Original: American Fisheries Society
cc: Institute for Fisheries Research
Education-Game
Mr. Carbine
Mr. Applegate
Mr. Benjamin Young, National Bank of Detroit, Detroit, Michigan
Fish Division

September 4, 1946

REPORT NO. 1069

The fish population of Deep Lake, Michigan [1]

[1] Contribution from the Michigan Institute for Fisheries Research

W. F. Carbine and Vernon C. Applegate
Michigan Department of Conservation,
Ann Arbor, Michigan

Abstract

The fish population of Deep Lake (Oakland County, Michigan) was killed by poisoning with rotenone. It is believed that almost all of the fish one year old and over were recovered. An unknown number of the young of the year fish may not have been found, although a special effort was made to recover as many of these small fish as possible. A total of 27,329 fish weighing 562.7 pounds, was recovered, or 38.0 pounds per acre. Bluegills were the most abundant species. Legal game fish made up 3.2 percent of the number and 56.1 percent of the weight of all fish recovered. Data are presented on the length, weight, and numbers of fish by age groups and year classes for the individual species. Comparison is made between the total fish population (in pounds per acre of lake surface) of Deep Lake and other natural lakes in Michigan, Wisconsin, Florida, and Nova Scotia.

Introduction

On September 12, 1941, the fish population of Deep Lake was killed by poisoning with rotenone and removed from the lake. This poisoning climaxed a 4-year study, initiated by Dr. R. W. Eschmeyer formerly of the Institute staff and concluded by the senior author, on the spawning habits, production and survival of four centrarchid species in Deep Lake. The present study is an analysis of that portion of the fish population of Deep Lake that was recovered subsequent to the poisoning.

Deep Lake has been privately owned for many years. It has never been used extensively for swimming, boating, or fishing. Since 1936, the owners, a few friends and neighbors, and members of the Institute staff have been the only people who have fished on the lake. In 1937, the owners requested that the Institute make a survey of the lake and submit recommendations for its management because they believed the lake would support trout. A preliminary survey made in 1937, indicated that the lake would be ideal for certain experiments. In 1938, permission was granted by the owners to use the lake for experimental purposes. A general biological inventory was made in 1939. Observations and experiments were begun in 1938 on many phases of the life history and reproduction of the largemouth bass, rock bass, bluegill, and pumpkinseed sunfish (Carbine, 1939). These experiments were concluded in September 1941, by the poisoning and removal of the fish population. During this period of investigation, prior to the poisoning, a total of 924 fish of all sizes were removed from the lake by Institute personnel, including the lake-inventory party.

The only record of management was the introduction in May 1937 of 1,000 bluntnose minnows (*Hyborhynchus notatus*) and golden shiners (*Notemigonus crysoleucas*). Both species of minnows failed to establish themselves in Deep Lake and were never taken by seining.

Angling pressure at Deep Lake evidently has never been excessive, although prior to 1937 it is alleged to have been fished "fairly heavily." In 1938, someone was fishing on the lake nearly every day during the summer. From that year until 1941, fishing dropped off under increasingly stringent control of the use of the lake by the owners. As compared with the state as a whole, angling quality was found to be somewhat below average by Institute personnel who used the lake from 1938 to 1941. Bluegills dominated the catch, followed by the pumpkinseed and largemouth bass in that order. Yellow perch were taken only occasionally. Rock bass were taken frequently before 1939 but seldom entered the catch in 1940 and 1941.

Description of the lake

Deep Lake is located in Section 27, T. 4 N., R. 7 E., Rose Township, Oakland County, in southeastern Michigan. The lake falls nearly perfectly into the category of pit lakes (Scott, 1921); it is surrounded by high, steep banks. Soils and terrain in the drainage area of the lake are all morainic, and the land is in cultivation, pasturage, or in farm woodlots. The high banks, from the water level to the undulating ridges above the lake, are sparsely wooded.

A biological inventory of Deep Lake was made by a survey party from the Institute for Fisheries Research on July 24, 1939. Their measurements and findings were supplemented by later examinations of the lake during the investigational work carried on there. Deep Lake has a surface area of 14.84 acres; a maximum length of 1,230 feet in a WNW-ESE direction, and a maximum width of 660 feet (Figure 1). The lake is approximately oval and consists of two basins, an eastern with a maximum depth of 61 feet and a western with a maximum depth of 51 feet. The interdepressional

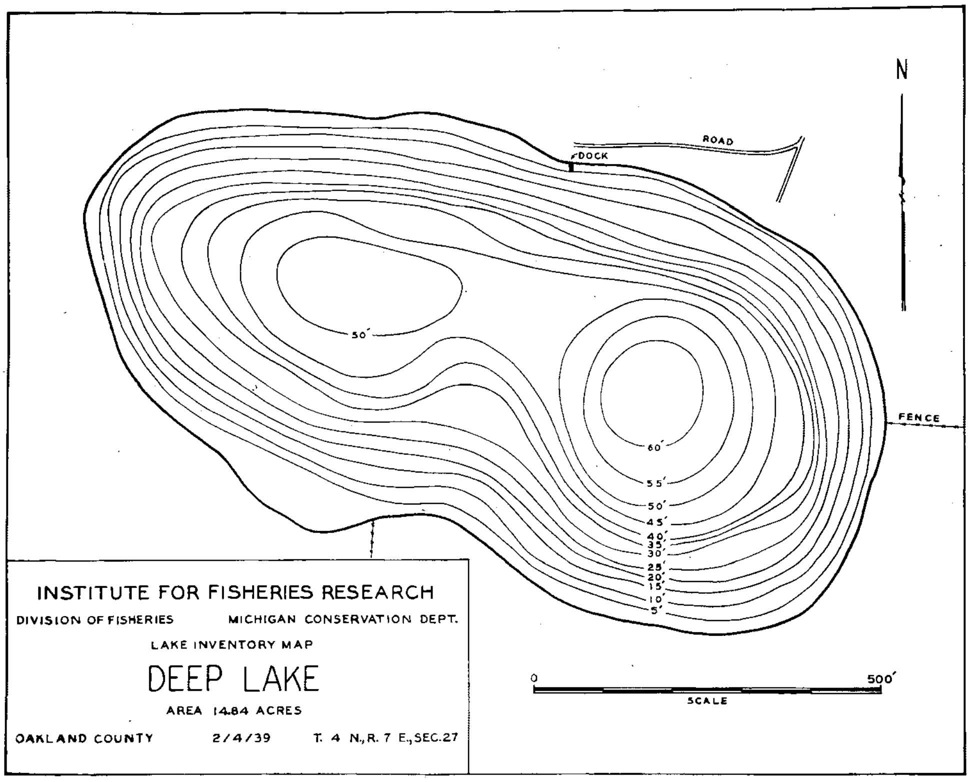

Figure 1.--Map of Deep Lake, Michigan (depth contours in feet), in which the fish population was killed by poisoning with rotenone.

area averages approximately 45 feet deep. The shoreline development is 1.12. The dropoff from the shoreline toward the center is extremely steep. That portion of the littoral zone that may be considered suitable for spawning for the warm-water species present (shore to 5 feet) constitutes only 11.8 percent of the area of Deep Lake. However, the entire littoral zone, as measured by the lakeward limit of higher submerged aquatic plants, contained 37.0 percent of the lake's surface area. Higher submerged aquatic plants grow in Deep Lake up to depths of 20 feet. The northern, southern, and eastern shoal areas, varying from 12 to 62 feet in width, are composed chiefly of sand interspersed with patches of gravel, rocks, roots, and vegetation. The bottom of the western shoal area, varying from 20 to 70 feet in width, is composed principally of fibrous peat, decaying vegetation, roots, and aquatic plants. There is some underlying sand and gravel in this area. Patches of clay are present in some of the shoal areas, apparently deposited by the runoff from adjoining property. Marl formed from decomposed Chara is also present in some parts of the shoal areas.

Deep Lake has neither an outlet nor a permanent inlet. One 6-inch tile, located at the southeast end of the lake, drains a nearby pasture. The lake is supplied principally by the seepage of ground water. Several small, subsurface springs are known to be present. The entire lake receives the runoff from less than 10 acres of land. Fluctuations in lake level seldom amount to more than a foot in one year.

The water in Deep Lake is relatively clear. A Secchi disk disappeared at depths of 20 to 24 feet. The degree of transparency of Deep Lake is much greater than the average for southern Michigan lakes. At the time the survey was made (late July) the lake was both thermally and chemically stratified. A thermocline was present between 16 and 39 feet. The temperature of the water ranged from 79° F. at the surface to 42.8° F. at the bottom (61 feet). At this time oxygen was found in quantities sufficient to maintain fish life (3.0 p.p.m.) to depths of about 50 feet. Subsequent chemical analyses in late August and late September indicate that oxygen was plentiful (3.3 p.p.m.) to a depth of 45 feet. The methyl-orange alkalinity ranged from 84 to 93 p.p.m. at the time of the survey. The pH ranged from 8.6 at the surface to 6.9 at a depth of 61 feet.

The aquatic vegetation was judged to be fairly abundant in Deep Lake, in relation to the area of suitable depth and bottom. Species found to be abundant were the pondweed (Potamogeton natans), and the cattail (Typha angustifolia). Those considered common were the swamp loosestrife (Decodon verticillatus), bushy pondweed (Najas flexilis), Needle rush (Eleocharis acicularis), white water lily (Nymphaea odorata), yellow water lily or spatterdock (Nuphar advena), pickeral weed (Pontederia cordata), the pondweeds (Potamogeton americanus, P. amplifolius, P. angustifolius, P. gramineus, P. vaseyi, and P. zosteriformis), the bulrush (Scirpus validus), and chara (Chara sp.). There is a sparse occurrance of water marigold (Megalodonta Beckii), and coontail (Ceratophyllum demersum).[2]

---

[2] Identification of the aquatic plants was made by Mrs. Betty R. Clarke of the Botany Department of the University of Michigan.

Dense patches of bulrush were scattered over the sandy, shoal areas. Water lilies were distributed more or less evenly around the lake. An abundant patch of cattail grew at the outlet of the tile drain. The widest shoal area was covered with a rather dense mat of pondweeds, water lilies, and Chara. Some portions of the sandy, shoal areas were relatively free of aquatic plants. Although there was a fairly good growth of aquatic plants in Deep Lake, cover was still deemed inadequate during certain seasons of the year for all species of fish present. A few fallen trees, logs, and boulders provided a minimum of permanent shelter that could have been used during the late fall, winter, and early spring.

Methods

The destruction of the fish population of Deep Lake was accomplished by means of powdered derris root (5 percent rotenone content). Approximately 665 pounds of derris root were used which quantity amounts to about 0.5 p.p.m. (1 part of powder to 2 million parts of water by weight). The method of applying the poison was similar to that used by Eschmeyer (1937, 1938a) and Greenbank (1940). In order to distriubte the poison in the colder waters of the thermocline and the hypolimnion, large burlap bags were filled with a stiff paste of derris root, weighted and towed systematically at various depths behind a motorboat for 18 hours. The remainder of the poison was mixed with water to form a very thin suspension. This mixture was poured onto the surface of all parts of the lake from a motorboat.

The later examination of cages containing live fish placed in the lake before poisoning revealed that the poison penetrated to depths greater than 40 feet. The burlap-bag method of distributing the poison into the deeper water obviously was successful. The failure to take any fish in later netting operations indicates that all fish in Deep Lake succumbed to the poison.

A concerted effort was made to collect as many fish as possible after the poisoning at Deep Lake. Visits were made daily for 17 days following the poisoning to assure as complete a recovery as possible. It is believed that almost all of the fish one year old and over were picked up. No estimate can be offered as to the percentage of the young of the year that were found. A special effort was made to recover as many of these small fish as possible. However, it is believed that the recovery of the young-of-the-year bluegills, pumpkinseeds, green sunfish, and rock bass was far from complete. The problems incident to the locating of the young and the very small fish after poisoning are manifold. The roiling of the water by collectors conceals many specimens on the bottom with a fine layer of silt and detritus. Many more are hidden by beds of emergent vegetation. Furthermore in the poisoning of a lake, the smaller fish die first and Eschmeyer (1939) has shown that numbers are eaten by larger fish before the latter are affected by the poison. Insects, snakes, turtles, and birds also take advantage of this sudden abundance of available food.

All of the fish collected at Deep Lake were sorted and identified in the field and in the laboratory by Dr. Carl L. Hubbs and Mr. Walter R. Crowe. Scale samples and length measurements were obtained from all fish over 100 millimeters long, except for the bluegills of which only a sample was taken (approximately half of the specimens above 100 millimeters). Similar data were obtained also for a large random sample of all fish less than 100 millimeters long. Aggregate weights were obtained of all of the fish recovered while individual weights were taken on only a random sample of the fish of each species. Measurements of standard and total length (to the tip of the tail with the upper and lower edge parallel) were made in millimeters and the fish were weighed to the nearest gram on a platform balance. All data on length and weight were converted to the English system and are presented here in that form.

Tentative data on the average growth rate of certain species in Michigan waters which have been quoted in later pages have been taken from an unpublished report[3] of the Institute for Fisheries Research.

---

[3] Beckman, William C. Growth rate of some Michigan game fishes. Report No. 741, February 3, 1942.

Acknowledgements

The investigation of Deep Lake was made possible through the courtesy of the owners, Messrs. James Inglis and Ben E. Young. We are indebted to Dr. R. W. Eschmeyer for the early data and for suggestions for the continuation of the investigation.

We are grateful to Dr. Carl L. Hubbs who checked identifications of fish recovered after poisoning, and who, with Mrs. Hubbs and students, helped sort and measure the samples of fish.

Most of the Institute staff aided with the poisoning and recovery of fish. Without their aid our recoveries would have been much less complete.

We are indebted to Dr. Ralph Hile for critically reviewing the manuscript.

Numbers and weights of fish recovered

The fish population was composed of 14 species at the time of poisoning. Game fish and pan fish recovered were the largemouth bass (Huro salmoides), bluegill (Lepomis macrochirus), pumpkinseed (Lepomis gibbosus), green sunfish (Lepomis cyanellus), hybrid sunfish in the three combinations of parent species, rock bass (Ambloplites rupestris), and yellow perch (Perca flavescens). Coarse fish recovered were yellow bullheads (Ameiurus natalis), mud pike (Esox vermiculatus), and common suckers (Catostomus commersonnii). Forage fish present were mudminnows (Umbra limi), and a single specimen of the golden shiner (Notemigonus crysoleucas). All species in the association are believed to have been native to the lake except the common suckers, the mudminnows, and the golden shiner. The negligible number recovered (Table 1) and the size distribution of the common suckers and golden shiners leaves little doubt that they had been introduced accidently from fishermens' bait

Table 1.--Summary of the total number and weight of each species and the number and pounds per acre of all fish recovered from Deep Lake

Species	Number of fish	Weight (pounds)	Percentage of total number	Percentage of total weight	Number of fish per acre	Pounds per acre	Number of legal fish	Percentage of legal fish by number	Weight of legal fish (pounds)	Percentage of legal fish by weight	Number of legal fish per acre	Pounds of legal fish per acre
Bluegill	16,059	256.0	58.8	45.5	1,085.	17.3	544	3.4	174.9	68.3	36.8	11.8
Pumpkinseed	5,935	68.9	21.7	12.2	401.	4.7	33	0.6	7.3	10.6	2.2	0.5
Largemouth bass	785	106.0	2.9	18.8	53.	7.2	97	12.4	79.8	75.3	6.6	5.4
Rock bass	585	22.9	2.1	4.1	40.	1.5	46	7.9	9.9	43.2	3.1	0.7
Yellow perch	817	20.4	3.0	3.6	55.	1.4	26	3.2	6.4	31.4	1.8	0.4
Yellow bullhead	1,082	38.4	4.0	6.8	73.	2.6	[1] 85	7.9	30.1	78.4	5.7	2.0
Green sunfish	1,090	11.0	4.0	2.0	74.	0.7	[1] 5	0.5	0.6	5.5	0.3	0.0
Mud pike	369	11.4	1.4	2.0	25.	0.8	...	...	...	...	...	...
Common sucker	5	8.9	0.0	1.6	0.3	0.6	...	...	...	...	...	...
Mudminnow	3	0.0	0.0	0.0	0.2	[2] 0.0	...	...	...	...	...	...
Golden shiner	1	0.0	0.0	0.0	0.1	[2] 0.0	...	...	...	...	...	...
Bluegill x pumpkinseed	589	18.4	2.2	3.3	40.	1.2	27	4.6	6.3	34.2	1.8	0.4
Green sunfish x pumpkinseed	7	0.3	0.0	0.0	0.5	[2] 0.0	1	14.3	0.1	33.3	0.1	...
Green sunfish x bluegill	2	0.1	0.0	0.0	0.1	[2] 0.0	...	...	...	...	...	...
Totals	27,329	562.7	...	...	1,847.2	38.0	864	3.2	315.4	56.1	58.4	21.2

[1] In Michigan there is no legal length on bullheads and green sunfish. Therefore, the desirable length for these species was arbitrarily set at 6-inches.

[2] Less than 0.05.

buckets, and the mudminnows, by occasional overflow from an adjoining permanent marsh.

A total of 27,329 fish weighing 562.7 pounds, was recovered from the lake. These recoveries amount to approximately 1,847 fish and 38.0 pounds per acre. Of the total number of fish taken, 864 or 3.2 percent of the total had attained, or were greater than, legal or "desirable" length. (Legal length for the game and pan fishes is 6-inches except for the largemouth bass for which the legal length is 10-inches. Since there is no legal length for green sunfish and bullheads in Michigan, we have arbitrarily set 6 inches as the desirable length.) These "legal" fish were present at the rate of 58.4 fish per acre. The total weight of legal- and desirable-sized specimens was 315.4 pounds (21.2 pounds per acre) or 56.1 percent of the total poundage recovered. Data on the numbers and weight of fish of the species removed are summarized in Table 1.

Size and age composition of the individual species

No outstanding irregularities appeared in the age composition of any component species of the total population. The low number of young of the year recovered for each of the "native" species can be attributed to the difficulties of recovery (many, doubtless were not found), to a low production of young in the 1941 season, and to natural death and cannibalism. In presenting these data, it is recognized that the recovered population is probably considerably less than the actual population. Young fish are, because of their size, missed more often than larger fish. Likewise young bluegills, pumpkinseeds, rock bass, and green sunfish may be missed more readily than young largemouth bass, perch, and mud pike. The spring of 1941 in southern Michigan was apparently average and a normal production of eggs and young could have been expected in that season. The presence of strong and weak year classes in fish populations has been commonly observed. It is not known positively whether the 1941 year class was good or bad. Considerable mortality probably occurred between the time of hatching and poisoning. A period of slightly less than two months had elapsed since the end of spawning in Deep Lake. It is natural to expect that the number of young of the year fish of all species would be greatly reduced at the time of poisoning by death from various causes including cannibalism.

These data suggest a weakness in the 1939 year class (age-group II) in all species aged with the exception of the rock bass and yellow perch. In general, the differences in the strength of year classes do not follow the same pattern for all species, with the possible exception of the 1939 year class. The discussion of the age composition and the strength of the year classes will be given in subsections for the individual species.

Bluegill. Bluegills were the most abundant species in Deep Lake (Table 1). A total of 16,059 fish of this species weighing 256.0 pounds was recovered. These figures represent 58.8 percent of the number and 45.5 percent of the weight of the entire population. There were 544 legal size (36.8 per acre) bluegills (6-inches and over) which amounted to 3.4 percent of the total bluegill population recovered. The legal-sized bluegills weighed 174.9 pounds (68.3 percent of the total weight of bluegills recovered and 11.8 pounds per acre). The ratio of the number of legal to undersized fish was nearly 1:30. This ratio appears large in view of the fact that the population was removed from the lake only slightly less than two months after the last period of bluegill spawning. The relative scarcity of young probably can be attributed best to an incomplete recovery of the young of the year.

The length, weight, and number of bluegills by age groups and year classes is presented in Table 2. Of the total bluegills sampled at the

Table 2.--The minimum, maximum, and average length and weight, and the number of bluegills of each age group recovered from Deep Lake

Age group	Year class	Number of fish aged	Estimated total number of fish in age group	Percentage of total number	Total length (inches)		Number of fish weighed[1]	Weight (ounces)	
					Range	Average		Range	Average
0	1941	73	9,872	61.5	0.6- 2.6	1.8	...	...	...
I	1940	224	5,390	33.6	1.8- 3.8	2.5	...	...	...
II	1939	36	69	0.4	3.6- 4.8	4.2	16	0.6- 1.2	0.8
III	1938	125	183	1.1	4.5- 6.7	5.4	118	0.8- 2.9	1.6
IV	1937	103	218	1.4	4.9- 8.4	6.4	104	1.1- 8.3	3.1
V	1936	20	56	0.3	7.0- 9.3	8.1	16	4.0-10.1	7.1
VI	1935	48	142	0.9	8.1- 9.9	8.9	59	6.7-13.0	9.2
VII	1934	42	123	0.8	8.6-10.0	9.4	50	7.3-14.7	11.4
VIII	1933	2	6	0.0	9.6-10.7	9.9	3	10.3-16.8	12.6
Total	...	673	16,059	...	...	...	366	...	...

[1] Individual weights were obtained from only a part of the fish from which age determinations were made.

time of poisoning, a random sample of 673 fish comprising principally the older and larger specimens were used for age determinations. The balance were assigned to age groups according to the observed percentage age composition within the individual length intervals. (This same procedure was followed for several other species.) The representations of the different age groups in the bluegill were decidedly unequal. Age-groups III, IV, VI, and VII were much stronger than age-groups II and V. The unequal representations of the different age groups is probably due to the varying degrees of success of natural reproduction in different calendar years. Hile (1941) pointed out that although numbers of fish in age groups may point rather conclusively to the presence of rather rich or poor year classes in a population, they do not provide an exact measure of the true relative strength of the year classes. In estimating the relative strength of a year class it is particularly important to give consideration to the age of the fish at the time of capture. To quote from Hile (p. 246): "Assuming that the samples are adequate, it is true generally that a strong representation of an old age group indicates a much richer year class than does an equally large number of fish several years younger. On the other hand, a scarcity of old fish may be merely the result of natural mortality over a long period of years, whereas a scarcity of fish in a young age group is definitely suggestive of a poor year class." For the Deep Lake bluegill population, the 123 VII-group fish (1934 year class) and the 142 VI-group fish (1935 year class) indicate a far greater original abundance for those year classes than do the numbers in groups V, IV, and III for the year classes 1936, 1937, and 1938. The 1934 and 1935 year classes had been subjected to more years of natural mortality and death from capture by anglers than had the 1936, 1937, and 1938 year classes. Likewise, the 56 V-group fish can be said to indicate a much stronger 1936 year class than the 69 II-group fish indicate for the 1939 year class. The 1939 year class (age-group II) was poorly represented and may be classed as an exceptionally weak year class. It is believed that the 1940 year class was exceptionally strong. The 1941 year class cannot be evaluated satisfactorily because of the apparent failure to recover every fish.

The growth rate of the bluegills compares favorably with the tentative average growth rate determined for the state (Figure 2). On the average, the bluegills were attaining legal length during their fourth season of growth. At the time of poisoning, 20.8 percent of age-group III, 71.8 percent of age-group IV, and all members of age-groups V to VIII had attained legal length. The sex ratio, based on a random sample of 365 fish (all were fish greater than 4-inches) was 42 percent males to 58 percent females.

Pumpkinseed sunfish. The pumpkinseed ranked second in abundance and third in weight among the species in Deep Lake. A total of 5,935 pumpkinseeds weighing 68.9 pounds was removed (Table 1) or 21.7 percent of the total fish population and 12.2 percent of the total weight of all fish recovered. There were 33 legal pumpkinseeds (2.2 per acre) weighing 7.3 pounds (0.5 pounds per acre) in the lake. Legal fish comprised 0.6 percent of the number and 10.6 percent of the weight of the total number of pumpkinseeds recovered. The ratio of legal to undersized fish in this species was about 1:180. This ratio is much larger than that for the bluegill, but still appears disproportionate in view of the fact that there were so few legal pumpkinseeds in Deep Lake and fewer young of the year fish than there were I-group fish. The growth rate of the pumpkinseeds in Deep Lake was slower than that of the bluegills and a lesser number of them appear to attain legal length

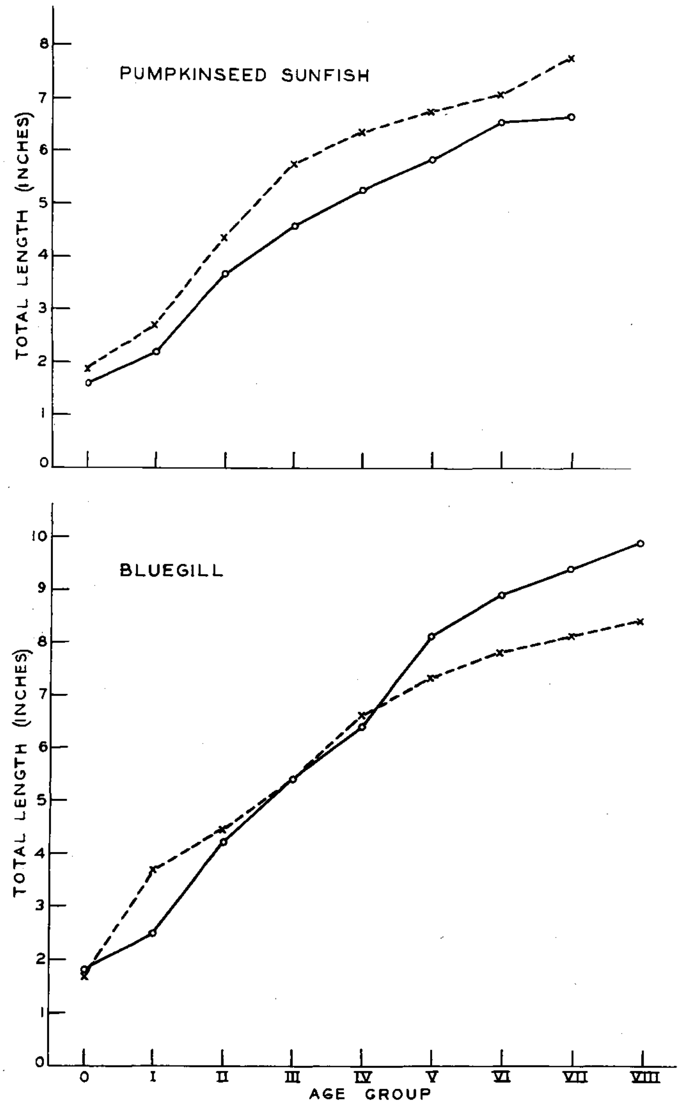

Figure 2.--Growth in length of bluegills and pumpkinseed sunfish in Deep Lake (solid line). For comparison, the tentative state (Michigan) average has been added (broken line).

(6 inches); few of them ever exceed 8 inches either in Deep Lake or in Michigan as a whole. Members of the Institute staff have noted that pumpkinseeds are much easier to catch on hook and line than bluegills. It is possible, therefore, that the few anglers that fished Deep Lake were cropping the pumpkinseeds as soon or shortly after they reached legal length. The effect of the slow growth rate of the pumpkinseeds cannot be ignored as a possible factor in the small number of legal-sized fish present in the lake. There is the possibility that natural mortality would catch up with many of the pumpkinseeds before they reached legal size. The scarcity in the number of young-of-the-year pumpkinseeds cannot be attributed entirely to poor recovery because 9,872 young-of-the-year bluegills were recovered as compared to 1,402 pumpkinseeds. This scarcity of the number of pumpkinseeds is best attributed to a poor hatch in 1941.

The length, weight, and number of pumpkinseeds by age groups as determined from a sample of 383 fish is presented in Table 3. Of the 33 pumpkinseeds that were over 6 inches long, only 23 had scales that could be read with any degree of confidence. Two questionable specimens were discarded entirely. For this reason, the accuracy of the estimates of the number of fish in age-groups V to VII is open to some question. Age-group II (1939 year class), as among the bluegills, appears weak. Age-group 0 (1941 year class) likewise appears weak. Age-groups III (1938 year class) and I (1940 year class) show evidence of being exceedingly strong and indicate a much greater original abundance than age-groups 0 and II. The unequal representations of the different age groups is probably due to the varying degrees of success of natural reproduction in different calendar years, especially for the 1941 year class. The ease with which pumpkinseeds take the baited hook is probably

Table 3.--The minimum, maximum, and average length and weight, and the number of pumpkinseed sunfish of each age group recovered from Deep Lake

Age group	Year class	Number of fish aged	Estimated total number of fish in age group	Percentage of total number	Total length (inches)		Number of fish weighed[1]	Weight (ounces)	
					Range	Average		Range	Average
0	1941	36	1,402	23.6	0.8-1.8	1.6	...	...	...
I	1940	144	4,134	69.7	1.5-3.0	2.2	74	0.1-0.3	0.2
II	1939	64	119	2.0	3.1-4.4	3.7	59	0.3-1.0	0.6
III	1938	54	142	2.4	3.8-5.6	4.6	53	0.6-1.8	1.1
IV	1937	59	102	1.7	4.3-6.7	5.3	63	0.8-3.5	1.8
V	1936	12	16	0.3	5.6-6.4	5.9	14	1.6-3.9	2.5
VI	1935	12	17	0.3	6.2-7.5	6.6	14	1.9-4.2	3.2
VII	1934	2	3	0.0	6.4-6.9	6.7	2	3.2-4.3	3.7
Total	...	383	5,935	...	...	...	279	...	...

[1] Individual weights were obtained from only a part of the fish from which age determinations were made.

responsible, in part at least, for the poor representation of the older and larger specimens. The natural mortality rate for these older and larger fish is also probably great.

The growth rate of the pumpkinseeds was somewhat slower than that tentatively considered average for the state (Figure 2). Pumpkinseeds are usually expected to attain the legal length of 6 inches in southern Michigan in their fourth summer of life. The pumpkinseeds in Deep Lake were attaining legal length, on the average, late in their fifth or in their sixth growing seasons. At the time of poisoning, 8.5 percent of age-group IV, 50.0 percent of age-group V, and all of age-groups VI and VII had attained legal length. The sex ratio, based on a random sample of 145 fish (all 4 inches or more in length), was 59 percent females to 41 percent males.

Bluegill x pumpkinsedd hybrid sunfish. A relatively large number of this hybrid combination was found in Deep Lake. A total of 589 specimens weighing 18.4 pounds was recovered (Table 1). Bluegill x pumpkinseed hybrids made up 2.2 percent of the number and 3.3 percent of the weight of all fish recovered from the lake (rank of seven in both numbers and weight). A total of 27 hybrids (1.8 fish per acre) weighing 6.3 pounds (0.4 pounds per acre) had attained the legal size designated for the parent species. Legal fish therefore made up 4.6 percent of the total number and 34.2 percent of the total weight of the bluegill x pumpkinseed hybrids removed from the lake. The ratio of legal to undersized hybrids of this combination was about 1:22. This ratio may not be as unnatural as it appears since it is known that a number of factors, such as crowding on the spawning beds, which influence favorably the incidence of hybridization may be present only in occasional years. The small number of legal hybrids that were recovered may have been reduced somewhat because of the fact that hybrid sunfish were easier to catch on hook and line than were either of the parent species.

Scale samples were obtained from 423 of the 589 bluegill x pumpkinseed hybrids recovered from Deep Lake. Only 409 of these 423 specimens were useful for age determinations (Table 4). It was not possible to assign age groups to the 180 fish that are not considered in Table 4, because adequate records of their lengths are not available. The relative strength of year classes does not appear other than normal except for the young of the year where very few were collected.

The growth curve of these hybrids is plotted in Figure 3 with the growth curves of the parent species for comparative purposes. These hybrids had a growth rate that was intermediate to the parent stock but was closer to that of their bluegill parent. On the average they were attaining legal length late in their fourth or in their fifth season of growth. It has been observed by Hubbs and Hubbs (1931, 1933) that some centrarchid hybrids have a growth rate faster than either of the parent species. This observation applied particularly to those sunfish species which in nature have comparable growth rates. In the present instance we are dealing with parent species having noticeably divergent growth rates, as the bluegills grew faster than the pumpkinseeds. Our data indicate a growth rate for the hybrids of the combination as being faster in each age group than the mean rate of growth of the parent species. This agrees in general with the findings of Bailey and Lagler (1938) for the same combination of species in New York waters.

Sex data for the hybrids were not obtained at the time of collection but in all probability they were predominantly male and generally infertile (Hubbs and Hubbs, 1933).

Other centrarchid hybrids. A total of seven green sunfish x pumpkinseed hybrids weighing 0.3 pounds was recovered. These and two

Table 4.--The minimum, maximum, and average length, the average weight and number of hybrid sunfish (bluegill x pumpkinseed) of each age group in a sample recovered from Deep Lake

Age group	Year class	Number of fish	Total length (inches) Minimum	Average	Maximum	Average weight (ounces)
0	1941	11	1.4	1.6	1.9	...
I	1940	269	1.7	2.7	3.8	...
II	1939	56	3.1	4.1	5.3	0.9
III	1938	40	4.3	5.1	6.4	1.5
IV	1937	25	4.5	6.0	8.1	2.3
V	1936	5	6.1	7.1	8.9	4.8
VI	1935	3	8.3	8.4	8.5	8.1
Total	...	409	...	...	...	...

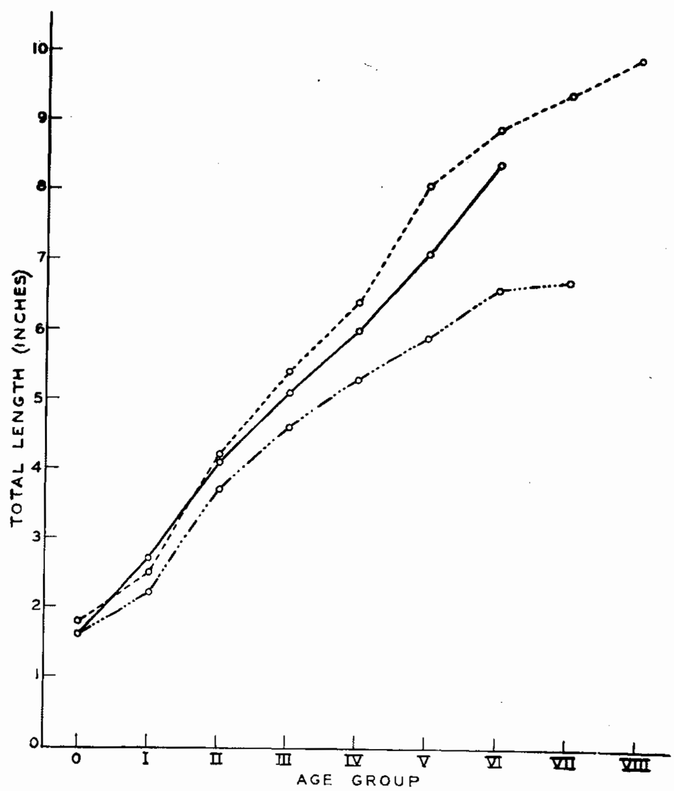

Figure 3.--Growth in length of the hybrid sunfish (bluegill x pumpkinseed) in Deep Lake (solid line). For comparison the growth in length of each parent species in Deep Lake has been added (bluegills, broken line; pumpkinseed, dots and dashes line).

bluegill x green sunfish hybrids recovered constituted such a small fraction of the total numbers and weight of fish in the lake that they will not be treated in detail. Scale samples were taken from all specimens and were used for age determinations. Six of the green sunfish x pumpkinseed hybrids were in age-group I. Their total lengths ranged from 2.0 - 2.4 inches and averaged 2.2 inches. The seventh specimen had a total length of 6.7 inches and was in its fifth summer of life (age-group IV). Of the two bluegill x green sunfish hybrids recovered, one had a total length of 2.0 inches and was in its second summer (age-group I) and the other had a total length of 4.3 inches and was in its third summer (age-group II).

Green sunfish. Green sunfish were the third most abundant species (4.0 percent of the total number) in Deep Lake but ranked only ninth in weight (2.0 percent of the total weight). A total of 1,090 specimens weighing 11.0 pounds was recovered (Table 1). There is no minimum legal length for green sunfish in Michigan but 6 inches is arbitrarily considered to divide the desirable from the undesirable. There were no green sunfish of "desirable" length in the random sample used for age determinations. However, five specimens, 6 inches or over in total length, were recovered from the lake (0.3 desirable-sized fish per acre). The largest of these had a total length of 6.4 inches. The ratio of desirable to undesirable green sunfish was 1:218.

Scale samples were saved from a random sample of 184 specimens. Data by age groups and year classes for this sample only are summarized in Table 5. The relative strength of year classes appears normal except for the 1939 year class which like the bluegill and pumpkinseed shows evidences of being weak. The rate of growth, (Figure 4) was slow. On the average, the green sunfish had not attained the desirable length

Table 5.--The minimum, maximum, and average length and the number of green sunfish of each age group in a sample recovered from Deep Lake

Age group	Year class	Number of fish in age group	Total length (inches)		
			Minimum	Average	Maximum
0	1941	10	1.2	1.5	1.7
I	1940	124	1.8	2.4	3.0
II	1939	12	3.1	3.7	4.5
III	1938	25	3.7	4.8	5.8
IV	1937	12	4.4	5.4	5.9
V	1936	1	...	5.9	...
Total	...	184	...	...	...

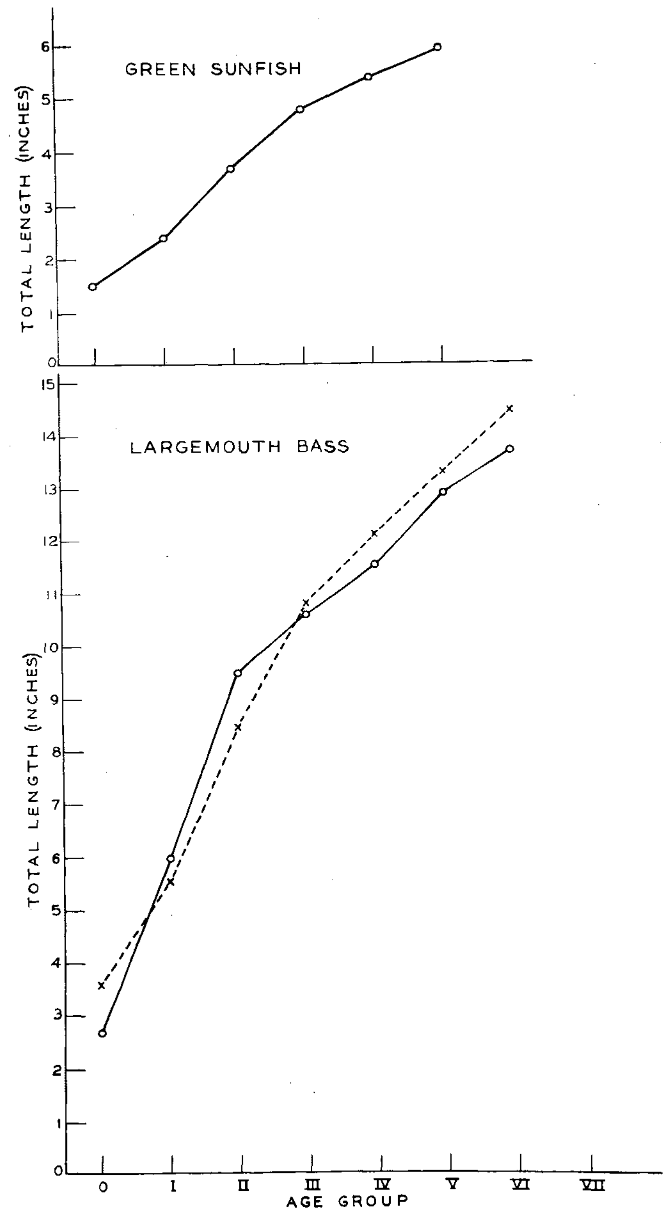

Figure 4.--Growth in length of the largemouth bass and green sunfish in Deep Lake (solid line). For comparison, the tentative state (Michigan) average for the largemouth bass has been added (broken line).

of 6 inches as late as the end of their sixth growing season. This growth rate, though seemingly poor, is faster than that found by Hubbs and Cooper (1935) for this species in the same general area of Michigan. These authors concluded from their study that relatively few green sunfish (in Michigan) ever attain a length of 6 inches. This and subsequent studies strongly influenced the removal of size and bag limits on this species in Michigan.

Largemouth bass. Although the largemouth bass was only the sixth most abundant species in the lake, it ranked second in weight. The total of 785 fish recovered from the lake weighed 106.0 pounds (Table 1). Largemouth bass therefore accounted for 2.9 percent of the number and 18.8 percent of the weight of all fish removed from Deep Lake. The 97 legal-sized largemouth bass (10 inches and over) recovered weighed 79.8 pounds. The legal fish represented 12.4 percent of the total number and 75.3 percent of the total weight of the largemouth bass recovered. The ratio of legal to undersized largemouth bass was about 1:8. This ratio appears high and, as among the sunfish, may be attributed to an incomplete recovery of the young of the year or to a poor hatch.

The length, weight, and number of largemouth bass by age groups and year classes is presented in Table 6. These data are based on a sample of 246 fish, including all of the fish in age-group II and older. The balance (all in age-groups 0 and I) were assigned to age groups according to the observed percentage age composition within the individual length intervals. The representations of the various age groups in the largemouth bass were decidedly unequal. This irregular representation is probably due to the fact that fish resulting from a particularly successful hatch prey upon the young produced in succeeding years. The 1939 year class appears weaker than earlier year classes which situation conforms with an apparently similar phenomenon among the sunfish species. The young of

Table 6.--The minimum, maximum, and average length and weight, and the number of largemouth bass of each age group recovered from Deep Lake

Age group	Year class	Number of fish aged	Estimated total number of fish in age group	Percentage of total number	Total length (inches)		Number of fish weighed[1]	Weight (ounces)	
					Range	Average		Range	Average
0	1941	59	569	72.5	1.6- 4.0	2.7	569	0.1- 0.5	0.1
I	1940	75	104	13.2	4.7- 7.5	5.9	91	0.8- 2.8	1.6
II	1939	16	16	2.0	8.1-10.5	9.5	16	3.3- 9.3	6.1
III	1938	25	25	3.2	9.3-11.6	10.6	25	6.4-12.2	8.7
IV	1937	43	43	5.5	10.8-13.1	11.5	42	7.0-14.4	10.9
V	1936	18	18	2.3	11.4-13.9	12.9	18	8.5-22.0	17.8
VI	1935	7	7	0.9	12.5-15.0	13.7	7	14.5-25.0	18.2
VII	1934	1	1	0.1	15.4	15.4	1	31.5	31.5
VIII	1933	1	1	0.1	18.0	18.0	1	48.5	48.5
IX	1932	1	1	0.1	20.7	20.7	1	79.0	79.0
Total	...	246	785	...	...	...	771	...	...

[1]Individual weights were obtained from only a part of the fish from which age determinations were made.

the year comprising the 1941 year class might have been more abundant than the data indicate, as the recovery probably was not complete. For the largemouth bass population of Deep Lake, the 43 IV-group fish indicate that the 1937 year class was originally far more abundant than the 1938, 1939, and 1940 year classes. The 1937 year class had been subjected to more years of natural mortality and to a longer exposure to fishing than had the 1938, 1939, and 1940 year classes (all 1940 fish were below legal size). The relative strength of age-groups V to IX appears quite normal.

The growth rate of the largemouth bass in Deep Lake (Figure 4) closely approximates the tentative average rate of growth considered for this species in Michigan waters. On the average the Deep Lake largemouth bass were attaining the legal length of 10 inches late in their third or early in their fourth growing season. At the time of poisoning, 25.0 percent of age-group II, 88.0 percent of age-group III, and all of age-groups IV to IX had attained legal length. The sex ratio, based on a random sample of 153 specimens, was 57.0 percent females to 43.0 percent males.

Rock bass. This species ranked eighth in abundance (2.1 percent) and fifth in weight (4.1 percent) in the total fish population of Deep Lake. A total of 585 fish (40.0 fish per acre) weighing 22.9 pounds (1.5 pounds per acre) was recovered from the lake (Table 1). A total of 46 legal-sized (6 inches and over) rock bass (3.1 fish per acre) that weighed 9.9 pounds (0.7 pounds per acre) was recovered. Legal rock bass made up 7.9 percent of the total number and 43.2 percent of the weight of this species. The ratio of legal to undersized rock bass was about 1:13. As in several of the species discussed previously, the ratio of legal to undersized fish is probably invalidated by incomplete recovery of young of the year.

The length, weight, and number of rock bass by age groups and year classes (based on a sample of 115 fish) are presented in Table 7. The relative strength of age-groups I to VII appears quite normal, and all of these age groups apparently indicate a far greater original abundance than age-group O. The apparent weakness of the 1941 year class cannot be entirely due to poor recovery when we consider that a total of 4,134 pumpkinseeds and ~~over~~ nearly 10,000 bluegills of similar size were recovered.

The rate of growth of the rock bass in Deep Lake (Figure 5) was measurably better than that rate tentatively set up as average for this species in Michigan. This advantage of the Deep Lake fish was particularly apparent in age-groups II to V. On the average, the rock bass were attaining the legal length of 6 inches late in their fourth or in their fifth growing season. Rock bass in southeastern Michigan are usually expected to attain legal length late in their fifth or in their sixth growing season. A random sample of 69 fish (all larger than 4 inches) indicated that the sex ratio was 53.0 percent females to 47.0 percent males.

Yellow perch. Perch were fifth in abundance (3.0 percent) and sixth in weight (3.6 percent) among the entire fish population recovered in Deep Lake. A total of 817 specimens weighing 20.4 pounds was recovered (Table 1). There were 26 legal-sized (6 inches and over) yellow perch (1.8 fish per acre) which amounted to 3.2 percent of the total perch population recovered. The legal perch weighed 6.4 pounds (0.4 pounds per acre) and thus made up 31.4 percent of the perch population recovered. The ratio of legal to undersized perch was about 1:31.

A random sample of 283 perch was used for purposes of age determination. Data on the age, length and weight of the perch contained in this random sample are summarized in Table 8. It was not possible to assign the

Table 7.—The minimum, maximum, and average length and weight, and the number of rock bass of each age group recovered from Deep Lake

Age group	Year class	Number of fish aged	Estimated total number of fish in age group	Percentage of total number	Total length (inches)		Number of fish weighed[1]	Weight (ounces)	
					Range	Average		Range	Average
0	1941	7	73	12.5	1.3-2.0	1.6	73	...	0.1
I	1940	19	396	67.7	2.4-3.7	3.0	396	0.2-0.7	0.3
II	1939	42	56	9.6	4.2-5.9	4.8	43	0.5-2.2	1.2
III	1938	22	29	5.0	5.2-6.9	6.0	22	1.1-3.5	2.3
IV	1937	14	18	3.1	5.6-7.0	6.5	18	1.8-4.2	2.9
V	1936	7	9	1.5	6.7-8.0	7.4	9	2.7-5.6	4.4
VI	1935	2	2	0.3	8.1-8.3	8.2	2	5.6-6.2	5.9
VII	1934	2	2	0.3	7.4	7.4	2	4.9-5.6	5.3
Total	...	115	585	...	...	...	565	...	...

[1] Individual weights were obtained from only a part of the fish from which age determinations were made.

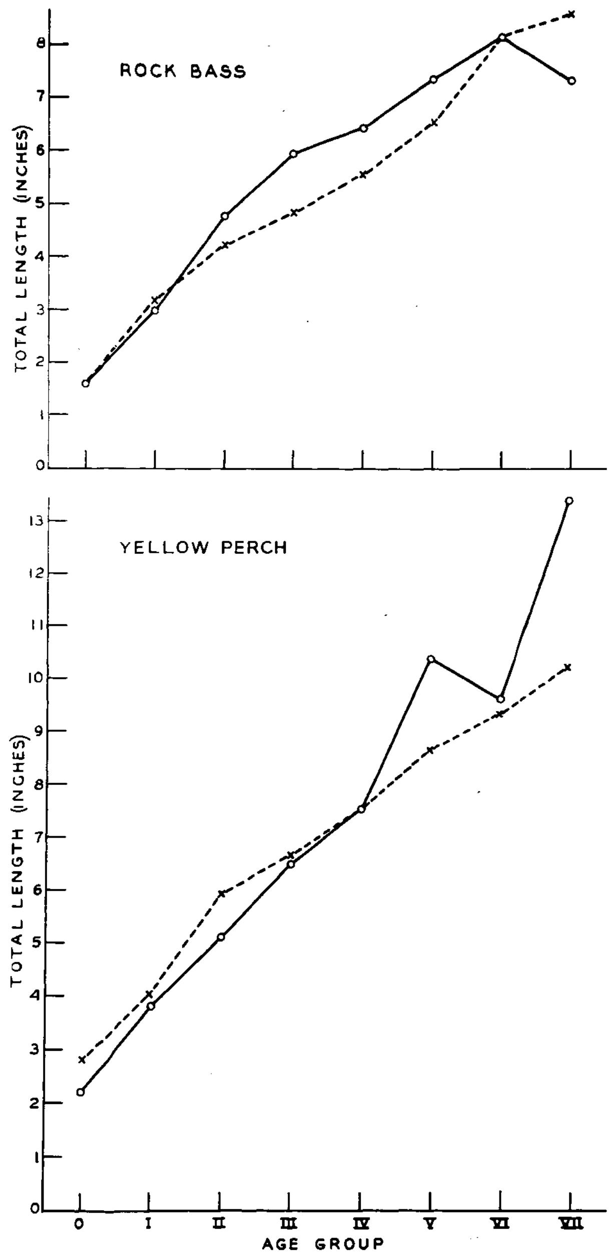

Figure 5.--Growth in length of the rock bass and yellow perch in Deep Lake (solid line). For comparison, the tentative state (Michigan) average has been added (broken line).

Table 8.--The minimum, maximum, and average length, the average weight, and the number of yellow perch of each age group in a sample recovered from Deep Lake

Age group	Year class	Number of fish in age group	Total length (inches) Minimum	Average	Maximum	Average weight (ounces)
0	1941	53	1.6	2.2	3.1	...
I	1940	175	2.8	3.8	5.1	0.4
II	1939	30	4.2	5.1	7.2	0.9
III	1938	5	5.2	6.5	7.4	1.6
IV	1937	13	6.4	7.5	9.3	2.4
V	1936	2	10.3	10.4	10.5	6.7
VI	1935	2	9.1	9.6	10.1	...
VII	1934	1	...	13.4	...	14.5
Total	...	281	...	...	...	...

remainder of the perch population to age groups because of the lack of data on their length distribution. Recovery of young-of-the-year perch may not have been complete, as was true also of all other species present in Deep Lake. The data in Table 8 suggest a numerical weakness in age-group III (1938 year class). Perch never were important as a game species in Deep Lake and seldom entered the catch.

The growth rate of the yellow perch in Deep Lake was somewhat slower than the tentative average for the species in Michigan (Figure 5). The perch was the only game or pan species in the lake, other than the pumpkinseeds, that had a consistently substandard rate of growth when compared with the tentative state average growth rates. Yellow perch in Michigan waters are normally expected to attain the legal length of 6 inches late in their third or early in their fourth growing season. On the average, the perch in Deep Lake required a year longer than average to attain this length. The sex ratio, based on a random sample of 203 specimens all of which were over 3 inches in length, was 55 percent females to 45 percent males.

Yellow bullheads. The yellow bullhead was the more abundant of the two coarse-fish species considered native to the lake. It ranked fourth in both abundance and weight among the species present. A total of 1,082 specimens weighing 38.4 pounds was recovered. These fish represented 4.0 percent of the number and 6.8 percent of the weight of the entire population. Lengths were obtained on all specimens and the population was arbitrarily divided into four size groups. No frequency distribution was compiled. The first group, including all specimens up to 3 inches in total length, contained 860 fish. This group included 79.4 percent of all bullheads recovered. The second group (size range: 3.1- 6.0 inches, total length) contained 137 specimens; the third group (size range: 6.1-9.0 inches), included 50 specimens; the fourth group, (size range: 9.1-12.0 inches), contained 35 specimens. The 85 bullheads comprising the third and fourth size groups are considered to be of "desirable" size. They amounted to 7.9 percent of the bullheads recovered and were present in the lake at a rate of 5.7 fish per acre (2.0 pounds). Bullheads 6 inches and over in length accounted for 78.4 percent of the weight of all bullheads recovered. Anglers almost never fished for bullheads in Deep Lake; therefore few if any were ever removed.

Mud pike. The mud pike was the less abundant of the two native coarse species in Deep Lake. A total of 369 fish of this species weighing 11.4 pounds was recovered. These figures represented 1.4 percent of the total number and 2.0 percent of the total weight of the fish population. An examination of the scales of a random sample of fish indicated that ages could not be determined satisfactorily. A size-frequency distribution revealed only one distinct group which was assumed to be composed of the young of the year. The mode of this group was at 4.1 inches and the range was 2.5 to 5.1 inches. The group contained about 300 specimens or 81.2 percent of the population of mud pike recovered. The balance of the size-distributions contained few specimens and the significance of their modes was obscure. We assume that they were probably composed of fish of age-groups II and III. The length of the larger specimens ranged up to 12.5 inches. However, only five mud pike had attained a total length greater than 10.0 inches. This species never entered the anglers' catch and may therefore be considered as a "normal" population.

Common sucker. A total of five common suckers weighing 8.9 pounds was removed from Deep Lake. This species made up a negligible percentage of the total number and only 1.6 percent of the total weight of the fish population removed. The five specimens varied from 12.9 to 19.1 inches in total length and from 1.25 to 2.9 pounds in weight. A scale sample, saved from a 15.6-inch specimen, indicated that this fish was in its fourth season of growth (age-group III). The suckers recovered at the time of poisoning are not believed to have been native to the lake. It is thought that they were introduced by fishermen who emptied their bait buckets into the lake. Suckers evidently had not become established and would probably have disappeared from the lake eventually. The reason for the failure of this species to establish itself is not apparent. Inadequate numbers, unfavorable ecological conditions, or introduction of specimens of only one sex are the possibilities suggested. Four of the suckers were recovered several days after Deep Lake was poisoned and consequently were badly decomposed. Therefore, it was impossible to determine the sex of any of the suckers.

Golden shiner. Only one specimen of the golden shiner was recovered. This fish was 2.5 inches long and was probably in its second season of growth (Cooper, 1936). This species, like the common suckers, is not considered native to the lake. Recovery of a single specimen of this size leaves only the conclusion that like the suckers, it was introduced from a fisherman's bait bucket.

Mudminnow. Two specimens, 1.8 and 2.1 inches long, were recovered. They were probably in their second season of growth (Applegate, 1943). It is believed that these individuals were the result of accidental introduction but the method of their introduction is debatable. Mudminnows are not commonly used as a bait minnow in southern Michigan which fact minimizes the possibility of their introduction by anglers. A small marsh lies just northeast of Deep Lake and is separated from the lake by a low ridge. This marsh is known to contain mudminnows. Approximately once every four or five years a very wet spring causes this marsh to overflow slightly into the lake. This overflow provides opportunity for a periodic introduction of mudminnows into Deep Lake. However, even though they possibly are introduced frequently, they apparently have failed to establish themselves at any time in the lake.

The game and pan species in Deep Lake were considered to be the largemouth bass, rock bass, bluegill, pumpkinseed, hybrid sunfishes and yellow perch. These five species and the hybrids accounted for 90.7 percent of the number and 87.6 percent of the weight of all fish recovered from the lake. The green sunfish has, in the past, been variously considered a pan fish or a coarse fish. Although in some southern waters it does attain a satisfactory size, it seldom exceeds 6 inches in total length in Michigan. For present purposes it is therefore considered undesirable as a pan species. The green sunfish combined with the coarse species (yellow bullhead, mud pike, and common sucker) comprised 9.3 percent of the number and 12.4 percent of the weight of all fish recovered.

Although the data that have been presented in the preceding discussions point rather conclusively to the presence of relatively strong and weak year classes in the fish population of Deep Lake, they do not provide an exact measure of their relative original strength. The varying degrees of success of natural reproduction in different calendar years may be in large measure responsible for the unequal representations of the different age groups. However, such factors as incomplete recovery, annual fluctuations in angling and predation must also be considered for all species. Especially disturbing in the interpretation of the data was the distorting effect of age at capture. Despite the obvious defects in the data, however, the differences in the representation of several of the year classes are so great that a number of them can be classified by such terms as strong or weak. The following discussion on the relative abundance of the year classes was based on a careful examination of the data with allowance for the age at capture.

Certain trends in the fluctuations in the strength of various year classes doubtless have become obvious to the reader of the discussion of the age and growth of the individual species. The 1941 year class for the pumpkinseed, rock bass, yellow perch, and green sunfish seemingly was weak. For example, only 1,402 pumpkinseeds of the 1941 year class (age-group 0) were recovered as compared with 4,134 fish of the 1940 year class (I-group). This scarcity of young of the year is definitely suggestive of a poor year class. The 1940 year class appeared stronger for the bluegill, pumpkinseed, rock bass, perch, and green sunfish. For example, the number of fish in the 1940 year class recovered amounted to 5,390 fish for the bluegill (9,872 for the 1941 year class), 4,134 for the pumpkinseeds (1,402 for the 1941 year class), and 396 for the rock bass (73 for the 1941 year class). The 1939 year class for the bluegill, pumpkinseed, largemouth bass, and green sunfish can be classed as weak. For example, only 69 bluegills of the 1939 year class were recovered as compared to the 183 bluegills comprising the 1938 year class. Similar figures for other species were: pumpkinseed 119 fish in the 1939 year class, and 142 for 1938; for the largemouth bass 16 fish as compared with 25; and green sunfish 12 compared with 25. From the data presented above it is apparent that in certain years survival for most species was either exceptionally good or exceptionally poor. For neither 1939 nor 1940 did we find that some species had strong year classes and other species weak year classes. Also, that when a good hatch of several species was evidenced by a strong year class (such as 1940) a weak year class developed the fallowing year (1941). This phenomenon in all probability is due only to predation. The fluctuation in abundance of various year classes offers suggestions of cycles which are more prominent in earlier year classes than in older year classes.

The strength of year classes over the period 1938 to 1934 is exceedingly difficult to evaluate, but some year classes of certain species are obviously strong or weak. The weak year classes were as follows: 1938--largemouth bass and perch; 1936--bluegill. The strong year classes were: 1938--pumpkinseed and green sunfish; 1937--largemouth bass and perch; 1935--bluegill; 1934--bluegill. A strong representation of an old age group indicates a much richer year class than does an equally large number of fish several years younger. On the other hand, the scarcity of old fish (especially true for the pumpkinseed) may be merely the result of natural mortality over a long period of years. These data show that the 1938 year class for the largemouth bass and perch were rather weak, whereas the 1937 year classes for the same species appeared strong and therefore offer suggestions of cycles.

It is difficult to state whether the standing crop of fish in Deep Lake (38.0 pounds per acre) represents good or poor production. A comparison with a number of fish population studies made on natural lakes in Michigan, Wisconsin, Florida, and Nova Scotia leaves little doubt that regional location (regional is used here in a broad sense and is not to be construed with small regions) is a poor index of lake productivity (Table 9). O'Donnell (1943) reported standing crops of 92 to 186 pounds per acre in three lakes in northern Wisconsin, Brown and Ball (1943) determined that Third Sister Lake in the southern part of the Lower Peninsula of Michigan had a population of 86.6 pounds per acre. Again in Michigan, six lakes in the upper part of the Lower Peninsula (Eschmeyer, 1938b) yielded recoveries of 21 to 194 pounds per acre. Smith (1938) found the stocks of fish in three Nova Scotian lakes to amount to 17.0,

Table 9.--The total fish population (in pounds per acre of lake surface) of natural lakes in Michigan, Wisconsin, Florida, and Nova Scotia

Name of lake	Locality (state or province)	Area (acres)	Total population (pounds per acre)	Reference
Burke	Michigan	1.8	60.1	...[1]
Section Four	do.	3.3	23.0	Eschmeyer (1938b)
South Twin	do.	4.3	29.0	do.
Third Sister	do.	10.0	86.6	Brown and Ball (1943)
Walsh	do.	10.2	92.4	...[1]
Ford	do.	10.7	49.0	Eschmeyer (1938b)
Clear	do.	11.3	194.0	do.
Howe	do.	13.4	34.0	do.
Standard	do.	16.0	21.0	do.
East Twin	Wisconsin	13.0	186.0	O'Donnell (1943)
West Twin	do.	13.5	92.0	do.
Long	do.	27.1	135.0	do.
Little Steep Pond	Florida	2.1	105.2	Meehean (1942)
Big Prairie Pond	do.	4.0	60.8	do.
First Pond	do.	7.0	110.4	do.
Buck Pond	do.	18.0	32.7	do.
Clearwater	do.	24.0	22.2	do.
Tedford	Nova Scotia	5.2	36.0	Smith (1938)
Jesse	do.	45.0	19.9	do.
Boar's Back	do.	55.8	17.0	do.

[1] Unpublished data in files of the Institute for Fisheries Research.

19.9, and 36.0 pounds per acre. Five natural lakes in Florida (Meehean, 1942) contained from 22 to 110 pounds per acre.

Data, as yet unpublished, in the files of the Institute for Fisheries Research on the populations and production of two lakes (Walsh, Burke) in the southern part of the Lower Peninsula were examined. These two lakes combined with Third Sister Lake (Brown and Ball, 1943) had an average standing crop of 79.7 pounds per acre (range: 60.1 to 92.4 pounds). Average production of legal game fish in the three lakes was 57.2 pounds per acre (range: 22.9 to 78.9 pounds). Deep Lake, although situated in the same general latitude in the Lower Peninsula as the aforementioned three lakes, had a population of less than half as many pounds of fish per acre as the average for Walsh, Burke, and Third Sister Lakes.

With the exception of one lake (Clear), Deep Lake had a population in pounds per acre comparable with those examined by Eschmeyer in the northern half of the Lower Peninsula. The population was also similar to that found by Smith in the Nova Scotian lakes. Pounds of fish per acre was considerably lower than the figures reported by O'Donnell for three lakes in northern Wisconsin.

Literature cited

Applegate, Vernon C.

1943. Partial analysis of growth in a population of mudminnows, Umbra limi (Kirtland). Copeia, 1943, No. 2, pp. 92-96.

Bailey, Reeve M., and Karl F. Lagler.

1938. An analysis of hybridization in a population of stunted sunfishes in New York. Pap. Mich. Acad. Sci., Arts, and Let., Vol. 23 (1937), pp. 577-606.

Brown, C. J. D., and Robert C. Ball.

1943. A fish population study of Third Sister Lake. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 177-186.

Carbine, W. F.

1939. Observations on the spawning habits of centrarchid fishes in Deep Lake, Oakland County, Michigan. Trans. Fourth N. Am. Wildlife Conf., pp. 275-287.

Cooper, Gerald P.

1936. Age and growth of the golden shiner (*Notemigonus crysoleucas auratus*) and its suitability for propagation. Pap. Mich. Acad. Sci., Arts, and Let., Vol. 21 (1935), pp. 587-597.

Eschmeyer, R. William.

1937. Some characteristics of a population of stunted perch. Pap. Mich. Acad. Sci., Arts, and Let., Vol. 22 (1936), pp. 613-628.

1938a. Further studies of perch populations. Pap. Mich. Acad. Sci., Arts, and Let., Vol. 23 (1937), pp. 611-631.

1938b. The significance of fish population studies in lake management. Trans. Third N. Am. Wild. Conf., pp. 458-468.

1939. Analysis of the complete fish population from Howe Lake, Crawford County, Michigan. Pap. Mich. Acad. Sci., Arts, and Let., Vol. 24 (1938), pp. 117-137.

Greenbank, John.

1941. Selective poisoning of fish. Trans. Am. Fish Soc., Vol. 70 (1940), pp. 80-86.

Hile, Ralph.

1941. Age and growth of the rock bass, *Ambloplites rupestris* (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wisc. Acad. Sci., Arts, and Let., Vol. 33, pp. 189-337.

Hubbs, Carl L., and Gerald P. Cooper.

1935. Age and growth of the long-eared and the green sunfishes in Michigan. Pap. Mich. Acad. Sci., Arts, and Let., Vol. 20 (1934), pp. 669-696.

Hubbs, Carl L., and Laura C. Hubbs.

1931. Increased growth in hybrid sunfishes. Pap. Mich. Acad. Sci., Arts, and Let., Vol. 13 (1930), pp. 291-301.

1933. The increased growth, predominant maleness, and apparent infertility of hybrid sunfishes. Pap. Mich. Acad. Sci., Arts, and Let., Vol. 17 (1932), pp. 613-641.

Meehean, O. Lloyd.

1942. Fish populations of five Florida lakes. Trans. Am. Fish. Soc., Vol. 71 (1941), pp. 184-194.

O'Donnell, D. John.

1943. The fish population in three small lakes in Northern Wisconsin. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 187-196.

Scott, I. D.

1921. Inland lakes of Michigan. Mich. Geol. and Biol. Surv., Publ. No. 30. Geol. Ser. No. 25.

Smith, M. W.

1938. A preliminary account of the fish populations in certain Nova Scotian lakes. Trans. Amer. Fish. Som., Vol. 67 (1937), pp. 178-183.

INSTITUTE FOR FISHERIES RESEARCH

W. F. Carbine and Vernon C. Applegate

Report approved by A. S. Hazzard

Report typed by M. A. Klaphaak

Appendix to Report No. 1069

In the process of comparing Deep Lake with the three other lakes (Walsh, Burke, Third Sister) examined in the same area of the Lower Peninsula, points of similarity were noted between Third Sister Lake and Deep Lake in nearly every respect but their productivity in pounds of fish per acre (Table 10). However, it proved difficult to ascertain which of the many variables affecting lake productivity created the difference in the productive quality of the two lakes. Additional data for Third Sister Lake, other than those appearing in the report (Brown and Ball, 1943) were kindly provided by Dr. R. C. Ball.

From data collected on the two lakes during a comparable season of the year, no significant differences could be noted in the following characteristics: Shore development, maximum depths, drop-off, hydrosols, littoral zone as percentage of surface area, dominant plant species, methyl orange alkalinity, pH, location of thermocline, character of surrounding country and vegetative cover and land use on immediate shore. Both lakes lie within a soil area designated in Michigan as "First Class" (Millar, 1940[1]) and both lakes are of the same geologic origin. Deep Lake has a surface area of 14.8 acres; Third Sister Lake a surface area of 10.0 acres. Deep Lake has no outlet; Third Sister has an intermittent outlet.

[1] Millar, C. E. 1940. Soils of Michigan. Mich. State Col., Agric. Exp. Sta., Section of Soils, Circular Bull. 176, Dec. 1940.

The essential differences and further similarities between the two lakes are best evaluated under the following headings:

(1) The fish associations:--Small populations of rock bass and yellow perch were found in Deep Lake which were not present in Third Sister Lake. A comparable population of chub suckers in Third Sister Lake was not

Table 10.--Comparison of the fish population as well as various physical and chemical factors of Deep Lake and Third Sister Lake

	Deep Lake	Third Sister Lake
Fish population:		
Total poundage	562.7	866.6
Pounds per acre	38.0	86.6
Total pounds of legal fish	315.4	606.6
Pounds of legal fish per acre	21.2	60.7
Area (acres)	14.8	10.0
Maximum depth (feet)	61	55
Littoral zone (percent of total area)	37 (to depth of 20 feet)	35 (to depth of 10 feet)
Maximum depth plant zone (feet)	20	10
Slope of drop-off	Steep	Steep
Color of water	Clear	Clear to greenish brown
Secchi-disc transparency (feet)	20-24	Average about 8
Methyl orange alkalinity	84-93	85-95
pH	6.8-8.4	6.8-8.4
Oxygen (late summer) [1]	45-50 feet	Depleted below thermocline
Average position of thermocline (feet)	15-27	12-21
Outlet	None	Intermittant
Inlet	Intermittant (drainage tile)	Intermittant--large volume when it rains
Drainage area (acres)	About 10	320
Shore development	1.12	1.24
Nature of immediate shore	Steep, sparsely wooded slopes	Gentle, sparsely wooded slopes
Nature of surrounding country	Cultivated, pasture, wood lots	Cultivated, pasture, wood lots, forest plantations
Forage fish	No established populations	6 species making up about 54 percent of the total number of fish

[1] The depth to which oxygen, sufficient to maintain fish life, is found.

found in Deep Lake. Other than these exceptions, the two associations of game, pan, and coarse species were identical. Perhaps the most outstanding difference was the presence of large numbers of well established forage minnows of six species in Third Sister Lake. An inconsequential number of forage minnows were recovered from Deep Lake and these were apparently not reproducing in the lake. Until more is known of the relation of forage minnows to the productivity of game and pan species, we hesitate to stress this distinction in the fish associations. Bluegills were the dominant game species in both lakes. The bass-bluegill ratio in Third Sister Lake was 1:8 while that in Deep Lake was 1:20. Recent studies (Bennett, 1943, 1944[2]) have indicated that a differing ratio of numbers

---

[2] Bennett, George W. 1943. Management of small artificial lakes; a summary of fisheries investigations, 1938-1942. Ill. Nat. Hist. Surv. Bul. Vol. 22, Art. No. 3, pp. 357-376.

Bennett, George W. 1944. The effect of species combinations on fish production. Trans. Ninth N. Am. Wildlife Conf., pp. 184-188.

---

between these two species can effect production. It is possible that the ratio of this combination in Third Sister Lake favored a greater production for these two species than that ratio in Deep Lake. When compensation was made for differences in the times of collection, there were no significant differences in the rates of growth of the principle game species in the two lakes. Nor were there any outstanding irregularities in the age composition of either population.

(2) <u>Fertility</u>:--Exhaustive qualitative and quantitative analyses of food organisms which might be used as an index of fertility were available for Third Sister Lake. However, no such data suitable for comparative purposes exists for Deep Lake. Aquatic vegetation, sometimes positively correlated

with fertility, was similar in character but visually appeared somewhat more abundant in Third Sister Lake. No volumetric data for the vegetation at Deep Lake is available. Since these potential indices were rendered useless by the inadequacy of the available data for Deep Lake, it was necessary to reach an estimate of the degree of fertility of the two lakes indirectly by examining the sources of their nutrient materials. Drainage areas of the two lakes were compared. As indicated previously, soil type, and soil character of the surrounding areas of both lakes were identical. Land utilization in the immediate vicinity of the lakes was similar, being devoted to pasture, woodlot and cultivation. However, Deep Lake with its steep shoreline drained no more than 10 acres of land while Third Sister Lake in more level terrain drained an area of at least 320 acres. No permanent inlet exists for either lake. Third Sister Lake receives an intermittent stream which frequently reaches flood proportions during heavy rains and at that stage is capable of carrying into the lake an appreciable volume of mineral and organic substances. A six inch drainage tile, flowing occasionally in the spring is the only surface tributary to Deep Lake. Both the volume and character of total drainage areas and the tributaries, permanent or intermittent, therein contribute decisively to the fertility of the lake receiving these waters. Other factors appearing equal, these data suggest that the comparatively low production in pounds per acre in Deep Lake was the result of a limited fertility, induced by a restricted drainage area and the ineffectual nature of its intermittent tributary.