Presented before
N. Am. Wildlife Conf.
February, 1936

Original: Fish Division
cc: R. W. Eschmeyer

INSTITUTE FOR FISHERIES RESEARCH
UNIVERSITY MUSEUMS
UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN

January 29, 1936

REPORT NO. 341

ESSENTIAL CONSIDERATIONS FOR FISH MANAGEMENT IN LAKES

Introduction

A study of the history of the several phases of fish management suggests a rather one-sided development. In artificial propagation and stocking, the emphasis has been on more and cheaper production. The effectiveness of stocking and the planting of fish in suitable waters has received relatively little attention. The benefits which may have been derived from our fish propagation units have never been adequately determined. Fish legislation has not always been sound and the results desired from legislation have not always been forthcoming. Introduction of exotic species has done good and has done harm. It is easier to plant fish, to make laws and to introduce exotic species than it is to determine whether these activities are sound conservation. Likewise, in connection with environmental improvement, the most recent factor in fish management, it is easier to install an "improvement" than to determine whether that "Improvement" is beneficial or injurious.

The biologist, cognizant of the lack of a scientific basis for much of the fisheries work, has bombarded the practical fisheries worker with a variety of words: inventory, rate of growth, environmental improvement, maximum utility, chemical analysis, hypolimnion, vegetation studies, food studies, sun spots, sub-species, and the coefficient of condition. It is not to be wondered at that the practical fisheries worker, after listening to the multitude of large words, has gone back to

his study on a comparison between the relative merits of sheep plucks and liver as food for trout.

The degree to which the various phases of fish management will eventually depend on an understanding and application of scientific information depends, to a considerable extent, on the degree to which the fisheries biologist can organize his field and can point out the practical application which may be made of his studies. The purpose of this paper is not so much to suggest certain essentials for fish management as to indicate how some of these essentials may be coordinated and how their study may lead to practical application. Three essentials: inventory, creel census, and studies in rate of growth will be briefly discussed.

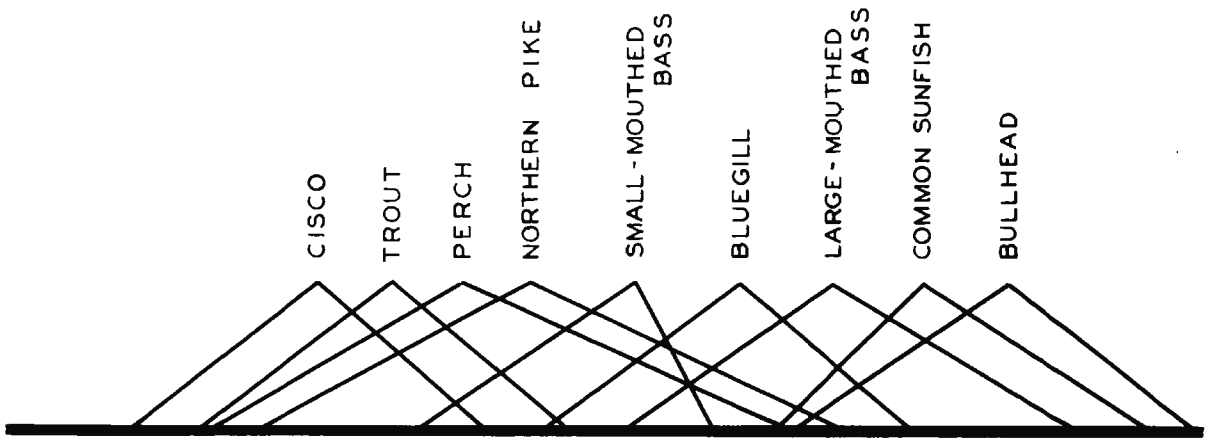
Inventory

During the summers of 1930, '31 and '32 the lake investigation party of the Institute for Fisheries Research under the general direction of Dr. Carl L. Hubbs and under the writer's immediate supervision made a chemical, physical and biological inventory of approximately 150 Michigan lakes. This inventory provided considerable information of immediate value but any attempts at classification and coordination of data were not immediately successful. The lakes would not fit into any well organized scheme of classification. Yet, if Michigan's four or five thousand lakes were to be inventoried the development of a system of classification and of "short-cut" methods of inventory were imperative. Eventually, a recognition of the facts that the lakes are in various stages of their evolution; that in this normal evolution gradual and relatively uniform changes in the biological, chemical and physical properties are taking place, though not at a uniform rate; and that this continuous variation cannot well be expressed by placing the lakes in a series of definite and well defined classes, lead to an organization of the material which made possible a better understanding of some of the problems of fish management. Although the data have not yet been fully prepared and certain definite changes obviously will need to be made, the general nature of a suitable means of classification is here presented.

(Insert Fig. 1)

In Figure 1 the heavy line indicates the evolution of a lake from the stage where it will first support fish life to the end of the "bullhead" stage. On the left are shown some of the physical, chemical and biological conditions which are characteristic of a young lake and, on the right, are shown conditions common to lakes which are approaching the end of their evolution. The peaks indicate the range in the lake's evolution where conditions for each of the several species mentioned are suitable, the apex indicating ideal conditions for the species and the extremities showing where the species will be barely able to exist. The various ranges and peaks have been somewhat arbitrarily placed on the chart. However, their proper location may be ascertained by correlating the abundance of fish of each species (as indicated by the inventory) in the lakes surveyed. Furthermore, by correlating the abundance of fish of each species with each of the several chemical, physical and biological factors listed, it may be possible to show which of these factors are most significant. By a study of these several significant factors, it may be possible to determine, in a relatively short time, how well the lake is suited for each of the several species. There will be limiting factors which are not indicated in the figure: in a very deep lake the shoal may have approached the "bullhead" stage and the strata in the vicinity of the thermocline may still be suitable for cisco; a lake which has approached the end of its evolution may still be suitable for fish characteristic of relatively young lakes if a cold stream enters the lake; size of lake appears to effect the nature of the population; competition between species is definitely a deciding factor.

The rate of change will depend on altitude, latitude, richness of soil in the immediate vicinity, on the original depth of the lake, on the rate of deposition of marl and on other factors. The evolution of a shallow lake in a rich agricultural area may progress very rapidly while, in a lake in high mountainous country, the changes may be very slow. A shallow lake having rapid deposition of marl may become unsuited for fish life because of extreme shallowness before having progressed very far in its evolution; it may die prematurely. Other lakes may eventually become acid bogs.



HIGH OXYGEN
LOW CARBON - DIOXIDE
INORGANIC SOIL
SPARSE VEGETATION
SPARSE FOOD (CHIEFLY PELAGIC)
HIGH TRANSPARENCY
LOW FERTILITY
USUALLY ALKALINE

LOW OXYGEN
HIGH CARBON-DIOXIDE
ORGANIC SOIL
ABUNDANT VEGETATION
ABUNDANT FOOD
LOW TRANSPARENCY
HIGH FERTILITY
INCREASING ACIDITY

(HYPOTHETICAL)

Fig. 1

Evolution of lakes with reference to suitability for several species of fish

As the development progresses conditions become more suitable for some species and less suitable for others. The conditions as they exist, at various stages, meet the requirements of certain fishes but not of others. This may be indicated by a brief discussion of some habits of several of the fishes:

The cisco is an open-water fish which lives chiefly on the minute animal and plant life. It spawns over shallow water, the eggs dropping on the bottom. In a new lake the first food to form in abundance is plankton, conditions are not yet suitable for bottom-feeding fish or for predator species. Bottom conditions might not yet be suitable for a fish with highly specialized spawning needs. There is little or no vegetation or other protection. Consequently an open-water form, living on plankton and with relatively unspecialized spawning needs can live in the water, provided other factors, such as suitable temperature, are satisfactory. The needs of the lake trout are in many respects similar to those of the cisco except that it lives to a considerable extent on larger food with the cisco probably serving as the chief food item. The other trouts spawn in inlets or outlets in gravel; gravel is usually present in streams entering relatively new lakes. Perch, the next fish in the series, have a wide range of tolerance. They are intermediate between the cold-water and warm-water fishes. They eat a variety of food and drop their spawn in shallow water where it adheres to dead-heads, vegetation or other objects present on the shoal. The northern pike likewise has a wide range of tolerance, and, like the perch is intermediate between the cold-water and warm-water fishes. It spawns in marshy outlets of streams or in marshy bays. By the time the lake has reached the "northern pike" stage it is old enough to have developed vegetation at the margin of the bays and especially at the mouth of the inlets which have, by that time, accumulated considerable nutrative material. The pike is decidedly predatory and primarily pisciverous. By the pike stage cisco, perch or suckers will usually have become abundant. Any or all of the three species are suitable food for the pike.

The small-mouthed bass, in selecting its spawning site, shows a decided preference for gravel. By the "small-mouthed bass" stage sufficient gravel will usually have been

washed on the shoal by wave action to satisfy its needs. Bluegills, large-mouthed bass and sunfish will use gravel but can apparently also spawn quite successfully on the roots of vegetation. By the time the lake has reached suitable stages for these fish the shoal is usually covered with organic soil and vegetation is generally abundant. The gravel will tend to be covered, making imperative the use of something other than gravel for spawning. The bullhead can spawn suitably in lakes with organic bottom. Space does not permit a detailed discussion of a comparison of the evolutionary trend and the needs of the fishes. Those who have studied a variety of glacial lakes will recognize immediately many more possible comparisons.

A few further brief statements regarding the trend are made:

1. Oxygen. In general oxygen decreases as a lake gets older and, in general, the fish farther down the scale require less oxygen. The reason for oxygen decrease is obviously due to an increasing amount of decay.
2. Soil. The nature of the soil becomes increasingly organic. Old lakes almost invariably have a thick layer of organic peat covering the original bottom.
3. Vegetation. There appears to be a more or less general change in the kind of vegetation, with a tendency for the total amount to increase during most of the lake's development.
4. Fertility. Naturally, the fertility tends to increase during most of the development. A "young" lake is relatively unproductive.
5. Fish production. The potential production of fish probably increases during most of the development. The total value of the fish may however be greater in a younger lake than in an older one because of the differences in size, taste, or some other characteristic.
6. Food. The total food probably gradually increases during most of the development. Forage fishes could be arranged on the graph along with the fishes mentioned. A fish such as the Great Lakes Shiner (in Michigan)

would probably have a range on the scale similar to that of the cisco; the mud-minnow would be even below the "bullhead" stage. The range of other food organisms would probably also fit into the chart.

7. Parasites. A study of the distribution of parasites might indicate a correlation between the kind and degree of parasitism and the degree of the lake's suitability for any species.

8. Resort value. There appears to be an inverse correlation between resort value and capacity for fish production. A young lake with sandy, weedless shoals and clear water is excellent for boating and bathing, but relatively unproductive of fish; in an older lake the reverse is true.

The method of classification used not only permits coordination of some of the studies and visualization in the field of lake management but it offers immediate assistance in stocking. When the stage of the lake's development has been determined, a line drawn vertically through the graph at that stage will indicate how well it is suited for each of the several species which are propagated. It should help to indicate which species might well be encouraged or be introduced.

A recognition of the stages of development of the lakes should be of great value in lake improvement. The chief problem in a "young" lake is one of fertility and any considerable degree of increase in production must probably be dependent on an enrichment of the water. The planting of vegetation would probably be unsuccessful. Since the fish suited to a "young" lake are largely open-water fish, the installation of brush shelters would be of little benefit because these fishes use them very little. A few species such as the rock bass might be encouraged by installing shelters. With limited food and in water poorly suited for them, they would probably grow slowly and remain stunted, competing with the more desirable fish and being of little or no value for fishing because of slow growth and small size. While improvement in a "young" lake consists primarily of advancing the evolution, improvement in an old lake consists primarily of retarding it. Improvement in an old lake would involve the removing of vegetation, preventing winter killing (increasing oxygen), and increasing the number of fish. In a "young" lake the balance between fish and food favors the former, in an

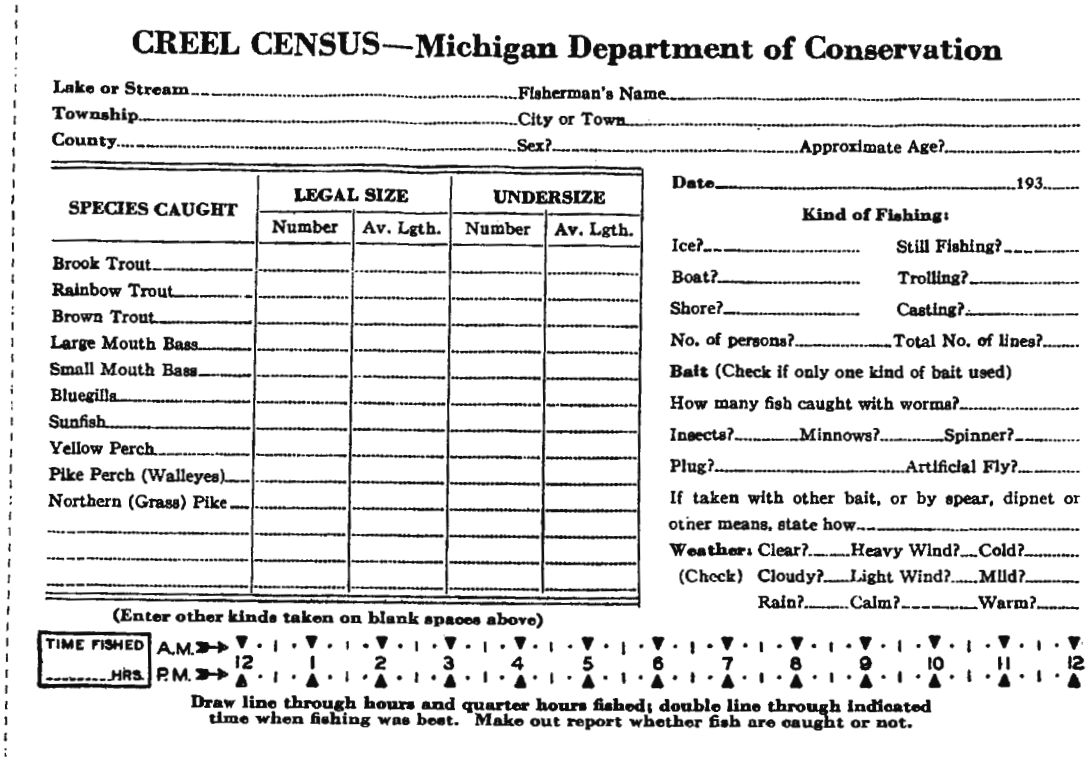
"old" lake it favors the latter. In intermediate lakes the improvements, to be effective, must be installed with a recognition of their possible effect on the fish and with a recognition of the natural needs of the species in question. At a point where a lake is equally suited for perch and small-mouthed bass, the latter can be encouraged by providing gravel for spawning and shelter for the young fish. Experimentation suggests that perch use the shelters very little while bass use them to a considerable extent. The shelters not only help provide food for the young bass by concentrating insects and other organisms, but protect them from the predators. In this connection it might be pointed out that the species probably become progressively less active in winter; the pike are apparently more active in winter than are the bass, bluegills and sunfish and therefore may be better able to prey on them at that season than at other times.

A knowledge of the needs of the species is essential to intelligent improvement work, and an inventory and classification of the lakes is essential in determining the immediate needs of the fish.

Creel Census

The Michigan Department of Conservation has conducted, since 1927, a general census on lakes and streams of the state. The census was primarily taken by the conservation officers. This sampling of the fishing throughout the state over a period of years provides considerable information of help to fish management.

Through the combined efforts of the Michigan Emergency Conservation Work and the Institute for Fisheries Research an intensive census was begun on several lakes late in 1934. The census was taken by crews of especially selected enrollees from a number of C.C.C. camps. In general the crews were large enough to check the returns of almost all fishermen on the lakes where the census was taken. During the last fishing season, crews were present on nine Michigan lakes and were contacting the fishermen as they reached the shore. At present a winter census is being taken on a number of our lakes. Figure 2 shows the census blank which is now used.



CREEL CENSUS—Michigan Department of Conservation

Lake or Stream ..... Fisherman's Name .....
Township ..... City or Town .....
County ..... Sex? ..... Approximate Age? .....

SPECIES CAUGHT	LEGAL SIZE		UNDERSIZE	
	Number	Av. Lgth.	Number	Av. Lgth.
Brook Trout				
Rainbow Trout				
Brown Trout				
Large Mouth Bass				
Small Mouth Bass				
Bluegills				
Sunfish				
Yellow Perch				
Pike Perch (Walleyes)				
Northern (Grass) Pike				

(Enter other kinds taken on blank spaces above)

Date ..... 193.....

Kind of Fishing:

Ice? ..... Still Fishing? .....
Boat? ..... Trolling? .....
Shore? ..... Casting? .....
No. of persons? ..... Total No. of lines? .....
Bait (Check if only one kind of bait used)
How many fish caught with worms? .....
Insects? ..... Minnows? ..... Spinner? .....
Plug? ..... Artificial Fly? .....
If taken with other bait, or by spear, dipnet or other means, state how .....
Weather: Clear? ..... Heavy Wind? ..... Cold? .....
(Check) Cloudy? ..... Light Wind? ..... Mild? .....
Rain? ..... Calm? ..... Warm? .....

TIME FISHED ..... HRS.
A.M. 12 1 2 3 4 5 6 7 8 9 10 11 12
P.M. 12 1 2 3 4 5 6 7 8 9 10 11 12

Draw line through hours and quarter hours fished; double line through indicated time when fishing was best. Make out report whether fish are caught or not.

Fig. 2. Blank used for the Michigan Creel Census

A detailed discussion of the census cannot be given here (the census on one lake was reported on at the last meeting of the American Fisheries Society). A few of the ways in which the census may be helpful in fisheries management are here listed. The intensive census, as taken in Michigan, provides means of determining for the lake: the amount of the annual crop, the catch per hour, the abundance in the catch of each species at each season, the effectiveness of the various fishing methods and of various baits, the residence of the anglers, the number of undersized fish caught (which helps to predict the fishing trend for the next year or two), the time of day when fishing is best, the relationship between weather conditions and fish "biting", the size distribution of the fish caught, and the seasonal fluctuation of each species in the catch.

Over a period of years the census will tend to indicate the maximum annual catch which may be taken without injury to future fishing. Coupled with an extensive marking program, it will help indicate the total population of adult fish and the percentage of these fish removed annually. Coupled with stocking and marking, the census can, in time, provide data sufficient to evaluate the benefits derived from stocking. Coupled with lake improvement, it can similarly be made to indicate, in time, the effectiveness of lake improvement work in general, and of devices of different sorts. The census, taken on lakes at different evolutionary stages will tend to indicate the production from lakes at these stages. It will show, in time, the effect of one species on another. If carried out on a number of representative lakes, it will help to determine approximately the combined annual fish catch for all lakes in the state. It will test the effectiveness of existing legislation and will help to indicate what restrictions would be of greatest benefit to the lake and least objectionable to the fisherman.

The benefits to be derived from the census are obviously many and the Michigan Emergency Conservation Work, in cooperating so extensively in this work in a number of camps, has made an outstanding contribution to fisheries management.

Rate of Growth

A number of studies have been made on the rate of growth of various species. These studies have not generally lead to any alteration of the stocking programs. When the average rate of growth of the propagated species has been determined for various types of lakes in different areas and when, by inventory (aided by creel census studies), it has been determined which of these species are most suited for the lakes, an examination of the growth rate of a small number of fish would be of decided help in determining the stocking program. This may best be illustrated by comparison with directing the operation of a farm from an office or sick bed. The owner knows, from previous study, that he has the right kind of livestock for his pasture. He has a small representative number of them taken to him for examination and, by examining them, he can immediately decide whether or not the herd should be increased. If the cattle are in excellent condition he may safely conclude that the pasture will hold a few more

head; if the specimens are average, he will probably let well enough alone; if they are in very poor condition, he would certainly not add more to the herd--he would probably reduce the number of cattle or improve food conditions.

Since the rate of growth of fishes is dependent, within limits, on the amount of food available for the fish, stocking intensity may be determined on the basis of growth without an intensive study of the food or of the concentration of fish in the lake. Based on a periodic study of fishing intensity and on a continuous study of growth, stocking may eventually be placed on a scientific foundation.

Should a relatively large number of scientifically trained men work on the problems which were here briefly mentioned (and on associated problems) it appears possible that eventually, in lake management, there may be a considerable curtailment of that one item which has been so characteristic of conservation work in the past, viz. guess-work.

INSTITUTE FOR FISHERIES RESEARCH

R W Eschmeyer

By: R. W. Eschmeyer