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THE PLANKTON

OF

Lake Winnebago and Green Lake

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CHAPTER I.

OUTLINE OF STUDY.

The attempt in this investigation has been to make a comparative study of the plankton of two lakes of different types, with a collateral study of such other lakes as could be easily reached.

It was thought that if, after a somewhat careful preliminary study, the plankton of the two lakes could be kept under observation for a considerable period of time, many facts in regard to the annual and geographical distribution of the animals and plants could be secured, and perhaps some generalizations could be reached in regard to the principles controlling such distribution.

LAKE WINNEBAGO AND GREEN LAKE.

Lake Winnebago was chosen for the type of the shallow lake mainly because of its importance from the standpoint of the production of fish. It is known to be an enormously productive body of water, and the fishing industry has employed a great many men in Oshkosh. Netting has been forbidden by legislative enactment for several years, and, in spite of many infractions of the law, it is generally acknowledged among all but interested parties, that the number of fish has greatly increased in that time. There is now hardly a better lake in the state for fishing for sport for some kinds of fish. The perch are especially large and handsome, and the black bass are numerous and gamy, although rarely exceeding three or four pounds in weight. Pike, too, are caught in large numbers, and white bass are abundant in the spring.

Lake Winnebago is some 28 miles long by 10 or 12 broad in its greatest width. There has never been an accurate hydrographic survey of the lake, but it is probable that it is nowhere over about 25 feet in depth. It is evident to a superficial observer that the plant life during the summer is very large, and it has been assumed that the abundant production of fish is correlated with the plant growth. The principal inlet of the lake, the Fox river, enters it about midway of the western shore, and leaves it as its outlet, at the northern end. Thus the lake may be considered simply as an expansion of the river.

Connected with the Fox and its principal tributary the Wolf, is a number of lakes and streams which receive the drainage of a large section of the northeastern part of Wisconsin, extending from the southern boundaries of Marquette, Green Lake, and Fond du Lac counties to the southern parts of Forest and Oneida counties.

Many of these lakes are merely expansions of the rivers, and although covering areas of considerable size, are for the most part very shallow. Lake Buttes des Morts, Lake Winneconne, Lake Poygan, and Lake Puckaway are the most prominent of these lakes; their shores are for the most part low and swampy, and their depth rarely exceeds 10 or 15 feet. There are a few deeper lakes in this drainage area: Stone lake is between 75 and 80 feet in its greatest depth; the Waupaca lakes, though small in area, are in some cases from 60 to 95 feet in depth, and Green lake, with a maximum depth of 237 feet, is the deepest lake in the state.

The deep lakes, as would be expected, are more distinctly cut off from the other parts of the drainage area than the shallow lakes. In the case of the shallow lakes, many open one into the other so that there is no distinct line of separation between them. It would be expected that this separation of the deeper lakes would have some effect on the character of their fauna and flora, besides the effect produced by the difference in environment.

The east shore of Lake Winnebago is, for the most part, high, and in some places rocky. At the south end the shore is swampy,—in fact it is rather difficult to distinguish between lake and shore. At this end the Fond du Lac river flows in, and there is a gradual encroachment of the shore line upon the lake. The west shore of the lake is low, but not, to any considerable extent, swampy, and is gradually being dotted over with summer cottages. At the north end of the lake are extensive sand beaches. The material of the lake shores is glacial drift, so that everywhere the shores are lined with boulders washed out of the drift by the waves.

The bottom of the lake is generally composed of a fine mud filled with organic matter. In many cases, however, a bottom of boulders extends quite a distance from shore. Off Stony Beach this rocky bottom extended perhaps a half a mile from shore, and then is succeeded by a mud bottom without any distinct change in depth. In other cases the bottom near shore is composed of sand or red clay.

Before this work was undertaken, very little was definitely known of the plankton of Lake Winnebago. Only occasional collections had been made. It seemed necessary therefore to make a continuous series of collections lasting over a considerable period in order to get a basis of comparison. It was necessary, too, that there should be an opportunity to examine the living collections, as many things are sure to be overlooked in preserved material.

Accordingly a summer station was established at Stony Beach, a small summer resort about two miles south of Oshkosh. Comfortable quarters were found in an old hotel building, the dining room being fitted up as a laboratory. The laboratory equipment and a working library were brought from Ripon College. A row boat was provided for the regular daily work, and, through the kindness of Mr. Chas. Schreiber of Oshkosh, we had the use of a sail boat for longer trips. Through the courtesy of Mr. M. W. Peck and Mr. D. Jack of Fond du Lac, we were provided with transportation in their gasoline yacht for an extended trip through Lakes Buttes des Morts, Winneconne, and Poygan. Acknowledgment should be rendered, too, for unnumbered services rendered by Mr. D. O. Fernandez of Oshkosh.

The location proved to be particularly convenient, as Stony Beach is reached by an electric line from Oshkosh and yet is so far removed from the city that under ordinary conditions it is not probable that this part of the lake is contaminated by the city sewage.

Systematic work on Lake Winnebago was commenced the fifth of July, 1899. During July and August, with the exception of a few days spent on other lakes, daily plankton collections were made at at least two locations. For these daily collections a station was selected about a mile from the shore on the muddy bottom common to all the deeper parts of the lake, and another nearer shore on the rocky bottom. This was with a two-fold object, first to have two stations some distance apart in order to get an average of plankton, and second to determine whether there was any decided difference in the plankton over the mud and over the rocky bottom, for the fishermen think that some fish have a decided preference for the stony bottom. Some days a considerable number of collections was made, the locations being widely distributed over the lake. During the summer the collections extended over a distance of some twelve or fourteen miles on the west shore of the lake; many were made in the central region of the lake, and some on the east shore.

A number of collections, for comparison, were made on other lakes synchronously with those on Lake Winnebago, my assistant remaining on that lake while I did the work at other locations. After the month of August the collections were kept up at intervals of about two weeks, the collections being made ordinarily at the two regular summer stations off Stony Beach.

These collections were continued through a period of two years and a half.

Collections at a similar interval of two weeks were also made on Green lake. Green lake was selected for comparative work, partly because of its convenient location, but mainly because its conditions are so different from those of Lake Winnebago.

Green lake is situated in Green Lake county, about 25 miles west of the southern end of Lake Winnebago. It is about 7¾ miles long, with a maximum width of 2 miles. Nearly the whole lake is over a hundred feet in depth, and the western part has a maximum depth of 237 feet. The shore slopes are, for the most part, very abrupt, only a small part of the shore being swampy. The waters of Green lake are exceedingly clear, rarely being markedly discolored by vegetable growths, while in Lake Winnebago during most of the year the water is much discolored. On account of the small depth of Lake Winnebago, storms disturb its water to the very bottom over most of its area, while in the depths of Green lake there is a large body of water which is never appreciably affected even by the severest storms. Because of its depth Green lake has a distinct "thermocline" during the summer months, and the water at the bottom has an annual range of temperature of only about ten degrees Fahrenheit. Lake Winnebago, on the other hand, has, during the summer, a nearly uniform temperature from top to bottom.

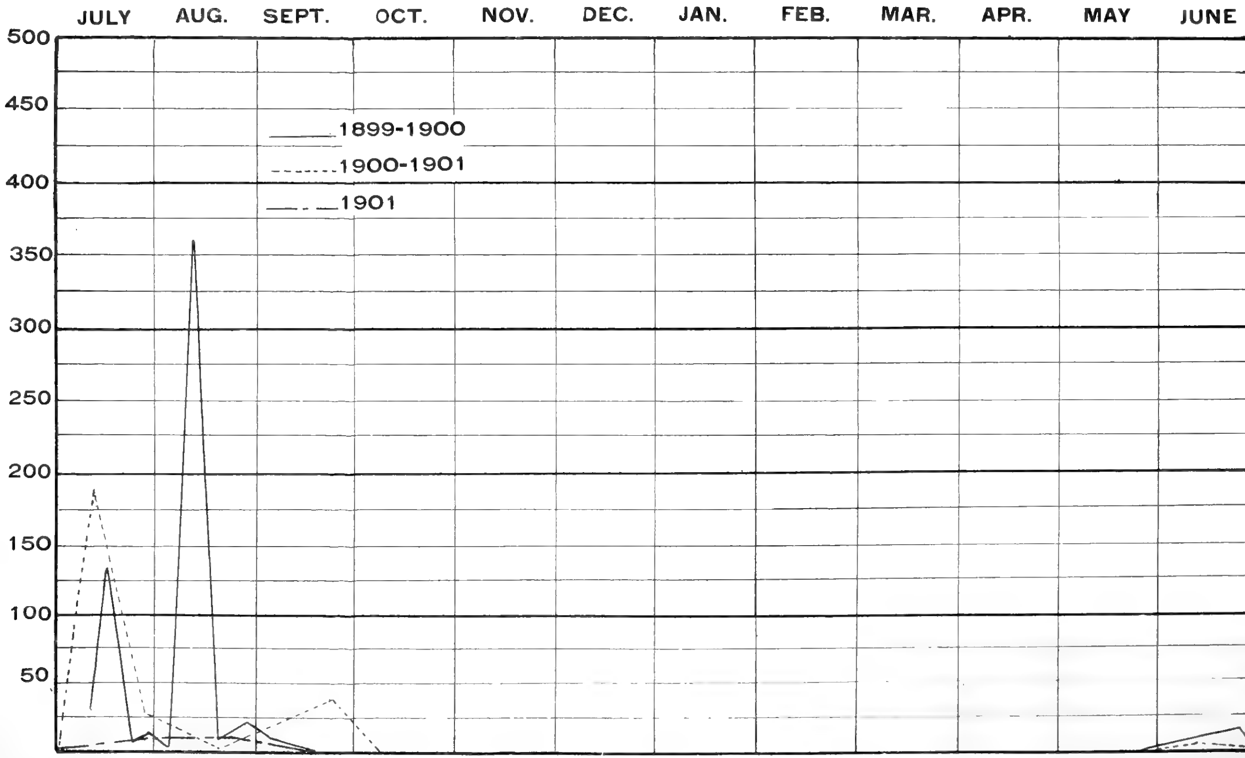
Lake Winnebago, because of its slight depth, and the fact that the whole body of water is so easily affected by storms, becomes warmed much earlier in the spring than does Green lake, and cools off with corresponding rapidity in the fall. The result is that Lake Winnebago is covered with a thick coat of ice long before Green lake is frozen over.

Green lake is seldom covered with ice before the first of January, and parts of the lake sometimes remain open through the whole winter. As a result of the late freezing, the ice never reaches the thickness on Green lake that it does on Lake Winnebago. Because of its great depth, and the consequent existence of a thermocline in Green lake in summer, this body of water has a true "abyssal" fauna, organisms which can exist only in the peculiar environment of uniform low temperature and little or no light. Lake Winnebago, on the other hand, cannot be said to have an abyssal fauna, the animals of the bottom in the deeper parts of the lake not differing appreciably from those of the littoral region.

With such differences in physical conditions we should expect corresponding differences in fauna and flora. The writer has already suggested in a former publication (Marsh '97, 181) that lakes may be divided into the two classes of "deep" and "shallow," the dividing line between the two classes being at about forty meters. Later (Marsh, '99, 171) I was led to think that the limit should be placed at a lower figure,—perhaps thirty or thirty-five meters. It would be better, doubtless, to make the main classification of lakes depend upon the existence or non-existence of a thermocline. In the shallow lakes there is no thermocline. Taking the presence or absence of a thermocline as the basis of classification, the depth limit between deep and shallow lakes would not be definite but would bear a constant relation to the area and character of the shore; for the thermocline is much more marked in small lakes with high shores.

Deep lakes are susceptible of a two-fold classification into the large and the small. In the small deep lakes the abysssal water stagnates, and the conditions of life become so hard that an abyssal fauna can hardly be said to exist. In the large deep lakes, on the other hand, the movement of the surface waters under the influence of the winds produces slow return currents along the bottom which serve to relieve the condition of stagnation, and permit the existence of a somewhat abundant abyssal fauna. Green lake and Lake Geneva have the characteristics of large deep lakes, while Elkhart and the Waupaca lakes are types of small deep lakes.

On the whole this seems to me the most satisfactory classification of lakes, and in this paper I shall use the terms "deep," "shallow," "large deep," and "small deep," as indicated above. While, as will be seen later, faunal and floral distinctions do



Curves of annual distribution of *Gloiotrichia* per square meter in Lake Winnebago, the numbers being reckoned in thousands.

not follow absolutely this classification, yet they have a close relation to it.

Green lake may be considered the typical deep lake of Wisconsin, and, as observations have been carried on upon its fauna and flora for a number of years, it was natural to select it for comparison with Lake Winnebago.

Collections were made on as large a number of lakes in other localities as time would permit. Some of these lakes were selected because they had apparently different conditions from those prevailing on Lake Winnebago and Green lake, but others were taken for the express reason that their conditions seemed to resemble very closely those of the lakes which were made the standards of work.

Inasmuch, as will be shown later, experience has shown that plankton collections are really significant only as averages can be obtained of a considerable number of collections, and that single collections may be very misleading, so far as possible an attempt was made to visit a certain number of lakes repeatedly, rather than to make a large number of single collections from different bodies of water. Unfortunately the time at command did not permit of as many of these trips as was desirable, so that in some cases single collections only could be made: as it was important that there should be as wide a basis of comparison as possible, it seemed better to make these single collections than no collections at all. The author clearly recognizes, however, that it would have been much better had it been possible to work a circuit of a considerable number of lakes continuously. If lakes could be classified into a series of a few types, of course, it would be necessary only to take one of each type. But, so far, no entirely satisfactory classification, from the standpoint of the fauna and flora, has been proposed, so that one can not be certain when he limits his work to a few lakes, that he may not miss some important principles of distribution which are only exemplified in the bodies of water which he has not examined.

Four somewhat extended trips, in four successive years, were made to lakes in the forest region of Wisconsin, including lakes in Shawano, Forest, Oneida, and Langlade counties. The first of these trips was made in September, the last three in the middle of August. To some of these lakes visits were made at other times. Such collections, as intimated before, while giving a very imperfect idea of the faunal and floral conditions of these bodies of water, are yet very valuable as a matter of comparison.

In this work the objects kept in view have been the following:

1st. Lists of the fauna and flora. Inasmuch as the work has been done entirely by one person, with the aid of an assistant for a part of the time, and my exact systematic knowledge is very largely confined to the entomostraca, it is not to be expected that this list will be complete. It will, however, serve to show such important differences as may exist between the fauna and flora of Lake Winnebago, Green lake, and the other lakes.

2nd. A quantitative study of the plankton which should give a clear idea of the annual variations, and of the quantitative difference between the plankton of Lake Winnebago and Green lake.

3rd. A qualitative study of the plankton in order to determine the variations in its components in the course of the year.

4th. It was hoped that the studies of the above topics would furnish material for some exact additions to our knowledge of the distribution of the animals and plants of the plankton, and might help in the solution of the very complex problem of the relation of the plankton to the fish.

METHODS OF MAKING COLLECTIONS.

In settling upon the methods which should be used in making the collections, it was necessary to choose a method which would be practicable in a permanent station, and yet which should not involve so cumbersome apparatus that it could not readily be carried from place to place without making too much of a burden of weight. This latter consideration made the pump impracticable. Moreover, I am inclined to agree with the conclusions reached by Reighard (Reighard '98) that it is very doubtful if the pump gives one a representative collection of a column of water. In deep waters, of course, the pump involves very unwieldy apparatus. In shallow waters, especially for making collections at specific levels, the pump is a useful adjunct to plankton apparatus. In the opinion of the author no method has yet been devised that serves the purpose so well as a vertical net. It is very much to be desired that the net should have a wide opening, as is stated by Reighard. Portability was so necessary in my case, however, that size had to be sacrificed. The undoubted fact that nets vary in their collecting ability because of the clogging of the meshes, especially in silt laden waters, was deemed in these researches as of minor importance, partly because the waters examined were for the most part fairly clear, and partly because, as will be seen later, the author attaches very little importance to exact measurements of the plankton, but relies for results on averages.

The net used was of the pattern of Hensen, the upper cone being of copper, with an opening 10.5 cm. in diameter. The net was of bolting silk, attached below to a removable bucket, of a form devised by Professor Birge. The net was drawn from the bottom to the surface, the net washed down from the outside, and the bucket, by the aid of a wash bottle filled with alcohol, emptied directly into the collecting bottle. I made it a rule to make three collections at each station, and in stating results the three collections were averaged.

To determine the gross amount of plankton it was decided to use the centrifuge. The objections to the method of settling in graduated tubes have been well stated by other authors. (Ward '95, Kofoid '97.) The lack of exactness in plankton measurements does not warrant the labor of the gravimetric method. It was decided to use the centrifuge, as being the best method yet devised. For this purpose the ordinary urinary centrifuge was used, with tubes graduated to tenths of a centimeter. After a little experience it was decided to run the centrifuge in the following way: 1st, two revolutions of the crank; 2nd, two revolutions in the reverse direction; 3rd, a continuous run of ½ min.; 4th, ½ min. in the opposite direction; 5th, one minute straight ahead. The centrifuge was run at from 1200 to 1500 revolutions per minute, any greater rapidity being almost certain to break the tubes. It was found that the work was most successful when the percentage of alcohol in the collected material was rather high. This method has some inaccuracy, as well as the method by settling, for the different kinds of material are not equally well thrown down. Some of the algae, in spite of long continued running of the centrifuge, will always lie in a more or less flocculent mass on top, and in some cases, even after being thrown down, will afterwards rise into the supernatant liquid. The supernatant fluid, even when apparently perfectly clear, always contains a little of this plant material. The amount is so small, however, that it has no evident effect on the measurements of the plankton.

The examination of the plankton was by the method explained in my former paper. (Marsh '97, p. 188.) At first all the counting was done by means of the dissecting lens, but later, for the smaller forms, a compound microscope was used, with a stage especially arranged to receive the counting plate. Only the crustacea were counted exactly, with the exception of *Gloiotrichia,* of which a careful count was made. But notes were made of the occurrence of the other forms and a rude estimate of the numbers made and recorded under the terms "few," "many," "very many," and "nos."

CHAPTER II.

ANNUAL DISTRIBUTION OF THE ORGANISMS OF THE PLANKTON.

Asterionella gracillima Heib.

Asterionella occurs in both lakes through the entire year. In Lake Winnebago there seems to be a minimum in June, July, and August, but no very pronounced maximum period.

In Green lake there is a similar paucity of numbers in the summer months and a strong maximum in February, March, and April. This winter maximum was first noticed in 1900 when *Asterionella* was found in such numbers as to make a layer of water two feet in thickness almost opaque,—the water having a milky appearance. This winter increase was confirmed in the two succeeding winters, and it would seem to be a fair inference that its maximum in Green Lake occurs regularly in the winter.

Cyclotella flocculosa (Roth) Kg.

Cyclotella is never found in any numbers in Green lake. I have found it only in November, January, February, and May.

In Lake Winnebago, in the years under observation, *Cyclotella* was at its maximum of development in the fall months, September, October, and November. In 1900 there was an increase in May, and in 1901 in the last of April. I think, then, that we may say that *Cyclotella* in Lake Winnebago has two maxima, the principal one in the fall with its greatest development about the first of November, and the other one less pronounced about the first of May.

Melosira.

Melosira is found in very small numbers in Green lake, and no inferences can be drawn as to its annual distribution.

In Lake Winnebago its appearance seems somewhat erratic, but there is evidence of two maxima, one in May, and one in September.

Synedra pulchella Kütz.

Synedra pulchella occurs in Lake Winnebago in all the months of the year. In 1900 there was evidence of a spring maximum in May and a fall maximum in October. In the other years there was no pronounced increase at any time.

In Green lake it is practically absent in July and August, and only few are found in September, October, and November. Large numbers are present in December, January, and February, and there is another increase in April and May.

Synedra acus var. *delicatissima* Grun.

This variety occurs in both Green lake and Lake Winnebago, but in much greater abundance in Green lake. I have found it in Lake Winnebago in February, March, April, and June.

In Green lake I have found it in nearly every month of the year, but it is in the winter that it especially flourishes, being very numerous from January to May. With *Asterionella* it forms one of the most important elements of the winter plankton of Green lake.

Fragilaria.

I have not found *Fragilaria* in Lake Winnebago in July, August, September, or October, and only once have I found it at any time very abundant,—that was in the middle of May, 1900.

In Green lake it occurs at the same times, my only large collection being at the middle of May, 1901.

Stephanodiscus.

Stephanodiscus I have not found at all in Green lake. In Lake Winnebago it may occur from February to July, with a maximum at some time in the spring. In 1900 there were two important periods of large numbers, one the middle of May, and one the last of June. In 1901 the first increase came the last of April and the second the first week in June. Other diatoms were noticed in the plankton, but none in sufficient numbers to be of any importance in the total amount.

Navicula.

Navicula was found in Green lake a few times and occurred in Lake Winnebago in many of the collections, especially in the winter months.

Surirella and Pleurosigma.

Surirella and *Pleurosigma* were found a few times in Lake Winnebago.

Nassula.

Nassula, also, was noted in the flora of Lake Winnebago.

COMPARISON OF RESULTS ON ANNUAL DISTRIBUTION OF DIATOMS WITH WORK OF OTHER AUTHORS.

I find very few recorded facts in regard to the annual distribution of the various genera of diatoms.

Apstein (Apstein '96) finds the two maxima of *Melosira* much as I do. His maxima for *Asterionella* do not correspond to my results.

Whipple (Whipple '94), in a discussion of the growth of diatoms in surface waters, comes to the conclusion that the growth of diatoms is directly connected with the phenomena of stagnation, that in deep ponds there are two well defined periods of growth,—one in the spring and one in the fall: that in shallow ponds there is usually a spring growth but no regular fall growth, and that other growths may occur at irregular intervals as the wind happens to stir up the water; that the two most important conditions for the growth of the diatoms are a sufficient supply of nitrates and a free circulation of air, and that both these conditions are found at those periods of the year when the water is in circulation. Whipple gives facts in regard to the annual distribution of diatoms in Massachusetts ponds which seem thoroughly to substantiate his contention. I have already referred to this work in a former paper (Marsh '99), accepting these conclusions. In looking over the occurrence of the diatoms in Green lake and Lake Winnebago I find nothing to contradict this theory in the occurrence of *Cyclotella, Melosira, Synedra, Fragilaria,* or *Stephanodiscus.* The occurrence of *Cyclotella* in Lake Winnebago especially seems to confirm his statements.

The occurrence of *Asterionella* in Green lake, however, differs distinctly from his results in Massachusetts waters. His general conclusion in regard to *Asterionella* is that its two maximum periods come after the spring and fall overturning when the spores,—if diatoms have spores,—are brought to the surface accompanied by the food materials that have been forming in the abyssal waters during the stagnation period. Now in Green lake the maxima, as found in three winters, came in the depth of winter when the lake was covered with eighteen inches or more of ice, and at a period midway between the two overturnings of the water. It is evident that Whipple's explanation does not apply in this case. Why there should be this enormous production of *Asterionella* in mid-winter I do not at all understand. Voigt (Voigt '02) reports *Asterionella* as having a similar winter maximum in Trammer-See and Edeberg-See.

Closterium.

Two or three species of *Closterium* occur in both lakes as occasional members of the plankton. They cannot be considered as true limnetic species, but rather as migrants from the littoral flora.

Pediastrum.

I have found *Pediastrum* in Lake Winnebago in every month of the year except March and April. It is most abundant in the summer and fall months but seems to have no pronounced maximum.

Staurastrum.

Staurastrum is found in Lake Winnebago from May to November but never in any considerable numbers.

Eudorina.

Eudorina I have found in small numbers in June and July.

Merismopedia.

Merismopedia was found in small numbers through the summer and fall of 1899 in Lake Winnebago. In 1900 it was found only in the fall months, continuing to the middle of February. In 1901, too, it did not appear until fall except in a single collection in June.

Clathrocystis aeruginosa Henfr.

I have never found *Clathrocystis* in the plankton of Green Lake. In Lake Winnebago it occurs throughout the summer, appearing as early as June, and sometimes remaining as late as October. I have found it in great numbers in Lake Buttes des Morts in August. It appears in the same month in Pelican lake and the Eagle River lakes. It does not appear to be a constituent of the plankton in the deeper lakes.

Anabaena.

Anabaena is one of the most important constituents of the summer plankton. It occurs in Green lake, sometimes in noticeable amount, so that little ridges of it are thrown upon the shore by the waves. It is in the shallow lakes, however, that it flourishes in especial abundance. It appears in Lake Winnebago as early as May, and may be found as late as October. It reaches its greatest abundance in July and August. The numbers in September are ordinarily very small. Yet I have found it in Pelican lake in great numbers in the latter part of September.

Aphanizomenon.

Aphanizomenon occurs in Lake Winnebago associated with *Anabaena,* its period of growth being very similar although it does not appear so early nor remain so long. While I have not counted *Anabaena* and *Aphanizomenon,* and so cannot state their maximum period with any exactness, I get the impression that *Anabaena* reaches its maximum earlier than *Aphanizomenon.* It is found in other shallow lakes associated with *Anabaena.*

Oscillaria.

Oscillaria is not a constituent of the plankton in either Green lake or Lake Winnebago. In some of the shallow lakes, however, it is very abundant at certain times in the summer. This is notably so in Shawano lake where it seems to assume the importance that *Anabaena* and *Aphanizomenon* do in Lake Winnebago.

Lingbya.

Lingbya is associated with *Anabaena* and *Aphanizomenon* in Lake Winnebago, especially in July, sometimes in large numbers, but is of less importance than the other two genera.

Gloiotrichia echinulata Richt.

Gloiotrichia has no importance in the plankton of Green lake. In Lake Winnebago it is found in great numbers in July and August. In the summer of 1899 (Plate I) there was a rapid increase from the first of July to the middle, followed by a decrease, from which there was again a rise to a maximum about the twelfth of August. In 1900 there was a single maximum early in July. The total production of *Gloiotrichia* in 1899 was much greater than in 1900.

The collections of *Gloiotrichia* in the other lakes of the state were made on only a few dates so that a comparison of numbers would be subject to revision after a more complete knowledge of those lakes. So far as appears, however, *Gloiotrichia* occurs in vastly greater abundance in Lake Winnebago than in the other bodies of water from which collections were made.

The only exception to this was a very large collection of *Gloiotrichia* made on Pelican lake August 12, 1902. Other collections made on Pelican lake in preceding years, however, did not indicate so large a production of this plant as in Lake Winnebago.

Sphaerella lacustris (Girod) Wittrock.

This organism I have found a fairly constant constituent of the plankton of Green lake. During the first year it occurred in the collections from September until the next June. During the second year it was found from early in August until the last of December. In the third year it appeared through the fall months, and after that the collections were discontinued. Its maximum of appearance seems to be from September to January. In Green lake it seems to be distinctly characteristic of the cold season.

I have not found this form in Lake Winnebago, but it does occur in a number of the other lakes, generally in small numbers, but in August, 1900, I found large numbers in Shawano and Pelican lakes.

Although it is found in the plankton more in the colder season, it does not follow that it lives in Green lake only at that time, for I have found it in enormous numbers in Dartford Bay in boats that were standing half full of water in the summer.

Dinobryon.

Dinobryon occurs in both Green lake and Lake Winnebago. In Green lake the largest collections have been in May, June, and July, but it may occur in any month.

In Lake Winnebago I have never found it in July and August, but it comes in with September, is found in small numbers in the fall and winter, and reaches a maximum of numbers in March.

In the European lakes, according to Apstein and Zacharias, this genus occurs from April or March to August, but it would appear from my collections that it may be found in our lakes at any time except that in Lake Winnebago it fails at the hottest time of the year. It would seem to be a fair presumption that the heat of mid-summer is unfavorable to its growth although it has been found in Green lake in great numbers in July.

Synura uvella Ehrenberg.

I have found *Synura* in Green lake only in two collections made in May, 1901.

In Lake Winnebago it sometimes forms an important element in the winter plankton. I have found it in the months from November to April, with the largest numbers in January, February, and March. It seems to be very distinctly confined, in its development, to the months when the lake is covered with ice.

Uroglaena.

I have not found *Uroglaena* as a constituent of the plankton of either Green lake or Lake Winnebago. I did find it, however, in large numbers in the plankton of the Eagle River lakes in August, 1901 and 1902, and it seems probable that in some shallow lakes it may be in the summer an important element in the plankton.

Ceratium hirundinella O. F. Müller.

Only once did I find *Ceratium* in Lake Winnebago in any considerable numbers,—in a collection made August 22, 1900. It cannot be said ever to form an important part of the plankton of this lake. It may be found at almost any time of the year but always in small numbers.

In Green lake it is distinctly a summer form. It is almost entirely absent except in the months from July to October, inclusive. In the summer of 1899 its maximum was reached the last of July, in 1899 its greatest development was early in October, and in 1901 it reached a maximum about the middle of September. The total production in 1901 was much greater than in the preceding years.

Codonella lacustris Entz.

Codonella does not occur in Green lake. In Lake Winnebago it is found most abundantly in the winter months, although it occurs at other times of the year. It is never present in sufficient numbers to affect the total plankton.

Epistylis galea Ehrenberg.

Epistylis was found in small numbers in the plankton of Lake Winnebago in the fall of 1900 and 1901.

I found it also in the plankton of Birch lake in August, 1900.

Anuraea cochlearis Gosse.

Anuraea cochlearis is found at all times of the year in both lakes. There is no uniform maximum period. Apstein states for Plöner See that the greatest numbers are found in July. Seligo finds for various lakes maxima in May, June, July, and September.

The largest single collection in Green lake was made in August, while the largest collection in Lake Winnebago was made in January. The occurrence of the species, however, was very erratic, and I can draw no conclusions as to its annual periodicity.

Anuraea aculeata Ehrenberg.

Anuraea aculeata was found in Green lake only in two collections,—in July and December, 1901, and then in very small numbers. In Lake Winnebago it was pretty constantly in the plankton from October or November until the next May. The largest single collection was in January, 1900. Thus *Anuraea aculeata* would appear to be a distinctly winter form. This agrees with the statements of Seligo and Voigt, but Apstein has found it a summer form.

I have, however, found it in other lakes in the summer. It occurred in August, 1901, in both Shawano and Stone lakes in small numbers. In August of both 1900 and 1901 it was found in large numbers in Birch lake. I have found it also in Cedar lake in March and June. It is evident then that *Anuraea aculeata* may occur at any time of the year, and I see no reason why in Lake Winnebago it should be limited to the colder months, for the conditions of Shawano lake are very similar to those of Lake Winnebago.

Anuraea quadridentata Ehrenberg.

Anuraea quadridentata I have not found in Lake Winnebago. It appeared in Green lake in 1901 from February through the month of April.

Polyarthra platyptera Ehrenberg.

Polyarthra is a perennial form in Lake Winnebago. Generally speaking the numbers are greater from July to October, but in one year there was a very large production in February and March.

In Green lake it occurs from June through the month of October. I have never found it in the winter months.

The European authors speak of *Polyarthra* as a perennial. The occurrence in Green lake would seem to be somewhat peculiar, and I cannot see what circumstances in Green lake should be more unfavorable to it than in Lake Winnebago.

Triarthra longiseta Ehrenberg.

Triarthra is never found abundantly in either lake. In both it is found from June to November, and only occasionally in the winter months.

Notholca longispina Kellicott.

Notholca longispina is much more numerous in Green lake than in Lake Winnebago. In both lakes it may occur at any time of the year, with no pronounced maximum period. The largest single collection in Green lake was in February, 1900.

In general, the collections of the fall and winter months were larger than those of the summer.

The conditions of a deep lake seem to be more favorable to the production of *Notholca longispina* than those of a shallow one. Seligo states that it was found in greater numbers in the deeper of the Stuhmer lakes.

Notholca foliacea Ehrenberg.

Notholca foliacea is not a common member of the plankton of these lakes. I have found it in Green lake only once, on May 4, 1901. In Lake Winnebago I found it in collections made in the middle of February and in the middle of March, 1901.

Asplanchna sp.

An undetermined species of *Asplanchna* was found in Green lake in January and March, 1900. In the same winter it was found in Lake Winnebago as early as November and was a fairly constant member of the plankton until the middle of March.

Synchaeta pectinata Ehrenberg.

Synchaeta pectinata occurred in Green lake in the winters of 1900 and 1901. In the winter of 1900 it was found in the months of February, March, and April. In 1901 it was found from January to March. It was found in a single collection also in October, 1900. In both winters the largest numbers were in the collections made on the twenty-third of February.

In Lake Winnebago it is also a winter form with a somewhat more extended period of occurrence than in Green lake. I have found it in the months from October to April, inclusive, and in a single collection in June, 1901.

This occurrence of *Synchaeta pectinata* corresponds fairly well with the results obtained by European investigators. Apstein finds it a perennial form, with its maximum in the winter months. He states, however, that in his counting he has not distinguished the species of *Synchaeta,* and it would seem possible that *pectinata* did not occur in the summer months.

Seligo says that *S. pectinata* occurs through the whole year with a maximum in September.

Voigt (Voigt '02) says that *S. pectinata* is generally absent in the summer months, but is found in the fall, winter, and spring, while other species occur in the summer.

Conochilus volvox Ehrenberg.

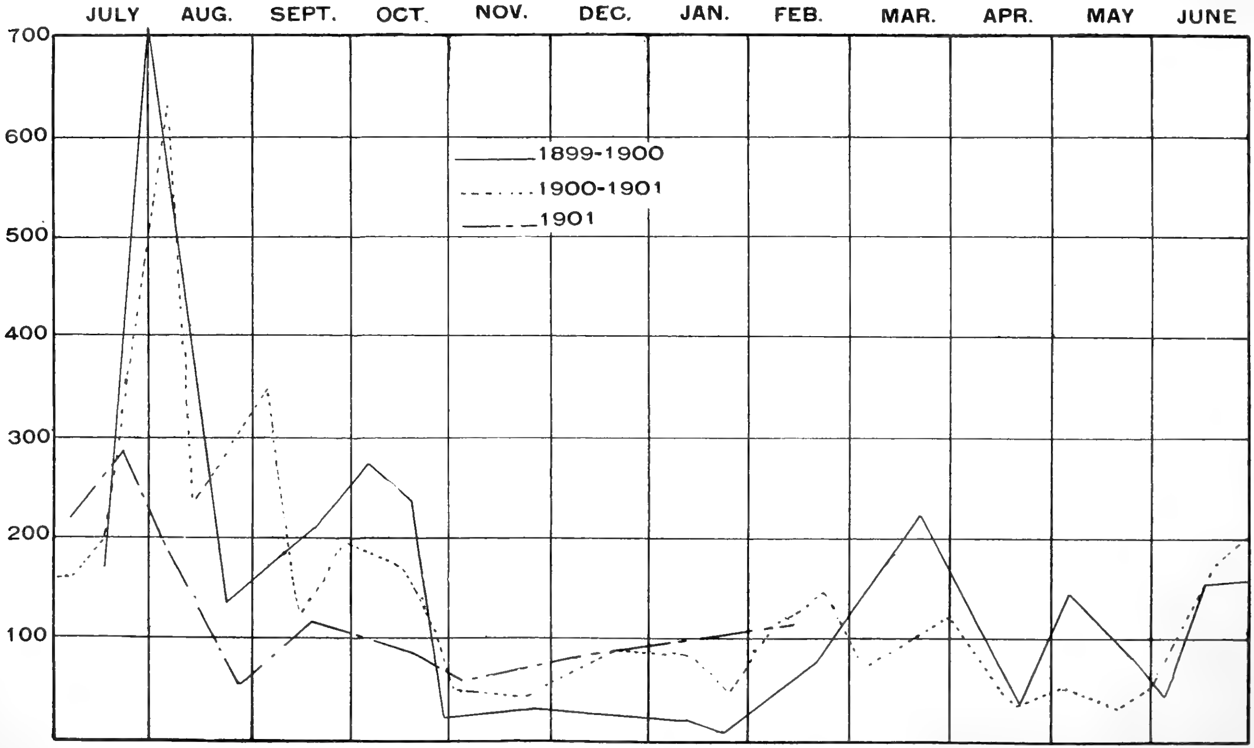
Conochilus was found in Lake Winnebago in the summers of 1899 and 1901. In 1899 it reached its greatest numbers in the last week in July. In 1900 I found the largest numbers July 9. In 1900 a few were found in October and November. I have not found it in any of the collections from Green lake, nor does it seem to be distributed very generally in other lakes. In September, 1899, I found it in Birch lake, in June, 1900, in Cedar lake, Washington county, in August, 1900, in Pelican and the Eagle River lakes, and in August, 1901, in considerable numbers in one of the Clover Leaf lakes. While it is not at all uncommon in the summer months, its distribution seems to be somewhat erratic.

Apstein finds a much longer period for *Conochilus,* but states that it is irregular in its maximum period.

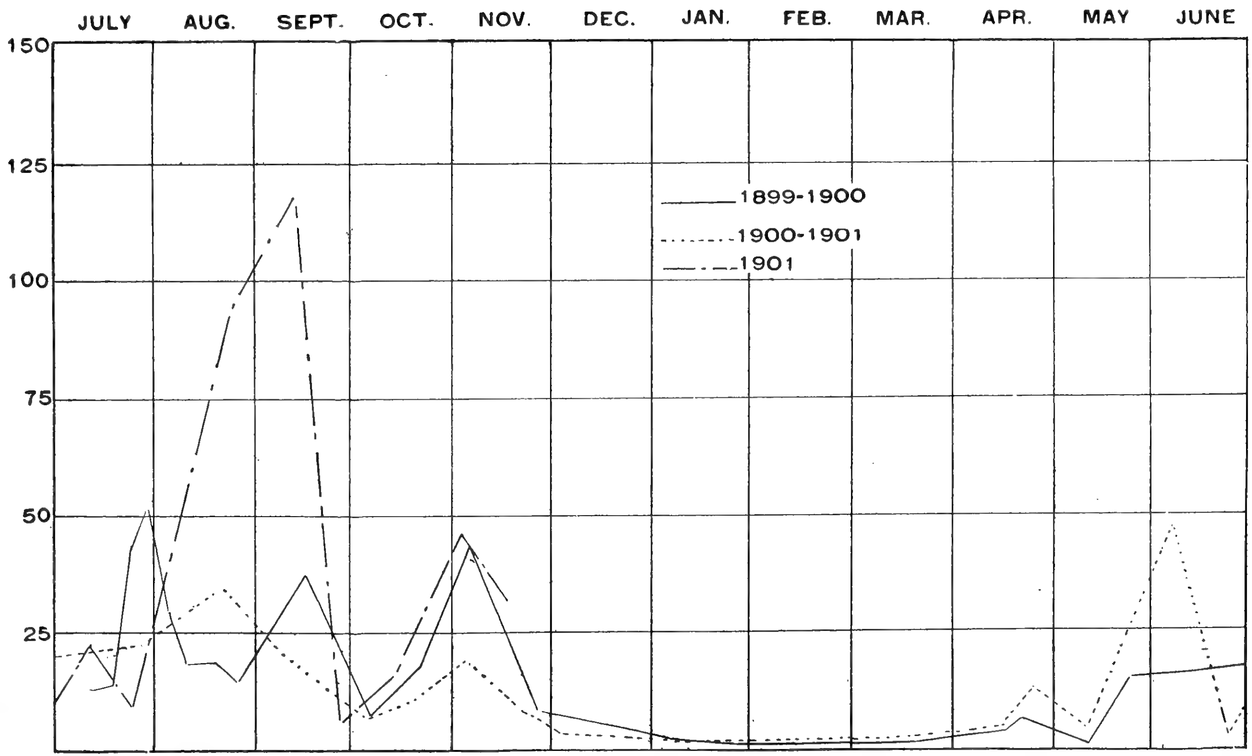
Voigt (Voigt '02) states that the period for *Conochilus volvox* extends from August to November, but other species of *Conochilus* may occur in the winter months.

Diaptomus minutus Lilljeborg and *sicilis* Forbes.

D. oregonensis does not occur in Green lake but its place is taken by *D. minutus* and *D. sicilis.* In a former paper (Marsh '97) I discussed the annual distribution of these *Diaptomi,* and the curves given in Plate II, while they modify the conclusions reached at that time, do not do so in any material way. As in my former work, I did not in the counting distinguish between the two species, but, in every case, careful examination was made as to the presence of the two species. I have very little to add to the statement already made (Marsh '97, 193) in regard to the annual distribution of these two species. *D. minutus* occurs in the months from July to Decem-



Curves of annual distribution of *Diaptomus sicilis* and *Diaptomus minutus* per square meterin Green lake, the numbers being reckoned in thousands.



Curves of annual distribution of *Diaptomus oregonensis* per square meter in Lake Winnebago, the numbers being reckoned in thousands.

ber, inclusive. *D. sicilis* is found from the last of September or first of October until the first of July. *D. sicilis* is rarely present in the summer months as *D. minutus* is seldom found in the winter and spring months. In considering the curve, then, it must be remembered that the summer maxima are for *minutus* while the winter maxima are for *sicilis*. In November and December and again the last of June the species are found together in the plankton. In the three years under observation the greatest production of *minutus* was not far from the first of August with a smaller fall maximum the last of September or first of October. This differs from the only complete curve in my former paper in that then the greatest maximum was in September.

D. sicilis reaches its greatest numbers in February and March.

It may be remarked that this maximum of *D. sicilis* corresponds with the maximum period of development of *Asterionella*, but whether there is any causal relation between the two I am unable now to say.

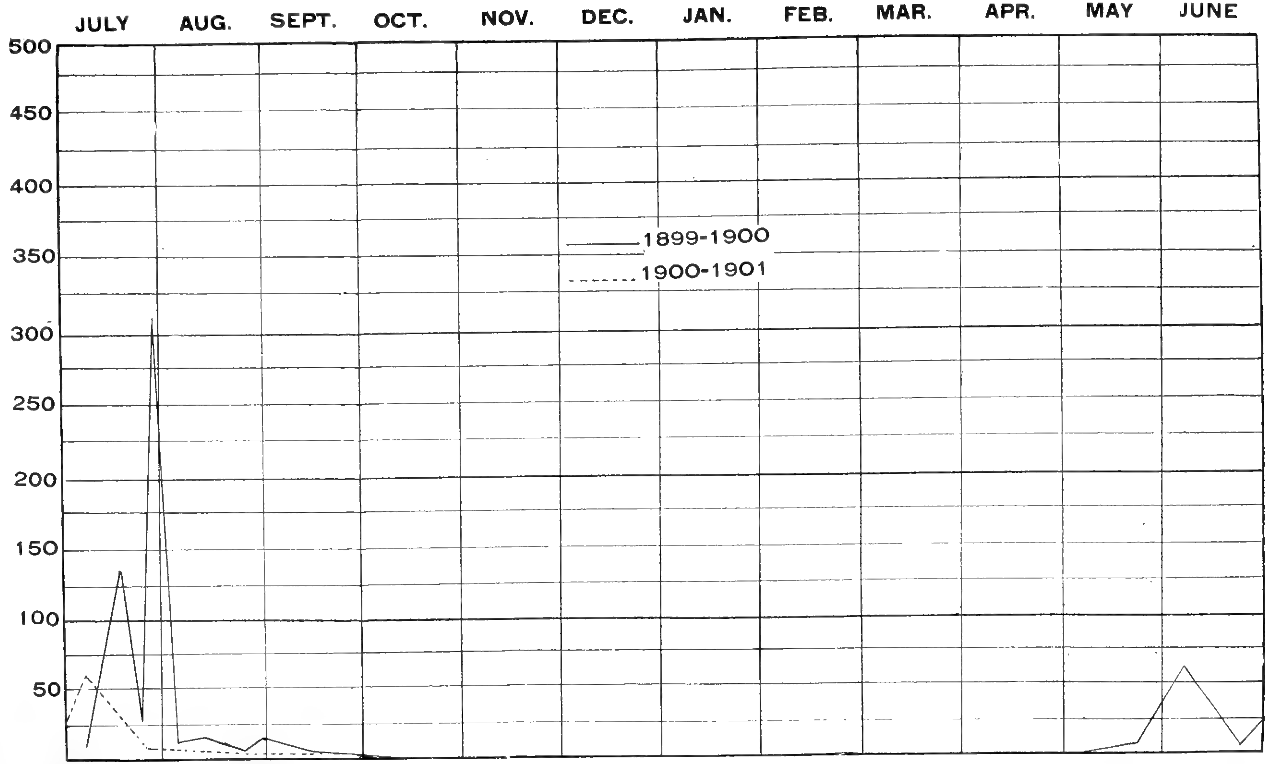
Diaptomus oregonensis Lilljeborg.

Diaptomus oregonensis is the only form of the genus found in Lake Winnebago, and is the common form in the greater majority of Wisconsin lakes. The curves of annual occurrence are shown in Plate III. It will be noticed that in the first summer there were three marked maxima, the last of July, the middle of September, and the first of November. There was then a rapid decline, a constant winter minimum during January, February, and nearly through the month of March, when there commenced a slow increase in numbers. In the second year the maxima were in the middle of August, the early part of November, and a heavy maximum in the next June. In the third year the summer maximum occurred the first of September with a fall maximum the early part of November. In comparing the three years the uniformity of the November maxima is very remarkable. With the July maximum of 1900 there is nothing to correspond in the other years.

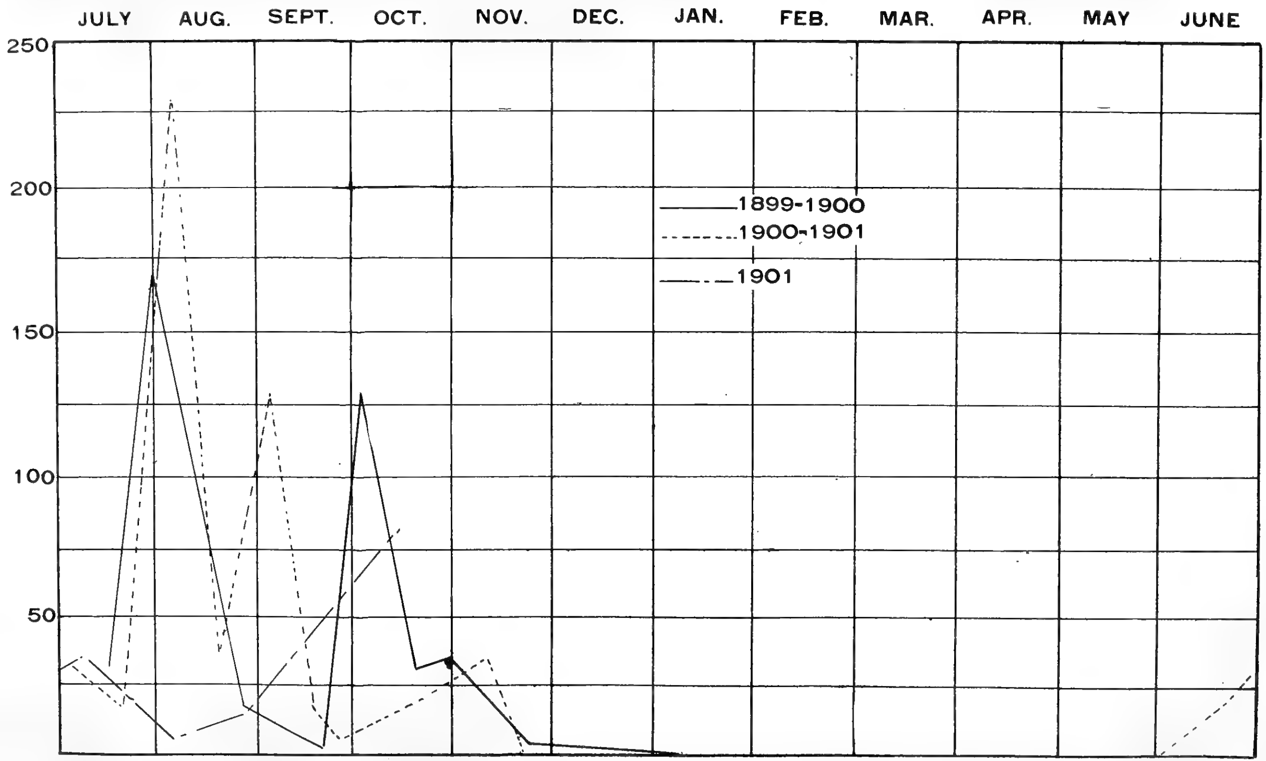
We can say, in general, that *Diaptomus oregonensis* occurs in its greatest abundance during the months from June to November, inclusive, that it is found only in very small numbers from the latter part of November until the last of March; that it has a constant fall maximum and one or more mid-summer maxima which occur between the last of July and the first week in September. So far as I know there are no preceding observations on the annual periodicity of *D. oregonensis* except those recorded by Birge (Birge '97).

The curves of *D. gracilis* and *D. graciloides* as recorded by Apstein, Steuer, and Seligo correspond in general with these curves, but differ in details. Especially noticeable is the statement of Apstein that the maximum of *D. graciloides* in Lake Plön occurs in the winter. In comparing my results with those of Birge, while there is a general resemblance in the curves, there are certain marked differences. He states that in Lake Mendota the smallest catches of the year were made in the latter part of April, and he infers that the conditions of life are harder for them after the going out of the ice. In Lake Winnebago there was a distinct increase during the month of April with a drop during the first half of May. I am unable to explain this increase, but it does not appear that the going out of the ice worked any hardship in the case of the Lake Winnebago *Diaptomus*.

In Lake Mendota there seems to have been no increase corresponding to the November maximum of Lake Winnebago. It is possible that this fact has some bearing upon the question of the effect of temperature upon the species. Birge (Birge '97, 326) states that the reproduction of *D. oregonensis* is more promptly checked by a fall of temperature than is that of any other species. Of course there is no question of the truth of the general proposition that the reproduction of this *Diaptomus* is dependent upon higher temperatures. The general character of the curves shows that at once. If, however, it were particularly sensitive to a decline in temperature, should we not expect fall reproduction to stop soonest in the lake that cools off the most quickly? Lake Mendota has a maximum depth



Curves of annual distribution of *Epischura lacustris* per square meter in Lake Winnebago, the numbers being reckoned in hundreds.



Curves of annual distribution of *Epischura lacustris* per square meter in Green lake, the numbers being reckoned in hundreds.

of about eighty feet, while the maximum depth of Lake Winnebago is only about twenty-five feet, and because of its greater extent is doubtless much more affected by the winds. It seems to me that if the species were especially sensitive to temperature we should expect the fall maximum in the deeper lake rather than in the shallower, as seems to be the case.

Epischura lacustris Forbes.

Epischura is distinctly a summer form. As shown in the curves (Plates IV and V) it appears sometimes as early as May and may be found as late as December or even January. In Green lake the larval forms appear in February and March. This is not indicated on the curves of the *Epischura* plate, as in the counting the *Epischura* larvae were not distinguished from those of the other copepods. The period of maximum development occurs in July or August. It will be noticed that the spring increase occurs a little later in Green lake than in Lake Winnebago, and that the summer maximum of Green lake is also a little later than that of Lake Winnebago. *Epischura* remains in Green lake, too, later into the fall than it does in Lake Winnebago. This is without doubt due to the fact that Green lake warms up so much more slowly, and cools off in the fall with corresponding slowness.

The curves conform quite closely with the results given in my '97 paper, except that in the winter of '95 there was a large rise in March. This difference is accounted for by the fact that in the '95 collections a distinction was made between the *Epischura* larvae and the other copepod larvae.

The annual occurrence of *Epischura* in Lake Winnebago resembles very closely the results given by Birge for Lake Mendota.

The nearest European relative of *Epischura, Heterocope,* is stated by Apstein to occur from July to November, with a maximum in the summer, thus showing a resemblance in its periodicity to *Epischura.*

Limnocalanus macrurus Sars.

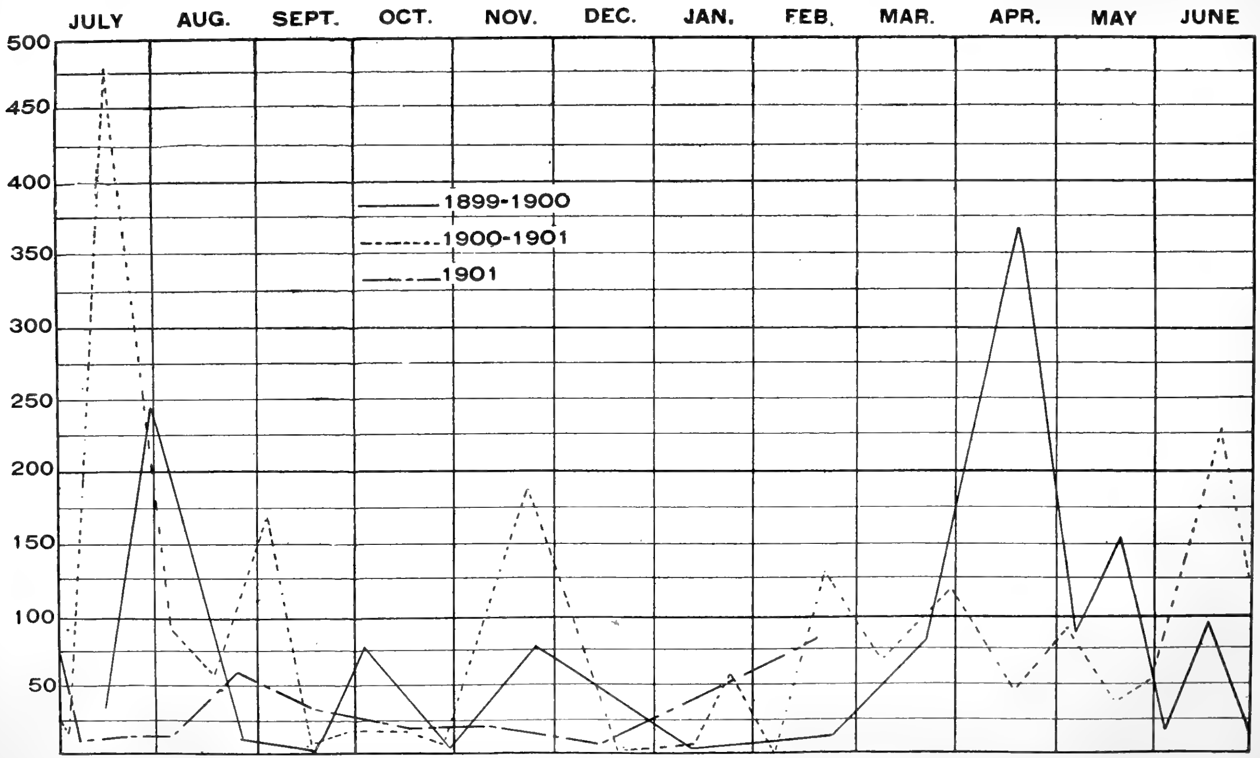
Limnocalanus only occurs in deep lakes, so it is not found at all in Lake Winnebago. In Green lake it is found at all times of the year. In my former paper (Marsh '97) I stated that its maxima were in May and November. The curves from the present series of observations (Plate VI) seem to confirm the former results, although the spring maximum occurs as early as April in some years, in others as late as June, and in the summer of 1900 the greatest number during the year was in July, although there had been a marked rise in April. During the winter months most of the individuals are larval forms.

It will be noticed that the maxima of *Limnocalanus* are not very widely different from the smaller numbers found at other times. This is doubtless due to the habits of this species, which, as I have shown before, prefers a low temperature of the water, and during the summer months is found to very little extent above the thermocline. In the winter it is found at all depths. While, for the sake of the lower temperature, it succeeds in adapting itself to the stagnant conditions of the deeper waters of the summer, it does not flourish at that time as it does when, the temperature being favorable, it can find a home at any depth.

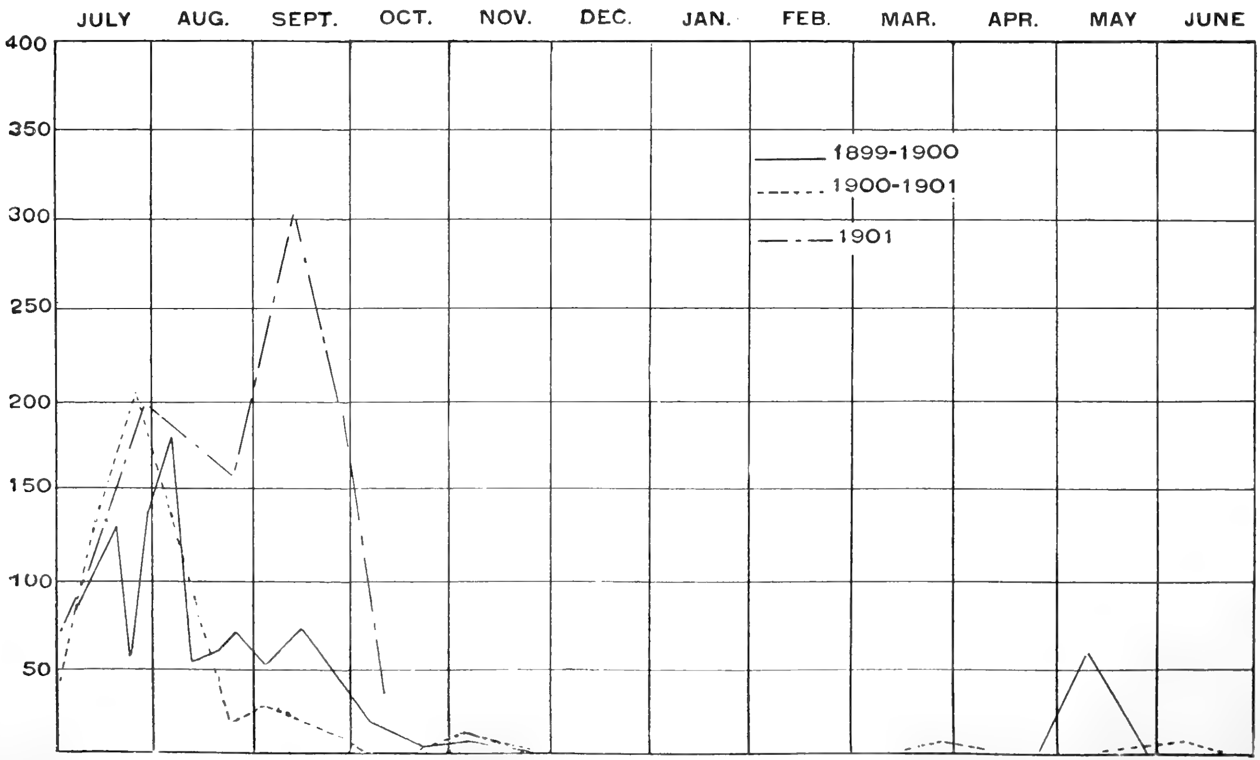
Cyclops brevispinosus Herrick.

C. brevispinosus is found in both Green lake and Lake Winnebago. The curves (Plates VII and VIII) show that it should be ranked as a summer form, although it may be found at all times of the year. In the three summers under observation there was a marked increase the latter part of July or the first of August. In 1902, however, the greatest number of the year was found about the middle of September.

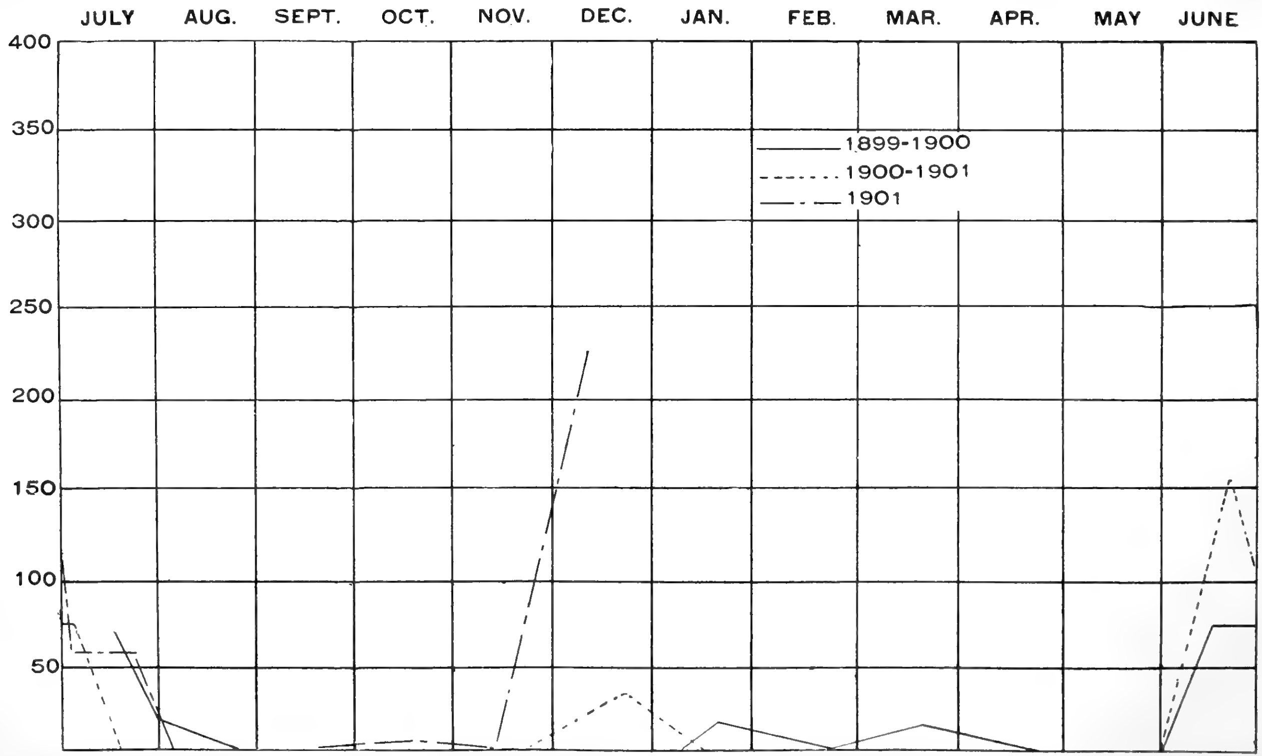
In Green lake apparently there may be expected a great increase in the latter part of June or in July. In December, 1902, however, I took the largest collections of the whole period of two and a half years. These results correspond with the results reported for Green lake in my former paper (Marsh '97).



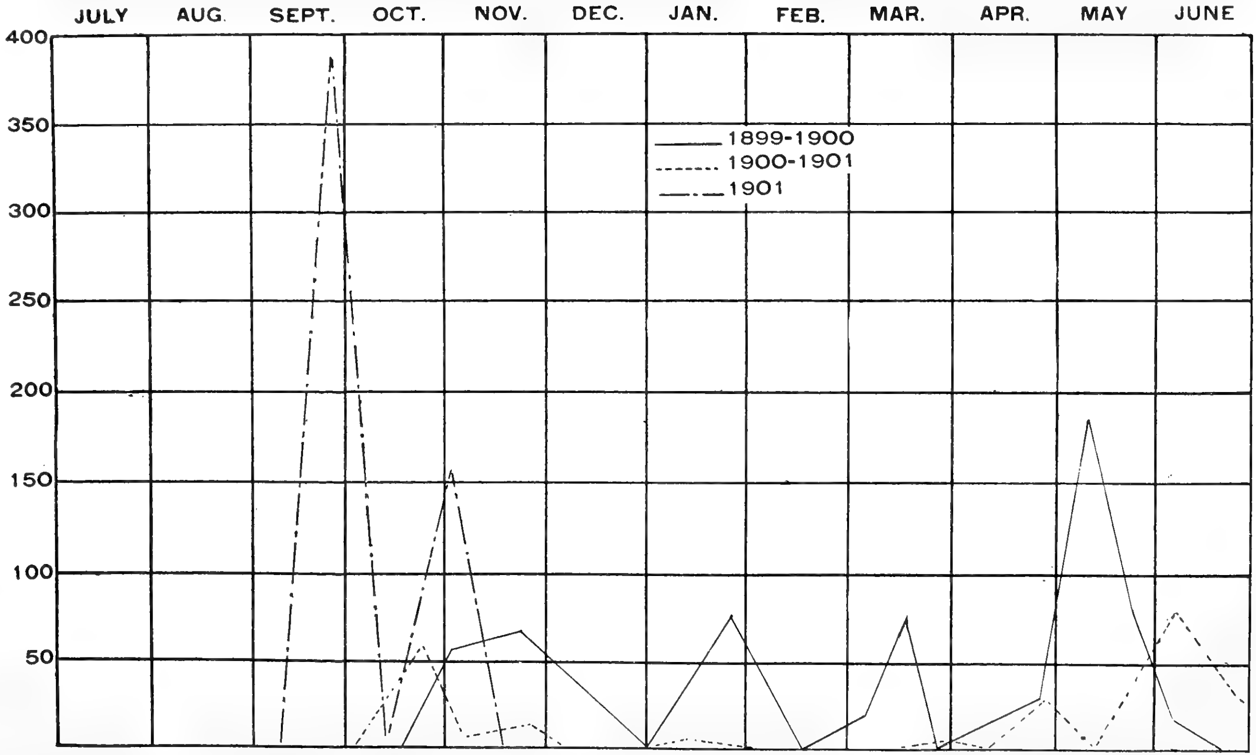
Curves of annual distribution of *Limnocalanus macrurus* per square meter in Green lake, the numbers being reckoned in hundreds.



Curves of annual distribution of *Cyclops brevispinosus* per square meter in Lake Winnebago, the numbers being reckoned in hundreds.



Curves of annual distribution of *Cyclops brevispinosus* per square meter in Green Lake, the numbers being reckoned in hundreds.



Curves of annual distribution of *Cyclops pulchellus* per square meter in Lake Winnebago, the numbers being reckoned in hundreds.

Birge reports for Lake Mendota that the largest collections were made in May. This does not correspond to the results of either Green lake or Lake Winnebago, although in one year there was a considerable rise in Lake Winnebago in May. In general it may be stated that *C. brevispinosus* is a perennial form, flourishing especially in the months from May to October.

Cyclops pulchellus Koch.

Cyclops pulchellus does not occur in Green lake.

In Lake Winnebago it is found from early October to the last of June. As the curves show (Plate IX) it has no very pronounced maximum, but it is evident that it is present in the greatest numbers in May or June. This species is then, in Lake Winnebago, distinctly a winter species.

Distribution of *C. brevispinosus* and *C. pulchellus* in Wisconsin Lakes.

While I have found *C. pulchellus* in Lake Winnebago only in the months from October to June, inclusive, it is the common limnetic form in some other lakes. This is notably so in the Great lakes. In certain of the Wisconsin lakes, so far as my observations have gone, *C. pulchellus* is always present as the limnetic form as *C. brevispinosus* is in Lake Winnebago and Green lake.

I have gone over very carefully the list of lakes, from which I have had collections, to determine, if possible, what is the factor which makes one lake a *brevispinosus* lake and another a *pulchellus* lake, but so far without entire success.

The following lakes, so far as I know, always have *C. pulchellus:* Lake Geneva, Elkhart, Chain o' Lakes, Cedar lake Washington county, Birch lake, Stone lake, Sand lake, Lake Michigamme, and Long lake Fond du Lac county. All other examined lakes have *brevispinosus.* All the lakes having *pulchellus,* with the exception of Sand lake, are of the deeper lakes, and Sand lake has a maximum depth of fifteen meters, thus being one of the deeper lakes of this type.

C. pulchellus found in pond in Richmond, Ind. Mar 9 1905

On the other hand all of the lakes having *brevispinosus,* with the exception of Green lake, are of the shallow lake type. Inasmuch as *pulchellus* is found in the colder waters of the Great lakes, it would be a natural inference to suppose that its presence in Lake Winnebago in winter had immediate relation to the winter temperature of the water, and that it might be found during the summer in other lakes where the water retains a low temperature through the year. It seems impossible, however, to establish any such rule. Generally speaking it is true that in the shallower lakes *brevispinosus* is the common limnetic form, while in the deeper lakes, which have a marked thermocline in the summer we find *C. pulchellus,* but the exceptions are so startling as to destroy most of the effect of the generalization.

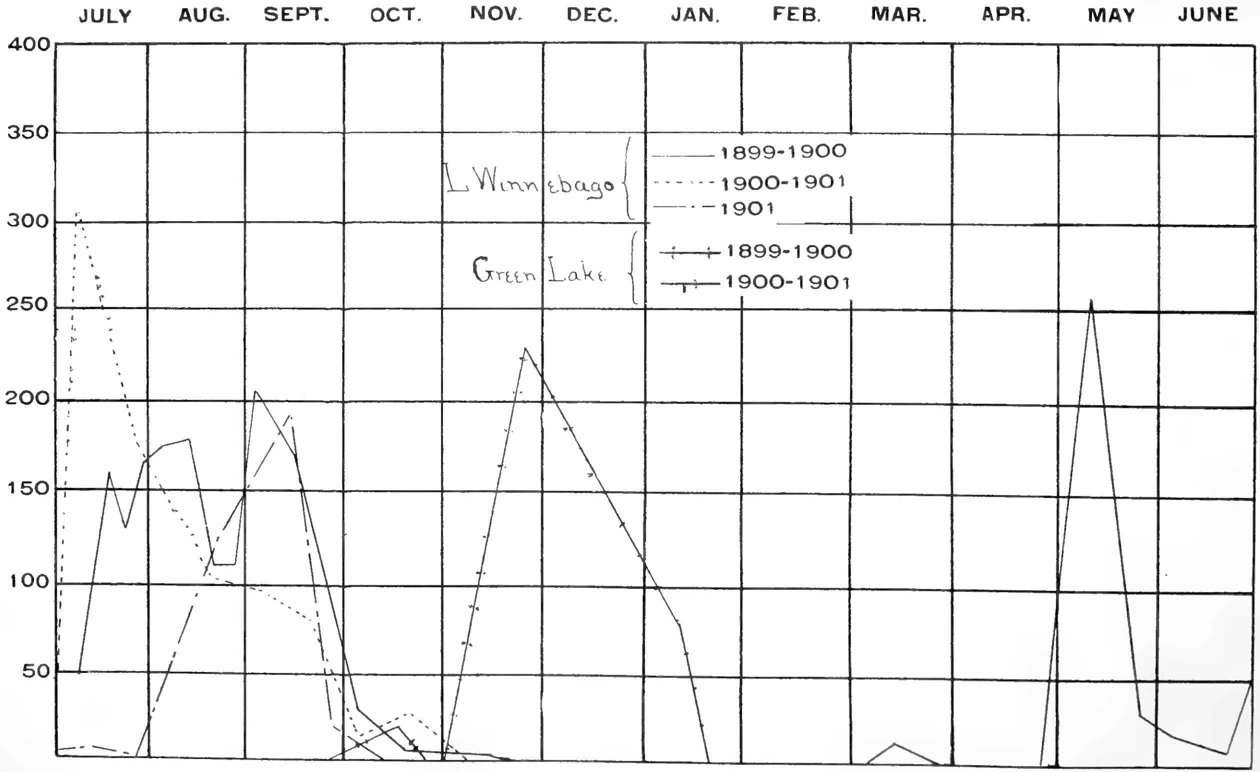
Cyclops Leuckarti Sars.

C. Leuckarti occurs in both Green lake and Lake Winnebago, but at somewhat different periods.

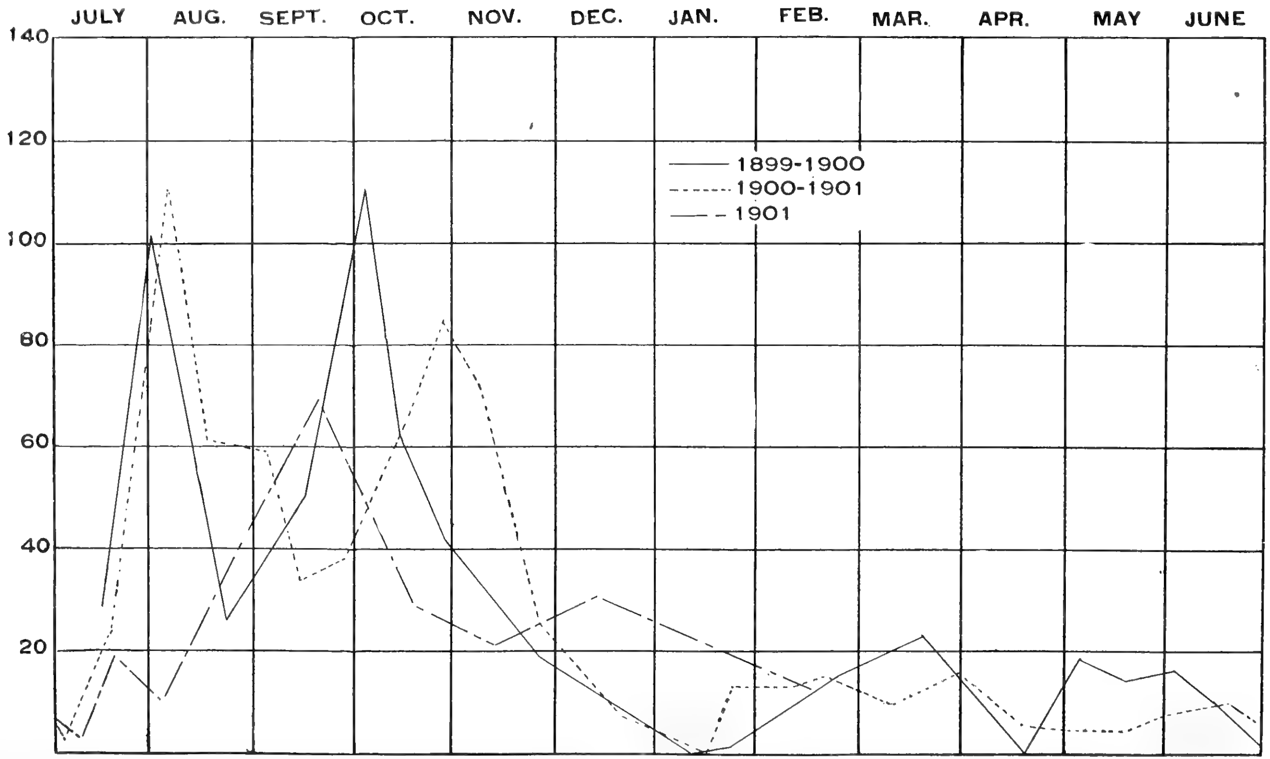
In Lake Winnebago it is perennial, but the numbers in winter are very small. It is found in considerable numbers from April to the last of October. It is apparent from the curves of frequency (Plate X) that its maximum period is in July and August, although in one year there was a great increase in May.

In Green lake, on the other hand, it appears to have a fall maximum, although the total numbers observed were so small as to make one careful about drawing any exact inferences.

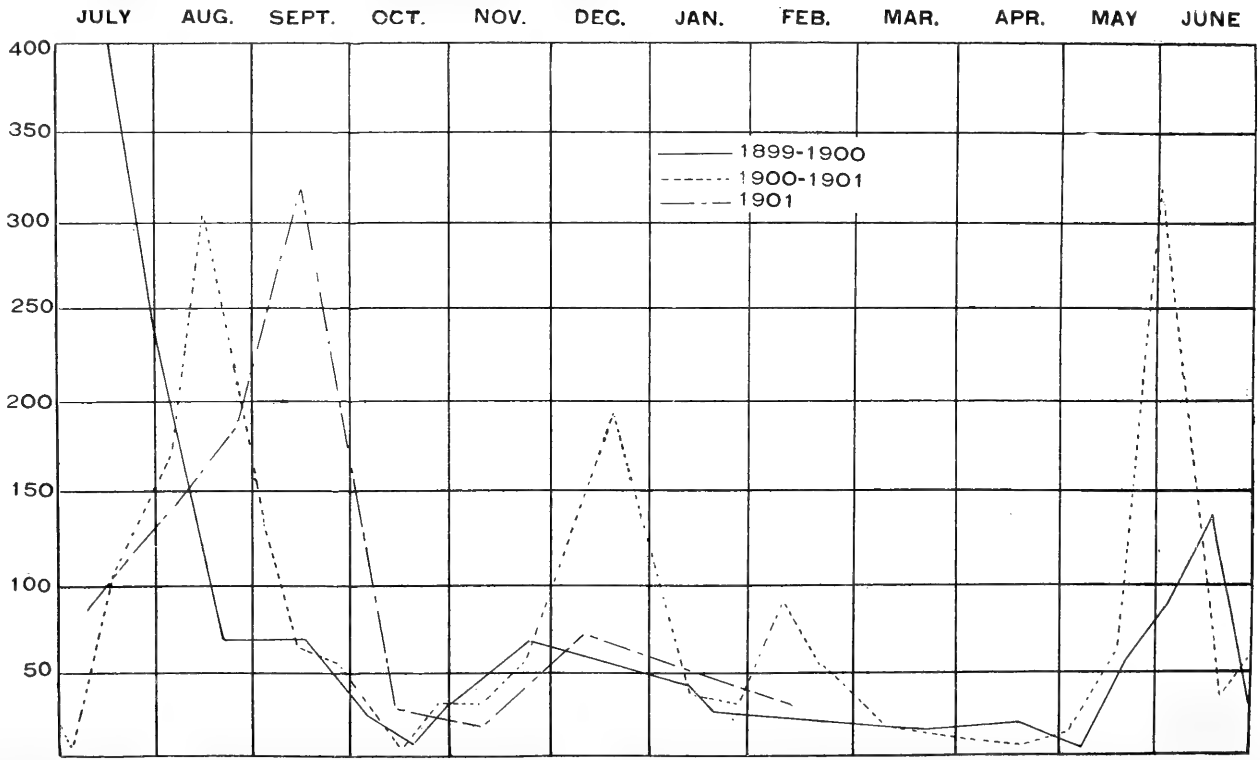
The cause of the difference in the curves of the two lakes is difficult to state. If the maximum of Green lake occurred somewhat later than that in Lake Winnebago it might be thought that the difference was due to the fact that the deeper body of water is heated more slowly, but in the curve of 1900 the maximum in Green lake is late in the fall, so that this can not be considered the real reason.



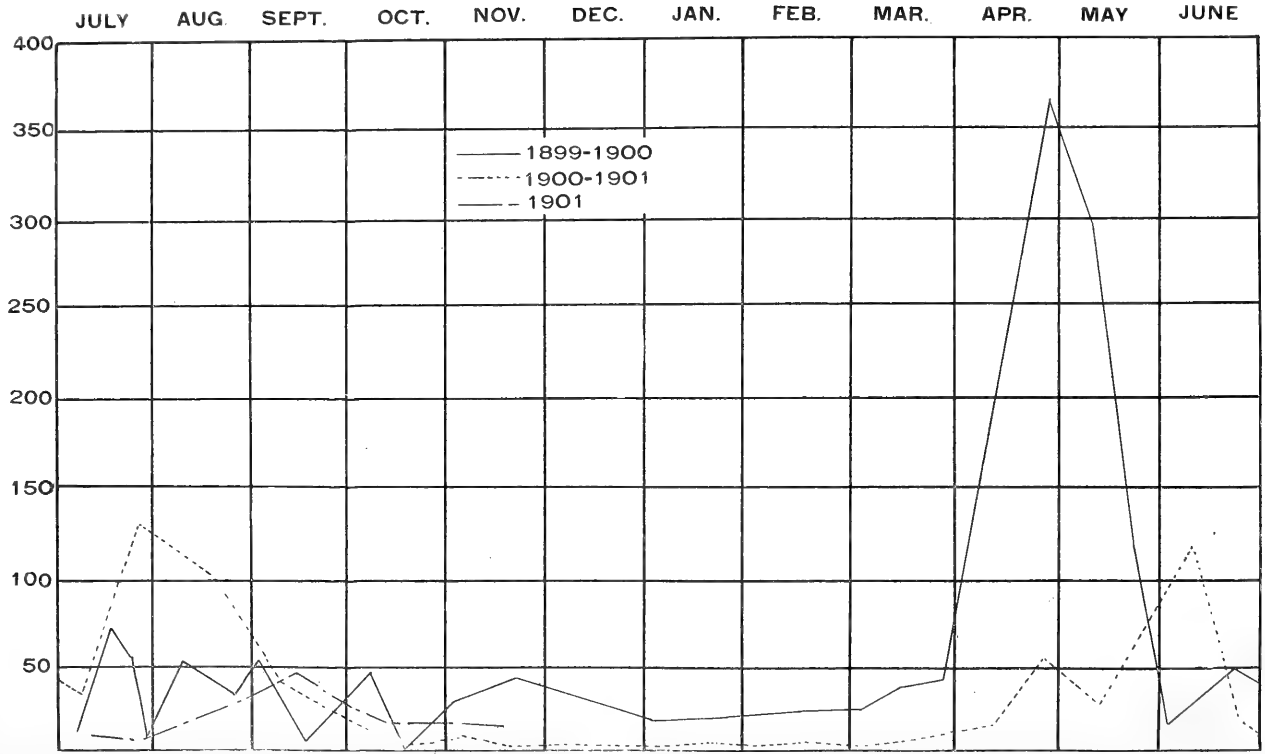
Curves of annual distribution of *Cyclops Leuckarti* per square meter in Green lake and Lake Winnebago, the numbers being reckoned in hundreds.



Curves of annual distribution of *Cyclops prasinus* per square meter in Green lake, the numbers being reckoned in thousands.



Curves of annual distribution of copepod larvae per square meter in Green lake, the numbers being reckoned in thousands.



Curves of annual distribution of copepod larvae per square meter in Lake Winnebago, the numbers being reckoned in thousands.

Cyclops prasinus Fischer.

C. prasinus occurs in Lake Winnebago only in very small numbers, so that a curve of annual occurrence would mean very little. I have found it in every month of the year except in March, April, and May. The largest numbers I have found in September and October.

In Green lake (Plate XI) it is a perennial form, but occurs in considerable numbers only from July to November, inclusive. In 1899 there were marked maxima the first of August and the first of October. In 1900 there was a similar increase in August, a few days later than the preceding year, and a fall maximum the first of November. In 1901 there was only one maximum and that occurred just after the middle of September. *C. prasinus* then seems to be distinctly dependent upon the summer temperature for its period of greatest development.

COPEPOD LARVAE.

Under this head were counted, not only nauplii, but all forms of immature copepods which were not sufficiently advanced in structure to be specifically determined. Inasmuch as it is impossible to determine the species of these larvae, it is difficult to explain the maxima of the curves (Plates XII and XIII) as due to the increase of particular copepods. It is only by comparing these curves with those of the various species that we can conjecture to what species a given maximum is due. In many cases these maxima are doubtless due to more than one species.

A glance at the plates shows that the total numbers of larval forms in Green lake are considerably larger than in Lake Winnebago as only once in the two years and a half under observation did the number in Lake Winnebago much exceed that in Green lake. This is no more than would be expected from the fact that the copepods play a much more important part in the plankton of deep water lakes than they do where the water is shallower.

In Lake Winnebago larval forms are found at all times of the year with two pronounced maxima, one in the spring and one in the summer or early fall. In the summer of 1899 the summer increase was distributed from July to December, with no great rise at any time. In the summer of 1901 there was a single maximum in the middle of July, while in 1902 this maximum did not come until the first of September. In the spring of 1900 there was, about the first of April, the largest number found at any time in the whole period under observation. In the next year, 1902, the maximum came about the middle of June.

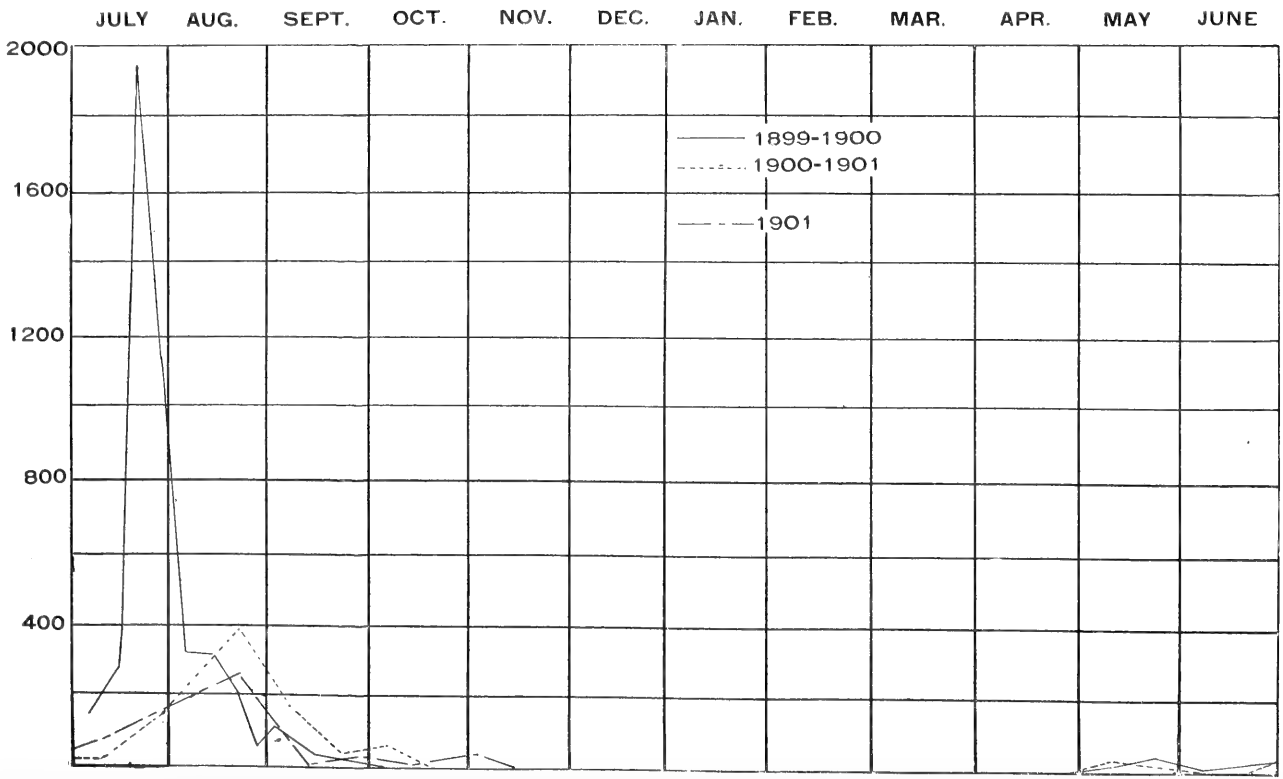
It is extremely difficult to correlate these curves with those of the mature copepods. The summer increase is doubtless largly composed of *Diaptomus oregonensis* and *Cyclops brevispinosus,* with some specimens of *Cyclops Leuckarti* and *Epischura.* A comparison of the summer curves of these species shows a very close relation with the curves of larvae. The winter larvae are probably entirely of *Cyclops pulchellus.* The spring maximum is composed of the three species, *Cyclops Leuckarti, Cyclops pulchellus,* and *Diaptomus oregonensis.*

In Green lake the curves resemble in general those of Lake Winnebago, with the exception of the marked increases in the winter months. In the three summers under observation there was a single maximum coming in the successive years in July, August, and September. I know of no reason why there should have been this difference. In the summer the larvae probably belong to all the species of copepods except *D. sicilis, Limnocalanus,* and *Epischura.* The rises in the winter months are due largely to the two latter forms. I have found larval *Epischura* only in February and March. The increase in October and November is because of the coming in of *Diaptomus sicilis.*

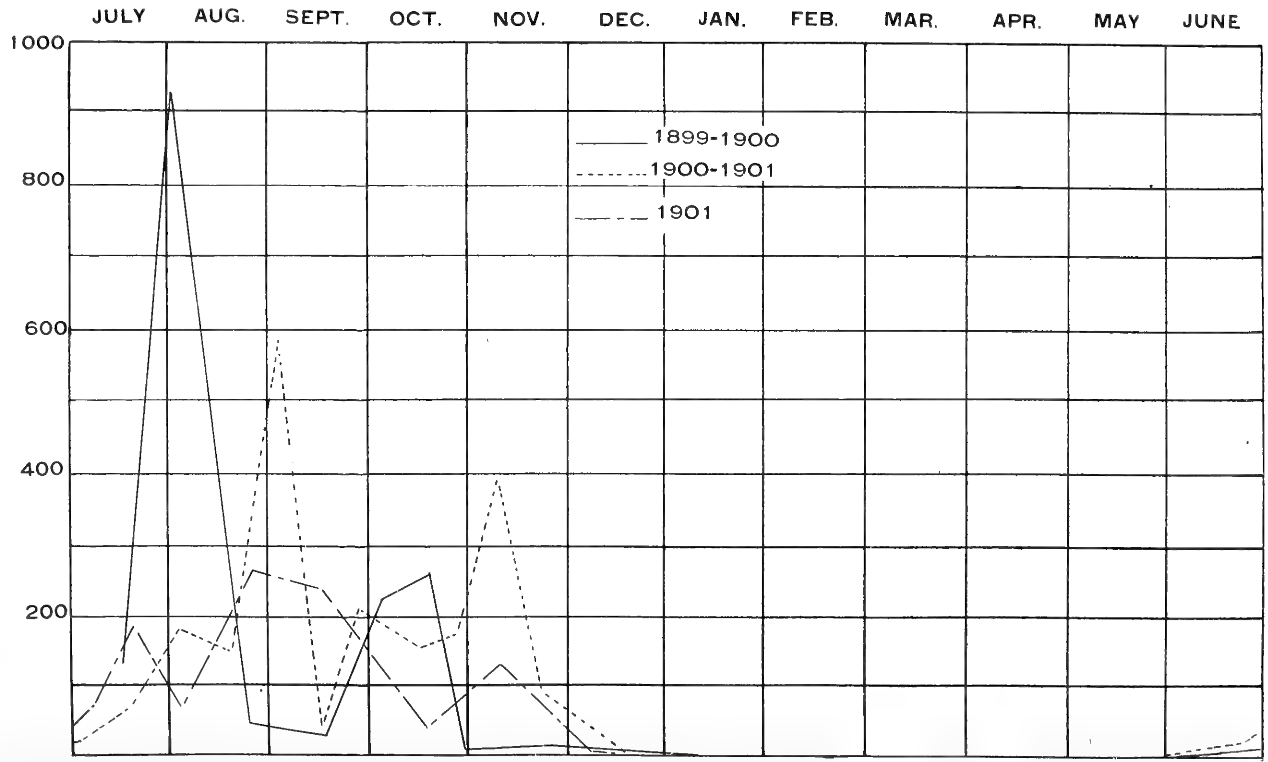
The rise in the curve in May and June is doubtless largely due to the increase in *D. minutus,* which later forms one of the chief elements in the plankton.

Diaphanosoma brachyurum Liév.

Diaphanosoma is distinctively dependent for its development upon the high temperature of the summer months. In Lake



Curves of annual distribution of *Diaphanosoma brachyurum* per square meter in Lake Winnebago, the numbers being reckoned in hundreds.



Curves of annual distribution of *Daphnia hyalina* per square meter in Green lake, the numbers being reckoned in hundreds.

Linder in Port finds one maximum in Aug—

Winnebago (Plate XIV) it appears as early as the middle of May and reaches its maximum in July or August, then rapidly diminishes, to disappear entirely the last of October.

In Green lake it does not appear ordinarily until into July, and reaches its maximum in August or September. Here, too, it disappears the last of October. These results compare very closely with those reached by Birge for Lake Mendota and those noted by the European authors, Apstein, Fric and Vavra, Burkhardt, Steuer, and Seligo.

It will be noted that the season for *Diaphanosoma* in Green lake is later than in Lake Winnebago, as we would expect, because of the more rapid warming of the shallower body of water. The total number in Lake Winnebago, too, is greater, and the maximum much more sharply marked.

Daphnia hyalina Leydig and *D. retrocurva* Forbes.

Under this head I have placed all the common limnetic *Daphnias,* without attempting a closer specific distinction. In Green lake I think the form is *retrocurva,* while in Lake Winnebago both *hyalina* and *retrocurva* are found.

In Green lake *Daphnia* may be found at all times in the year but between January and the last of May only in occasional specimens. Its principal time of life is between the first of June and the last of December. The results of the three summers given in Plate XV, compared with the curves of my former paper (Marsh '97), do not give sufficiently uniform results to indicate maxima occurring with any great regularity. In the summer of 1899 there were two distinct maxima, one the middle of July and one about the middle of October. In 1900 the two maxima were the last of August and the first of November, while in 1901 there were three maxima, all less pronounced than in the preceding years, one in July, one the latter part of August, and one the first of November. The curves would seem to indicate the common occurrence of two pronounced maxima, one in July or August, and one in October or November. The curves of my '97 paper indicate the same general principle.

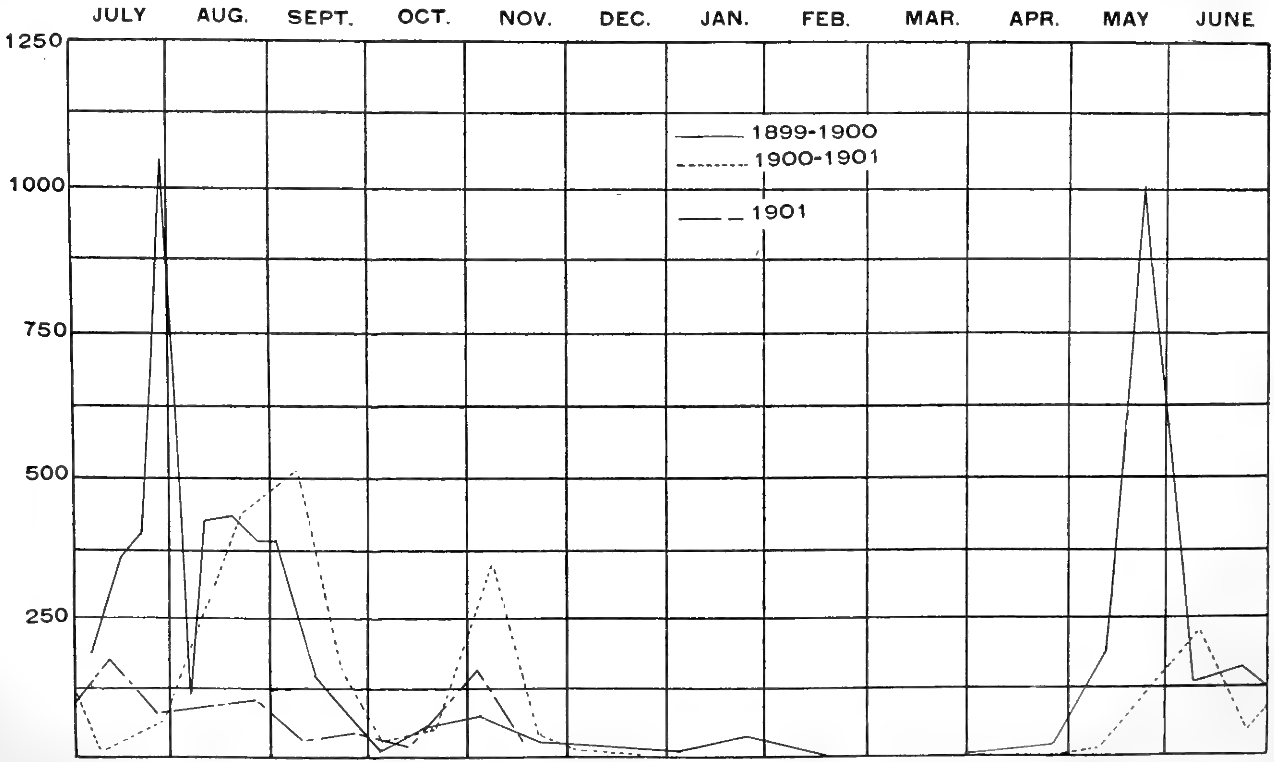
In Lake Winnebago (Plate XVI) the maxima during the summer months bear a fairly close resemblance to those of Green lake, but there is, in addition, a pronounced maximum in May or early June. This spring maximum may be due to the increase of *hyalina*, as Birge's results would indicate the existence of a spring maximum for this species.

A comparison of the work of Birge on Lake Mendota and the published results of the European authors Zacharias, Apstein, Burckhardt, Seligo, and Steuer shows that the occurrence of limnetic *Daphnia* is very similar the world over, the winter months having the minimum of production, and the greatest numbers appearing in the summer and fall. The absence of the spring maximum in Green lake is doubtless due to the slow warming of the deep body of water.

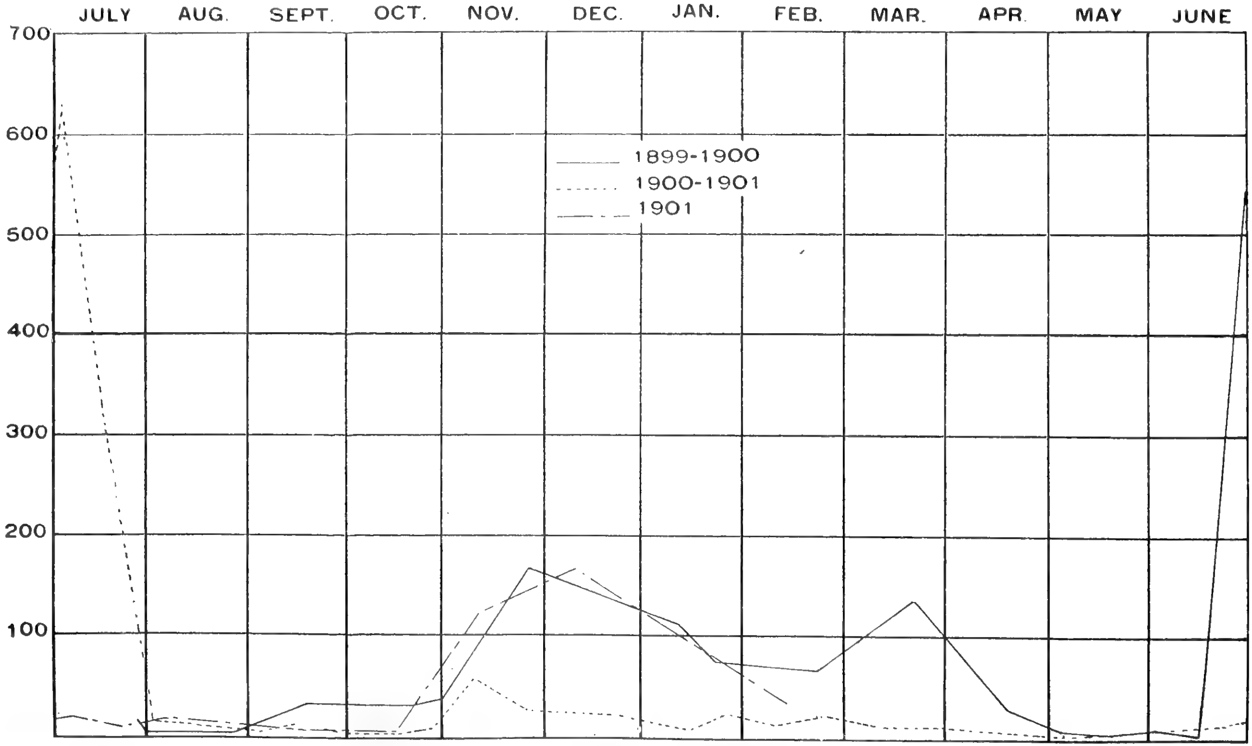
Daphnia pulex var. *pulicaria* Forbes.

This species I have not found at all in Green lake.

In Lake Winnebago it appeared May 11, 1900, and was found in large numbers in June and then entirely disappeared. In 1901 I found it in a single collection,—that of June 8. When it occurred it was in the bottom waters, and was very noticeable because of its size. It is possible that scattering individuals at other times were counted as *hyalina*, but if it occurred at all it must have been in very small numbers. Birge (Birge '97) has discussed in detail the occurrence of this species in Lake Mendota, stating that it occurs there in numbers only in the odd numbered years. This does not seem to be true in Lake Winnebago. He also states that it is confined to the region of the thermocline, being limited above by the high temperature of the water and below by the impurity of the bottom waters. If this were true it would explain the disappearance of this species in Lake Winnebago in summer, because this lake has no thermocline, and the whole body of water is heated to a high degree. It would seem that the conditions



Curves of annual distribution of *Daphnia hyalina* and *D. retrocurva* per square meter in Lake Winnebago, the numbers being reckoned in hundreds.



Curves of annual distribution of *Bosmina* per square meter in Green lake, the numbers being reckoned in thousands.

in Green lake would be peculiarly favorable for *Daphnia pulicaria,* but I have never found it, although my collections have now covered a considerable number of years.

In the other lakes examined in this investigation I found *Daphnia pulicaria* only in Shamrock and Pansy of the Clover Leaf lakes and in Pelican lake in two years. In the Clover Leaf lakes it occurred below the thermocline. Its occurrence in Pelican lake was somewhat unexpected, as this lake has no thermocline, and the species was found in August, after the lake was thoroughly warmed up.

In former collecting trips I have found *Daphnia pulicaria* in the deep waters of Lake Beulah in July and August, and Professor Birge (Birge '97) has already noted that it is common in the deep waters of the Oconomowoc lakes, which probably should be classed with the small deep lakes.

Bosmina.

In Lake Winnebago I have not found *Bosmina* at all in the months of July and August. In 1899 it did not appear until the first of December, and very few were found in the winter months. There was a very large increase about the first of June. Then it abruptly disappeared and reappeared the last of September. There was a fall maximum the first of November, and then a rapid decline. During the winter months there were very few, and no marked increase until the first of June, 1901, when there was an increase corresponding to that of the preceding year. It then disappeared and was found again the first of October, when it commenced to increase with great rapidity.

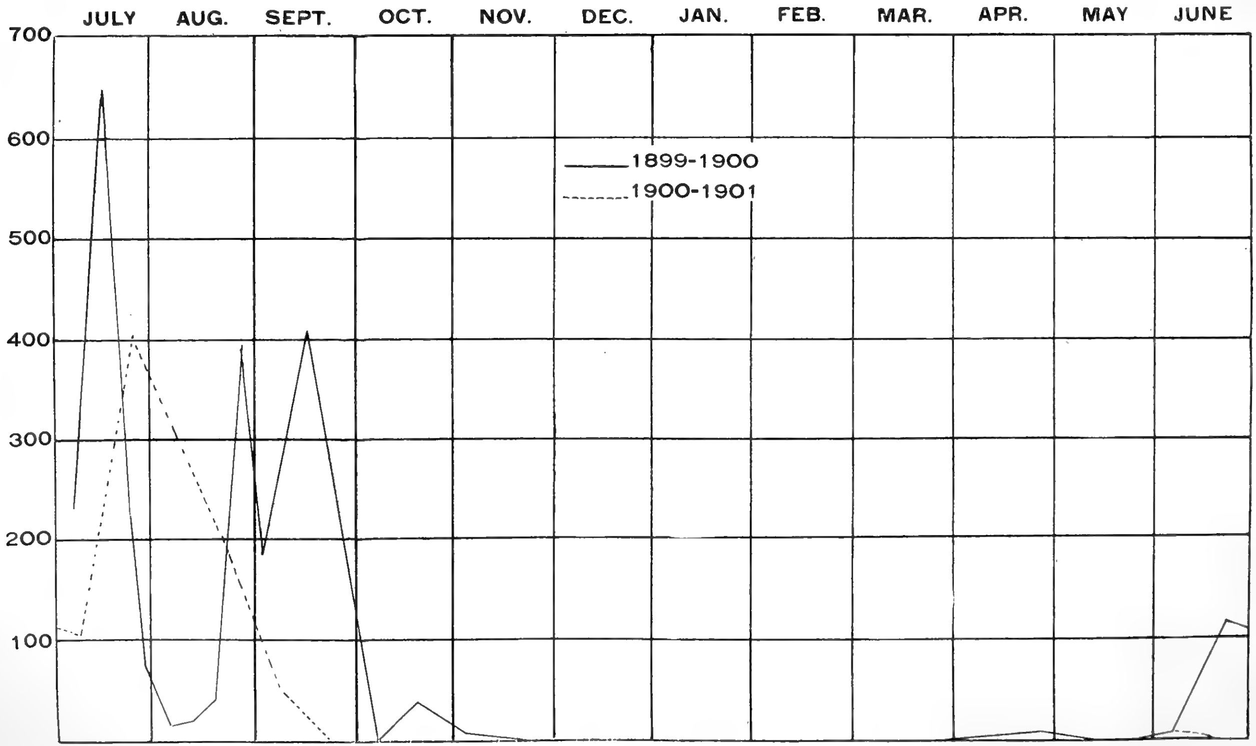
In Green lake, as shown by the curves (Plate XVII) *Bosmina* occurs at all times of the year. Comparing these curves with the curves in my former paper (Marsh '97) it would appear that we may expect *Bosmina* to have a fall maximum in November or December. After this maximum there is a sharp decline and the number then grows gradually smaller until June or July, when generally there is a slow increase followed by a rapid rise in the fall, which may come as early as September, but more commonly occurs in October or November. In 1900, by far the largest number of the year occurred in July. Nothing like this appeared in the other years, although there was an increase in July, 1899.

I think it can be said safely that *Bosmina* has two annual maxima, one in the late spring or early summer, and one late in the fall. In comparing the two lakes under consideration we find that the spring maximum occurs earlier in Lake Winnebago than in Green lake, probably due to the fact of the more rapid warming of the water in the shallow Lake Winnebago. In some years the spring maximum fails to appear in Green lake. The fall maximum seems, on the whole, to appear in Green lake somewhat later than in Lake Winnebago. If this maximum is dependent on some conditions following the fall cooling of the water, this later appearance in Green lake is easily explained. But so little is known of the life history of *Bosmina* that one would hardly feel safe in hazarding an explanation.

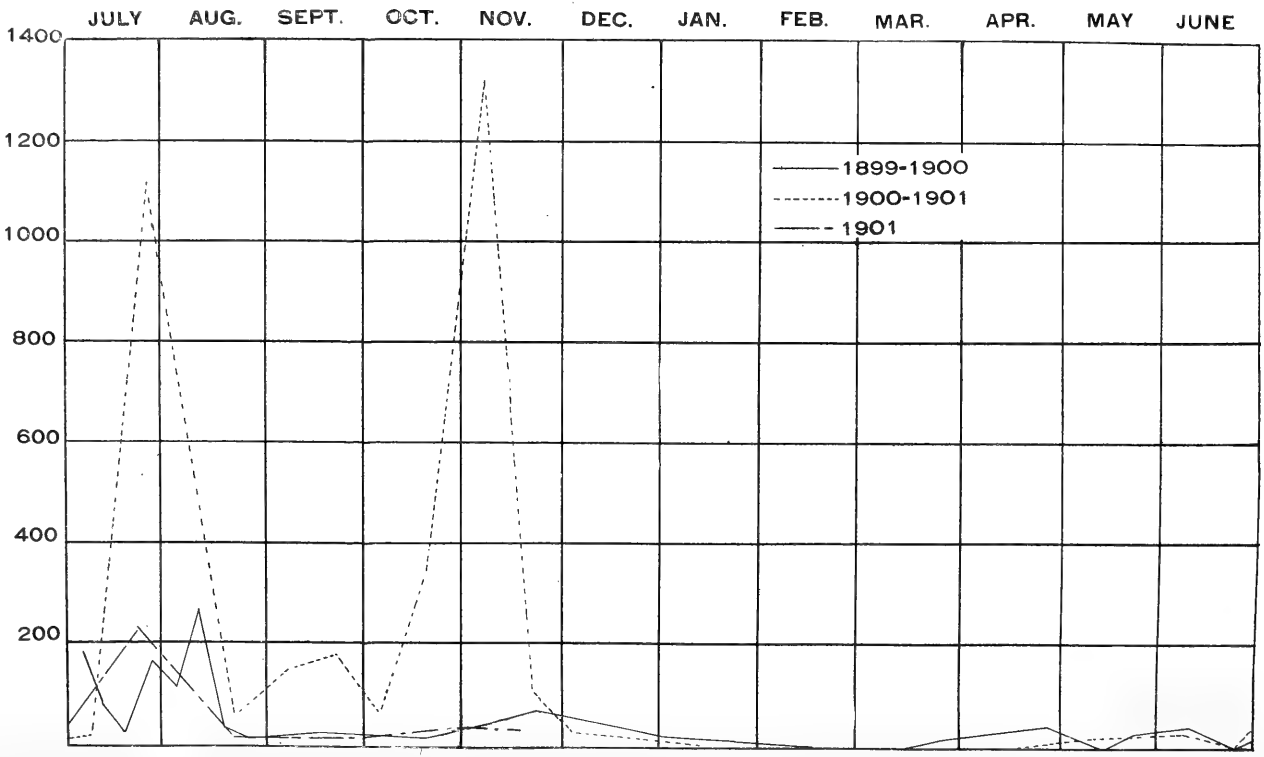
In comparing my results of the annual distribution of *Bosmina,* there seems to be a good deal of discrepancy, but probably the differences can be explained either by differences in local conditions or by the fact that most of the statements have been based on observations carried on for only a comparatively short time. No other observations, so far as I know, have been published in America, and the statements of European authors would indicate that in some cases there were two distinct maxima, but not in others.

Eurycercus lamellatus O. F. Müller.

Eurycercus lamellatus does not occur in the limnetic plankton of Green lake, but in Lake Winnebago (Plate XVIII) it was an important element of the summer plankton in 1899 and 1900. Curiously enough I found it in only one collection in 1901,—that of June 8. In the summer of 1899 it was found in great numbers about the middle of July, but had almost dis-



Curves of annual distribution of *Eurycercus lamellatus* per square meter in Lake Winnebago, the numbers being reckoned in hundreds.



Curves of annual distribution of *Chydorus sphaericus* per square meter in Lake Winnebago, the numbers being reckoned in hundreds.

appeared by the first of August. There was a rapid increase the last of August, another decrease and a rise again about September 20. It then decreased until the middle of October, and had entirely disappeared in December. In July and August it was perhaps the most noticeable element of the plankton, its greater specific gravity causing it to settle first in the centrifuging process. In 1900 it appeared as early as March, but did not commence to increase until well into June, and reached a single maximum about the first of August, then decreased rapidly and disappeared about the first of October. In 1901 it is evident that some untoward circumstances must have prevented its development.

In the collections made early in July, 1899, *Eurycercus* was much more abundant over the mud bottom well out in the lake than it was over the stony bottom nearer shore. Late in July the conditions were reversed, that is, *Eurycercus* was more numerous over the stony bottom nearer shore. An attempt was made to correlate this fact with the movements of fish, but not with entire success. It was found that while *Eurycercus* was prevalent, it was an important article of food for the sheepsheads, and apparently there was some movement of the sheepsheads corresponding to the change in position of the greatest numbers of *Eurycercus,* but the observations were not sufficiently numerous so that any final statement could be made.

Chydorus sphaericus O. F. Müller.

Chydorus occurs only occasionally in Green lake. In the summer of 1899 none were found. Considerable numbers were found in October of 1900, and it continued in small numbers in the collections until January, but was found in none of the later collections.

In Lake Winnebago (Plate XIX) it appears to be a perennial form. In the summer of 1899 it had a sharp maximum early in August. It then declined rapidly and only few were found until July of 1900, when there was a sudden and great increase. A still greater increase occurred about the first of November.

I have made no systematic collections from other lakes, but I have found *Chydorus* in great numbers in Stone, Sand, and Pelican lakes in September.

I think we may say this,—that *Chydorus* is a perennial form, reaching its greatest numbers in the months from July to November, with its maximum probably in October or November, but with sometimes a very marked increase also in July.

Leptodora hyalina Lilljeborg.

Plate XX shows the annual distribution of *Leptodora* in Lake Winnebago. It was entirely absent from both lakes from November until May. In Lake Winnebago it occurs as early as the beginning of May, but in Green lake it does not appear until into July. It disappears in Green lake, too, early in September. In both lakes its principal occurrence is in the months of July, August, and September. The occurrence in Lake Winnebago corresponds very closely with Birge's statement in regard to Lake Mendota, although he has found them there as late as December.

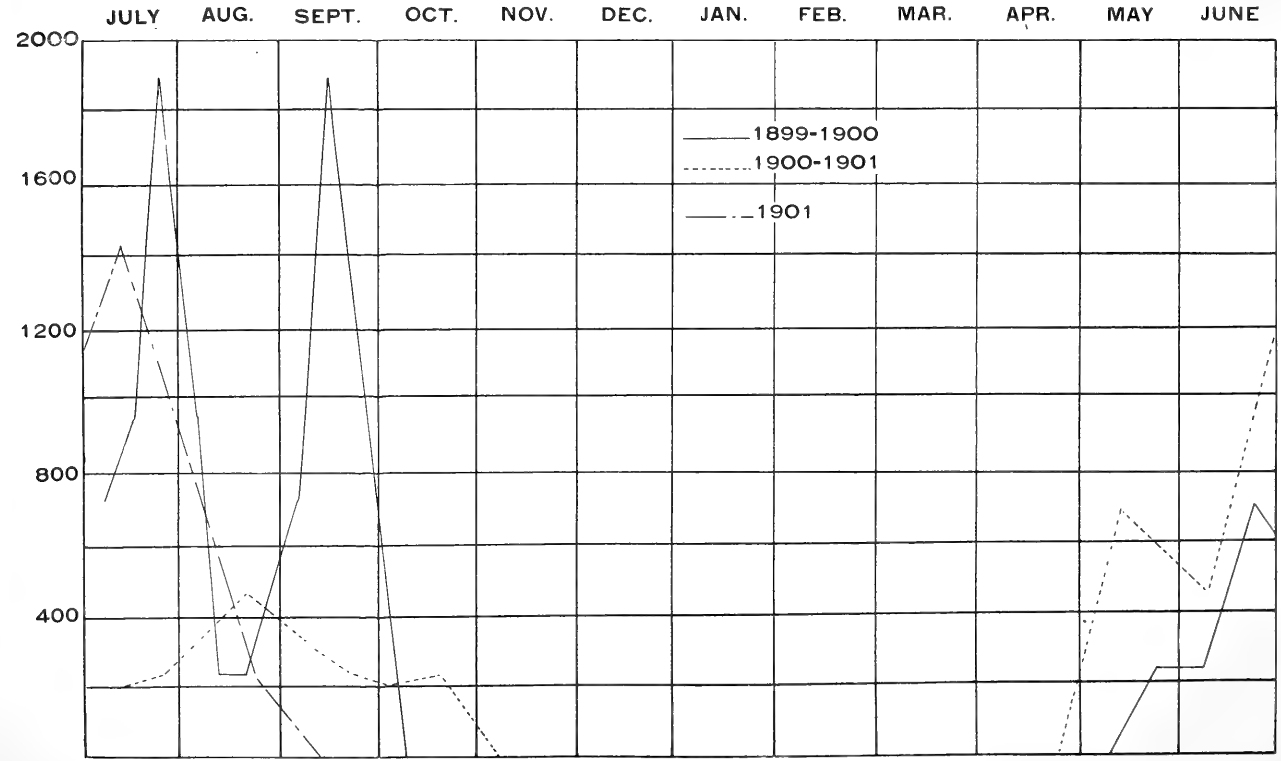
The observations of Burckhardt, Steuer, and Seligo in Europe in regard to this species show that the occurrence there is very nearly the same as in this country.

Cypris.

An undetermined species of ostracod was found in both Green lake and Lake Winnebago collections. In Green lake it was found in September and October of two years and in February and March of one year. In Lake Winnebago its range seems to have been from the first of April to the last of September. It was very much more abundant in the summer of 1899 than in that of 1900. It was not at any time present in sufficient numbers to play any noticeable part in the total amount of plankton.

The Bloom.

The phenomenon of the "bloom" or the "working of the lakes," or the "breaking of the meres" as it is called in Great



Curves of annual distribution of *Leptodora hyalina* per square meter in Lake Winnebago.

Britain, should receive a little attention although it has been thoroughly discussed, in its general aspects, by other authors. This phenomenon is especially marked in Lake Winnebago in some summers. It is due, of course, to the enormous growth of the plants of the plankton, that growth being particularly fostered by the hot weather of midsummer. The plants especially concerned in forming the bloom are *Clathrocystis, Anabaena, Aphanizomenon, Oscillaria, Lingbya,* and *Gloiotrichia.* The times of occurrence of these plants have already been noticed in the discussion of the individual constituents of the plankton. At the middle of August, in some summers, on a still day, the surface of Lake Winnebago is apparently a solid, opaque green. Some of this material decomposes, and as the currents slowly move along the surface material, it shows a wavy streaked appearance like the surface of polished malachite. Its intrinsic beauty, however, does not attract the average person, for he looks upon it as "scum," and he thinks of it simply as an evidence of filth. This material is thrown upon the shores by the waves until the rocks alongshore are completely covered with it, and it may in its decay become very offensive. Following the maximum period of the "bloom" *Cladophora* appears and covers the littoral rocks with a thick mat of green. This great growth of "bloom" naturally attracts the attention of the non-scientific observer, and many absurd explanations of its presence are given. The most common one in Oshkosh is that it is a mass of seeds coming from the marshy shores of the Fox and Wolf above Oshkosh. Doubtless the *Anabaena* and *Gloiotrichia* have given rise to the supposition that the bloom is a mass of seeds. The decomposition of *Gloiotrichia* produces a blood red coloring matter which is sometimes very noticeable on the shores of Lake Winnebago, and has led people to question as to whether the lake is not affected by one of the plagues of Egypt.

When the water is still the plants of the bloom are in greatest abundance, close to the surface, and are distributed very uniformly over the lake. Frequently, in the latter part of July and in August, there may be seen floating about yellowish green masses of a more or less spherical outline, perhaps as much as three inches or more in diameter. These masses, which are composed of aggregations of *Aphanizomenon* mingled with scattered fronds of *Gloiotrichia* and *Anabaena,* have very little coherence and elude the collector by falling in pieces almost at a touch. As is evident from the discussion of the occurrence of the algal constituents of the plankton, the bloom is not a prominent feature of the deep lakes,—in fact in some years the growth of these algae is hardly noticed by the ordinary observer,—and of the shallow lakes few seem to produce so large an amount as is seen in Lake Winnebago. Of the lakes under observation, Shawano and Pelican were the only ones that could be compared at all with Lake Winnebago.

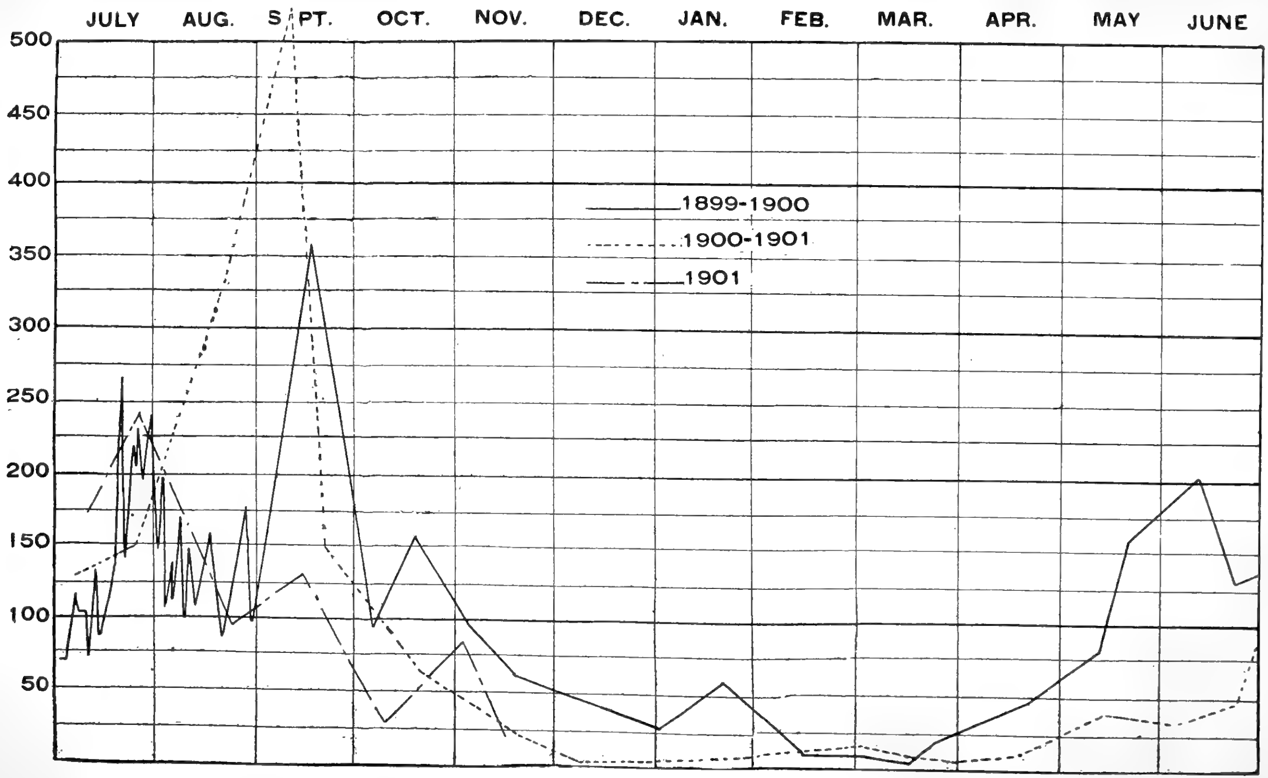
ANNUAL DISTRIBUTION OF THE TOTAL PLANKTON.

Plates XXI and XXII shows the annual distribution of the total plankton in Green lake and Lake Winnebago during the two years under observation.

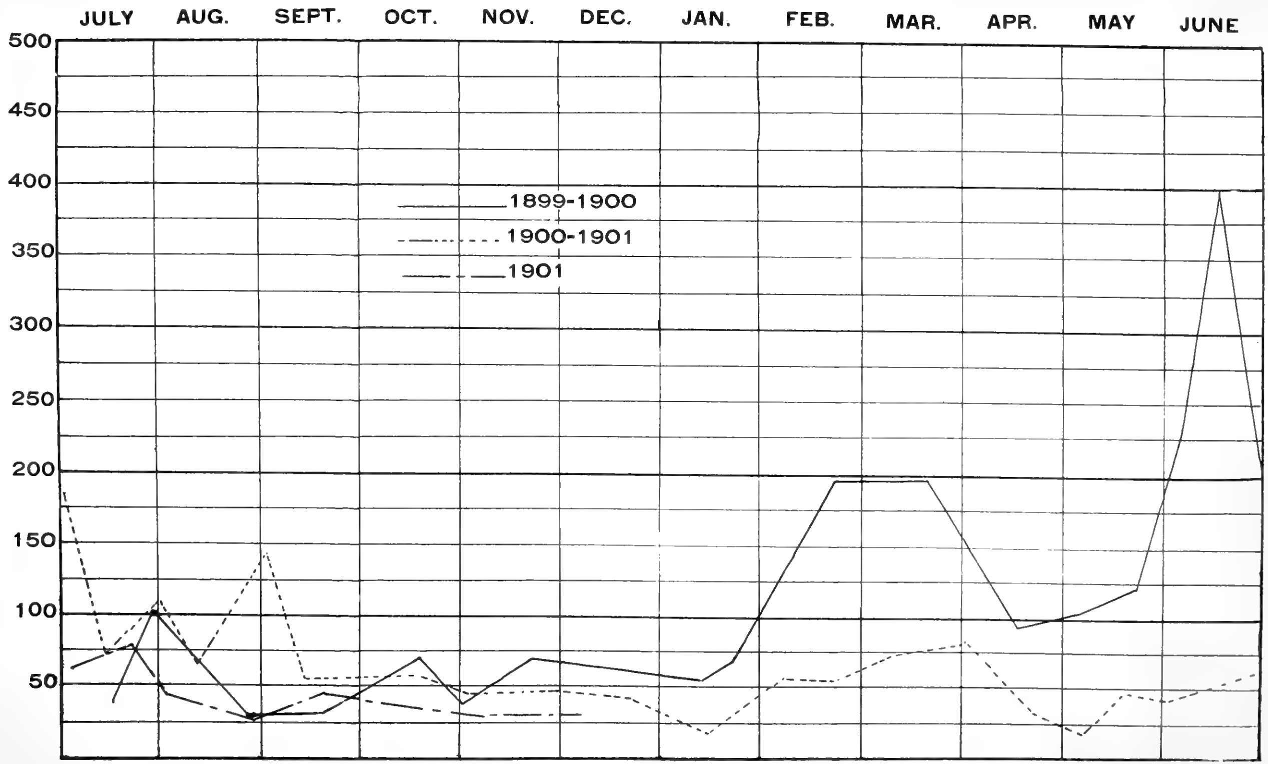
An examination of the curves, while it shows marked similarity in the production of the years studied, shows also almost as marked differences. In general it may be said that the summer months are the time of greatest productiveness, although Green lake shows an exception to this. We notice also that the successive years not only differ somewhat in the time of maximum production, but that there is a marked difference in the total amount of plankton.

In Lake Winnebago in the first year there were four periods of large production,—the last of July, the middle of September, and the early part of June. In the second year there was a single maximum which occurred early in September, with not even slight increases at other times. In the third summer there was a pronounced maximum in the last of July, with slight increases in September and October.

In Green lake there are similar differences.



Curves of annual distribution of total plankton in Lake Winnebago per square meter, estimated in cubic centimeters.



Curves of annual distribution of total plankton in Green lake per square meter, estimated in cubic centimeters.

In the first summer the greatest amount of plankton was about the first of August and the middle of October. In the following February and March, however, the total of plankton was much larger than even in the summer months, while the greatest record of the year was reached about the middle of June. From this point there was a decrease followed by lesser maxima the first of August and the first of September. There was then a steady decrease to a minimum in the middle of January. From this point there was an increase to a March maximum corresponding to that of the preceding year, but the total of this March maximum was much smaller than that of the March of the preceding year. It then fell to a May minimum, which was almost as small as that of the winter. This was followed by a slow increase to a single summer maximum in the latter part of July, from which there was a slow fall through the remainder of the summer and autumn months.

CONSTITUENTS WHICH PRODUCE PLANKTON MAXIMA.

It is a matter of great interest to determine what organisms are responsible for the maxima, and what are lacking at the minimum periods. Steuer has stated that the result of his work indicates that the general plankton curve follows closely the rotatoria curve. This is hardly true of either of the lakes under consideration. But what organisms are responsible for these maxima? A comparison of the general plankton curves with those of the individual animals and plants shows no close relation between the total plankton and the species. There is this general relation that most forms are produced in greatest numbers in the months from May and June until October; this is especially true of the plants. But no one organism seems to have a controlling influence on the total amount of plankton, except in one or two particular cases. This is shown by a careful analysis of the plankton constituents at the various maximum periods.

In the summer of 1899, in Lake Winnebago, there were two maxima. These correspond to the maxima of *Eurycercus lamellatus*. *Eurycercus* is a very bulky form, and when it is present in considerable numbers is a large element in the total plankton. A careful analysis of the summer collections shows, however, that while *Eurycercus* was an important factor in these maxima, it was by no means alone responsible for them. They were rather caused by a general increase in a number of forms of crustacea, accompanied by a large development of the plants.

In the maximum of June, 1900, *Daphnia pulicaria,* another bulky form, also reached its maximum development for the year. But at this time, too, other forms are as important in making up the total. There was a general increase of most of the crustacea,—among others *Diaptomus oregonensis* being very prominent. Many of the plants, too, were present in considerable numbers, especially *Asterionella.*

In the summer of 1900 the maximum early in September was coincident with a maximum of *Daphnia hyalina.* But this was not in itself sufficient to produce the maximum. The real determining cause was the enormous number of *Anabaena, Clathrocystis,* and an unnamed alga. The winter maximum was characterized by an almost total lack of crustacea and algae, while rotatoria, diatomaceae, and protozoa in small numbers formed the bulk of the plankton.

In the summer of 1901 there was one pronounced maximum the last of July. At this time there was a large number of crustacea, but the size of the collections was mainly caused by the enormous numbers of *Anabacna, Lingbya,* and *Aphanizomenon.*

In Green lake the maximum of Aug. 1, 1899, was due to the large number of several of the entomostraca, especially of *Diaptomus minutus* and *Daphnia.* The increase of the first of October was due mostly to the crustacea, *Diaptomus minutus* and *Cyclops prasinus* being important elements, while the increase in *Bosmina* is another factor. The rise the last of November is due mainly to the very large number of *Bosmina,* combined with large numbers of *Asterionella* and *Sphaerella.*

The striking feature of the Green lake curve for the year

1899–1900, however, is the great increase in the total plankton in February and March when the lake was covered with nearly two feet of ice. The entomostraca figuring in this maximum were *Diaptomus sicilis* and *Bosmina.* With these were associated many rotatoria. But it was to *Asterionella* that the great increase was mainly due. This organism was present in countless numbers. In the maximum in June *Diaptomus sicilis* and copepod larvae were prominent, but here again *Asterionella* was perhaps the most important.

The maximum of the first of August, 1900, was due to several entomostraca, as in the case of the preceding year. *Daphnia* was less abundant than in 1899 but formed perhaps the most important factor in the larger maximum of Sept. 1. In March again occurs a winter maximum, as in 1900, but the total is much less. This was caused, as the year before, mainly by the enormous increase in *Asterionella,* associated with great numbers of *Synedra pulchella* and *Synedra acus* var. *delicatissima.*

In the summer of 1901 there was a single maximum in the latter part of July in which, as in the former years, *Diaptomus minutus* played a very prominent part; at this time, too, *Ceratium* and *Dinobryon* were very numerous.

In the winter of 1902 there was again an increase as in the two preceding years caused in part by the numbers of *Diaptomus sicilis,* but more by the enormous numbers of *Asterionella* and *Synedra pulchella.*

COMPARISON OF AMOUNT OF PLANKTON IN DIFFERENT YEARS.

It will be seen, by a glance at the curves, that the total amount of plankton varies quite widely in the years under consideration, and the question arises whether there may be plankton poor years and plankton rich years. Three summers would hardly give material to decide such a question, but it may be noticed that the summer production in 1901 was distinctly less in both lakes than in the preceding years. It is interesting to notice in this connection, the plankton collections made in a series of northern lakes about the middle of August in 1900 and 1901. In all the lakes the collections of 1901 were much smaller than in 1900. It would seem probable then that the summer of 1901 was a plankton poor summer. I do not know what reason can be assigned for this fact. It is a somewhat significant fact, however, that the curve of mean temperature for 1901 differs distinctly from the mean in that it rises sharply to a maximum in the middle of July and then declines rapidly, instead of continuing at practically the same height through most of August as is commonly the case. It is possible that the short duration of the extreme hot weather of summer may have had some effect in reducing the amount of plankton.

COMPARISON OF PLANKTON IN GREEN LAKE AND LAKE WINNEBAGO.

In comparing the curves of the two lakes, perhaps the most noticeable difference is the enormously greater summer production in Lake Winnebago. This is due to the very much greater production of plants in the shallower lake. Green lake varies from the mean much less during the year than does Lake Winnebago. The winter production in Green lake is absolutely considerably greater than in Lake Winnebago. This, as has been pointed out before is due both to the greater number of entomostraca, and to the enormous production of *Asterionella* in Green lake, accompanied sometimes by a corresponding increase in the species of *Synedra*. I can only conjecture as to the cause of the greater winter production in Green lake, but I think it is possibly connected with the fact that it is very late before it is frozen over. Lake Winnebago, because of its slight depth, is cooled off early in the fall and is covered with ice while Green lake is still open and exposed to aeration. The actual amount of water in Lake Winnebago is small as compared with its superficial dimensions, and its supply of oxygen must be much smaller than that of a body of deep water like Green lake: thus it seems to me that the conditions for animal life must be much less favorable in Lake Winnebago in winter than in Green lake. I have very little to offer in the way of proof of this suggestion; it is significant, however, that the only other lake from which I have winter collections,—Cedar lake, Washington Co.,—has an amount of plankton intermediate between Green lake and Lake Winnebago. Because of its smaller size Cedar lake must be earlier than Green lake in freezing over, and bcause of its greater depth,—nearly 100 feet,—the amount of water as compared with its area is much larger than in Lake Winnebago, and we might expect a larger production of plankton than in that lake.

COMPARISON WITH THE PLANKTON OF OTHER LAKES.

The other lakes connected with the Fox river, namely Lake Poygan, Lake Wineconne, and Lake Buttes des Morts, resemble Lake Winnebago very closely in the plankton, but the amount is not so great. Of the other lakes, Pelican and Shawano were particularly rich in plankton. Shawano, at the time of one set of collections, had more plankton than Lake Winnebago. Pelican, in three of the four years in which examinations were made, was considerably richer than Lake Winnebago. Both Shawano and Pelican are shallow lakes and comparable with Lake Winnebago in their general characteristics. Sand lake in 1899 had about the same amount of plankton as Pelican, but much less in the three succeeding years. Stone, Birch, Cedar, and the Waupaca lakes may, in a general way, be classed together, all having considerably less plankton than the shallower lakes.

The Eagle River lakes are connected by wide thoroughfares so that they resemble each other very closely, but the larger ones seem to have the greater amount of plankton. The same thing is true of the Waupaca chain of lakes.

In the case of the large collections which were made in all these lakes, it was the plants also that formed the prominent part of the plankton.

In Table III have been listed the volumes of plankton as obtained in the various lakes of the state. In addition to what has just been said in comparing the results with those in Green lake and Lake Winnebago, something should be said of the lakes as compared with each other. The collections on the northern lakes were made in the course of four rapid trips in four successive years. The collections of 1899 were made in the latter part of September, and those of the succeeding years about the middle of August. The collections were practically synchronous in each year, and a comparison of the figures is interesting, although, as I have said in another part of this paper, one must be careful about drawing inferences from a small number of collections, and it is only averages upon which one can place much reliance.

In the following table, in which I have listed the lakes of this circuit for the sake of comparison, I have placed first Birch and Stone lakes which belong distinctly to the class of small deep lakes, next Sand lake, which is intermediate between the two classes, then the Clover Leaf lakes, which, although shallow, yet because of their small size, have a marked thermocline; the rest of the list belong distinctly to the shallow lake type. As the Eagle River lakes do not differ materially in the amount of their plankton, I have listed only one, the largest,—Eagle lake.

	1899.	1900.	1901.	1902.
Birch	80.97	114.24	79.25	59.50
Stone	71.4	171.36	52.36	54.55
Sand	205.16	152.32	63.43	124.95
Clover Leaf:				
Golden rod	....	90 44	59.50	71.4
Pansy	....	114.24	33 80	92.11
Shamrock	....	107.10	35.70	232.05
Bass	53.55	....	....	....
Silver	63 78	....	....	....
Summit	107.10	....	....	....
Long	....	214.2	....	....
Eagle	....	233 24	185.64	345.10
Pelican	122.09	466.48	376.04	517.65
Shawano	....	114.24	107.10	....

When one examines this table, the degree of uniformity in successive years is somwhat surprising, for we must expect annual variations in the maxima of the total plankton. I have already called attention to the fact that all the collections of 1900 were larger than those of 1902. This was especially marked in the case of Birch, Stone, and Sand lakes, and was largely due in each case to the greater number of crustacea, especially of the *Diaptomi;* in Sand lake there was also a larger number of the algae in 1900, but it was in the crustacea that there was the greatest difference.

The large collection in Shamrock in 1902 was due in the main to the comparatively large number of *Daphnia pulicaria;* the great size of this form makes it, when present, an important factor in the total plankton.

In the distinctively shallow lakes, Eagle, Pelican, and Shawano, the uniformity in the successive years was very marked, the differences being hardly greater than might be expected from hauls made on successive days in the same year. It will be noticed that the uniformity in the case of the shallow lakes is much greater than in the deep lakes.

In comparing the lakes with each other at each period of collection we find that Pelican has the greatest amount of plankton in the last three years, but was outranked by Sand lake in 1899. This large amount of plankton in Sand lake in 1899 was due to the abundance of "bloom," in which the most prominent plant was *Anabaena.* I think this is an exceptional record for *Anabaena* for, as I have stated before, the plants of the bloom flourish especially in warm weather, and we should not expect them late in September. The time of the collection, too, had been preceded by cold weather, and on the day of the collection ice had formed by the roadside in the morning.

Eagle lake was a constant second to Pelican in the years under examination. In regard to the other lakes there seems to be no fixed order of precedence.

In comparing the years 1900 and 1901 it is interesting that the relative difference is much greater in the case of the deep lakes than is true of the shallow lakes.

I have already remarked, in comparing the plankton of Green lake with that of Lake Winnebago, that Green lake has the greater amount of plankton in the winter, and Lake Winnebago the greater amount in the summer. I think we may say that this general comparison holds in regard to all deep and shallow lakes. The deep lakes because of the later date of freezing, the larger amount of water, and hence the larger amount of available oxygen, will have a greater amount of winter plankton, while the shallower lakes will in summer have the greater amount of plankton because of the favorable conditions for plant growth produced by the higher temperature of the water and the relatively large area of the bottom that is reached by the sunlight.

CHAPTER III.

DISCUSSION OF RESULTS-

VALUE OF PLANKTON COLLECTIONS.

It is a little difficult to state just what value should be placed on the measurement of plankton collections in limnology.

It is, of course, evident that such collections give material for the qualitative determination of the fauna and flora, so that lakes can be compared with each other with reference to the distribution of forms. Care must be taken in this, however, unless the lakes are under examination for a long period of time, for, while in general the annual appearance of any form will be at about the same time in all lakes, nevertheless this appearance is subject to considerable variation, partly from differences in local conditions, and partly from differences in other conditions of environment; I think there is no doubt that the algae of the "bloom" may differ in their maximum periods not only days, but perhaps weeks, when the lakes appear to have similar conditions. Thus it may happen that a form may be abundant in one lake, and absent or present in small numbers in another at any given time, but later or earlier it may be abundant in the second lake. The absence of a form at a particular time is not always proof that the form is never present. For example, *Diaptomus sicilis* might easily be overlooked in the fauna of Green lake if we were to depend entirely on summer collections, or *Cyclops pulchellus* in Lake Winnebago if no winter collectons were made. As has been indicated already, also, forms may be very abundant in one year and either entirely lacking or present in small numbers in another.

So even for qualitative determinations, it is necessary, if one would be strictly accurate, to make collections not only at all seasons of the year, but for a series of years.

When one makes plankton measurements, and compares one lake with another from such records, the results are valuable, but it must be recognized that they are subject to certain sources of error. It has been already indicated that the horizontal distribution of the plankton is remarkably uniform. Yet this uniformity is subject to wide variations, so that inferences from single plankton collections might be very erroneous. Safety in drawing conclusions lies only in averages, and the larger the number of collections from which those averages can be drawn the safer are the conclusions.

It follows, I think, that refinements in plankton measurement are unprofitable. It must be acknowledged that the measurement by settling is inaccurate, and that the use of the centrifuge, while more accurate, nevertheless still leaves a large margin of error. Of course measurement by weighing is exact, but the results hardly justify the labor necessary.

I would not have it understood, from what has just been said, that I would throw discredit on plankton measurement, for this paper is evidence of the importance I attach to it, but I wish to emphasize the fact that such measurements never can have the merit of exactness, for allowance must always be made for error.

It is very desirable if lakes are to be compared with each other in regard to the amount of plankton, that they should be under continuons observation for a long time, preferably for a term of years, for there may be considerable differences in the plankton of successive years.

RELATIVE IMPORTANCE OF PLANKTON CONSTITUENTS IN PRODUCING MAXIMA.

In Lake Winnebago and shallow lakes of a similar type it is evident that the great maxima are produced by plants. We have found in the discussion of the Lake Winnebago plankton that certain cladocera, like *Eurycercus,* sometimes form an important part of the plankton, but it may be said generally that all large maxima are dependent for their size on plants.

In deep lakes of the type of Green lake, the crustacea, as compared with the plants, are much more abundant than in the shallow lake, but even here, too, the plants, especially the diatoms, are to a considerable extent responsible for the maxima. This is shown very strikingly in the March maxima of Green lake.

It will be noticed, too, that when crustacea are largely important in producing plankton maxima, it is not as a rule the result of the development of a single kind, but the result of the simultaneous development of several kinds.

In the discussion of the total plankton of the lakes in the northern part of the state, I have stated that the August plankton of the shallow lakes in successive years is more uniform than that of the deep lakes. This is explained, I think, by the greater relative importance of the crustacea in the deep lakes, for there is greater variation in the maxima of the crustacea than in those of the "bloom." In plankton collections covering a period of years, we may expect the curves for the shallow lakes to show much greater uniformity than those of the deep lakes because of the greater importance of the vegetable part of the plankton.

COMPARISON OF PLANKTON AND TEMPERATURE CURVES.

The temperature curves of the lake waters are similar to the mean curves of the localities in which the lakes are situated, with of course fewer variations and with a summer maximum at a somewhat later period. The summer maximum of the surface in Green lake ordinarily comes in the early part or middle of August, while the annual mean of this part of the state has its maximum about the middle of July. Lake Winnebago, because of its slight depth, warms up more quickly and cools with corresponding quickness.

In comparing the temperature curves with the total plankton curves we find only a general resemblance. The greatest amount of plankton, generally speaking, is found in the hottest months. Remembering what I have said before, that the plankton is largely dependent for its amount on the plants, this is what would be expected, inasmuch as a high temperature is favorable to plant growth. In some cases a maximum seems to follow the period of highest temperature, but this is by no means always the case. Inasmuch as plants are more important in the plankton of the shallow lakes, it follows that the plankton of such lakes follows the temperature curve more closely than does that of the deep lakes. The deep lakes have annual conditions more closely approaching uniformity, hence the variations during the year are less marked, and as they never reach the high summer temperature of the shallow lakes, they never have such a large production of plants like *Gloiotrichia*, *Anabaena*, and *Lingbya.*

The fact, too, that the crustacea form so much greater proportion of the plankton in the deep lakes, makes the correspondence with the temperature curve less, for some of the crustacea have winter maxima.

In comparing the annual curves of the crustacea, it appears that the summer maxima of most of them came somewhat earlier in 1899 than in 1900. This does not seem to be true of the general plankton. I have been interested to know what made the difference, but I am not sure that I have detected the real reason. The maxima of the general plankton, as has been said, are largely dependent on the plants rather than the animals. It would seem then, that the cause which made the 1899 summer maxima of crustacea greater than those of 1900 must have been something that would affect crustacea but would not affect plants. A comparison of the temperature curves of the two years shows that the summer maximum came somewhat earlier in 1899 than in 1900. This might explain the earlier maxima of the crustacea, but I do not quite undestand why the plants should not have been equally affected.

COMPARISON OF CURVES OF TOTAL PLANKTON WITH CURVES OF PLANKTON CONSTITUENTS.

As has already been noted, the curves of plant production follow very closely the curves of total plankton, for it is to plants that the great differences in the amount of plankton are due. There are some marked exceptions to this general rule, like the great maxima of certain of the diatoms.

In general terms it may be said that the curves for animals also follow the total plankton curves, most of them reaching their maxima in the summer months. There are many exceptions, however. Some of the crustacea are perennial in their occurrence, and some have winter maxima. Some of the rotifera, too, occur only in the winter months. Generally speaking, it is in the deep lakes that we find more of those animals having winter maxima, although there are some exceptions. Some of the Lake Winnebago rotifera, for instance, are found only in the winter season. It is evident, however, that the greater uniformity of conditions in the deep lakes would make winter production more possible.

HORIZONTAL DISTRIBUTION.

One of the questions to which especial attention was paid was the matter of the uniformity of horizontal distribution. I discussed this question in some detail in a former paper (Marsh '97, pp. 218–223) expressing my own belief that the numbers of crustacea might vary widely in different parts of a lake, and that they might, at some times, be aggregated together in swarms, but I did not attempt to explain the reason of the existence of swarms. I also stated my belief that single plankton collections might give erroneous impressions, and that an accurate measure of plankton could only be obtained by averaging a considerable number of collections.

Reighard (Reighard '98) acknowledges the uniformity of distribution of the individual constituents of the plankton. Yung (Yung '99), as the result of his studies on the plankton of Lake Leman, states positively that the horizontal distribution varies within wide limits and that there is no doubt of the existence of aggregations of organisms in certain localities. The causes of these aggregations he states are diverse, but intimates that sometimes currents may accomplish this.

Steuer (Steuer '01) states that in his opinion there is no further call for discussion, but that it must be admitted that under similar physical conditions there will be uniformity in horizontal distribution. He does not, however, give the reasons for this opinion.

While I felt quite sure that my position on the question was, in the main, correct, it seemed to me desirable to make a considerable number of collections to test the correctness of my statement in a somewhat conclusive way.

Two questions presented themselves for solution. First, the comparative amounts of the plankton at different parts of the lake at any given time. Second, if it was proved that there was a difference in horizontal distribution, is this a fairly constant difference between any two localities, or is it one that may vary from day to day or from hour to hour?

To answer the first question, at several times collections were made at a considerable number of locations on the same day. The following table will show the results. In preparing this table, I have listed no collections where less than four locations were tested. In most cases the figures for the plankton were the average of three collections.

Table showing comparative amounts of plankton at different parts of the lakes at given times.

Name of Lake.	Date.	Amount of Plankton.	Coll. No.
	1899		
Lake Winnebago	July 10	142 8	99.22
Lake Winnebago	July 10	154.7	99 24
Lake Winnebago	July 10	59.5	99 25
Lake Winnebago	July 10	101 15	99.27
Lake Winnebago	July 10	83.3	99.28
Lake Winnebago	July 11	41 65	99.30
Lake Winnebago	July 11	62.48	99.31
Lake Winnebago	July 11	59.5	99.32
Lake Winnebago	July 11	107.1	99.33
Lake Winnebago	July 18	130 9	99.62
Lake Winnebago	July 18	107.1	99.65
Lake Winnebago	July 18	172 55	99 66
Lake Winnebago	July 18	163.74	99.65
Lake Winnebago	July 18	139.94	99.67
Lake Winnebago	July 18	72 83	99.68
Lake Winnebago	July 18	119.	99.69
Lake Winnebago	July 22	245.85	99 87
Lake Winnebago	July 22	206.11	99.88
Lake Winnebago	July 22	333 2	99.89
Lake Winnebago	July 22	130.9	99.90
Lake Winnebago	July 22	144.70	99 91
Lake Winnebago	July 22	126 85	99.92
Lake Winnebago	July 27	204.85	99.118
Lake Winnebago	July 27	226.1	99.122
Lake Winnebago	July 27	194 45	99.124
Lake Winnebago	July 27	261.8	99.125
Lake Winnebago	July 27	224 2	99.126
Lake Winnebago	Aug. 4	130.9	99.160
Lake Winnebago	Aug. 4	83.3	99.161
Lake Winnebago	Aug. 4	124.95	99.162
Lake Winnebago	Aug. 4	91.15	99.163
Lake Winnebago	Aug. 22	166 6	99.223
Lake Winnebago	Aug. 22	154.7	99.224
Lake Winnebago	Aug. 22	154 7	99 224
Lake Winnebago	Aug. 22	154.7	99 226
Lake Winnebago	Aug. 22	130.9	99.228
Lake Winnebago	Aug. 22	190.4	99.229
Lake Buttes des Morts	Aug. 24	95 2	99.230
Lake Buttes des Morts	Aug. 24	66.64	99 231
Lake Buttes des Morts	Aug. 24	107.1	99.232
Lake Buttes des Morts	Aug. 24	130 9	99.233
Lake Buttes des Morts	Aug. 24	114 24	99 234
Lake Buttes des Morts	Aug. 24	59 5	99 235
Cedar lake, Washington Co.	Aug. 4	124.95	99 154
Cedar lake, Washington Co.	Aug. 4	119.	99.155
Cedar lake, Washington Co.	Aug. 4	130 9	99.156
Cedar lake, Washington Co.	Aug. 4	130.9	99.158
Cedar lake, Washington Co.	Aug. 4	130 9	99.159

Table showing comparative amounts of plankton at different parts of the lakes at given times—continued.

Name of Lake.	Date.	Amount of Plankton.	Coll. No.
	1900		
Cedar lake, Washington Co...	Mar. 24...........	57.6	0.16
Cedar lake, Washington Co...	Mar. 24...........	59.5	0.17
Cedar lake, Washington Co...	Mar. 24...........	90.44	0.18
Cedar lake, Washington Co...	Mar. 24...........	83.3	0.19
Cedar lake, Washington Co...	Mar. 24...........	71.4	0.20
Cedar lake, Washington Co...	Mar. 24...........	59.5	0.21
Cedar lake, Washington Co...	Mar. 24...........	9.52	0.22
	1899		
Lake Poygan................	July 23...........	111.15	99.93
Lake Poygan................	July 23...........	85.20	99.96
Lake Poygan................	July 23...........	87.35	99.97
Lake Poygan................	July 23...........	81.40	99.98
Lake Poygan................	July 23...........	107.1	99.99
Lake Poygan................	July 23...........	111.15	99.100
Lake Poygan................	Aug. 6...........	123.76	99.166
Lake Poygan................	Aug. 6...........	95.2	99.168
Lake Poygan................	Aug. 6...........	23.8	99.169
Lake Poygan................	Aug. 6...........	62.36	99.170
Lake Poygan................	Aug. 6...........	95.2	99.171
Lake Poygan................	Aug. 6...........	92.34	99.172
Lake Poygan................	Aug. 6...........	53.55	99.173
Lake Winneconne	Aug. 6...........	95.2	99.176
Lake Winneconne	Aug. 6...........	89.25	99.177
Lake Winneconne	Aug. 6...........	86.28	99.178
Lake Winneconne	Aug. 6...........	81.33	99.179
Lake Winneconne	Aug. 6...........	107.1	99.180
Lake Winneconne	Aug. 6...........	110.08	99.181
Lake Winneconne	July 24...........	101.15	99.109
Lake Winneconne	July 24...........	130.9	99.110
Lake Winneconne	July 24...........	117.10	99.111
Lake Winneconne	July 24...........	114.24	99.112
Lake Winneconne	July 24...........	112.57	99.113
Shawano lake	Aug. 8...........	119.	99.186
Shawano lake	Aug. 8...........	130.9	99.187
Shawano lake	Aug. 8...........	249.9	99.188
Shawano lake	Aug. 8...........	220.15	99.189

The stations where these collections were made were chosen much at random, with the exception of those in Cedar lake, which were for the most part in the limnetic region. In many cases the stations of a given date were widely separated. In lakes Poygan and Winneconne they were scattered from one end of the lake to the other. In Lake Winnebago most of them were within two or three miles of the laboratory at Stony Beach. The route traversed on July 18, however, must have covered 16 or 18 miles.

In looking over the table, the amount of uniformity is certainly very striking. This is especially true of the collections in Cedar lake on Aug. 4, 1899, when five collections varied only from 119 to 130.9. These collections were all made in the limnetic region, and the depths at the different stations did not vary greatly.

The collections made in Cedar lake on March 24, 1900, were made through the ice, and the depth at the different stations varied from six meters to thirty-one meters. Collections 0.18, 0.19, and 0.20 were made at a depth of thirty-one meters, the depths at the other stations being as follows: 0.16 thirty meters, 0.17 twelve, and 0.22 six. There would seem in these collections to be a connection between the depth and the amount of plankton. This is perhaps, as would be expected, for the temperature conditions in winter are practically uniform for all depths, and as temperature is one of the most important factors limiting distribution we might infer that increasing depth, under such conditions, would tend to increase the amount of plankton.

Winter collections made on Green lake at other dates, not listed in the foregoing table, seem to confirm this generalization that during the winter months in a deep lake the amount of plankton varies, in a general way, with the depth.

These facts in regard to the winter plankton led me to look over my notes to see whether there was evidence of any similar difference in the summer. My only available collections for this purpose were those made on Green lake, for the collections from Lake Winnebago were nearly all taken from what was practically a uniform depth, and the collections from other lakes were not numerous enough to have much bearing on the question; it is interesting to notice, however, that in collections made in Birch lake in September, 1899, and August, 1900, which were made at different depths, the amount of plankton varied with the depth. It appears from the Green lake collections that there is a distinct relation between the depth and the plankton, the amount of plankton increasing with the depth, but this difference is much less marked in summer than in winter.

I do not remember to have seen any statements by other authors of the effect of depth on plankton. It is known, of course, that there is a difference in amount between littoral and limnetic plankton, but I think it is without doubt true, that in the limnetic plankton, depth is a factor in distribution, the variation in accordance with depth being most clearly marked in the winter. It does not follow, of course, that the deeper lakes necessarily have the greater amount of plankton—this certainly is not true, but simply that depth, in any given lake, is a factor to be considered in horizontal distribution.

In the collections from Lake Winneconne, the uniformity is very marked. In this case the collections were made at different locations over the lake, and may be considered as typical of the whole lake. This is true in this lake, however, that the conditions vary little in different parts of the lake, and we would expect greater uniformity.

In Lake Poygan the conditions are much as in Lake Winneconne, both lakes being expansions of the Fox river: it is shallow, the depth varying but little, with low swampy shores. We should expect, of course, a somewhat different fauna and flora in the weeds alongshore from that existing in the limnetic region. But in the limnetic region, where the collections were taken, the winds and the currents must produce all the changes in environment. While the plankton differed more in Poygan than in Winneconne, yet, if we throw out 99.169, the variation is not very great. This collection was made in a place surrounded by weeds, and it was noted at the time of the collection that the water was remarkably clear, although in most parts of the lake it was quite opaque because of the presence of vegetable matter.

In Shawano lake the variation was somewhat greater than in Winneconne and Poygan. Shawano varies more in its depths, but otherwise the conditions are much as in other lakes.

It was from the collections made on Lake Winnebago, however, that I hoped for the most conclusive results. These were made in considerable numbers and at such widely separated localities that it seemed to me it would be a fair test of the uniformity of horizontal distribution.

I have placed in the foregoing table the amounts of plankton obtained in Lake Winnebago on seven different days when collections were made at several locations. The amount of uniformity is certainly very remarkable, and was, I must confess, somewhat disheartening to me, for I had a theory to maintain. The variation does not, in any case, exceed the limits which Hensen says are compatible with uniformity, as he defines the term.

In former papers (Marsh '97, and Marsh '01), I have discussed this subject in detail, but the results of these collections in Lake Winnebago and adjoining waters have led me to modify somewhat the opinions then expressed, although I think they were, in the main, correct. There seems to be no question that in Lake Winnebago the horizontal distribution of the plankton is practically uniform. How then can I explain the results of collections as given in my former paper (Marsh '97)? In the former paper I was discussing only crustacea, and came to the conclusion that some of them were at times present in aggregations which might be called swarms. These aggregations have been noticed by other observers, as for example Birge (Birge '97, 371).

I acknowledge now that I have, in the past, attached too much importance to crustacea as an element in the plankton. As will be shown later, the controlling element in the amount of

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plankton is the vegetable material. This is especially true in shallow lakes in which the crustacea form relatively a much smaller part of the plankton than they do in the deep lakes. The conclusions which I reached in my former papers were very largely derived from work on Green lake, in which the crustacea are more abundant than in Lake Winnebago, not only relatively to the vegetable organisms, but absolutely. It would follow that aggregations of crustacea would affect the total plankton much more in the deep lakes. In lakes like Lake Winnebago crustacea seldom form a controlling part of the plankton except when large numbers of certain of the cladocera are present, and then the total may be appreciably affected. For instance, in the collections listed for July 10, '99, the larger totals were caused by the presence of *Eurycercus* which was present in unusual numbers, and the evidence from my collections seems to show that *Eurycercus* occurs in moving aggregations or swarms that perhaps move under the influence of slow currents.

The collections from the deeper lakes, like Green lake and Stone lake, show greater differences when taken on the same day at different localities than do the collections from shallow lakes. In these deeper lakes the crustacea form a larger proportion of the plankton.

My conclusions then are as follows:

1. I must acknowledge that the uniformity of horizontal distribution is greater than I had formerly supposed.

2. Variations in uniformity, when general conditions remain the same, are largely due to variations in the numbers of crustacea.

3. Inasmuch as crustacea in deep water lakes are not only more abundant relatively to the plants, but are absolutely more numerous, it follows that the horizontal distribution of the plankton in deep water lakes will be less uniform than in shallow water lakes. Large variations in the horizontal distribution of the plankton in shallow lakes will only be noticed, under ordinary conditions, when, for some reason, there is a local aggre-

gation of some of the larger cladocera, such as *Daphnia* or *Eurycercus*.

4. In winter the horizontal distribution of plankton in deep water lakes will bear a more or less close relation to the depth. This is explained by the fact that temperature is one of the most important factors in the control of the distribution of the plankton, and in winter the uniform temperature of the whole depth of water makes possible a larger production of plankton in deep water than in shallow.

COMPARISON OF PLANKTON COLLECTIONS OVER MUDDY AND STONY BOTTOMS.

As intimated earlier in this paper, in the regular collections on Lake Winnebago, one series was made over the muddy bottom, well out in the lake, and another over the stony bottom nearer shore. The average of the collections made in the summer of 1899, when they were made daily through the months of July and August, seems to show that the collections over the muddy bottom were decidedly larger than those over the stony bottom. This difference may be explained by the different effect of the character of the bottom on the plankton, or by the effect of the slight difference in depth. I have shown elsewhere that the depth has an influence on the amount of plankton, and it is entirely conceivable that in the averages of a large number of collections, a difference of a meter or so in depth may have had a marked effect on the amount. Inasmuch as the greatest depth at which collections were taken was only about five meters, a difference of a meter would mean a difference of twenty per cent., which might have a decided influence on the amount of plankton. I am, therefore, inclined to explain the difference between the muddy bottom and the stony bottom as due rather to the difference in depth than to the difference in the character of the bottom.

CHAPTER IV.

DISTRIBUTION OF SPECIES.

GEOGRAPHICAL DISTRIBUTION.

The ease with which plankton forms can be carried from place to place makes it unlikely that any lake will have a peculiar fauna or flora. The agencies by which this distribution is brought about have been fully discussed in other papers. Except, then, as the physical conditions are distinctly different, we should expect uniformity rather than diversity. As has been intimated already, there is a distinct difference between the constituents of the plankton of the Great Lakes and of smaller bodies of water, and in the smaller bodies there is a marked difference between the deep lakes and the shallow lakes. I have already discussed the distribution of *Cyclops brevispinosus* and *Cyclops pulchellus,* the first, as a rule, being confined to the shallow lakes and the latter to the deep ones.

Diaptomus oregonensis is common to all the shallow lakes. *Diaptomus minutus* is not found in Lake Winnebago and the lakes immediately connected with it; it occurs in the deep lakes, but is not strictly confined to them, as it may be found in others, especially in those that are further north.

Cedar lake, Washington county, is peculiar in being the only lake in the state in which I have found *Diaptomus siciloides.* This is common in the states to the south and west of us, and it seems probable that it may be found in other lakes in Wisconsin.

Pelican lake is, I believe, the only lake of any size, which does not have large numbers of *Diaptomus.* I made a large number of collections at different times without finding a single specimen of this genus, and I had concluded that it was entirely absent from the lake, but in 1900 I found two or three individuals. This absence of *Diaptomus* is one of the most peculiar facts in distribution which I have run across. Pelican lake is a large body of water, with a maximum depth of about twelve and a half meters and with a large amount of plankton. It is considered a fine fishing lake, and one would expect an abundance of the ordinary crustacea of the plankton.

In the collections on the northern lakes work was carried on in two distinct drainage areas and I was interested to see whether any difference in the faunae and florae of the two areas could be detected. As I expected, there was no difference except that due to the difference in depth and general physical conditions of particular lakes.

Generally speaking, the result of these collections was to confirm the statements made by other authors and myself that there is practical uniformity in the fauna and flora of lakes over wide extents of territory, except as differences in depth produce conditions of especial character. It is strange, however, that with this general uniformity there should be cases of isolation like that of *Diaptomus siciloides* in Cedar lake or of failure of occurrence like the lack of *Diaptomus* in Pelican lake.

In the discussion of the means by which organisms are distributed from lake to lake I am inclined to think that too much importance has been attached to the work of water fowl. While, doubtless, it is a proven fact that water fowl carry organisms, seeds, and eggs, from lake to lake, I imagine this is a very minor factor in distribution. It is a fact that communicating bodies of water are pretty certain to have the same fauna and flora. This is very noticeable in the lakes in Michigan which are connected with Lake Michigan, for their faunae are identical with that of the larger lake. The same is true of Lake Winnebago and its connecting waters. When lakes are pretty distinctly separated from each other, there is likely to be a difference in fauna and flora. In other words "isolation" plays a large part in producing differences in lake faunae. The chance planting of certain forms may determine the character of the fauna for a long period. Everything in Green lake would seem to favor the growth of *Cyclops pulchellus* as the limnetic form of *Cyclops*. That it does not exist there, it seems to me, must be simply because it has not been planted, and there is no way it can reach that lake except through the agency of water-fowl. *Diaptomus siciloides* in some way got a foothold in Cedar lake, and remains there because of its isolation and is not carried to other lakes, because there are not suitable connecting bodies of water.

I have noted in a former paper (Marsh '95), that *Diaptomus Reighardi* was found only in a few lakes in the northern part of the southern peninsula of Michigan. If water-fowl readily carried entomostraca from one body of water to another, it would seem very strange that this species should not appear in the lakes in northern Wisconsin, instead of being confined to such a narrow habitat. It is noticeable, too, that *Diaptomus Reighardi* in Michigan is, for the most part, found in lakes closely connected with each other.

It appears, then, that isolation caused by the physical configuration of the country will tend to produce distinct differences in plankton constituents, in spite of the other causes which may be at work to distribute animals and plants.

COMPARISON OF THE FAUNAE AND FLORAE OF DIFFERENT CLASSES OF LAKES.

The preceding subject leads naturally to the question of the faunal and floral distinctions between the different classes of lakes. The classification, as made in the earlier part of this paper, was based on physical distinctions which must affect the environment and produce characteristic differences in the animals and plants. As a matter of fact it was such differences which first led me to suggest the division of lakes into deep and shallow.

In the discussion of the annual occurrence of the various organisms, these differences have already been noticed in detail, but it may be well to present them in a summarized form.

In the case of plants the distinction between the different classes of lakes is more quantitative than qualitative, for the littoral conditions of deep lakes are such as to permit a great variety of forms, although they do not allow any large multiplication of numbers. So that while the plant production in the shallow lakes is vastly more prominent than in the deep lakes, most of the species of the shallow lakes can be found in greater or less numbers in the deep lakes.

Clathrocystis and allied forms, and *Oscillaria,* however, may be considered peculiar to shallow lakes. *Gloiotrichia,* too, is a shallow lake form, but not exclusively so, as it occasionally occurs in large numbers in a deep lake.

Anabaena is the ordinary form of the "bloom" of the deep lakes but it is not peculiar to them, but is even more abundant in the shallow lakes. Of the protozoa, *Ceratium* is characteristic of the deep lakes. It occurs in shallow lakes, but in limited numbers. I do not find that *Dinobryon* can be considered as characteristic of any class of lakes, although European authors have made the distinction between *Chroöcoccaceae* and *Dinobryon* lakes. So far as our Wisconsin lakes are concerned, *Dinobryon* can not be said to be characteristic of any class of lakes. Of the rotifers, *Notholca longispina,* while found in both classes of lakes, is found characteristically in the deep lakes; there it is common and sometimes in great numbers. *Conochilus,* while not found in all shallow lakes, seems, nevertheless, to be pretty well confined to this type. Of the other rotifers, it can hardly be said that they are characteristic of either class of lakes.

Of the *Diaptomi, D. sicilis* belongs distinctly to the large deep lakes although it may be found as a migrant in some of the Michigan lakes, connected with the Great Lakes. *D. minutus* belongs to the large deep lakes but not exclusively so, for in northern Wisconsin and northern Michigan it may be found in some of the shallow lakes. *D. Ashlandi* has never been found outside the Great Lakes, and certain bodies of water immediately connected with them. *D. oregonensis* is typical of the shallow lakes, but occurs in some lakes that would naturally be classed with the deep lakes, like Lake Mendota.

Epischura lacustris is not confined to any class of lakes, but is more common in the deep lakes.

Limnocalanus macrurus is found only in the large deep lakes. Of the lakes within the limits of Wisconsin, only Green lake and Lake Geneva seem to furnish the necessary environment of low temperature with a certain amount of circulation.

I have already discussed the distribution of *Cyclops brevispinosus* and *Cyclops pulchellus.* Of the species of *Cyclops*, *C. pulchellus* is, generally speaking, characteristic of the deep lakes. The other species are common to both classes of lakes. *C. brevispinosus, C. pulchellus,* and *C. prasinus* are limnetic in habit, *C. Leuckarti* is common to both the limnetic and the littoral regions, while *C. fuscus, C. albidus,* and *C. serrulatus* are littoral species.

Of the cladocera, *Leptodora, Daphnia hyalina, Bosmina, Diaphanosoma,* and *Chydorus* are common to all classes of lakes, but *Bosmina* is much more numerous in the deep lakes, and *Leptodora* and *Diaphanosoma* are found in greater numbers in the larger lakes. *Daphnia pulicaria* is found for the most part in the small deep lakes, while *Eurycercus,* which occurs in such numbers in the plankton of Lake Winnebago, is never found in the limnetic collections of the deep lakes.

Peculiar to the abyssal fauna of Green lake are *Mysis* and *Pontoporeia* which are also abundant in the abyssal fauna of the Great Lakes.

To sum up, while most of the constituents of the plankton are common to all classes of lakes, some few species are confined strictly to one class of lakes, while some of the others may be considered characteristic of one class, although found in small numbers in other classes. The following may be considered characteristic of the deep lakes: *Ceratium, Notholca longi-*

spina, Diaptomus sicilis, Cyclops pulchellus. Peculiar to the large deep lakes are *Limnocalanus macrurus, Mysis,* and *Pontoporeia,* all being forms favored by the deep water conditions of the lakes of this class.

Diaptomus Ashlandi should be added to the forms found only in large deep lakes, although it is not common to all large deep lakes, but is peculiar to the Great Lakes.

Daphnia pulicaria may, I think, be considered a distinctive form of the small lakes, although sometimes found in lakes that perhaps would not fall in this class.

The following may be considered as distinctively shallow lake forms: *Clathrocystis, Oscillaria, Diaptomus oregonensis,* and, perhaps, *Eurycercus.* The cladocera are much more abundant both in numbers and in species in the shallow lakes than in the deep lakes, but the forms are not peculiar, as they are generally littoral forms which have become limnetic in the lakes where the littoral and limnetic environments are very similar.

COMPARISON OF PLANKTON OF SUCCESSIVE YEARS.

It is evident that the plankton varies greatly in one year as compared with another, and that the variation has no immediate connection, in many cases, with differences in annual temperature. I take it that the variations may be explained by the relations of the organisms to each other.

It has been a favorite notion of many biologists, in which I have shared, that the balance of life in a lake undisturbed by man is maintained with a good degree of exactness; that the animal production is based, in amount, on the plant production, and that the number of predaceous animals is conditioned on the numbers of the animals that serve as their prey. It would follow, of course, that in a lake where there were great possibilities in the way of plant growth, there would be a correspondingly large number of animals. From this has arisen the common inference that it is the shallow lakes, in which the amount of vegetation is greatest, that are the best for the production of fish. It has also been inferred,—I have made the statement myself,—that inasmuch as in a state of nature there must be brought about an equilibrium between plant and animal growth, it is possible that man in his work of fish planting may disturb this equilibrium so as to interfere with the highest productiveness of a lake; for it seems apparent that if an equilibrium between plants and animals is once established, the introduction of any considerable number of either plant-eating or predaceous animals would bring in an element that would disturb nature's balance. The result of my work on these lakes leads me to think that this idea is very far from correct. Of course, it is true that in the long run a balance will be reached, but there may be wide swings of the pendulum on either side of this condition of equilibrium. It is evident that the maxima, under similar conditions of light and temperature, are not reached at the same time in different years, nor is the annual rotation of forms the same in different years. Some animals, according to Birge, seem to have biennial periodicity, but others, in which this is certainly not the case, appear in great numbers in some years and not in others. There is great variability in the annual records of a lake. It is apparent that certain forms, under favorable conditions,—conditions which it is frequently impossible to define,—seem to get such a start in the competition of life that they are produced in great numbers in some years, while in others they may hardly appear. Some animals, if the expression may be used, seem at times to get a momentum which carries them on to great production. When one stops to think of it this is no more than would be expected. Just as weeds overrun a farm, so certain forms of aquatic vegetation may overtop everything else in a given year's production. The condition of a lake cannot be compared with that of a forest untouched by man, for in the forest the vegetation is largely perennial, while in the lake the vegetation disappears each year, and in the annual reappearance it is conceivable that some form, from some little changes in the environment, may get a start that will shut off other forms. Thus, in spite of the fact that the conditions of water are more stable than those of the land, there will be, in some ways, greater variability in the annual productiveness of the water. The changes in the vegetation will have a greater or less influence in controlling the animals, but in some cases, the animals seem to grow almost independently of the plants.

Examples of this apparently erratic production are seen in the comparison of the *Gloiotrichia* curves in Lake Winnebago in the summers of 1899 and 1900, and in animals in the *Diaptomus* curve of 1901 in Lake Winnebago as compared with that of the preceding years, or the *Diaphanosoma* curve of 1899 as compared with the succeeding years.

It is apparent that the balance of life is maintained much more evenly in deep lakes than in those that are shallower.

It is to be noticed, too, that in the shallow lakes there is always an overproduction of plants in the summer as compared with the animals. This has been remarked by many other authors. The overproduction becomes so great at some times in mid-summer that the water through the decay of the plants may become actually poisonous to the fish.

RELATIVE VALUE OF DEEP AND SHALLOW LAKES FOR THE PRODUCTION OF FISH.

If lakes are to be ranked for fish production in accordance with their amount of plankton, the shallow lakes must be considered vastly the most valuable. As has been stated before, this is generally considered to be the fact. It seems to me, however, that this difference, if it exists, has been much overstated. Fish are dependent for their food, for the most part, on the animal part of the plankton, not on the plants. It is the entomostraca that furnish the basis of food for fishes. Now, in Green lake the entomostraca are not only more numerous than in Lake Winnebago relatively to the plants, but are also absolutely more numerous. They are at least as numerous in the summer, and during the winter there is a considerable production when they have almost disappeared in Lake Winnebago. May it not be, then, that Green lake may have as much of that part of the plankton that is useful for food for fishes as Lake Winnebago? I have not facts, from my study of Wisconsin lakes, to prove this, but it seems to me to be at least a reasonable conjecture. It is a somewhat significant fact to me that Stone lake is considered one of the best fishing lakes in the northern part of this state, and it is one of the deeper lakes, being nearly eighty feet in depth. It is true that Green lake is not a particularly good lake for fishing at the present time, but this is probably because it is, to a considerable extent, "fished out."

There is doubtless a difference between large and small deep lakes in favor of the larger lake in productiveness. As I indicated in a former paper (Marsh, '97, p. 180), this may be explained by the more complete stagnation in the abyssal waters of the small deep lake. In the larger lake, in which the winds have better play, the waters are piled up by the prevailing winds at one end of the lake and return, in part, at least, by bottom currents, thus aerating to some extent the abyssal regions. This may explain the productiveness of Stone lake, for it is a long, narrow body of water extending in a direction from north to south and frequently violently disturbed by southwest winds which prevail in this location. It is probable that its abyssal regions are much less stagnant than, for instance, those of the Chain o' Lakes which are still deeper, but smaller, and surrounded by elevations which cut off the wind. I do not think it probable that, under similarly favorable conditions, deep lakes are ever as productive as the shallower ones, but I think the difference between the two has been much exaggerated.

In a deep lake the littoral, limnetic, and abyssal regions are quite sharply distinguished. There is, of course, no distinct dividing line between the littoral and limnetic regions, and the organisms of one may be found in the other, and yet the difference between the fauna of the central regions of a lake and its shore is very marked. In a very shallow lake there is no true abyssal fauna, and in a pool the distinction between the limnetic and littoral regions is lost.

In Lake Winnebago, as I have indicated in a former paper (Marsh '99, p. 181), in spite of its great size there is an intermingling of littoral and limnetic forms. Cladocera like *Eurycercus* which are ordinarily considered strictly littoral are common in the limnetic regions, and, on the other hand, limnetic forms like *Diaptomus* and the limnetic species of *Cyclops* may be found in the littoral region. In this lack of distinction between the limnetic and littoral forms, Lake Winnebago is like an enormously overgrown puddle.

LIST OF PAPERS QUOTED.

APSTEIN, '96. Das Süsswasserplankton; Methode und Resultate der quantitativen Untersuchung. C. Apstein. Kiel und Leipzig.

BIRGE, '97. Plankton Studies on Lake Mendota. II. The crustacea of the plankton, July, 1894–Dec., 1896. E. A. Birge. Trans. Wis. Acad. Vol. XI, pp. 274–448.

BURCKHARDT, '00. Quantitative Studien über das Zooplankton des Vierwaldstättersees. G. Burckhardt. Mittheil. der Naturforschenden Gesellschaft Luzern. 3 Heft.

FRIC UND VAVRA, '94. Untersuchungen über die Fauna der Gewässer Böhmens. Fric und Vavra. Achiv der naturwissenschaftlichen Landesdurchforschung von Böhmen. IX Band. Nro. 2.

KOFOID, '97. On Some Important Sources of Error in the Plankton Method. C. A. Kofoid. Sci. N. S., Vol. VI, pp. 829–832.

MARSH, '95. On the Cyclopidae and Calanidae of Lake St. Clair, Lake Michigan, and certain of the inland lakes of Michigan. C. D. Marsh. Bull. Mich. Fish Com. No. 5.

MARSH, '97. The Limnetic Crustacea of Green Lake. C. D. Marsh. Trans. Wis. Acad., Vol. XI, pp. 189–224.

MARSH, '99. The Plankton of Fresh Water Lakes. C. D. Marsh. Trans. Wis. Acad., Vol. XIII, pp. 163–187.

REIGHARD, '98. Methods of Plankton Investigation in their Relation to Practical Problems. J. Reighard. Bull. U. S. Fish Com., Vol. XVII, pp. 169–175.

SELIGO, U. SCHROEDER, '00. Untersuchungen in den Stuhmer Seen. Nebst einem Anhang; das Pflanzenplankton preussischer Seeen. A. Seligo u. B. Schroeder. Danzig.

STEUR, '01. Die Entomostrakenfauna der "alten Donau" bei Wien. Adolph Steur. Zoolog. Jahrb. XV Band, Heft.

Voigt, '02. Einige Ergebnisse aus den Untersuchungen ostholsteinischer Seen. Max Voigt. Forschungsber. aus der Biolog. Station zu Plön. pp. 47–61.

Ward, '95. A New Method for the Quantitative Determination of Plankton Hauls. H. B. Ward. Proc. Amer. Mic. Soc., Vol. XVII, pp. 255–260.

Whipple, '94. Some Observations on the Growth of Diatoms in Surface Waters. G. C. Whipple. Technology Quarterly, Vol. VII, pp. 214–231.

Yung, '99. Des Variations Quantitatives du Plankton dans le Lac Leman. E. Yung. Arch. Sci. Phys. et Nat. Genève. T. VIII, p. 344–364.

APPENDIX.

Table I.—*Record of total volumes of plankton per square meter in Green lake.*

These statistics are of limnetic plankton, averages being made when more than one collection was made at a given date.

Date.	Vol. in ccm.	Date.	Vol. in ccm.	Date.	Vol. in ccm.
1899.		1900.		1901.	
July 16....	38.67	July 2....	181.36	Apr. 1....	77.35
July 31....	103.29	July 16....	71.4	Apr. 20....	32.37
Aug. 25....	34.75	Aug. 4....	104.72	May 4....	22.13
Sept. 18....	35.7	Aug. 13....	64.26	May 18....	47.6
Oct. 11....	65.45	Sept. 3....	142.8	June 1....	40.46
Oct. 19....	57.6	Sept. 15....	53.55	June 22....	59.5
Oct. 31....	43.55	Sept. 29....	51.65	July 8....	61.88
Nov. 27....	71.4	Oct. 16....	53.55	July 20....	76.16
1900.		Oct. 27....	49.98	Aug. 3....	45.22
Jan. 13....	50.69	Nov. 10....	47.6	Aug. 27....	30.7
Jan. 20....	65.45	Nov. 24....	47.6	Sept. 18....	43.32
Feb. 23....	197.54	Dec. 21....	35.7	Oct. 19....	35.7
Mar. 22....	197.54	1901.		Nov. 9....	30.94
Apr. 20....	95.2	Jan. 14....	19.01	Dec. 9....	29.75
May 5....	107.1	Jan. 26....	33.8	1902.	
May 21....	122.81	Feb. 9....	53.55	Feb. 19....	46.17
June 2....	226.1	Feb. 23....	54.74	Sept. 12....	77.35
June 16....	399.84	Mar. 9....	73.78	Sept. 13....	71.4

TABLE II.—*Record of total volumes of plankton per square meter in Lake Winnebago.*

Statistics prepared as for Green lake.

Date.	Vol. in ccm.	Date.	Vol. in ccm.	Date.	Vol. in ccm.
1899		1899		1900	
July 5....	71.4	Aug. 11....	124.95	Aug. 22....	316.55
July 6....	71.4	Aug. 12....	90.20	Sept. 8....	523.6
July 7....	119.	Aug. 14....	147.32	Sept. 22....	152.12
July 8....	111.15	Aug. 15....	133.76	Oct. 6....	99.01
July 10....	108.29	Aug. 16....	116.38	Oct. 20....	66.64
July 11....	67.69	Aug. 17....	111.03	Nov. 6....	40.46
July 12....	136.85	Aug. 19....	120.19	Nov. 21....	18.8
July 13....	86.28	Aug. 21....	128.52	Dec. 5....	6.43
July 14....	111.79	Aug. 22....	158.51	1901	
July 15....	116.86	Aug. 26....	144.22	Jan. 5....	8.92
July 17....	124.24	Aug. 28....	83.30	Jan. 19....	7.26
July 18....	136.61	Aug. 30....	176.12	Feb. 2....	11.30
July 19....	137.92	Aug. 31....	95.2	Feb. 16....	9.52
July 20....	183.26	Sept. 16....	368.9	Mar. 2....	17.13
July 21....	268 70	Oct. 7....	92.82	Mar. 16....	8.33
July 22....	191.83	Oct. 21....	162.55	Mar. 30....	6.54
July 25....	138.04	Nov. 4....	99.92	Apr. 13....	8.57
July 26....	162.75	Nov. 25....	59.98	Apr. 27....	16.94
July 27....	220.39	1900		May 11....	35.22
July 28....	210.63	Jan. 1....	33 32	June 8....	29.75
July 29....	232.53	Jan. 27....	65.17	June 25....	42.84
July 30....	193.26	Feb. 17....	10.	July 12....	172.55
July 31....	239.19	Mar. 3....	10.47	July 27...	233.
Aug. 1....	173.5	Mar. 17....	7.38	Aug. 24....	99.72
Aug. 2....	146.61	Mar. 27....	20.94	Sept. 13....	127.09
Aug. 3....	194.92	Apr. 28....	46.65	Sept. 28....	79.73
Aug. 4....	107.58	May 11..	78.30	Oct. 12....	32.74
Aug. 5....	101.15	May 24....	180.40	Nov. 2....	83.3
Aug. 7....	138.75	June 9....	202.3	Nov. 16....	23.8
Aug. 8....	138.75	June 25....	128.5	1902	
Aug. 9....	114.95	July 9....	138.04	Aug. 16....	204.68
Aug. 10....	170.41	July 28....	145.11	Sept. 2....	123.76

TABLE III.—*Record of total volumes of plankton per square meter in various Wisconsin lakes.*

Name of Lake.	Date.	Vol. in ccm.
Bass	Sept. 25, 1899	53.55
Birch	Sept. 22, 1899	80.97
Birch	Aug. 11, 1900	114.24
Birch	Aug. 7, 1901	79.25
Birch	Aug. 15, 1902	59.50
Buttes des Morts	Sept. 23, 1898	21.42
Buttes des Morts	Aug. 24, 1899	85.68
Buttes des Morts	May 30, 1900	128.52
Cedar, Washington county	Aug. 4, 1899	129.47
Cedar, Washington county	Mar. 24, 1900	70.21
Cedar, Washington county	Jan. 29, 1900	104.72
Cedar, Sheboygan county	Oct. 15, 1898	49.98
Clover Leaf lakes:		
Golden Rod	Aug. 9, 1900	90.44
Golden Rod	Aug. 10, 1901	59.50
Golden Rod	Aug. 10, 1902	71.4
Pansy	Aug. 9, 1900	114 24
Pansy	Aug. 10, 1901	33.80
Pansy	Aug. 10, 1902	92.11
Shamrock	Aug. 9, 1900	107.10
Shamrock	Aug. 10, 1901	35.70
Shamrock	Aug. 10, 1902	232.05
Eagle River lakes:		
Eagle	Aug. 14, 1900	233.24
Eagle	Aug. 12, 1901	185.64
Eagle	Aug. 13, 1902	345.10
Otter	Aug. 14, 1900	197.54
Otter	Aug. 12, 1901	140.42
Link	Aug. 13, 1902	404.6
Duck	Aug. 14, 1900	290.36
Duck	Aug. 12, 1901	119.
Duck	Aug. 13, 1902	428.4
Yellow Birch	Aug. 14, 1900	309.4
Yellow Birch	Aug. 12, 1901	172.55
Yellow Birch	Aug. 13, 1902	452.2
Elkhart	Oct. 1, 1898	83.3
Long, Forest county	Aug. 10, 1900	214.2
Michigamme, Mich	Nov. 27, 1902	48.74
Pelican	Sept. 24, 1899	122 09
Pelican	Aug. 14, 1900	466.48
Pelican	Aug. 12, 1901	376.04
Pelican	Aug. 12, 1902	517.65
Poygan	July 23, 1899	97.23
Poygan	Aug. 6, 1899	77.06
Poygan	Aug. 6, 1899	87.11
Poygan	May 30, 1900	64.26
Sand	Sept. 23, 1899	205.16
Sand	Aug. 11, 1900	152.32
Sand	Aug. 11, 1901	63.43
Sand	Aug. 11, 1902	124.95
Shawano	Aug. 8, 1899	179.93

TABLE III.— Continued.

Name of Lake.	Date.	Vol. in ccm.
Shawano	Aug. 9, 1900	114.24
Shawano	Aug. 8, 1901	107.10
Silver, Forest county	Sept. 22, 1899	63.78
Stone	Sept. 23, 1899	71.4
Stone	Aug. 12, 1900	171.36
Stone	Aug. 11, 1901	52.36
Stone	Aug. 12, 1902	54.55
Summit	Sept. 25, 1899	107.10
Waupaca lakes:		
Rainbow	July 29, 1899	111.15
McCrossen	July 29, 1899	73.30
Round	July 29, 1899	107.10
Columbian	July 30, 1899	104.
Beasley's	July 30, 1899	95.2
Winneconne	July 24, 1899	110.91
Winneconne	Aug. 6, 1899	94.6
Winneconne	Aug. 24, 1899	64.26
Winneconne	May 30, 1900	17.6

TABLE IV.—*Numbers of Diaptomus minutus and Diaptomus sicilis per square meter in Green lake.*

Date.	No.	Date.	No.	Date.	No.
1899.		1900.		1901.	
July 16....	163,744	July 2....	159,936	Mar. 9....	66,640
Aug. 1....	706,384	July 16....	198,016	Apr. 1....	121,856
Aug. 25....	134,470	Aug. 4....	634,032	Apr. 20....	32,368
Sept. 18....	205,156	Aug. 18....	289,408	May 4....	57,120
Oct. 4....	280,840	Sept. 3....	447,440	May 18....	34,272
Oct. 19....	241,808	Sept. 15....	127,568	June 1....	47,600
Oct. 31....	25,704	Sept. 29....	198,016	June 22....	177,072
Nov. 27....	32,368	Oct 16....	171,360	July 8....	215,152
1900.		Oct. 27....	102,816	July 20....	293,216
Jan 13....	28,560	Nov. 10....	43,792	Aug. 3....	205,632
Jan. 20....	10,472	Nov. 24....	38,556	Aug. 27....	60,928
Feb. 23....	78,064	Dec. 21....	87,584	Sept. 18....	116,144
Mar. 22....	228,480	1901.		Oct. 19....	95,200
Apr. 20....	34,272	Jan. 14....	79,968	Nov. 9....	53,312
May 5....	146,608	Jan. 25....	55,216	Dec. 9....	72,352
May 21....	91,392	Feb. 9....	106,624	1902.	
June 2....	47,600	Feb. 23....	137,088	Feb. 19....	110,432
June 16....	158,032				

TABLE V.—*Numbers of Diaptomus oregonensis per square meterin Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899.		1900.		1901.	
July 5-11..	12,138	Mar. 3....	238	Jan. 5....	357
July 12-18..	12,852	Mar. 17....	476	Feb. 12....	595
July 19-25..	44,030	Mar. 27....	952	Feb. 16....	357
Ju. 26-Aug. 1	54,978	Apr. 28....	7,616	Mar. 2....	238
Aug. 2-8..	33,320	May 11....	952	Mar. 16....	714
Aug. 9-15..	21,420	May 24....	16,184	April 13....	5,712
Aug. 16-22..	21,896	June 9....	16,184	April 27....	9,044
Aug. 23-29..	16,184	June 25....	19,992	May 11....	2,380
Aug. 30-		July 9....	18,564	June 8....	48,552
Sept. 5....	19,992	July 28....	20,944	June 25....	952
Sept. 16...	37,128	Aug. 22....	34,272	July 12....	21,896
Oct. 7....	8,092	Sept. 8....	19,516	July 27....	11,186
Oct. 21....	17,136	Sept. 22....	15,232	Aug. 24....	94,486
Nov. 4....	39,984	Oct. 6....	5,712	Sept. 13....	119,000
Nov. 25....	9,758	Oct. 20....	11,424	Sept. 28....	7,616
1900.		Nov. 6....	21,182	Oct. 12....	15,708
Jan. 1....	714	Nov. 21....	7,616	Nov. 2....	44,006
Jan. 27....	952	Dec. 5....	2,856	Nov. 16....	32,368
Feb. 17....	238				

TABLE VI.—*Numbers of Epischura lacustris per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1899		1900	
July 5-11.	714	Aug. 16-22.	476	June 9....	6,188
July 12-18.	13,566	Aug. 23-29.	1,428	June 25....	238
July 19-25.	2,656	Aug. 30-		July 9....	5,950
July 26-		Sept. 5	952	July 28....	476
Aug. 1	31,178	Sept. 16....	476	Aug. 22....	238
Aug. 2- 8.	1,428	1900		Sept. 22....	238
Aug. 9-15.	1,666	May 24....	714		

TABLE VII.—*Numbers of Epischura lacustris per square meter in Green lake.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1900	
July 16....	3,808	July 2....	2,856	Nov. 10....	3,808
Aug. 1....	17,136	July 16....	1,904	1901	
Aug. 25....	1,904	Aug. 4....	22,848	June 22....	1,904
Sept. 18....	238	Aug. 18 ...	3,808	July 8....	3,808
Oct. 4....	13,328	Sept. 3....	13,328	Aug. 3....	952
Oct. 19....	3,332	Sept. 15....	1,904	Aug. 27....	1,428
Oct. 31....	3,808	Sept. 29....	476	Oct. 19....	8,468
Nov. 27....	238	Oct. 27....	2,142		

TABLE VIII.—*Numbers of Limnocalanus macrurus per square meter in Green lake.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1901	
July 16....	3,808	July 2....	1,904	Apr. 20....	4,760
Aug. 1....	24,752	July 16....	47,600	May 4....	9,520
Aug. 25....	952	Aug. 4....	9,520	May 18....	3,808
Oct. 4....	7,616	Aug. 18....	5,712	June 1....	7,616
Oct. 19....	3,094	Sept. 3....	17,136	June 22....	22,848
Oct. 31....	238	Sept. 15....	952	July 8....	714
Nov. 27....	7,616	Sept. 29....	1,904	July 20....	952
1900		Oct. 16....	1,904	Aug. 3....	952
Jan. 13....	238	Oct. 27....	476	Aug. 27....	5,712
Feb. 23....	952	Nov. 24....	19,040	Sept. 18....	3,808
Mar. 22....	7,616	1901		Oct. 19....	1,904
Apr. 20....	36,176	Jan. 14....	476	Nov. 9....	1,904
May 5....	8,468	Jan. 25....	5,712	Dec. 9....	238
May 21....	15,232	Feb. 23....	13,328	1902	
June 2....	1,428	Mar. 9....	6,664	Feb. 19....	7,616
June 16....	9,520	Apr. 1....	12,376		

TABLE IX.—*Numbers of Cyclops brevispinosus per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1899		1900	
July 5-11.	8,806	Sept. 16....	7,140	Sept. 22....	1,904
July 12-18.	13,090	Oct. 7....	2,380	Nov. 6....	1,904
July 19-25.	5,236	Oct. 21....	476	1901	
July 26-		Nov. 4....	952	Mar. 30....	238
Aug. 1	13,328	1900		July 12....	10,472
Aug. 2-8.	17,612	May 11....	5,712	July 27....	19,992
Aug. 9-15.	5,236	July 9....	12,376	Aug. 24....	15,232
Aug. 16-22.	5,750	July 28....	20,944	Sept. 18....	30,464
Aug. 23-29.	6,664	Aug. 22....	1,904	Sept. 28....	19,992
Aug. 30-		Sept. 8....	2,856	Oct. 12....	3,808
Sept. 5	5,236				

TABLE X.—*Numbers of Cyclops pulchellus per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1901	
Nov. 4....	5,712	May 24....	8,568	Mar. 30....	238
Nov. 25....	6,664	June 9....	1,904	April 27....	3,808
1900		Oct. 20....	5,712	June 8....	7,616
Jan. 27....	7,616	Nov. 6....	952	June 25....	3,808
Mar. 3....	238	Nov. 21....	1,428	Sept. 28....	3,880
Mar. 17....	7,616	1901		Oct. 12....	952
April 28....	3,808	Jan. 19....	238	Nov. 2....	15,232
May 11.....	18,088				

TABLE XI. –*Numbers of Cyclops Leuckarti per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1898		1900	
July 5-11..	4,998	Sept. 16....	17,136	July 28....	18,088
July 12-18..	16,136	Oct. 7....	3,094	Aug. 22....	10,472
July 19-25..	13,804	Oct. 21....	476	Sept. 8....	9,996
July 26–		Nov. 4......	238	Sept. 22....	7,616
Aug. 1	16,660	1900		Oct. 6....	1,904
Aug. 1-8 .	17,136	Mar. 17....	952	Oct. 20....	2,856
Aug. 9-15.	17,612	May 11	25,704	1901.	
Aug. 16-22.	11,424	May 24.....	2,856	July 12....	952
Aug. 23-29.	11,424	June 9....	1,904	Aug. 24....	12,614
Aug. 30–		June 25....	952	Sept. 13....	19,040
Sept. 5	21,420	July 9....	32,368	Sept. 28....	1,904

TABLE XII.—*Numbers of Cyclops prasinus per square meter in Green lake.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1901	
July 16 ...	28,560	July 16....	22,848	Apr. 1....	13,328
Aug. 1....	104,720	Aug. 4....	112,336	Apr. 20....	5,712
Aug. 25....	23,672	Aug. 18....	60,928	May 4....	3,808
Sept. 18....	55,216	Sept. 3....	59,024	May 18....	3,808
Oct. 4....	112,336	Sept. 15....	34,272	June 1....	7,618
Oct. 19....	62,832	Sept. 29....	38,080	June 22....	9,520
Oct. 31....	41,888	Oct. 16....	65,212	July 8....	1,904
Nov. 27....	19,040	Oct. 27....	85,680	July 20....	19,040
1900		Nov. 10....	72,352	Aug. 3....	15,232
Jan. 20....	1,428	Nov. 24....	26,656	Aug. 27....	39,984
Feb. 23....	15,232	Dec. 21....	9,520	Sept. 18....	74,256
Mar. 22....	22,848	1901		Oct. 19....	30,464
May 5....	19,040	Jan. 25....	13,328	Nov. 9....	20,944
May 21....	15,232	Feb. 9....	13,328	Dec. 9....	32,368
June 2....	17,136	Feb. 23....	15,232	1902	
June 16....	11,424	Mar. 9....	9,520	Feb. 19....	17,136
July 2....	1,904				

TAALE XIII.—*Numbers of copepod larvae per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1901	
July 5-11.	11,186	Mar. 17....	40,222	Jan. 19....	1,904
July 12-18.	74,970	Mar. 27....	45,696	Feb. 2....	952
July 19-25.	69,496	Apr. 28....	367,472	Feb. 16....	1,904
July 26–		May 11....	297,976	Mar. 2....	952
Aug. 1	8,568	May 24....	115,906	Mar. 16....	1,190
Aug. 9-15.	50,932	June 9....	12,376	Apr. 13....	17,136
Aug. 16-22.	43,078	June 25....	49,980	Apr. 27....	57,120
Aug. 23-29.	34,510	July 9....	31,416	May 11....	30,464
Aug. 30–		July 28....	129,472	June 8....	118,048
Sept. 5	51,408	Aug. 22....	101,150	June 25....	15,232
Sept. 16....	6,664	Sept. 8....	42,840	July 12....	5,712
Oct. 7....	49,504	Sept. 22....	25,704	July 27....	3,808
Nov. 4....	32,368	Oct. 20....	2,856	Aug. 24....	27,608
Nov. 25....	48,552	Nov. 6....	8,568	Sept. 13....	48,744
1900		Nov. 21....	1,428	Sept. 28....	39,508
Jan. 1....	12,376	Dec. 5....	1,904	Oct. 12....	21,896
Jan. 27....	13,804	1901		Nov. 2....	22,848
Feb. 17....	18,088	Jan. 5....	952	Nov. 16....	20,944
Mar. 3....	21,896				

TABLE XIV.—*Numbers of copepod larvae per square meter in Green lake.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1901	
July 16....		July 2....	1,904	April 1....	11,424
Aug. 1....	249,424	July 16....	100,912	April 20....	5,712
Aug. 25....	69,258	Aug. 4....	172,264	May 4....	13,328
Sept. 18....	73,304	Aug. 18....	310,352	May 18....	62,832
Oct. 4....	28,560	Sept. 3....	137,088	June 1....	319,872
Oct. 19....	9,520	Sept. 15....	67,544	June 22....	32,368
Oct. 31....	34,176	Sept. 29....	57,120	July 8....	84,152
Nov. 27 ...	72,352	Oct. 16....	1,904	July 20....	118,048
1900		Oct. 27....	36,176	Aug. 3....	144,704
Jan. 13....	47,600	Nov. 10....	36,176	Aug. 27....	180,880
Jan. 20....	28,560	Nov. 24....	51,408	Sept. 18....	317,968
Feb. 23....	20,944	Dec. 21....	196,112	Oct. 19....	28,560
Mar. 22....	19,040	1901		Nov. 9....	22,848
April 20....	22,848	Jan. 14....	45,696	Dec. 9....	74,256
May 5....	1,904	Jan. 25....	32,368	1902	
May 21....	59,024	Feb. 9....	95,200	Feb. 19....	38,080
June 2....	81,872	Feb. 23....	51,408		
June 16....	142,800	Mar. 9....	20,944		

TABLE XV.—*Numbers of Diaphanosoma brachyurum per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1899		1900	
July 5-11..	14,280	Sept. 16....	1,428	Oct. 6....	7,616
July 12-18..	28,322	1900		1901	
July 19-25..	194,208	May 11....	238	May 11....	476
July 26–		May 24....	4,760	July 12....	9,520
Aug. 1	116,620	June 9....	238	July 27....	12,376
Aug. 2- 8.	32,368	June 25....	952	Aug. 24....	22,848
Aug. 9-15.	30,464	July 9....	1,428	Sept. 13....	952
Aug. 16-22.	19,992	July 28....	12,852	Sept. 28....	2,142
Aug. 23-29.	5,712	Aug. 22....	39,984	Oct. 12....	714
Aug. 30–		Sept. 8....	17,850	Nov. 2....	3,808
Sept. 5	11,424	Sept. 22....	4,284		

TABLE XVI.—*Numbers of Daphnia hyalina per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1900	
July 5-11.	16,660	Jan. 1....	238	Nov. 21....	4,284
July 12-18	30,464	Jan. 27....	2,142	Dec. 5....	476
July 19-25.	38,060	Apr. 28....	952	1901	
July 26–		May 11....	18,088	May 11....	476
Aug. 1	105,196	May 24....	100,198	June 8....	22,848
Aug. 2- 8.	12,376	June 9....	13,328	June 25....	5,712
Aug. 9-15.	42,840	June 25....	14,280	July 12....	17,136
Aug. 16-22.	44,268	July 9....	952	July 27....	8,568
Aug. 23-29.	40,936	July 28....	6,664	Aug. 24....	10,472
Aug. 30–		Aug. 22....	43,792	Sept. 12....	2,856
Sept. 5	40,936	Sept. 8....	51,646	Sept. 28....	4,998
Sept. 16....	14,756	Sept. 22....	16,184	Oct. 12....	1,904
Oct. 7....	476	Oct. 6....	3,808	Nov. 2....	14,518
Oct. 21....	5,712	Oct. 20....	5,236	Nov. 16....	4,284
Nov. 4....	7,140	Nov. 6....	36,176		
Nov. 25....	4,284				

TABLE XVII.—*Numbers of Daphnia hyalina per square meter in Green lake.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1901	
July 16....	13,328	July 16....	6,664	June 22....	952
Aug. 1....	93,396	Aug. 4....	19,040	July 8....	7,616
Aug. 25....	4,760	Aug. 18....	15,232	July 20....	19,040
Sept. 18....	3,094	Sept. 3....	59,024	Aug. 3....	6,664
Oct. 4....	22,848	Sept. 15....	3,808	Aug. 27....	26,656
Oct. 19....	26,894	Sept. 29....	20,944	Sept. 18....	24,752
Oct. 31....	1,190	Oct. 16....	15,232	Oct. 19....	3,808
Nov. 27....	1,428	Oct. 27....	17,136	Nov. 9.....	13,328
1900		Nov. 10....	39,984	Dec. 9.....	238
June 16....	476	Nov. 24....	9,520		
July 2....	1,904				

TABLE XVIII.—*Numbers of Bosmina per square meter in Green lake.*

Date.	No.	Date.	No.	Date.	No.
1899		1900		1901	
July 16....	53,312	June 2....	9,520	Jan. 25....	19,040
Aug 1....	3,808	June 16....	7,616	Feb. 9....	7,616
Aug. 25....	2,380	July 2....	635,936	Feb. 28....	11,424
Sept. 18....	23,800	July 16....	325,584	Mar. 9....	3,808
Oct. 4....	24,752	Aug. 4....	12,376	Apr. 1....	3,808
Oct. 19....	24,752	Aug. 18....	5,712	May 4....	1,904
Oct. 31....	38,080	Sept. 3....	1,904	June 22....	5,712
Nov. 27....	173,264	Sept. 15....	13,328	July 8....	7,616
1900		Sept. 29....	5,712	July 20....	3,808
Jan. 13....	114,240	Oct. 16....	1,904	Aug. 3....	9,520
Jan. 20....	79,968	Oct. 27....	5,712	Sept. 18....	7,616
Feb. 23....	74,256	Nov. 10....	59,024	Oct. 19....	3,808
Mar. 22....	138,992	Nov. 24....	20,944	Nov. 9....	118,048
Apr. 20....	36,176	Dec. 21....	19,040	Dec. 9....	165,648
May 5....	9,520	1901		1902	
May 21....	4,760	Jan. 14....	3,808	Feb. 19....	30,940

TABLE XIX.—*Numbers of Eurycercus lamellatus per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1899		1900	
July 5–11..	23,086	Aug. 23–29.	39,270	June 9....	238
July 12–18..	66,402	Aug. 30–		June 25....	12,852
July 19–25..	22,134	Sept. 5	19,040	July 9....	10,948
July 26–		Sept. 16....	40,460	July 28....	40,460
Aug. 1	8,568	Oct. 21....	4,046	Aug. 22....	20,944
Aug. 2– 8.	952	Nov. 4....	238	Sept. 8....	4,284
Aug. 9–15.	1,428	1900		1901	
Aug. 16–22.	3,332	Apr. 28....	238	June 8.....	238

TABLE XX.—*Numbers of Chydorus per square meter in Lake Winnebago.*

Date.	No.	Date	No.	Date.	No.
1899		1900.		1900	
July 5–11.	19,516	Jan. 27...	238	Dec. 5....	1,904
July 12–18.	9,520	Mar. 27....	476	1901	
July 19–25.	2,856	Apr. 28....	2,856	Jan. 5....	238
July 26–		May 24....	1,904	Apr. 27....	952
Aug. 1	16,184	June 9....	3,208	May 11....	1,904
Aug. 2–8..	11,900	July 9....	952	June 8....	2,142
Aug. 9–15.	28,560	July 28....	118,048	July 12....	4,760
Aug. 16–22.	1,904	Aug. 22....	6,664	July 27....	21,896
Aug. 23–29.	238	Sept. 8....	14,280	Aug. 24....	1,904
Sept. 16....	952	Sept. 22....	18,088	Sept. 28....	476
Oct. 21....	476	Oct. 6....	7,616	Oct. 12....	952
Nov. 4....	2,618	Oct. 20....	34,272	Nov. 2....	3,808
Nov. 25....	4,522	Nov. 6....	133,518	Nov. 16....	2,856
1900		Nov. 21....	10,472		
Jan. 1....	952				

TABLE XXI.—*Numbers of Leptodora per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1899		1900	
July 5–11.	714	Aug. 30–		Sept. 8....	357
July 12–18.	952	Sept. 5	714	Sept. 22....	238
July 19–25.	1,904	Sept. 16....	1,904	Oct. 20....	238
July 26–		1900		1901	
Aug. 1	1,666	May 24....	238	May 11....	714
Aug. 2– 8.	952	June 9....	238	June 8....	476
Aug. 9–15.	238	June 25....	714	July 12....	1,428
Aug. 16–22.	238	July 28....	238	Aug. 24....	238
Aug. 22–29.	476	Aug. 22....	476		

TABLE XXII.—*Numbers of Cypris per square meter in Lake Winnebago.*

Date.	No.	Date.	No.	Date.	No.
1899		1899		1900	
July 5–11.	1,428	Aug. 23–29.	11,186	June 25....	476
July 12–18.	10,510	Aug. 30–		July 9....	16,184
July 19–25.	53,788	Sept. 5	9,520	Aug. 22....	1,904
July 26–		Sept. 16....	17,612	1901	
Aug. 1	714	1900		June 8....	714
Aug. 2– 8.	5,712	May 11....	952	June 25....	9,520
Aug. 9–15.	15,232	May 24....	7,616	July 12 ...	952
Aug. 16–22.	16,422	June 9....	2,856		

TABLE XXIII.—*Maximum depths of Wisconsin lakes.*

NOTE—It has been found, by experience, that the popular ideas in regard to the depths of lakes are utterly unreliable. Consequently, although only a small number of the Wisconsin lakes have been accurately sounded, it seems best to append a table of those depths that are known, to serve as a matter of reference.

In 1897 a reconnaissance of a considerable number of the Wisconsin lakes was made by the author as preliminary to the study of the lakes undertaken by the Natural History Survey of Wisconsin. Although this was a hasty trip, considerable care was taken to determine the greatest depths of the lakes visited, and where subsequent detailed surveys were made, it appeared that the record of the preliminary trip was quite accurate. Under the auspices of the Survey detailed hydrographic surveys were afterwards made of the following lakes: Lake Geneva, the Oconomowoc lakes, Lake Beulah, Elkhart lake, the Waupaca lakes, Delavan lake, the Lauderdale lakes, Green lake, Lake Mendota, and Lake Monona. The figures given for these lakes, then, are authoritative. The figures given for the other lakes are the result of only a cursory examination, with the probability that the deepest parts of the lakes were examined, but with the possibility of some error. The depths are the result of a personal examination by the author and were not obtained by any hearsay evidence.

Name.	Township.	Range.	County.	Depth.
				Feet.
Bass lakes	33 N.	X E.	Langlade	19.5
Beaver	8 N.	XVIII E.	Waukesha	47.6
Beulah	4 N.	XVIII E.	Walworth	
Lower				55.5
Mill				51.5
Round				40.
Upper				67.
Birch	36 N.	XV E.	Forest	61.7
Booth	4 N.	XVII E.	Walworth	25.4
Buttes des Morts	18 & 19 N	XV & XVI E	Winnebago	9.7
Cedar	16 N.	XXXI E.	Sheboygan	39.
Cedar	11 N.	IXX E.	Washington	104.7
Clover Leaf	26 N.	XV E.	Shawano	
Golden Rod				37.4
Grass				48.7
Shamrock				35.7
Crooked	7 N.	XVII E.	Waukesha	16.
Delavan	2 N.	XVI E.	Walworth	36.7
D'Eneveu	15 N.	XVII E.	Fond du Lac	52.
Eagle River lakes	39 & 40 N	X & XI E.	Vilas & Oneida	
Catfish				16.6
Duck				16.2
Eagle				49.7
Otter				29.2
Yellow Birch				15.5
East Troy	4 N.	XVIII E.	Walworth	16.5
Elkhart	16 N.	XXI E.	Sheboygan	113.2
Fowler	8 N.	XVII E.	Waukesha	50.
Garvin	8 N.	XVIII E.	Waukesha	36.1
Genesee, North	7 N.	XVII E.	Waukesha	36.4
Genesee, South	7 N.	XVII E.	Waukesha	47.6

TABLE XXII.—*Maximum depths of Wisconsin lakes*—Continued.

Name.	Township.	Range.	County.	Depth.
				Feet.
Geneva	1 N	XVI, XVI E	Walworth	142.
Green	15 & 16 N	XII & XII E	Green Lake	237.
Kegonsa	6 N	X & XI E	Dane	46.6
Lac LaBelle	8 N	XVII E	Waukesha	46.6
Lauderdale	4 N	XVI E	Walworth.	....
Green				56.8
Middle				50.
Mill				50.
Little Green	15 N	XIII E	Green Lake	26.
Long	14 N	XIX E	Fond du Lac	45.5
Long	34 N	XV E	Forest	16.2
Medicine	38 N	XI E	Oneida	13.
Mendota	7 & 8 N.	IX E	Dane	84.
Monona	7 N	IX & X E	Dane	74.
Mouse	8 N	XVIII E	Waukesha	66.3
Nagawicka	7 N	XVIII E	Waukesha	94.5
Nashotah, Upper	7 N	XVII E	Waukesha	51.2
Nashotah, Lower	7 N	XVII E	Waukesha	46.2
Nemahbin, Upper	7 N	XVII E	Waukesha	62.
Nemahbin, Lower	7 N	XVII E	Waukesha	35.4
North	8 N	XVIII E	Waukesha	73.6
Oconomowoc	7 N	XVII E	Waukesha	62.6
Okauchee	8 N	XVII & XVIII E	Waukesha	94.
Otis	7 N	XVII E	Waukesha	28.3
Pelican	35 N	X & XI E	Oneida	40.6
Pewaukee	7 N	XVIII & XIX E	Waukesha	45.3
Pine	8 N	XVIII E	Waukesha	90.
Powers	1 N	XVIII & XIX E	Walworth and Kenosha	32.5
Poygan	19 & 20 N	XIII, XIV & XV E	Winnebago & Waushara	11.4
Sand	35 & 36 N	XIII E	Forest	48.7
Shawano	27 N	XVI, XVII E	Shawano	17.9
Silver	36 N	XIV E	Forest	19.5
Silver	7 N	XVI E	Waukesha	44.
Spring	15 N	XIII E	Green Lake	42.2
Stone	35 & 36 N	XIII E	Forest	76.4
Summit	33 N	X E	Langlade	16.2
Tomahawk	38 & 39 N	VI & VII E	Oneida & Vilas	45.5
Twin	1 N	XIX E	Kenosha	....
Lake Mary				26.
Vieux Desert	42 N	XIX E	Vilas	19.5
Waubesa	6 & 7 N.	X E	Dane	36.6
Waupaca	21 & 22 N	XI E	Waupaca	....
Bass				9.
Beasley				52.

TABLE XXII.—*Maximum depths of Wisconsin lakes.*—Continued.

Name.	Township.	Range.	Conntу.	Depth.
Waupaca:				Feet.
Columbian	....	....	....	66.6
Dake	....	....	....	28.5
Long	....	....	....	77.7
McCrossen	....	....	....	70.
Marl	....	....	....	60.
Minor	....	....	....	46.6
Mud	....	....	....	32.
Otter	....	....	....	40.
Pope	....	....	....	40.6
Rainbow	....	....	....	95.1
Round	....	....	....	66.7
Taylor	....	....	....	55.7
Winnebago	15 & 20 N	XVII & XVIII E..	Winnebago and Fond du Lac	25.1
Winneconne	19 & 20 N	XV E	Winnebago	9.7

INDEX.

PUBLICATIONS

OF THE

Wisconsin Geological and Natural History Survey.

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1. Bulletins.

The publications of the Survey are issued as bulletins, which are numbered consecutively. Each bulletin is independently paged and indexed, no attempt being made to group them in volumes. The bulletins are issued in three series,

A. *Scientific Series.*— The bulletins so designated consist of original contributions to the geology and natural history of the state, which are of scientific interest rather than of economic importance.

B. *Economic Series.*— This series includes those bulletins whose interest is chiefly practical and economic.

C. *Educational Series.*— The bulletins of this series are primarily designed for use by teachers and in the schools.

The following bulletins have been issued:

Bulletin No. I. Economic Series No. 1.

On the Forestry Conditions of Northern Wisconsin. Filibert Roth, Special Agent, United States Department of Agriculture. 1898. Pp. vi., 78; 1 map. Sent on receipt of 10c.

Bulletin No. II. Scientific Series No. 1.

On the Instincts and Habits of the Solitary Wasps. George W. Peckham and Elizabeth G. Peckham. 1898. Pp. iv., 241; 14 plates, of which 2 are colored; 2 figures in the text. Sold at the price of $1.50 in paper and $2.00 bound.

Bulletin No. III. Scientific Series No. 2.

A Contribution to the Geology of the Pre-Cambrian Igneous Rocks of the Fox River Valley, Wisconsin. Samuel Weidman, Ph. D., Assistant Geologist, Wisconsin Geological and Natural History Survey. 1898. Pp. iv., 63; 10 plates; 13 figures in the text. Out of print.

Bulletin No. IV. Economic Series No. 2.

On the Building and Ornamental Stones of Wisconsin. Ernest Robertson Buckley, Ph. D., Assistant Geologist Wisconsin Geological and Natural History Survey. 1898 (issued in 1899). Pp. xxvi., 544; 69 plates, of which 7 are colored, and 1 map; 4 figures in the text. Sent on receipt of 30c.

Bulletin No. V. Educational Series No. 1.

The Geography of the Region About Devil's Lake and the Dalles of the Wisconsin, with some notes on its surface geology. Rollin D. Salisbury, A. M., Professor of Geographic Geology, University of Chicago, and Wallace W. Atwood, B. S., Assistant in Geology, University of Chicago. 1900. Pp. x., 151; 38 plates; 47 figures in the text. Sent on receipt of 30c.

Bulletin No. VI. Economic Series No. 3. Second Edition.

Preliminary Report on the Copper-Bearing Rocks of Douglas county, and parts of Washbnrn and Bayfield Counties, Wisconsin. Ulysses Sherman Grant, Ph. D., Professor of Geology, Northwestern University. 1901. Pp. vi., 83; 13 plates. Sent on receipt of 10c.

Bulletin No. VII. Economic Series No. 4.

The Clays and Clay Industries of Wisconsin. Part I. Ernest Robertson Buckley, Ph. D., Geologist, Wisconsin Geological and Natural History Survey. In charge of Economic Geology. 1901. Pp. xii., 304; 55 plates. Sent on receipt of 20c.

Bulletin No. VIII. Educational Series No. 2.

The Lakes of Southeastern Wisconsin. N. M. Fenneman, Ph. D., Professor of General and Geographic Geology, University of Wisconsin. 1902. Pp. xv., 178; 36 plates, 38 figures in the text. Sent (bound) on receipt of 50 cents.

Bulletin No. IX. Economic Series No. 5.

Preliminary Report on the Lead and Zinc Deposits of Southwestern Wisconsin. Ulysses Sherman Grant, Ph D., Professor of Geology, Northwestern University. 1903. Pp. viii, 103; 2 maps, 2 plates, 8 figures in the text. Sent on receipt of 10 cents.

Bulletin No. X. Economic Series No. 6.

Highway Construction in Wisconsin. Ernest Robertson Buckley, Ph. D., State Geologist of Missouri, formerly Geologist, Wisconsin Geological and Natural History Survey. 1903. Pp. xvi, 339; 106 plates, including 26 maps of cities. Sent on receipt of 30 cents.

Bulletin No. XI. Economic Series No. 7.

Preliminary Report on the Soils and Agricultural Conditions of North Central Wisconsin. Samuel Weidman, Ph. D., Geologist, Wisconsin Geological and Natural History Survey. 1903. Pp. viii, 67; plates 10, including soil map. Sent, paper bound, without charge, cloth bound, on receipt of 20 cents.

Bulletin No. XII. Scientific Series No. 3.

The Plankton of Lake Winnebago and Green Lake. C. Dwight Marsh, A. M., Professor of Biology, Ripon College. 1903. Pp. vi, 94. 22 plates. Sent, paper bound, without charge; cloth bound, on receipt of 25 cents.

In Press.

Bulletin No. XIII. Economic Series No. 8.

The Baraboo Iron Bearing District. Samuel Weidman, Ph. D., Geologist, Wisconsin Geological and Natural History Survey.

2. Biennial Reports.

The Survey has published three biennial reports, which relate to administrative affairs only and contain no scientific matter.

First Biennial Report of the Commissioners of the Geological and Natural History Survey. 1899. Pp. 31.

Second Biennial Report of the Commissioners of the Geological and Natural History Survey. 1901. Pp. 44.

Third Biennial Report of the Commissioners of the Geological and Natural History Survey. 1903. Pp. 35.

3. Hydrographic Maps.

There have been prepared hydrographic maps of the principal lakes of southern and eastern Wisconsin. This work is in charge of L. S. Smith, Assistant Professor of Topographical Engineering, University of Wisconsin.

The following maps are now ready:

		Size of Plate, Inches.	Scale, Inches per mile.	Contour Interval, Feet.
No. 1.	Lake Geneva	17.5x10.8	2	10
No. 2.	Elkhart Lake	15.5x13.1	5	10
No. 3.	Lake Beulah	22.5x20.0	6	10
No. 4.	Oconomowoc-Waukesha Lakes	29.8x19.1	2	10
No. 5.	The Chain of Lakes, Waupaca	21.7x20.6	6	10
No. 6.	Delavan and Lauderdale Lakes	22.5x16.8	4	10
No. 7.	Green Lake	26.0x17.8	3.2	20
No. 8.	Lake Mendota	23.7x19.5	6	5
No. 9.	Big Cedar Lake	18.0x13.5	2.9	10
No. 10.	Lake Monona	17.6x17.3	4	5

In all of these maps the depth of the lakes is indicated by contour lines, and by tints in all except No. 1. They are sent on receipt of 15 cents each except Nos. 4 and 8, for which 20 cents are required. They may be had either mounted in a manilla cover, or unmounted.

All correspondence relating to the survey should be addressed to

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Madison, Wis.