

Prepared for presentation at
Mich. Academy of Science, Arts and Letters
March 17-19, 1938

Original copy: Mich. Acad.
cc: Fish Division
Dr. Eschmeyer
Mr. Rühl

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REPORT NO. 457

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

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 catchable size. Three of these populations have been discussed by the writer (Eschmeyer, 1937, 1938); studies on several others have not yet been completed.

Howe Lake, contrary to the lakes described previously, had a population of fish which were growing at a reasonable rate, were attaining a relatively large size, and were the object of considerable fishing. 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 to be

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

restocked later, but who may be expected to protest if a good fishing lake is to be cleaned out. Removal of the fish from Howe Lake seemed to the sportsmen to be justified because of the presence of carp. It is improbable that many such 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.

Description of 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 highway M 76. The lake is on state-owned land and has no resort development. The surrounding country is a sandy, level, jackpine plain, low in fertility and unsuited to agriculture.

A survey of Howe Lake was made in the summer of 1937 by an Institute lake survey party, consisting of Dr. David Chandler, Walter Crowe and E. L. Cheatum. According to their observations, 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 Peterson, District Supervisor of Fisheries Operations, it is now about four feet below the level of ten years ago. Howe Lake has a maximum depth of 24 feet and the basin is regular in form.

At the time of the examination in early August, the water was unstratified. Temperatures were 76° F. at the surface, and 72° F. at a depth of 21 feet. The colorless and moderately clear water gave a Secchi Disc reading of 12.5 feet. It was quite alkaline (pH 8.1). The methyl orange alkalinity (51) was decidedly lower

than that of most alkaline lakes which have been previously examined by the Institute. The dissolved oxygen, which ranged from 8.3 ppm. at the surface to 6.0 ppm. at a depth of 21 feet, was adequate to support fish life at all depths.

Howe Lake is almost completely devoid of vegetation. A few stunted yellow pond-lilies, a limited amount of Chara (sp.) and a small bed of pond weed (Potamogeton sp.) apparently comprise all of the larger aquatics present. Several of these forms have been introduced. Fish food, too, is scarce. A plankton net with 10.5 centimeter diameter at the mouth yielded only 0.4 cc. of plankton in a vertical 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.

History of Fish Management on Howe Lake

Much of the early history of fish management on Howe Lake is not known to the writer, but for recent years the information is probably complete. A number of species of fish have been introduced and a variety of environmental adjustments have been made. Carp (Cyprinus carpio) have been present for many years. According to reports, they were first planted in Crawford County in the period from 1888 to 1892 and they were possibly introduced in Howe Lake at that time. Attempts were made by the Grayling Fish Hatchery to use the lake to raise fish for stocking in other waters, hence ^{several hundred} ~~250~~ adult ~~small-mouthed~~ bass (Micropterus dolomieu) were introduced in ^{about} ~~1930~~ ¹⁹²⁶ as brood stock. The attempt met with indifferent success and was abandoned in 1935. In 1933 about 4,500 blunt-nosed minnows

(Hyborhynchus notatus) were introduced, and 20,000 more were planted the next year. The stocking included also 3,000 brook silversides (Labidesthes sicculus) in 1934 and 75 adult common suckers (Catostomus c. commersonii) in 1935.

Apparently none of the five species mentioned above was native to the lake. As will be noted later, the small-mouthed bass and brook silversides were already exterminated by 1937; carp and suckers seemed to be definitely approaching extinction and the fifth species, the blunt-nosed minnow, was not especially well represented in the population. One bluegill (Helioperca macrochira) and one rock bass (Ambloplites rupestris) were found. These two specimens were probably introduced as young with one of the plantings of forage fish. Their chances of becoming established were obviously nil.

The original population probably consisted of large-mouthed bass, common sunfish, perch and darters.

Environmental "improvements" included the introduction of pond-lilies and Chara, fertilization with stable manure, ^{the} installation of brush shelters for the protection of the young fish, and of slabs for use by spawning minnows, and the provision of gravel for spawning beds. Attempts to increase the vegetation were relatively unsuccessful. The value of the fertilizing was not ascertained. The slabs were used by the minnows in spawning. The shelters and gravel apparently influenced the fish population very decidedly, as will be noted later.

The fish removed from Howe Lake for stocking in other waters, according to the Grayling Hatchery records, were all bass fingerlings (both species) and included the following numbers: 1931: 17,000; 1932: 27,000; 1933: 16,000; 1934: 21,000; 1935: 27,000.

Fishing was prohibited for the period from 1930 to 1933.

Methods

On September 7, 1937, the fish in Howe Lake were killed with powdered derris root. About 186 pounds (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 successfully in other waters to annihilate all fishes and since no live fish were in evidence later.

The introduction of the poison and the collecting of fish were carried out with the assistance of the survey party which had examined the lake earlier in the summer, and of employees from the Grayling Hatchery, and Conservation Officer Harry 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 specimens 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 fish were seen after the 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.

Unless otherwise indicated, the ensuing discussions concern only the fishes poisoned in 1937. The fish for laboratory examinations were preserved in formalin and were later transferred to

alcohol. Measurements were made after preservation except on those fish which were discarded immediately after they were collected.

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 of the Howe Lake fish had apparently been consumed a very short time before the larger ones died because there was little or no digestion of these smaller individuals. Fish taken from the stomachs of the larger specimens are therefore invariably included in the totals.

Measurements of standard and total length were made in millimeters and the fish were weighed to the nearest gram on a Welch balance except for the carp which were measured in inches and weighed in pounds. Weights are generally expressed in both grams and pounds, and lengths in both millimeters and inches; in some tables, however, weights are expressed only in pounds and, for some very small fish, weights of individuals are indicated only in grams. In work on the rate of growth of fishes, the metric system of measurement has almost invariably been used; in fish production studies the data are generally expressed (in America) in pounds per acre. An effort has been made, in this discussion, to express measurements in the most usable form, hence the apparent inconsistencies.

Since the fish were taken in early September, they were probably actually older in terms of growth than is indicated; fish of the I group (1 annulus), for example, had completed the greater portion of their second growing season.

The Fish Population

The entire fish population is calculated to have been 23,508 individuals at the time of the poisoning. These fish had a total weight of about 510 pounds, representing approximately 38 pounds per acre. Data on the number and weight of fish of each species and of all species combined are shown in Table 1.

Table 1

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 because of their large size, comprised almost two-thirds of the population on a weight basis. Both species, however, would have 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. Large-mouthed

bass ranked first in abundance and were undoubtedly the most valuable of the several species which were present in the lake.

Each species is discussed separately below.

COMMON SUCKER, Catostomus c. commersonii. A total of 37 suckers, or half the number reported to have been planted in 1935, was collected. Because of their large size, it is improbable that any were overlooked. Eighteen fish taken at random measured 481 mm. (18.9 inches) and weighed 1185 grams (41.8 ounces). The 37 suckers therefore weighed approximately 96.7 pounds. Since the smallest fish had a length of 15.5 inches, all of the suckers were probably from the single planting.

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 produced during the two spawning seasons had been eaten by the time of the poisoning, because no small suckers were found. If the fish had reproduced successfully, a few probably would have survived, even in a lake where food was scarce and where predatory bass were relatively abundant. Their apparent failure to reproduce may be explained partially as follows:

Suckers generally prefer to spawn in streams but also reproduce successfully in many land-locked lakes. Perhaps spawning conditions were unfavorable in Howe Lake. Or, the failure in reproduction may have been partially due to an abnormal sex ratio. Reighard (1920) stated 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. Peterson states that females were definitely included since eggs were flowing freely from some of the fish. 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 this sex.

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 removed in recent years.

Thirteen large carp were collected after the poisoning. Nine of these had an average length of 33 inches and ten had an average weight of 16.1 pounds. The 13 fish had a combined weight of 211 pounds. 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, 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 is 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 total weight of these 13 carp was greater than the total weight of fish of any other species.

BLUNT-NOSED MINNOW, Hyborhynchus notatus, AND OTHER MINNOWS.
Blunt-nosed minnows were probably not present until they were 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 present. Very few 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 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: two Nocomis biguttatus, two Notropis d. stramineus, and one Notropis cornutus frontalis. It is assumed that these fish were introduced by anglers or were inadvertently 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 I group was represented by 733 individuals. 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 2.8 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 but is easily explained. During the spawning season of this fish in 1937, it was decided to destroy the nests. The eggs had been laid but few if any had hatched. The method used in destroying the beds 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. Possibly not every nest was destroyed, or, perhaps, the eggs of a few may have hatched before this activity.

It cannot be proven that the destruction of the spawning beds was responsible for the small number of young, but it is improbable that the condition is due to any other cause. The method may prove entirely practicable as a means of reducing the numbers of fish of those species which nest in clear, shallow waters, where they have become over-abundant or where they are undesirable. The destruction of the beds in Howe Lake would have been done more carefully had the poisoning been anticipated.

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 which were 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, although the fish were apparently from 3 to 5 years old. 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 7.9 pounds. Five of the preserved sunfish were females, six were ~~males~~ males. The number, average size and weight of the fishes in the several groups are shown in Table 2.

Table 2

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

Age Group	Number	Average Length in Inches	Average Weight in Ounces	Total Weight in Pounds
0	12	1.4	...	...
I	733	3.5	0.4	18.3
Age not determined (probably II)	5	...	0.8	0.3
Adults (II-IV)	25	7.1	1.8	7.9
Total	775	...	...	26.5

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; for one-summer-old sunfish to adults the ratio was about 1:2.

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

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

* For formula see my earlier paper (1937).

stocked in 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 a desirable 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.

Calculations indicate a presence of 18,669 bass having a total weight of about 155 pounds. These figures are based on the assumption that the fish which were discarded had the same average weight as those of the same age which were examined. Numbers and weights of bass of different age groups are given in Table 3.

Table 3
Number and Weight of Large-mouthed Bass
in Howe Lake, by Age Groups

Age Group	Number	Total Weight
0	18,374	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.

A study of the young showed that cannibalism was prominent, that certain of them 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 in the bimodal curve.

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

* These fish might better be referred to as piscivorous fish or as fast-growing fish. They undoubtedly included fish other than bass in their diet and a few may have been subsisting entirely on food other than bass. Since the term "cannibal" is generally applied to these fish, it is also used here.

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 a total of 43 bass of the O group were present in these larger fish. 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., an average total length of 53.9 mm. (2.1 inches), and an average weight of 0.82 grams. The entire lot weighed 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 at tremendously different rates in natural waters as well as in hatchery ponds.

The larger cannibals were in much better condition than were the smaller ones. The average K for the 108 specimens which were examined 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 consisted almost entirely of 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 consisted of 82 perch, 14 bass, 67 darters, 1 blunt-nosed minnow and 4 unidentified (partly digested) fish.

To determine what percentage of the adult fish had been cannibals during the first year, measurements were taken of scales from 27 normal young, 79 cannibals, and 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 4. The young and cannibals had not yet attained a full year's growth and the zones would have been somewhat longer by the time the first annulus would have formed. Normal growth during the first season was probably somewhat greater in earlier years (before 1936) because a considerable percentage of young were removed in those years by the Crayling Hatchery, leaving more food, presumably, for the remaining young. A study of Table 2 shows that the older fish (II to V groups) had not attained an exceptionally large size 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. Of the legal-sized fish, only one had apparently attained an exceptionally large size in its first year of life.

Table 4

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

Several explanations might be given regarding the apparent fact that the older fish did not grow rapidly 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 question of hatchery feeding. In those fish which require several years to reach a catchable size, the general tendency to obtain rapid growth in hatchery fish might be unwise. It is possible that in our northern waters such fish die from natural causes before reaching a catchable 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 5. 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. The number in each age group is shown in Table 6.

Table 5
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)	...	0.27	0.52	0.75	0.98	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 6) 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 latitude, the Howe Lake fish may be considered to have grown at a moderately rapid rate.

Table 6
 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	September 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	September 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	" " "	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 from a four year period and the number of fish in the remaining population for each year are shown in Table 7.

Table 7

Number of Fish in Each Age Group and
Number Removed, as Fingerlings, From Each Group

Age Group	Number of Fish in Age Group	Year Born	Number of Young Removed Each Year
I	25	1936	None
II	10	1935	27,000
III	105	1934	21,000
IV	7	1933	16,000

One change was made in the environment which might well explain the abundance of fish in the group born in 1934 (III group): Gravel was introduced in the summer of 1933 and the number of young bass in 1934 may have been much greater than usual because of these improved spawning conditions. The large number which survived from that spawning may have greatly reduced the number of fish born during the next several seasons by consuming a large percentage of these fish. 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.

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 O 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 had been uniform for several years, the data could be construed to indicate that one adult might be expected to result from 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. There are no data with which to compare these figures and no statement can be made regarding their being representative for bass in general.

PERCH, Perca flavescens. Perch were second in abundance, but constituted only a very small percentage of the total pounds of fish present.

The 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 was representative.

Two hundred specimens taken at random from the preserved lot (0 group) 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).

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.

Differences in the rate of growth of the two sexes of perch has been noted by Schneberger (1935) and others.

The entire perch population totaled 2,826 fish, weighing 13.6 pounds. This number includes 2,678 young of the year, weighing 9.3 pounds, 131 two-summer-old fish weighing 2.5 pounds, and 17 adults weighing 1.8 pounds.

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.

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 contents 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 estimated population, if similar in weight to the 96 preserved specimens, had a total weight of 588 grams or 1.3 pounds.

Trend of the Population

Within a period of four years the relative abundance of perch and bass changed very decidedly. Frequent examinations (observations and fishing) by the writer in 1933 suggested that perch were abundant and that bass were relatively few. The perch were slender and had abnormally large heads, and were obviously stunted in growth. At the time of the poisoning in 1937 perch were decidedly fewer than bass, the ratio being about 1:7 and apparently were in better condition than were the perch a few years previously.

The change in population is attributed to environmental "improvements," i.e. providing gravel for bass spawning and the installation of brush shelters which, according to limited investigation, are frequented more by bass than by perch. It seems probable that the bass

increased as a result of these improvements and that they reduced the number of perch.

An examination of the stomachs of the larger fish suggests why the perch may have declined as the number of bass increased. When rotenone is used the young fish tend to die first and the larger fish are 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 their location in the lake also may have been influential. The figures on relative abundance of fish in the stomachs are given in Table 8.

Table 8
Number of Perch and Bass (0 Group) Present in
The Stomachs of Other Fish, Per 100 Stomachs

Predator	Prey	Number Per 100 Stomachs	Prey	Number 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.

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. Peterson 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 were caught. Mr. Peterson 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. This survey party took no fish in experimental gill nets placed in the 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, Dorothy Woodbury, Myrtle Moffett and O. H. Clark for help in the laboratory, and Dr. A. S. Hazzard and Dr. Ralph Hile for valuable suggestions in the preparation of the manuscript.

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