Prepared for Mich. Acad. Sci., Arts & Letters

Original: Fish Division
cc: Mr. Ruhl
cc - Titus.

INSTITUTE FOR FISHERIES RESEARCH
DIVISION OF FISHERIES
MICHIGAN DEPARTMENT OF CONSERVATION
COOPERATING WITH THE
UNIVERSITY OF MICHIGAN

ALBERT S. HAZZARD, PH.D.
DIRECTOR

ADDRESS
UNIVERSITY MUSEUMS
ANN ARBOR, MICHIGAN

January 7, 1938

REPORT NO. 450

# ANALYSIS OF THE COMPLETE FISH POPULATION FROM HOWE LAKE, CRAWFORD COUNTY, MICHIGAN

by

R. William Eschmeyer

Over a period of several years the Institute for Fisheries Research has been eradicating the fish in a small number of Michigan lakes. With one exception, these populations were almost valueless for angling because the fish were stunted in growth and few attained a catchable size. Three of these populations have been discussed by the writer (Eschmeyer, 1937, 1938); studies on several others have not yet been completed.

The exception, Howe Lake, had a population of fish which were growing at a reasonable rate, were attaining a relatively large size, and were being fished for to a considerable extent. Studies of populations such as the one from Howe Lake are probably more valuable to fish management than are the examinations of the abnormal ones, but consideration must be given to the reaction of the anglers who have no objection to the eradication of fish which are valueless, especially if the lakes are later restocked, but who may be expected to react very differently if fish from a desirable fishing lake are destroyed. Removal of the fish from Howe Lake seemed to meet with the approval of the interested anglers because of the presence of carp. It is improbable that many more or less normal

populations of fish will be studied in the near future by similar methods.

This discussion is, primarily, an analysis of the fish which were in Howe Lake at the time of the poisoning. It is based on a study of almost the entire population. Emphasis is placed on fish management and especially on problems of fish cultural significance.

## Howe Lake

Howe Lake is in Section 32, T. 27 N., R. 4 W., Crawford County, Michigan. It is about six miles west of Grayling, approximately a mile north of M 76. The lake is on state-owned land and has no resort development. The surrounding country is sandy, level, jackpine plain, and is low in fertility and unsuited to agriculture.

A survey of Howe Lake was made by an Institute lake survey party, consisting of Dr. David Chandler, Walter Crowe and E. L. Cheatum, in the summer of 1937. According to their investigation, the lake has an area of 13.4 acres at its current level, has sandy margin and shoal and a peat bottom in the deeper water. The level has dropped decidedly in recent years and, in the opinion of Mr. Hans Petersen, District Superintendent of Fisheries, it is now about four feet below the level of ten years ago. The lake has a maximum depth of 24 feet and the basin is regular in form.

When examined early in August, the water was unstratified. Surface temperature was 23.5°C; at a depth of 21 feet it was 21.4°C. The water was colorless and was moderately clear, having a Secchi Disc reading of 12.5 feet. It was quite alkaline (pH 8.1). The methyl orange alkalinity was decidedly lower than that of most alkaline lakes which have been previously examined by the Institute (methyl orange alkalinity 51). Oxygen was adequate to support fish life at all depths; it ranged from 8.3 ppm. at the surface to 6.0 ppm. at a depth of 21 feet.

Howe Lake is almost completely devoid of vegetation. A few stunted pond-lilies, a limited amount of Chara and a small bed of pond weed apparently comprise all of the larger aquatics present. Several of these forms have been introduced. Food for fishes was likewise not abundant. A plankton net with 10.5 centimeter diameter at the mouth yielded only 0.4 cc. of plankton in a haul from a 15 foot depth to the surface. Examination of food organisms taken by Ekman dredge showed variations in volume of bottom organisms from 0.2 cc. per square foot at a five foot depth to none at a 21 foot depth. Forage fish were relatively few. The food was not studied thoroughly, but it was obviously not abundant.

## History

Much of the history of fishing and fish management on Howe Lake is not known to the writer. Carp are known to have been present for many years. According to reports, they were first planted in the county in the period from 1888 to 1892 and it is possible that they were introduced into Howe Lake at about that time. The lake was closed to fishing during the years 1930 to 1933, when it was used by the Department of Conservation to obtain fish for stocking other lakes in the area. According to Mr. Petersen, several hundred ~~250~~ adult small-mouthed bass were planted in the lake in 1926 ~~about 1930~~ to serve as brood stock. Sixteen spawning beds (gravel) were placed in water about three feet deep during the same year. A truck load of Chara was placed in the lake in May, 1932 and another load in June, 1933. Five truck loads of manure were taken to the lake in June, 1933. The above attempts to improve fish conditions were made by the Grayling Hatchery.

The project was abandoned in 1933 and fishing was again permitted after it became apparent that the attempts to raise bass for stocking in other waters were relatively unsuccessful. The number of fingerling bass which had been removed during the period from 1931 to 1933 were, according

to the Grayling Hatchery, 17,000, 27,000 and 16,000 respectively.

Environmental conditions were unfavorable for the production of large numbers of bass: Food was scarce. The only forage fish known to have been present were darters and even these were apparently not abundant. There was almost no protection for the young fish. Vegetation was sparse. The gravel spawning beds were probably in water which became too shallow within a very few years after they were introduced, leaving only sand or peat bottom for spawning. Perch, apparently stunted, were numerous according to the limited observations of the writer, and, with few forage fish present, probably lived largely on young bass and young perch. According to reports, the lake was fished to a considerable extent by poachers who disregarded the signs indicating that fishing was not permitted. It is not surprising that the project met with failure.

In 1933 a number of environmental improvements were made. Soon after the CCC was organized, a camp (Camp Higgins) was established only a few miles away. Lake improvement had been in progress for several seasons on an experimental basis and this new phase of fish management was included as part of the CCC work program. A crew of men from Camp Higgins under Mr. I. A. Rodeheffer installed 30 brush shelters, 19 slab devices for the spawning of blunt-nosed minnows and 140 bass spawning beds. Most of the latter consisted merely of small heaps of gravel (about a bushel each) placed on the firm bottom in approximately three feet of water. The crew also planted seven ten-gallon cans of Chara and an equal number of cans of yellow pond-lilies. The weeds were obtained from another lake a few miles away. Approximately 4,500 blunt-nosed minnows (Hyborhynchus notatus) were seined from Lake Margarethe and planted in Howe Lake.

Mr. Petersen reports that the Grayling Hatchery planted 20,000 blunt-nosed minnows in 1934 and 3,000 skipjacks (Labidesthes sicculus) in 1935, also that 75 adult suckers (Catostomus c. commersonii) averaging about 15 inches in length were taken from the outlet of Lake Margarethe in the spring of 1935 and transferred to Howe Lake.

The writer has visited Howe Lake rather frequently since 1933, and has made a number of observations. The beds of pond lilies became established and apparently attracted fish to the vicinity. Numerous insects were found on the plants. Each year, however, the leaves became smaller and, while some of the plants are still present, they are now very small and of little value. It seems that some elements essential to the growth of the plants are lacking although this has not been investigated. The Chara which was planted on several occasions, and a small amount of which may have been present originally, is not abundant. The planting of vegetation was therefore relatively unsuccessful.

The bass nests were observed frequently during the 1934 spawning season. Between 30 and 40 nests were used that season and no bass spawning was noted except on the gravel which had been provided. Examinations in later years have indicated that the gravel has invariably been used since it was introduced, at least no bass beds were found elsewhere in the lake. A few common sunfish nests, however, were on the sand, although most of these were also on the gravel.

Activity under some of the slab devices in 1937 indicated that one or both of the plantings of blunt-nosed minnows had been successful to some degree and that the slab-devices were serving their intended purpose. Not many nests were in evidence however, suggesting that the population of blunt-nosed minnows was not large. The brush shelters with few exceptions remained where placed and fish apparently frequented them.

A decided change in the fish population has apparently taken place between 1933 and 1937. In 1933, observations suggested that perch were abundant and were generally small and appeared to be growing very slowly. The schools of young bass on the shoals were being repeatedly pursued by perch (and by larger bass). A small number of the bass fingerlings were seined by the writer in 1934 and used as bait to determine whether or not these were acceptable to the perch. A number of the latter were taken in a relatively short time.

Observations indicate that since 1933 the bass have very noticeably increased in number and that the perch have declined. This condition has been noted also in another lake, Clear Lake, Montmorency County, where a number of brush shelters have been installed. Removal of a limited number of brush shelters, surrounded by seines before removal, suggest that the bass tend to seek these shelters more than do the perch. Improved spawning conditions and shelter have apparently favored the bass which, in turn, have probably reduced the number of perch. Mr. Petersen and Conservation Officer Harry Souders also agree that the perch in Howe Lake were much fewer in recent years. The numbers of young large-mouthed bass (Aplites salmoides) seined and planted in other waters after the improvements had been installed were, according to the Grayling Hatchery: 21,000 in 1934 and 27,000 in 1935.

During the spawning season of the sunfish (Eupomotis gibbosus) in 1937, it was decided to destroy the nests of these fish. The eggs had been laid but few if any had hatched. The method used in destroying the nests was a crude one, consisting merely of kicking the nest apart. A careful check of the number of beds which had been wrecked was not made, but they numbered somewhere between ten and twenty. It is possible that not every nest was destroyed or that the eggs of a few had already hatched.

It seems probable that the number of young-of-the-year sunfish (0 group) which were recovered later was very small because of this activity. It may prove entirely practicable to destroy the beds of those species of fish which nest in clear, shallow waters as a means of reducing their numbers where they have become overabundant or where they are undesirable.

On September 7, 1937, the fish in Howe Lake were killed with powdered derris root. About 186 pounds of the poison (approximately 14 pounds per acre) were used. The method of administering the poison was similar to that described previously (Eschmeyer, 1937). It is almost certain that all fish were killed, since the dosage applied was relatively greater than had been used in other waters to annihilate fishes and since no live fish were in evidence later.

The poisoning and the collecting of fish were carried out with the help of the survey party which had inventoried the lake earlier in the summer, men from the Grayling Hatchery staff and Conservation Officer Souders. Efforts were made to examine all the fish and a large number were preserved for later study. The sandy shoal was ideal for collecting. All those which were not preserved were counted and the fish other than minnows, darters, young-of-the-year game fish and a few suckers and carp were measured as well as counted. The collecting was continued for five days, although few were seen after the first and second day. Many of the darters did not float and it is possible that some of these remained submerged in water too deep to wade. It is believed that almost all (probably over 95 per cent) of the fish were secured for examination.

## The Fish Population

Unless otherwise indicated, the discussion below concerns only the fishes poisoned in 1937. The large number of fish taken for study in

the laboratory was preserved in formalin and later transferred to alcohol. Measurements were made after preservation except those fish which were discarded immediately after they were collected.

Fish taken from the stomachs of the larger specimens are invariably included. During the poisoning of a lake the smaller fish tend to die first and are readily available for the larger ones. Almost all of the young fish taken from the stomachs had apparently been consumed a very short time before the larger fish died because there was little or no digestion of these smaller individuals.

Measurements were made in millimeters and except for the carp, the fish were weighed to the nearest gram on a Welch balance. The several species are considered separately below.

COMMON SUCKER, Catostomus c. commersonii. A total of 37 suckers, or half the number reported to have been planted in 1935, were collected. Because of their large size, it is improbable that any were overlooked. Eighteen of these fish taken at random were measured and weighed; they had an average total length of 481 mm. (18.9 inches) and an average weight of 1,185 grams (41.8 ounces). The 37 suckers therefore weighed 96.7 pounds, if the weight of the 18 fish was average. The smallest sucker had a length of 15.5 inches and was very probably one of those stocked.

The adult suckers had been planted as brood stock to provide food for the bass and the other fish present. No suckers are known to have been present before the planting of 75 specimens in 1935. This attempt apparently met with complete failure, unless it be assumed that all the young had been eaten by the time of the poisoning because no small suckers were found. If the fish had reproduced successfully, a few would have been expected to survive even in a lake where food was scarce and where predatory

bass were relatively abundant. Their apparent failure to reproduce is not explained but another partial explanation might be given:

Suckers generally prefer to spawn in streams but also reproduce successfully in many land-locked lakes. Perhaps spawning conditions were unfavorable in Howe Lake. Reighard (1920) indicates that the males precede the females to the spawning grounds and that during most of the spawning period only males are present on the riffles. The Howe Lake suckers had been taken from the outlet of Lake Margarethe during the spawning run and few females may have been present in the number which were introduced. Mr. Petersen states that females were definitely included since eggs were flowing freely from some of them. The importance of determining the sex of the suckers in Howe Lake was not realized until after they had been discarded. If for some reason or other the females suffered an early mortality, the absence of young may be due to the absence of one of the two sexes.

The fish had grown from about 15 inches in length when planted in 1935 to about 19 inches in 1937.

CARP, Cyprinus carpio. It is reported that carp were once numerous in Howe Lake but that in recent years they have declined in number. According to reports a few were speared in 1933 and two years later a small one about nine inches long was taken with hook and line. So far as is known, no others have been taken in recent years.

Thirteen large carp were collected after the poisoning. Nine of these had an average length of 8382 mm. (33 inches) and ten had an average weight of 16.1 pounds. The 13 had a combined weight of 211 pounds. The fish were weighed to the nearest half pound. There were no young carp and it is probable that eventually the species would have been eliminated even if further efforts to reduce their numbers by spearing had not been made.

The extent to which carp are injurious to other fishes needs yet to be determined. In one end of the lake in 1934 the bass nests were from six to eight inches deep and the gravel was more or less scattered. Elsewhere in the lake on similar heaps of gravel the nests were all of the usual saucer-shaped kind. It is possible that the condition of the nests in the one end of the lake was due to the activity of the carp in an effort to obtain what food might have accumulated on the gravel.

The general impression was that the carp were responsible for the relatively small yield of fish, but ecological conditions are such that the lake would not be exceptionally productive regardless of the presence or absence of carp. The current antipathy for the carp is probably as extreme and unjustified as was the enthusiasm for this fish in or before the "gay '90's," when in at least one locality the local band is reported to have played as part of the celebration which took place at the time the fish were originally introduced.

The total weight of these 13 carp was greater than the total weight of any other species.

BLUNT-NOSED MINNOW, Hyborhynchus notatus. Blunt-nosed minnows were probably not present until introduced in 1933. Observations since that time have failed to indicate that the species was in any degree abundant.

The forage fish which were discarded were not sorted by species and the number of blunt-nosed minnows reported to have been present is based on the assumption that they were relatively as abundant in the forage fish which were discarded as in the random sample which was preserved, also on the assumption that they were equally abundant in the stomachs of the bass and perch which were examined and in those which were discarded.

Of 193 blunt-nosed minnows and darters combined, half (97) were of the former species. Assuming that half of those discarded were blunt-nosed minnows, 484 were found. Almost none were found in the stomachs of the larger fish.

The preserved fish had an average weight of 4.5 grams each and a combined weight of 2,178 grams or 4.9 pounds. The ratio of adults to young in the sample was five to one, a rather unusual ratio since the young would normally be much more abundant than the adults. Possibly not many young were hatched, but it is quite probable that even if considerable young were produced their numbers would have been very decidedly decreased by the many bass and perch present.

Five specimens of minnows other than the blunt-nosed were taken: 2 Nocomis biguttatus, 2 Notropis d. stramineus and 1 Notropis cornutus frontalis. It is assumed that these fish were introduced by anglers or were inadvertantly planted with the blunt-nosed minnows.

COMMON SUNFISH, Eupomotis gibbosus. Adult sunfish were not abundant but were of a relatively large size.

The distribution of the age groups of sunfish was unusual. Only 12 young-of-the-year (0 group) were found. Of these, one was taken from a bass stomach, one was preserved and the other ten were discarded. The lone preserved specimen had a total length of 40 mm. and a weight of 1.1 grams. The fish were of relatively uniform size and the total weight of the young was therefore only about 13 grams or less than a half ounce.

The two-summer-old fish (I group) totaled 733. Of these, 117 were preserved, 9 were taken from the stomachs of the adult bass and 607 were measured in the field and discarded. Average length and weight, based on 116 preserved specimens are: total length 88.3 mm. or 3.5 inches, standard length 70.8 mm. or 2.3 inches and weight 11.3 grams or 0.4 ounces. The smallest specimen in this group had a total length of 70 mm. and the largest had a total length of 108 mm. The total weight of the 733 specimens was about 8,283 grams (18.3 pounds).

The proportion of 12 one-summer-old to 733 two-summer-old sunfish is obviously abnormal. It cannot be proven that the destruction of the spawning beds was responsible for the small number of the former, but it is improbable that the condition is due to any other cause.

Five specimens varying in total length from 110 to 125 mm. were discarded and their age was not determined. They are possibly three-summer-old fish. Their combined weight is estimated at 125 grams or about 4 ounces.

Of the adult legal-sized fish, 25 in number, 14 were discarded and 11 were preserved. Those preserved varied in size from 171 mm. to 190 mm. and in weight from 119 grams to 159 grams. Efforts were made to determine the ages of these adult fish, but the scales could not be read with certainty. They varied in age from 3 summer-old to 5 summer-old fish. These adults had an average standard length of 145.3 mm. (5.7 inches), an average total length of 180.1 mm. (7.09 inches) and an average weight of 51.5 grams (1.8 ounces). The total weight of the adult population was about 3,595 grams (7.9 pounds). Five of the preserved sunfish were females, six were males. The number, average size and weight of the fishes in the several groups are shown in Table 1.

The total sunfish population consisted of 775 specimens weighing approximately 26.5 pounds. The ratio of two-summer-old fish to adults was 29:1. The ratio of one-summer-old sunfish to adults was about 1:2.

Condition (K) was determined for the preserved specimens. The 116 two-summer-old fish had an average condition factor of 3.09; the condition of 11 adults averaged 4.68.

One bluegill and one rock bass were recovered. Neither species was known to have been present, and it is probable that these two specimens were introduced as young with the forage fish planted.

Table 1

Number, average total length, average weight and total weight of common sunfish in the various size groups based on measurements and weights of number of specimens indicated in text.

| Year Group | No. | Ave. Length in Inches | Ave. Wt. Ounces | Total Wt. Pounds |
|---|---|---|---|---|
| 0 | 12 | 1.4 | ... | ... |
| I | 733 | 3.5 | 0.4 | 18.3 |
| Age not determined (probably II) | 25 | 7.1 | 1.8 | 7.9 |
| Adults (II-IV) | 5 | ... | 0.8 | 0.3 |
| Total | 775 | ... | ... | 26.5 |

LARGE-MOUTHED BASS, (Aplites salmoides). Large-mouthed bass were more abundant than any other species and were the chief attraction for the angler. Small-mouthed bass (250 adults) had been stocked about 1930 and reproduced successfully, but by 1934 this species was no longer in evidence and in 1937 it had entirely disappeared. Whether its failure to become established was due to a lack of suitable spawning grounds (gravel had been introduced in 1930, but, with a lowering lake level, was probably not available at suitable depth a few years after it was introduced) or to some other cause could not be determined.

No young-of-the-year bass were removed by the hatchery in 1936 or 1937. Previously bass had been seined each year since 1931 and placed in other lakes in the vicinity.

A study of the young showed that cannibalism was prominent, that certain young had grown very much more rapidly than had the others. Cannibalism in bass has been studied to a considerable extent by Langlois (1936), who also summarizes the literature on the subject, by Cooper (1937), and by others. These studies were invariably made in hatcheries or rearing ponds; investigations of cannibal bass in natural waters have not been made so far as the writer is able to ascertain.

The question naturally arises as to whether or not the fish regarded as cannibals in Howe Lake were really young of the year. No annuli or irregularities which might possibly be construed as annuli were present on the scales. The annuli were readily noted on the older fish and there is no doubt in the writer's mind regarding the age of the fish considered cannibal young-of-the-year. The largest cannibal which was studied was 18 mm. shorter than the smallest fish of the next oldest group (I). No such gap in size appeared, however, between the cannibals and the normal young. A large majority of the latter were between 50 and 60 mm. in total length. There were very few bass between 65 and 70 mm. in length and 70 mm.

was arbitrarily chosen as the dividing line between cannibals and non-cannibals. This figure represented approximately the low point between the two curves.

The fact that there is a wide range in the size of the cannibals suggests that some of these fish may have become cannibalistic earlier than others.

Of the normal young 6,872 were preserved and 11,459 were discarded. From the stomach analysis of the larger bass which were examined, it was determined that 43 had been present in the total number of larger bass. The number of young which were accounted for therefore totaled 18,374, or 1,371 per acre. On the basis of a study of 600 of these fish, taken at random, they had an average standard length of 43.1 mm., a total length of 53.9 mm. (2.1 inches) and an average weight of 0.82 grams and a total weight of 15,067 grams (33.2 pounds).

The fingerling bass regarded as cannibals totaled 229,of which 108 were preserved for study. These bass had an average standard length of 89 mm., an average total length of 108 mm. and an average weight of 17.1 grams. The total weight of the cannibal population (229 individuals) was 3915.9 grams (8.6 pounds). On the average, a single cannibal was equivalent in weight to 21 normal bass of the same age, the largest cannibal examined weighed as much as 49 normal fish. These data indicate that bass are capable of growing attremendously different rates in natural waters as well as in hatchery ponds.

The larger cannibals were in much better condition than the smaller ones. The average K for the 108 specimens was 2.14; for the fish between 70 and 100 mm. long (36 specimens) K was 1.93, for those from 101 to 144 mm. (72 specimens) the average K was 2.23.

Howe Lake contained one cannibal per 80 normal young at the time the fish were collected.

Almost without exception the stomachs of the cannibals were distended and the food was almost entirely fish. In 116 stomachs (including those of 8 fish which were slightly smaller than those recognized as cannibals) a total of 168 fish were found. These included 82 perch, 14 bass, 67 darters, 1 blunt-nosed minnow and 4 unidentified (partly digested) fish. The small fish died sooner than the larger ones after the poisoning and the cannibals had their choice. The small bass tended to be inshore to a greater extent than the young perch, and the cannibals and perch probably more nearly occupied the same habitat at that time of day. The proportion of fish in the stomachs have been different under normal conditions.

To determine what percentage of the adult fish had been cannibals during the first year, measurements were taken of the scales of 27 normal young, 79 cannibal and of the scales from older fish which had been preserved. Key scales were used in all instances.* The scales of the young and cannibals were measured from the center to the edge of the anterior field; those from older fish were measured similarly except that the measurements were taken only to the first annulus. These measurements, magnified 44.3 diameters, are shown in Table 2. The young and cannibals had not yet attained a full year's growth and the radii would have been somewhat larger by the time the first annulus would have formed. A study of Table 2 shows that the older fish (II to V groups) had not been cannibals, or at least had not been very large cannibals during their first year of life. In the I group about half the specimens had become relatively very large during their first year; in the II group only one had a large first year's growth.

---

* These key scales were taken by counting back along the lateral line 10 scales, then downward along the diagonal row for 3 scales, then taking the 3 scales in the horizontal row, going in the direction of the tail.

Table 2

Grouping of large-mouthed bass from Howe Lake according to the length of the radius of key scales (magnification 44.3) to edge of scale for young-of-year and to first annulus in older fish.

| Length of radius (x 44.3) by 3 mm. groups | Age Group | | | | | | |
|---|---|---|---|---|---|---|---|
| | Normal 0 | Cannibal 0 | I | II | III | IV | V |
| 18-20.9 | 4 | ... | ... | ... | ... | ... | ... |
| 21-23.9 | 15 | 1 | ... | 1 | ... | ... | ... |
| 24-26.9 | 8 | 3 | ... | 4 | 2 | ... | ... |
| 27-29.9 | ... | 2 | 1 | 1 | 7 | ... | 1 |
| 30-32.9 | ... | 2 | 3 | 1 | 5 | 1 | 1 |
| 33-35.9 | ... | 4 | ... | ... | 8 | ... | 2 |
| 36-38.9 | ... | 7 | ... | ... | 6 | ... | ... |
| 39-41.9 | ... | 2 | ... | ... | 15 | 1 | ... |
| 42-44.9 | ... | ... | 2 | ... | 5 | ... | ... |
| 45-47.9 | ... | 4 | ... | ... | 4 | ... | ... |
| 48-50.9 | ... | 5 | ... | ... | ... | ... | ... |
| 51-53.9 | ... | 4 | ... | ... | ... | ... | ... |
| 54-56.9 | ... | 7 | ... | ... | ... | ... | ... |
| 57-59.9 | ... | 3 | ... | 1 | ... | ... | ... |
| 60-62.9 | ... | 11 | 1 | ... | ... | ... | ... |
| 63-65.9 | ... | 9 | 1 | ... | ... | ... | ... |
| 66-68.9 | ... | 7 | 1 | ... | ... | ... | ... |
| 69-71.9 | ... | 2 | ... | ... | ... | ... | ... |
| 72-74.9 | ... | 5 | ... | ... | ... | ... | ... |
| 75-77.9 | ... | ... | ... | ... | ... | ... | ... |
| 78-80.9 | ... | 1 | 2 | ... | ... | ... | ... |
| Total | 27 | 79 | 11 | 8 | 52 | 2 | 4 |

The other fish were probably no larger at the end of the first year than the normal young of 1937 would have been by the time the annulus would have formed. Of the legal-sized fish, only one had apparently been a cannibal in its first year of life.

Several explanations might be given regarding the apparent fact that the older fish were not cannibals when young. Perhaps those which had been cannibals were more vigorous and were caught by the anglers or perhaps there was no cannibalism several years prior to the poisoning. Neither explanation seems suitable however. Even with extensive fishing a few of the more voracious bass should have survived the angler and, since food had not been abundant for some few years at least, cannibalism was probably common each year.

A possible explanation which is supported to a considerable extent by the literature is the apparent relationship between growth and mortality. Schneberger (1935) found that some young perch had a very large first year's growth, but that this condition was not noted in the older perch. Eschmeyer (1936) made the same observation for this species. In connection with the discussion of the possible causes of Lee's phenomenon in a cisco population, Hile (1936) quotes the literature as follows:

> "The relation between individual growth rate and individual length of life has been studied experimentally by several investigators. Osborne et al (1917) found that a temporary preliminary stunting delayed maturity and extended the life span of rats. Titcomb et al. (1928) and McCay et al. (1931) found that trout that did not grow lived longer than those which showed growth on a similar diet. Zabinski (1929) by effecting a retardation of growth was able to prolong life in the black beetle and the roach. McCay (1933) presented a brief discussion of the general problem of the relationship of rate of growth to longevity."

It is possible that these fast-growing individuals have an early mortality. The problem is an important one in fish culture, although little mention seems to be made of it in connection with the selection of

brood stock or on the question of feeding. In those fish which require several years to reach a catchable size, the selection of brood stock from the fastest growing fish and the general tendency to obtain rapid growth in hatchery fish might be unwise. It is possible that such fish die from natural causes before reaching a suitable size.

Eighty-seven fish which were older than the young-of-the-year were examined in the laboratory. Information on the age, length, weight and condition is given in Table 3. In addition to these 87 fish, 69 were discarded after measurements were taken. These 69 were placed into the age groups on the basis of length and, because of an over-lap in size of different age groups, a few may have been placed in the wrong group. If they were properly grouped, the number of each age was as follows:

| Age Group | No. of Specimens |
|---|---|
| I | 25 |
| II | 10 |
| III | 105 |
| IV | 7 |
| V and older | 9 |
| Total | 156 |

Table 3

Average length, weight and condition of large-mouthed bass from Howe Lake for different age groups.

| Item | Age Group 0 | I | II | III | IV | V |
|---|---|---|---|---|---|---|
| No. of specimens | 18,603 | 13 | 9 | 58 | 2 | 4 |
| Ave. standard length (mm.) | 43.1 | 174.9 | 216.1 | 242.2 | 265.8 | 322.0 |
| Ave. total length (mm) | 53.9 | 210.5 | 258.7 | 290.9 | 320.5 | 385.8 |
| Ave. total length (in.) | 2.1 | 8.3 | 10.2 | 11.5 | 12.6 | 15.2 |
| Ave. weight (grams) | 0.8 | 123.1 | 234.5 | 338.4 | 442.3 | 802.7 |
| Ave. weight (pounds) | ... | .27 | .52 | .75 | .98 | 1.77 |
| Ave. K | ... | 2.24 | 2.30 | 2.38 | 2.28 | 2.40 |

Except for the 0 group, which had not yet attained a full year's growth, the fish compare favorably in growth with those from other waters, including more southern lakes where growth might be expected to be more rapid. The specimens from Wintergreen Lake and Watkins Lake (see Table 4) were from relatively rich southern Michigan lakes, but the fish in these grew no faster, in general, than those from Howe Lake. Bennett's extensive data indicate that fish in 12 northern Wisconsin waters grew in general at about the same rate as those from Howe Lake, growing more rapidly in some years and more slowly in others. The southern Wisconsin fish grew more rapidly than did the Howe Lake fish. Considering the latitutde, the Howe Lake fish may be considered to have grown at a moderately rapid rate.

Table 4

Comparison of the growth of large-mouthed bass in Howe Lake and in other waters.

Total length in inches.

| Lake | Date of Capture | Age 0 | I | II | III | IV | V |
|---|---|---|---|---|---|---|---|
| Howe | Sept. 7 | 2.1 | 8.3 | 10.2 | 11.5 | 12.6 | 15.2 |
| Wintergreen[1] | Winter--various dates | 4.0 | 8.7 | 11.3 | 11.7 | 12.0 | 12.7 |
| Watkins[2] | Sept. 29 | 3.1 | ... | 9.5 | 10.7 | ... | 13.6 |
| Average for 12 lakes in northern Wis.[3] | Calculated for full growing season | 2.8 | 6.5 | 9.7 | 11.7 | 13.2 | 13.9 |
| Average for 4 lakes and 1 river in southern Wis. | " | 3.7 | 8.7 | 11.9 | 13.7 | 14.9 | 16.2 |

[1] Determined by G. P. Cooper (unpublished), Kalamazoo County, Michigan.

[2] " " Cooper and Eschmeyer (unpublished), Jackson County, Michigan.

[3] " " Bennett (1937), calculated lengths for the full growing season.

The unusual distribution of fish in the age groups cannot be explained on the basis of removal of young by the hatchery, since the figures below show no correlation. The number of fish removed each year for a four year period and the number of fish in the remaining population for each year are:

| Age Group | Year Born | No. of Young Removed | No. of Fish Present Which Were Born in The Year Stated in Column 1 |
|---|---|---|---|
| I | 1936 | None | 25 |
| II | 1935 | 27,000 | 10 |
| III | 1934 | 21,000 | 105 |
| IV | 1933 | 16,000 | 7 |

One change was made which might well explain the abundance of fish in the group born in 1934 (III group): Gravel was introduced in the summer of 1933, as mentioned above, and was first available for spawning in 1934. The large number from that year group which survived may have reduced the fish born subsequently because of the greater demand for food. The distribution of fish in the age groups suggests (though it does not conclusively prove) that the gravel may have been decidedly effective in increasing the number of bass. The number of young obtained each year by the hatchery is not an index of the abundance of young present in the lake because of the difference in seining intensity during the several years.

The total weight of the bass population was approximately 155½ pounds. These figures are based on the assumption that the fish which were discarded were similar to the average weight of fish of the same age which were examined. Weights of the different age groups were as follows:

| Age Group | Number | Total Weight |
|---|---|---|
| 0 | 18374 | 33.2 lbs. |
| 0 (cannibals) | 229 | 8.6 " |
| I | 25 | 6.8 " |
| II | 10 | 5.2 " |
| III | 105 | 78.8 " |
| IV | 7 | 6.9 " |
| V and older | 9 | 15.9 " |
| Total | 18,669 | 155.4 lbs. |
| Weight, per acre | | 11.6 lbs. |

None of the I group had attained a legal length of 10 inches, but in the II group all except 3 were of legal length. The total number of legal-sized fish was therefore 128 or about $9\frac{1}{2}$ per acre. The 0 group included 18,603 specimens, including the cannibals, and the ratio of legal-sized bass to young-of-the-year bass was therefore 1:145. If the population was uniform for several years, the data could be construed to indicate that one adult might be expected for each 145 young (2.1 inches long) present. A considerable number of adults had been removed during the summer by anglers, but in that same period many young-of-the-year also were eaten by the other fish and by some of their own group. The ratio of game fish to forage fish was 20:1 at the time of the poisoning, and, since other food appeared to be scarce, the young game fish were very probably the chief source of food for the larger fish. The ratio of legal-sized fish to young may therefore be much lower than in lakes where forage fish are more abundant or where food in general is more common. The ratio might possibly be more nearly normal for lakes in general if the number of young were multiplied by 2 or 3.

It is interesting, in this connection, to speculate on the number of 2.1 inch bass which would need to be stocked in Michigan lakes to increase the number of catchable bass by one fish per acre, assuming that the ratio of young to legal-sized fish in Howe Lake applied to lakes in general (such assumption is of course mere speculation). To determine the approximate

total area of our inland lakes, the writer totaled areas for all lakes as listed in the Michigan Lakes and Streams Directory (Henshaw, 1931) and, since not all lakes are included, assumed this area to be 90 per cent of the total area. The area of the lakes, computed by the above method, is about 830,000 acres. This figure is, of course, only a rough approximation. On the basis of these figures, it would be necessary to stock a total of about 120 million 2.1 inch bass to increase the legal-sized bass in Michigan by one per acre if we ignore the important matter of fish concentration and assume that the lakes are not already stocked to capacity. However rough these approximations may be, it appears obvious that almost all of the bass taken by anglers result from natural reproduction. In 1936, a total of 888,500 bass (large-mouthed and small-mouthed combined)were stocked. Most of them were 4 to 5 months old when stocked. Size was not recorded.

Scott (1920) states that "It has been estimated that lakes constitute about one-fiftieth of the total area of the state." Estimated on this basis, the area of the lakes is about 736,000 rather than 830,000. If the area of the lakes is considered 736,000 acres, the number of 2.1 inch bass needed to increase the adults later by one bass per acre would be about 105,000,000.

It is possible that if no bass were stocked, the effect on fishing over the state as a whole would be negligible. The reaction of the anglers to such action, however, would certainly be far from negligible.

PERCH, Perca flavescens. Perch were probably more abundant than bass in Howe Lake until within the last few years. Those perch casually examined in 1933 were apparently stunted in growth. Adult perch were very few at the time of the poisoning.

The total number of young (0 group) was 2,678, including 528 preserved specimens, 1,934 discarded fish, 200 in bass stomachs and 16 in the stomachs of larger perch. The latter two figures are based on the assumption that the number of small perch in 195 bass and 41 larger perch were representative.

Two hundred specimens taken at random from the preserved lot had an average standard length of 47.3 mm. and an average total length of 57.2 mm. (2.3 inches). Fifty females had an average total length of 58.3 mm. and 50 males had an average total length of 56.2 mm. The females were growing more rapidly than the males even during the first season. The two sexes were about evenly divided; of 108 individuals taken at random, 57 were females and 51 were males.

The 200 specimens had a weight of 319 grams. The entire lot of young-of-the-year perch (2,678 fish) therefore weighed about 4,218 grams (9.3 pounds). The ratio of young-of-the-year bass to young-of-the-year perch was approximately 7:1 (18,374:2,678).

An examination of the stomachs of the larger fish suggests why the perch may be on the decline as the number of bass increase. As previously indicated, the young fish tended to die first and the larger fish were able to take their choice of the smaller ones. So far as could be determined, both young bass and young perch died at about the same time. If they took fish indiscriminately, the stomachs should have contained seven young bass per young perch because the fish were present in that ratio. Actually, the ratio of bass to perch, in the stomachs of larger fish was 1:4 (27:106). Cannibal bass, adult bass and perch all showed a preference for young perch, with cannibal bass decidedly the most destructive to these young-of-the-year. The young bass and young perch were of about the same length but, naturally, were shaped quite differently. The difference in the shape of the fish was probably a chief factor in the consumption of fish of the two species and, as mentioned above, their location in the lake also may have been influential. The figures on relative abundant of fish in the stomachs are given in Table 5.

Table 5

Number of perch and bass (0 group) present in the stomachs of other fish, per 100 stomachs.

| Predator | Prey | No. per 100 Stomachs | Prey | No. per 100 Stomachs |
|---|---|---|---|---|
| Bass, cannibal | Bass | 12 | Perch | 71 |
| Bass, adult | Bass | 10 | Perch | 23 |
| Perch | Bass | 5 | Perch | 12 |

Young perch were perhaps the chief food item of the older bass and perch at the time the lake was poisoned.

Forty-three two-summer-old perch were preserved and 88 were discarded. In a sample of 41 of these fish, 15 were females and 26 were males. The females averaged 92.4 mm. standard length, 109.7 mm. total length, 12.2 grams in weight and had an average K of 1.47; for males these figures were, respectively: 77.8, 93.5, 6.7 and 1.40. The fish had a total weight of approximately 1,140 grams or 2.5 pounds.

Of the perch older than two summers, 5 were preserved and 12 were discarded. The discarded fish were measured but sex determinations were not made. Because of the difference in growth of the two sexes, it could not be determined from the measurements whether these fish were females of a certain age or males a year older. The five preserved specimens included three age groups. All had attained the legal length of six inches. The combined weight of the 17 specimens was about 822 grams or 1.8 pounds.

The difference in the growth of the two sexes of perch has been noted by a number of authors.

The total number and weight of perch taken was:

| Age Group | No. | Total Weight |
|---|---|---|
| 0 | 2,678 | 9.3 lbs. |
| I | 131 | 2.5 " |
| Adults | 17 | 1.8 " |
| Total | 2,826 | 13.6 lbs. |

Perch represented only one pound of fish per acre.

The ratio of young to two-summer-old perch to adults was about 158:8:1. On the same basis as the determinations for bass, it would require 115,000,000 to 130,000,000 perch 2.3 inches long to increase the number legal-sized perch in Michigan lakes by one fish per acre.

The ratio suggests that there is still a heavy mortality between the first and second summers, but that the chances of survival after the second summer are good. If the conditions were similar in 1936 and 1937, a two-summer-old perch was equivalent to 20 one-summer-old fish so far as survival is concerned.

DARTERS, Boleosoma nigrum and Poecilichthys exilis. Two species of darters were present but were not differentiated in the fish which were discarded. A sample of 96 specimens contained 92 Johnny darters and 4 Iowa darters. Most of the specimens were therefore of the former species. If half the discarded "minnows" were darters, a total of 385 were discarded. If the stomach content of the bass and perch discarded were similar to those of the bass and perch examined, 253 were present in the stomachs. The total population was therefore estimated as 634 individuals. This figure is less reliable than the data for other species, since the darters tended to remain on the bottom even several days after the poisoning. The population if estimated as 634 individuals and if similar in weight to the 96 preserved specimens had a total weight of 588 grams or 1.3 pounds.

Entire population.

Data on the number and weight of fish of each species and of all species combined are shown in Table 6. The lake contained about 23,508 individuals having a total weight of about 510½ pounds or a per acre weight of 38 pounds.

Table 6

Number and weight of the Howe Lake fish, by species.

| Species | Number | Weight in Pounds | |
|---|---|---|---|
| | | Entire Lake | Per Acre |
| Common sucker | 37 | 96.7 | 7.2 |
| Carp | 13 | 211.0 | 15.7 |
| Blunt-nosed minnow | 484 | 4.9 | 0.4 |
| Common sunfish | 755 | 26.5 | 2.0 |
| Large-mouthed bass | 18,759 | 155.4 | 11.6 |
| Perch | 2,826 | 13.6 | 1.0 |
| Darters | 634 | 1.3 | 0.1 |
| Totals | 23,508 | 510.3 | 38.1 |

Carp were the poorest represented in numbers but ranked first in weight. Carp and suckers, both almost valueless for angling and of no value as food for the other fish, comprised almost two-thirds of the population on a weight basis. Both species, however, were due to become extinct and it is probable that some years later the poundage of fish present would have been much reduced with little or no injury to the fishing.

The ratio of game fish to forage fish was 20:1 and young game fish probably constituted the chief food supply of the adult game fish.

## SUMMARY AND DISCUSSION

In the several phases of fish management, the study of Howe Lake and especially the examination of the Howe Lake fishes yields the following information, much of which is suggested rather than proven by this study of a single lake:

Lake improvement. The introduction of gravel for bass spawning seems to have decidedly influenced the production of bass. To what extent the brush-shelters may have been responsible for the apparent increase in bass was not determined. Planting of aquatic vegetation was relatively unsuccessful, perhaps because of the lack of proper nutrients. Destruction of the nests (and eggs) of sunfish probably was responsible for the almost complete absence of young-of-the-year sunfish in the population. The method might prove practicable in other waters to reduce the number of nest-building fish where these are undesirable or over-abundant. Introduction of forage fish (blunt-nosed minnows) was successful, although they were few in number, and the slabs which were installed for the spawning of these forage fish served the purpose for which they were intended.

Stocking. Small-mouthed bass (adults) were introduced and spawned successfully, but failed to become permanently established. Unfavorable spawning conditions for this species, after a decline in water level preventing their use of gravel beds, may have been responsible for their failure. Brook silversides (skipjacks) were stocked but did not become established. Carp were present for many years, but apparently were becoming extinct for no young were present. Suckers were planted, but no young were found. The introduction of these several species was only partially successful.

The removal of relatively large numbers of young bass seems not to have decidedly influenced the number of fish of the same age groups which became adults.

The adults apparently did not start life as large cannibals. It is possible that very fast-growing fish have an early mortality and that for species which require several years to reach a catchable size, the selection of brood stock from the fastest growers may not be desirable and exceptionally rapid growth of these fish in hatcheries and rearing ponds may likewise not prove to be preferable.

Cannibal bass were present in Howe Lake. At the time of the poisoning (September 7), the ratio of cannibals to non-cannibals was 1:80. The largest cannibal had 49 times the weight of the average fish of the same age, indicating that the difference in growth of two fish of the same species and same age, and in the same water, may vary decidedly with difference in food habits.

The ratio of young-of-the-year bass to legal-sized bass (10 inches or larger) was 145:1; the ratio for perch (legal size 6 inches or larger) was 158:1. If these ratios apply for all lakes in the state, about 120,000,000 2.1-inch bass and about 130,000,000 2.3-inch perch would need to be stocked to increase the abundance of adult fish of each species by one fish per acre in the waters of the state. There is a possibility that

fishing for these two species over the state as a whole is not influenced appreciably by our stocking.

If adult suckers, introduced as brood stock, are taken from a spawning "run" they need to be carefully selected for sex, because of the abnormal sex ratio of adult suckers at certain times on the spawning grounds.

## Angling

Had the poisoning on the Howe Lake fishes been anticipated, an intensive creel census would probably have been maintained on this lake during the summer. No estimate of the number of fish which were caught can be made. Mr. Petersen indicates that Howe Lake was fished heavily for several years during the early part of the season but that in the middle of the fishing season, and later, few are caught. Mr. Petersen made inquiry of some of the anglers and learned that one party took 27 bass, 2 perch and 6 sunfish in 12 trips to the lake. The writer caught 4 perch and 4 sunfish in 3 attempts. The lake survey party noted, on a Sunday late in the summer, that of approximately 25 anglers, only one had caught a bass. The survey party took no fish in experimental gill nets placed in this lake for two days. The meager information suggests that over half of the fish may have been removed by angling. This is in decided contrast with the removal of fish in several southern Michigan lakes, where it is estimated (Hazzard and Eschmeyer 1938) that less than 8 per cent of the available fish were removed by angling.

After all the fishing on Howe Lake, over 9 adult bass per acre remained. This number is probably ample for brood stock. It seems improbable that fishing by ordinary means will reduce the number of fish to a point where an inadequate brood stock remains. Before that point is reached, the catch probably becomes so low that angling is discouraged.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. David Chandler, Walter Crowe, E. L. Cheatum, Hans Petersen and his assistants in the Grayling Hatchery and Conservation Officer Harry Souders for assistance in poisoning the lake and in collecting the specimens, and Dorothy Woodbury, Myrtle Moffett and O. H. Clark for help in the laboratory.

LITERATURE CITED

COOPER, GERALD P. 1937. Food habits, rate of growth and cannibalism of young largemouth bass (Aplites salmoides) in state-operated rearing ponds in Michigan during 1935. Trans. American Fisheries Society, Vol. 66, pp. 242-266.

ESCHMEYER, R. WM. 1937. Some characteristics of a population of stunted perch. Papers Mich. Acad. Sci., Arts and Letters, Vol. XXII, pp. 613-628.

_____ 1938. Further studies of perch populations. Papers Mich. Acad. Sci., Arts and Letters. In press.

HAZZARD, ALBERT S. and ESCHMEYER, R. WM. 1938. Analysis of the fish catch for one year in the Waterloo project area. Papers, Mich. Acad. Sci., Arts and Letters. In press.

HENSHAW, FRED W. 1931. Michigan lakes and streams directory. Magazine of Michigan Co. 115 pages.

HILE, RALPH 1936 Age and growth of the cisco Leucichthys artedi (Le Sueur) in the lakes of the northeastern highlands, Wisconsin. U. S. Bureau of Fisheries, Bull. No. 19, pp. 211-317.

LANGLOIS, T. H. 1936. A study of the small-mouth bass, Micropterus dolomieu (Lacepede) in rearing ponds in Ohio. Ohio Biological Survey, Bulletin 33, Vol. VI, No. 4, pp. 191-225.

REIGHARD, JACOB 1920. The breeding behavior of the suckers and minnows. I: The suckers. Biol. Bull. Vol. XXXVIII, No. 1. January.

SCHNEBERGER, EDWARD 1935. Growth of the yellow perch (Perca flavescens Mitchill) in Nebish, Silver and Weber Lakes, Vilas County, Wisconsin. Wis. Acad. Sci., Arts and Letters, Vol. 29, pp. 103-130.

SCOTT, I. D. 1921. Inland lakes of Michigan. Mich. Geol. and Biol. Survey. Pub. 30, Geol. Series 25, pp. i-xxi, 1-383.

INSTITUTE FOR FISHERIES RESEARCH

By R. W. Eschmeyer
Assistant Aquatic Biologist