XIII.—THE FIRST FOOD OF THE COMMON WHITEFISH.

(*Coregonus clupeiformis, Mitch.*)

By S. A. Forbes.

In a very large lake the conditions of life are remarkably uniform. The volume of water remains, of course, constant from season to season and from year to year, and the extremes of summer heat and winter cold have but a moderate effect upon the temperature of the lake as a whole. Consequently both plant and animal life exhibit there a regularity and stability which are in remarkable contrast to their fluctuations in smaller bodies of water and on the surrounding land. Not only do the relative numbers of individuals in the various species remain about the same, but the absolute number of each must necessarily change but little, as a rule.

Such a state of affairs is eminently favorable to an exact and *economical* balance of supply and demand, of income and expenditure, of multiplication and destruction, among the inhabitants of the lake. Here every species of animal, whether predaceous or vegetarian, must find, in the surplus products of growth and reproduction among the species upon which it depends for food, a far more constant and unvarying supply for its needs than elsewhere; and the species fed upon must be subject to a far more regular drain upon their surplus numbers or unessential structures. Where there is little fluctuation there is little waste.

A system of life like this, running on with relatively even tenor for centuries, must of course be much less *flexible* than one where wide and violent fluctuation and continual readjustment are the rule; and a species in any way deeply affected will here have within itself far less recuperative power than one which has been forced again and again—each year, perhaps—to rally against the most destructive attacks as the price of its continued existence. Disturbances of the natural balance of life, of the primitive and spontaneous system of reactions by which the different groups of organisms are related, will therefore be unusually serious and lasting; and where such disturbances result from human interference, as by the yearly capture of large numbers of any important fish, it is especially desirable that artificial means of compensation be taken to restore the disturbed balance as nearly as possible. Excessive loss will be made good by natural reactions far more slowly than if it occurred to a pond or river species, accustomed, as most of the latter are, to fill up rapidly enormous gaps in their numbers.

On the other hand, to multiply *unduly* by artificial measures any species naturally abundant in such a lake will have scarcely a less disturbing influence than to *diminish* its numbers in the same ratio. The relatively nice balance between the demand for food and food supply which here naturally obtains is such that an extraordinary increase in a species must soon react to diminish greatly its food resources—a fact which will then take effect on the species itself, reducing it below its natural original level; and if both excessive capture and excessive multiplication go on side by side we shall have this result finally aggravated to an extreme degree.

As fishes are caught before the end of their natural lives, but planted by the fish-culturist when young, it is evidently the food of the young which will be first and most seriously affected by overproduction. Only a part of the adults, perhaps a small fraction, will live a life of ordinary natural length, many being captured before they have attained even the average size; but a far greater number, perhaps nearly every one, must survive the earliest period and must consequently draw most heavily upon the earliest food resources of the species when these differ from those of the adult.

The above considerations are brought forward here to show the especial importance to us of a study of the system of natural interactions by which the animals of our great lakes affect each other, if we would avoid the necessarily injurious consequences of our own interference with the natural order there obtaining, and above all to show the extraordinary value of a knowledge of the food habits and food capital of the *young*. They apply perhaps more forcibly to the whitefish than to any other species in the lakes; because this is for several reasons the most important purely fresh-water fish of the Great Lake region, and proves to have a distinctly different food when young from that upon which it is dependent later.

According to the recent census report,* more than twenty-one million pounds of whitefish were taken in the Great Lakes in 1879, valued at over three-quarters of a million dollars, and representing nearly half the total sum derived from the lake fisheries of all kinds. These fisheries employ over five thousand men, and a fixed capital of one million three hundred and forty-six thousand dollars. When we reflect that this enormous drain upon the number of the species is necessarily, to a considerable extent, an addition to the natural tax levied upon it by its enemies other than man, we see that there must be an artificial supply provided, or the fisheries will gradually fail.

The importance of the knowledge of the food of so valuable a species needs no demonstration, especially when we consider that, consistently

*Census Bulletin No. 261, September 1, 1881.

with what has been said above, it may not be difficult to overdo the work of propagation.

If the whitefish were to be multiplied indefinitely, without any attention to the character or abundance of its food supply, it would soon reach such a number that it must infringe upon its own food capital, diminish the average number of the animals upon which it depends for subsistence, and so finally indirectly cripple itself. Then the money and labor expended in its culture would be principally lost, and the last state of the species would be worse than the first. An acquaintance with the food of the young is especially necessary, because they are planted by the fish-culturist when, having already absorbed the egg-sack (the supply of food by which they are under natural conditions supported until they have time to scatter themselves widely through the water), they are in a peculiarly helpless condition, unable to wander far in search of subsistence, and compelled to find food speedily or perish. One would say, therefore, that their alimentary resources and habits should be well and thoroughly known, that the range, period, and abundance of the organisms upon which they feed should be carefully determined, and that each locality where the young are deposited should be closely searched for the purpose of ascertaining whether their food species occur there at the time in sufficient quantity to prevent immediate starvation.

Previous studies of the food of young fishes of a variety of families, reported in the third paper of this series, had shown that, with exceptions presently to be mentioned, the earliest food of all the families studied consisted almost wholly of various species of Entomostraca and some equally minute and delicate dipterous larvæ. When that paper was prepared, I had, however, no opportunity to study the food of the young of any members of the family Salmonidæ, to which the whitefish belongs, neither could I learn that any such studies had been made by others; and I could only infer the same fact with regard to this family from the general character of the results obtained by the study of the other groups. Even this inference, however, was rendered doubtful by the discovery that the youngest individuals of two of the toothless families (Catostomidæ and Cyprinidæ) were not strictly dependent upon the food elements above mentioned, but were likewise able to draw upon much smaller organisms, namely, the minutest Protozoa and unicellular Algæ; and as the adult whitefish is likewise destitute of teeth, it was not by any means certain that their young would not fall under the latter category. Upon looking up the literature of the subject, I found that, although the food of the adult had been very well made out in a general way,* only two items had been published respecting the food of the young. In the report of the United States Fish Commission for 1872-'73, an assistant commissioner, Mr. J. W. Milner, made some experiments on young whitefish hatched artificially, sup-

* Report of the United States Fish Commission for 1872-'73, pp. 44-46.

plying them with a number of articles of food, in the hope of finding something suitable for their nourishment.

"A few crawfish," he says, "were procured and pounded to a paste, and small portions put into jar No. 1; the young fish ate it readily. They were fed at night, and the next morning every one of them was found to be dead. Jar No. 2 was supplied with bread crumbs, and the fish were seen to take small particles in their mouths; they did not die so suddenly. Jar No. 3 was supplied with sweet cream, but no evidence was afforded that the occupants fed upon it. A quantity of rain-water was exposed to the rays of the sun for the purpose of generating minute forms of life, and a teaspoonful was poured into jar No. 4, morning and evening, in the hopes that their proper food was of this character. In jar No. 5 a variety of food was provided—dry, fresh beef, milk, boiled potato, and bread. The crumbs of bread and the scrapings from the beef were all that the fish were seen to take into their mouths. They died, one after another, very rapidly, and in a few days all were dead." He further remarks: "This difficulty of procuring a suitable food for the young whitefish has been the experience of the few fish-culturists who have hatched them."

With the hope of ascertaining the natural food of these fishes, a few specimens, representing young captured in the Detroit River, and others from the hatchery, were submitted by Mr. Milner to Mr. S. A. Briggs, a microscopist, of Chicago. Four examples were examined by Mr. Briggs, two from each of the above situations. Those from the hatchery contained nothing whatever, while those from Detroit River contained numerous specimens of two species of Diatomaceæ, viz, *Fragilaria capucina* and *Stephanodiscus niagaræ*. The only fact at that time known would consequently indicate that the earliest food of the species consisted of Diatomaceæ.

The whitefish, as is well-known, lays its eggs in the open lake in autumn, the young not appearing until early in the following spring. At this cold and stormy season, in the exposed situations where they are to be sought it is practically impossible to find the young fish; a fact which rendered the study of their earliest food a subject of unusual difficulty. There seemed, in fact, no practicable way to reach satisfactory conclusions upon it except by experiment upon individuals artificially hatched.

In December, 1880, I made an arrangement, through the kindness of Professor Baird, of the Smithsonian Institution, with Mr. F. N. Clark, superintendent of the United States fish hatchery at Northville, Mich., for a supply of young whitefish to be sent me at intervals from the hatchery under his control. The specimens furnished were taken from two lots. The fishes of one lot, hatched January 18, were kept in a tank in the hatchery, where they were supplied with water from a spring, which had been cooled by exposure to the air in artificial ponds before entering the hatchery, in order to retard the development of the fry. The ordinary range of temperature in the tank was from 35° to 39°. These fishes were fed daily with a paste made by grinding small amphipod crustaceans (Gammarus) in a mortar.

The second lot, hatched January 20, was kept, unfed, in a perforated tin box, in a rivulet flowing from a spring, about 60 feet from its source. The water had a uniform temperature of 47°.

Those in the spring, being in warmer water than the others, developed much more rapidly, and it was believed that the character and source of this water was such as to furnish them at least a small supply of such food as young fishes are accustomed to appropriate.

Ninety specimens were received from the hatchery February 9, at which time they were three weeks old. They were thirteen mm. (half an inch) in length by one in depth. The egg-sac was but partially absorbed in most of the lot, but in those most advanced was represented by an oil globule back of the head. The pectoral fins were well developed, but no trace of the ventrals had as yet appeared. The single median fin extended well in front of the vent, and forwards on the back nearly to the head. The opercles did not fully cover the gills. The most highly developed specimens—those whose gill-sacs had nearly disappeared—had, at a short distance on either side of the symphysis of the lower jaw, a sharp, strong, raptatorial tooth, curved backwards and slightly inwards. The base of this tooth was very broad, and the point acute and slender. At a point behind each of these teeth, about half their distance from each other, was a second much smaller tooth, directed almost exactly inwards. The upper jaw was, however, wholly toothless.

These fishes were all passed under the microscope, after having been rendered transparent, but only four of them contained anything whatever; three a little dirt, and the fourth a minute fragment of the crust of the Gammarus, with which they had been fed.

Of one hundred and eleven specimens received February 17, seventeen had taken food. I dissected nine of these and found fragments of Gammarus and nothing else. Ninety specimens from the same lot were examined February 25, and food was found in fourteen. Four of these had eaten Gammarus fragments; two, larvæ of gnats; one, a small Cypris, and eight contained small fragments of the leaves and stems of vascular plants, including a bit of a netted-veined leaf and a little piece of pine wood. Thirty-nine specimens, the last of the lot, were received March 15, and food was found in fourteen. I dissected nine of these, finding fragments of Gammarus in four, a larva of a gnat, a Chironomus larva, a larva of some undetermined fly, a minute vegetable fragment, a Cyclops, a Cypris, and an undetermined Entomostracan each in one. Three hundred and forty fry from the hatching-house were examined in all, in forty-seven of which (fourteen per cent.) more or less food was discernible. Of the thirty-five dissected, eighteen had eaten Gammarus fragments; five, minute insect larvæ; four, Entomostraca, and eight, small particles of vegetation.

Only four lots were received from the spring, on the 9th, 14th, 17th, and 25th of February, after which all died of starvation. In the first hundred only one was found which had taken food, and this had eaten a trace of filamentous Algæ and a minute fragment of the parenchyma of some higher plant, with a few diatoms. But one of the second hundred contained even a trace of food, a minute quantity of some thread-like Alga, the cells of which still contained a little chlorophyll. In the third hundred likewise, food was found in but one. This consisted of a few particles of vegetable parenchyma, doubtless derived from the decaying plant structure in or around the water. In the third lot of only forty-two specimens, six showed traces of food, consisting almost entirely of a few filamentous Algæ (including a fragment of Oscillatoria) and a little vegetable parenchyma. Desmids and diatoms were observed in trivial numbers.

The total number received from the spring was two hundred and forty-two, of which but eight were found to have eaten anything (a little over three per cent. of the whole), and these had taken only Algæ and vegetable fragments.

An example of the water of the spring sent me contained many Algæ but no animals larger than rotifers. The water of the hatchery, being exposed in ponds of considerable size, afforded a better opportunity for the development of animal life, to which fact was doubtless due the occurrence of insect larvæ and Entomostraca in the intestines of the fishes reared in it. The situation of the spring, on the other hand, was particularly unfavorable, as it was under the hatchery, and consequently in the dark.

The observations above described on the specimens kept in spring water have but little value, for the reason that evidently very little food was contained in the water flowing through their cage. The vegetation in the streams being chiefly filamentous Algæ and the number of Entomostraca apparently trivial, very little of either vegetable or animal food could reach the little prisoners. It is not surprising, therefore, that, notwithstanding their greater age and the higher temperature of the water in which they were kept, a much smaller ratio of the specimens had taken food than of those captured in the hatchery. From the contents of their intestines we can only infer that these fishes, reduced to a desperate strait by starvation, will snatch at almost anything contained in the water. The result obtained by a study of those from the hatching-house was more significant, but still unsatisfactory. It seemed to indicate that in confinement whitefish fry will feed upon both animal and vegetable structures to some extent, and that they can be induced to take minute fragments of the higher crustaceans, but not in sufficient quantity to keep them alive. The fact that animal food was more abundant than vegetable in this last lot indicates nothing of their natural preference, since it was doubtless also more abundant in the water containing them.

More light was thrown upon the earliest food habits of these fishes by the discovery of raptatorial teeth upon the lower jaw than by these dissections of their alimentary canals. All the families of fishes which I had previously studied, whose young were provided with teeth, were found strictly dependent at first upon Entomostraca and the minuter insect larvæ; while only those whose young were toothless fed to any considerable extent upon other forms. The discovery of teeth in the young whitefish, therefore, placed this species definitely in the group of those carnivorous when young. The fact that the adult was itself toothless interfered in no way with this inference, because other toothless fishes (Dorsoma) whose young were furnished with teeth had been found carnivorous at an early age.

The inconclusive character of the results thus far obtained made it necessary to attempt to imitate more closely the natural conditions of the young when hatched in the lake. In February, 1881, I obtained, through the kindness of Mr. Clarke, twenty-five specimens of living young whitefish, saved from a lot which he was planting in the waters of Lake Michigan, off Racine, Wis. I succeeded in conveying these to the laboratory without loss, and there kept them for several days in a glass aquarium and supplied them with an abundance of the living objects to be obtained by drawing a fine muslin net through the stagnant pools of the vicinity. These consisted of many diatoms and filamentous fresh-water Algæ, of two or three species of Cyclops, of *Canthocamptus illinoisensis*, and *Diaptomus sanguineus* among the Copepoda, and of two rather large Cladocera, *Simocephalus vetulus* and *S. americanus*. These little fishes were kept under careful observation for several days, the water in the aquarium being frequently aerated by pouring. Many of them had, however, been injured by handling, and eleven of the specimens died without taking food. It was soon evident that the larger Entomostraca (the Simocephalus, and even the Diaptomus) were quite beyond the size and strength of these little fishes, and that only the smaller Copepoda among the animals available could afford them any food at first. These they followed about from the beginning with signs of peculiar interest, occasionally making irresolute attempts to capture them. Two days after their arrival, one of the young whitefish had evidently taken food, which proved, on dissection, to be a small Cyclops. During the next two days nine others began to eat, dividing their attentions between the Cyclops above mentioned and the Canthocamptus, and on the 22d two others took a Cyclops each and a third a Canthocamptus. One of these fishes contained still a large remnant of the egg-sac, showing that the propensity to capture prey must antedate the sensation of hunger. On the 25th the fourteenth and last remaining fish captured its Cyclops and was itself sacrificed in turn. As an indication of the efficiency of the raptatorial teeth, it may be worth while to note that I saw one of the smallest fishes make a spring at a Cyclops, catch it, give three or four violent wriggles, and drop it dead to the bottom of the tank.

As a general statement of the result of the observations made on these fourteen fishes, we may say that eight of them ate a single Cyclops each, that one took two, and another three of the same, that one took a single Canthocamptus, that two specimens captured two each of this genus, and that finally a single fish ate Cyclops and Canthocamptus both. The final conclusion was a highly probable inference that the smallest Entomostraca occuring in the lake would prove to be the natural first food of the species.

In order to test this conclusion with precision, I arranged a similar experiment on a larger scale and under more natural conditions. Through the generosity of the Exposition Company, of Chicago, I was allowed the use of one of the large aquarium tanks in the exposition building on the lake shore, and by the repeated kindness of Mr. Clarke, of Northville, Mich., I was furnished with a much larger number of living whitefish. Five thousand fry were shipped to me in a can of water, but through unfortunate delays in changing cars at intermediate points, about two-thirds of these were dead when they reached my hands. Those living were immediately transferred to the tank through which the water, taken from the city pipes, had already been allowed to run for several hours. As this water is derived from Lake Michigan at a distance of two miles from the shore, and had at this time the exact temperature of the open lake, the conditions for experiment were as favorable as artificial arrangements could well be made.

Sending a man with a towing net out upon the lake with a boat, or upon the remotest breakwaters, immense numbers of all organic objects in the water were easily obtained. After inclosing the exit of the tank with a fine wire screen, to prevent the escape of objects placed in it, we poured these collections of all descriptions indiscriminately into the water from day to day, thus keeping the fishes profusely supplied with all the various kinds of food which could possibly be accessible to them in their native haunts. From this tank one hundred fishes were taken daily and placed in alcohol for dissection and microscopic study, to determine precisely the objects preferred by them for food. These were examined at a later date, and all contents of the intestines were mounted entire as microscopic slides, and permanently preserved. A careful study was of course made of the organisms of the lake, as shown by the product of the towing net, and when the experiment was finally ended an equally careful examination followed of the living contents of the water of the tank at that time.

These fishes, like those previously described, had already reached the age and condition at which it is customary to "plant" them in the lake. The ventrals were still undeveloped, the egg-sac had nearly disappeared, the four mandibular teeth were present, and the median fin extended from the tips of the pectorals on the belly to a point opposite the middle of the same fins on the back. In most the egg-sac did not protrude externally, being reduced in some to a droplet of oil, but remaining in a few of a size at least as great as that of the head. The alimentary canal was, of course, a simple straight tube, without any distinction of stomach and intestine.

The sufferings of these fry in transit had doubtless weakened the vitality of the survivors, and although every care was taken to keep the water of the tank fresh and pure, about one-third of those remaining died during the progress of the experiment. The aquarium in which they were confined was built of glass, and had a capacity of about one hundred cubic feet. The temperature, tried repeatedly, stood at 42° F. A steady current of the water of the lake was maintained through this tank, entering through a rose, from which it fell in a spray, thus insuring perfect aeration.

By far the greater part of the organic contents of the water of the lake, as shown by the product of the towing-net, consisted of diatoms in immense variety, which formed always a greenish mucilaginous coating upon the inner surface of the muslin net. In this were entangled a variety of rotifers, occasional filamentous Algæ, and many Entomostraca, the latter belonging chiefly to the genera Cyclops, Diaptomus, and Limnocalanus among the Copepoda, and to Daphnia among the Cladocera.

As the Entomostraca proved to be far the most important elements of this food supply, the particulars respecting them may be properly more fully given. The smallest of all was a Cyclops, then new, but since described by me under the name of *Cyclops thomasi*.* This little Entomostracan is only .04 inch long, by .011 wide. The next in size, and by far the most abundant member of this group, was a Diaptomus, likewise new, described in the paper just cited, under the name of *Diaptomus sicilis*. This appears in two forms, one evidently young in the stage just preceding the adult. Full-grown individuals were .065 inch long by one-fourth that depth. The Limnocalanus was a much larger form, evidently preying, to a considerable extent, upon the two just mentioned. All the Cladocera noticed were *Daphnia hyalina*, an elegant and extremely transparent species, occurring likewise in the lakes of Europe. A single insect larval form (Chironomus) should likewise be mentioned in this connection, since it had about the same size and consistence of the Entomostraca, and was consequently equally available for food.

The specimens of each of the above species from a certain quantity of these collections were counted, in order to give a definite idea of their relative abundance in the lake. The Diaptomus numbered 225, the Cyclops 75, Limnocalanus 7, Daphnia 3, and Chironomus larvæ 1.

* On some Entomostraca of Lake Michigan and adjacent waters. American Naturalist, Vol. XVI., No. VIII, August, 1882, pp. 640 and 649.

It was a curious fact, however, that when the water was drawn off at the end of the experiment, more than half the Entomostraca were Limnocalanus; a fact partly to be explained by the predaceous habit of the latter, and partly by the facts relating to the food of the fishes themselves, which are presently to be detailed.

The fry were placed in the tank and supplied with their first food on the evening of the 12th of March. On the 14th, one hundred specimens were removed, and twenty-seven of these were dissected. Twenty were empty, but the remaining seven had already taken food, all Cyclops or Diaptomus. Three had eaten Cyclops only, and six Diaptomus, while two had eaten both. Fourteen of these Entomostraca, seven of each genus, were taken by these seven fishes. From those captured the next day, twenty-five specimens were examined, of which nineteen were without food. Of the remaining six, three had eaten Diaptomus and three Cyclops; five of the former being taken in all, and ten of the latter. Three specimens were next examined from those caught on the 19th of March, two of which had devoured Diaptomus and a third a single *Cyclops thomasi* and a shelled rotifer, *Anuræa striata*. The character of the food at these earliest stages was so well settled by these observations that I deemed it unnecessary to examine the subsequent lots in detail, but passed at once to the specimens taken on the 23d. Twenty-six of these were examined, and found to have eaten thirty three individuals of *Cyclops thomasi*, fourteen of *Diaptomus sicilis*, and fourteen of the minute rotifer already mentioned (*Anuræa striata*). Two had taken a few diatoms (*Bacillaria*), and one had eaten a filament of an Alga. Cyclops was found in sixteen of the specimens, Diaptomus in nine, and Anuræa in eight, only two of them being empty. The amount of food now taken by individual fishes was much greater than before, one specimen dissected having eaten two Cyclops and six *Diaptomus sicilis*, male and female. Another had taken five Cyclops, one Diaptomus, and five examples of *Anuræa striata*. Still another had eaten four of the Cyclops, four Diapotomus, and one Anuræa.

Twenty five specimens were examined from those removed on the 24th of the month, at which time the water of the tank was drawn off and all the remaining fishes bottled. Four of these had not eaten, but the twenty-one others had devoured fifty specimens of *Diaptomus sicilis*, forty-seven of *Cyclops thomasi*, fourteen of *Anuræa striata* and a single *Daphnia hyalina*, the latter being the largest object eaten by any of the fishes. A few examples of their capacity may well be given. The ninth example had eaten six Diaptomus, two *Cyclops thomasi*, and one Anuræa; the tenth had taken eight Diaptomus, two Cyclops, and an Anuræa; and the twentieth, seven Diaptomus and three *Cyclops thomasi*. In two of these examples were small clusters of orange globules, probably representing unicellular Algæ.

Summarizing these data briefly, we find that of the 106 specimens dissected sixty-three had taken food, and that the ratio of those which were eating increased rapidly the longer the fishes were kept in the aquarium. Only one-fourth of those examined on the 14th of the month had taken food, while more than five-sixths of those bottled ten days later had already eaten. The entire number of objects appropriated by these sixty-three fishes was as follows: *Cyclops thomasi*, ninety-seven; *Diaptomus sicilis*, seventy-eight; *Anuræa striata*, twenty-nine; *Daphnia hyalina*, one. Seven of the fishes had eaten unicellular Algæ, two had eaten diatoms, and one filamentous Algæ.

From the above data we are compelled to conclude that the earliest food of the whitefish consists almost wholly of the smallest species of Entomostraca occurring in the lake, since the other elements in their alimentary canals were evidently either taken accidentally or else appeared in such trivial quantity as to contribute nothing of importance to their support. In fact, two species of Copepoda, *Cyclops thomasi* and *Diatomus sicilis*, are certainly very much more important to the maintenance of the whitefish in this earliest stage of independent life than all the other organisms in the lake combined. As the fishes increase in size, vigor, and activity they doubtless enlarge their regimen by capturing larger species of Entomostraca, especially Daphnia and Limnocalanus.

A few words respecting the relative abundance of these species at different seasons of the year and their distribution in the lake will have some practical value. We may observe here an excellent illustration of the remarkable uniformity of the life of the lake as contrasted with that of smaller bodies of water already referred to in the introduction to this paper. While in ponds minute animal life is largely destroyed or suspended during the winter, the opening spring being attended by an enormous increase in numbers and rate of multiplication, in Lake Michigan there is but little difference in the products of the collecting apparatus at different seasons of the year.* There is a slight increase in the number of individuals during spring and early summer, but scarcely enough appreciably to affect the food supply of fishes dependent upon them. They are not by any means equally distributed, however, throughout the lake, my own observations tending to show that there are relatively very few of these minute crustaceans to be found at a distance of a few miles from shore, and that in fact by far the greater part of them usually occur within a distance of two or three miles out. Indeed, the mouths of the rivers flowing into the lake are ordinarily much more densely populated by these animals than the lake itself, as has been particularly evident at Racine and South Chi-

*For definite assurance of this fact, I am indebted less to my own observations (which are, however, consistent with it as far as they go) than to the statements of B. W. Thomas, esq., of Chicago, who, while making a specialty of the Diatomaceæ of the lake, has collected and studied all its organic forms for several years, obtaining them from the city water by attaching a strainer to a hydrant many times during every month throughout the year.

cago. Neither are they commonly equally distributed throughout the waters in which they are most abundant, but, like most other aquatic animals, occur in shoals. In the deeper portions of the lake many species shift their level according to the time of day, coming to the surface by night, and sinking again when the sun is bright.

These facts make it important to the fish-culturist that the particular situation where it is proposed to plant the fry should be searched at the time when these are to be liberated, to determine whether they will find at once sufficient food for their support. A little experience will easily enable one to estimate the relative abundance of the Entomostraca at any given time and place, and they require nothing for their capture more complicated or difficult of management than a simple ring net of cheese-cloth or similar material, towed behind a boat. This may be weighted and sunk to any desired depth, so that the contents of the water either at the surface or at the bottom may be ascertained by a few minutes' rowing.

In conclusion, I wish again to express my great obligation to the United States Fish Commissoner, Prof. S. F. Baird, and to Frank N. Clark, superintendent of the United States hatchery at Northville, Mich., through whom, as already stated, the specimens were derived upon which these studies were made. My best thanks are also due to the Exposition Company of Chicago, and especially to their secretary, the Hon. John P. Reynolds, for the use of a tank in the Exposition building, and for many courtesies received while the experiment there was in progress.