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THE SIGNIFICANCE OF FISH POPULATION STUDIES IN LAKE MANAGEMENT*

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As we gradually change our concepts in fish management to correspond with those of agriculture, the need for certain phases of investigation becomes more evident. The former notion that a planting of fish, together with certain legal restrictions, could be expected to assure good angling has been found erroneous, and those management methods which have been adhered to for many decades now are recognized as highly inadequate.

The past methods in fish management are comparable with a farmer's placing calves in a pasture without regard for the capacity of the area, the number of cattle already present or the number annually removed; or with planting trees without regard for the stand already present, the natural reproduction or the annual removal. Fish management today occupies the same status that agriculture had in the Dark Ages. With ever increasing demands on our fishing waters, changes in our fish management procedure are obviously necessary. A more rational fish management program will be slow in taking form so long as anglers continue to have the deep rooted conviction that stocking by present methods is the answer to our fishing ills. The use of almost all available funds for a continual

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expansion of our fish rearing program rather than for inquiry into this and other methods of fish management is not justified until it has been definitely ascertained that public funds so used are well spent. Increasing the dosage of a medicine will not necessarily cure an ailment, especially if the general effectiveness of that medicine has not been thoroughly tested.

We are beginning to recognize that intelligent fish management requires a knowledge of the annual catch and of the standing crop. In Michigan, the sampling of the fishing by Conservation Officers for ten years, and the intensive creel census taken in recent years by the CCC and other agencies, have given a fair picture of the take in various parts of the state and have provided some data on the trend of the catch.

The "standing crop," too, is receiving some consideration. In recent years efforts have been made to learn more about the fish populations in lakes or streams in Illinois, Michigan, New Hampshire, Nova Scotia and elsewhere. The work by Thompson in Illinois has been outstanding. These studies are only a beginning, but already they have yielded considerable information of value to fish management.

This general discussion is intended to show the kind of information obtained by one method of examining the standing crop. Methods which have been employed to obtain the po ulations for study are not generally applicable or desirable in lakes which support an appreciable amount of fishing. This paper is confined only to population studies made in Michigan lakes. More detailed accounts of several of the studies have been published (Eschmeyer, 1937, 1938); for the other lakes data are now being prepared for publication. Many of the details are therefore omitted; methods employed in determining the number of fish per acre, pounds of fish per acre, growth, etc. are found elsewhere as are verifications for some of the statements made in this discussion.

To date the fish in six lakes have been studied after removal by poisoning. All of the lakes from which the fish were removed have also been examined by survey parties of the Institute for Fisheries Research. All six are located in the northern portion of the Lower Peninsula, all are land-locked, and all are alkaline lakes. They vary considerably, however, in depth, kind of bottom, clearness, and in other respects. Some general data regarding them is presented in Table 1.

The information given below is based on the assumption that all fish were killed and that all were counted. All were probably killed, for later examinations of three lakes failed to indicate that any of the fish remained, and in the other three the dosage of poison used was considered adequate to kill all fish present. The lakes were examined for a number of days after the poisoning, and it is believed that few fish remained in the deeper water after the collecting and counting had been completed. In several of the lakes dynamite was used to raise the dead fish. Not quite all of the fish were seen and not all of those seen were taken to the laboratory for study (they were counted, however, and in some instances were measured), but a large random sample constituting a considerable portion of the total population was invariably used. The fish from one lake, Standard Lake, are only from the southern half of this lake, which has the shape of a figure 8 and is really two separate basins. In data on the population from Clear Lake young-of-the-year sunfishes are not included.

Some of the findings which are of interest in fish management are listed below under separate headings together with some generalizations made on the basis of the information.

Overabundance of Fish

Had a person fished the lakes which were poisoned (except Howe), he would have taken few if any fish of catchable size. Very probably he would have concluded that these lakes needed more stocking. A study of the

Table 1

Some physical and chemical data obtained on six lakes

from which the fish populations were removed.

	Lake					
	South Twin	Ford	Section Four	Howe	Clear	Standard
Location (Town and Range)	32 N., 1 W.	32 N., 1 W.	32 N., 1 W.	27 N., 4 W.	26 N.,6 E.	32,33N., 3, 4 W.
Area (Acres)	4.3	10.7	3.3	13.4	11.3	16.0
Maximum Depth (Feet)	42	33	71	24	9	31
Dominant Bottom Type:						
Shoal	Sand	Sand, Peat, Marl	Marl	Sand	Peat	Marl
Deep Water	Peat	Peat	Marl	Peat	...	Peat
Vegetation on Shoal	Common	Abundant	Common	Almost None	Sparse	Common
Secchi Disc (Feet)	24.8	18.2	22.4	12.5	6.0	14.0
Thermocline	Present	Present	Present	Absent	Absent	Absent
Chemical Data:						
Date	7/27/32	8/1/32	8/1/32	8/2/37	7/19/37	8/6/37
Temperature (Surface, Farenheit)	73	75	76	74	73	75
Oxygen (Ppm., Surface)	6.4	9.4	9.1	8.3	7.9	8.8
PH (Surface)	8.1	8.2	7.9	8.1	...	8.1
MO Alkalinity (Surface)	106	126	149	51	167	125
Date Fish Were Eradicated	9/20/34	9/9/36	9/19/35	9/7/37	8/27/37	9/6/37

populations clearly indicated that fishing would have been very poor. The cause for such poor fishing, however, would have been an overabundance of fish rather than a scarcity of them. In five of the lakes the fish were apparently too numerous for the food supply and were failing to reach a catchable size. The few which attained legal size were generally less than an inch longer than the minimum legal length and in some lakes were in very poor condition. In view of the popular belief that lakes are overfished and that predators are almost invariably injurious, these populations are of special interest, for the removal of a considerable proportion of the fish by very intensive fishing for them, or by a decided increase in the number of predators, would undoubtedly have been beneficial rather than injurious.

The number of legal-sized game (and pan) fish per acre varied from about 3 in Standard Lake to 99 in Ford Lake (see Table 2). In contrast, several southern Michigan lakes which had severe winter-kill are estimated to have contained well over 500 legal-sized fish per acre.

Size and Bag Limits

In lakes where fish are growing so slowly that they are stunted in growth, size and bag limits may be definitely detrimental. An angler taking a large number of small fish from the five lakes mentioned above would have been doing more good than harm. When made for an entire state, uniform regulations limiting the fishing are probably beneficial to some waters and are undoubtedly injurious to other waters.

Overpopulation limits the yield of catchable fish in a considerable number of northern lakes. More needs to be known about the management of waters containing too many fish. Legal restrictions and stocking with fish of the same sizes and species as those already present obviously cannot be considered intelligent management for these lakes.

Table 2

Number of legal-sized game fish per acre (fractions omitted).

Species	Legal Length (Inches)	Lake					
		South Twin	Ford	Section Four	Howe	Clear	Standard
Trout	7	...	2	...	...	...	...
Perch	6	59[1]	97[1]	31[1]	1	...	2
Large-mouthed Bass	10	...	...	...	10	...	...
Rock Bass	6	...	...	...	...	...	...
Sunfish	6	...	...	...	2[2]	11[3]	...
Total		59	99	31	13	11	3[4]

[1] With few exceptions these fish were only a fraction of an inch over the legal length.

[2] Common sunfish (Eupomotis gibbosus).

[3] Various species of sunfish.

[4] The number of legal-sized fish per acre in Standard Lake included 2.4 perch and 0.3 rock bass, totaling more nearly three than two.

Total Populations

The number of fish present in the six lakes at the time of the poisoning varied from 3,443 fish per acre in Ford Lake to 526 fish per acre in Section Four Lake; total weights varied from 194 pounds per acre in Clear Lake to 21 pounds per acre in Standard Lake. The three lakes with the greatest shoal area (in proportion to the entire area) also contained the largest number of pounds of fish. Data for the number, kind and weight of fish from each lake are given in Table 3.

Evidence (Thompson, unpublished) suggests that the number of pounds of fish per acre tends to remain constant from year to year. It seems improbable, therefore, that lakes such as those which were discussed here (Clear Lake excepted) will support intensive fishing even when not overpopulated, except by heavy stocking with legal-sized fish soon to be recaptured by the angler, by very intensive fertilizing or by some other currently impracticable means. In lakes where the standing crop is small, a rapid turnover is perhaps desirable for maximum yield. Some waters may eventually be regarded as marginal or submarginal, not of sufficient fertility or recreational value to justify any intensive management.

Cannibal Bass*

A number of studies have been made of bass cannibalism in rearing ponds (Langlois, 1936, Cooper, 1937). Cannibalism a parently also exists in natural waters, for an examination of the Howe Lake fishes showed it to be prevalent among the bass in this lake. At the time the fish were poisoned, Howe Lake contained one cannibal young of the year per 80 normal young. The largest cannibal was 49 times heavier than the average young of the same age,

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* As used here, the term cannibalism does not mean an exclusive diet of fish of the same species. The diet may have included more perch than bass and probably included other forms of food as well. Bass referred to in this paper are invariably large-mouthed black bass (Aplites salmoides).

Table 3

Number, kind and weight of fish per acre.

Total populations from six lakes.

	South Twin	Ford	Section Four	Howe	Clear	Standard
Number of Fish Per Acre:						
Trout	tr.	2	...	...	...	...
Perch	955	452	526	211	...	302
Suckers	...	...	...	3	...	5
Large-mouthed Bass	...	...	...	1,400	...	...
Rock Bass	...	...	...	...	...	77
Sunfish	...	...	...	56[1]	1,602[2]	...
Carp	...	...	...	1	...	...
Goldfish	...	...	...	...	166	...
Forage fish	...	3,443	...	83	456	878
Total Number	955	3,897	526	1,754	2,224	1,262
Weight of Fish Per Acre (To Nearest Pound):						
Trout	tr.	1	...	...	...	...
Perch	29	33	23	1	...	9
Suckers	...	...	...	7	...	5
Large-mouthed Bass	...	...	...	8	...	...
Rock Bass	...	...	...	...	...	3
Sunfish	...	...	...	2	40	...
Carp	...	...	...	16	...	...
Goldfish	...	...	...	...	152	...
Forage Fish	...	15	...	tr.	2	4
Total Weight (Pounds)	29	49	23	34	194	21

1 Common sunfish (Eupomotis gibbosus).

2 Various sunfishes (common, green, long-eared sunfish, warmouth bass, bluegills, and hybrids). Young of year not included under number and weight.

indicating that, in fishes, extensive varations in growth are possible.

Of interest to fish management is the finding from a study of the scales of the Howe Lake fish that only one of 63 legal-sized bass (10 inches or more in length) had attained an exceptionally large size during its first year. This one specimen was relatively young (3 summers old) and was barely legal-sized. About half of the two-summer-old fish (below legal length), however, had been cannibals, indicating that these fish of exceptional growth had excellent survival during the first two summers of life.

Several explanations might be given for 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, possibly there was no cannibalism several years prior to the poisoning. Neither explanation seems suitable. 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. The writer (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 (1937) 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."

The data obtained on the Howe Lake bass are inadequate to prove that the rapid growers generally die early, but are significant because of similar evidence found in other studies of fish (and of other animals).

In northern waters where bass require three or more years to reach "a catchable" size, the question is especially significant. Cannibal bass stocked in such waters may be of little value for angling because of early mortality. The tendency to seek rapid growth from fish in hatcheries, in northern states, may be undesirable. The practice of raising bass in southern Michigan hatcheries (to obtain good growth in short time) for stocking northern Michigan lakes may not be in the best interests of the angler. This question certainly deserves serious consideration from those interested in the management of northern waters. It is possibly even more important in some other states than in northern Michigan.

Hybrids

Five species of sunfish (bluegills, common sunfish, long-eared sunfish, green sunfish and warmouth bass*) were present in Clear Lake together with a number of hybrid combinations. For two species, hybrids were more common than were the pure species according to preliminary examination of the fish. The lake was decidedly overstocked with fish, but whether or not the stock would eventually have been reduced by the extensive production of sterile hybrids or whether some species might have become exterminated through hybridization is not known.

There is one important aspect to the hybrid sunfish question with relation to fish management: The use of hybrid sunfishes as brood stock is not desirable for, according to Hubbs and Hubbs (1933), these fish are sterile. It was also found by these investigators that the hybrids grow

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* Scientific names of these fish, in the order given: Helioperca macrochira, Eupomotis gibbosus, Xenotis megalotis, Apomotis cyanellus and Chaenobrythus gulosus.

more rapidly than do the parent species. The "crosses" are not readily distinguished from the parent. In obtaining bluegill or sunfish brood stock for rearing ponds, hybrids might easily be selected because of their large size and their similarity in appearance to the parent species. In one federal hatchery results obtained in a bluegill pond were negligible. The matter was readily understandable after it was determined by Dr. Carl L. Hubbs that the brood stock was almost exclusively hybrids.

Forage Fish

Forage fish were present in four of the six lakes. In Ford Lake they had been introduced two years before the population was poisoned and had become established and doubled in number even though perch were extremely abundant. In Clear Lake and Standard Lake they were probably native. The blunt-nosed minnows in Howe Lake were introduced; the darters were originally present. South Twin Lake and Section Four Lake contained no "minnows."

The ratio of food and game fish to forage fish in the several lakes containing forage fish was: Howe Lake 20:1, Clear Lake 4:1, Standard Lake 1:2, Ford Lake 1:8. Only in Howe Lake were the food and game fish showing good growth even though forage fish were fewer here, as compared with other fish, than in the other three lakes. The presence of forage fish is apparently not always an indication of adequate food for such fish as perch, rock bass and sunfish, since these fish will grow very slowly and apparently become overpopulated even when limited numbers of forage fish are available.

Had the forage fish in Howe Lake decidedly increased in number, would such increase have benefited the fishing? There is a possibility that such increase might have resulted in the survival of more bass than the lake could support and that therefore a stunted bass population might possibly have resulted. The role of forage fish needs further investigation. It is known that some species can be successfully introduced even if the population density of fish is already great, but the ultimate value of these fish to

the lake has not yet been fully determined. Do we tend to overstress the value of forage fish? The population studies which have been made are too few to answer the question.

Age and Size Distribution

The study of complete fish populations makes possible a determination of the distribution of fish of various sizes and ages. It might be expected, theoretically, that each successive year group is more poorly represented in the population; i.e. three-year-old fish would be more poorly represent than two-year-old fish, and the latter would be much less abundant than one-year-old fish. The data obtained on the lakes in this connection are interesting.

In the Howe Lake bass the young of the year were decidedly more abundant than were fish of any other age, but four-summer-old fish were much more common than were individuals two and three summers old. The number of each year group for the entire lake was approximately as follows:

Age in Summers	Number of Fish
1	18,603
2	25
3	10
4	105
5	7
6 and older	9

The distribution as shown above is not what might be expected. However, a logical explanation for the large number of four-summer-old fish and a smaller number of bass in the next two age groups can be given: The first spawning on gravel placed in the lake by the CCC (see below) was in the spring of 1934 and the four-summer-old fish resulted from that spawning. Previously the bass spawned on sand. A decided improvement in spawning conditions therefore may have been responsible for an increase in hatch and survival of that group. The fish born in the next several years may have been very much reduced in number by the increase in older bass and the resulting greater consumption of the young by these older fish.

The Howe Lake perch were distributed in age groups more nearly according to expectation. The fish included 2,678 one-summer-old perch, 131 two-summer-old perch and 17 adults.

Age distribution of perch in South Twin Lake was comparable to the distribution of ages of bass in Howe Lake, perhaps for a similar reason. In South Twin Lake most of the fish apparently died of starvation at or near the end of their third year of life. It is possible that one age group normally predominated here, that it kept succeeding age groups decidedly reduced in number by eating most of the fish of these groups, that later this dominant group was very much reduced in number by starvation and that the survival of the age group born immediately after this starvation again was exceptionally good. The 3,615 fish examined from South Twin Lake (most of those found present and without selection) had the following age distribution according to a study of the scales:

Age in Summers	Number of Fish
1	3
2	99
3	2,774
4	482
5	235
6	18
Over 6	4

The perch in Section Four Lake showed a somewhat similar tendency. In what was presumably a random sample, the number in the several size groups was as follows:

Age in Summers	Number of Fish
1	447
2	231
3	957
4	94
5	7

Age of the perch from Ford Lake could not be determined with any degree of certainty, but there were relatively few young of the year; for Clear Lake and Standard Lake fish the ages have not yet been studied, although a

superficial examination of the perch in the latter lake indicates a condition in age distribution not unlike those for perch in Section Four Lake.

If the data given above are representative for lakes in general, decided increases or decreases in the catch of a species from one year to another are explained because of the dominance of certain age groups. Intelligent fish management would involve consideration of the relative abundance of the age groups, and stocking especially should be determined by this distribution.

Stocking

Little is known about the survival rates of lake fishes at different sizes, or about the ratio of young to adults or to legal-sized fish. The ratio of young-of-the-year fish to legal-sized fish in Howe Lake at the time of the poisoning was 145:1 for bass and 158:1 for perch. The young bass had an average length of 2.1 inches; the young perch averaged 2.3 inches. Legal lengths for the two species are 10 inches and 6 inches respectively. If conditions were constant from year to year, almost 2000 young bass or perch would need to be planted in this small lake to increase the legal-sized bass or perch by one per acre, it being assumed that the lake could support this added number—an assumption which has by no means been proven for this or other lakes.

Lake Improvement

Environmental improvement was attempted only on Howe Lake. This lake was closed to fishing from 1930 to 1933, when it was used, with relatively little success, to raise bass for stocking in other waters. Sixteen gravel spawning beds for bass were installed in about 1930; a truck load of *Chara* was placed in the lake in 1932, another in 1933. Five truck loads of manure were also taken to the lake in the latter year. These attempts at environmental improvement were made by the Grayling Fish Hatchery.

In 1933 a number of environmental changes 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 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 7 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.

The Grayling Hatchery planted 20,000 blunt-nosed minnows in 1934 and 3,000 skipjacks (Labidesthes sicculus) in 1935, also 75 adult suckers (Catostomus c. commersonii) averaging about 15 inches in length.

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 are 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 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 skipjacks did not become established and the suckers apparently failed to reproduce successfully, for no small suckers were found. The brush shelters with few exceptions remained where placed and fish apparently frequented them.

A decided change in the fish population has 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 as well as by larger bass. Observations indicate that since 1933 the bass have very noticeably increased in number and that the perch have declined. Improved spawning conditions and shelter have apparently favored the bass which, in turn, have probably reduced the number of perch.

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 deposited but few if any had hatched. The method used in destroying the nests was a crude one, consisting merely of kicking the nest apart. It seems probable that the number of young-of-the-year sunfish which were recovered later (12 young of the year compared with 766 two-summer-old fish) was very small because of this activity. Destruction of the beds of those

species of fish which nest in clear, shallow waters may prove practicable as a means of reducing the numbers of these species in those lakes where they have become overabundant or where they are undesirable.

Activities on the other five lakes might also be regarded as lake improvement since, in four lakes, the undesirable populations were eradicated and more suitable fishes were stocked; in the other, Standard, the fish were removed from one basin which constituted about half of the entire lake. Studies on the latter will be continued to note changes in growth as a result of a decided reduction in the population.

Lake improvement may be used as an effective tool in fish management, but, like the other management phases, it is seriously in need of more thorough testing. In Howe Lake some improvements were successful, others were not; for still others the success could not be determined.

Discussion

A study of only six populations, most of them abnormal, does not give a fair picture of the standing crop in Michigan lakes, and does not permit generalization. It is anticipated that such studies will be extended to other waters in various portions of the state with enough data available, eventually, to permit correlating of pounds per acre and other items with the environmental factors.

Removal of some of the populations and later restocking with more desirable fish is in itself a worthwhile activity, but the chief value of the studies made so far in Michigan is probably the suggestion that present management methods are still in need of testing, that accepted practices are still subject to question. It is hoped that the studies may also have one other effect; that they will help in a small way to convince the sportsmen that stocking is not always the answer to our fisheries problems.

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