

II.—THE INVESTIGATION OF RIVERS AND LAKES WITH REFERENCE TO THE FISH ENVIRONMENT.

BY BARTON W. EVERMANN, PH. D.

It is the aim of this paper to call attention to the work of the U. S. Fish Commission in connection with the study of the streams and lakes of the country.

The Commission has always held that such investigations as it might properly undertake should have as their ultimate object the discovery of facts and the attainment of results which possess an economic value; and it is believed that all its investigations should be conducted upon scientific methods. Most, perhaps all, investigations possess an economic value when their results and their relations come to be properly understood. Rarely is the importance of any investigation fully comprehended at the time of its beginning. As every one knows, it is a matter of almost daily occurrence that investigations begun as purely scientific studies are yielding results of the greatest economic importance.

So certainly is this true, and so firmly has this important fact become established, that, in the proper conduct of any work undertaken by such a branch of the public service as the Fish Commission, it would seem that the investigations should be comprehensive and thorough, and the method should be the scientific method, the method which has yielded such brilliant results in other lines, the only method by which definite progress is made.

The U. S. Fish Commission is essentially and necessarily a scientific branch of the Government. It was originally established by act of Congress February 9, 1871, for the express purpose of conducting an inquiry into a scientific question where scientific method was demanded, namely: "(1) An investigation into the cause of the decrease of the sea-coast fishes and those of the rivers and lakes, with suggestions as to the best methods of restoring the same; and (2) active measures looking toward the propagation and multiplication of the useful food-fishes, either by restocking depleted waters or by introducing desirable species into new localities."

Thus it is seen that the Fish Commission began as a scientific inquiry whose results, it was hoped, might redound to the good of mankind; and neither its true purpose nor its method has changed.

The problems which properly come within the scope of the Commission are among the most intricate and difficult with which the biologist has to deal, and they are, as individual problems, very numerous, although all more or less intimately related.

For the sake of brevity, let us take it that the proper and ultimate purpose of the Fish Commission is to increase the quantity and improve the quality of the fish food-supply of the United States.

This brings us at once to a consideration of the life-histories of the fishes themselves. We must determine under what conditions each of the various species of food-fishes thrives in its natural state; we must determine the temperature and chemical character of the water in which it is found, the volume or size of the stream or lake, the character of the shores and bottom and the surrounding country; we must also determine what other species of fishes are found associated with it, their abundance and habits; and the same regarding any and all other species of animals and plants found in or about the fish's home. And then, after the determination of the facts regarding the fish's environment, a second and vastly more difficult series of investigations must be taken up, namely, the bearing of each of these facts upon the life of the fish.

The fact is one thing; its value as a factor in the life of the fish is a very different thing. I find a certain species of fish in a stream which has a mud bottom and whose water has a temperature of 60 degrees at noon during dog-days. Am I justified in concluding that a mud bottom and water of 60 degrees temperature are favorable conditions for the growth of that species of fish? Not by any means. In the mountains of East Tennessee last week I saw cornfields on mountain slopes too steep for an ordinary man to climb with any comfort, but I must not infer that steep hillsides are a favorable condition for the growth of corn.

One of the divisions of the Fish Commission, as now organized, is the division of fish-culture. This division has to do with the breeding, hatching, and rearing of various species of food-fishes and the stocking and restocking of different streams and lakes of the country.

To do this work intelligently it must necessarily be based upon a knowledge of the natural conditions under which each species thrives, which of the factors in its environment are essential, which only desirable, which negative, and which detrimental to the best life and growth of the fish. And when it comes to stocking, the division must know the conditions which obtain in every stream and lake which it is proposed to stock.

Another branch of the Commission—the division of scientific inquiry—in addition to its many and important lines of investigation regarding the marine fishes and fisheries, has endeavored not to neglect the fresh-water species. It has undertaken to carry on such a series of comprehensive and exhaustive investigations as will, in time, result in a pretty thorough understanding of all the conditions under which our various food-fishes thrive best and the particular significance of each factor in this best environment.

We have undertaken such a study of the streams and lakes as will enable us to know the peculiar conditions which exist in each important hydrographic basin in the United States.

This, of course, means careful observation and study of all the physical, chemical, and biological features of each stream, for these are the conditions, forces, or elements which together constitute the fish environment, and which determine the presence, abundance, distribution, and condition of the various kinds of fishes found in each particular stream or lake.

Most of the work which has been done so far has been in the line of determining the factors in each environment, rather than guessing what the factors mean. Heretofore great harm has been done by guessing at the facts and also guessing at

their meaning. We believe it is much better to be content for the present with the observation and recording of facts, and wait until more facts are in before interpreting their meaning.

As indicating the character and scope of the field work which we have been doing in this line, I shall give the substance of the directions or suggestions which have been furnished for the guidance of the various parties which the Commission has had engaged upon this work. During the last year or two there have been several volunteer observers, and during the present summer six parties were engaged upon field work in accordance with this plan.

Separate outlines were prepared for those parties engaged in lake study and those studying rivers, but in this connection it will be sufficient to give but one of the outlines.

The outline for lake study will serve our purpose, and I give it essentially as it was sent to the field parties, without taking time to put it in better form for this paper, as I perhaps should have done.

In the study of any lake attention should be given to the following:

OUTLINE FOR LAKE STUDY.

PHYSICAL FEATURES.

Geographic position:

Size: Form; greatest length and width and the direction of each; length of shore line.

Depth: Maximum and average; soundings should be made in many different places and the configuration of the bottom determined as accurately as possible.

Temperature: Determine the bottom temperature in various places; also at different depths, say at intervals of 10 feet. At what depth does the temperature of the air cease to affect that of the water? Or, in other words, at what depth does the temperature remain constant? These observations should be repeated once a week if possible and should extend through at least one year. The temperature of the air should also be taken at the same time.

Ice: When and where does the lake begin to freeze, in what direction does the ice spread most rapidly, and when does the lake become frozen over? What places remain unfrozen and what is the cause? Note the thickness and character of the ice from time to time; when and where is the maximum thickness reached? Depth of snow covering ice from time to time. When and where does the ice begin to melt in spring, how and in what direction does it progress, and when does the ice finally break up? Upon what shore and to what extent is it piled up? Is there any regularity in the formation of ice-cracks in different parts of the lake?

Purity: Character of the water, whether clean or muddy, hard or soft; sources and extent of contamination.

Bottom: Whether of sand, gravel, bedrock, or mud, and character in different places. Determine depth of bottom deposit if possible.

Shores: Whether high or low; dry, marshy, or muddy; and of what material made up, as mud, sand, gravel, clay, or rock; geologic age to which outcropping rocks belong; depth and character of drift, if any, in the immediate vicinity of the lake. This can be determined by learning the depth at which bed-rock is struck in the wells of the neighborhood. How do you explain the origin of the lake?

Inlet: What streams flowing into the lake and the amount of water carried by them; temperature, purity, and general character of the water. Locate and note the character of all springs connected with the lake, not omitting any that may be in the lake's bottom.

Outlet: What the outlet is, into what it flows; character as to size, rate of current, and volume of water discharged per minute. Compare amount of inflow with outflow, and make investigations for the purpose of determining the amount of evaporation which takes place from the surface of the lake during each month. This may be approximated by evaporating, in the open air, the water in a large, shallow pan. This, of course, would need frequent repetition.

Obstructions, such as dams, waterfalls, etc., in the outlet, and their influence upon the movements of fish; where fish-ladders have been placed and where not.

Rainfall: Amount for the year; month of greatest and month of least rainfall. Is the lake subject to any changes or fluctuations in level? Does the history of the lake show that it is increasing or decreasing in area?

Winds: Prevailing direction; any relation noticed between this and character of shore? A comparative study of a number of small lakes situated near together would be required in this connection. Direction of wind at time of breaking up of ice in spring. In addition to the observations indicated above, the observer should note any and all other physical phenomena which come under his notice, and which have any bearing whatever upon the lake. Few, if any, observations are unimportant, and every fact observed should be carefully recorded. Many of these observations should be repeated as frequently as possible, and at regular intervals.

BIOLOGICAL FEATURES.

Botanical: Plants found growing in the water, such as water-lilies, sedges, pickerel-weed, cat-tails, water-arum, rushes, arrow-head, pond-weed, water-milfoil, water-weed, eel-grass, chara, etc.; also the smaller forms, such as the various species of algae, duck-weed, diatoms, desmids, etc. The abundance, distribution, and life-history of each should be studied, especial effort being made to determine as accurately as possible the amount of the various kinds of vegetation found in the lake and the area covered by each. Give much attention to the study of the relations which the various species of plants sustain to the animal life of the lake. In studying the life-histories of the various plants, the observations should be as complete as possible, paying attention to their growth from first appearance in spring, through flowering and fruiting to time of dying. What becomes of the dead plants and stems—do they sink to the bottom and decay, or are they drifted upon the shores?

Shore vegetation, including plants growing in or near the water's edge; trees and bushes whose branches overhang the water more or less, and the bearing of these various facts upon the life of the lake.

Information as to the abundance, character, and distribution of all the species of plants found growing, say within 100 yards of the lake, would be of interest and value.

ZOOLOGICAL.

Fishes: As to species, abundance, distribution, and condition; feeding habits, upon what the various species feed, when and how they feed; can any estimate be made as to the amount of food required to supply the fishes of the lake. Breeding habits; when the different species spawn; location and character of spawning-grounds; what species feed on the eggs of other species? Migrations and other movements; where the various kinds of fish are found at different times of the day and at different seasons. Diseases; by what parasites affected, to what extent, and at what season; when is mortality greatest?

Size: Observe any and all facts which throw any light upon the average size of the individuals of each species; their age, relation of age to size; at what age they begin to breed. Note any change in color occurring during the breeding season.

What food-fishes taken in the lake; extent and value of commercial fisheries, if any; species taken and methods employed; game fishes of the lake; value of the lake to anglers.

Other animal life found in the lake, such as mollusks, crustaceans, insects, and insect larvae, worms, protozoans, etc., their abundance and distribution; make such observations as you can regarding their habits and study each of these forms with reference to its bearing upon the fish-life of the lake; the relation of these animals to the plants should receive attention.

Animal life found in the vicinity of the lake that may have any bearing upon that of the lake, such as batrachians, reptiles, muskrats, raccoons, minks, and various species of water birds, such as ducks, snipes, gulls, terns, herons, fish-hawks, etc., the abundance and time of appearance and disappearance of each. Make attempts to determine the abundance of any and all animal forms in and about the lake, especially of those forms serving as food for the fishes.

These are by no means all the facts which should be observed, recorded and studied.

That there is great necessity for accurate observation in these matters is evident from the different opinions expressed by different gentlemen regarding the menhaden yesterday. The truth is, we have very little exact information regarding the life-history of the menhaden, and have but little if any more about any of our fresh-water fishes. We possess some facts, it is true, and upon these few facts we have based broad generalizations; but are they warranted by the facts? For example, we know that vast quantities of sawdust and vast amounts of refuse from paper-mills and other factories are let into our streams, and we know, perhaps, that great mortality has occurred with the fishes in some of those streams; but do we *know* that the *one* is the *cause* of the *other*? We *think* that sawdust injures the fish, but do we *know* it?

In conclusion let me say that the whole subject of the relation and interrelation of the various animal and plant forms found in our waters, their action and reaction upon each other, and their relation to the physical as distinguished from their biological environment, is the subject which is demanding investigation and upon whose investigation must depend all important advance in fish-culture and fishery legislation.