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The Biological Survey of a River System---Its Objects, Methods and Results

BY

STEPHEN A. FORBES

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THE BIOLOGICAL SURVEY OF A RIVER SYSTEM—ITS OBJECTS, METHODS, AND RESULTS*

Stephen A. Forbes

In taking up my complex and rather difficult subject, I greatly regret that I have not a larger field from which to draw my data. The attention of biologists especially interested in the aquatic biota was naturally drawn, first, to the wonderful assemblage of animals and plants and the system of life in the great seas and, next, to those of the fresh-water lakes, concerning both of which there are ample stores of knowledge from various sources to draw upon; but the rivers of the country have received so little comprehensive attention from our biologists that I do not know of a single attempt anywhere in America to develop and disclose the complete biology of a river system except that which has been made by us in Illinois, and it is for this reason that I am forced to make our own operations rather unpleasantly conspicuous.

It was in 1874, when serving as curator of a small public museum which ten years later became the Illinois State Laboratory of Natural History, that I first began, with only casual assistance and with trifling funds, to investigate, as one of the items of a too complex program, the zoology of the Illinois River system, and in 1876 and 1877 that I began to publish the result of such investigations in the first of a series of bulletins now in the seventeenth volume.

By 1894 this incipient survey, although limited and fragmentary and frequently interrupted by other operations, had developed to a degree that made desirable and possible a permanent field station to be established by the State on the Illinois River, at which investigations could be carried on continuously throughout the year, and such a station, provided with an excellent portable equipment, was opened April first of that year, with a program directed especially to two main objectives—one the effect on the plant and animal life of a region produced by the periodical overflow and gradual recession of the waters of great rivers, of which the Illinois affords a notably marked example; and the other the collection of materials for a comparison of chemical and biological conditions of the water of the Illinois River at the time then present and after the opening of the sewage canal of the Sanitary District of Chicago which occurred five years later.

* Read at a public meeting of the Committee on Aquiculture of the National Research Council at Nashville, Tennessee, December 29, 1927.

The bearing of this program of over 33 years ago upon the fundamental objects of our present committee on aquiculture may be inferred from the following letter sent me in October, 1894, by Col. Marshall McDonald, then the U. S. Commissioner of Fish and Fisheries.

"I have carefully gone over the plans of the biological station proposed by you, and am particularly struck with the comprehensiveness of the plan of work to be undertaken. The knowledge to be obtained by such investigation as you contemplate is absolutely necessary as a foundation upon which to build an intelligent, rational administration of our fishery interests. A knowledge of life in its relation to environment is an important subject which biological investigators have not heretofore sufficiently dealt with, but which, it seems to me, is necessary in order to give practical value to special studies of the different species. After all, it is the relations and interdependence of life in the aggregate, and of the conditions influencing it adversely or otherwise, that mainly concern those who are seeking to apply scientific methods of investigation to economic problems.

"I need not tell you that you may count on the Commission for any cooperation and aid that we may be able to give you in this direction, which, looked at from a purely economic standpoint, I consider of the utmost importance."

This station at Havana was maintained for the first year under the immediate charge of Mr. Frank Smith, then instructor and later professor of zoology at the University of Illinois; for the years 1895-1900 under that of Dr. Charles A. Kofoid, now and for many years professor of zoology at the University of California; and from the latter date to 1923 under that of Mr. R. E. Richardson, still in active service as aquatic biologist of the State Natural History Survey. During these fifty-odd years we have published twenty bulletins on strictly Illinois river biology, containing a total of 1,856 pages and illustrated by 142 plates, and we are now preparing for the press manuscripts which will add about 150 pages to this total. We have had from the beginning the unstinted cooperation of the State Water Survey, which has answered all our calls for chemical and bacteriological data; and in 1923 these cooperative conditions were reversed, the Water Survey continuing its Illinois River studies with Peoria as its central station and the Natural History Survey cooperating as it may be called upon.

The more comprehensive program on which we are now working was determined in 1923 by an expansion of our aquatic operations, proposals for which were presented to our board of control in the following terms:

"For our further work in aquatic biology, I would like to take up a comprehensive, systematic survey of the waters of the state, one river system after another, to be studied as features of our natural resources, especially for recreation, scientific study, and the production of food, in all of which our streams might be made very much more profitable to us if they were well understood.

"Illinois is essentially a river state. About three-fourths surrounded by the Mississippi, Ohio, and Wabash, and traversed diagonally by the Rock, Illinois, and Kaskaskia systems with their many branches, it contains in all 480 permanent streams, with a combined length of 11,912 miles, 8,213 miles of which is that of streams at least 20 miles long.* This is exclusive of the large surrounding rivers, although Illinois extends on the west to the middle of the Mississippi and has concurrent jurisdiction with Indiana over the Wabash, where this river forms the common boundary.

"Moreover, most of our streams are by nature remarkably productive because of the richness of the land from which they derive their organic content and because of their sluggish flow over a level surface by which ample time is given for the organization of their food materials into forms fit for the maintenance of animal life and, finally, by means of this, for the life of man. I especially ask your attention to the fact that this wealth of waters has one decided advantage over the land area through which it flows, as a source of animal food for man, in the fact that this is produced in our streams from materials which have no other use to us, while our butcher's meats cost us several times their nutritive value in the vegetable products which our pigs and cattle devour; and yet our native waters still lie a primitive wilderness, not only wholly unimproved, but seriously injured in many places by various kinds of appropriation and pollution. I believe that our river systems are well worthy of the same kind of serious study which the Agricultural Experiment Station has given for many years to the land areas of the state, and such a study I would like to see initiated without delay. For these, among other reasons, one of which is the certainty of many important additions to biological science which an intelligent survey of this field would produce, I would like the approval of this Board to the general plan, details of which I should be ready to present at your next meeting."

This proposal being unanimously approved by our board of control, it thus became the permanent charter of our aquatic operations in Illinois, and in accordance with it we transferred our principal activities as a new project to the Rock River system, to which area I have now to ask your attention.

Rock River, which enters Illinois from Wisconsin somewhat east of the middle point of the common boundary and swings thence in a fairly even curve to the south and west to empty into the Mississippi at Rock Island, is one of the most beautiful, interesting, and popular streams in Illinois, quite unlike any other important river in the state, excepting perhaps the Fox, which flows through a similar territory. It is approximately 286 miles long, the lower 169 miles in Illinois and the remainder in Wisconsin, where it is fed by numerous glacial lakes, the total area of which is about 80 square miles. Its width in Illinois varies from 500 to 800 feet, its mid-channel depth is about 4 feet at average stages, and

* Data from a "Gazetteer of Illinois Streams", in "Water Resources of Illinois", published by the State Rivers and Lakes Commission in 1914.

its ordinary rate of flow averages 2 to 3 miles per hour, rising to 5 miles when the stream is in flood. Its banks are steep, often abrupt, and its shores are bold, frequently rocky, and sometime precipitous. Its bottom in Illinois is mostly of rock and gravel, except in its lower section, through which the Mississippi River formerly flowed, in which there is a good deal of sand. Its basin has a rolling surface with hills sometimes rising to a hundred feet or more above the valley floor, and it is generally covered by glacial drift, especially deep in the northern division except along its principal branch, the Pecatonica, which flows in Wisconsin through a district that was never glaciated and in Illinois over a glacial deposit older than, and very different from, that of the adjoining basin of the main stream. The total area of the entire Rock River basin is 10,820 square miles, about equally divided between Wisconsin and Illinois. The Pecatonica, whose basin is about two-thirds that of the Rock above the mouth of this tributary, is in strong contrast to the main stream in its broad bottom lands and its tortuous course, which is about three times its air-line length. Oxbow loops some miles long are often separated by only a few feet at their beginning and end. It differs from the Rock also in its generally muddy bed, in its much slower current, and in its extreme and rapid changes of level, amounting in one observed instance to 14 feet in 6 hours and in another, as reported, to 22 feet, although 8 feet is about the maximum variation of the Rock River gauge. Great pains have been taken by us to make comparable collections from these two neighboring but widely different streams. Details of the comparison have not yet been worked out, but it is obvious that the Pecatonica is, for various reasons, relatively poor in plankton and in bottom fauna, and hence in fishes.

The current of Rock River is much beset by several hydro-electric power dams which disturb the natural tenor of its life, especially that of its fishes. When the river is low and the power plants are idle, the water accumulates quickly in reservoirs above the dams, leaving a shrunken stream below, thus stranding and killing large numbers of fishes, especially the younger ones. As the entire flow of the river goes through these power plants during most of the year, the fishes which try to pass them are almost always killed, or injured so that they die from wounds or later fungous infection.

The stream is frequently tormented also in late winter and early spring, by great ice gorges, 10 to 40 feet in depth, which break loose before the dammed-up waters and plow their way downward, trapping and killing many fishes between the ice and the shores and bottom. One such gorge of unexampled depth and size crushed and ruined our cabin boat last spring. Great quantities of fishes are sometimes lost by the spread of the waters over the bottoms above the ice dams and their sudden recession, leaving the fishes in them stranded, when the barriers give way.

The principal items of our equipment for the Rock River work, mainly transferred from the Illinois as we were leaving it, were a cabin boat, 15 by 30 feet, a 24-foot gasoline launch, two flat-bottom skiffs, 16

and 18 feet in length, with a 4-horsepower outboard motor, four seines of various mesh and of lengths from 10 to 300 feet, a trammel net, common hoop nets, dip nets of several sizes, fish spears and assorted tackle for hook-and-line fishing, a beam trawl, a quantitative bottom sampler, a naturalist's dredge, a mussel dredge, two crow-foot mussel bars, a plankton net, and a Juday-Foerst centrifuge. We have also used an automobile and its trailer for cross-country travel between small streams and for the transportation of a skiff and the necessary light apparatus.

With this equipment and a party of three or four men in the field with Dr. David H. Thompson in charge, working steadily each year through the spring, summer, and early fall, with occasional visits in the winter also, collections have been made (and data secured from them) amounting in round numbers to 90,000 fishes belonging to 90 species of the 151 species occurring in the state; 2,400 stomachs of fishes, the contents of 1,100 of which have been analyzed and studied; 15,000 river mussels belonging to 40 species; 820 quantitative collections of the small invertebrates of the bottom fauna, among which 300 species have been identified; and 500 collections of plankton and algae, about half the former taken with filter paper and the remainder with a plankton net of silk bolting cloth, except for a few concentrated by the centrifuge. Special attention has also been paid, by a botanist detached for the purpose from our plant disease survey, to the rooting plants of the river and its tributary waters. Records have been entered as frequently as necessary of water temperatures, rates of flow, turbidity, percentages of dissolved oxygen, of acidity or hydrogen ion concentration, and of biological oxygen demand; and a multitude of data of observation and experiment of kinds too miscellaneous for convenient classification have been entered in the field notes. The permanent collections have all been shipped to the laboratories in Urbana, where their contents have been assorted, determined, and studied by another group of two to four men of whom Mr. Richardson was chief. Our expenses since the work was fully organized have averaged about $10,000 a year, of which $7,280 was for salaries and wages and $1,450 for purposes classed as travel.

Significant data concerning the basic elements of productivity in the river as shown by its plankton and small bottom invertebrates have been assembled and generalized, and I give a few examples. Taking the weight of the total nitrogen contained in the bodies of the plankton obtained by use of the centrifuge, as a measure of the richness of the water of Rock River in elementary fish food, surprisingly high results were obtained in August, 1925, normally a time of low production in rivers. The figures ran to more than twenty times the largest quantities obtained by Juday in August and September in Lake Mendota in Wisconsin, and more than three times the largest obtained in the same lake in *any* month, including the months of the spring maxima. General indications are that the Rock River produces very much more plankton in a single year than could be utilized by a fish population many times as great as the river has ever contained. Valuations of the small bottom fauna in pounds

per acre for the year 1925 gave us the richest yield where small rocks were the principal constituent of the bottom. The figures there ran to over 700 pounds per acre made up largely of May-fly larvae which hide under stones, a situation difficult of access to hungry fish, which fact doubtless accounts in part for the extraordinary abundance. In the mud-bottom sections of the river, on the other hand, the poundage per acre in 1925 ran only slightly over 300 pounds, to be compared with 2,693 pounds per acre given by an exceptionally rich mud-bottom section of the Illinois River in 1915. The largest items in the mud-bottom sections of the Rock River were large burrowing May-fly larvae and small oligochaete worms.

We notice a striking decline in the abundance of the plankton both in the Rock and Illinois rivers as we go down stream. For example, in August, 1921, the numbers per cubic meter of water for the upper part of the Rock in Illinois (Beloit to Dixon) were to those in the lower part (Sterling to Colona), as follows:

Diatoms	1.11 to 1
Other algae	8.7 to 1
Protozoa	7.6 to 1
Rotifers	2.4 to 1
Entomostraca	4 to 1

Similarly, in the Illinois we found in May, 1899, that the entire plankton measured, in volumes, 1.77 parts per million of water for the section from Peoria south to Liverpool (35 miles) and 0.12 p. p. m. for the section from LaGrange to the mouth of the river (56 miles), being thus nearly 15 times as abundant in the middle region of the stream as in its lowest part. To this fact I can only call attention here without attempting an explanation of it, as the subject is so complicated that a full discussion of it would take too much of the time allotted to this paper.

The more fundamental elements of the nutrition of fishes are the algae, protozoa, and animal plankton, the algae and the protozoa serving mainly as a food to small invertebrates, including those of the plankton, which in turn is an indispensable food for the young of fishes of every description. An accessible abundance of these elements is thus a preliminary requisite in aquiculture, and this fact at once raises the question as to what constitutes an accessible abundance of them in the various seasons and in any given situation.

Those algae and protozoa which are not themselves parts of the plankton are easily enough dealt with, for they are stationary in their habit, and if they are continuously and uniformly numerous in collections at times and places when and where they are needed, this is sufficient evidence that the supply is adequate, except as they may be so situated as to be inaccessible to the organisms requiring them. The case is somewhat different, however, with the plankton of a flowing stream, for as this is always being carried downward by the current, the supply at any one place is dependent on its receipts from above, and a local surplus may be followed by a scarcity farther down unless the rate of multiplication of its constituent

organisms is sufficient to replace the losses from normal death and from depredation incurred on the way. On this account the plankton of a river system must be studied as a whole, including sources and tributaries of every description, and the complex data of abundance thus obtained must be everywhere correlated with all the local demands. The plankton of that expansion of the Illinois River which is called Peoria Lake, is, for example, enormously superabundant, as has been already noted, and its constituent organisms seem to multiply there at a prodigious rate, but we must go beyond it down to the mouth of the stream and outward into the associated waters before we can pass judgment on the competency of the supply for the river system as a whole, and if it is anywhere found inadequate, we must study ways and means for its enlargement.

One of the novelties in the ecology of fishes discovered by us in Rock River was an epidemic infestation, in winter only, of a single species of buffalo fish by a single species of leech, an occurrence of the winter of 1925 and 1926 wholly unexampled within the knowledge of the oldest fishermen and never seen by us in any other stream. Nearly every redmouth buffalo caught was infested by leeches varying in number from two to fifty and averaging about twenty to each fish, with a notable lowering of the market value of the fish. The details are given in an article by Dr. Thompson, published as a recent Survey bulletin.

This is the place to mention also a *new disease* of the European carp, quite general and very injurious in the middle section of the Illinois River, but diminishing and finally disappearing down stream. It is wholly unknown in Rock River, a difference between the streams which confirms our inference that it is due to the pollution of the Illinois by sewage. It affects the fish from the fingerling stage upwards, reduces its rate of growth by about one-half, causes deformities, especially of the head, from which it gets the common name of "knot-head", embarrasses respiration, and apparently impairs metabolism in nearly every part of the body. We know, however, of nothing to indicate that the food value of carp so affected is in any way impaired. Our only present evidence that this disease is produced by sewage pollution is a complete coincidence in the distribution of the two, and parallel variations in their intensity. An exhaustive study of this disorder is now being made by us, and a bulletin on the subject amply illustrated will soon be ready for distribution.

There are several other parts of our program on which I have not the time to report, but I hope that this sketchy outline of our objects and operations and these few samples of our product may serve to give some general idea of the kind and value of the materials which the survey biologist offers to the aquiculturist. They seem to me to be not very unlike the materials which the soil surveyor and the crop specialist give to the agronomist and through him to the actual farmer; but their assortment, selection, and practical application is altogether a different matter from their accumulation, and calls for a liaison agency now non-existent in Illinois—one competent to sift out from our bulletins and reports the facts, generalizations, inferences, and speculations even, which may

be brought to bear on aquiculture as an art, and so to rearrange, assimilate, and present them as to bring them within the reach and comprehension of the fisherman, the fish culturist, the conservation office or department, and the legislative committee on fish and fisheries.

Agriculture *has* that kind of middle man in the county farm adviser, who must be an agricultural college graduate competent to prepare and pass on to the farmer the experiment station product in predigested form; and these farm advisers are useful also to the college and the station in bringing to their better knowledge practical problems still to be solved, and the need of a closer adaptation of the college teaching to the essential operations of the farm; but I know of nothing in the field of aquiculture, in this country at least, at all corresponding to this machinery of practical education. Without it the harvest of our biological researches, however well chosen our objects and sound our methods may have been, fails to reach the ultimate consumer, and with this failure at a critical point everything else fails which has preceded it. So my conclusion to this brief paper may be taken as an introduction to another topic which I can not now discuss but which I wish might be found to lie within the province of this committee, or if not, of some other agency toward whose creation our organization might profitably lend its advice and cooperation.