvested. The rate of exploitation was 8.4 percent.

Yellow Perch

On August 26 the maximum number of marked yellow perch, 107, were present in the lake. This was 5.6 percent of the estimated number of yellow perch in the lake. At the experiment's conclusion there were 106 marked perch present and final population estimate was 2,276 by the Schnabel method, but the average estimate was 2,213. This resulted in a percentage of 4.7 for marked to unmarked fish. The first recapture was not made until August 1 when there were 90 marked fish present in the lake. Marked to unmarked ratio at this time was 1.3 percent. Estimated population by the Schnabel method was 6,711. From this time to the close of the experiment on September 16 the population estimate declined to 2,276.

Average weight of the yellow perch caught by angling throughout the spring and summer was 150.1 grams and mean total length was 23.14 cm. or 9.1 inches. Total weight of yellow perch in Wintergreen Lake was estimated at 732.3 pounds, or 18.6 pounds per acre. This amount composed 7.1 percent of the total weight of fish in the lake.

Ice fishermen, during the first three months of 1951, removed 63.6 pounds of yellow perch. Summer angling in 1951 removed 41.4 pounds and trap netting accounted for 4.3 pounds. Thus, we have a total yield of 109.3 pounds, or 2.8 pounds per acre. This is an exploitation rate of 14.9 percent.

There were only 9 recaptures made for this species over the spring and summer period. The 95 percent confidence limits for the Schnabel method are 1,198 and 5,122. This upper limit may be closer to the actual number of desirable size yellow perch present. This statement is made after consideration of ice fishing results of 1950 and 1949. In 1950 there were 879 perch caught and in 1949 1,223 were removed by anglers. If the population in 1949 was the same as the 1951 estimate of 2,213, exploitation rate over the winter would have been 55.3 percent. This would be a very high rate if the population had been as low as the 1951 estimate. It is suspected that a rapid drop in population is possible, for the winter catch in 1950 dropped to 879, and to 192 in 1951. In a verbal communication, Dr. A. E. Staebler, present director of the sanctuary, stated that the winter fishing for perch in the first three months of 1952 has been very poor. These data seem to offer two possible alternatives of interpretation.

(1) There has been a rapid drop in the yellow perch population from 1949-1952.

(2) The population, as a whole, has remained fairly constant, but larger size groups were depleted in 1949 and 1950 and recruitment to these groups and to the catchable size has not yet entered the population that was measured in this study.

The effect of schooling and a high degree of chance has presumably entered the calculations for the estimation of this population. On August 9 a reliable angler caught 22 perch. His creel census card stated that three of these fish had been marked. He evidently was catching perch from a school that I had previously sampled and to which I had returned several fish. On September 16 I visited Wintergreen Lake to collect specimens of bluegill parasites and caught one yellow perch. This fish was marked. These four recoveries seem slightly out of the ordinary. If they were eliminated from the recovery list the total population estimate by the Schnabel method would be 4,097. Of course, this number cannot be accepted, for the whole method of population estimation is based on the theory of random sampling, but it is interesting to note what a large difference in population estimate may be effected by a small change in the number of recoveries.

Common Sunfish X Common Bluegill Hybrid

Identification of this hybrid was a difficult task. All sunfishes handled by the author were examined for length of gill-rakers. If length of gill-rakers did not coincide with the overall visual identification of the fish, it was classified as a hybrid. Apparently a majority of the identifications were correct, for the hybrid's K factor, 5.684, differed from the K factors of bluegills, 4.715, and common sunfish, 5.233. The hybrids mean standard length was 14.60 cm., or 5.7 inches. This measurement differed from the bluegill by 1.68 cm. and from the common sunfish by .33 cm. Average weight in grams was 176.9 as contrasted to average weights for bluegill and common sunfish of 203.4 and 174.2 respectively.

At the close of experimental sampling of hybrids on August 29, there were 76 marked fish in the lake. This was a percentage of 11.3 of the estimated population. At the midpoint of this experiment on July 18, there were 40 marked fish in the lake making up 5.6 percent of the estimated population of 715. The final estimate was 675 by the Schnabel method, but the average was 712.

The total weight of hybrids present in the lake was estimated at 277.7 pounds, 7.1 pounds per acre, and made up 2.7 percent of the total poundage of all species. During the spring and summer experimentation period 8.6 pounds were removed by trap netting and 8 fish amounting to 3.1 pounds were removed by angling. No further records are available due to lack of proper identification. Undoubtedly some bluegills and common sunfish captured during the winter fishing period of 1950 were hybrids, but they were lumped in with the more numerous species. This fish had a total yield of 11.7 pounds, or .3 pounds per acre. Exploitation rate was 4.2 percent.

Yellow Bullhead

This species exhibits a great affinity for trap nets and consequently, in spite of the small population present, a large percentage of the fish were tagged. It is generally known that bullheads are quiescent and seek shelter during the daylight hours. Perhaps trap nets appear to offer this protection. Another possibility is that bullheads follow a lead into the net more readily than other fish. A third choice is that they were attracted to the nets by dead fish inside.

On August 27 there were 94 marked bullheads present in the lake. They made up 56.6 percent of the estimated population on this date. This was the maximum number of marked fish alive at any one time.

The average weight of these fish was 521.3 grams, their mean total length was 32.46 cm. or 12.8 inches. This average weight multiplied by the estimated population gives a total weight of 191.9 pounds, 4.9 pounds per acre, and is 1.9 percent of the total weight of all fish present. The yield of these fish amounts to 4.6 pounds by hoop netting, 12.6 pounds by trap netting, 6.9 pounds by angling, and 1.1 pounds by ice fishing, or a total of 25.2 pounds or .64 pounds per acre. Exploitation rate was estimated to be 13.1 percent.

Bowfin

This fish is the only large fish present in the lake that is not classified as a game fish. Most fisheries men term the bowfin a predator. However, their presence in many lakes may be advantageous as a check on overpopulation. Their feeding habits are highly carniverous and it is likely that this fish is one reason Wintergreen Lake has not become seriously overpopulated. During the spring season bowfin were more active in Wintergreen Lake than throughout the rest of the summer. Four fish were speared by sanctuary personnel during the early spring months and these account for the four mortalities by angling listed in Table IV.

Although several bowfin were seen during the spring their relative abundance could not be estimated. The first trap net set on May 27 captured 12 bowfin. This certainly indicated a high population. However, only 18 more bowfin were captured by all methods after that initial catch. Final proportion of marked fish to unmarked by the Schnabel method was 1:4.2 or 23.9 percent.

Population was estimated to be 46 fish, averaging 1,611.3 grams and 56.9 cm. total length, or 22.4 inches. Total weight of bowfins present was approximately 163.4 pounds, 4.2 per acre, or 1.6 percent of the total weight of all species combined. The total yield of bowfin was 63.9 pounds, or 1.6 pounds per acre. Constituents of this amount were 49.7 pounds by trap netting and 14.2 pounds by angling and spearing. Exploitation rate was about 8.7 percent.

LENGTH-FREQUENCY DISTRIBUTIONS

The length-frequency distributions of all fish of importance to the angler in Wintergreen Lake are presented in Tables XXI - XXVI. Ice fishing records for the winter of 1935 - 1936 were drawn from unpublished Report No. 365, by David S. Shetter (1936) of the Michigan Institute for Fisheries Research. The winter fishing records for 1948 - 1951 were taken from the annual reports of the Kellogg Bird Sanctuary prepared by Dr. A. E. Staebler.

In Table XXI it is interesting to note the sudden drop in mean length of yellow perch from the winter season of 1948 - 1949 to the corresponding season in 1949 - 1950. In the latter season fishermen were requested to keep all fish they caught, regardless of size, whereas in the former season they were permitted to select the fish they removed from the lake. It is not known how much effect this ruling had on recorded length-frequency data. The dominant grouping between 22 and 26 centimeters during 1948 - 1949 is not evident in the following winter. In the winter of 1949 - 1950 the fish are spread over a larger span and their average size drops 3.31 centimeters to 21.36. It is possible that the heavy harvest of the former season depleted the larger size classes and recruitment was not sufficient to maintain that yield.

Table XXII again illustrates the drop in mean length when the ruling of non-selective fishing was applied at the beginning of the 1949 - 1950 season. Data from 1935 - 1936 include 6 fish that fell below 15 centimeters in length. Their length was estimated at 14 centimeters. The number of bluegills taken by ice fishing in 1950 - 1951 is considered

too small to estimate whether or not there was a significant drop in mean length from the previous season. The smaller mean length computed for the summer of 1951 may indicate that at present the average length of bluegills is declining.

Length-frequency data for largemouth bass presented in Table XXVI illustrate an interesting natural phenomenon. Five hundred and four of the 1013 largemouth bass measured were between 18 and 22 centimeters in standard length. This is a percentage of 49.8, or approximately half. The conversion factor to convert this standard length to total length is 1.227, computed from data from 100 fish, in this length range, captured by angling in Wintergreen Lake during the summer of 1951. Thus, half of the bass captured in the lake range from about 22.1 cm. to about 27.0 cm. in total length. Converted to inches, these figures become 8.7 and 10.6 respectively.

In Michigan a largemouth bass must be 10 inches long before it is of legal length. Presumably these fish from Wintergreen Lake are in their third growing season. If this same situation exists in publicly fished lakes in the state, almost half of the largemouth bass in the catchable class are not available to fishermen because of the 10 inch law. The point arises that these fish will probably grow to legal length by next summer and then they will be available to fishermen. However, an examination of the length-frequency data for the species in Table XXVI will suggest that this dominant group does not carry over into the next season.

The data offer three choices of interpretation: There is a very high natural mortality after the third growing season; larger fish are not as susceptible to the angler's method of capture; or the most logical, this is a dominant year class. Of course, data from one year of sampling cannot set a precedent to be followed, but they indicate that a large part of the dominant year class, which could add much to the total yield of the lake, is legally not available to fishermen at this time. It is possible that this dominant year class will carry over and its effect will be seen in the summer catch for 1952.

If sampling in the summer of 1952 indicates that a length-frequency pattern similar to the one for 1951 exists, it would seem logical to harvest part of this dominant class before natural mortality depletes it. This could be accomplished by allowing the taking of 9 inch largemouth bass.

Data for bluegills may be interpreted to support the findings of Cooper (1935b) that this species grows to a large size rapidly and then slows down to very small annual increases. Standard lengths of 519 (69.5 percent) of the 749 bluegills measured were between 15.25 and 17.25 centimeters. These lengths may be converted to total lengths by use of the factor 1.261. This conversion factor is based on measurements from 93 bluegills in this size range, captured by angling in Wintergreen Lake during the summer of 1951. Thus, the total lengths of 69.3 percent of the bluegills captured ranged between 19.2 and 21.8 centimeters, or between 7.6 and 8.6 inches.

Length-frequency data for yellow perch presented in Tables XXI and XXVI may be translated to agree with Cooper's (1935b) statement that the growth of this species in Wintergreen Lake is evenly distributed throughout the different years of life.

TABLE XXI

TOTAL LENGTH-FREQUENCY DISTRIBUTION OF YELLOW PERCH FROM WINTERGREEN LAKE. ALL FISH CAPTURED BY ANGLING.

Class[1] in cm.	Winter* '48-'49	Winter* '49-'50	Winter* '50-'51	Class[1] in cm.	Summer* 1951
12		1			
13		2	1	12.5	
14	3	9	0	13.5	
15	0	29	2	14.5	
16	3	75	5	15.5	
17	2	92	8	16.5	
18	22	67	19	17.5	5
19	38	80	23	18.5	5
20	38	70	24	19.5	7
21	72	84	22	20.5	14
22	102	80	16	21.5	22
23	162	64	30	22.5	10
24	163	55	10	23.5	14
25	207	62	6	24.5	12
26	234	41	10	25.5	10
27	93	37	8	26.5	8
28	50	17	4	27.5	4
29	24	13	0	28.5	2
30	9	1	4	29.5	
31	1	2		30.5	
Totals	1223	879	192		119
Mean length	24.67	21.36	21.96		23.14
Standard deviation	± 2.50	± 3.71	± 3.24		± 2.65

1 Measurements of fish in the periods before the summer of 1951 were tabulated with the even centimeter forming the lower limit of the class interval. Measurements of this fish during the summer of 1951 were made using the even centimeter as the mid-point of the class interval.

* Ice fishermen, during the seasons of '49-'50 and '50-'51, were requested to keep all the fish they captured. Winter fishermen in the '48-'49 season were selective of size of fish they removed from the lake. Results from the summer of 1951 include all sizes of fish caught.

TABLE XXII

TOTAL LENGTH-FREQUENCY DISTRIBUTION OF COMMON BLUEGILLS FROM WINTERGREEN LAKE. ALL FISH CAPTURED BY ANGLING.

Class[1] in cm.	Winter* '35-'36	Winter* '48-'49	Winter* '49-'50	Winter* '50-'51	Class[1] in cm.	Summer* 1951
10			1			
11			1		10.75	
12					11.75	
13			14		12.75	
14	6		18		13.75	3
15			31		14.75	2
16			21	1	15.75	8
17	11		9		16.75	6
18	24				17.75	16
19	36		4	2	18.75	26
20	72	1	4	3	19.75	65
21	165	3	16	1	20.75	82
22	164	6	9		21.75	18
23	315	48	28		22.75	1
24	231	66	104		23.75	2
25	20	50	148	1	24.75	4
26		39	68	1	25.75	2
27		22	14		26.75	
28		1	1		27.75	
29		1			28.75	
30	2				29.75	
Totals	1046	237	491	9		235
Mean length	22.73	25.05	23.13	21.17		20.36
Standard deviation	±1.75	±1.44	±4.12	±2.91		±1.84

1 Measurements of fish in the periods before the summer of 1951 were tabulated with the even centimeter forming the lower limit of the class interval. Measurements of this fish during the summer of 1951 were made using the even centimeter as the mid-point of the class interval.

* Ice fishermen, during the seasons of '49-'50 and '50-'51, were requested to keep all the fish they captured. Winter fishermen in the '48-'49 season were selective of size of fish they removed from the lake. It is unknown if the fishermen in '35-'36 were selective. Results from the summer of 1951 include all sizes of fish caught.

TABLE XXIII

TOTAL LENGTH-FREQUENCY DISTRIBUTION OF COMMON SUNFISH FROM WINTERGREEN LAKE. ALL FISH CAPTURED BY ANGLING.

Class[1] in cm.	Winter* '48-'49	Winter* '49-'50	Winter* '50-'51	Class[1] in cm.	Summer* 1951
13		2		13.75	
14		1		14.75	
15		8		15.75	6
16		4		16.75	1
17		3		17.75	8
18		7	1	18.75	6
19	1	8		19.75	7
20	3		2	20.75	3
21	1			21.75	1
22	4	1		22.75	
23	1		1	23.75	
24			1	24.75	
25		1	1	25.75	
26	2		1	26.75	
27				27.75	
28	1			28.75	
Totals	13	35	7		32
Mean length	22.89	17.64	22.79		18.88
Standard deviation	±2.53	±2.32	±2.76		±1.67

1 Measurements of fish in the periods before the summer of 1951 were tabulated with the even centimeter forming the lower limit of the class interval. Measurements of this fish during the summer of 1951 were made using the even centimeter as the mid-point of the class level.

* Ice fishermen, during the seasons of '49-'50 and '50-'51, were requested to keep all the fish they captured. Winter fishermen in the '48-'49 season were selective of size of fish they removed from the lake. Results from the summer of 1951 include all sizes of fish caught.

TABLE XXIV

TOTAL LENGTH-FREQUENCY DISTRIBUTIONS OF YELLOW BULLHEADS CAPTURED BY NETTING AND COMMON SUNFISH X COMMON BLUEGILL HYBRIDS CAPTURED BY ANGLING IN WINTERGREEN LAKE, MAY - AUGUST, 1951

	Yellow bullheads summer 1951	Class[1] in cm.	Hybrids summer 1951
		15.5	
	1	16.5	4
	0	17.5	7
	0	18.5	5
	0	19.5	1
	1	20.5	1
	0	21.5	1
	1	22.5	
	1	23.5	
	0	24.5	
	1	25.5	
	2	26.5	
	6	27.5	
	7	28.5	
	10	29.5	
	9	30.5	
	8	31.5	
	9	32.5	
	21	33.5	
	19	34.5	
	6	35.5	
	7	36.5	
	3	37.5	
Totals	112		19
Mean length	32.46		18.53
Standard deviation	±3.54		±1.31

1 The even centimeter is the midpoint of the class interval.

TABLE XXV

TOTAL LENGTH-FREQUENCY DISTRIBUTION OF BOWFINS CAPTURED BY ANGLING, SPEARING, AND TRAP NETTING IN WINTERGREEN LAKE, APRIL - AUGUST, 1951

	Class in centimeters[1]	Frequency
	42.5	1
	43.5	0
	44.5	0
	45.5	0
	46.5	1
	47.5	0
	48.5	0
	49.5	0
	50.5	1
	51.5	0
	52.5	4
	53.5	5
	54.5	0
	55.5	1
	56.5	1
	57.5	1
	58.5	4
	59.5	2
	60.5	1
	61.5	0
	62.5	0
	63.5	0
	64.5	1
	65.5	0
	66.5	1
	67.5	0
	68.5	2
Total		26
Mean length		56.96
Standard deviation		± 6.03

[1] The even centimeter is the midpoint of the class interval.

TABLE XXVI

STANDARD LENGTH-FREQUENCY DISTRIBUTIONS OF LARGEMOUTH BASS, YELLOW PERCH, COMMON BLUEGILL, COMMON SUNFISH, AND THE COMMON SUNFISH X COMMON BLUEGILL HYBRID FROM WINTERGREEN LAKE, APRIL - SEPTEMBER, 1951. ALL FISH CAPTURED BY ANGLING AND TRAP NETTING.

Class[1] in cm.	Largemouth bass	Yellow perch	Class[1] in cm.	Common bluegill	Common sunfish	Hybrid
10.5			10.75	2	1	
11.5			11.75	7	9	3
12.5			12.75	36	32	13
13.5	3		13.75	51	37	37
14.5	4	3	14.75	87	89	24
15.5	12	9	15.75	324	37	4
16.5	13	8	16.75	195	10	4
17.5	21	16	17.75	13	3	
18.5	72	19	18.75	12		
19.5	176	12	19.75	16		
20.5	170	20	20.75	6		
21.5	86	16	21.75			
22.5	45	12	22.75			
23.5	36	4	23.75			
24.5	15	3	24.75			
25.5	22		25.75			
26.5	27		26.75			
27.5	22		27.75			
28.5	28		28.75			
29.5	34		29.75			
30.5	36		30.75			
31.5	51		31.75			
32.5	41		32.75			
33.5	45		33.75			
34.5	29		34.75			
35.5	10		35.75			
36.5	10		36.75			
37.5	5		37.75			
Totals	1013	122		749	218	85
Mean length	24.51	19.94		16.27	14.95	14.54
Standard deviation	±5.68	±2.40		±1.43	±1.26	±1.05

1 Measurements of largemouth bass and yellow perch were made using the even centimeter as the mid-point of the class interval. Measurements of the common bluegill, common sunfish, and their hybrid were made using two groups for each centimeter class and these two groups have been combined in the data above which has the .75 as the lower limit of the centimeter class.

COMPARISON OF THE STANDING CROP AND ANNUAL YIELD OF WINTERGREEN LAKE WITH OTHER LAKES

Knowledge of productivity of various bodies of water is of vital concern to fisheries biologists. Growth rate, mortality rate, density of population, and rate of exploitation of the fish of a lake are all factors which influence productivity. Standing crop of fish and the yield are the two most direct measurements of productivity used by biologists. Several methods for determining the standing crop of fish in a body of water have been used. The best known of these is draining the area covered by water and recovering as many fish as possible. Other methods are by the use of poison, electric shockers, nets, or estimation of population by the mark and recapture method. All methods listed above are subject to error. The most accurate is draining while the one most subject to sampling error is probably the mark and recapture method. See section on Estimated Fish Populations.

The following data are presented with the understanding that all information is subject to probable variation and error. Although figures given for standing crops are discrete, the reader must realize the overall inaccuracy of methods of fish population estimation.

Carlander (1950) and Rounsefell (1946) both have examined a large portion of the available literature on lake production and have published extensive lists and tables incorporating the data. Carlander includes the method used by the numerous investigators for estimating the population, but does not give the species of fish dominating the production figures. Rounsefell reverses the situation, by excluding methodology and including type of fish present. A complete summary of this information would be a valuable contribution to fisheries management.

Before entering into a discussion of the standing crops and yields of warm water lakes, the reader should be cognizant that rough fish, such as carp, Cyprinus carpio, goldfish, Carrassius auratus, and buffalofish and other suckers, Catostomidae, have the ability to produce a much heavier standing crop in pounds than the game fish dealt with in the present study. This is due primarily to their ability to convert vegetation and other low forms of life into body building substances. Game fish may be generally grouped as secondary converters, or those fish that depend on higher forms of life than vegetation for their food. The broad classification of rough fish may also include bowfin and gar, Lepisosteidae. These two fish are included as secondary converters. In some sections of the country they are termed game fish by sportsmen, but their usual classification is that of predator. Rounsefell (1946) also includes bullheads as rough fish. For the purpose of comparing Wintergreen Lake data with data from lakes included in the papers presented by Carlander (1950) and Rounsefell (1946), bowfin and bullheads will be excluded from the estimations calculated for Wintergreen Lake. Thus the standing crop includes only "desirable size" gamefish, no rough fish, forage fish, or small sized game fish.

The total estimated population in pounds per acre of "desirable size" game fish in Wintergreen Lake is 254.4 pounds. Rounsefell (1946) lists standing crop estimates from 51 lakes and ponds. He does not include any lake or pond whose estimated standing crop of game fish surpasses the figure for Wintergreen Lake. The body of water most nearly approaching this figure is 0.8-acre Delta Pond, Illinois which Thompson and Bennett (1939) state had a standing crop of 234 pounds of game and pan fish per acre.

Rounsefell lists 17 bodies of water whose standing crop exceeds that of Wintergreen Lake, but 11 of them include carp and all of them include rough fish. Carlander (1950) lists the standing crop of fish in pounds per acre in 301 natural ponds and lakes. His data list 163 bodies of water which have a higher standing crop. He cites references for his data, but the writer did not investigate to find if all estimates listed above Wintergreen Lake's included rough fish. It is probable that a very great percentage of them did include species other than game fish.

It is possible that Wintergreen Lake possesses the highest standing crop of "desirable size" fish for any natural lake of comparable size. Probably the artificially fertilized, properly managed, man-made ponds of the South exceed this figure. Wintergreen Lake is natural in all respects except that it annually receives abnormally large amounts of natural fertilizer from droppings of waterfowl present during their southward migration.

Fishing pressure is lighter on Wintergreen Lake than it is on most other lakes with a high population of game fish. According to the theories of modern fishery biologists, this would tend to cause a degree of stunting in fish of the lake. The length-frequency data do not seem to agree with this supposition until the fish have reached a large size. Apparently conditions are excellent for rapid growth of young fish into the "desirable size" classification and then the effect of competition asserts itself and growth rate drops suddenly. Perhaps the natural fertilization of this lake is one prominent reason why the estimated standing crop of game fishes may be the highest so far recorded for a natural lake.

The total annual yield of fish taken by angling from Wintergreen Lake lends itself to a more accurate estimation than standing crop. During 1951 there were approximately 575.8 pounds of fish removed by angling. This is 14.6 pounds per acre. If bullheads and bowfin are excluded from these figures, the total annual yield of game fish removed by angling in 1951 was about 553.6 pounds, or 14.1 pounds per acre. The total yield of fish removed by all methods during the year of this experiment was 827.0 pounds, or 21.0 pounds per acre.

The above data result in an approximate exploitation rate by all methods of 8.0 percent and by angling alone of 5.4 percent. The annual yield varies tremendously. Ice fishing in the winter of 1949 and 1950 yielded a total of about 600 pounds of fish. How many additional pounds of fish were removed during the summer is unknown. Exploitation rates cannot be calculated because it is not known if the various species were present in past years in the same numbers that they are at present.

When the 1951 yield of fish caught by angling in Wintergreen Lake, 14.6 pounds per acre, is compared to data presented by Carlander (1950) and Rounsefell (1946), it is found that the harvest of fish is not outstanding. The figure from the lake is close to the average presented by these men. It would be an interesting experiment to allow increased fishing pressure on the lake. This would probably result in a much heavier yield without seriously depleting the large population already present.

SUMMARY

1. From April 21 to September 16, 1951, 3,924 fish were captured in Wintergreen Lake by angling and trap netting. Angling was a superior method of capturing largemouth bass, while netting was more successful for all other species present.

2. There was a high mortality of fish in the trap nets. Condition factor of fish removed from the nets was significantly lower than the condition factor of fish captured by angling. Mortality was considered to be caused by a combination of oxygen deficiency, net-caused abrasions, lowered physical vitality, and fungus infections.

3. The lake was divided into quarters by imaginary lines. Fish captured in each quarter were given a distinctive marking by removal of the appropriate fin. Fish captured by angling were marked by cutting the soft-rays of the dorsal fin and were released at the point of capture. Soft-rays of the dorsal fin were not cut on fish captured by netting. Netted fish were released at a central station.

4. Results of a statistical analysis of movements of largemouth bass suggested that this species exhibits a territorial tendency in this lake. Similar tests indicated that common bluegills and yellow bullheads distributed themselves randomly from the central release station and did not exhibit a statistically significant homing behavior. Recaptures of other species were insufficient to yield satisfactory movement patterns.

5. Comparison of the above data with similar investigations by Cooper (1951) on two other lakes showed that there were generally

similar behavior patterns of the fish with respect to redistribution after release.

6. Populations were estimated by the mark and recapture method, using the formulae of Schnabel (1938) and Schumacher and Eschmeyer (1943). Final figures were based on the average of the estimates derived by both methods. Confidence limits were applied to the former method and limits of one standard error to the latter. Explanation of the methods and sources of error were presented.

7. Population estimates were based on fish considered to be of a "desirable size" for the angler to catch and to use as food.

8. Estimates of the population of "desirable size" game and pan fish, followed by their mean standard length in centimeters and weight in grams were: Common bluegill, 13,046 (16.28 and 203.4); largemouth bass, 2,616 (24.50 and 327.4); common sunfish, 3,267 (14.93 and 174.2); yellow perch, 2,213 (19.94 and 150.1); and common sunfish X common bluegill hybrid, 712 (14.60 and 176.9). Population estimates of yellow bullheads and bowfin followed by mean total length in centimeters and weight in grams were: Yellow bullhead, 167 (32.46 and 521.3) and bowfin, 46 (56.90 and 1611.3).

9. The estimated standing crop of "desirable size" fish present 10,358.2 pounds, or 263.5 pounds per acre. By subtracting the weight of the standing crop of yellow bullheads and bowfin the total of game and pan fishes alone was 254.4 pounds per acre. This latter figure is heavier than any standing crop of game and pan fishes listed by Rounsefell (1946) or Carlander (1950) for a natural lake.

10. The total annual yield for 1951 by all methods was 827.0 pounds,

or 21.0 pounds per acre, an exploitation rate of 8.0 percent. Angling alone removed 575.8 pounds, or 14.6 pounds per acre, an exploitation rate of 5.4 percent.

11. The length-frequency distributions showed that 49.8 percent of the largemouth bass were between 8.7 and 10.6 inches total length and 69.3 percent of the common bluegills were between 7.6 and 8.6 inches total length.

LITERATURE CITED

Ball, Robert C.
1944. A tagging experiment on the fish population of Third Sister Lake, Michigan. Trans. Amer. Fish. Soc. 74: 360-369.

Birge, E. A.
1904. The thermocline and its biological significance. Trans. Am. Micr. Soc. 25: 5-33.

Brower, Alfred D.
1952. Ms., Fisheries and Wildlife Dept., Mich. State Coll., East Lansing, Michigan.

Carlander, Kenneth D.
1950. Handbook of Freshwater Fishery Biology. William C. Brown Co., Dubuque, Iowa. v-281.

Clopper, C. J., and E. S. Pearson
1934. The use of confidence or fiducial limits applied to the case of the binomial. Biometrika 26: 404-413.

Cooper, Gerald P.
1935a. Age and growth of three species of game fishes in Wintergreen Lake on the W. K. Kellogg Bird Sanctuary, Kalamazoo County, Michigan. Mich. Dept. Conserv., Instit. Fish. Res., Unpub. Rept. #280: 3 typed pages.

. . . . . .
1935b. The fish fauna of Wintergreen Lake on the Kellogg Bird Sanctuary, Kalamazoo County, Michigan. Mich. Dept. Conserv., Instit. Fish. Res., Unpub. Rept. #289: 25 typed pages.

. . . . . .
1936a. Studies on the fish fauna of Wintergreen Lake, May 8 and 9, 1936. Mich. Dept. Conserv., Instit. Fish. Res., Unpub. Rept. #366: 6 typed pages.

. . . . . .
1936b. Fisheries investigations on Wintergreen Lake. Mich. Dept. Conserv., Instit. Fish. Res., Unpub. Rept. #366-A: 2 typed pages.

. . . . . .
1951. Estimating fish populations in Michigan Lakes. Mich. Dept. Conserv., Instit. Fish. Res., Rept. #1298: 21 typed pages. In press for the Trans. Amer. Fish. Soc. 81.

Dixon, Wilfrid J., and Frank J. Massey, Jr.
1951. Introduction to Statistical Analysis. McGraw Book Company, Inc., New York, N. Y. x-370.

Eschmeyer, R. W.
1942. The catch, abundance, and migration of game fishes in Norris Reservoir, Tennessee, 1940. Jour. Tenn. Acad. Sci. 12(1): 90-114.

Fetterolf, Carlos M., and Allan Hirsch
1951. Plankton counts from Wintergreen Lake, Kellogg Bird Sanctuary, Kalamazoo County, Michigan. Michigan State College, East Lansing, Michigan. Unpub. Rept.: 12 typed pages.

Foerster, R. E.
1935. The occurrence of unauthentic marked salmon. Biol. Board Canada, Progress Repts.(Pacific), 25: 18-20.

Fredin, Reynold A.
1950. Fish population estimates in small ponds using the marking and recovery technique. Iowa State Coll. Jour. Sci. 24(3): 363-384.

Funk, John
1942. The food of bluegills, perch, and pumpkinseeds from Wintergreen Lake, Michigan, for 1935-1938. Mich. Dept. Conserv., Instit. Fish. Res., Unpub. Rept. #790: 20 typed pages.

Hansen, Donald F.
1944. Rate of escape of fishes from hoopnets. Trans. Ill. State Acad. Sci. 37: 197-204.

Hubbs, Carl L., and Karl F. Lagler
1949. Fishes of the Great Lakes Region. Cranbrook Institute of Science, Bloomfield Hills, Michigan. xi-186.

Manges, Daniel E.
1950. Fish tagging studies in TVA storage reservoirs, 1947-1949. Jour. Tenn. Acad. Sci. 15(2): 126-140.

Martin, G. W.
---- A modified method of making plankton counts. Iowa State College, Ames, Iowa. Unpub. Rept.: 4 typed pages.

Petersen, C. G. J.
1896. The yearling immigration of young plaice into the Limfjord from the German Sea, etc. Rept. Danish Biol. Sta. for 1895. 6: 1-48.

Ricker, William E.
1937. The concept of confidence or fiducial limits applied to the Poisson frequency distribution. J. Amer. Statistical Assn. 32: 349-356.

. . . . . .
1942. Creel census, population estimates and rate of exploitation of game fish in Shoe Lake, Indiana. Invest. Ind. Lakes and Streams 2(12): 215-253.

. . . . . .
1948. Methods of estimating vital statistics of fish populations. Ind. Univ. Pub., Bloomington, Ind., Sci. Series #15: 1-101.

Rodeheffer, Immanuel A.
1939. Experiments in the use of brush shelters by fish in Michigan Lakes. Pap. Mich. Acad. Sci., Arts, and Lett. 24(II): 183-193.

. . . . . .
1940. The use of brush shelters by fish in Douglas Lake, Michigan. Pap. Mich. Acad. Sci., Arts, and Lett. 25: 357-366.

. . . . . .
1941. The movements of marked fish in Douglas Lake, Michigan. Pap. Mich. Acad. Sci., Arts, and Lett. 26: 265-280.

Rounsefell, G. A.
1946. Fish production in lakes as a guide for estimating production in proposed reservoirs. Copeia 1946(1): 29-40.

Schnabel, Zoe E.
1938. Estimation of the total fish population of a lake. Amer. Math. Monthly, 45(6): 348-352.

Schumacher, F. X., and R. W. Eschmeyer
1942. The recapture and distribution of tagged bass in Norris Reservoir, Tennessee. Jour. Tenn. Acad. Sci. 17(3): 253-268.

. . . ., and . . . .
1943. The estimate of fish populations in lakes and ponds. Jour. Tenn. Acad. Sci. 18(3): 228-249.

Scott, I. D.
1921. Inland Lakes of Michigan. Mich. Geol. and Biol. Sur. Pub. #30, Geol. Series 25. Wynkoop Hallenbeck Crawford Co., State Printers, Lansing, Mich. xxi-383.

Shetter, David S.
1936. Results from tagging operations on Wintergreen Lake, Kellogg Bird Sanctuary, Kalamazoo County, Michigan. Mich. Dept. Conserv., Instit. Fish. Res., Unpub. Rept. #305: 7 typed pages.

Simpson, George G., and Anne Roe
1939. Quantitative Zoology. McGraw-Hill Book Co., New York, N. Y. xvii-414.

Snedecor, George W.
1950. Statistical Methods. Iowa State Coll. Press, Ames, Iowa. vii-485.

Staebler, Arthur E.
1948-51. Annual Reports of the Kellogg Bird Sanctuary, Hickory Corners, Michigan. Unpublished Ms.

Thompson, David H., and George W. Bennett
1939. Fish management in small artificial lakes. Trans. N. Amer. Wildlife Conf. 4: 311-317.

Welch, Paul S.
1935. Limnology. McGraw-Hill Book Co., New York, N. Y. xiv-471.