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Institute for Fisheries Research
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October 8, 1951



Supplement to Report No. 1298
# 1298a

# ESTIMATING FISH POPULATIONS IN MICHIGAN LAKES

By

Gerald P. Cooper

## Preface

Institute report No. 1298 was written for publication in the Transactions of the American Fisheries Society. Because of limitations of space, the report was brief. It seems desirable to have a more detailed record of the methods and of the tabular data of this study, in the Institute Report series, in the form of this supplement.

Four figures included in the report are referred to in this supplement but not repeated here. Tables are numbered by a continuation of the numbers used in the report proper. For literature cited, see the report proper.

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## Abstract

One addition might be made to the abstract given at the beginning of the report.

The population study on Fife Lake gave figures on the survival of hatchery plantings of smallmouth bass fingerlings. During 1946 to 1948, a total of 25,709 smallmouth fingerlings were planted in the lake. These were fin-clipped for later recognition. During the netting in 1950, 198 smallmouth bass over 6 inches long were collected, of which 16 were survivors from the marked plantings. Allowing for error because of fin-regeneration (the amount was determined by control lots of fish), the following computations were made: Number of "adult" smallmouth in the lake in 1950 was 7,264 of which 654 (or 9%) were survivors of the hatchery plantings. These 654 bass represent a survival of 2 1/2 percent of the 25,709 fish planted in 1946 to 1948.

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## A POPULATION STUDY OF FISH IN SUGARLOAF LAKE, WASHTENAW COUNTY

A special study is being made of fish and fishing in Sugarloaf Lake. A five-year experiment of liberalized fishing regulations was begun in 1946. The first of an anticipated series of population estimates by netting was made in October and November of 1948.[1] The population study was repeated in the spring of 1949 and again in the spring of 1950. Between the start of the experiment on regulations in March, 1946, and the time of the first population study, fishermen had two seasons of ice fishing during winter and three seasons of open-water fishing during spring to fall.

Under the experimental regulations there were no closed seasons on panfish; bass fishing was permitted from June 25 to December 31; the open season for northern pike was May 15 to March 15; and the usual size and creel limits on all species, as for non-trout inland lakes, remained in effect. A 6-inch legal size limit on panfish, in effect on Sugarloaf Lake as well as on a state-wide basis, was discontinued by legislative act effective September 23, 1949.

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[1] Important contributions to this study, in 1948, were made by the late Henry E. Predmore, Jr.

The purpose of making the population study has been to aid in evaluating the results of the liberalized-fishing experiment. A creel census of the fishing is giving data on total catch and fishing quality. The population study is designed to show the numbers of fish present in the lake. Together, the two studies should reveal the rate of exploitation by fishing.

## Lake Features

Sugarloaf Lake is located in sections 31 and 32 of T. 1 S., R. 3 E., Washtenaw County. The lake lies within the Waterloo Recreation Area, a large area of state-owned land being managed by the Conservation Department as a multi-purpose project. Government ownership of the area was originally Federal, but ownership was transferred recently to the State. There are some privately owned lands within the Area boundaries.

The lake has an area of 180 acres. It is relatively shallow, with most of the area less than 5 feet deep. The maximum depth is 20 feet. (Figure 1.) Much of the bottom supports a lush growth of chara and in late summer pondweeds are thick in parts of the lake. The southeast shoals contain mostly bulrushes in water depths of one to two feet, and there are patches of this vegetation on the north and northeast shoals. Bottom materials vary from muck to sand and rubble. Hard bottom extends from the southeast shore northward to the northeast shore. Most of the soft bottom is found along the western shore.

Approximately 80 cottages occupy most of the suitable, privately owned frontage lots. Part of the western shore is swampy. A public fishing site on the southwest shore and a boat livery provide public access. Fishing pressure is fairly heavy. Most of the summer angling is by local residents. The majority of non-local anglers fish in the wintertime.

Fish Population Estimate, Fall of 1948

Equipment and Procedure

Trap nets of two sizes were used in this study. (A) A three-foot net; single pot 3' wide, 3' deep, and 6' long, 1 1/2" mesh (in some nets) and 2 1/2" mesh (in other nets) (all mesh sizes here given as stretched), #12 thread seine twine; wings plus hearts 12' x 3' with 3" mesh; lead 100' x 3' with 3" mesh; #9 thread seine twine elsewhere than in pot; without spreader. (B) A six-foot trap net; with double pots, each pot 6' wide, 4' deep, and 8' long, the back pot with mesh 2 1/2" stretched, the front pot with 3" mesh, both pots of #15 thread seine twine; wings plus hearts 20' x 4' with 4" mesh; lead 150' to 165' x 4' with 4" mesh; #12 thread seine twine elsewhere than in pots; net rigged with single spreader.

A high-sided, 16-foot dinghy, with seats removed, was used in setting and lifting nets. A 5-h.p. outboard motor powered the boat and assisted in tightening nets.

The field work was done by a three-man crew: Messrs. G. F. Myers, R. C. Barber and D. F. Thomas. Two men could lift the nets, but the marking and releasing operations were made easier with a third man.

The technique of the population study was to capture fish by nets, mark them by fin-clipping for later recognition, release them to the lake, and then continue the netting until a large number of recaptures (of marked fish) had been included in the total catch. The marked and unmarked fish were recorded separately, and the data were used to calculate, by proportion, the total number of fish in the lake. This method (the Petersen Method) has been used many times by fisheries workers generally, but it involves certain assumptions on fish movements which are not yet proven or completely understood. Principally, one must assume a random distribution and/or susceptibility to netting among marked and unmarked fish (Ricker, 1948).

The use of a single point of release for marked fish is of special significance.

To better understand the sources of bias in the method, a large number of netting stations were established; also, the lake was arbitrarily divided into two halves (east and west), and the fish from the two halves were marked differently so as to give a check on the amount of movement of fish throughout the lake. There were 15 stations in each half of the lake (Fig. 1): 8 A-stations plus 7 B-stations in the west half, and 7 A-stations plus 8 B-stations in the east half. Three-foot trap nets were fished at stations in the A series, and six-foot nets at B-stations.

Generally, a given net was set at a station for three nights, and fish were collected on three successive days. The net was then reset at the next unoccupied station in sequence, i.e., A-1 west, A-1 east, A-2 west, A-2 east, etc. An orderly sequence was planned which involved starting an A-net and a B-net, in different halves of the lake, on the first day of the netting period; followed by starting another pair on the second day and another on the third; followed by moving the first two nets on the fourth day, and so on. It was then possible to alternate the two types of nets between the two halves of the lake so that there were constantly 3 nets in each half of the lake, and also in each half the combinations of two large nets plus one small one and two small nets plus one large one were alternated on every consecutive second day. This planned sequence was followed closely, except for some irregularity at the start (Table 5). A central release station for marked fish was established by marker near the center of the lake, on the dividing line (Fig.1b).

Table 5

Schedule of operating trap nets in Sugarloaf Lake, fall of 1948

A= three-foot trap nets, B= six-foot trap nets. Stations numbered 1 to 7 or 8 in west half (W) or east half (E) of the lake, see Figure 1. B-3WN and B-3WS refer to north and south pots at B-3W. X= days when nets were fished. O= days when nets were in water but were not fishing. Nets set at one station over 3 nights were moved on the 4th day.

| Net and station | October | | | | | | | | | | | | November | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| A-1W | x | x | x | x | | | | | | | | | | | | | | | x | x | x | x | x | 0 | x | x | x | x | x | x | x | x | x | x | x | x |
| A-2W | | | | x | x | x | x | | | | | | | | | | x | x | x | x | x | x | | | | | | | | | | | | | | |
| A-3W | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-4W | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-5W | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | |
| A-6W | | | | | | | | | | | | x | | x | x | x | | | | | | | | | | | | | | | | | | | | |
| A-7W | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | |
| A-8W | | | | | | | | | | | | | | | x | x | x | x | x | | | x | x | 0 | x | x | x | x | x | x | x | x | x | x | x | x |
| B-1W | x | x | x | x | | | | | | | | | | | | x | x | x | x | x | x | | | | | | | | | | | | | | | |
| B-2W | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B-3W | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B-4W | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B-5W | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | |
| B-6W | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | |
| B-7W | | | | | | | | | | | | | | x | x | x | x | | | | | x | x | 0 | x | x | x | x | x | x | x | x | x | x | x | x |
| B-3WN | | | | | | | | | | | | | | | | | | | | x | x | x | x | 0 | x | x | x | x | x | x | x | 0 | x | x | x | x |
| B-3WS | | | | | | | | | | | | | | | | | | | | x | x | x | x | 0 | x | x | x | x | x | x | x | 0 | x | x | x | x |
| A-1E | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-2E | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-3E | | | | | | x | x | x | x | | | | | | | x | x | x | x | x | x | | | | | | | | | | | | | | | |
| A-4E | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-5E | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | |
| A-6E | | | | | | | | | | | x | x | x | x | | | | | | | x | x | x | 0 | x | x | x | x | x | x | x | x | x | x | x | x |
| A-7E | | | | | | | | | | | | | | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | x | x | x |
| B-1E | x | x | x | x | | | | | | | | | | | x | x | x | x | x | x | x | x | | | | | | | | | | | | | | |
| B-2E | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B-3E | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B-4E | | | | | | | | x | x | x | x | | | | | | | | | | x | x | x | 0 | x | x | x | x | x | x | x | x | x | x | x |
| B-5E | | | | | | | | | x | x | x | x | | | | | | | | | x | x | x | 0 | x | x | x | x | x | x | x | x | x | x | x |
| B-6E | | | | | | | | | | | | x | | x | x | x | | | | | | | | | | | | | | | | | | | |
| B-7E | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | |
| B-8E | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | |

At most stations the orientation of the net was with the lead extending from the pot towards the nearest shore. Exceptions to this usual procedure occurred when strong winds interfered with the operation. Since the lake is uniformly very shallow (mostly 3 to 10 feet), except for one spot where the water is 20 feet deep, the netting was done entirely in shallow water.

Using three trap nets of each type, netting was started on October 20, and by November 5 to 8 one round of the 30 netting stations had been completed (a net set for three days at each station). For the remainder of the netting period, through November 24, nine trap nets (4 three-foot, and 5 six-foot) were fished quite continuously, principally at stations A-1W, A-8W, B-3W, B-7W, A-6E, A-7E, B-4E, and B-5E. During the late-season netting at station B-3W, two pots were fished at opposite ends of one lead; and these two pots are recorded as separate nets in Table 1, i.e., B-3WN and B-3WS (north and south).

Records on fish were kept separately for each net station. All fish taken by nets were fin-clipped, transported to the central release point and liberated; recaptures were not marked a second time and were liberated also at the common release station. Initial captures in the west half of the lake were marked by removal of the distal one-half of the soft dorsal fin ( of spiny-rayed species) or the distal half of the posterior half of the dorsal fin (of soft-rayed species). Fish caught in the east half of the lake were marked by removal of the entire soft dorsal (of spiny-rayed fish) or the entire posterior half of the soft dorsal (of soft-rayed fish). Thus all recaptured fish could be distinguished as to which half of the lake was their initial location of capture. There is no basis for suspecting that fin-regeneration during the 35-day netting period might have interfered with recognition of marked fish. Individual length

measurements and combined (lot) weights were taken on a generous sample of fish from the lake. There was no observed mortality of any of the fish netted and released. The fact that the work was done while water temperatures (records were taken) were cool was a favorable factor.

## Computations[2]

The method used here to calculate total fish population from the netting and recapture records, as stated above, is based on a simple idea. A known number of marked fish are released in the lake. Then a sample of fish is again collected. The relative numbers of marked and unmarked fish in this sample, and the total number of marked fish known to be present, are used to compute the total number of unmarked fish present, hence the total. The method is based on the assumption that there will be proportionate distribution of marked fish throughout the population of unmarked fish, from which the subsequent sample is drawn; or else that there is a random distribution over the lake of numerous collection stations which would compensate for a failure on the part of marked fish to migrate extensively. The method would be completely worthless if the fish showed a strong homing tendency for their original net site, and if, in addition, netting was done at relatively few stations.

The total population could be computed by a simple, 4-item formula, if it were possible to collect very large numbers of fish in a short time, say several thousand fish in 3 or 4 days. But equipment and personnel are usually limited to several nets and a three- or four-man crew, and collection of adequate numbers of fish ordinarily has been found to involve a period of several weeks. Therefore mathematical methods have been developed to handle data on rather small daily numbers of fish, and to average such

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[2] Assistance in laboratory analysis of the records was given by some members of the field crew and by R. N. Schafer and K. E. Christensen.

data, collected during an extended period, into a composite calculation of the total population. At least two mathematical approaches to this procedure have been used.

One approach has been credited to unpublished work of D. H. Thompson of Illinois (Krumholz, 1944). It was described mathematically by Schnabel (1938), employed by Krumholz (op. cit.), and has been used by W. R. Crowe and outlined by him (1947) in Institute for Fisheries Research Methods Memorandum No. 3 (mimeographed). A second approach has been outlined by Schumacher and Eschmeyer (1943). Both approaches have been used on the records for Sugarloaf Lake, but mostly only the results obtained by the Schumacher method (Schumacher and Eschmeyer, op. cit.) are recorded.

The present study is concerned only with "legal-size" fish, the limits being set at 14 inches for pike and 6 inches for bluegills, perch, crappies, other panfish, bullheads, dogfish and largemouth bass. Very few "sublegal" fish were caught by the trap nets. The daily catch of each species in all nets was tabulated, with separate records for recaptures and for fish which were captured for the first time (Table 6).

Application of the Schumacher method in calculating the total population of each species is illustrated by the data for bluegills (Table 7). The following formulae are involved:

$$P \text{ (total population)} = \frac{\Sigma\left[n^2 \ (m + u)\right]}{\Sigma(nm)}$$

$$S^2 \text{ (variance)} = \frac{1}{k-1}\left[\Sigma\left(\frac{m^2}{(m + u)}\right) - \frac{1}{P}\Sigma(nm)\right]$$

$$= \frac{1}{k-1}\left[\Sigma\left(\frac{m^2}{m + u}\right) - \frac{\left[\Sigma(nm)\right]^2}{\Sigma\left[n^2 \ (m + u)\right]}\right]$$

$$\sigma_e \text{ (standard error)} = P\sqrt{\frac{P \ S^2}{\Sigma(nm)}}$$

$$= \frac{\Sigma\left[n^2 \ (m + u)\right]}{\Sigma(nm)}\sqrt{S^2 \ \frac{\Sigma\left[n^2 \ (m + u)\right]}{\left[\Sigma(nm)\right]^2}}$$

in which:

u = number of fish caught each day, not including marked recaptures.

n = accumulating daily total of number of fish initially caught (then marked and released), minus the number of marked fish removed from the lake population (fishing and all other mortality), at the beginning of the day in question. Stated more simply, n is the number of marked live fish present in the lake at the beginning of a particular day.

m = number of marked fish recaptured on the particular day.

$\Sigma$ = sum of the daily values for k days.

k = the number of daily items of $n^2$ (m + u), i.e., the number of days, after the first, on which fish were caught.

The standard error of each estimate, computed by the above formulae, gives an indication of the degree of accuracy of the estimate. There is 68 percent probability that the true population figure is within the range of plus or minus one standard error.

The population estimates and their standard errors for "legal-size" fish are given in Table 8, where a summation gives an estimate of total population for all species. In this table, numbers of fish are also converted

Table 6

Daily tabulation of number of fish of "legal" size[1] initial captures (u) and recaptures (m) listed separately, by species, all nets combined, Sugarloaf Lake, fall of 1948.

| Date Oct.-Nov. | Bluegill | | Large-mouth bass | | Rock bass | | Pumpkin-seed | | Bullhead[2] | | Black Crappie | | Bowfin | | Northern pike | | Gar pike | | Warmouth | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m |
| 21 | 61 | | 2 | | 1 | | 1 | | 18 | | 16 | | 1 | | 1 | | | | 4 | | 105 | 0 |
| 22 | 35 | | 2 | | 3 | | 2 | | 25 | | 9 | | 4 | | 1 | | | | | | 81 | 0 |
| 23 | 30 | | | | 2 | | 1 | | 32 | 2 | 6 | | 4 | | 1 | | | | 2 | | 78 | 2 |
| 24 | 17 | | 2 | | 2 | | 1 | | 11 | 3 | 8 | | | | 2 | | | | | | 43 | 3 |
| 25 | 24 | | 2 | | 4 | | 1 | | 20 | 3 | 9 | 1 | 2 | | 1 | | | | 3 | | 66 | 4 |
| 26 | 35 | 1 | 5 | | 15 | | 2 | | 23 | 8 | 13 | 1 | 2 | | 1 | | | | 4 | | 100 | 10 |
| 27 | 52 | | 4 | | 4 | | 9 | | 24 | 14 | 8 | 1 | 3 | | 1 | | | | 4 | | 109 | 15 |
| 28 | 86 | 3 | 7 | | 4 | | 5 | | 23 | 10 | 20 | 2 | | | 1 | | | | 3 | | 149 | 15 |
| 29 | 53 | | 18 | | 1 | | 8 | | 9 | 15 | 22 | 3 | 2 | | 1 | | 1 | | 2 | | 117 | 18 |
| 30 | 40 | | 11 | 1 | 2 | | 3 | | 22 | 9 | 14 | 3 | 1 | | 2 | | | | 2 | | 97 | 13 |
| 31 | 31 | 2 | 8 | | 1 | | 3 | | 20 | 9 | 3 | 1 | 5 | | | | | | 2 | | 73 | 12 |
| 1 | 40 | 1 | 6 | | 2 | | 2 | | 12 | 2 | 7 | 6 | 1 | | | | 18 | | 1 | | 89 | 9 |
| 2 | 49 | | 2 | | 1 | | 1 | | 12 | 6 | 3 | 2 | 2 | | | | 2 | | | | 72 | 8 |
| 3 | 62 | 3 | 4 | | | 1 | 2 | 1 | 14 | 12 | 2 | 1 | | | | | 1 | 1 | 2 | | 87 | 19 |
| 4 | 67 | 3 | 5 | | 1 | | 2 | | 12 | 8 | 6 | 3 | 5 | | | | | | 1 | | 99 | 14 |
| 5 | 80 | 2 | 5 | | 5 | | 6 | | 13 | 17 | 2 | 2 | 2 | | | | | | | | 113 | 21 |
| 6 | 46 | | 4 | | 3 | | 2 | | 14 | 11 | 7 | 2 | | | | | | | | | 76 | 13 |
| 7 | 35 | 1 | 1 | | 8 | | | | 10 | 15 | 2 | | 5 | | | | | | | | 61 | 16 |
| 8 | 23 | | 2 | | 2 | | 1 | 1 | 12 | 11 | 2 | 1 | 1 | | | | | | | | 43 | 13 |
| 9 | 55 | 6 | 10 | 1 | 4 | | 2 | | 20 | 29 | 10 | 2 | | | | | | | 1 | | 102 | 38 |
| 10 | 32 | 5 | 5 | | | 1 | 2 | | 6 | 20 | 8 | 3 | 2 | | 1 | | | | | | 56 | 29 |
| 11 | 24 | 3 | 1 | | 2 | | | | 4 | 8 | 6 | 1 | 2 | | | | | | 1 | | 40 | 12 |
| 12 | | | | | | | | | | | | | | | | | | | | | 0 | 0 |
| 13 | 26 | 3 | 1 | | 5 | | 1 | | 10 | 18 | 5 | 1 | 8 | | 1 | | | | 2 | | 59 | 22 |
| 14 | 14 | 1 | | | 3 | | | | 4 | 10 | 5 | 3 | 1 | | | | | | 1 | | 28 | 14 |
| 15 | 8 | | 3 | | | | | | 1 | 4 | 2 | 2 | 1 | | 1 | | | | | | 16 | 6 |
| 16 | 24 | 2 | 4 | 1 | 2 | | | | 3 | 4 | 4 | 4 | 3 | | | 1 | | | 2 | | 42 | 12 |
| 17 | 10 | | 3 | 1 | 2 | | | | 6 | 19 | 3 | 2 | 1 | 2 | | | | | 3 | | 28 | 24 |
| 18 | 2 | 1 | 6 | | | 1 | 2 | | 4 | 7 | 2 | 4 | 2 | | 2 | | | | | | 20 | 13 |
| 19 | 3 | 3 | 3 | | 1 | | | | 3 | 12 | 1 | 2 | 2 | | | | | | | | 22 | 17 |
| 20 | 5 | 1 | | | 1 | | 1 | | 3 | 6 | 3 | 2 | 5 | 3 | | | | | | | 18 | 12 |
| 21 | 14 | 2 | 9 | 1 | 1 | | | | 13 | 26 | 4 | 4 | 11 | 1 | | 1 | | | 1 | | 53 | 35 |
| 22 | 9 | 1 | | | | | | | 2 | 6 | 4 | 1 | 1 | | 1 | | | | | | 17 | 8 |
| 23 | 4 | 2 | 1 | | | | | | 2 | 3 | 2 | | 1 | | 1 | | | | | | 11 | 5 |
| 24 | 8 | | | | | | | | 2 | 7 | | 1 | | | | | | | | | 10 | 8 |
| Total | 1113 | 46 | 136 | 5 | 82 | 3 | 60 | 2 | 409 | 334 | 218 | 61 | 80 | 6 | 19 | 2 | 22 | 1 | 41 | 0 | 2180 | 460 |

[1] Partially arbitrary limits set at 14 inches for northern pike and 6 inches for all other species.

[2] Mostly yellow bullhead, but few brown bullhead included.

Table 7

Population estimation of legal-size bluegills, Sugarloaf Lake, fall of 1948, following the method of Schumacher and Eschmeyer (1943).

| Date | n | m | m+u | $n^2$ (m+u) | nm | $\frac{m^2}{m+u}$ |
|---|---|---|---|---|---|---|
| October | | | | | | |
| 21 | .. | .. | 61 | .. | .. | ... |
| 22 | 61 | .. | 35 | 130,235 | 0 | 0.0 |
| 23 | 96 | .. | 30 | 276,480 | 0 | 0.0 |
| 24 | 126 | .. | 17 | 269,892 | 0 | 0.0 |
| 25 | 143 | .. | 24 | 490,776 | 0 | 0.0 |
| 26 | 167 | 1 | 36 | 1,004,004 | 167 | 0.027778 |
| 27 | 202 | .. | 52 | 2,121,808 | 0 | 0.0 |
| 28 | 254 | 3 | 89 | 5,741,924 | 762 | 0.101124 |
| 29 | 340 | .. | 53 | 6,126,800 | 0 | 0.0 |
| 30 | 393 | .. | 40 | 6,177,960 | 0 | 0.0 |
| 31 | 433 | 2 | 33 | 6,187,137 | 866 | 0.121212 |
| November | | | | | | |
| 1 | 464 | 1 | 41 | 8,827,136 | 464 | 0.024390 |
| 2 | 504 | .. | 49 | 12,446,784 | 0 | 0.0 |
| 3 | 553 | 3 | 65 | 19,877,585 | 1,659 | 0.138462 |
| 4 | 615 | 3 | 70 | 26,475,750 | 1,845 | 0.128571 |
| 5 | 682 | 2 | 82 | 38,140,168 | 1,364 | 0.048780 |
| 6 | 762 | .. | 46 | 26,709,624 | 0 | 0.0 |
| 7 | 808 | 1 | 36 | 23,503,104 | 808 | 0.027778 |
| 8 | 843 | .. | 23 | 16,344,927 | 0 | 0.0 |
| 9 | 866 | 6 | 61 | 45,747,316 | 5,196 | 0.590164 |
| 10 | 921 | 5 | 37 | 31,384,917 | 4,605 | 0.675676 |
| 11 | 953 | 3 | 27 | 24,521,643 | 2,859 | 0.333333 |
| 12 | .. | .. | .. | .. | .. | .. |
| 13 | 977 | 3 | 29 | 27,681,341 | 2,931 | 0.310345 |
| 14 | 1,003 | 1 | 15 | 15,090,135 | 1,003 | 0.066667 |
| 15 | 1,017 | .. | 8 | 8,274,312 | 0 | 0.0 |
| 16 | 1,025 | 2 | 26 | 27,316,250 | 2,050 | 0.153846 |
| 17 | 1,049 | .. | 10 | 11,004,010 | 0 | 0.0 |
| 18 | 1,059 | 1 | 3 | 3,364,443 | 1,059 | 0.333333 |
| 19 | 1,061 | 3 | 15 | 16,885,815 | 3,183 | 0.600000 |
| 20 | 1,073 | 1 | 6 | 6,907,974 | 1,073 | 0.166667 |
| 21 | 1,078 | 2 | 16 | 18,593,344 | 2,156 | 0.250000 |
| 22 | 1,092 | 1 | 10 | 11,924,640 | 1,092 | 0.100000 |
| 23 | 1,101 | 2 | 6 | 7,273,206 | 2,202 | 0.666667 |
| 24 | 1,105 | .. | 8 | 9,768,200 | 0 | 0.0 |
| Totals | | | | 466,589,640 | 37,344 | 4.864793 |

$$P = \frac{\Sigma[n^2 (m+u)]}{\Sigma (nm)} = \frac{466,589,640}{37,344} = 12,494$$

$$s^2 = \frac{1}{k-1}\left[\Sigma\left(\frac{m^2}{m+u}\right) - \frac{1}{P}\Sigma(nm)\right] = \frac{1}{32}\left[4.864793 - \frac{(37344)^2}{466,589,640}\right] = 0.058623$$

$$\sigma_e = P\sqrt{\frac{Ps^2}{\Sigma(nm)}} = 12,494\sqrt{\frac{732.4358}{37,344}} = 12,494\sqrt{0.019613} = 1,749$$

$k = 33$

to pounds of fish, and pounds of fish per acre, based on data on average weights of fish handled during the netting operations (Table 9).

In the bottom line of Table 8 are given the estimates of total population obtained by the Schnabel method. The Schnabel method gave regularly somewhat higher (but not greatly different) estimates than the Schumacher formula.

The question arises as to the relative accuracy of two procedures which might be used in calculating the total population of fish of all species in a lake. One method is to compute estimates for each species separately and obtain a total by addition. A second method would be to add the daily totals of fish caught, and then make a single computation of population for all species combined (e.g., applying the method of Table 7 to the daily totals for all fish given in Table 6). The second procedure gave a population estimate for total "legal-size" fish of 6397 ± 344. This is considerably less than the total (17,648) obtained by addition of separate estimates for species. The reason for the lower, and erroneous, estimate by the lumping method is that undue weight is given to the high recapture figures for species (specifically the bullheads) which showed a high percentage of recaptures. The cause of error is readily understood by working out the computations of a simple example (See Crowe, 1947). Some species are more readily captured in nets than are others (See Table 11), and it is therefore essential that population estimates be computed for each species separately.

For certain species, so few individuals were collected (reflecting rarity) that the data do not give useful estimates of populations, or at least one would be reluctant to place much confidence in the figures. This was true to varying degrees for the warmouth (no recaptures), gar pike, northern pike, bowfin, pumpkinseed, rock bass, and largemouth bass. In fact, rather precise estimates were obtained only for the

Table 8

Computed estimates (by Schumacher method) of total numbers of "legal-size" fish[1] by species, Sugarloaf Lake, fall of 1948, with standard error and probability range of estimates, and with population numbers converted to total pounds and pounds-per-acre[2] from average weights.

| | Bluegill | Large-mouth bass | Rock bass | Pumpkin-seed | Bull-head[3] | Black Crappie | Bowfin | Northern pike | Gar pike[4] | Total[5] |
|---|---|---|---|---|---|---|---|---|---|---|
| Total number | 12,494 | 1,718 | 972 | 775 | 543 | 511 | 478 | 80 | 77 | 17,648 |
| St. error | 1,749 | 416 | 704 | 420 | 18 | 41 | 143 | 40 | 50 | .. |
| Range: Max. | 14,243 | 2,134 | 1,676 | 1,195 | 561 | 552 | 621 | 120 | 127 | .. |
| Min. | 10,745 | 1,302 | 268 | 355 | 525 | 470 | 335 | 40 | 27 | .. |
| Total pounds | 3,286 | 2,215 | 316 | 222 | 350 | 187 | 1,940 | 107 | .. | 8,623 |
| Max. | 3,746 | 2,751 | 545 | 343 | 362 | 202 | 2,521 | 160 | .. | .. |
| Min. | 2,826 | 1,678 | 87 | 102 | 339 | 172 | 1,360 | 53 | .. | .. |
| Pounds/acre | 18.3 | 12.3 | 1.8 | 1.2 | 1.9 | 1.0 | 10.8 | 0.6 | .. | 47.9 |
| Max. | 20.8 | 15.3 | 3.0 | 1.9 | 2.0 | 1.1 | 14.0 | 0.9 | .. | .. |
| Min. | 15.7 | 9.3 | 0.5 | 0.6 | 1.9 | 1.0 | 7.6 | 0.3 | .. | .. |
| Total population (Schnabel method) | 13,702 | 1,847 | 1,656 | 864 | 537 | 527 | 563 | 100 | 98 | 19,894 |

[1] Warmouth not included.

[2] Lake area equals 180 acres.

[3] Brown bullhead and yellow bullhead collectively, mostly the latter.

[4] No data on average weight for Gar pike.

[5] Totals in this table are derived by adding the values computed for individual species.

Table 9

Average weight of "legal-size" fish, by species, from Sugarloaf Lake, fall of 1948, based on aggregate weighing of samples of each species collected during the population study.

| Species | Number weighed | Average weight:ozs. | Average weight:lbs. |
|---|---|---|---|
| Bluegill | 475 | 4.21 | 0.263 |
| Largemouth bass | 79 | 20.62 | 1.289 |
| Rock bass | 10 | 5.20 | 0.325 |
| Pumpkinseed | 27 | 4.59 | 0.287 |
| Bullhead[1] | 223 | 10.32 | 0.645 |
| Black crappie | 106 | 5.86 | 0.366 |
| Bowfin | 16 | 64.94 | 4.059 |
| Northern pike | 3 | 21.33 | 1.333 |
| Longnose gar | .. | .. | .. |
| Warmouth | 7 | 6.29 | 0.393 |

[1] *Ameiurus nebulous* and *A. natalis*, not differentiated; mostly the latter.

bluegill, bullhead (2 species collectively) and black crappie. But the latter are among the more abundant and more important species (particularly the bluegill), and the other species are of relatively less consequence. A greater number of returns on largemouth bass would have been especially helpful.

The high frequency of recapture of bullheads was outstanding, which is explainable by the well-known habit of these fish to "hole up" in objects which afford cover--in this instance, the trap nets. A strong "homing" tendency by the bullheads would be another possibility, except that analysis of recovery records (below) did not show that such a tendency was operating. Carlander and Lewis (1948) have noted a habit of the black bullhead which interfered with a similar population estimate, in a small pond in Iowa; an erroneously small estimate was caused by a large portion of the bullhead population being inactive in the bottom mud. That this was a major factor on Sugarloaf Lake seems highly improbably, in view of the results of three population estimates described in this report. The separate estimates (543, 374 and 992) have a significant degree of uniformity, and the estimates were made in early fall or late spring when fish generally are active.

Since the validity of the mark-and-recapture procedure depends upon the marked fish being redistributed at random, or, as an alternative, upon a random distribution of collecting stations, we might be satisfied if only one of the conditions were met. However, a precise knowledge of both problems is needed, and if neither condition is met, the estimate is biased. If, for example, individual fish were mostly non-migratory and became established in some ecological niche in the lake with a very limited geographical range of movement, and if this were coupled with

a strong homing instinct on the part of the fish to return to the point of first capture, then one would be estimating mostly only the populations close to the netting stations, i.e., fish whose restricted movements were intercepted by the collecting gear; an additional increment, probably small, would be represented by captures of fish en route from release station to "home." A substantial part of the population might be found in the areas (interstices) between the effective "fields" of the netting stations, and such fish would not be included in the estimate.

The operation at Sugarloaf Lake was designed to circumvent some of these difficulties and to give a quantitative measure of others. The employment of netting stations and the rotation pattern of netting were for the purpose of getting random distribution of collections over the lake and at closely spaced geographical locations. Marking fish differently from the two halves of the lake and noting the origins of subsequent recoveries gave a measure of the homing tendency. It might have been ideal to mark fish at each of the 30 stations distinctively, but this seemed impractical because of the large number of stations, and unjustified in view of what might be learned by marking separately for the two halves of the lake only.

An analysis of markings and recaptures, according to the two halves of the lake, is summarized in Tables 10 and 11. Of 2,180 fish marked and released, 1,199 were originally caught in the west half of the lake, 981 in the east half. From the 1,199 fish marked in the west, there were 181 (15.1 %) recoveries in the west and 96 (8.0 %) recoveries in the east; and from the 981 fish marked in the east, there were 112 (11.4 %) recoveries in the west and 70 (7.1 %) recoveries in the east. Thus a significant preponderance of west recaptures was matched by a significant excess of east departures. A Chi-square test on the ratios 181:96 and

Table 10

Tabulation of numbers of "legal-size" fish recovered in the "West" and "East" halves of Sugarloaf Lake (fall of 1948) according to the half of the lake (E = east; W = west) where originally they were caught and marked.

| Species[1] | | Bluegill | | | | Bullhead | | | | Black Crappie | | Largemouth bass | | | | Rock bass | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Recovered | | West | | East | | West | | East | | West | | East | | | | West | | East | |
| Marked | | E | W | E | W | E | W | E | W | E | W | E | W | E | W | E | W | E | W |
| Oct. | 21 | | | | | | | | | | | | | | | | | | |
| | 22 | | | | | | | | | | | | | | | | | | |
| | 23 | | | | | | 1 | 1 | | | | | | | | | | | |
| | 24 | | | | | 1 | 1 | | 1 | | | | | | | | | | |
| | 25 | | | | | | 2 | 1 | | | | 1 | | | | | | | |
| | 26 | | 1 | | | 3 | 2 | | 3 | | | | 1 | | | | | | |
| | 27 | | | | | 2 | 6 | 4 | 2 | | 1 | | | | | | | | |
| | 28 | | 1 | | 2 | | 6 | 2 | 2 | | | 2 | | | | | | | |
| | 29 | | | | | 1 | 3 | 2 | 9 | | | 2 | 1 | | | | | | |
| | 30 | | | | | 2 | 4 | 1 | 2 | | | 3 | | | 1 | | | | |
| | 31 | | | | 2 | 2 | 6 | | 1 | 1 | | | | | | | | | |
| Nov. | 1 | | | 1 | | | 1 | | 1 | 1 | 1 | 3 | 1 | | | | | | |
| | 2 | | | | | | 1 | 2 | 3 | 1 | | 1 | | | | | | | |
| | 3 | 3 | | | | 2 | 3 | 3 | 4 | | | 1 | | | | | | | 1 |
| | 4 | 1 | | 2 | | 1 | 2 | 1 | 4 | 1 | | 2 | | | | | | | |
| | 5 | 1 | 1 | | | 2 | 8 | 3 | 4 | | | 2 | | | | | | | |
| | 6 | | | | | 6 | 2 | | 3 | 1 | | 1 | | | | | | | |
| | 7 | | | | 1 | | 4 | | 11 | | | | | | | | | | |
| | 8 | | | | | | 4 | 3 | 4 | | | 1 | | | | | | | |
| | 9 | 3 | 2 | 1 | | 9 | 15 | 2 | 3 | | 1 | | 1 | 1 | | | | | |
| | 10 | | 5 | | | 3 | 8 | 3 | 6 | | 2 | | 1 | | | | 1 | | |
| | 11 | 1 | 2 | | | 3 | 3 | 2 | | | 1 | | | | | | | | |
| | 12 | | | | | | | | | | | | | | | | | | |
| | 13 | 1 | 2 | | | 7 | 6 | 3 | 2 | 1 | | | | | | | | | |
| | 14 | | 1 | | | 3 | 2 | 1 | 4 | 1 | | 2 | | | | | | | |
| | 15 | | | | | | 2 | | 2 | | | 2 | | | | | | | |
| | 16 | 1 | 1 | | | 1 | 2 | | 1 | 2 | | 1 | | | 1 | | | | |
| | 17 | | | | | 2 | 11 | 2 | 4 | | | 2 | | | 1 | | | | |
| | 18 | | 1 | | | 2 | 4 | | 1 | 3 | 1 | | | | | | | | 1 |
| | 19 | 1 | 1 | 1 | | 5 | 6 | | 1 | 1 | 1 | | | | | | | | |
| | 20 | 1 | | | | 3 | 2 | | 1 | | | 1 | 1 | | | | | | |
| | 21 | | 2 | | | 13 | 11 | | 2 | 3 | 1 | | | 1 | | | | | |
| | 22 | | 1 | | | 1 | 4 | | 1 | 1 | | | | | | | | | |
| | 23 | | 2 | | | 1 | 2 | | | | | | | | | | | | |
| | 24 | | | | | 3 | 4 | | | | 1 | | | | | | | | |
| Totals | | 13 | 23 | 5 | 5 | 78 | 138 | 36 | 82 | 17 | 10 | 27 | 6 | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 2 |

[1] Figures for other species are: Pumpkinseed, 1 west recovery of a west release and 1 east recovery of an east release. Bowfin, 6 west recoveries of west releases. Northern pike, 1 west recovery of an east release and 1 east recovery of an east release. Gar pike, 1 west recovery of a west release. Warmouth, no recovery.

Table 11

Analysis of markings and recoveries of fish according to half of the lake, seasonal totals, Sugarloaf Lake, fall of 1948.

| Species | Marking | | Number recovered | | Percent recovered | | Number recovered | |
|---|---|---|---|---|---|---|---|---|
| | Half of lake | Number marked | West half | East half | West half | East half | Same half | Opposite half |
| Bluegill | West | 619 | 23 | 5 | 3.7 | 0.8 | 23 | 5 |
| | East | 494 | 13 | 5 | 2.6 | 1.0 | 5 | 13 |
| Largemouth bass | West | 79 | 2 | 1 | 2.5 | 1.3 | 2 | 1 |
| | East | 57 | 2 | .. | 3.5 | .. | .. | 2 |
| Rock bass | West | 46 | .. | 2 | .. | 4.3 | .. | 2 |
| | East | 36 | 1 | .. | 2.8 | .. | .. | 1 |
| Pumpkin-seed | West | 35 | 1 | .. | 2.9 | .. | 1 | .. |
| | East | 25 | .. | 1 | .. | 4.0 | 1 | .. |
| Bullhead | West | 231 | 138 | 82 | 59.7 | 35.5 | 138 | 82 |
| | East | 178 | 78 | 36 | 43.8 | 20.2 | 36 | 78 |
| Black Crappie | West | 65 | 10 | 6 | 15.4 | 9.2 | 10 | 6 |
| | East | 153 | 17 | 27 | 11.1 | 17.6 | 27 | 17 |
| Bowfin | West | 68 | 6 | .. | 8.8 | .. | 6 | .. |
| | East | 12 | .. | .. | .. | .. | .. | .. |
| Northern Pike | West | 8 | .. | .. | .. | .. | .. | .. |
| | East | 11 | 1 | 1 | 9.1 | 9.1 | 1 | 1 |
| Gar pike | West | 21 | 1 | .. | 4.8 | .. | 1 | .. |
| | East | 1 | .. | .. | .. | .. | .. | .. |
| Warmouth | West | 27 | .. | .. | .. | .. | .. | .. |
| | East | 14 | .. | .. | .. | .. | .. | .. |
| All species | West | 1,199 | 181 | 96 | 15.1 | 8.0 | 181 | 96 |
| | East | 981 | 112 | 70 | 11.4 | 7.1 | 70 | 112 |
| | West & East | 2,180 | 293 | 166 | 13.4 | 7.6 | 251 | 208 |

112:70 does not show a high degree of significance in difference--$X^2$ = 0.69; P = 12 percent probability of difference. There was a strong tendency among both lots of fish to travel from the release station to the west half, but the data show that this must have been caused by something other than a homing tendency. By inference, then, we conclude that the fish returning to the west half were not necessarily returning to the original home ground. Or perhaps it would be safer to conclude that the degree of an effective homing instinct on the part of the "west" fish was represented by the extent to which the west:east ratio of "west" fish exceeded the west:east ratio of "east" fish; or 181/96 - 112/70 = 3.8 percent. This figure (3.8 %) might be termed a "homing index," and it could be applied as a correction index to the population estimate. However the above Chi-square test shows that this difference lacks significance, and therefore there is no point in making the small correction to the population estimate which would be involved.

The whole procedure of recording east and west recoveries separately has served to demonstrate that the primary assumption of the method was quite valid (with no more than a small degree of bias), namely that the marked fish redistributed themselves over the lake without regard to their home territory; so that they and the unmarked fish were equally subject to capture by the subsequent netting. It must be recognized that this behavior might change considerably with the season.

## Estimate, Spring of 1949

A repeat of the population estimate on Sugarloaf Lake was made during the spring of 1949. This appeared desirable as a check on the results of the previous fall, since it was suspected that seasonal differences in fish movements might give variable results in the two studies. Also, the initial

population estimates on the principal game species in the lake were relatively low as compared to annual removal by fishermen and as compared to expectations of population size based on winterkill studies on southern Michigan lakes.

The field personnel included K. E. Proshek, D. E. Parsons and R. F. Stinauer. The netting period was April 20 to May 22. Nets used were the same as in 1948. The three-foot trap nets were designated in the A-series, the six-foot nets in the B-series. These nets were fished on an orderly schedule (See Table 12) at five A-stations and five B-stations in both west and east halves of the lake (Fig. 1c). Fish were marked by fin-clipping, the entire anal fin on fish caught in the east half of the lake, the distal half of the anal fin on fish caught in the west half. Marked fish were immediately transported to, and released at a common release station (Fig. 1c). Recaptures (fish previously marked, liberated, then captured again) were not marked a second time, and were released at the common release station.

In two ways the procedure of 1949 was somewhat different from that of 1948. In 1948, "legal length limits" were put on pike at 14 inches and all other species arbitrarily at 6 inches, and population estimates dealt merely with fish of "legal" size; there were insignificant numbers of "sub-legal" fish. In 1949 all fish caught in the nets were handled collectively, so that the population estimates included some fish of "sub-legal" size. However, individual length measurements were recorded on large numbers of fish in random samples of the trap net catches, from which percentages of "sub-legal" and "legal" fish were determined, and the population estimates were adjusted accordingly to conform with the 1948 figures. Secondly, in 1949, there was quite a mortality among marked fish in the lake during the period of netting, and there was some removal of

Table 12

Schedule of operating trap nets, Sugarloaf Lake, spring of 1949

A = 3-foot traps, B = 6-foot traps. Net stations numbered 1-5 for each type of net in west (W) and east (E) halves of the lake. Nets were set over 3 nights, moved on the 4th day.

| Net Station | April | | | | | | | | | | | May | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| A-1W | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | |
| A-2W | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| A-3W | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | |
| A-4W | | | | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | |
| A-5W | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | |
| B-1W | | x | x | x | x | | | | x | x | x | x | | | | | x | x | x | x | | | | x | x | x | x | | | | | |
| B-2W | | | | | x | x | x | x | | | | x | x | x | x | | | | x | x | x | x | | | | | x | x | x | x | | |
| B-3W | | | | | | | | x | x | x | x | | | | x | x | x | x | | | | | x | x | x | x | | | | x | x | x | x |
| B-4W | | | x | x | x | x | | | | | x | x | x | x | | | x | x | x | x | | | | | | x | x | x | x | | | | |
| B-5W | | | | | | x | x | x | x | | | | | x | x | x | x | | | | x | x | x | x | | | | | | x | x | x | x |
| A-1E | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | |
| A-2E | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| A-3E | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | |
| A-4E | | | | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | |
| A-5E | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | |
| B-1E | | x | x | x | x | | | | x | x | x | x | | | | | x | x | x | x | | | | x | x | x | x | | | | | |
| B-2E | | | | | x | x | x | x | | | | x | x | x | x | | | | x | x | x | x | | | | | x | x | x | x | | |
| B-3E | | | | | | | | x | x | x | x | | | | x | x | x | x | | | | | x | x | x | x | | | | x | x | x | x |
| B-4E | | | x | x | x | x | | | | | x | x | x | x | | | x | x | x | x | | | | | | x | x | x | x | | | | |
| B-5E | | | | | | x | x | x | x | | | | | x | x | x | x | | | | x | x | x | x | | | | | | x | x | x | x |

marked fish by angling which was recorded by the creel census clerk and by members of the netting crew. The greater mortality during 1949 (none was observed during the fall of 1948) must have been due largely to the effects of higher water temperatures and decreased post-winter vitality aggrevated by handling. Or, the netting may not have been even a contributing factor; spring mortality of fish in lakes is a common phenomenon. Daily records were kept of marked fish found dead on the lake, or in anglers' creels, as well as of any unmarked and marked fish found dead in the nets. Recoveries found dead, of course, were then removed from the lake.

All fish taken in the netting operations (including fish which died while in the net) are recorded in Table 13, initial captures in the u column, and recaptures of fish previously marked in the m column. Most of the initial captures (except for a few which died or were sacrificed for sex determination in age and growth studies) were marked and released (Table 14). In computing the population estimate (refer to Table 7), column n is an accumulating total of the number of live marked fish present in the lake at the beginning of any given day; the number of newly marked fish is added, and the number of makred fish found dead (tabular data not included in this report) on the lake or in the nets or in fishermen's creels (all then being removed from the lake) is subtracted, to give n for the following day.

Population estimates were made by both the Schnabel method and the Schumacher method, for the purpose of comparison; and the probable limits of accuracy of the estimates by the latter method were also obtained (Table 15). The estimates for total populations, first based on fish of both "legal" and "sub-legal" size, were converted to "legal"

Table 13

Daily catch of fish by trap nets, Sugarloaf Lake, spring of 1949.
Initial captures (u) and recaptures of marked fish (m).

| Date, | Bluegill | | Largemouth bass | | Rock bass | | Pumpkin-seed | | Bullhead[1] | | Black crappie | | Bowfin | | Northern pike | | Gar pike[2] | | Warmouth | | Perch | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| April-May | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m |
| 21 April | 11 | | | | 1 | | | | 9 | | | | | | | | | | 3 | | | |
| 22 | 78 | | 2 | | 1 | | 8 | | 13 | | 4 | | | | 2 | | | | 9 | | | |
| 23 | 63 | | 4 | | 6 | | 3 | | 10 | 2 | 13 | | | | 4 | | 1 | | 8 | | 1 | |
| 24 | 167 | | 5 | | 3 | | 9 | | 19 | 2 | 17 | | 3 | | 4 | 1 | 2 | | 1 | | | |
| 25 | 141 | 2 | | | | | 3 | | 17 | | 12 | | 1 | | 2 | 1 | | | 5 | | | |
| 26 | 72 | 1 | 2 | | 3 | | 6 | | 14 | 1 | 17 | 1 | | | | 1 | 1 | | 5 | | 3 | |
| 27 | 64 | | 6 | | 2 | | 10 | | 9 | 4 | 27 | 1 | 2 | | 3 | | | | 12 | | | |
| 28 | 114 | | 2 | | 3 | | 12 | | 9 | 2 | 44 | 8 | 1 | | | | 1 | | 11 | | | |
| 29 | 88 | | 3 | | 1 | | 2 | | 3 | 4 | 16 | 5 | | | | | | | 14 | | | |
| 30 | 74 | 2 | 4 | | 4 | | 4 | | 5 | 3 | 6 | 6 | | | | | | | 15 | 1 | | |
| 1 May | 38 | | 2 | | | | 4 | | 6 | 2 | 6 | 6 | 1 | | 1 | | | | 4 | | | |
| 2 | 30 | 1 | 3 | | 1 | | 6 | | 4 | 1 | 1 | 3 | 1 | | 1 | | | | 2 | | | |
| 3 | 29 | 3 | 2 | | 5 | | 12 | 1 | 4 | | 1 | 2 | | | 2 | | | | 4 | 1 | | |
| 4 | 40 | 5 | 1 | | 3 | 1 | 2 | | 5 | 1 | 10 | 7 | 1 | | | | | | 9 | | | |
| 5 | 52 | 7 | 3 | 1 | 2 | | 4 | 1 | 2 | 1 | 11 | 13 | 1 | | | | | | 14 | | | |
| 6 | 61 | 5 | 3 | | 2 | | 8 | | 3 | | 11 | 12 | 4 | | 2 | | | | 13 | 1 | | |
| 7 | 189 | 20 | 3 | 1 | 3 | 1 | 30 | 3 | 12 | 4 | 2 | 10 | 4 | 1 | | | | | 12 | | | |
| 8 | 153 | 19 | 7 | | 3 | | 43 | 3 | 9 | 7 | 5 | 5 | 5 | 2 | 1 | | | | 21 | 2 | | |
| 9 | 147 | 21 | 3 | 1 | 1 | | 20 | 2 | 10 | 5 | 5 | 9 | 6 | | | | 1 | | 37 | 1 | | |
| 10 | 188 | 22 | 3 | 1 | | | 33 | 3 | 9 | 5 | 14 | 19 | 8 | 1 | | | | | 12 | 4 | 1 | |
| 11 | 50 | 5 | 1 | | 3 | | 15 | 4 | 3 | 8 | 3 | 16 | 9 | 4 | | | | | 6 | 1 | 1 | |
| 12 | 89 | 14 | 3 | | 4 | | 13 | 5 | 2 | 5 | 1 | 7 | | 1 | 1 | | | | 5 | 2 | | |
| 13 | 65 | 18 | 1 | | 4 | | 5 | 5 | | 3 | | 4 | 2 | 2 | | | 1 | | 10 | 1 | | |
| 14 | 81 | 18 | 2 | | 5 | 3 | 1 | 3 | 4 | | 1 | 2 | 4 | 2 | | | | | 14 | 3 | | |
| 15 | 106 | 21 | 1 | 1 | 1 | | 15 | 3 | 5 | 4 | 1 | 7 | 3 | | 1 | | | | 25 | 5 | | |
| 16 | 119 | 17 | 4 | 1 | 2 | | 8 | 3 | 5 | 1 | | 6 | 5 | 2 | 1 | | | | 16 | 2 | 1 | |
| 17 | 69 | 14 | 3 | | 2 | | 11 | | 3 | 1 | | 2 | 4 | | 1 | | 1 | | 11 | 4 | | |
| 18 | 89 | 14 | | | 2 | 2 | 7 | 4 | 3 | | 1 | 7 | 4 | | | 1 | | | 7 | | 1 | |
| 19 | 31 | 7 | 3 | 1 | | 1 | 2 | 2 | 2 | 2 | | 5 | 3 | | 2 | | 1 | | 4 | | | |
| 20 | 30 | 10 | 2 | | | | 2 | 1 | 1 | 1 | | 2 | 1 | 3 | | | | | 2 | 2 | | |
| 21 | 21 | 4 | 1 | 1 | 1 | | 6 | 2 | 2 | | | 1 | 2 | 3 | | | | | 1 | 1 | | |
| 22 | 10 | 2 | | | | | | | | | | 2 | 1 | | 1 | | | | 1 | | | |
| Total | 2,559 | 252 | 79 | 8 | 68 | 8 | 304 | 45 | 202 | 69 | [illegible] | 168 | 76 | 21 | 29 | 4 | 9 | 0 | 313 | 31 | 8 | 0 |

[1] Mostly A. natalis, very few A. nebulosus.

[2] All longnose gar except for one shortnose gar on May 9.

Table 14

Number of fish marked and released, from west (W) and east (E) halves of Sugarloaf Lake, spring of 1949.

| Species | Bluegill | | Bullhead | | Black crappie | | Warmouth | | Pumpkin-seed | | Bowfin | | Largemouth | | Rock bass | | Pike | | Perch | | Gar | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Half of lake | W | E | W | E | W | E | W | E | W | E | W | E | W | E | W | E | W | E | W | E | W | E |
| April 21 | 6 | 5 | 2 | 7 | | | 1 | 2 | | | | | | | 1 | | | | | | | |
| 22 | 53 | 25 | 7 | 6 | 2 | 2 | 5 | 4 | 6 | 2 | | | 2 | | 1 | | | 2 | | | | |
| 23 | 11 | 52 | 2 | 8 | | 13 | 3 | 5 | 2 | 1 | | | 2 | 2 | 2 | 4 | 3 | 1 | | 1 | | 1 |
| 24 | 65 | 102 | 12 | 7 | 8 | 9 | 1 | | 7 | 2 | 2 | 1 | | 5 | 1 | 2 | 2 | 2 | | | | 2 |
| 25 | 25 | 116 | 9 | 8 | 2 | 10 | 3 | 2 | 1 | 2 | | 1 | | | | | 2 | | | | | |
| 26 | 34 | 38 | 4 | 10 | 10 | 7 | 3 | 2 | 6 | | | | 1 | 1 | 1 | 2 | | | 3 | | | 1 |
| 27 | 28 | 36 | 5 | 4 | 26 | 1 | 5 | 7 | 4 | 6 | 1 | 1 | 3 | 3 | 1 | 1 | 3 | | | | | |
| 28 | 61 | 53 | 6 | 3 | 27 | 17 | 8 | 3 | 5 | 7 | 1 | | 1 | 1 | 2 | 1 | | | | | 1 | |
| 29 | 66 | 22 | 2 | 1 | 14 | 2 | 5 | 9 | | 2 | | | 2 | 1 | | 1 | | | | | | |
| 30 | 58 | 16 | 1 | 4 | 6 | | 7 | 8 | 3 | 1 | | | 4 | | 1 | 3 | | | | | | |
| May 1 | 27 | 11 | 2 | 4 | 4 | 2 | 1 | 3 | 1 | 4 | | 1 | 1 | 1 | | | | 1 | | | | |
| 2 | 14 | 16 | 3 | 1 | 1 | | | 2 | | 6 | 1 | | 1 | 2 | 1 | | | | | | | |
| 3 | 7 | 22 | 3 | 1 | | 1 | 1 | 3 | 3 | 9 | | | | 2 | 5 | | | 2 | | | | |
| 4 | 25 | 15 | 4 | 1 | 6 | 4 | 5 | 4 | | 2 | 1 | | 1 | | 1 | 2 | | | | | | |
| 5 | 36 | 16 | 1 | 1 | 10 | 1 | 14 | | 3 | 1 | | 1 | 1 | 2 | | 2 | | | | | | |
| 6 | 20 | 41 | | 2 | 9 | 2 | 9 | 4 | 5 | 3 | 2 | 2 | 1 | 2 | | 2 | 1 | | | | | |
| 7 | 74 | 115 | | 1 | 1 | 1 | 6 | 6 | 12 | 18 | 2 | 2 | 2 | 1 | | 3 | | | | | | |
| 8 | 63 | 90 | | 3 | 4 | 1 | 4 | 17 | 21 | 22 | 2 | 3 | 2 | 5 | | 3 | | 1 | | | | |
| 9 | 65 | 82 | | | 4 | 1 | 14 | 23 | 8 | 12 | 5 | 1 | | 3 | | 1 | | | | | 1 | |
| 10 | 64 | 124 | 4 | 5 | 10 | 4 | 7 | 5 | 19 | 14 | 5 | 3 | 3 | | | | | | 1 | | | |
| 11 | 18 | 32 | | | 2 | 1 | 1 | 5 | 10 | 5 | 2 | 7 | 1 | | 1 | 2 | | | 1 | | | |
| 12 | 28 | 61 | | | 1 | | 4 | 1 | 3 | 10 | | | 1 | 1 | 3 | 1 | | | | | | |
| 13 | 21 | 44 | | | | | 3 | 7 | 3 | 2 | | 2 | 1 | | 2 | 2 | | | | | | 1 |
| 14 | 33 | 46 | 1 | 3 | 1 | | 8 | 6 | | 1 | 1 | 3 | 1 | 1 | 2 | 2 | | | | | | |
| 15 | 37 | 69 | | | 1 | | 17 | 8 | 6 | 9 | 2 | 1 | 1 | | 1 | | | 1 | | | | |
| 16 | 35 | 84 | | | | | 10 | 6 | 4 | 3 | 2 | 3 | 3 | 1 | 1 | 1 | | 1 | 1 | | | |
| 17 | 26 | 43 | 1 | 2 | | | 5 | 6 | 6 | 5 | | 4 | 3 | | 2 | | 1 | | | | 1 | |
| 18 | 29 | 60 | 2 | 1 | | 1 | 4 | 2 | 4 | 2 | 2 | 2 | | | 2 | | | | | | | |
| 19 | 23 | 7 | 2 | | | | 1 | 3 | | 2 | 1 | 2 | | 3 | | | 2 | | | | | 1 |
| 20 | 12 | 17 | 1 | | | | | 2 | | 2 | 1 | | | 2 | | | | | | | | |
| 21 | 2 | 19 | 2 | | | | | 1 | | 6 | 2 | | 1 | | | 1 | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | |
| Totals | 1,066 | 1,479 | 76 | 83 | 149 | 80 | 155 | 156 | 142 | 161 | 35 | 40 | 39 | 39 | 31 | 36 | 14 | 11 | 4 | 3 | 3 | 6 |

Table 15

Computed estimates of fish populations[1] Sugarloaf Lake, spring of 1949.

| | Blue-gill | Large-mouth bass | Rock bass | Pumpkin-seed | Bull-head[2] | Black Crappie | Bow-fin | Northern pike | Warmouth | Total[5] population |
|---|---|---|---|---|---|---|---|---|---|---|
| "Legal-size" plus "sub-legal" | | | | | | | | | | |
| Total population | | | | | | | | | | |
| Schnabel method | 13,768 | 406 | 317 | 1,096 | 379 | 326 | 176 | 95 | 1,699 | 18,262 |
| Schumacher method | 12,949 | 367 | 277 | 1,013 | 374 | 302 | 183 | 119 | 1,570 | 17,154 |
| "Legal-size" only | | | | | | | | | | |
| Schumacher method | | | | | | | | | | |
| Number | 11,641 | 367 | 232 | 883 | 374 | 302 | 183 | 119 | 1,430 | 15,531 |
| St. error[3] | 613 | 74 | 36 | 123 | 40 | 16 | 32 | 68 | 202 | |
| Range: Max. | 12,254 | 441 | 268 | 1,006 | 414 | 318 | 215 | 187 | 1,632 | |
| Min. | 11,028 | 293 | 196 | 760 | 334 | 286 | 151 | 51 | 1,228 | |
| Total pounds | 2,957 | 663 | 94 | 237 | 272 | 125 | 625 | 292 | 448 | 5,713 |
| Max: | 3,113 | 796 | 108 | 270 | 301 | 131 | 734 | 459 | 511 | |
| Min. | 2,801 | 529 | 79 | 204 | 243 | 118 | 516 | 125 | 384 | |
| Pounds/acre[4] | 16.4 | 3.7 | 0.5 | 1.3 | 1.5 | 0.7 | 3.5 | 1.6 | 2.5 | 31.7 |
| Max. | 17.3 | 4.4 | 0.6 | 1.5 | 1.7 | 0.7 | 4.1 | 2.5 | 2.8 | |
| Min. | 15.6 | 2.9 | 0.4 | 1.1 | 1.3 | 0.7 | 2.9 | 0.7 | 2.1 | |

[1] No recoveries of gar pike and perch; hence these species are not included.

[2] Brown bullhead and yellow bullhead collectively, mostly the latter.

[3] Standard error was computed for the entire catch of "legal-size" fish plus the few fish of "sub-legal" size--cf., Table 14. This slight irregularity in method presumably had no important effect on the results.

[4] Lake area is 180 acres.

[5] Obtained by summation of values for individual species.

fish only by applying the percentages on fish of "legal" size in large samples of trap-net catches (tabular data not included here). Population figures are converted to total poundages (Table 15) by applying data on average weight for each species (Table 16). These average weights involve a few fish of sub-legal size, but the error involved on this account is of little significance.

Where fish from the east and west halves of the lake were marked distinctively, the data afford another check, this time for spring, of the tendency on the part of marked fish when released to return to their original half of the lake. All recovery records were tabulated according to the half of the lake where they were first caught and marked and the half of the lake where they were recovered. An analysis of these recovery data (Table 17) becomes quite involved. For two species, the bluegill and pumpkinseed, there was a marked tendency for recaptures to occur in the same half where the fish were first marked. For example, of 1,066 bluegills marked in the "west," 74 were recovered in the west and 46 in the east. The degree of departure of the 74:46 ratio from a 46:46 ratio represents the amount by which redistribution of the marked fish differed from equality. That is, an excess of 74 - 46 = 28 out of 120 bluegills (23%) represented a homing tendency. These 28 fish (excess) were caught in the home half of the lake, not necessarily at the home net station. Only by the degree that the fish returned to the original site site, and were not therefore redistributed at random, are the essential assumptions of the method invalidated. In this instance we know the maximum possible extent of the error to be 23 percent, but because of the design of the experiment the minimal limit of the error is not known--it may be anything under 23 percent. To continue to use the "west" bluegills as an example, the population estimate is subject to correction to the extent of a maximum of 23 percent.

Table 16

Weights of fish in random samples from trap net catches, population study, Sugarloaf Lake, spring of 1949, "legal-size" and "sub-legal" fish combined.

| Species | Number weighed | Total weight:ounces | Average weight:ounces | Average weight:pounds |
|---|---|---|---|---|
| Bluegill | 1,036 | 4,209 | 4.06 | 0.254 |
| Largemouth bass | 60 | 1,734 | 28.90 | 1.806 |
| Rock bass | 19 | 123 | 6.47 | 0.404 |
| Pumpkinseed | 63 | 270 | 4.29 | 0.268 |
| Bullhead | 112 | 1,304 | 11.64 | 0.728 |
| Black crappie | 173 | 1,142 | 6.60 | 0.412 |
| Bowfin | 29 | 1,585 | 54.66 | 3.416 |
| Pike | 23 | 903 | 39.26 | 2.454 |
| Warmouth | 106 | 530 | 5.00 | 0.313 |
| Perch | 1 | 6 | 6.00 | 0.375 |
| Gar | 6 | 310 | 51.67 | 3.229 |

Table 17

Analysis of markings and recoveries of fish according to west and east halves of the lake, seasonal totals, Sugarloaf Lake, spring of 1949, population study by trap netting.

| Species[1] | Half of lake | Number marked | Number recovered | | Percent recovered | | Number recovered | |
|---|---|---|---|---|---|---|---|---|
| | | | west half | east half | west half | east half | same half | opposite half |
| Bluegill | west | 1,066 | 74 | 46 | 6.9 | 4.3 | 74 | 46 |
| | east | 1,479 | 51 | 81 | 3.4 | 5.5 | 81 | 51 |
| Bullhead | west | 76 | 15 | 20 | 19.7 | 26.3 | 15 | 20 |
| | east | 83 | 15 | 19 | 18.1 | 22.9 | 19 | 15 |
| Black crappie | west | 149 | 84 | 29 | 56.4 | 19.5 | 84 | 29 |
| | east | 80 | 44 | 11 | 55.0 | 13.6 | 11 | 44 |
| Warmouth | west | 155 | 10 | 10 | 6.5 | 6.5 | 10 | 10 |
| | east | 156 | 5 | 6 | 3.2 | 3.8 | 6 | 5 |
| Pumpkinseed | west | 142 | 14 | 3 | 9.9 | 2.1 | 14 | 3 |
| | east | 161 | 2 | 26 | 1.2 | 16.1 | 26 | 2 |
| Bowfin | west | 35 | 6 | 5 | 17.1 | 14.3 | 6 | 5 |
| | east | 40 | 3 | 7 | 7.5 | 17.5 | 7 | 3 |
| Largemouth bass | west | 39 | 1 | 1 | 2.6 | 2.6 | 1 | 1 |
| | east | 39 | 1 | 5 | 2.6 | 12.8 | 5 | 1 |
| Rock bass | west | 31 | 3 | 1 | 9.7 | 3.2 | 3 | 1 |
| | east | 36 | 2 | 2 | 5.6 | 5.6 | 2 | 2 |
| Northern pike | west | 14 | 2 | 2 | 14.3 | 14.3 | 2 | 2 |
| | east | 11 | .. | .. | 0.0 | 0.0 | .. | .. |
| Totals | west | 1,707 | 209 | 117 | 12.2[2] | 6.9 | 209 | 117 |
| | east | 2,085 | 123 | 157 | 5.9 | 7.5 | 157 | 123 |
| | west & east | 3,792 | 332 | 274 | 8.8 | 7.2 | 366 | 240 |

[1] No recoveries from 9 marked gar pike or 7 marked perch.

[2] Percentage totals are based on numerical totals.

Similarly the "east" bluegills showed a homing tendency of 31/132 = 23 percent, all bluegills 58/252 = 23 percent, all pumpkinseeds 35/45 = 73 percent (this number would be of much importance, except that the species is relatively not abundant), and all fish 126/606 = 21 percent. In the case of bullheads there was little evidence of bias in recaptures, while with the black crappie a strong homing bias of the "west" fish was matched by a strong tendency toward departures by the "east" fish.

For most of the more common species (except pumpkinseeds), and for all fish collectively, this study of redistribution of marked fish has been quite reassuring to the mark-recover method. It is indicated that limits of error of the population estimates, resulting from non-random distribution of marked fish, are something in the neighborhood of 25 percent (a maximum figure), or likely much less than 25 percent because the non-random distribution would be partially compensated by the extensive pattern of netting stations. With this degree of accuracy (or inaccuracy, depending upon point of view), the estimates still have much significance to the fishing experiments which are in progress.

## Estimate, spring of 1950

The spring population estimate[2] in 1950 was based on netting operations during the period April 18 to June 1, inclusive. The field personnel included Messrs. John J. Minel (Manual Worker C), Rudolph F. Stinauer (Fisheries Research Technician A), and John H. Claridge (Fisheries Biologist I) as leader. The same trap nets were used, and again the lake was divided into east and west halves in a systematic netting schedule (Table 18) in which one 3-foot net and two 6-foot nets were in operation continuously in each of the two halves of the lake. For stations A-1 to A-5 and B-1 to B-5, two and four complete rounds, respectively, of the

stations were made; then during the final ten days of the netting period, the nets were fished at stations (A-6 to A-10 and B-6 to B-10, west and east) closer to the lake shore line than where the bulk of the netting was done, to give better coverage of the lake surface (Fig. 1). In Figure 1 each heavy line is drawn to scale to show the length of the trap net plus lead. Thus, the extent to which the pattern of net symbols extends over the lake surface (in Fig. 1) represents the extent to which fish movement was subject to interception by these net leads, keeping in mind that only six nets were in operation in the lake at any one time.

All fish captured during this netting period for the first time were marked by fin clipping and then immediately released at the central station (Fig. 1). Fish captured in the west half of the lake had the right pelvic fin removed; fish captured in the west half had the left pelvic fin removed.

This study was concerned only with northern pike of lengths greater than 14 inches and all other species of lengths greater than 6 inches. Fish smaller than these lengths taken by the netting operations were merely released nearby. Daily records were kept for each net of the number of "legal-size" and "sub-legal" fish taken, keeping separate records on initial captures and recaptures. Records on recaptures included also the identity of the clipped fin--in other words, the half of the lake where the fish was first captured. The marking by fin clipping was continued from the beginning on April 18 through May 28 and included only a portion of the fish caught on May 29. Marking was not done during the final four days of the netting period (May 29-June 1), on the theory that there would remain too little time for these fish to be redistributed in the lake so that they would be subject to recapture.

## Table 18

Schedule of operating trap nets, Sugarloaf Lake, spring of 1950. A = 3-ft. nets; B = 6-ft. nets. W = west half of lake, E = east half.

| Station | April | | | | | | | | | | | | | May | | | | | | | | | | | | | | | | | | | | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | ✓* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 1 |
| A-1W | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| A-2W | | | | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | |
| A-3W | | | | | | | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | |
| A-4W | | | | | | | | | | x | x | x | 0 | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | |
| A-5W | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | |
| B-1W | | x | x | x | x | | | | x | x | x | x | | | | | | x | x | x | x | | | | x | x | x | x | | | | | x | x | x | x | | | | | | | |
| B-2W | | | | | x | x | x | x | | | | x | 0 | x | x | x | | | | | x | x | x | x | | | | | x | x | x | x | | | | | | | | | | | |
| B-3W | | | | | | | | x | x | x | x | | | | x | x | x | x | | | | | | x | x | x | x | | | | | x | x | x | x | | | | | | | | |
| B-4W | | | x | x | x | x | | | | | x | x | 0 | x | x | | | x | x | x | x | | | | | | x | x | x | x | | | | | | | | | | | | | x | x | x |
| B-5W | | | | | | x | x | x | x | | | | | | x | x | x | x | | | | x | x | x | x | | | | | | x | x | x | x | | | | | | | | | | |
| A-1E | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| A-2E | | | | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | |
| A-3E | | | | | | | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | |
| A-4E | | | | | | | | | | x | x | x | 0 | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | |
| A-5E | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | |
| B-1E | | x | x | x | x | | | | x | x | x | x | | | | | | x | x | x | x | | | | x | x | x | x | | | | | x | x | x | x | | | | | | | |
| B-2E | | | | | x | x | x | x | | | | x | 0 | x | x | x | | | | | x | x | x | x | | | | | x | x | x | x | | | | | | | | | | | |
| B-3E | | | | | | | | x | x | x | x | | | | x | x | x | x | | | | | | x | x | x | x | | | | | x | x | x | x | | | | | | | | |
| B-4E | | | x | x | x | x | | | | | x | x | 0 | x | x | | | x | x | x | x | | | | | | x | x | x | x | | | | | | | | | | | | | x | x | x |
| B-5E | | | | | | x | x | x | x | | | | | | x | x | x | x | | | | x | x | x | x | | | | | | x | x | x | x | | | | | | | | | | |
| A-6W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| A-7W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | |
| A-8W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | |
| A-9W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| A-10W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| B-6W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | |
| B-7W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| B-8W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | |
| B-9W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | |
| B-10W | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | |
| A-6E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| A-7E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | |
| A-8E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | |
| A-9E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| A-10E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| B-6E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | |
| B-7E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| B-8E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | |
| B-9E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | |
| B-10E | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | |

*✓ Nets were in position but not fishing during the period of April 29 to June 1.

A certain number of newly caught fish were found to be dead in the nets, and a few live fish from the nets were removed from the lake for special study; such fish, then, were not marked and returned to the lake. A daily record was kept of this removal of unmarked fish from the lake. Daily, during the netting operation, the entire shore line was cruised for a record of any fin-clipped fish which might have died, and a moderate number were found. This mortality probably was partly the result of netting operations, but to a considerable extent it was likely the result of low vitality of fish after the winter. During the course of the netting operations, a moderate amount of sport fishing was done on the lake. A special creel census of this fishing by the regular census clerk and by the netting crew gave a record of the numbers of fin-clipped fish and unmarked fish removed by fishermen.

During the period April 17 to 28, maximum daily water temperatures varied between 46°and 52°F. while maximum temperatures were between 40° and 66°; from May 1 to 15, water temperatures were 48° to 63° with air temperatures from 51° to 78°; and from May 16 to June 1, maximum water temperatures were 63° to 73° with air temperatures of 55° to 78°. These rather cool water temperatures were favorable for the handling of fish without undue mortality.

The mathematical estimates (Table 20) of population, by the Schumacher method, are based upon daily tabulations of initial captures (including dead fish), daily recaptures, and daily removal of marked fish from the lake by the various mortality causses--each species separately. The daily accumulative total of the number of fish marked and released, minus the daily totals on marked fish removed from the lake by all factors of mortality, represents a step in the procedure of estimation.

In the accompanying Table 19 initial captures are identified by the letter u, recaptures by m; the accumulating daily totals of marked fish present in the lake by n.

Table 19

Daily catch[1] of fish by trap nets, Sugarloaf Lake, spring of 1950. Initial captures (u) and recaptures of marked fish (m).

| Date April-June | Bluegill | | Largemouth bass | | Rock bass | | Pumpkin-seed | | Bullhead | | Black crappie | | Northern pike | | Warmouth | | Perch | | Bowfin | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m |
| 18 | | | | | 3 | | 2 | | 2 | | | | | | 7 | | 10 | | | | 24 | |
| 19 | 7 | | 4 | | 1 | | 1 | | 2 | | | | 2 | | 4 | | 59 | | | | 80 | |
| 20 | 80 | | 10 | | 18 | | 9 | | 9 | | 12 | | 4 | | 3 | | 1 | | 3 | | 149 | |
| 21 | 132 | 1 | 9 | 1 | 14 | | 3 | | 29 | | 11 | 1 | 8 | 1 | 3 | | 5 | | 5 | | 219 | 4 |
| 22 | 142 | 1 | 10 | | 23 | | 2 | | 31 | 3 | 10 | 1 | 12 | | 6 | | 1 | | 4 | | 241 | 5 |
| 23 | 109 | 2 | 7 | | 29 | 3 | 10 | | 30 | 2 | 2 | 3 | 6 | | 1 | | 6 | 1 | 4 | | 204 | 11 |
| 24 | 119 | 2 | 21 | 1 | 17 | 5 | 9 | | 39 | 3 | 4 | 3 | 2 | 1 | 10 | | 4 | | 2 | | 227 | 15 |
| 25 | 67 | 4 | 7 | | 11 | | 4 | 1 | 21 | 8 | 4 | 2 | 5 | | 1 | | 1 | | 7 | | 128 | 15 |
| 26 | 61 | 2 | 5 | | 14 | | 1 | | 34 | 7 | 1 | 1 | 4 | | 7 | | | | 4 | | 131 | 10 |
| 27 | 43 | 1 | 1 | | 15 | | 1 | 1 | 19 | 6 | 3 | 2 | 1 | | 1 | | 29 | | 1 | | 114 | 10 |
| 28 | 79 | 2 | 1 | | 9 | 2 | 2 | | 19 | 9 | 4 | 2 | 4 | 1 | 1 | | 5 | | | | 124 | 16 |
| 2 | 75 | 9 | 6 | 1 | 28 | 5 | 11 | | 23 | 19 | | 1 | 2 | | 13 | | 10 | 2 | 5 | | 173 | 37 |
| 3 | 59 | 6 | 2 | | 17 | 5 | 8 | 1 | 16 | 8 | 3 | 2 | 7 | 2 | 18 | 1 | 16 | | 2 | | 148 | 25 |
| 4 | 88 | 7 | 5 | 1 | 16 | 4 | 2 | | 21 | 12 | 10 | 14 | 4 | | 20 | 1 | 7 | 1 | | | 173 | 40 |
| 5 | 165 | 9 | 10 | | 14 | 6 | 5 | | 20 | 8 | 19 | 14 | | 2 | 31 | 1 | 5 | 1 | 3 | | 272 | 41 |
| 6 | 202 | 14 | 10 | 2 | 7 | 4 | 14 | | 16 | 13 | 4 | 5 | 4 | | 9 | | 4 | | 6 | | 276 | 38 |
| 7 | 181 | 11 | 6 | 1 | 6 | | 10 | | 14 | 5 | 1 | 1 | 9 | | 1 | | 2 | | 6 | | 236 | 18 |
| 8 | 164 | 24 | 5 | | 4 | 1 | 15 | | 29 | 11 | 2 | | 2 | 2 | 8 | 1 | 2 | | 4 | | 235 | 39 |
| 9 | 144 | 19 | 2 | | 4 | 1 | 8 | 2 | 36 | 17 | 2 | 3 | 1 | 4 | 15 | 1 | 3 | | 7 | | 222 | 47 |
| 10 | 138 | 27 | 2 | 1 | 11 | 2 | 4 | 1 | 29 | 27 | 2 | 3 | 2 | 1 | 10 | | 1 | | 7 | | 206 | 62 |
| 11 | 101 | 25 | 4 | | 7 | 1 | 7 | | 18 | 13 | | 2 | 1 | 1 | 12 | | 6 | 1 | 3 | | 159 | 43 |
| 12 | 126 | 14 | 3 | | 4 | 1 | 6 | 2 | 14 | 29 | 1 | 4 | 2 | | 27 | 1 | | | 3 | | 186 | 51 |
| 13 | 64 | 14 | | 1 | 4 | 2 | 6 | 1 | 13 | 13 | 1 | 3 | 2 | | 24 | 3 | 2 | | 2 | | 118 | 37 |
| 14 | 105 | 24 | 4 | | 10 | 4 | 10 | 2 | 4 | 8 | | 4 | | | 13 | 1 | 5 | | 2 | | 153 | 43 |
| 15 | 59 | 12 | 3 | 2 | 5 | 6 | 6 | 1 | 6 | 11 | | 7 | | | 32 | 4 | 7 | | 2 | | 120 | 43 |
| 16 | 52 | 14 | 6 | 2 | 12 | 2 | 2 | 1 | 13 | 6 | 1 | 4 | 2 | 1 | 12 | 2 | 3 | 1 | 1 | 1 | 104 | 34 |
| 17 | 57 | 19 | 2 | 2 | 12 | 4 | 3 | 2 | 8 | 11 | 1 | | 2 | 1 | 19 | 7 | 2 | 1 | 3 | 1 | 109 | 48 |
| 18 | 80 | 29 | 4 | 1 | 6 | 6 | 4 | 3 | 8 | 11 | | 2 | 1 | | 32 | 5 | 2 | 3 | 4 | | 141 | 60 |
| 19 | 76 | 27 | 2 | 1 | 11 | 3 | 12 | 3 | 6 | 4 | 1 | 4 | 1 | | 13 | 3 | 4 | 1 | 4 | 1 | 130 | 47 |
| 20 | 87 | 21 | 2 | 5 | 3 | 1 | 10 | 3 | 8 | 2 | 2 | | | | 19 | 4 | 10 | 1 | 6 | 2 | 147 | 39 |
| 21 | 50 | 28 | | | 3 | 2 | 7 | 2 | 10 | 5 | 1 | 5 | | | 17 | 1 | 1 | | 7 | 3 | 96 | 46 |
| 22 | 72 | 42 | 5 | 4 | 2 | 1 | 4 | 1 | 14 | 10 | | 2 | 3 | | 10 | 3 | 1 | | 9 | | 120 | 63 |
| 23 | 71 | 22 | 7 | 4 | 4 | 1 | 10 | 3 | 5 | 9 | | 2 | | | 24 | 3 | | | 3 | | 124 | 44 |
| 24 | 121 | 35 | 6 | | 11 | 3 | 8 | 2 | 12 | 10 | | | | | 32 | 7 | | | 10 | 5 | 200 | 62 |
| 25 | 193 | 48 | 4 | 2 | 6 | 6 | 9 | 2 | 7 | 10 | | 2 | | | 26 | 2 | | 1 | 8 | 4 | 253 | 77 |
| 26 | 192 | 47 | 1 | 3 | 8 | 5 | 5 | 1 | 9 | 10 | | 1 | | | 19 | 4 | 1 | | 5 | 4 | 240 | |
| 27 | 104 | 42 | 1 | 3 | 11 | 7 | 6 | 3 | 16 | 9 | | | 1 | | 19 | 7 | 1 | | 11 | 6 | 170 | 77 |
| 28 | 88 | 27 | 3 | 1 | 6 | 2 | 5 | 4 | 12 | 18 | | | 1 | | 46 | 13 | 6 | | 10 | 4 | 177 | 69 |
| 29 | 95 | 18 | 3 | | 6 | 4 | 8 | 3 | 17 | 16 | | 3 | | | 28 | 8 | 6 | 1 | 9 | 7 | 172 | 60 |
| 30 | 171 | 37 | 1 | 1 | 5 | 5 | 4 | 2 | 17 | 17 | 1 | 6 | | | 26 | 10 | 1 | | 19 | 12 | 245 | 90 |
| 31 | 114 | 27 | 4 | 1 | 4 | 1 | 6 | 1 | 9 | 8 | | 5 | | | 19 | 7 | 1 | | 11 | 4 | 168 | 54 |
| 1 | 26 | 4 | 2 | | 1 | 2 | 2 | | 10 | 10 | | 2 | | 1 | 9 | 1 | 1 | | 7 | 2 | 58 | 22 |
| Total | 4,159 | 717 | 190 | 41 | 402 | 107 | 261 | 48 | 675 | 398 | 103 | 116 | 95 | 18 | 647 | 101 | 231 | 15 | 209 | 56 | 6,972 | 1,617 |

[1] The total catch included 15 gars (including both longnose and spotted gar) but no recaptures.

Table 20

Computed estimates of populations of "legal-size" fish, by Schumacher method, Sugarloaf Lake, spring of 1950.

| Population | Bluegill | Largemouth bass | Rock bass | Pumpkinseed | Bullhead[1] | Black crappie | Northern pike | Warmouth | Perch | Bowfin | Totals[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | 14,012 | 518 | 997 | 825 | 992 | 126 | 271 | 2,389 | 1,615 | 433 | 22,178 |
| St. error | 687 | 33 | 62 | 68 | 43 | 9 | 63 | 127 | 371 | 29 | .. |
| Range: Max. | 14,699 | 551 | 1,059 | 893 | 1,035 | 135 | 334 | 2,516 | 1,986 | 462 | .. |
| Min. | 13,325 | 485 | 935 | 757 | 949 | 117 | 208 | 2,262 | 1,244 | 404 | .. |
| Total pounds | 3,818 | 660 | 378 | 229 | 619 | 75 | 644 | 772 | 383 | 1,231 | 8,809 |
| Max. | 4,005 | 703 | 401 | 248 | 646 | 81 | 793 | 813 | 471 | 1,314 | .. |
| Min. | 3,631 | 618 | 354 | 210 | 592 | 70 | 494 | 731 | 295 | 1,149 | .. |
| Pounds/acre | 21.2 | 3.7 | 2.1 | 1.3 | 3.4 | 0.4 | 3.6 | 4.3 | 2.1 | 6.8 | 48.9 |
| Max. | 22.2 | 3.9 | 2.2 | 1.4 | 3.6 | 0.4 | 4.4 | 4.5 | 2.6 | 7.3 | .. |
| Min. | 20.2 | 3.4 | 2.0 | 1.2 | 3.3 | 0.4 | 2.7 | 4.1 | 1.6 | 6.4 | .. |

[1] Including brown and yellow bullheads, mostly the latter.

[2] Obtained by summation of values for individual species.

During the netting operations, fish were measured for length, only to the extent of determining whether they were above or below the 14-inch and 6-inch limits. Virtually all of the initial captures, during the period from April 18 to May 29, were weighed. Weighing was done on a pan balance, accurate to the nearest ounce. Fish of each species were weighed separately, but, in numerous instances, several individuals of a given species were weighed collectively. All of the weight data were totaled and averaged to give a grand average weight for each species (Table 21). Total numbers of fish in the population were converted to total weights and average weight per acre for each species (Table 20).

The record of recoveries of marked fish, according to the half of the lake where they were first caught and marked, are summarized in Table 22. The results, in general, are somewhat different from those obtained in the spring of 1949, for the fish in 1950 showed a somewhat greater tendency to return to their home-half of the lake. The total number of fish which were marked was 6,249, of which 3,136 were marked in the west half and 3,133 were marked in the east half. Of those marked in the west, a total of 790 were recaptured, and of those marked in the east the recaptures totaled 827, the two results being quite comparable. The homing instinct was exhibited more strongly by the bluegill, which was the most abundant species in the lake and provided the bulk of the records in the present study. Of 343 recaptures which had been marked in the west half, 183 were recovered in the west half, and 160 in the east; while of 374 recaptures which had been marked in the east half 137 were recovered in the west but 237 were recovered in the east. In this instance, the east "recaptures" exhibited the homing tendency more strongly than did the west "recaptures." Another rather striking instance is represented by the bullheads where, among fish marked in the west, 139 were recovered in the west while only 84 were recovered in the east. The bullheads marked in the east likewise showed a greater (but less striking) rate of recovery

Table 21

Weights of "legal-size" fish in random samples from trap net catches, population study, Sugarloaf Lake, spring of 1950.

| Species[1] | Number weighed | Total weight: ounces | Average weight: ounces | Average weight: pounds |
|---|---|---|---|---|
| Bluegill | 3,270 | 14,241 | 4.35 | 0.27 |
| Largemouth bass | 155 | 3,165 | 20.4 | 1.28 |
| Rock bass | 353 | 2,141 | 6.07 | 0.38 |
| Pumpkinseed | 209 | 929 | 4.44 | 0.28 |
| Yellow bullhead | 240 | 1,989 | 8.29 | 0.52 |
| Brown bullhead | 132 | 1,952 | 14.8 | 0.93 |
| All bullheads[2] | 544 | 5,437 | 9.99 | 0.62 |
| Black crappie | 93 | 889 | 9.56 | 0.60 |
| Northern pike | 72 | 2,735 | 38.0 | 2.38 |
| Warmouth | 537 | 2,778 | 5.17 | 0.32 |
| Perch | 211 | 800 | 3.79 | 0.24 |
| Bowfin | 146 | 6,639 | 45.5 | 2.84 |

[1] Total trap net collections also included 3 Longnose gar, 6 Spotted gar, 13 Chubsuckers, and 11 Mud pickerel.

[2] Includes 172 bullheads spp., both browns and yellows.

Table 22

Analysis of markings and recoveries of fish according to east and west halves of the lake, seasonal totals, Sugarloaf Lake, spring of 1950, population study by trap netting.

| Species [1] | Half of lake | Number marked | Number recovered | | Percent recovered | | Number recovered | |
|---|---|---|---|---|---|---|---|---|
| | | | west half | east half | west half | east half | same half | opposite half |
| Bluegill | west | 1,897 | 183 | 160 | 9.6 | 8.4 | 183 | 160 |
| | east | 1,845 | 137 | 237 | 7.4 | 12.8 | 237 | 137 |
| Largemouth bass | west | 93 | 21 | 2 | 22.6 | 2.2 | 21 | 2 |
| | east | 83 | 8 | 10 | 9.6 | 12.0 | 10 | 8 |
| Rock bass | west | 154 | 18 | 27 | 11.7 | 17.5 | 18 | 27 |
| | east | 232 | 17 | 45 | 7.3 | 19.4 | 45 | 17 |
| Pumpkinseed | west | 122 | 18 | 2 | 14.8 | 1.6 | 18 | 2 |
| | east | 116 | 9 | 19 | 7.8 | 16.4 | 19 | 9 |
| Bullhead | west | 325 | 139 | 84 | 42.8 | 25.8 | 139 | 84 |
| | east | 254 | 80 | 95 | 31.5 | 37.4 | 95 | 80 |
| Black crappie | west | 49 | 38 | 12 | 77.6 | 24.5 | 38 | 12 |
| | east | 53 | 33 | 33 | 62.3 | 62.3 | 33 | 33 |
| Northern pike | west | 68 | 8 | 2 | 11.8 | 2.9 | 8 | 2 |
| | east | 21 | 6 | 2 | 28.6 | 9.5 | 2 | 6 |
| Warmouth | west | 302 | 20 | 21 | 6.6 | 7.0 | 20 | 21 |
| | east | 264 | 18 | 42 | 6.8 | 15.9 | 42 | 18 |
| Perch | west | 34 | 2 | 4 | 5.9 | 11.8 | 2 | 4 |
| | east | 184 | 4 | 5 | 2.2 | 2.7 | 5 | 4 |
| Bowfin | west | 92 | 18 | 11 | 19.6 | 12.0 | 18 | 11 |
| | east | 61 | 7 | 20 | 11.5 | 32.8 | 20 | 7 |
| All species | west | 3,136 | 465 | 325 | 14.8 | 10.4 | 465 | 325 |
| | east | 3,113 | 319 | 508 | 10.2 | 16.3 | 508 | 319 |
| | west & east | 6,249 | 784 | 833 | 12.5 | 13.3 | 973 | 644 |

[1] No recoveries from 9 marked gar pike.

in the east. This rather pronounced tendency towards the home-half of the lake also tended to hold among those species where the numbers of records are rather low, so that the accumulated total for all species combined, as illustrated in the two right-hand columns of Table 22 is very striking; for, of 1,617 recoveries, 973 were fish recovered in the same half of the lake where they had been marked, while the remaining 644 were fish recovered in the opposite half from where they were marked. The difference might be used as a rather crude correction factor to be applied to the population estimates. This correction factor would approximate 50 percent. It must be understood that a correction factor of this amount would be the theoretical maximum which should be applied. The true correction factor might logically be something considerably less than this figure, for the tendency of the fish to return to the same half of the lake where they were marked does not necessarily mean that fish must have returned rather quickly to the particular netting station where they were first captured. In spite of the rather large error (possibly as great as 50 percent) which might be involved in the present population estimates, the population figures still have a great deal of significance because they are not very large in relation to the estimated annual catches of fish by anglers (Cooper and Christensen, 1951).

One of the potential sources of error in the population estimate arises from the possibility that restricted fish migration might result in a small effective "field" around each net station. If such "fields" do not overlap, the interstices would contain fish which would not be included in the total estimate. The error would be minimized to the extent that marked fish after release are redistributed proportionately among "field" and interstitial areas; but the studies made thus far have shown an appreciable tendency for "homing" to the half of the lake where

marked, which is interpreted to mean some homing tendency for the original trap-net "field." Thus there is a definite probability that a systematic error is present, which results from the "field" effect. One approach to estimating this error is provided by a comparison of the three population estimates on Sugarloaf Lake. The estimate of 1949 was based on netting at 20 separate stations; of 1948 on 30 stations; and of 1950 on 40 stations. The sequence of netting at the various stations was not completely comparable during the three years, but sufficiently so to allow a comparison. If the "field" factor had a big effect of error, one would expect proportionately higher population figures for years when the greater number of stations were employed. Corresponding to the 20, 30 and 40 stations, the population estimates (Schumacher method) for 1949, 1948 and 1950, respectively were 15,531, 17,648 and 22,178 "legal-size" fish. Complete confidence should not be put in this comparison, because of the possibility that the actual population would tend to vary some in numbers from year to year. But, significantly, the estimate increased with an increase in number of stations. To indulge in a little speculative arithmetic, netting at 4 1/2 acres per trap net, as compared to 9 acres per net, resulted in an increase of 29 percent in the estimate; and if this rate of correction is extrapolated to the theoretical limit, the population estimate amounts to something less than 30 thousand fish. The basis for this prediction is not exact, but it does serve to show that the estimate of 22,000 represents a major portion of the total fish population.

It can be assumed safely that progressively more importance will be attached to such fish-population estimates in the future and therefore it is essential that a study of the procedure be continued. What is needed is a more critical study of the sizeable error which is due to

non-random redistribution, and to determine the appropriate correction; also, to determine the size of the effective "field" covered by a trap-net station, and therefore the number of netting stations needed for complete coverage on a lake of a given size. This will involve further population estimates similar to those which are here described for Sugar-loaf Lake, but in which the fish from each separate netting station are marked distinctively.

A POPULATION STUDY OF FISH IN FIFE LAKE, GRAND TRAVERSE COUNTY

During the summer of 1950 a population estimate of fish in Fife Lake, Grand Traverse County was made by the mark-and-recapture method based on trap-net collections. The purpose of this study has been twofold--to learn the size of the populations of various game species in comparison with the anglers' catch; and to determine the survival of smallmouth bass in the lake from hatchery plantings. An intensive creel census has been taken on Fife Lake during the past five years to evaluate the effects of no closed season on bluegills and sunfish and to record the contribution of these marked bass to the fisherman catch.

The marked plantings of bass made in Fife Lake were as follows:

| Date | Number | Average length | Age | Clipped fin |
|---|---|---|---|---|
| October, 1946 | 9,848 | 3.4" | 4 mo. | Right pectoral |
| November, 1947 | 5,861 | 2.75" | 6 mo. | Left pectoral |
| October, 1948 | 10,000 | 3.29" | 5 mo. | Left pelvic |

Fife Lake is located almost entirely in Grand Traverse County, but a thin slice of the east end of the lake is in Kalkaska County, The lake is in T. 25 N., R. 8, 9 W., Sections 18, 11, 12, 13 and 14. Its area is 575 acres. The maximum depth is 55 feet, with a major depression in the east half and a minor depression of 45 feet in the west half; 67 percent of the lake area has water depths of less than 20 feet, and the remaining 33 percent is over 20 feet deep. Practically all net sets were made between the 20- and 25-foot contours. Limited water analysis data

obtained by an Institute survey party on June 22, 1936, givesa fairly reliable indication that the lake is subject to a considerable oxygen depletion in deep water during the summer stagnation period. Thus it can be inferred that the bulk of the fish population of the lake during summertime (with perch partly excepted because of their known ability to descend into oxygen-poor water for short periods) is to be found in water less than approximately 25 feet deep in Fife Lake.

The field party consisted of Messrs. John H. Claridge (party leader), Rudolph F. Stinauer and Henry J. Vondett. The netting period was from June 16 to July 19, 1950. Trap nets of two sizes, 6-foot and 3-foot were used, including several nets of each type. A detailed description of these nets is given earlier in this report.

Sixty, serially numbered, net stations (11-70) were distributed over the lake in a systematic pattern, avoiding the central area of depths over 20 feet, half in the east half of the lake and half in the west. In addition, the distribution was equalized among the four quarters of the lake area. This systematic pattern was applied to stations for 3-foot nets and 6-foot nets separately. On Figure 2, symbols representing nets are drawn to scale to show length of trap net plus lead; the 3-foot nets had 100-foot leads, and the 6-foot nets had 150- to 165-foot leads. The schedule of dates for netting at the various stations was also systematized (Table 23) according to type of net, portion of the lake, and even- versus odd-numbered stations, with only slight (and presumably unimportant) irregularity. This pattern and the schedule of netting operations were designed to give extensive and random collecting in the initial capture of fish and in the recapture of marked fish as they became redistributed from two central release stations. Each net was fished at a particular station over 3 nights, and fish were removed after each of the 3

overnight periods. The netting schedule was continuous from June 16 to July 19, except that fish in nets were not processed on July 2 and July 12 which meant that these two days were merely ignored in the netting schedule.

Only fish of "legal size" are concerned in this report, including northern pike over 14 inches and all other species over 6 inches. The fact that 6 inches is far below the legal-size limit on bass and walleyes is of little consequence, because very few individuals of these species of sizes less than the true legal limit were taken. Records were kept, for each species, each day, and each netting station separately, and the data were tabulated and analyzed separately for even- and odd-numbered stations and for the two halves of the lake, according to where fish were either first captured or recaptured. A separate release station was established in each of the two halves of the lake (Fig. 2) at which all fish caught and marked in the respective half were released. Because of the plan to tabulate markings and recoveries separately for even- and odd-numbered stations and for the two halves of the lake, as an approach to an understanding of the degree to which marked fish redistribute themselves at random over the lake, an involved system of marking by fin-clipping was used (in this system, smallmouth bass were treated differently from other species to avoid confusion with fin-clipped hatchery smallmouth bass planted in the lake during 1946 to 1948), as follows:

| Species | East half | | West half | |
|---|---|---|---|---|
| | Odd stations | Even stations | Odd stations | Even stations |
| Smallmouth bass | 1/2 soft dorsal | All soft dorsal | 1/2 soft anal | All soft anal |
| All other species | Left pectoral | Right pectoral | Left pelvic | Right pelvic |

Fish initially caught at any one station were marked, as indicated above, and liberated at the release station for the half of the lake where captured. Recaptures of fish previously marked by fin clipping during the present study were also liberated at the release station corresponding to the half of the lake where recaptured.

A majority of all "legal-size" fish taken by netting were weighed, usually by lumping several individuals of a given species. The practice was followed of always weighing fish except on days where very rough wave action interfered seriously. Thus, data on average weights for the several species are based on large and representative samples.

It was planned to make daily examinations of most of the lake surface and shore line to tabulate fish mortality, since a moderate amount of mortality seems to occur on numerous lakes in the spring, and some mortality resulting from the operation of trap nets might logically be expected. Because pressure of other work interfered somewhat with this activity, such mortality counts were made on only slightly more than half of the days during the netting period. It might be expected that fishes on the lake surface or shore not counted on one particular day would be available for count on the following day. On the other hand, it is well known that dead fish on a lake may be quickly removed by scavengers, or they may settle to the bottom, or for perhaps other reasons complete counts on extensive fish mortalities are virtually impossible. Thus any mortality figures in this report would be subject to some revision, with an upward correction.

From the trap netting done at 60 stations on Fife Lake, a total of 5,641 fish were caught, marked and released, and 309 (5.5 percent) of these marked fish were recaptured (Table 24). An analysis of these initial captures and of the recaptures has been made according to half

Table 23

Schedule of operating trap nets in Fife Lake, summer of 1950

| Type of trap net | Lake quarter | Net station serial number | Date (June-July) 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 1 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Six-foot | NE | 11 | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 12 | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 13 | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | |
| | | 14 | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | |
| | | 15 | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | |
| | | 16 | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| | | 17 | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| | | 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | |
| | | 19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| | | 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | SE | 41 | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 42 | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | |
| | | 43 | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | |
| | | 44 | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | |
| | | 45 | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | |
| | | 46 | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| | | 47 | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| | | 48 | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | |
| | | 49 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x |
| | | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | NW | 21 | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 22 | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | |
| | | 23 | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | |
| | | 24 | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | |
| | | 25 | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | |
| | | 26 | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| | | 27 | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| | | 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | |
| | | 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x |
| | | 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | SW | 31 | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 32 | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | |
| | | 33 | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | |
| | | 34 | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | |
| | | 35 | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | |
| | | 36 | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| | | 37 | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| | | 38 | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | |
| | | 39 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| | | 40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Three-foot | NE | 54 | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | |
| | | 56 | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| | | 58 | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| | | 59 | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | |
| | | 60 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| | SE | 51 | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 52 | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 53 | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | |
| | | 55 | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | |
| | | 57 | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| | NW | 61 | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 62 | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 63 | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | |
| | | 65 | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | |
| | | 67 | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | |
| | SW | 64 | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | | | | | |
| | | 66 | | | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | | |
| | | 68 | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | | |
| | | 69 | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | | |
| | | 70 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

[1] Nets in operation, but fish not processed, on July 2 and 12.

of the lake and station number where the marking and recaptures were accomplished (Table 25). This analysis is significant in connection with two important questions: (1) the extent to which marked fish were recaptured in their home half of the lake, and (2) the extent to which they were recaptured at the home station. The latter would be reflected by a summary of the returns to even-numbered versus odd-numbered stations, for if all fish showed a strong tendency to return to their home station, then, by lumping, one would find that fish marked at even-numbered stations would be recaptured mostly at even-numbered stations, and the same for odd-numbered stations. The percentage figures (top section of Table 25) show that there was a strong tendency for fish to be recaptured in the same half of the lake where they were marked, but not a strong tendency for them to be recaptured in their home-type of station (even-numbered or odd-numbered). For example, note that, for all fish marked at "west-odd" stations, 2.92 percent were recaptured at west-odd stations, 2.18 percent were recovered at west-even stations, 0.85 percent at east-odd stations and 0.61 percent at east-even stations. In connection with measuring the degree to which these fish return to their home station, one should consider the nature of the netting schedule, in that each net remained in one location for 3 nights only, and was not returned to that station thereafter. This allowed a maximum of 2 days for recaptures at home stations to occur, after which there would be no opportunity for a strong homing instinct to interfere with the provision of random redistribution which is an essential part of the population estimate. Or, more precisely, the effect of a strong homing instinct after a trap net had been removed from a particular station would tend to compensate for that bias which resulted from a strong homing instinct being effective during the first 2 days.

Table 24

Recaptures of marked fish, grand totals, Fife Lake, Summer of 1950

| Species | Number marked | Number recaptured | Percent recaptured |
|---|---|---|---|
| Bluegill | 2,773 | 70 | 2.5 |
| Rock bass | 517 | 29 | 5.6 |
| Pumpkinseed | 727 | 24 | 3.3 |
| Black crappie | 680 | 25 | 3.7 |
| Walleye | 77 | 2 | 2.6 |
| Smallmouth bass | 198 | 30 | 15.2 |
| Largemouth bass | 302 | 26 | 8.6 |
| Pike | 58 | 1 | 1.7 |
| Bullhead sp. | 224 | 93 | 41.5 |
| White sucker | 72 | 8 | 11.1 |
| Perch | 13 | 1 | 7.7 |
| All species | 5,641 | 309 | 5.5 |

Table 25

Analysis of recaptures of marked fish, weighted as to distances between release stations and points of recapture, Fife Lake, summer of 1950.

| Group | Marked | Recaptured | | | |
|---|---|---|---|---|---|
| | | West, odd | West, even | East, odd | East, even |
| Percentage of marked fish recaptured, all species | West, odd | 2.92 | 2.18 | 0.58 | 0.16 |
| | West, even | 2.74 | 1.07 | 0.48 | 1.43 |
| | East, odd | 0.52 | 0.52 | 1.78 | 1.44 |
| | East, even | 1.19 | 0.93 | 2.12 | 2.29 |
| Average distance between release station and trap-net stations (15 each category), in hundredths of mile (from Fig. 1) | West | 30 | 32 | 68 | 66 |
| | East | 68 | 69 | 30 | 28 |
| Migration index, after correction for distance, all species | West, odd | 88 | 70 | 39 | 11 |
| | West, even | 82 | 34 | 33 | 94 |
| | East, odd | 35 | 36 | 53 | 40 |
| | East, even | 81 | 64 | 64 | 64 |
| Migration index, bluegill only | West, odd | 66 | 7 | 16 | 0 |
| | West, even | 43 | 0 | 24 | 94 |
| | East, odd | 13 | 13 | 29 | 13 |
| | East, even | 35 | 0 | 47 | 34 |
| Migration index, bullhead only | West, odd | 581 | 241 | 439 | 71 |
| | West, even | 585 | 390 | 332 | 1,127 |
| | East, odd | 145 | 587 | 383 | 477 |
| | East, even | 632 | 642 | 488 | 326 |

Another important consideration is that the percentage of recovery which would logically be expected at various stations would be a function of the average distance between stations of release and recapture. For example, fishes released at the east station, and subsequently wandering at random, would be more apt to be recaptured at east stations than at west, because netting stations in the east half almost completely surround the east release station,and the same holds for the west half. Also, the possibilities for recapture must be dependent upon time (and distance) to quite an extent because the netting period was relatively short (1 month). If, then, the percentage figures on recapture ( from the upper part of Table 25) are multiplied by the average distance between the particular release station and all trap net stations in the corresponding half of the lake, the results are a series of figures, listed in Table 25 as "migration index," which seem to provide the best available index of homing instinct exhibited by these fish. Individual distances between net station and release station were measured on the map of Figure 2, and were averaged to the nearest hundredth of a mile. The values representing return to the home-series of stations are underlined, while other values are not underlined. These migration indices, given in Table 25 for all species collectively and for bluegills and bullheads separately, show how significantly, or insignificantly, the random redistribution of marked fish might have been interfered with because of a homing instinct. For example, for all species marked at west-odd stations, the migration index for recapture at west-odd stations was 88, for west-even 70, for east-odd 39, and for east-even 11. Continuing further with the index figures for all species, there are 4 values (underlined in Table 25) representing fish which returned to their home-series stations, namely, 88, 34, 53, and 46. The average of these 4 values is 60, whereas the average of the 12

remaining values is 54. The difference, 6 or about 10 percent, represents the degree to which a homing instinct was reflected by all species collectively. A glance at the corresponding figures for bluegills only shows results somewhat more erratic, with a high homing-value for west-odd fish, balanced by a low corresponding value for west-even fish, and with the 4 homing-values (underlined in Table 25) averaging 32 as compared to an average of 25 for the 12 remaining values. On this basis, the tendency for homing among the bluegills was somewhat stronger than for all species collectively, amounting to something in the neighborhood of 20 percent. Corresponding values for the bullhead show a reversal in result, with a pronounced tendency for bullheads to be captured at other than their home station, the average of 4 homing-values being 420 as compared to an average of 481 for the 12 other values. The general conclusion to be made from this analysis is that there was no more than a small tendency for marked fish to be recaptured at their home station, which means that they were recaptured at other stations, and their redistribution must have been at random over the lake, or at random over sufficiently large portions of the lake to satisfy the assumptions of the present method.

Estimates of the populations of "legal-size" fish of different species have been made by the Schumacher method (Schumacher and Eschmeyer, 1943). For this procedure, daily tabulations were made, for each species separately, of initial captures ($u$) and recaptures ($m$) for all nets combined (Table 26). In addition, the method involved daily tabulations of initially captured fish which were not subsequently marked and released (for various reasons) and of marked fish found dead in the lake (data tabulated, but omitted here), from which a daily tabulation was made of the number of living, marked fish which were known to be present in the lake at the beginning

Table 26

Daily tabulation of "legal-size"[1] fish among initial captures (u) and recaptures (m) of marked fish, all nets combined, Fife Lake, summer of 1950.

| Date[2] | Bluegill | | Rock bass | | Pumpkinseed | | Black crappie | | Smallmouth bass | | Largemouth bass | | Bullhead[3] | | Walleye | | Pike | | Perch | | White Sucker | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m | u | m |
| June 17 | 37 | | 35 | | 10 | | 1 | | 2 | | | | | | 2 | | | | | | | |
| 18 | 30 | 1 | 22 | 1 | 31 | | 3 | | 13 | | 7 | | 1 | | | | 2 | | | | 1 | |
| 19 | 20 | | 22 | | 34 | | 21 | 1 | 4 | | 10 | | 9 | | 1 | | 2 | | | | 2 | |
| 20 | 64 | | 22 | | 45 | 2 | 47 | 1 | 5 | | 20 | | 13 | 2 | 1 | | 1 | | | | 5 | |
| 21 | 35 | | 21 | 1 | 17 | | 40 | | 3 | | 13 | | 15 | 1 | 6 | | 2 | | | | 2 | |
| 22 | 20 | | 11 | 2 | 21 | 1 | 27 | 3 | 3 | | 6 | | 4 | | 1 | | 2 | | | | 1 | |
| 23 | 33 | 1 | 17 | | 25 | 1 | 21 | 4 | 5 | | 8 | | 6 | 1 | 2 | | 1 | | | | 2 | |
| 24 | 94 | | 17 | | 17 | 2 | 31 | 2 | 4 | | 7 | | 5 | 3 | 3 | | 1 | | | | | 1 |
| 25 | 108 | | 12 | 2 | 17 | | 12 | 2 | 8 | 1 | 13 | | 6 | 2 | 4 | | 5 | | 7 | | 6 | 1 |
| 26 | 250 | 2 | 22 | | 47 | 1 | 19 | | 12 | | 12 | | 15 | | 13 | | 4 | | 3 | | 5 | |
| 27 | 144 | 4 | 22 | | 31 | 2 | 25 | | 25 | 1 | 61 | 4 | 18 | 5 | 27 | | 5 | | 1 | 1 | 4 | |
| 28 | 58 | 2 | 24 | | 24 | | 8 | 1 | 2 | 3 | 18 | 2 | 15 | 2 | 4 | | 2 | | | | 4 | |
| 29 | 48 | 1 | 13 | 3 | 17 | 1 | 10 | | 3 | 1 | 15 | 1 | 5 | 4 | | | 3 | | | | 5 | |
| 30 | 94 | 3 | 11 | | 23 | 1 | 19 | | 9 | | 11 | 2 | 10 | 4 | 2 | | 1 | | | | 5 | |
| July 1 | 60 | | 11 | | 12 | 1 | 29 | 2 | 11 | | 1 | 1 | 1 | 4 | | | 2 | 1 | | | 4 | |
| 3 | 107 | 2 | 9 | 1 | 22 | | 31 | | 17 | 1 | 6 | 1 | 9 | 6 | | | 4 | | | | 3 | 1 |
| 4 | 30 | 1 | 15 | 1 | 15 | 1 | 36 | 1 | | 1 | 5 | 1 | 9 | 2 | | | 1 | | 1 | | 2 | |
| 5 | 137 | 3 | 5 | 1 | 32 | 3 | 2 | | 11 | 2 | 6 | 1 | 8 | 3 | | | 6 | | | | | |
| 6 | 98 | 2 | 31 | 3 | 29 | | 7 | | 11 | 4 | 1 | | 7 | 7 | | | 2 | | | | | |
| 7 | 234 | 3 | 38 | 3 | 41 | 2 | 14 | 1 | 8 | 1 | 5 | | 8 | 4 | | | 4 | | | | | |
| 8 | 273 | 14 | 29 | 1 | 23 | | 15 | | 11 | 2 | 8 | 1 | 6 | 2 | 3 | 1 | | | | | | |
| 9 | 278 | 11 | 20 | 1 | 20 | | 18 | | 5 | 2 | 7 | 1 | 2 | 5 | 1 | | | | | | 2 | 1 |
| 10 | 78 | 6 | 5 | 2 | 13 | | 8 | | 1 | | 2 | 1 | 8 | 1 | 2 | | 3 | | 1 | | | |
| 11 | 16 | 1 | 8 | | 13 | 1 | 2 | | 1 | 1 | 1 | | 2 | 1 | 1 | | | | 1 | | 3 | |
| 13 | 62 | 3 | 25 | | 22 | 2 | 9 | | 12 | 3 | 9 | 1 | 2 | 2 | 2 | | | | 2 | | 2 | |
| 14 | 102 | | 11 | 2 | 33 | | 27 | 1 | 1 | 2 | 5 | 1 | 4 | 5 | 1 | 1 | 2 | | | | 3 | 1 |
| 15 | 81 | 2 | 9 | | 29 | 2 | 13 | 1 | 4 | 2 | 2 | 1 | 13 | 5 | | | 4 | | | | 3 | |
| 16 | 119 | 3 | 10 | 1 | 36 | 1 | 18 | 1 | 2 | | 9 | | 7 | 7 | | | | | | | 3 | 1 |
| 17 | 46 | 1 | 5 | 2 | 14 | | 40 | | 4 | 3 | 6 | 3 | 10 | 5 | 1 | | 5 | | | | 1 | 1 |
| 18 | 22 | 3 | 11 | 1 | 10 | | 70 | 1 | | | 10 | 2 | 5 | 7 | 1 | | | | | | 4 | |
| 19 | 27 | 1 | 6 | 1 | 23 | | 76 | 3 | 3 | | 23 | 2 | 1 | 3 | 2 | | 1 | | | | 1 | 1 |
| Totals | 2,805 | 70 | 519 | 29 | 746 | 24 | 699 | 25 | 200 | 30 | 307 | 26 | 224 | 93 | 80 | 2 | 65 | 1 | 16 | 1 | 73 | 8 |

[1] "legal-size" means over 14" for pike and over 6" for all other species.

[2] Nets not fished on July 2 and 12.

[3] Bullheads were approximately 80% Ameiurus nebulosus plus a few A. melas and A. natalis.

Table 27

Computed estimates of populations of "legal-size" fish[1] by Schumacher method, Fife Lake, summer of 1950.

| Population | Bluegill | Rock bass | Pumpkinseed | Black crappie | Smallmouth bass | Largemouth bass | Bullhead[2] | White Sucker | Totals[3] |
|---|---|---|---|---|---|---|---|---|---|
| Number | 56,511 | 4,845 | 14,186 | 13,673 | 7,264 | 1,789 | 424 | 364 | 99,056 |
| St. error | 6,776 | 947 | 3,305 | 4,571 | 3,639 | 237 | 34 | 110 | .. |
| Range: Max. | 63,287 | 5,792 | 17,491 | 18,244 | 10,903 | 2,026 | 458 | 474 | .. |
| Min. | 49,735 | 3,898 | 10,881 | 9,102 | 3,625 | 1,552 | 390 | 254 | .. |
| Total pounds | 13,563 | 1,163 | 3,405 | 7,247 | 7,191 | 2,326 | 356 | 619 | 35,870 |
| Max. | 15,189 | 1,390 | 4,198 | 9,669 | 10,794 | 2,634 | 385 | 806 | .. |
| Min. | 11,936 | 936 | 2,611 | 4,824 | 3,589 | 2,018 | 328 | 432 | .. |
| Pounds/ acre[4] | 23.6 | 2.0 | 5.9 | 12.6 | 12.5 | 4.0 | 0.6 | 1.1 | 62.3 |
| Max. | 26.4 | 2.4 | 7.3 | 16.8 | 18.8 | 4.6 | 0.7 | 1.4 | .. |
| Min. | 20.8 | 1.6 | 4.5 | 8.4 | 6.2 | 3.5 | 0.6 | 0.8 | .. |

[1] The walleye, pike and perch are not included because recaptures were too few to warrent estimations.

[2] Approximately 80% Ameiurus nebulosus plus a few A. melas and A. natalis.

[3] Totals are derived by summation of estimates for individual species.

[4] Lake area is 575 acres.

Table 28

Weights of "legal-size"[1] fish in random samples from trap net catches, population study, Fife Lake, summer of 1950.

| Species | Number weighed | Total weight: ounces | Average weight: ounces | Average weight: pounds |
|---|---|---|---|---|
| Bluegill | 1,979 | 7,451 | 3.77 | 0.24 |
| Rock bass | 317 | 1,227 | 3.87 | 0.24 |
| Pumpkinseed | 440 | 1,682 | 3.82 | 0.24 |
| Black crappie | 412 | 3,507 | 8.51 | 0.53 |
| Smallmouth bass | 121 | 1,922 | 15.9 | 0.99 |
| Largemouth bass | 145 | 2,972 | 20.5 | 1.3 |
| Bullheads[2] | 137 | 1,845 | 13.5 | 0.84 |
| Walleye | 32 | 2,050 | 64.1 | 4.0 |
| Pike | 33 | 1,160 | 35.2 | 2.2 |
| Perch | 11 | 131 | 11.9 | 0.74 |
| White sucker | 49 | 1,307 | 26.7 | 1.7 |

[1] Over 14 inches for pike and over 6 inches for all other species.

[2] Bullheads identified as 80% Ameiurus nebulosus, plus few A. melas and A. natalis.

of each day. The formulae and procedure used in computing populations are given earlier in this report.

The calculated figures for each species (Table 27) give by summation a population figure for "legal-size" fish of 99,056, of which 56,511 were bluegills. Pumpkinseeds, black crappies, smallmouth bass and rock bass made up the bulk of the remainder. The accompanying figures on standard error show the range in which the true population figures would be expected to lie with 68 percent chance probability. Fish numbers are converted to total weight in pounds and pounds per acre (Table 27), from data on average weights of fish (Table 28). The total population of "legal-size" fish (mostly game species) per acre was thus calculated to be 172 fish, weighing 62.3 pounds.

## Fish Mortality

Prior to, and during the course of the field work on Fife Lake (June 16 to July 19), there was a considerable mortality of fish there, affecting both sub-legal and legal-size fish. The extent of the mortality was somewhat in proportion to the known relative abundance of the different species. Samples of fish were examined by the field party, but there was no obvious cause of death evident on the gills or external parts. Such late spring and early summer mortalities of fish are fairly common for Michigan lakes generally, and as to cause, we can do no better than to suggest low over-winter vitality, perhaps associated with rapid spring changes in chemistry and temperature of lake water. The field party, in examinations of the lake surface and shore line on somewhat over half of the days of the netting period counted a total of 746 dead fish of which 392 were unmarked ( i.e., not fin-clipped during the present study) fish of lagal size, 181 were unmarked fish of sub-legal

size and 173 were marked fish of "legal size." Adjusting for the fact that mortality counts were made on only about half of the days, the total mortality is calculated at 1,500 fish and this is to be regarded still as a very minimum figure for reasons discussed above. Some indication that the netting and marking operations aggravated the mortality to a marked degree is given by the results: of 565 "legal-size" fish enumerated in the mortality counts, 31 percent were fish fin clipped during the present field work; in contrast, the ratio of fin-clipped to unmarked legal-size fish in the lake as a whole approximated 6 percent at the time (5,641 / 99,056, from Table 24 and 27). However, it should be emphasized that netting was still not the major cause of the mortality, since 69 percent of the dead fish enumerated had not been handled by the netting party.

## Survival of Hatchery smallmouth bass

During the netting operation in 1950 a total of 198 smallmouth bass, over 6 inches in length, were collected. Included were 16 survivors from hatchery plantings made in 1946 to 1948. It would be expected that practically all of the surviving smallmouth bass from the 3 hatchery plantings (1946, 1947, 1948) should have been at least 6 inches long by the summer of 1950, even though one assumed only a fair rate of growth. The netting crew examined all smallmouth bass closely for such survivors. The 16 fish included 5 with the right pectoral clipped, 5 with the left pectoral, and 6 with the left pelvic. In using the total number of these recoveries (16) to compute the survival of hatchery bass up to the summer of 1950, a correction would need to be made for the extent to which clipped fins might have been completely regenerated and therefore the fish unrecognizable as to origin by an experienced fisheries worker. Several

lots of fin-clipped smallmouth bass have been held at state hatcheries since 1946, for various periods, as a check on the degree of clipped-fin regeneration. Based on information to date from these control fish, a correction factor of 10 percent might be applied. Applying the correction, we add two to the total of 16, making 18 recoveries (9 percent) of hatchery bass out of the 198 smallmouth bass which were collected (Table 24). This figure of 9 percent may then be taken to represent the proportion of the population of smallmouth bass (over 6") in Fife Lake which were survivors from the hatchery plantings of 1946 to 1948. Nine percent of the 7,264 bass (Table 27) in the population gives an estimate of 654 survivors (2 1/2 percent) from the 25,709 fingerlings planted in 1946 to 1948.

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