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G. P. Cooper

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Estimating fish populations in Michigan lakes

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[1]Contribution from the Michigan Institute for Fisheries Research

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Gerald P. Cooper

Michigan Department of Conservation

Ann Arbor, Michigan

Abstract

Fish population estimates, using trap nets in the Peterson mark-and-recapture procedure, were made during 1948, 1949 and 1950 on Sugarloaf Lake in Washtenaw County and during 1950 on Fife Lake in Grand Traverse County, Michigan. The nets were of two sizes: 3-foot and 6-foot. The lake acreages are 180 and 575, respectively. The important fish species were bluegill, pumpkinseed sunfish, yellow perch, largemouth bass, smallmouth bass, black crappie, northern pike, yellow and brown bullheads, and warmouth. The study was limited to fish over six inches in length.

In four separate netting periods, 17,887 fish (approximately half bluegills) were marked by fin clipping and released, and 2,991 of these (17 percent) were recaptured.

Distinctive markings were used for fish from two halves of each lake, and recaptures were tabulated accordingly. This showed a small tendency for marked fish, liberated at a common release station near the center of the lake, to return to the same half of the lake where marked; but the amount of this "homing" was not sufficient to invalidate the population estimations. Distinctive marking for two groups of stations, separated systematically according to even and odd numbers in series, gave returns which showed no marked tendency for fish to return to their home trap net site.

The three separate estimations of populations of legal-size fish in Sugarloaf Lake, computed by the Schumacher and Eschmeyer formula, gave 17,648 fish for the fall estimate of 1948, a total of 15,531 fish for the spring estimate in 1949, and 22,178 fish in the spring of 1950; these totals, correlated with the numbers of trap net stations on which the estimates were based--30, 20 and 40, respectively--suggest, by extrapolation, that the true population figure is something less than 30 thousand. The average computed total for the three years was 18,452 fish, or 102 fish and 43.1 pounds per acre. Estimations by the Schnabel formula gave totals which were generally a little higher than by the Schumacher and Eschmeyer formula. For Fife Lake the estimated total population was 99,056 fish or 172 fish of 62.3 pounds per acre. In both lakes the bluegill made up over half of the totals.

Records of marked and unmarked fish in angler's creels immediately following the trap netting provided another basis for estimating the fish populations in Sugarloaf Lake in 1949 and 1950. Such estimates were about double the estimates based on trap-net recaptures. The reason for the difference was not determined.

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ESTIMATING FISH POPULATIONS IN MICHIGAN LAKES

By

Gerald P. Cooper

Research and management on inland sport fisheries have reached the stage where a knowledge of total populations of fish is quite essential to any major advance in this science. Food habits, other ecological relations, life histories, stocking for introductions, and a basic pattern of regulations have been studied and/or applied where some application has been apparent. While there is still much need for research in ichthyology and basic limnology, a major emphasis must be on populations of fish.

The field of fish management includes: (1) stocking for maintenance, (2) restrictive regulations, and (3) various approaches to habitat improvement including population control. In these three aspects of fish management, the relative importance of which is not necessarily in the above order, we are in a transition from the descriptive to the quantitative approach---from the we-know-in-general stage to the average-plus-or-minus-a-standard-error stage. To satisfactorily evaluate changes in fishing regulations, the contribution made by maintenance stocking, or any type of habitat improvement, we must be able to directly estimate the total number of fish present in a given water, or else to get an indirect estimate of the population through quantitative creel census.

While the use of the electric shocker is proving invaluable in population estimates on streams, no comparable collecting tool has been devised for lakes, and perhaps never will be, considering the relative inaccessibility of lake fish. In lakes the general procedure must be

one of "dipping in" for a sample which will then give an estimate of the whole, and the sources of bias in this procedure must be recognized and appraised. A few significant population estimates have been made on small ponds which could then be drained (Schumacher and Eschmeyer, 1943) or poisoned (Fredin, 1950; Krumholz, 1944), allowing a check on the accuracy of the estimates, but on most lakes this is not possible.

Population estimates, by the Peterson method of mark-and-recapture (Ricker, 1948) elaborated mathematically as by Schnabel (1938) and by Schumacher and Eschmeyer (op. cit.), are dependent upon several assumed conditions (Ricker, op. cit.) of fish behavior and distribution. On the one hand each of the several assumptions may be critical to the acquisition of results of even usable accuracy; on the other hand, the validity of each assumption is not always (in fact, is seldom) obvious from available information on habits of the different species, especially for fish in lakes of considerable area. Estimates made on small ponds, subsequently drained, have generally been of usable accuracy (e.g., Schumacher and Eschmeyer, op. cit.).

The critical assumptions are that marked fish must retain their mark, must not suffer unrecorded mortality at a greater rate than do unmarked fish, and must be equally susceptible to subsequent recapture along with unmarked fish. The latter means that the marked fish must be distributed either at random over the lake or in numerical proportion among the unmarked population. If the distribution of marked fish is not at random or proportional, then the distribution of netting effort must be intensive and at random.

Several questions are of paramount importance: (1) Should fish be liberated at the netting site where captured, or at some distant point? If liberated at the point of capture, say by a trap net, should they be liberated in front of the net where recapture would be likely, or behind the net, where, in shallow water, recapture would be unlikely? (2) Does the individual fish have its own home niche with a limited range of normal movement? If so, what is this range of movement, and is the home niche a seasonal phenomenon? (3) When individual fish are removed from a home niche to some remote spot, do they become wanderers and are they therefore more susceptible to recapture by intercepting nets than are fish which have not been disturbed? To what extent and how quickly do transplanted fish return to a home niche? Generally the significance of these questions is greater in large lakes than in small ones.

The present paper deals with trap-net population estimates on two Michigan lakes on which experimental fishing regulations have been in effect (Cooper and Christensen, 1951). The aims have been to determine the size of the fish populations for comparison with the total anglers' catch computed by creel census, to calculate the amount of survival from plantings of hatchery smallmouth bass fingerlings (marked by fin clipping), and to study the habits and distribution of fishes which are significant in the assumptions of the mark-and-recapture procedure.

Sugarloaf Lake

This lake is located near Waterloo, in Washtenaw County, in gravel moraines. The lake was mapped in 1944 by a special field party, sounding on a grid pattern through the ice. The area is 180 acres.

Most of the lake is uniformly shallow, between 2 and 5 feet deep. A very small area is over 10 feet, and the maximum depth is 20 feet (Figure 1). Aquatic vegetation is abundant over most of the lake, except within the 10-foot contour. The fish population is typical of southern Michigan lakes, including northern pike, largemouth bass, bluegill, pumpkinseed sunfish, warmouth, black crappie, yellow perch, yellow and brown bullheads, bowfin, and several forage species. With about 80 cottages on the lake and public access, fishing intensity is quite heavy.

Population estimates on Sugarloaf Lake were made by trap netting in the fall of 1948 (October 20-November 24), in the spring of 1949 (April 20-May 22), and in the spring of 1950 (April 18-June 1). The several trap nets were of two sizes: 3-foot, and 6-foot. The 3-foot net was of single pot 3' x 3' x 6', 12-ft. wings and hearts, 100-ft. lead, 2 1/2" and 3" stretched mesh, #12 and #9 thread seine twine; the 6-ft. net with double pot 6' x 4' x 16', 20-ft. wings and hearts, 150-ft. lead, 2 1/2", 3", and 4" mesh (back pot, front pot, and lead, respectively), #15 and #12 thread seine twine. (See Crowe, 1950, for similar nets.) The nets were fished at 30 stations in 1948, 20 in 1949, and 40 in 1950. For experimental purposes the stations were grouped, and released fish were marked differently, according to two halves of the lake (east and west). All fish were released at a central station. The distribution of netting stations over the lake was systematic, and designed to give uniform distribution of netting effort, with the smaller trap nets fishing in shallower water. The patterns of net stations in 1948 and 1949 were similar to that employed in 1950 (shown in Figure 1), with fewer stations more widely scattered.

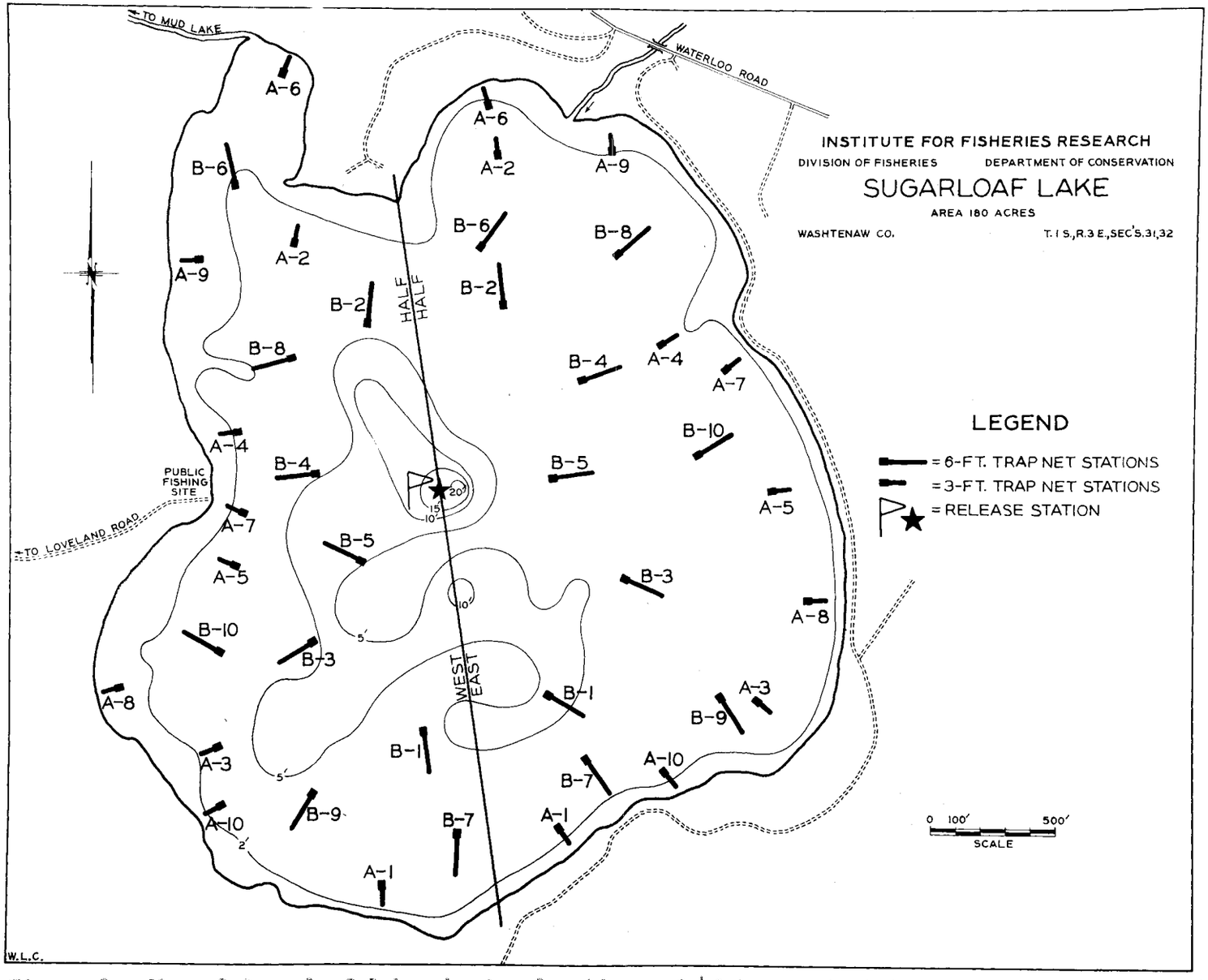

Figure 1.--Map of Sugarloaf Lake showing locations of 40 trap-net stations used in population study during 1950.

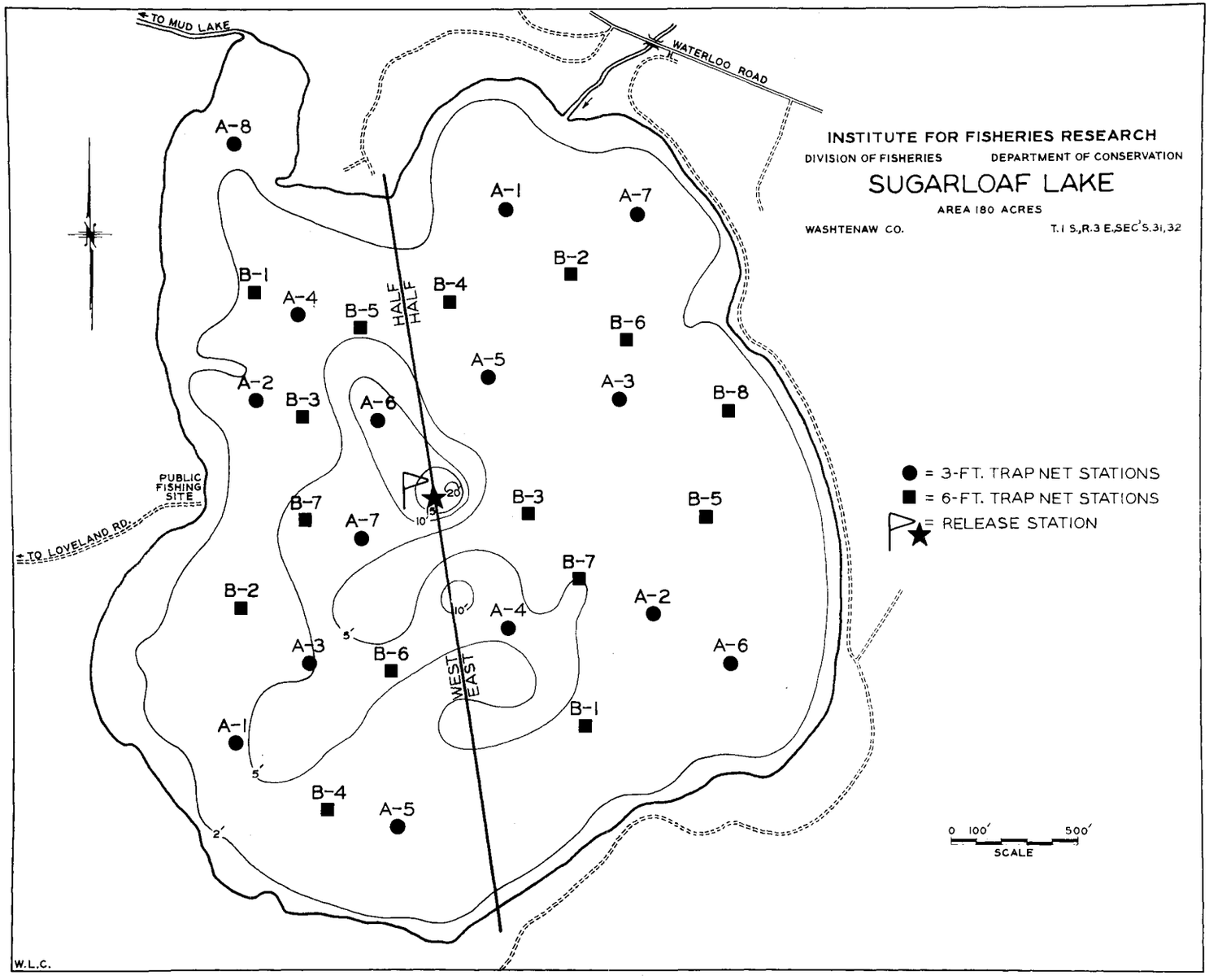

Figure 1b.--Map of Sugarloaf Lake showing locations of 30 trap-net stations used in population study during 1948.

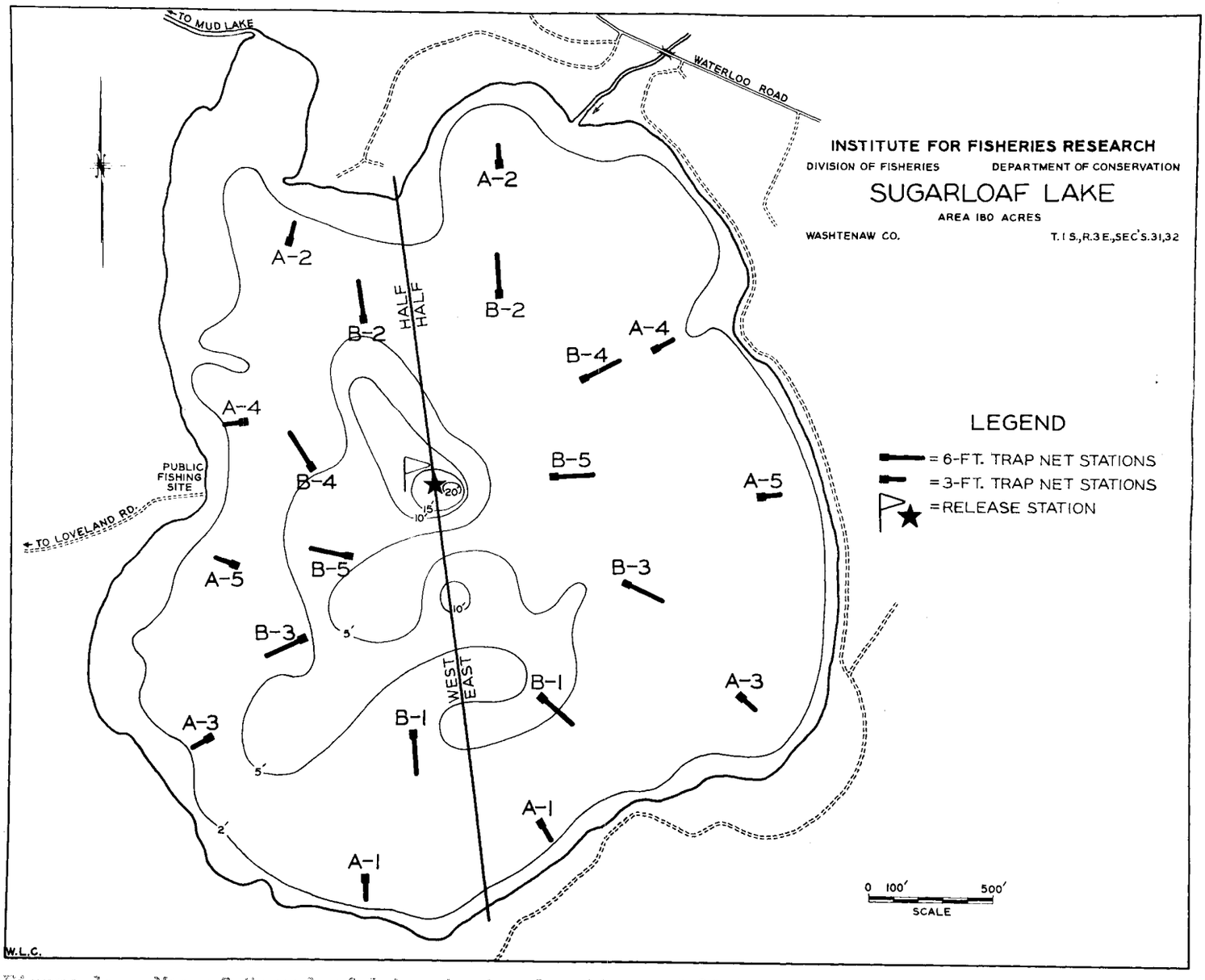

Figure 1a.--Map of Sugarloaf Lake showing locations of 20 trap-net stations used in population study during 1949.

The procedure was to fish a net at a given station over three nights, and to lift the nets and process and release the fish each morning. After a three-day set, the net was moved to a new station. The stations (numbered in Figure 1) were fished in numerical order, with nets of each size fishing concurrently in the two halves of the lake, usually with six nets in continuous operation. In 1948, the procedure was to fish a complete round of the 30 stations, followed by two weeks of continuous netting at 8 stations; in 1949, two complete rounds were made of the stations for 3-ft. trap nets and four complete rounds were made of the 6-ft. trap-net stations; in 1950, the 1949 procedure was followed for the 20 stations numbered 1 to 5, after which one round was made of stations numbered 6 to 10. The general procedure, then, was to fish several nets on a systematic schedule at numerous stations continuously for four to six weeks, marking and recording all fish.

Fife Lake

This lake is located in Grand Traverse and Kalkaska counties. It was mapped by a special field party in 1937. The area is 575 acres; the maximum depth, 55 feet. Throughout 67 percent of the lake area, the water is less than 20 feet deep. Submerged aquatic plants are generally abundant out to a depth of 15 feet. The fish population includes the yellow perch, bluegill, pumpkinseed sunfish, northern pike, largemouth bass, smallmouth bass, rock bass, black crappie, walleye, and bullheads, listed generally in order of importance to angling. There are about 80 cottages on the lake, and fishing is of moderate intensity.

For the population estimate, trap nets, 3-ft. and 6-ft., were fished, from June 16 to July 19, 1950, at 60 stations (numbered 11 to 70), mostly located in water less than 20 feet deep. The stations were

divided equally between east and west halves of the lake, and equally secondarily by quarters. Netting, three nights per station, was systematized, starting six nets at stations numbered 11, 21, 31, 41, 51, and 61, followed by moving the nets to stations in the 2-series (12,22,32), etc. The result was that a 6-ft. net was being fished continuously in each quarter of the lake, and a 3-ft. net continuously in each half. Separate release stations were used for the two halves of the lake. (See Figure 2)

Records

On both Sugarloaf and Fife lakes, fish were marked by fin clipping before release, using a different fin for each half of the lake and for each year. Capture and recovery records including type of marking were kept separately for each station. Recaptures were again transported to the release station. There is no basis for believing that fin regeneration would interfere during the short time that each study was in progress. In addition to the netting records, the field party regularly examined the lake surface and shoreline for a record of dead fish (marked ones) which might have been killed by netting operations; and an intensive creel census gave daily figures on the removal by anglers of marked and unmarked fish. This study is concerned with pike larger than 14 inches in length and other species over 6 inches; smaller fish were taken uncommonly by the trap nets.

Results

The total number of fish marked and released (Table 1) in the four population studies was 17,887; the total of recaptures was 2,991 or 17 percent (Table 1). The recovery figure is a little misleading

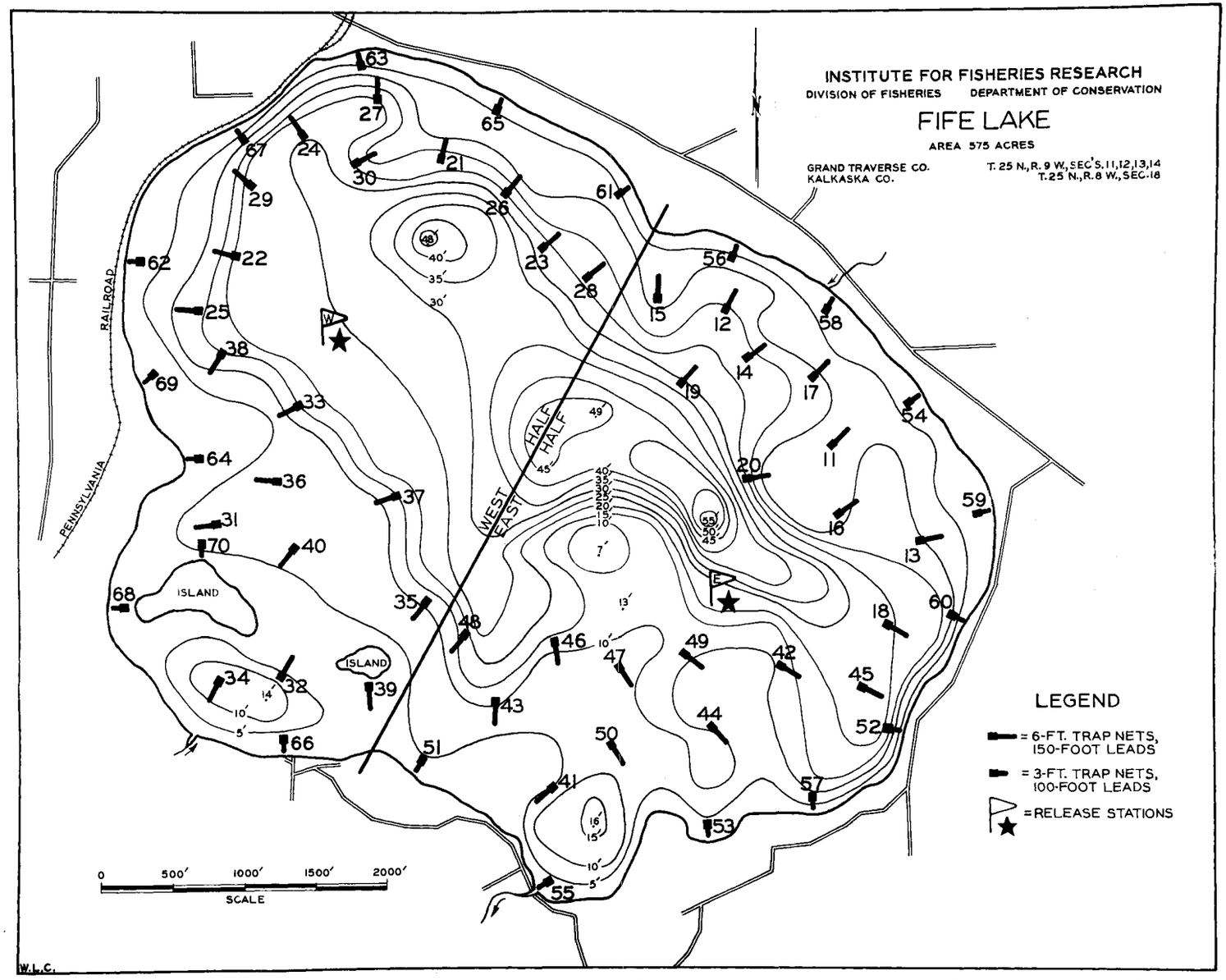

Figure 2.--Map of Fife Lake showing locations of 60 trap-net stations and 2 release stations used in population study during 1950.

Table 1.--Numbers of fish marked and released (a) and numbers recaptured (m) in trap-net population studies, Sugarloaf and Fife lakes.

Kind of fish	Sugarloaf Lake						Fife Lake	
	1948		1949		1950		1950	
	a	m	a	m	a	m	a	m
Bluegill *Lepomis macrochirus*	1113	46	2545	252	3742	717	2773	70
Rock bass *Ambloplites rupestris*	82	3	67	8	386	107	517	29
Pumpkinseed *Lepomis gibbosus*	60	2	303	45	238	48	727	24
Black crappie *Pomoxis nigromaculatus*	218	60	229	168	102	116	680	25
Largemouth bass *Micropterus salmoides*	136	5	78	8	176	41	302	26
Smallmouth bass *Micropterus dolomieu*	--	--	--	--	--	--	198	30
Bullheads *Ameiurus natalis, A. nebulosus*	409	334	159	69	579	398	224	93
Walleye *Stizostedion vitreum*	--	--	--	--	--	--	77	2
Northern pike *Esox lucius*	19	2	25	4	89	18	58	1
White sucker *Catostomus commersoni*	--	--	--	--	--	--	72	8
Warmouth *Chaenobryttus coronarius*	41	--	311	31	566	101	--	--
Yellow perch *Perca flavescens*	--	--	7	--	218	15	13	1
Bowfin *Amia calva*	80	6	75	21	153	56	--	--
Gars *Lepisosteus osseus, L. productus*	22	1	9	--	9	--	--	--
All species	2180	459	3808	606	6258	1617	5641	309

because some individual fish may have been counted as recoveries at least twice; e.g., see the black crappie under Sugarloaf Lake, 1950, in Table 1. The bluegill far outnumbered other species in total captures and gave the greatest number of recaptures. Bullheads, black crappie, pumpkinseed sunfish, rock bass, and largemouth bass were other dominant species. Angling records suggest that the yellow perch is far more abundant in the lakes than is indicated by the netting records, and it seems obvious that it is difficult to catch perch with trap nets of the types here used.

Homing in redistribution

Where fish were marked differently in the two halves of Sugarloaf Lake, and the recoveries were tabulated accordingly, the analysis gives a rough measure of the tendency ("homing") of the fish to return to the part of the lake where first captured. Because the distinctive marking was not applied to each of the numerous netting sites, some of the exactness to be desired in the study was lost. It might be inferred that the stimulus which directed a particular fish to his home half of the lake was an urge to return to his original niche. But this need not be so necessarily, for general habitat conditions may have been a factor, or peculiarities in the (systematic) pattern of netting sites and netting dates may have favored recapture in one half of the lake over the other half. Recoveries in the home half and in the opposite half of the lake were distributed rather evenly throughout the several weeks of each netting period.

There was a small, but obvious, tendency for fish to be recaptured in the same half of the lake where first captured and marked, even though all fish were released at one central station. The 12,246 fish

marked in Sugarloaf Lake (Table 1) included 6,055 fish marked in the west half and 6,191 fish marked in the east half. Of 2,682 recoveries on Sugarloaf (of which 1,393 were marked in the west half, and 1,289 were marked in the east), 1,590 were recovered in the same half where marked, while 1,092 were recovered in the opposite half. Furthermore, the tendency was consistent for the two halves of the lake: west fish tended to return to the west half, and east fish to the east, in two of the three periods, whereas in 1948 the tendency was for fish from both halves to be recaptured in the west (Table 2). The preponderance of homing fish amounted to 498, or 18 percent of the total. As a factor causing bias in the population estimates, this figure of 18 percent seems rather inconsequential, especially because it may have been only partly an expression of homing to the original netting site and also because the extensive pattern of netting sites would compensate somewhat for it. The significant conclusion is that most of the fish redistributed themselves over the lake generally and did not return quickly to a home niche.

The 5,641 fish marked in Fife Lake included 2,723 marked in the west half (1,885 at odd-numbered stations, 838 at even-numbered stations), and 2,918 marked in the east half (1,739 at odd- and 1,179 at even-numbered stations). The 309 recaptures (Table 1) had the following distribution according to the lake half and according to even- and odd-numbered stations, given as percentages of the numbers marked and (in parentheses) the numbers of fish recaptured:

Marked at:	Recovered at:			
	West-odd	West-even	East-odd	East-even
West-odd (1885)	2.92 (55)	2.18 (41)	0.58 (11)	0.16 (3)
West-even (838)	2.74 (23)	1.07 (9)	0.48 (4)	1.43 (12)
East-odd (1739)	0.52 (9)	0.52 (9)	1.78 (31)	1.44 (25)
East-even (1179)	1.19 (14)	0.93 (11)	2.12 (25)	2.29 (27)

Table 2.--Analysis of recaptures of marked fish in Sugarloaf Lake according to whether recovery was in same (S) or opposite (O) half as where originally marked. Numbers of fish marked are given in Table 1.

Kind of fish	Half of lake where marked	1948		1949		1950		Totals	
		S	O	S	O	S	O	S	O
Bluegill	West	23	5	74	46	183	160	280	211
	East	5	13	81	51	237	137	323	201
Rock bass	West	--	2	3	1	18	27	21	30
	East	--	1	2	2	45	17	47	20
Pumpkinseed	West	1	--	14	3	18	2	33	5
	East	1	--	26	2	19	9	46	11
Black crappie	West	10	6	84	29	38	12	132	47
	East	27	17	11	44	33	33	71	94
Largemouth bass	West	2	1	1	1	21	2	24	4
	East	--	2	5	1	10	8	15	11
Bullhead	West	138	82	15	20	139	84	292	186
	East	36	78	19	15	95	80	150	173
Pike	West	--	--	2	2	8	2	10	4
	East	1	1	--	--	2	6	3	7
Warmouth	West	--	--	10	10	20	21	30	31
	East	--	--	6	5	42	18	48	23
Yellow perch	West	--	--	--	--	2	4	2	4
	East	--	--	--	--	5	4	5	4
Bowfin	West	6	--	6	5	18	11	30	16
	East	--	--	7	3	20	7	27	10
Gar	West	1	--	--	--	--	--	1	--
	East	--	--	--	--	--	--	--	--
All species	West	181	96	209	117	465	325	855	538
	East	70	112	157	123	508	319	735	554
	West & East	251	208	366	240	973	644	1590	1092

Of the 1885 fish marked in the west half at odd-numbered stations, 55, or 2.92 percent, were recaptured at west-odd stations, 41 or 2.18 percent at west-even stations, etc; of the 838 fish marked at west-even stations 23, or 2.74 percent, were recaptured at west-odd stations, etc. These figures support two conclusions quite definitely:

(1) Fish marked at odd-type or even-type stations did not tend to be recaptured more frequently at the same type station as where marked, which means that they did not show a predominant tendency to return and be recaptured at their home net sites. The recapture figures which are significant to the point in question are only those for recaptures in the same half of the lake where marked and released. Thus in the above tabulation there are four pairs of data which should be considered as follows:

Same	Opposite	Difference
55	41	+14
9	23	-14
31	25	+ 6
27	25	+ 2

The mean difference is +2, and t is 0.6. It is highly improbable that the fish returned more frequently to the "home" stations.

(2) The fish were recaptured approximately twice as frequently in the same half of the lake where marked and released, which was to be expected in view of the fact that two respective release stations were used for the two halves of the lake making recapture more likely in the home half. This conclusion is so obvious in the preceding tabulation that a t-test on the data is unnecessary. In appraising the homing tendency, one might weigh the returns in proportion to the

distance between release stations and sites of recapture, with the idea that the probability of recapture must be a function of the distance which must be traveled to the recapture site. When the average distances in hundredths of a mile between the release stations and netting sites (as subdivided), as measured on the map, are multiplied by the corresponding figures on percentage of recapture for all species, the resulting distances and migration indexes are obtained as follows:

Subject	From	To stations			
		West-odd	West-even	East-odd	East-even
Average distances	West release	30	32	68	66
	East release	68	69	30	28
Migration indexes	West-odd	88	70	39	11
	West-even	82	34	33	94
	East-odd	35	36	53	40
	East-even	81	64	64	64

The absence of a homing tendency for even- or odd-numbered stations is again apparent in these "corrected" figures. The eight index figures which represent recapture in the home half may be compared statistically with the opposing eight values:

Same half: 88, 70, 82, 34, 53, 40, 64, 64

Opposite: 35, 36, 81, 64, 39, 11, 33, 94

in which the mean difference is 12.8, t is 1.09, and the probability of difference is only 70 percent. We conclude then that the tendency for fish to be recaptured more frequently in their home half of the lake was mostly a function of distance to the nets, not a matter of homing instinct.

Population totals

Estimates of populations were made in all instances by the formula of Schumacher and Eschmeyer (1943) and in most instances were repeated by that of Schnabel (1938). Only estimates by the former formula (generally somewhat lower than by the latter) are cited here. Computations were made for each species separately (necessary because of the species differences in rate of recovery), using the summation formula for records over the period of netting:

$$\text{Population} = \frac{\text{Sum of } \left[\sum_{2}^{N} (mnu)\right]}{\text{Sum of } (nm)}$$

in which the following are daily totals: m is the number of marked fish recaptured, u is the number of unmarked fish caught, and n is the accumulating total number of marked fish presumed to be alive in the lake at the beginning of a particular day. Thus n accumulates by the addition of newly marked fish and the subtraction of marked fish removed from the lake by angling or other mortality. (Figures were obtained by a census of angling and by inspection of the lake for mortality.) Variances and standard errors were calculated by additional formulae given by Schumacher and Eschmeyer (op. cit.).

Among the computed totals (Table 3) the bluegill led the list of species, making up more than 50 percent of the populations of the two lakes. Rock bass, pumpkinseed sunfish, black crappie, largemouth and smallmouth bass, bullheads, and warmouth were other important species. There is a general absence in the lakes of non-predaceous fish of large size. The three separate estimates of total population for Sugarleaf Lake were 15,531, 17,648 and 22,178; and these averaged 18,452 fish or 102 fish of 43.1 pounds per acre. The three estimates were correlated closely with the numbers of trap-net stations on which

Table 3.--Estimates by the Schumacher and Eschmeyer formula, of legal-size fish in Sugarloaf Lake (180 acres) and Fife Lake (575 acres) in Michigan, based on trap-net recaptures.

Species[1]	Sugarloaf Lake					Fife Lake	
	1948	1949	1950	Three-year averages		1950	
	Number	Number	Number	Number	Lbs/acre	Number	Lbs./acre
Bluegill	12,494	11,641	14,012	12,715	18.6	56,511	23.6
Rock bass	972	232	997	734	1.4	4,845	2.0
Pumpkinseed	775	883	825	827	1.3	14,186	5.9
Black crappie	511	302	126	313	0.7	13,673	12.6
Largemouth bass	1,718	367	518	868	6.6	1,789	4.0
Smallmouth bass	---	---	---	---	---	7,264	12.5
Bullheads	543	374	992	636	2.3	424	0.6
Northern pike	80	119	271	157	1.9	---	---
White sucker	---	---	---	---	---	364	1.1
Warmouth	---	1,430	2,389	1,273	2.3	---	---
Yellow perch	---	---	1,615	538	0.7	---	---
Bowfin	478	183	433	365	7.0	---	---
Gars	77	---	---	26	0.3	---	---
Totals	17,648	15,531	22,178	18,452	43.1	99,056	62.3

[1] Too few recaptures of walleyes for an estimate; same for pike, warmouth, perch and gars in certain instances.

the estimates were based---namely, 20, 30 and 40, respectively--and by extrapolation one might conclude that the true population figure was something closer to 30,000 fish. This hypothesis would mean that the estimates based on the lower numbers of stations were in error (underestimated) in that the effective "fields" of the trap-net stations did not completely overlap. Carrying this thought one step farther, if the use of trap nets at the rate of 9, 6 and 4.5 acres per net-station gave underestimations of 50 to 30 percent, the correct size of the trap-net field would be estimated at about 3 acres. Obviously there is much conjecture in the preceding thoughts. The idea that these estimations on Sugarleaf were considerably in error because of the "effective field" question, is not compatible with the results of analysis of recapture records; for, if marked fish were redistributed at random over the lake, i.e., not unduly consentrated within trap-net "fields," the degree of total coverage would not be a critical factor. The analysis of recaptures cited above showed that a "homing" tendency of marked fish was not over 18 percent for Sugarleaf Lake and much less than that for Fife Lake. There remain, for an explanation of the variation in Sugarleaf estimates, the possibilities that an accumulation of minor experimental errors are involved and that there may have been some annual fluctuation in numbers of fish present.

The total population of Fife Lake, of 99,056 fish, was equivalent to 172 fish or 62.3 pounds per acre.

Standard errors of the computed population estimates for Sugarleaf Lake were generally about 5 to 8 percent for the 12 to 14 thousand bluegills and from 10 to over 50 percent for species numbering less than a thousand; and the error percentages were similar for the larger population estimates for Fife Lake. For the general applications which might be made of these population estimates, the errors appear to be of inconsequential magnitude.

Estimates from angling records

Another approach used in computing total populations involved creel census records interpreted in conjunction with the records on marked fish in the lake. An intensive census on Sugarleaf Lake was in operation, during which approximately 14 percent of all angling was recorded. In 1949 and 1950, for three consecutive four-week periods immediately following the trap netting and marking, the census clerk recorded marked and unmarked fish separately. Generally, the anglers fished for the species which were of concern in the trap netting. The numbers of marked fish which were presumed to be present and alive in the lake at the termination of trap netting, and the creel census records, for species most commonly taken by angling, are given in Table 4. The figures appear to be especially good for the bluegill, and fair for the pumpkinseed and largemouth. Data for the bluegill show a rather definite decrease in ratio of marked to unmarked fish over the three four-week periods, but such a trend is not obvious for other species. In this instance the estimates were made by a direct-proportion formula in a single computation for each species.

The estimates based on census figures, for bluegills, show variation depending upon whether records for only the first 4 weeks are used as compared to records for the 12 weeks. The decrease in relative numbers of marked bluegills in the creel records may have been an expression of greater mortality of the marked bluegills or the result of recruitment from growth, or both. The lesser (earlier) figures should be more comparable with the trap-net estimates. The creel estimates are about double the trap-net estimates, rather consistently for all species. The grand totals for all species in 1949 and 1950 are around 35 and 45 thousand as compared to 15 and 20 thousand. The reason for the difference

Table 4.--Marked and unmarked fish in anglers' creels following trap netting, and resultant estimates of fish populations, for selected species.

Year and species	Periods following netting				Marked fish in lake	Estimates based on	
	First four weeks		Next eight weeks			First period	Two periods
	Marked	Unmarked	Marked	Unmarked			
1949							
Bluegill	46	482	16	236	2,236	25,670	28,130
Pumpkinseed	23	56	3	37	256	5,030	4,220
Rock bass	2	27	1	11	61	880	830
1950							
Bluegill	125	585	86	634	3,505	19,910	23,750
Pumpkinseed	12	79	14	126	222	1,680	1,970
Rock bass	2	43	5	63	380	8,550	6,130
Largemouth bass	4	74	16	157	173	3,370	2,170
Bullhead	1	8	8	20	571	5,140	2,350
Warmouth	3	16	6	32	565	3,580	3,580
Bowfin	1	13	4	42	148	2,070	1,780

is not apparent. Mortality, recruitment, and bias in sampling are possibilities. One argument supporting the estimates from creel data is that the combination of netting and angling is theoretically the better procedure, because the one method of collecting avoids some of the sources of bias of the other.

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INSTITUTE FOR FISHERIES RESEARCH

Gerald P. Cooper

Approved by A. S. Hazzard

Typed by B. A. Lowell