We may be sure, however, that these questions will be very slowly answered, since they open the most complex questions of lake life and those most difficult of solution. We know enough already to be confident that general statements regarding the relation of littoral and limnetic regions are very unsafe. It is true that lakes with steep banks are plankton-poor, yet it does not follow that lakes with large littoral areas are correspondingly rich in plankton. It certainly is not true that lakes are poor in plankton in proportion to their depth, so that even these most simple relations between the shore regions and the deeper water require careful and extended study in order that any safe conclusions may be drawn.

I have contented myself with pointing out a few of the directions in which limnology needs to move if the stock of facts which limnologists are accumulating is to receive an adequate interpretation. In order that such a result may be reached in the future, it is necessary for the student of lakes to propose to himself definite questions and to work as definitely toward their solution. The time has passed when the publication of the limnetic species, or even the quantitative determination of the constituents of plankton can materially further the advance of science. This work was useful, chiefly in disclosing to us the problems of limnology. These are now before us, in part at least, and the time has come when the student of lakes must attempt to answer some of them.

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*A PRELIMINARY ACCOUNT OF SOME OF THE RESULTS OF THE PLANKTON WORK OF THE ILLINOIS BIOLOGICAL STATION.**

THE Illinois River drains an area of 29,000 square miles, is over 500 miles in length, and has at low water a fall of but 31 feet in the last 227 miles of its course. The low gradient is due to the fact that, in a part of its course at least, the present stream and its bottom lands occupy the bed of an ancient outlet of Lake Michigan. The present flood plain is but partially developed—the bank height rarely exceeding 15 feet—and overflows are frequent and extensive. Floods rise from 16 to 24 feet above low water levels, increasing the total extent of water area to over 700 square miles. The impounding action of the bottom lands, the low gradient, and the backwater from the Mississippi River combine to prolong the flood period. The stream at low water is from 500 to 1500 feet in width and three to 12 feet in depth, and by reason of the dams forms a series of slackwater pools with a sluggish current of about one-half mile per hour. The waters of the adjacent lagoons, bayous, and lakes are also shoal and attain a high temperature during the period of summer heat. The water is rich in organic matter being derived from the run-off and seepage of fertile prairie soil and is further fertilized by the sewage of a metropolis and of a score of smaller cities along its banks, in addition to the offal of extensive cattle-yards and large amounts of distillery wastes. Under these conditions it is not surprising that ammonia, nitrites and nitrates are present in excessive quantities. The high temperature and the abundance of nutrition thus favor the development of the aquatic flora and in sequence that of the aquatic fauna.

Quantitative investigations of the plankton have been carried on at somewhat regular and frequent intervals from June, 1894, to April, 1899, in a series of representative localities near Havana, Ill.; (1) the main stream; (2) Spoon River, a typical tributary; (3) Quiver Lake, rich in vegetation much of the time and fed by spring water; (4) Thompson's Lake, a large (6 × .5 miles) open lake, fed by the river and usu-

* Abstract of address in opening discussion on Methods and Results of Limnological work at meeting of Naturalists at Chicago, December 28, 1899.

ally free from vegetation; (5) Phelps Lake, an ephemeral body of water without vegetation; (6) Flag Lake, a large swamp, choked with vegetation, rarely drying up in the summer. At times of high water all these localities are submerged. The quantitative and qualitative examination of the collections, as yet incomplete, indicate the following more or less tentative conclusions:

1. The waters contain a typical freshwater plankton, that is, one composed of limnetic organisms usually cosmopolitan and identical with or closely related to the plankton organisms of larger bodies of water. It has much in common with the plankton of German streams, and at low water is remarkably like that of the Nile at a corresponding stage. The admixture of littoral forms in the open water of the lakes and in the river is surprisingly small in the number of individuals, though presenting a considerable range of species. In all about 500 different species have been found, of which at least one-third may be called limnetic.

2. There is a marked seasonal variation in the amount of the plankton. A spring maximum, usually in May or June, follows the winter minimum and is in turn followed by an apparent mid-summer minimum in August. An autumn maximum of secondary importance precedes the return to the winter minimum. These statements are based, as usual, upon catches made with the silk net and are subject to the error arising from the leakage of the smaller organisms through the silk. The correction of this error by supplementary methods tends to eliminate the summer minimum and to augment the autumn maximum. The volume of plankton in the spring maximum is from 20 to 50 times that of the winter minimum. These fluctuations are repeated from year to year, but vary in time of appearance, in extent, and in relative development in successive years and in different waters. Irregular fluctuations also of great extent may occur in any locality especially during the summer and fall.

3. There is a marked seasonal variation in the organisms composing the plankton. During the winter minimum the chlorophyll bearing forms are relatively few, the plankton being composed of a few hibernal and a smaller number of perennial species principally of Rhizopoda, Copepoda and Rotifera. The presence of ice on the surface, and the low temperature of the water (0°–4° C.) do not interfere with the growth and reproduction of this winter plankton. Fouling of the water by an excess of sewage under the ice may, however, exterminate the animal life of the water. As the temperature rises, the brown flagellates and the diatoms increase in number and subsequently the green flagellates and other chlorophyll-bearing organisms multiply rapidly. This is accompanied by a marked development of animal forms, especially Cladocera and Rotifera, resulting in the spring maximum. This culmination is rarely due to the excessive development of a single species, but is typically polytonic. A rapid decline of the vernal species, principally Entomostraca and diatoms, produces the midsummer minimum, characterized by the relatively small number of individuals, and the very large number of species, principally Rotifera and the smaller green flagellates. The autumn maximum appears after the equinoctial rains and is often composed in large part of Synchæta, Synura, and diatoms. This is also the period of maximum numbers of the ciliate Protozoa. The total number of species in the fall plankton is not large and the predominant forms are few.

No two years present throughout the same sequence of species in the same relative numbers. In some instances, species abundant in one year have not been found or have occurred but sparingly in other years. As a rule the numbers of individuals and their seasonal range are alike subject to considerable fluctuations from year to year. The qualitative differences in the plankton from season to season are due to the adaptations of different species to different seasonal conditions, especially in the matter of temperature, and the differences from year to year are perhaps to be correlated with the fluctuating environment.

4. At times of high water all plankton stations at which examinations have been made are in one continuous body of water, and the plankton is quite similar throughout, especially in spring floods. As the water recedes and the several lakes and the river emerge as distinct units of environment, the planktons are very quickly differentiated by the disappearence of certain species and the multiplication of others as seasonal changes progress, so that in a few weeks each locality presents its own peculiar assemblage of organisms. This phenomenon is repeated from year to year and occasionally several times in one year, depending on the fluctuations in the river levels. The different localities examined thus present at times of low water great local differences in the amount and constitution of the plankton, corresponding to contrasts in the environment, especially in respect to vegetation, source of water and temperature. The assemblages of organisms characteristic of a given locality, though varying somewhat, present many points of similarity from year to year.

5. Waters in which aquatic plants, such as *Ceratophyllum*, *Elodea*, *Naias*, *Potamogeton* and *Nymphœa* are abundant, are, in the localities examined, as a rule poor in plankton. The removal of the vegetation by wind and flood or by fishermen's seines is followed by an increase in the amount of plankton. The same lake may then be plankton-rich one year and plankton-poor the next, according to the amount of vegetation it contains. The phyto-plankton thus apparently replaces the coarser aquatic flora.

6. The local distribution of the plankton in lakes with somewhat uniform conditions of bottom, water supply, and vegetation is remarkably even, in so far as the volume of the plankton is concerned, the variation from the average falling within the 30 per cent. observed by Apstein in the lakes of northern Germany. The distribution of many species is far less uniform. In the river, except near the mouths of large tributaries the distribution of the plankton is even more uniform than it is in the lakes, the variation in the amount of the plankton from shore to shore is less than 10 per cent. Under even conditions the amount of plankton in the current of the river ($\frac{1}{2}$ to $2\frac{1}{2}$ miles per hour) varies but little from hour to hour and day to day—being often within 10 per cent. and rarely exceeding 20 per cent. at one point of observation at Havana. Catches made at intervals of 10 miles in the lower 220 miles of the river show a considerable uniformity in amount and constitution, except where modified by local conditions such as sewage on tributary waters.

7. The plankton of tributary streams is relatively very small in amount and is composed of a different assemblage of organisms. The immediate effect of tributary waters is to dilute the plankton. The river is thus a unit of environment with its own peculiar fauna and flora.

8. Flood waters quickly and profoundly affect both the amount and the composition of the plankton, diluting it and washing it rapidly away toward the sea and to a slight extent replacing it with the more or less sessile forms torn away by the current of the creeks and of the river itself. The silt of flood waters is often disastrous to many species of Entomostraca. The recovery in the volume of the plankton after floods is

usually rapid, the chlorophyll bearing organisms, especially the green flagellates appearing first, followed in turn by the animal plankton, Protozoa, Rotifera and Entomostraca. The resubmergence of the bottom lands doubtless starts anew encysted forms left by receding waters. In general the recovery from the flood culminates in a plankton maximum of greater or less importance, depending upon the season of the year and the extent of the flood.

9. Species present in great numbers are often extremely variable, as for example, *Brachionus bakeri*. The varieties are often local, or seasonal, but may also be coëxistent. Variation is often very great in the case of species reproducing parthenogenetically as the rotifer just mentioned, in other rotifers, in Daphnia and in Bosmina.

C. A. Kofoid.

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*MALARIA AND TUBERCULOSIS.**

The visit of certain English physicians to Italy during the Christmas vacation, was in some respects so remarkable as to make a full description of it of general interest. Commendatore Florio, a wealthy and beneficent citizen of Palermo, invited certain English physicians first to Rome, in order to see the work done by their Roman brethren in the investigation of malaria; and, secondly, to Palermo, to inspect a sanatorium for the cure of consumption which Commendatore Florio has erected under the advice of Professor Cervello, of the University of Palermo. The party of English physicians with their friends was about twenty in number, among them being Sir T. Lauder Brunton, Sir Walter Foster, M.P., Professor Clifford Allbutt, of Cambridge, Dr. Manson, C.M.G., and Dr. Cantlie, of the London Tropical School. Dr. Malcolm Morris and Dr. St. Clair Thompson represented the National Association for the Prevention of Tuberculosis, and Dr. Gibson represented Edinburgh. They were received at Charing-cross Station by Commendatore Florio's representative and travelled with him to Rome, where they remained for some days in conference with Professors Grassi, Bignami, Celli, and Bastianelli. Signor Grassi, now Professor of Zoology in the University of Rome, is a Sicilian, and while a professor at Catania carried out the remarkable researches on the propagation of the eel which secured for him the Darwin Medal of the Royal Society.

Professor Grassi, since his removal to Rome, has performed work perhaps no less remarkable in demonstrating the propagation of malaria. This story is not only so interesting in itself, but of such vital importance to our own colonies, some of which are desolated by malaria, that I will try to sketch briefly what will be told in full by Professor Grassi in an illustrated volume to appear very soon both in Italian and English. A few years ago M. Laveran won a place for himself on the distinguished roll of Frenchmen of science by discovering in the blood of malarious patients a minute parasite, a form belonging to the humblest order of animal life. Three different but closely allied species of parasite are severally concerned in the causation of the three kinds of malarial fever. M. Laveran's researches were fully verified by observations both in Europe and in America, and further observations made of their behavior in man. Certain suggestive facts led Dr. Manson to suspect that a gnat or gnats were the means of propagating the parasite, and, having himself returned from the tropics, he pressed Major Ross, then of the Indian Medical Service, to follow up this clue in India. Himself an ardent engineer and now chief of the Liverpool Tropical School, Major Ross set to work with some success, but unfortunately his efforts were impeded by

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