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FURTHER STUDIES OF PERCH POPULATIONS *

R. WILLIAM ESCHMEYER

INTRODUCTION

A GROUP of lakes in the Pigeon River State Forest, in Otsego and Cheboygan counties, Michigan, is being used by the Institute for Fisheries Research for experimental studies in fish management. These small lakes, thirteen in number, are located on state-owned land. Certain of them are remarkably similar in their general characteristics. At the time of the Institute's original survey of these lakes in 1931 and 1932 they were found to contain a very limited fish fauna. They were little frequented and resembled virgin waters more nearly than any other group of lakes in the Lower Peninsula.

After the preliminary biological, physical, and chemical survey of these waters in 1931 and 1932 a number of experimental studies involving environmental changes and alterations in the fish fauna were made, particularly on a group of eight small lakes which are known locally as "pothole" lakes and which fit almost perfectly the description of pit lakes as given by Scott (1921). These eight lakes all have thermal stratification, all have high, steep, sandy banks, all but one are almost perfectly circular in outline, and all but one are landlocked.

In four of the lakes the survey party found only perch (except that one also yielded a few common suckers). Two of the others apparently contained only brook trout and minnows. In the other two only forage fish were found. The trout taken from the two lakes were of uniform size and, according to Mr. William Horsell, superintendent of the forest, had been introduced in 1927. The four lakes containing perch provided little or no fishing because the perch apparently were too small to be worth catching; the two lakes with

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation and the University of Michigan.

no game fish were obviously not fished; the two lakes that had been stocked with trout provided excellent fishing.

As a result of the findings of the survey party it was recommended that all eight lakes be stocked with brook trout. The recommendations were carried out in 1933 and 1934. It was found later that four lakes provided some good trout catches, but that the four lakes which contained perch still failed to produce worth-while fishing. Several of these lakes were fished with gill nets to determine the success of the stocking with trout. Apparently few trout had survived in the lakes which contained perch and those which had survived had grown very slowly.

As a further attempt to improve the fishing in the "perch" lakes several environmental changes were considered: (1) increase of the food by fertilizing; (2) removal of a considerable portion of the perch population, and (3) complete removal of the perch followed by stocking with some other species. If lack of food alone limited the growth, fertilization might be expected to increase the number of fish of legal size; if either competition or scarcity of food or crowding was responsible, fishing should be improved by removal of a large percentage of the stock.

One of the lakes was fertilized with several hundred pounds of phosphate fertilizer. The fish in the other three lakes were killed by poisoning (coupled with dynamiting in two of them), and the lakes were later stocked with other species. For methods employed my earlier paper (1937) may be consulted. This paper is confined chiefly to a study of the fish which were collected in three of the lakes after the poisoning.

Some characteristics of one of these populations (that from South Twin Lake) have already been described (Eschmeyer, 1937). It was found that in this lake perch grew very slowly and were in very poor condition. The females grew more rapidly than the males and lived longer. Males, however, were the more numerous. Over three fourths of the fish belonged to a single age group (II group). The evidence suggested further that most of the perch normally died of starvation before reaching legal size.

The discussion which follows includes primarily a consideration of some of the characteristics of the recently studied perch populations (from Ford Lake and Section Four Lake), together with a comparison of these populations with the South Twin Lake fish. The collections

of all three groups of fish were made in lakes in the same general vicinity and at the same time of year (in consecutive years). The methods used in killing and collecting the fish were the same for each lake except that dynamite was not used in Section Four Lake.

THE FORD LAKE FISH POPULATION

Ford Lake lies in Section 8, Township 32 North, Range 1 West, in the northeastern corner of Otsego County. A survey of the lake in 1932 by the Institute revealed an area of 11.7 acres (4.73 hectares) and a maximum depth of 10 meters. In summer the water is definitely stratified, with the thermocline between the depth of 5 meters and the bottom. The bottom soil in shoal is varied (sand in some areas, marl or peat in others) and in deeper water is entirely peat. The water is moderately clear (Secchi disk reading 5.5 meters) and is alkaline (pH 8.2). Dissolved oxygen was present at all depths (9.4 p.p.m. at surface, 8.6 p.p.m. at bottom on August 1, 1932). This landlocked lake is in sandy country covered by "second-growth" timber. The drainage area is small.

In September, 1936, the water level was considerably lower than at the time of the 1932 survey. The lake was resurveyed by Mr. J. B. Schwerdt, project superintendent of Camp Vanderbilt (U. S. Parks Service), and the area was determined as 10.66 acres. This determination is used below in the discussions of population density.

The yellow perch was the only species of fish taken in gill-net and seine collections made in Ford Lake by the survey party in 1932. These perch were mostly small. If fish other than perch were present, they were apparently quite rare, since the lake was fished rather intensively. So far as could be determined, the lake supported little angling.

Ford Lake was stocked with trout on several occasions in an effort to improve fishing conditions. The years in which plants were made and the number, species, and size of the fish are shown in Table I.

Gill nets were fished in this lake in 1934, and the entire population (apparently) was killed by poisoning and dynamiting in 1936. It was obvious in 1936 that the trout plantings had not been very successful. After the fish had been removed, the lake was stocked with Montana grayling.

Both the fish recovered by netting in 1934 and those taken by poisoning and dynamiting in 1936 are discussed below.

TABLE I

STOCKING RECORDS FOR FORD LAKE, 1933-35 *

Year	Species	Number	Age when planted	Average size in inches when planted
1933	Brook trout	500	8 months	4
1934	Brook trout	6,000	6 months	$3\frac{1}{4}$
	Brown trout	600	8 months	$3\frac{1}{2}$
	Rainbow trout	600	Yearlings	5
1935	Rainbow trout	300	Adults (3 years old)	12–15

* Data provided by Mr. Guy Lincoln, district superintendent of fisheries operations, Oden Hatchery.

Fish Taken in 1934

A total of 1,137 perch and 15 brook trout were taken in two experimental gill nets [1] fished continuously from July 23 to July 30. The trout were not preserved and were not measured. Their estimated average total length was 6 to 7 inches. Some of the perch were discarded, but a random sample of 602 specimens was preserved in a 10 per cent solution of formalin.

Sex determinations were made of all the preserved fish. Determinations of weight, length, and age were made for a random sample of 100 individuals. The average standard length and average total length in millimeters, the average weight in grams, and the average coefficient of condition (K) [2] of each age group in each sex are shown in Table II.

If the 100 specimens constituted a representative sample of all the perch taken in gill nets, the following conclusions may be made regarding the Ford Lake perch population:

Sex. — The two sexes were about equally represented. Of the 602 specimens, 298 were females, 304 were males.

Growth. — The females grew more rapidly than the males. In all age groups represented (except age group I) the fish of both sexes

[1] The sizes of mesh (stretched measure) in the nets varied from $1\frac{1}{4}$ to 4 inches.

[2] The formula $K = \frac{W \times 10^5}{L^3}$ was used, where W = weight in grams and L = standard length in millimeters.

TABLE II

AVERAGE STANDARD LENGTH (MILLIMETERS), AVERAGE TOTAL LENGTH (INCHES), AVERAGE WEIGHT (GRAMS), AND AVERAGE CONDITION FOR A RANDOM SAMPLE OF FEMALE AND MALE PERCH OF DIFFERENT AGES

All specimens were taken in July, 1934, by gill nets.

Age group	No. of specimens	Average standard length (mm.)	Average total length (inches)	Average weight (grams)	Average *K*
Females					
II	19	113	5.3	24	1.67
III	27	115	5.4	26	1.68
IV	7	123	5.8	31	1.65
Total or average	53	115	5.4	26	1.67
Males					
I	1	108	5.2	22	1.75
II	19	110	5.2	23	1.70
III	27	111	5.2	22	1.62
Total or average	47	111	5.2	22	1.65

had a very slow growth. (See Table II.) The growth zones of the scales of all age groups indicated that growth was moderately good during the first year and generally during the second year. After the second year the annual growth increments were small. It is probable that this change in growth resulted from a lack of food of a size suitable for larger perch.

Weight. — The perch had an average weight of 24 grams, or slightly less than one ounce (entire sample of 100 fish).

Condition. — The perch were in relatively good condition. The value of *K* decreased slightly as the age increased, but this decrease was probably too small to be significant. In general, condition varied little with either sex or age.

Length of life. — The sample suggests that the females tend to live longer than the males. Seven of the 53 females were of the IV group, but the oldest of the males were of the III group. This sex difference in longevity is in accord with findings of other studies of perch (Schneberger, 1935; Eschmeyer, 1937).

Total weight of sample. — If the average weight of the perch is assumed to be 24 grams, the number removed (1,137) had a total

weight of 27,288 grams (60.2 pounds), or a weight of 2,560 grams (5.6 pounds) per acre.

The ratio of trout to perch in 1934 (15 : 1137) was approximately 1 : 76. A computation of the fish removed in 1936 indicated a total population of approximately 5,000 perch at that time. If about the same number was present in 1933, the ratio of trout to perch immediately after the planting of 500 trout in 1933 was about 1 : 10. Apparently the number of trout in the population had declined very materially between 1933 and 1934, unless the difference in the two ratios (1 : 76 and 1 : 10) was due to net selectivity.

Gill nets were fished in 1934 in an effort to reduce the population, since there appeared to be a scarcity of food for the number of perch present, especially food of intermediate or large size (minnows). The perch removed in 1934 represented approximately 24 per cent of the perch recovered in 1936. It was, of course, impossible to determine what percentage of the fish present in 1934 had been removed.

Not only was the food per fish increased by the removal of some of the perch, but a total of about 15,500 forage fish was planted in July, 1934. These fish were taken from a small stream where it had been impounded by beaver. Most of them were northern dace (*Chrosomus eos*), although limited numbers of fathead minnows (*Pimiphales promelas*), sticklebacks (*Eucalia inconstans*), mud minnows (*Umbra limi*), and perhaps a few fish of some other species were also present.

Fish Taken in 1936

On the morning of September 9, 1936, Mr. W. F. Carbine and the writer, assisted by men from Camp Vanderbilt, poisoned the waters of Ford Lake with 200 pounds of powdered derris root (5 per cent rotenone content) mixed with water. On the afternoon of the same day recovery of the dead fish was facilitated by discharging 500 sticks of dynamite in the water. The fish began to die within about an hour after the poisoning. The collection of the dead fish was started immediately and was continued for three days. On the third day 183 dead perch were counted along the shore, but were not collected because of their semidecomposed condition.

It is probable that all the fish were killed, and it is also probable that almost all the perch were either collected or counted. (In two

other lakes where weaker concentrations of derris root had been used the entire perch population had been destroyed. Nets set in these lakes in 1936 failed to produce fish.) How many dead fish remained in deep water in Ford Lake is not known, but over that part of the bottom which could be seen from a boat (about a third of the entire area) no dead perch were observed other than the 183 specimens mentioned above. The evidence, therefore, though not conclusive, suggests that all fish were killed and that almost all the perch were definitely accounted for.

Total Fish Population

A collection of 3,762 perch was preserved in a 10 per cent solution of formalin and 1,055 perch were discarded. At least 4,817 perch are therefore definitely known to have been present. Computations based on the average weight of 1,050 specimens taken at random give an estimated weight of 347 pounds for the total perch population.

A total of 24 rainbow trout and 1 brown trout were preserved and 2 trout (partly decomposed) were discarded. These trout had a combined weight of 7 pounds (provided the 2 trout discarded were of average weight).

Dead minnows lined the shore, especially along the wave-swept side. On two representative 10-foot sections of shore line the dead minnows were counted by Dr. A. S. Hazzard and Mr. Carbine. According to the counts made, the lake shore contained 15.3 minnows per linear foot of shore line. Ford Lake, with an area of 10.66 acres, would have a circumference of about 2,400 feet if it were exactly circular. The exact length of shore line was not determined, but since the outline of the lake is roughly circular, its length may be estimated at that figure. On this basis the lake had contained approximately 36,700 minnows. Weight determinations of 61 specimens of minnows gave an average weight of about 2 grams. The minnows, therefore, weighed approximately 73,400 grams or 162 pounds. The weight of minnows per acre was about 15 pounds.

The total fish population in 1936 was approximately as follows:

	Pounds
Perch.....	347
Trout.....	7
Minnows....	162
Total.....	516

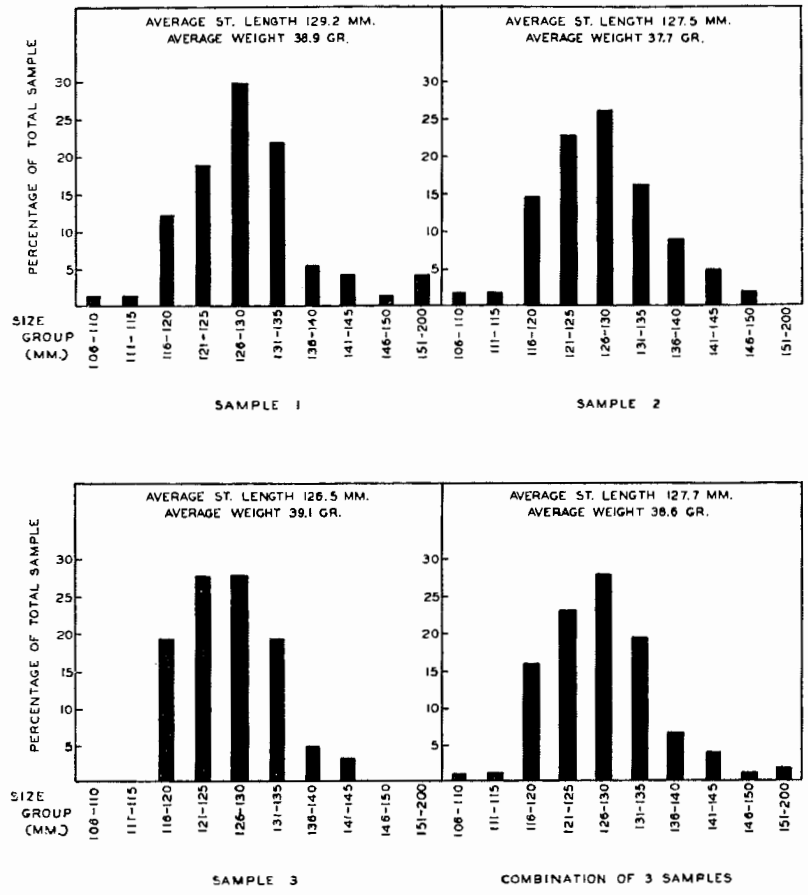

FIG. 1. Size distribution of 205 females in three lots of perch taken at random and also in the three lots combined

The lake therefore maintained about 50 pounds of fish per acre.

The first important evidence obtained from the collections was that the plantings of trout in Ford Lake were not very successful. A total of 8,000 trout had been planted since 1933, but only 28 were recovered in 1936 (and 15 in 1934). Relatively few were removed by fishermen. Some may have remained on the bottom at the time of the poisoning, but it seems safe to conclude that the survival from trout plantings in the lake was very slight. The few which were recovered were in relatively poor condition.

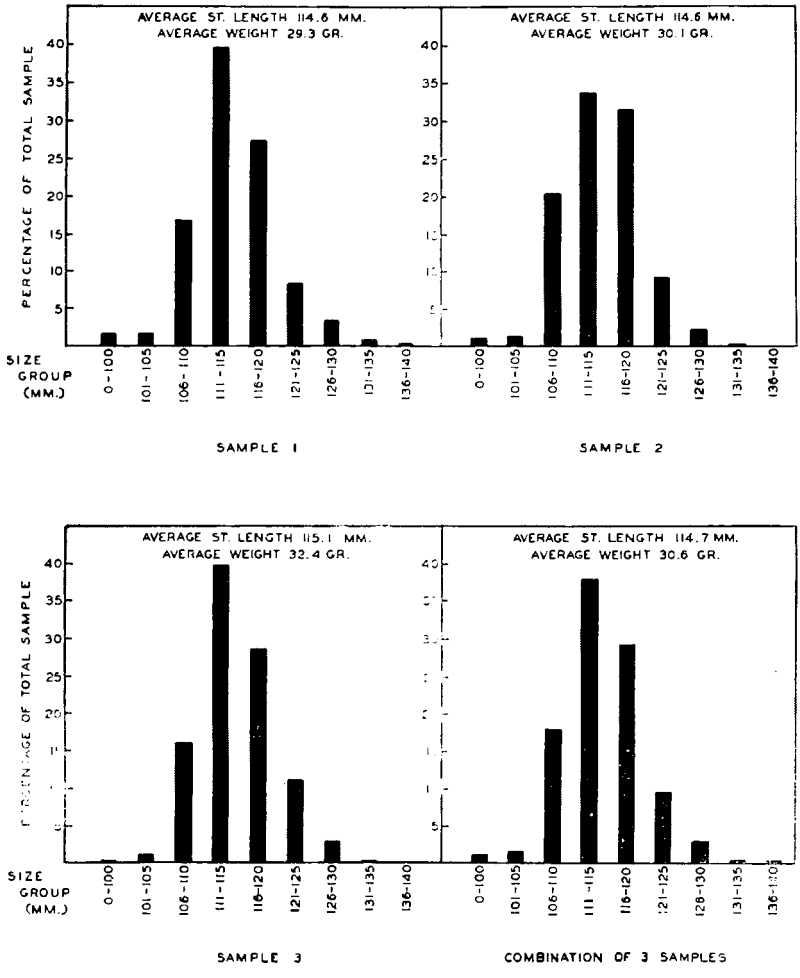

FIG. 2. Size distribution of 845 males in three lots of perch taken at random and also in the three lots combined

Because of the apparently unfavorable balance between fish and food at the time the minnows were stocked (in 1934) it was not expected that any of the species would become established. It was assumed that the minnows would soon be eaten by the perch. The minnows did serve as a food item for the perch, but evidently enough survived for them to become definitely established. All

species except sticklebacks known to have been stocked in 1934 were found in 1936. The number of minnows had apparently doubled in the two years.

The large number of perch in the collection made the use of samples advisable. Sex determinations were made for all the 3,762 preserved perch, but the data on length and weight are based on three samples of 350 fish each, taken at random. The close similarity of the data obtained from each of these three samples (Table III and Figs. 1–2) demonstrates that the results obtained from their combination (1,050 fish) may be considered representative for the entire population. In further discussions of length and weight it is assumed that the averages for the three samples (845 males and 205 females) represent the averages of the entire population. The error which might be involved in using these samples rather than the entire populations is obviously small.

TABLE III

AVERAGE STANDARD LENGTH (IN MILLIMETERS) AND AVERAGE WEIGHT (IN GRAMS) FOR THREE RANDOM SAMPLES OF FEMALE PERCH AND THREE RANDOM SAMPLES OF MALE PERCH AND FOR COMBINATIONS OF THE THREE SAMPLES (205 FEMALES, 845 MALES)

Sample	Average standard length (mm.)	Average weight (grams)
Females		
Sample 1	129.2	38.9
Sample 2	127.5	37.7
Sample 3	126.5	39.1
Combination of 3 samples	127.7	38.6
Males		
Sample 1	114.6	29.3
Sample 2	114.6	30.1
Sample 3	115.1	32.4
Combination of 3 samples	114.7	30.6

Size Distribution

The length distribution for each sex is shown in Figures 1–2 and in Table IV. The distribution of both male and female perch approaches a normal curve, but fails to indicate more than one age group except for the suggestion of a second group of males (at 71–80

millimeters) represented by a very few individuals. On the average, the females were 13 millimeters longer than the males.

TABLE IV

LENGTH DISTRIBUTION OF 205 FEMALE PERCH AND 845 MALE PERCH BY FIVE-MILLIMETER CLASSES (STANDARD LENGTH)

Length group (millimeters)	Females		Males	
	Number	Percentage of total	Number	Percentage of total
71–75	..	....	2	0.2
76–80	..	....	2	0.2
81–85	..	....	...	....
86–90	..	....	1	0.1
91–95	..	....	...	....
96–100	..	....	4	0.5
101–105	..	....	12	1.4
106–110	2	1.0	150	17.8
111–115	2	1.0	319	37.8
116–120	32	15.6	245	29.0
121–125	47	22.9	81	9.6
126–130	57	27.8	24	2.8
131–135	39	19.0	4	0.5
136–140	13	6.3	1	0.1
141–145	8	3.9	...	....
146–150	2	1.0	...	....
151–155	2	1.0	...	....
156–160	..	....	...	....
161–165	1	0.5	...	....
Total	205	100.0	845	100.0
Average standard length	127.7 mm.	....	114.7 mm.	....

Age Determinations

An effort was made to determine the ages of the 1,050 fish in the three samples. For some reason not known to the writer the annuli beyond the second year were very difficult, often impossible, to locate with certainty. After repeated efforts the attempt to determine the ages was abandoned except for approximately 150 specimens. Even on these it is not certain that the annuli were invariably counted correctly. Annuli were more easily located on the perch taken from Ford Lake in 1934 than on those taken from the same lake in 1936.

The size, weight, and condition of these fish as determined for the different age groups are shown in Table V.

TABLE V

LENGTH, WEIGHT, AND CONDITION OF PERCH OF EACH SEX, BY AGE GROUPS, BASED ON A STUDY OF 149 SPECIMENS

Age group	Number of specimens	Average standard length (mm.)	Average total length (inches)	Average weight (grams)	Average *K*
Females					
II	1	116	5.51	37.8	2.42
III	21	127	5.98	37.0	1.83
IV	4	130	6.14	41.1	1.88
V	1	131	6.30	41.7	1.85
Total or average (females)	27	127	5.98	37.8	1.86
Males					
0	1	90	4.06	14.0	1.92
I	1	111	5.31	32.9	2.41
II	7	113	5.35	29.2	2.00
III	90	116	5.51	32.7	2.08
IV	23	119	5.63	35.3	2.11
Total or average (males)	122	116	5.51	32.8	2.07

The position of the first two annuli showed that the growth was reasonably good during the first year and, in most specimens, during the second year, but growth was very poor in all succeeding years. The data on age groups II, III, and IV (Table V) suggest that the females grew more rapidly than the males. Fish of the III group apparently predominated, although fish of the IV group were fairly well represented. Young fish (0, I, and II groups) were scarce.

The approximate number of legal-sized perch of each sex was determined. All fish 150 mm. or more in length were regarded as legal-sized fish (6 inches or 152.4 mm. total length). Since all fish had been preserved before measurements were taken, some shrinkage undoubtedly occurred. The shrinkage factor 1.016 determined by Van Oosten (1929) for lake herring was used. Of the 845 males examined 44 (5.2 per cent) were of legal size, and of the 205 females 140 (68.3 per cent) were of legal size. Since the entire population of

4,817 perch (sexes were determined for 3,762 fish) was estimated to contain 3,572 males and 1,245 females, the total number of legal-sized fish in the lake included approximately 186 males and 850 females. The ratio of females to males in the lake was approximately 1 : 3, but the ratio of legal-sized females to legal-sized males was over 4 : 1. The only age groups whose average lengths were above the 6-inch legal limit were the IV and V group females.

It might be argued that the lake contained more males than females because few legal-sized males were taken by the fishermen, whereas a majority of the females were of legal length. The lake was fished so little, however, that this argument does not hold.

Sex Ratio

In the perch taken by gill nets in 1934 the two sexes were about equally divided. Nets, as stated earlier, were again set in Ford Lake just before the poisoning in 1936 and were lifted immediately after the poisoning operations had been completed. The fish taken in the nets were inadvertently placed with the dead fish collected, and consequently the sex ratio of the gill-net sample could not be determined. It was noted later, however, that of those fish having gill-net marks about half were females. It may be stated with assurance that the gill nets were highly selective with respect to the sexes, probably because most of the males were too small to be caught in them.

The 3,762 perch which were preserved consisted of 2,791 males and 971 females. There were 34.8 females per 100 males or approximately a 1 : 3 ratio. A fourth of the perch (25.8 per cent) were females. It is improbable that the percentage of females changed from about 50 per cent in 1934 to 25 per cent in 1936. It is more likely that the perch taken in gill nets set in 1934 were not representative, with respect to the sex ratio, of the fish which were then present in the lake.

Food

No investigation was made of the food available for the fish, but the stomach contents of 100 males and 100 females, taken at random, were examined. This study was especially interesting because it showed a difference in the food of the two sexes.

A fourth (25) of the stomachs from females contained minnows.

They were in various stages of digestion, and obviously many had been eaten before the poisoning. The stomach of one female contained a partly digested perch. Eight stomachs from females contained a half-dozen or more winged ants. It is probable that a flight of these ants had crossed the lake just before the poisoning and that ants were not ordinarily available in abundance as food. Twenty-four stomachs contained *Corethra* (mostly larvae) and 22 contained chironomid larvae. Other food organisms, including Ephemeridae, Amphipoda, Odonata, Coleoptera, Phyllopoda, and Trichoptera, were present in relatively insignificant numbers. Seventeen stomachs were empty.

Of the 100 stomachs from males only 3 contained minnows. Several ants were found in another. *Corethra* occurred in 31 stomachs, and Chironomidae in 14. Odonata, Ephemeridae, Phyllopoda, Amphipoda, and Cladocera were found in a very few stomachs. Over a third (36) of the stomachs were empty.

Death by poisoning is relatively rapid, and it is possible that the proportion of empty stomachs is representative of normal conditions.

It may be stated that minnows constituted the chief food of the females and that *Corethra* larvae were the chief food of the males. Earlier in the summer, when the young minnows were smaller, they may have served as an important food organism for the male perch also. The decided increase in the condition (K) and the slight increase in growth in 1936 over 1934 may have resulted from the introduction of minnows in 1934 or from reduction in population by netting.

Distribution of the Sexes within the Lake

The Institute's lake-survey parties have frequently observed that perch removed from their nets were mostly of one sex. Often catches of 50 or more were all of one sex. Members of the parties who failed to recognize this peculiarity often doubted for a while their ability to determine the sex of perch, despite the fact that the structure of the gonads makes sex determination of individual perch relatively simple. Since the sexes have different rates of growth, the dominance of one sex in the net may depend, partly, on net selectivity. It has been noted, however, that even in line fishing the fish taken may be largely of only one sex. It would seem, therefore, that, to some extent at least, the two sexes tend to school separately. Since such schooling

appears to take place during all or most of the summer, it is seemingly not connected with spawning. The food study offers further evidence of the schooling in separate sexes and gives a plausible reason for such segregation. The minnows were apparently normally in shallow water, and the ants were very probably floating on the surface. Since these two food items were prominent in the stomachs of the females, it appears probable that many of the females were feeding in shallow water. The males, on the contrary, were apparently in deeper water, where they fed primarily on midge larvae. In Ford Lake, at least, a difference in the distribution of the two sexes can be explained on the basis of the differences in the distribution of their favorite food organism. Differences in growth rate of the sexes account for differences in feeding habits of fish of the same age. Whether similar situations are to be found in other perch populations remains to be determined.

SECTION FOUR LAKE

Section Four Lake, Town 32 North, Range 1 West, is a pothole lake that is similar in many respects to South Twin Lake. According to the Institute's survey in 1932, it has an area of 3.3 acres and a maximum depth of 21.7 meters. The outline is almost perfectly circular, and the basin is bowl-shaped, with very little shoal area. In summer the water is definitely stratified, with a thermocline at 4–11 meters (August 1, 1932). The bottom soil on the shoal and the slope is marl, and in deeper water is peat. The water is relatively clear (Secchi disk reading 6.8 meters) and is alkaline (surface pH 7.9). The survey showed (August 1, 1932) that the dissolved oxygen is high at the surface and in the thermocline (11.1 p.p.m. at 8 meters), but is low near the bottom (1.8 p.p.m. at 14 meters; trace at bottom). This very small landlocked lake has high, steep, sandy banks and an extremely small drainage basin.

The survey records indicate that only perch were taken in the gill-net and seine fishing in 1932. It is doubtful whether other fish were present at that time. In 1932, and again in 1934, when a few perch were taken in gill nets, the fish were small (seldom over 6 or 7 inches long) in all samples.

Section Four Lake seemed well suited for trout except that here, as in the other landlocked lakes in the area, the trout could not, of course, be expected to maintain themselves by natural reproduction.

In 1933 Oden Hatchery officials stocked this lake with 300 brook trout eight months old. In 1935 the lake (after removal of the perch) was stocked with 150 adult rainbow trout.

On September 19, 1935, Dr. A. S. Hazzard and the writer distributed approximately 75 pounds of powdered derris root (5 per cent rotenone content) over the lake. The first dying fish were observed one and one-half hours after the introduction of the poison. Collecting of the dead fish was begun immediately and continued, at intervals, for the next fifty hours. Dead perch were still coming to the surface when the party left. Nets set in this lake a year later (September, 1936) produced no perch. It seems, therefore, that all perch were killed. Not all were collected, however.

Total Population

A total of 1,736 perch (526 per acre) were recovered. These fish had a combined weight of 76.36 pounds or a weight of 23.1 pounds per acre. The actual number and weight of the fish present were, of course, in excess of these figures.

TABLE VI

LENGTH DISTRIBUTION OF PERCH FROM SECTION FOUR LAKE BY CENTIMETER INTERVALS (STANDARD LENGTH)

The dotted line approximately divides the undersized and the legal-sized fish.

Length group (millimeters)	Both sexes	Females	Males
49.5–59.5	1	1	...
59.5–69.5	91	40	51
69.5–79.5	322	142	180
79.5–89.5	34	9	25
89.5–99.5	90	18	72
99.5–109.5	250	50	200
109.5–119.5	592	53	539
119.5–129.5	246	124	122
.....	.....	.....	.....
129.5–139.5	72	60	12
139.5–149.5	27	26	1
149.5–159.5	7	7	...
159.5–169.5	3	3	...
169.5–179.5	1	1	...
Total	1,736	534	1,202

TABLE VII

NUMBER OF FEMALE AND MALE PERCH IN EACH YEAR GROUP, AND AVERAGE LENGTH, WEIGHT, AND CONDITION OF FISH *

Item	Age group				
	0	I	II	III	IV
Number of fish:					
Females	192	82	171	82	7
Males	255	149	786	12	..
Total (both sexes)	447	231	957	94	7
Average standard length (mm.):					
Females	72.8	104.7	123.5	136.9	157.9
Males	76.5	100.0	115.2	131.3	....
Average weight (grams):					
Females	6.2	17.2	28.6	41.0	63.1
Males	6.0	15.8	24.3	34.4	....
Average total length (inches, approximate):					
Females	3.5	4.9	5.8	6.5	7.4
Males	3.6	4.8	5.4	6.2	....
Average weight (ounces):					
Females	0.2	0.6	1.0	1.4	2.2
Males	0.2	0.55	0.9	1.2	....
Average value of K:					
Females	1.66	1.53	1.54	1.59	1.60
Males	1.36	1.63	1.60	1.53	....

* Since these fish were taken in mid-September they were actually almost one growing season older than the figures (annuli) indicate.

Size and Age Distribution

All perch recovered were measured to the nearest millimeter and weighed to the nearest tenth of a gram after several months' preservation (first in 10 per cent formalin and later in 70 per cent alcohol). The 0 group fish were weighed in lots of 20–50 each; all other fish were weighed individually. The length distribution, by centimeter groups, is shown in Table VI. No really large perch were taken. The data suggest the presence of at least two age groups.

The ages of approximately 50 per cent of the fish were determined by a study of the scales. Many of the perch of the 0 and II groups could be placed in their age groups without examination of the scales.

This method of separating these two age groups was used for about half of these fish. If any error was involved, it was slight, for subsequent scale examination proved the ages estimated for several hundred fish to be correct.

In contrast with the perch from South Twin Lake and Ford Lake, most of the fish in Section Four Lake (Table VI) were young. The II group, which was represented by 957 specimens, comprised over half of the fish taken, but both the 0 group and the I group were also well represented. Only age groups III and IV, represented by a total of 101 specimens, averaged legal size (6 inches).

The females were larger than the males in all except the 0 group. Young fish were dominantly males, but the fish in the III group were 87 per cent females and all fish in the IV group were females (Table VII). Most of the legal-sized fish were females.

Sex Ratio

The ratio of males to females was 100 : 44 or approximately 2 : 1. Because the lake was fished very little this predominance of males cannot be attributed to the fact that most of the legal-sized perch were females and therefore more subject to capture by fishermen.

Condition

The perch of all age groups were in fair condition, except that the males in the 0 group were relatively slender. In general, the K varied little for the several age groups. The females tended to improve slightly in condition after the first year, but the averages of K for males decreased slightly with increase in age.

SOME CONCLUSIONS REGARDING THE THREE PERCH POPULATIONS

This summary is based on data for the two populations discussed above and for the South Twin Lake population described in an earlier paper (Eschmeyer, 1937). All three populations were removed in September, one in each of the years 1934, 1935, and 1936. Derris root was used to poison the fish in all three lakes, and dynamite was employed after the poisoning in two of them.

Total Populations

The fish of the two lakes which were both poisoned and dynamited were probably almost all collected or seen. The population was

approximately 30 pounds per acre in the lake with very little shoal (South Twin), and about 50 pounds per acre in the one with extensive shoal. The numbers of perch actually accounted for varied from 452 per acre in Ford Lake to 955 per acre in South Twin Lake.

Size and Age Distribution

The perch grew slowly in all three lakes. Their growth, except for the first year, was slower than the growth of perch for other waters as determined by Harkness (1922), Hile (1931), Jobes (1933), and Schneberger (1935). Comparative growth data are presented in Table IV of the study of the South Twin Lake perch (Eschmeyer, 1937). Since the other authors removed only a portion of the fish, data on comparative population densities are not available. It seems probable, however, that the populations from the three lakes in the Pigeon River State Forest were more dense than were those in the other lakes studied.

From a fishing standpoint, all three lakes were of little value. Some of the perch in each lake (5.8 per cent in Section Four Lake to 21.5 per cent in Ford Lake) were of legal size (6 inches), but very few had a length of 7 inches.

In two of the three lakes the young age groups (0 and I) were almost entirely absent. It is possible that most of the young perch of those lakes had been eaten by the larger fish.

In all three lakes the females grew more rapidly than the males. The females also tended to live longer. The oldest fish were invariably females.

In general, the perch grew very slowly after their first or second year of life. This slow growth is attributed to a scarcity of food organisms of moderate size (except in Ford Lake in 1936), but it is possible that the concentration of fish, rather than the food supply, may have been responsible for the slow growth.

Sex Ratio

Males predominated in all three perch populations. The ratios of males to females for each lake were: South Twin Lake, 100 : 74; Section Four Lake, 100 : 44; and Ford Lake, 100 : 35. The reason for the differences in the sex ratio in the three lakes has not been found. It cannot be attributed to the selective capture of females in sport fishing since all the lakes were fished very little. The lake with

the fish in poorest condition had twice as many females per 100 males as the lake containing perch in the best condition. Whether or not the greater viability of the females in the face of adverse conditions (Geiser, 1924) explains this difference cannot be stated. The predominance of males suggests that, in the early stages, the females tended to suffer a much greater mortality than the males unless, of course, the sexes were not equally represented in the fish immediately after hatching. In later years, however, the mortality of males exceeds that of the females.

Condition

The perch in South Twin Lake were in very poor condition; those in Ford Lake were in excellent condition. The average of K for Section Four Lake perch was intermediate. Nevertheless all three populations grew quite slowly. The condition of these fish was therefore not correlated with their rate of growth. Apparently the fact that a fish is in good condition is not an indication that it is also growing rapidly.

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UNIVERSITY OF MICHIGAN

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Mr. Ruhl
Mr. Eschmeyer

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REPORT NO. 409

FURTHER STUDIES OF PERCH POPULATIONS*

R. William Eschmeyer

Introduction

A group of lakes located in the Pigeon River State Forest, in Otsego and Cheboygan counties, is being used by the Institute for Fisheries Research for experimental studies in fish management. These small lakes, 13 in number, are located on state-owned land. Certain of them are remarkably similar in their general characteristics. At the time of the Institute's original survey of these lakes in 1931 and 1932, they were found to contain a very limited fish fauna. They were little frequented and resemble virgin waters more nearly than any other group of lakes in the Lower Peninsula.

After the preliminary biological, physical and chemical survey of these waters in 1931 and 1932, a number of experimental studies involving environmental changes and alterations in the fish fauna were made, particularly on a group of eight small lakes which are known locally as "pot-hole" lakes and which fit almost perfectly the description of pit lakes as given by Scott (1921). These eight lakes all have thermal stratification, all have high, steep, sandy banks, all but one are almost perfectly circular in outline and all but one are land-locked.

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* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation and the University of Michigan.

In four of the lakes the survey party found only perch (except that one also contained a few common suckers). Two of the others apparently contained only brook trout and minnows. In the other two only forage fish were found. The trout taken from the two lakes were of uniform size and, according to Mr. William Horsell, Superintendent of the forest, had been introduced in 1927. The four lakes containing perch provided little or no fishing because the perch apparently were too small to be worth catching; the two lakes with no game fish were obviously not fished; the two lakes that had been stocked with trout provided excellent fishing.

As a result of the findings of the survey party, it was recommended that all eight lakes be stocked with brook trout. The recommendations were carried out in 1933 and 1934. It was found later that four of the lakes provided some good trout catches but that the four lakes which contained perch still failed to produce worthwhile fishing. Several of these lakes were fished with gill nets to determine the success of the stocking with trout. Apparently few trout had survived in the lakes which contained perch and those which had survived had grown very slowly.

As a further attempt to improve the fishing in the "perch" lakes, several environmental changes were considered: (1) increase of the food by fertilizing; (2) removal of a considerable portion of the perch population and (3) complete removal of the perch followed by stocking with some other species. If food alone limited the growth, fertilization might be expected to increase the number of fish of legal size; if either competition, food or crowding were responsible, fishing should be improved by removal of a large percentage of the stock.

One of the lakes was fertilized with several hundred pounds of phosphate fertilizer. The fish were killed in the other three lakes by poisoning (coupled with dynamiting in two of them) and were later stocked with other species. For methods employed, consult my earlier (1937) paper.

This paper is confined primarily to a study of the fish which were collected in three of the lakes after the poisoning.

Some characteristics of one of these populations (that from South Twin Lake) have already been described (Eschmeyer, 1937). It was found that in this lake perch grew very slowly and were in very poor condition. The females grew more rapidly than the males and lived longer than the males. However, males were the more numerous. Over three-fourths of the fish belonged to a single age group (II group). The evidence suggested further that most of the perch normally died of starvation before reaching legal size.

The discussion which follows includes primarily a consideration of some of the characteristics of the recently studied perch populations (from Ford Lake and Section 4 Lake) together with a comparison of these populations with the South Twin Lake fish. The collections of all three groups of fish were made in lakes in the same general vicinity and at the same time of year (on consecutive years). The methods used in killing and collecting the fish were similar for each lake except that dynamite was not used in Section 4 Lake.

The Ford Lake Fish Population

Ford Lake lies in Section 8, Township 32 North, Range 1 West, in the northeastern corner of Otsego County. A survey of the lake in 1932 by the Institute revealed an area of 11.7 acres (4.73 hectares) and a maximum depth of 10 meters. In summer the water is definitely stratified with the thermocline between the depth of 5 meters and the bottom. The bottom soil in shoal is varied (sand in some areas, marl or peat in others) and in deeper water is entirely peat. The water is moderately clear (Secchi disc reading 5.5 meters) and is alkaline (pH 8.2). Dissolved oxygen was present at all depths (9.4 p.p.m. at surface, 8.6 p.p.m. at bottom on August 1, 1932). This land-locked lake is located in sandy country

covered by "second growth" timber. The drainage area is small.

In September, 1936, the water level was considerably lower than at the time of the 1932 survey. The lake was resurveyed by Mr. J. B. Schwerdt, Project Superintendent of Camp Vanderbilt (U. S. Parks Service), and the area was determined as 10.66 acres. This determination is used below in the discussions of population density.

The yellow perch was the only species of fish taken in gill-net and seine collections made in Ford Lake by the 1932 survey party. These perch were mostly small. If fish other than perch were present, they were apparently quite rare, since the lake was fished rather intensively. So far as could be determined, the lake supported little angling.

Ford Lake was stocked with trout on several occasions in an effort to improve fishing conditions. The years in which plants were made and the number, species and size of the fish are shown in Table 1.

Table 1

Stocking Records for Ford Lake, 1933-1935*

Year	Species	Number	Age When Planted	Average Size When Planted
1933	Brook Trout	500	8 months	4 inches
1934	Brook Trout	6,000	6 months	3¼ "
	Brown Trout	600	8 "	3½ "
	Rainbow Trout	600	Yearlings	5 "
1935	Rainbow Trout	300	Adults (3 yrs. old)	12-15 "

* Data provided by Mr. Guy Lincoln, District Superintendent of Fisheries Operations, Oden Hatchery.

Gill nets were fished in this lake in 1934 and the entire population (apparently) was killed by poisoning and dynamiting in 1936. It was obvious in 1936 that the trout plantings had not been very successful. After the fish were removed, the lake was stocked with Montana grayling.

Both the fish recovered by netting in 1934 and those taken by poisoning and dynamiting in 1936 are discussed below.

Fish Taken in 1934

A total of 1,137 perch and 15 brook trout were taken in two experimental gill nets[1] fished continuously over the period of days from July 23rd to July 30th. The trout were not preserved and were not measured. Their estimated average total length was 6 to 7 inches. Some of the perch were discarded, but a random sample of 602 specimens was preserved in a 10% solution of formalin.

Sex determinations were made of all the preserved fish. Determinations of weight, length and age were made for a random sample of 100 individuals. The average standard length and average total length in millimeters, the average weight in grams and the average coefficient of condition (K)[2] of each age group in each sex are shown in Table 2.

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[1] The sizes of mesh (stretched measure) in each net varied from $1\frac{1}{4}$ to 4 inches.

[2] The formula $K = \frac{W \times 10^5}{L^3}$ was used, where W = weight in grams and L = standard length in millimeters.

Table 2

Average Standard Length (Millimeters), Average Total Length (Inches), Average Weight (Grams), and Average Condition For a Random Sample Of Male and Female Perch Of Different Ages. All Specimens Were Taken In July, 1934, By Gill Nets.

	Age Group	No. of Specimens	Average Standard Length (mm.)	Average Total Length (inches)	Average Weight (grams)	Average K
Females	II	19	113	5.3	24	1.67
	III	27	115	5.4	26	1.68
	IV	7	123	5.8	31	1.65
Total or Average		53	115	5.4	26	1.67
Males	I	1	108	5.2	22	1.75
	II	19	110	5.2	23	1.70
	III	27	111	5.2	22	1.62
Total or Average		47	111	5.2	22	1.65

If the 100 specimens constituted a representative sample of all the perch taken in gill nets, the following conclusions may be made regarding the Ford Lake perch population:

Sex: The two sexes were about equally represented. Of the 602 specimens, 298 were females, 304 were males.

Growth: The females grew more rapidly than the males. In all age groups represented (except age group I), the fish of both sexes had a very slow growth. (See Table 2.) The growth zones of the scales of all age groups indicated that growth was moderately good during the first year and generally during the second year. After the second year the annual growth increments were small. It is probable that this change in growth resulted from a lack of food of a size suitable for larger perch.

Weight: The perch had an average weight of 24 grams or slightly less than one ounce (entire sample of 100 fish).

Condition: The perch were in relatively good condition. The value of K decreased slightly as the age increased, but this decrease was probably too small to be significant. In general condition varied little with either sex or age.

Length of Life: The sample suggests that the females tend to live longer than the males. Seven of the 53 females were of the IV group, but the oldest of the males were the III group fish. This sex difference in longevity is in accord with findings of other studies of perch (Schneberger 1935, Eschmeyer 1937).

Total Weight of Sample: If the average weight of the perch is assumed to be 24 grams, the number removed (1,137) had a total weight of 27,288 grams (60.2 pounds) or a weight per acre of 2,560 grams (5.6 pounds).

The ratio of trout to perch in 1934 (15:1137) was approximately 1:76. The removal of the fish in 1936 indicated a total population of approximately 5,000 perch at that time. If about the same number were present in 1933, the ratio of trout to perch immediately after the planting of 500 trout in 1933 was about 1:10. Apparently the number of trout in the population had declined very materially between 1933 and 1934 unless the difference in the two ratios (1:76 and 1:10) was due to net selectivity.

Gill nets were fished in 1934 in an effort to reduce the population since there appeared to be a scarcity of food for the number of perch present, especially food of intermediate or large size (minnows). The perch removed in 1934 represented approximately 24% of the perch recovered in 1936. It was, of course, impossible to determine what percentage of the fish present in 1934 had been removed.

Not only was the food per fish increased by the removal of some of the perch, but a total of about 15,500 forage fish was planted in July, 1934. These fish were taken from a small stream where it had been impounded by beaver. Most of them were northern dace (Chrosomus eos), although limited numbers of fat-head minnows (Pimiphales promelas), sticklebacks (Eucalia inconstans), mud minnows (Umbra limi) and perhaps a few fish of some other species were also present.

Fish Taken in 1936

On the morning of September 9, 1936, Mr. W. F. Carbine and the writer, assisted by men from Camp Vanderbilt, poisoned the waters of Ford Lake with 200 pounds of powdered derris root (5% rotenone content) mixed with water. On the afternoon of the same day recovery of the dead fish was facilitated by discharging 500 sticks of dynamite in the water. The fish began to die within about an hour after the poisoning. The collection of these dead fish was started immediately and was continued for three days.

On the third day 183 dead perch were counted along the shore, but these were not collected because of their semi-decomposed condition.

It is probable that all of the fish were killed, and it is also probable that almost all of the perch were either collected or counted. (In two other lakes where weaker concentrations of derris root had been used, the entire perch population had apparently been destroyed. Nets set in these lakes in 1936 failed to produce fish.) How many dead fish remained in deep water in Ford Lake is not known, but over that part of the bottom which could be seen from a boat (about a third of the entire bottom) no dead perch were seen other than the 183 specimens mentioned above. The evidence, therefore, though not conclusive, suggests that all fish were probably killed and that almost all of the perch were definitely accounted for.

Total Fish Population

A collection of 3,762 perch was preserved in a 10 per cent solution of formalin and 1,055 perch were discarded. At least 4,817 perch are therefore definitely known to have been present. Computations based on the average weight of 1,050 specimens taken at random give an estimated weight of 347 pounds for the total perch population.

A total of 24 rainbow trout and 1 brown trout were preserved and 2 trout (partially decomposed) were discarded. These trout had a combined weight of 7 pounds (provided the 2 trout discarded were of average weight).

Dead minnows lined the shore, especially along the wave swept side. On two representative 10 foot sections of shoreline, the dead minnows were counted by Dr. A. S. Hazzard and Mr. Carbine. According to the counts made, the lake shore contained 15.3 minnows per linear foot of shore line. Ford Lake, with an area of 10.66 acres, would have a circumference of about 2400 feet if it were exactly circular. The exact amount of shoreline was not determined, but since the outline of the lake is roughly circular,

the length of the shoreline may be estimated as 2400 feet. On this basis, the lake had contained approximately 36,700 minnows. Weight determinations of 61 specimens of minnows gave an average weight about 2 grams. The minnows, therefore, weighed approximately 73,400 grams or 162 pounds. The weight of minnows per acre was about 15 pounds.

The total fish population in 1936 was approximately as follows:

Perch	347 pounds
Trout	7 "
Minnows	162 "
Total	516 pounds

The lake therefore maintained about 50 pounds of fish per acre.

The first important evidence obtained from the collections was that the plantings of trout in Ford Lake were not very successful. A total of 8,000 trout had been planted since 1933, but only 28 were recovered in 1936 (and 15 in 1934). Relatively few were removed by fishermen. Some of the trout may have remained on the bottom at the time of the poisoning, but it seems safe to conclude that the survival from trout plantings in the lake was very poor. The few trout which were recovered were in relatively poor condition.

At the time the minnows were stocked (in 1934), it was not expected that any of the species would become established because of the apparently unfavorable balance between fish and food. It was assumed that the minnows would soon be eaten by the perch. The minnows did serve as a food item for the perch, but apparently enough survived for them to become definitely established. All species except sticklebacks known to have been stocked in 1934 were found present in 1936. The number of minnows had apparently doubled in the two years.

The large number of perch in the collection made the use of samples advisable. Sex determinations were made for all of the 3,762 preserved perch, but the data on length and weight are based on three samples of 350 fish each, taken at random. The close similarity of the data obtained

from each of these three samples (Table 3 and Fig. 1 and 2) demonstrates that the results obtained from their combination (1,050 fish) may be considered representative for the entire population. In further discussions of length and weight it is assumed that the averages for the 3 samples (845 males and 205 females) represent the averages of the entire population. The error which might be involved in using these samples rather than the entire populations is obviously small.

Table 3

Average Standard Length (In Millimeters) and Average Weight (In Grams) For Three Random Samples of Male Perch and Three Random Samples of Female Perch and For Combinations of the Three Samples (845 Males, 205 Females)

	Ave. Standard Length (mm.)	Ave. Weight (grams)
Females		
Sample 1	129.2	38.9
Sample 2	127.5	37.7
Sample 3	126.5	39.1
Combination of 3 samples	127.7	38.6
Males		
Sample 1	114.6	29.3
Sample 2	114.6	30.1
Sample 3	115.1	32.4
Combination of 3 samples	114.7	30.6

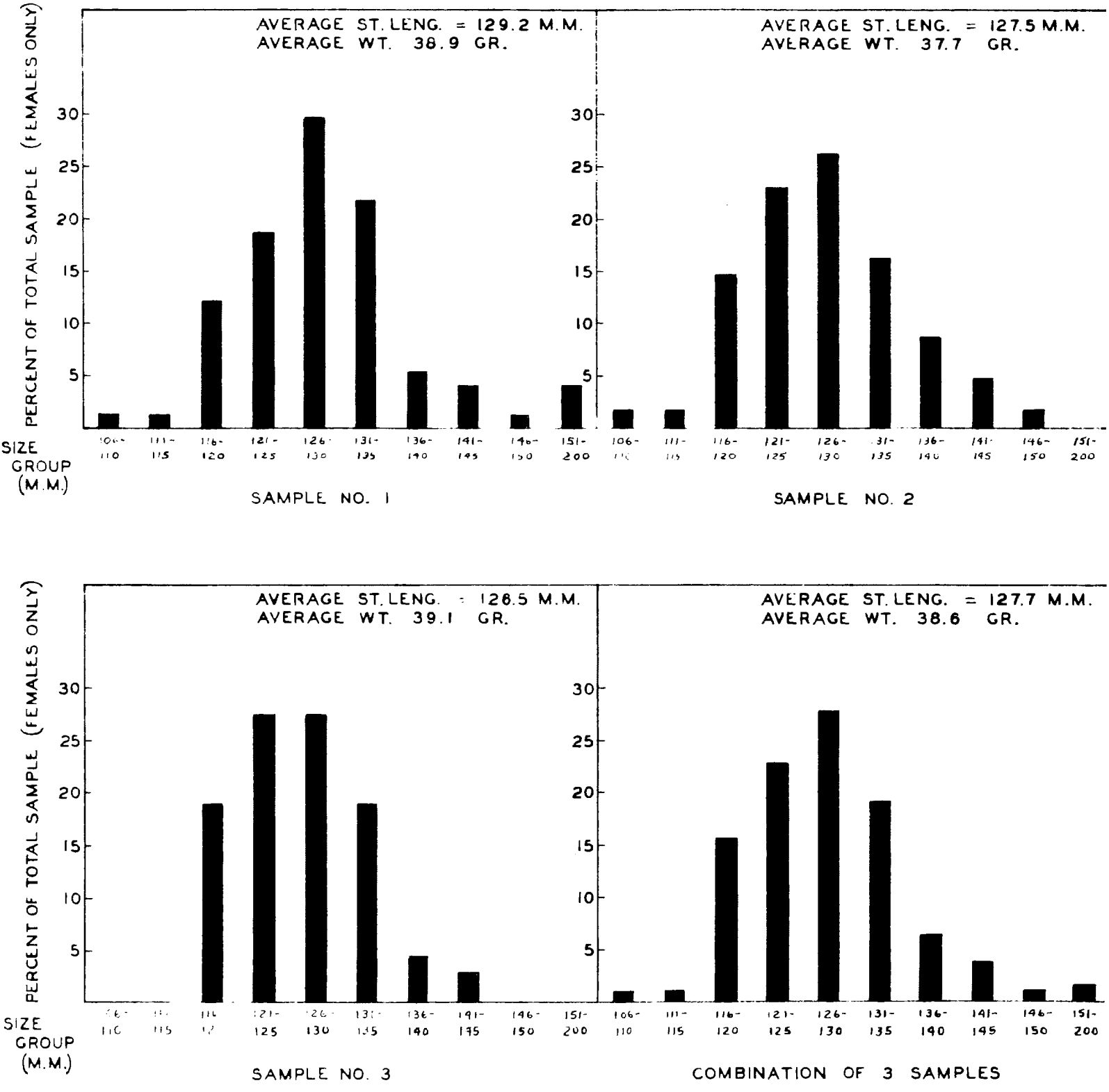

Fig. 1. Size distribution of the females in three lots of perch taken at random and size distribution of the females in the three lots combined (205 females).

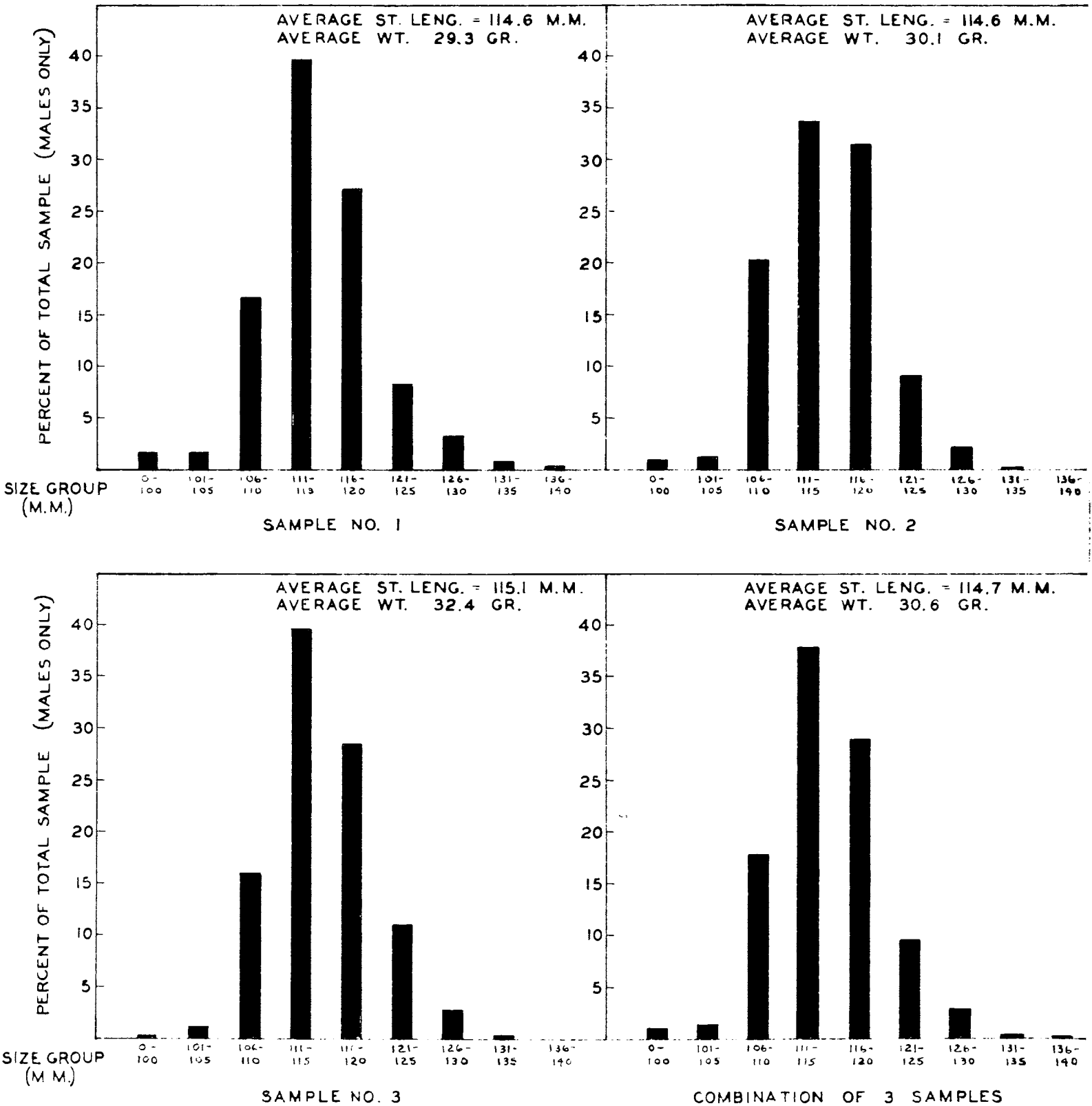

Fig. 2. Size distribution of the males in three lots of perch taken at random and size distribution of the males in the three lots combined (845 males).

Size Distribution

The length distribution for each sex is shown in Figures 1 and 2 and in Table 4. The distributions of both male and female perch approached a normal curve. The distribution fails to indicate more than one age group except for the suggestion of a second group of males (at 71-80 millimeters) represented by a very few individuals. On the average, the females were 13 millimeters longer than the males.

Table 4

Length Distribution of 845 Male Perch and 205 Female Perch by 5 Millimeter Classes (Standard Length)

Length Group (Millimeters)	Females		Males	
	Number	Per Cent of Total	Number	Per Cent of Total
71 - 75	...	...	2	0.2
76 - 80	...	...	2	0.2
81 - 85	...	...	...	...
86 - 90	...	...	1	0.1
91 - 95	...	...	...	...
96 - 100	...	...	4	0.5
101 - 105	...	...	12	1.4
106 - 110	2	1.0	150	17.8
111 - 115	2	1.0	319	37.8
116 - 120	32	15.6	245	29.0
121 - 125	47	22.9	81	9.6
126 - 130	57	27.8	24	2.8
131 - 135	39	19.0	4	0.5
136 - 140	13	6.3	1	0.1
141 - 145	8	3.9	...	...
146 - 150	2	1.0	...	...
151 - 155	2	1.0	...	...
156 - 160	...	...	...	...
161 - 165	1	0.5	...	...
Total	205	100.0	845	100.0
Average Standard Length	127.7 mm.	...	114.7 mm.	...

Age Determinations

An effort was made to determine the ages of the 1,050 fish contained in the three samples. For some reason not known to the writer the annuli beyond the second year were very difficult, often impossible, to locate with certainty. After repeated efforts the attempt to determine the ages was abandoned except for approximately 150 specimens. Even on these it is not certain that the annuli were invariably counted correctly. Annuli were more easily located on the perch taken from Ford Lake in 1934 than on the perch taken from the same lake in 1936. The size, weight and condition for these fish as determined for the different age groups are shown in Table 5.

Table 5

Length, Weight and Condition of Perch of Each Sex,

By Age Groups, Based on a Study of 149 Specimens

Sex	Age Group	Number of Specimens	Ave. Standard Length (mm.)	Ave. Total Length (Inches)	Average Weight (gr.)	Average K
Female	II	1	116	5.51	37.8	2.42
	III	21	127	5.98	37.0	1.83
	IV	4	130	6.14	41.1	1.88
	V	1	131	6.30	41.7	1.85
Total or Ave. (females)		27	127	5.98	37.8	1.86
Male	0	1	90	4.06	14.0	1.92
	I	1	111	5.31	32.9	2.41
	II	7	113	5.35	29.2	2.00
	III	90	116	5.51	32.7	2.08
	IV	23	119	5.63	35.3	2.11
Total or Ave. (males)		122	116	5.51	32.8	2.07

The position of the first two annuli showed that the growth was reasonably good during the first year and, in most specimens, during the second year, but was very poor in all succeeding years. The data on age groups II, III, and IV (Table 5) suggest that the females grew more rapidly than the males. Fish of the III group apparently predominated, although fish of the IV group were fairly well represented. Young fish (0, I, and II groups) were scarce.

The approximate number of legal perch of each sex was determined. Legal fish (6 inches or 152.4 mm. total length) were considered as all fish 150 mm. or more in length. Since all fish had been preserved before measurements were taken, some shrinkage undoubtedly occurred. The shrinkage factor 1.016 determined by Van Oosten (1929) for lake herring was used. Of the 845 males examined, 44 (5.2%) were of legal size, and 140 (68.3%) of the 205 females were of legal size. Since the entire population of 4,817 perch (sexes were determined for 3,762 fish) was estimated to contain 3,572 males and 1,245 females, the total number of legal fish in the lake included approximately 186 males and 850 females. The ratio of females to males in the lake was approximately 1:3, but the ratio of legal females to legal males was over 4:1. The only age groups whose average lengths were above the 6 inch legal limit were the IV and V group females.

It might be argued that the lake contained more males than females because few legal males were taken by the fishermen while a majority of the females were of legal length. The lake was fished so little, however, that this argument does not hold.

Sex Ratio

In the perch taken by gill nets in 1934, the two sexes were about equally divided. Nets, as stated earlier, were again set in Ford Lake just before the poisoning in 1936 and were lifted immediately after the

poisoning operations had been completed. The fish taken in the nets were inadvertantly placed with the dead fish collected and consequently the sex ratio of the gill net sample could not be determined. It was noted later, however, that of those fish having gill net marks about half were females. It may be stated with assurance that the gill nets were highly selective with respect to the sexes, probably because most of the males were too small to be caught in the nets.

The 3,762 perch which were preserved consisted of 2,791 males and 971 females. There were 34.8 females per 100 males or approximately a 1:3 ratio. A fourth of the perch (25.8 per cent) were females. It is improbable that the ratio changed from about 50 per cent females in 1934 to 25 per cent females in 1936. It is more likely that the perch taken in gill nets set in 1934 were not representative, with respect to the sex ratio, of the fish which were then present in the lake.

Food

No study was made of the food available for the fish, but the stomach contents of 100 males and 100 females, taken at random, were examined. This study was especially interesting because it showed a difference in the food of the two sexes.

A fourth (25) of the stomachs from females contained minnows. The minnows were in various stages of digestion and apparently many were eaten before the poisoning. The stomach of one female contained a partially digested perch. Eight of the stomachs from females contained a half dozen or more winged ants. It is probable that a flight of these ants had crossed the lake at some time just before the poisoning and that ants, as food, were not ordinarily available in abundance. Twenty-four stomachs contained Corethra (mostly larvae) and 22 contained chironomid larvae. Other food organisms including Ephemeridae, Amphipoda, Odonata, Coleoptera,

Phyllopoda and Trichoptera were present in relatively insignificant quantities. Seventeen stomachs were empty.

Of the 100 stomachs from males, only 3 contained minnows and one contained several ants. Corethra were present in 31 stomachs, and Chironomidae in 14. Odonata, Ephemeridae, Phyllopoda, Amphipoda, and Cladocera were present in a very few stomachs. Over a third (36) of the stomachs were empty.

Death by poisoning is relatively rapid and it is possible that the proportion of empty stomachs was representative of normal conditions.

It may be stated that minnows constituted the chief food of the females and that Corethra larvae were the chief food of the males. Earlier in the summer, when the young minnows were smaller, they may have also served as an important food organism for the male perch. The decided increase in the condition (K), and the slight increase in growth in 1936 over 1934 may have resulted from the introduction of minnows in 1934 or from reduction in population by netting.

Distribution of the Sexes Within the Lake

The Institute's lake survey parties have frequently observed that perch removed from their nets were primarily of one sex. Often catches of 50 or more were all of one sex. Members of the parties who failed to recognize this peculiarity often doubted, for a while, their ability to determine the sex of perch despite the fact that the structure of the gonads makes sex determination of individual perch relatively simple. Since the sexes have different rate of growth, the dominance of one sex in the net may depend, partially, to net selectivity. It has been noted, however, that even in line fishing the fish taken may be primarily of only one sex. It would seem therefore that, to some extent at least, the two sexes tend to school separately. Since such schooling appears to take

place during all or most of the summer, it is apparently not connected with spawning. The food study offers further evidence of the schooling in separate sexes and gives a plausible reason for such segregation. The minnows were apparently normally in shallow water and the ants were apparently floating on the surface. Since these two food items were prominent in the stomachs of the females, it appears probable that many of the females were feeding in shallow water. The males, on the contrary, were apparently in deeper water where they fed primarily on midge larvae. In Ford Lake, at least, a difference in the distribution of the two sexes can be explained on the basis of the differences in the distribution of their favorite food organism. Differences in growth rate of the sex account for differences in feeding habits of fish of the same age. Whether similar situations are to be found in other perch populations remains to be determined.

Section 4 Lake

Section 4 Lake, Town 32 North, Range 1 West, is a pot-hole lake that is similar in many respects to South Twin Lake. According to the Institute's survey in 1932, Section 4 Lake has an area of 3.3 acres and a maximum depth of 21.7 meters. The outline is almost perfectly circular and the basin is bowl-shaped with very little shoal area. The water, in summer, was definitely stratified with a thermocline at 4-11 meters (August 1, 1932). The bottom soil on the shoal and slope is marl, and in deeper water is peat. The water is relatively clear (Secchi disc reading 6.8 meters) and is alkaline (surface pH 7.9). According to the survey (August 1, 1932), the dissolved oxygen is high at the surface and in the thermocline (11.1 p.p.m. at 8 meters), but is low near the bottom (1.8 p.p.m. at 14 meters, trace at bottom). This very small land-locked lake has high, steep, sandy banks and has an extremely small drainage basin.

According to the survey records, only perch were taken in the gill net and seine fishing in 1932. It is doubtful whether other fish were present at that time. In 1932, and again in 1934 when a few perch were taken in gill nets, the fish were small (seldom over 6 or 7 inches long) in all samples.

Section 4 Lake seemed well suited for trout except that here, as in the other land-locked lakes in the area, the trout could not, of course, be expected to maintain themselves by natural reproduction. In 1933 Oden Hatchery officials stocked this lake with 300 8-months old brook trout. In 1935 the lake was stocked with 150 adult rainbow trout (after removal of the perch).

On September 19, 1935 Dr. A. S. Hazzard and the writer distributed approximately 75 pounds of powdered derris root (5% rotenone content) over the lake. The first dying fish were observed one and one half hours after the introduction of the poison. Collecting of the dead fish was begun immediately and continued, at intervals, for the next 50 hours. Dead perch were still coming to the surface when the party left. Nets set in this lake a year later (September, 1936) produced no perch. It seems, therefore, that all perch were killed. Not all were collected however.

Total Population

A total of 1,736 perch (526 per acre) were recovered. These fish had a combined weight of 76.36 pounds or a weight per acre of 23.1 pounds. The actual number and weight of the fish present were, of course, in excess of these figures.

Size and Age Distribution

All perch recovered were measured to the nearest millimeter and weighed to the nearest tenth-gram after several months' preservation (first in 10 per cent formalin and later in 70 per cent alcohol). The 0 group fish were weighed in lots of 20-50 each; all other fish were weighed individually.

The length distribution, by centimeter groups, is shown in Table 6. No really large perch were taken. The data suggest the presence of at least two age groups.

Table 6

Length Distribution of Perch From Section 4 Lake

By Centimeter Intervals. (Standard Length).

The Dotted Line Represents, Approximately,

the Dividing Line Between Undersized

and Legal-sized Fish.

Length Group (Millimeters)	Both Sexes	Females	Males
49.5 - 59.5	1	1	...
59.5 - 69.5	91	40	51
69.5 - 79.5	322	142	180
79.5 - 89.5	34	9	25
89.5 - 99.5	90	18	72
99.5 - 109.5	250	50	200
109.5 - 119.5	592	53	539
119.5 - 129.5	246	124	122
129.5 - 139.5	72	60	12
139.5 - 149.5	27	26	1
149.5 - 159.5	7	7	...
159.5 - 169.5	3	3	...
169.5 - 179.5	1	1	...
Total	1,736	534	1,202

The ages of approximately 50 per cent of the fish were determined by a study of the scales. Many of the (0 and II) perch could be placed in their respective age groups without examination of the scales. This method of separating these two age groups was used for about half of this number. If any error was involved in this method, it was slight, for subsequent scale examination proved the ages estimated for several hundred fish to be correct.

In contrast with the perch from South Twin Lake and Ford Lake, most of the fish in Section 4 Lake (Table 6) were young fish. The II group, which was represented by 957 specimens, comprised over half the fish taken, but both the 0 group and the I group were also well represented. Only age groups III and IV, represented by a total of 101 specimens, averaged legal size (6 inches).

The females were larger than the males in all except the 0 group. Young fish were dominantly males, but the fish in the III group were 87 per cent females and all fish in the IV group were females. Most of the legal-sized fish were females.

Table 7

Number of Female and Male Perch in Each Year Group, and Average Length, Weight and Condition of Fish in Each Group[1]

Item	Age Group 0	I	II	III	IV
Number of fish:					
Females	192	82	171	82	7
Males	255	149	786	12	...
Total (both sexes)	447	231	957	94	7
Average standard length (mm.):					
Females	72.8	104.7	123.5	136.9	157.9
Males	76.5	100.0	115.2	131.3	...
Average weight (grams):					
Females	6.2	17.2	28.6	41.0	63.1
Males	6.0	15.8	24.3	34.4	...
Average total length (inches, approximate):					
Females	3.5	4.9	5.8	6.5	7.4
Males	3.6	4.8	5.4	6.2	...
Average weight (ounces):					
Females	0.2	0.6	1.0	1.4	2.2
Males	0.2	0.55	0.9	1.2	...
Average value of K:					
Females	1.66	1.53	1.54	1.59	1.60
Males	1.36	1.63	1.60	1.53	...

[1] Since these fish were taken in mid-September, they were actually almost one growing season older than the figures (annuli) indicate.

Sex Ratio

The ratio of males to females was 100:44 or approximately 2:1. This predominance of males cannot be attributed to the fact that most of the legal perch were females and therefore more subject to capture by fishermen, because the lake was fished very little.

Condition of Perch

The perch of all age groups were in fair condition except that the males in the 0 group were relatively slender. In general the K varied little for the several age groups. The females tended to improve slightly in condition after the first year, but the averages of K for males decreased slightly with increase in age.

Some Conclusions Regarding the Three Perch Populations

This summary is based on data for the two populations discussed above and for the South Twin Lake population described in an earlier paper (Eschmeyer 1937). All three populations were removed in September, one each year in 1934, 1935 and 1936. Derris root was used to poison the fish in all three lakes and dynamite was used after the poisoning in two of them.

Total Populations

The fish of the two lakes which were both poisoned and dynamited were probably almost all collected or seen. The population was approximately 30 pounds per acre in the lake with very little shoal (South Twin), and about 50 pounds per acre in the lake with extensive shoal. The numbers of perch actually accounted for varied from 452 per acre in Ford Lake to 955 per acre in South Twin Lake.

Size and Age Distribution

The perch grew slowly in all three lakes. Their growth, except for the first year, was slower than the growth of perch for other waters as determined by Harkness (1922), Hile (1931), Jobes (1933), and Schneberger (1935). Comparative growth data were presented in Table 4 of the study of the South Twin Lake perch (Eschmeyer, 1937). Since the other authors removed only a portion of the fish, data on comparative population densities are not available. It seems probable, however, that the populations from the three lakes in the Pigeon River State Forest were more dense than were the populations in the other lakes studied.

From a fishing standpoint, all three lakes were of little value. Some of the perch in each lake (5.8 per cent in Section 4 Lake to 21.5 per cent in Ford Lake) were of legal size (6 inches) but very few had a length of 7 inches.

In two of the three lakes the young age groups (0 and I) were almost entirely absent. It is possible that most of the young perch of those lakes had been eaten by the larger fish.

In all three lakes the females grew more rapidly than the males. The females also tended to live longer than the males. The oldest fish were invariably females.

In general, the perch grew very slowly after their first or second year of life. This slow growth is attributed to a scarcity of food organisms of moderate size (except in Ford Lake in 1936), but it is possible that the concentration of fish, rather than the food supply, may have been responsible for the slow growth.

Sex Ratio

Males predominated in all three perch populations. The ratios of males to females for each lake were: South Twin Lake 100:74, Section 4 Lake 100:44, and Ford Lake 100:35. The reason for the differences in the sex ratio in the different lakes has not been found. It cannot be attributed to the selective capture of females in sport fishing since all of the lakes were fished very little. The lake with the fish in poorest condition had twice as many females per 100 males as the lake containing perch in the best condition. Whether or not the greater viability of the females in the face of adverse conditions (Geiser, 1924) explains this difference cannot be stated. The predominance of males suggests that, in the early stages, the females tended to suffer a much greater mortality than the males unless, of course, the sexes were not equally represented in the fish immediately after hatching. In later years, however, the mortality of males exceeds that of the females.

Condition

The perch in South Twin Lake were in very poor condition; those in Ford Lake were in excellent condition. The average of K for Section 4 Lake perch was intermediate. Nevertheless all three populations grew quite slowly. The condition of these fish was therefore not correlated with their rate of growth. Apparently the fact that a fish is in good condition is not an indication that it is also growing rapidly.

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