ON THE LIMNETIC CRUSTACEA OF GREEN LAKE.

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WITH PLATES V TO XIV.

The investigations on which this paper is based were commenced in August, 1893. At that time I constructed a vertical net, which could be closed at any depth. With this net I made twelve series of five meter hauls in a little more than twenty-four hours. My object was to determine the facts in regard to the diurnal migration of limnetic crustacea,— a migration which I was certain, at that time, took place. The material obtained in these collections was carefully counted, the results tabulated, and reduced to percentages, and a report on the subject was made at the summer meeting of the Wisconsin Academy, in June, 1894, and a brief *résumé* was published in the *American Naturalist* in the same year.

So far as difference of diurnal distribution was concerned, the experiments gave only negative results, but certain facts in regard to the general vertical distribution of the different species came out very clearly. It seemed to me probable, however, that the distribution might not be the same on different days, and, in all probability, would differ greatly in the different seasons. At that time, very little had been published in regard to the occurrence of the entomostraca in different seasons. It seemed to me that if a systematic series of collections could be made throughout the year, the results would be very interesting. The matter was brought to the attention of the trustees of Ripon College, who recognized its importance, and made a special appropriation to pay the necessary expenses of the investigation.

The work was commenced in the latter part of September, 1894. During the fall the lake was visited twice each week, and at each visit from one to four series of collections were made. In the winter, while the lake was closed by ice, only three collections were made. From the latter part of April, 1895, until July, collections were made at intervals of about one week. In July and August no collections were made, but in September the work was resumed, and collections were made at intervals of about one month until July, 1896. From July, 1896, to December, weekly collections were made. Thus I had a series of collections running through a little over two years, with the exception that for the months of July and August, I had only the collections of 1896.

During the time in which this work has been going on, considerable has been published on the periodicity and distribution of the limnetic crustacea, so that some of my results are simply corroborative of the work of others, especially in regard to the seasonal distribution of the crustacea. The peculiar character of Green Lake and its fauna and flora, however, makes simply corroborative work important, and some of the results, I think, are entirely new.

I wish to acknowledge the very efficient assistance of Mr. P. S. Collins, of Ripon, in the work of making the collections and observations. Sherwood Forest Hotel was the headquarters of the station work, and I am greatly indebted to the proprietor, Mr. Beckwith, and Mrs. Beckwith, for innumerable courtesies.

GREEN LAKE.

The general character of Green Lake has been indicated in my former paper. (Marsh, '91, b.) It is a long, narrow body of water, something over seven miles in length, and with a maximum width of less than two miles. At the eastern end where it is fed by a small stream, Silver Creek, the shore is low and swampy. At the western end another small stream enters, and here also the shore is low, but most of the shore line is made of bluffs of greater or less elevation. At Lucas's Point and Sugar Loaf are abrupt cliffs of Potsdam sandstone. There are a large number of springs on the south shore, and it is popularly supposed that most of the water is derived from this source.

The water of the lake is clear, of a beautiful green color, and reaches a maximum depth of two hundred and seventeen feet. The bottom in the deep water consists of a fine, blue clay, containing a large amount of organic matter, in which are found worms, none of which have been determined.

In the general character of its fauna, Green Lake resembles, in a striking manner, the Great Lakes. In its abysmal fauna, we find *Pontoporeia Hoyi* and *Mysis relicta*,—species which have not been found in America outside of the Great Lakes. In the intermediate depths is *Limnocalanus macrurus*,—a species seldom found except in the larger bodies of water, and in the upper layers are found the same species as in the Great Lakes with two exceptions,— *C. pulchellus* and *D. Ashlandi.* There is never any striking amount of vegetable matter in Green Lake except in the months of July and August, when ordinarily an *Anabaena*, which I think is either *flosaquae* or *circinalis* is found all over the lake, and forms little green ridges as it is washed up on the shore by the waves. But even this is not present in sufficient amount to form a scum, and never fouls the collecting net to any extent, as does the "scum" of shallower lakes.

Apstein divides lakes into two groups, which he styles *Chroococcaceae* lakes and *Dinobryon* lakes. According to the general characteristics which he gives to these two groups, Green Lake should be a *Dinobryon* lake, and yet I have never found *Dinobryon* in it.

It seems to me that our lakes in this part of North America can naturally be divided into the two classes of "deep" and "shallow" lakes, the faunae of the two classes being very distinct in their general character. The "shallow" lakes have, in the summer season, a large amount of the chlorophyll bearing algae; there is but little distinction between the littoral and limnetic species of *Cyclops*; *Limocalanus macrurus* is seldom present; and the abundant species of *Diaptomus* is *oregonensis*. *Epischura lacustris* may be present in shallow lakes, but is not always found.

In the deep water fauna of the "deep" lakes the common species of *Cyclops* are *brevispinosus*, *pulchellus* and *fluviatilis; Epischura lacustris* and *Limnocalanus macrurus* are commonly present, and *Diaptomus* is represented by *D. sicilis* and *D. minutus: D. Ashlandi*, is, so far as my observations go, confined to the Great Lakes and bodies of water in immediate connection with them.

The distinction thus made in regard to the distribution of *Diaptomus* is not without exception by any means, and I think that in more northern lakes *D. minutus* is found more abundantly in shallow lakes than it is in the region that has been more especially the subject of my studies. Inasmuch as *minutus* is found in great abundance in Greenland and Iceland, I presume that the real cause of its greater abundance in the deeper lakes of our latitude is not the depth of the water, but the low temperature which is coincident with depth.

In general, we may say that depth rather than extent of surface controls the character of the crustacean fauna. This is strikingly shown in a comparison of Green Lake with Lake Winnebago. Lake Winnebago is situated about twenty-five miles from Green Lake, and is about twenty-eight miles long by eight to ten miles broad. Through its whole extent it is very shallow, being for the most part from ten to thirty feet in depth. Its crustacean fauna consists of those species characteristic of shallow lakes, being very different from that of Green Lake. The same thing is noticed in comparing the fauna of Lake Mendota, as determined by Professor Birge, with that of Green Lake, Mendota falling distinctly into the class of shallow lakes. What depth may be considered as characterizing deep lakes, it is difficult to state with certainty, and I suppose it is doubtful if an exact limit can be fixed, but I think it is about forty meters. Lake Mendota, according to the soundings of Professor Birge, has a maximum depth of twenty-two meters. Lake Geneva is a little over forty meters in depth, and, judging from the collections of Professor Forbes, is somewhat intermediate in the character of its fauna between the shallow and deep lakes. Lake St. Clair is apparently an exception to this classification, as, although it is shallow, it has also the fauna of the deep lakes. This is easily explained, however, if we remember, as stated in my former report, (Marsh, '95, p. 4,) that Lake St. Clair has an immediate and constant connection with the deeper lakes, and there is, doubtless, continual migration into it of the forms characteristic of deep water.

DESCRIPTION OF THE DREDGE.—PLATES XIII, XIV.

The dredge which I have used was constructed after several experiments, and has, I think, answered admirably the requirements of my work. Inasmuch as I expected to use it entirely for vertical work, it did not seem necessary that it should be closed when descending, but that there should be some device for closing it at any desired point on its upward course. The upper frame of the dredge is a brass ring from which by three cords is suspended the bucket. The upper frame is thirty-one centimeters in diameter.

The bucket is like that described by Professor Birge. (Birge, '95, p. 428). Inasmuch as the wire gauze used in the bucket has meshes 1–100 of an inch in diameter, it does not retain the smallest organisms, but serves perfectly well as an apparatus for catching crustacea.

The dredge bag is of India linen, carefully selected so as to get cloth that is fairly uniform in texture, and is suspended between the upper frame and the bucket. The dredge bag is strengthened on its upper edge by heavy cloth, into which are let the eyelets, by which it is laced to the brass rings of the frame.

The cords between the frame and the bucket are continued below the bucket and fastened to a sounding lead weighing about six pounds. To the upper frame are attached three cords which unite in a brass ring, by which the dredge is suspended by the releasing apparatus. About half way of the length of the dredge there are attached to the suspending cords brass rings, through which a cord runs twice in such a way that when it is drawn tight it acts like a puckering string and closes the dredge. This cord is attached to the dredge rope, which, after being fastened to the releasing apparatus, hangs loosely over the edge of the dredge.

The releasing apparatus consists of a brass frame (see Pl.

XIII.) fifteen centimeters long, by five centimeters broad. The frame is strengthened by three transverse braces. The frame and braces are made of strips cut from sheet brass, one millimeter thick and two centimeters wide.

Through the horizontal pieces of the apparatus are drilled two holes large enough so that the heavy brass wire D E will slide easily up and down. To the middle of this wire at E is attached an upright piece which passes through the lower part of the frame B, and strikes against the brace C. The wire is held in place by a rubber band passing around the plate B. The dredge is hung from this central pin at E, and cannot be detached except as the wire D E is lowered so as to throw the ring off the pin.

The releasing apparatus is fastened to the dredge rope by copper wire passed through small holes drilled in the upper and lower plates. The messenger is a brass cylinder five centimeters long and four centimeters in diameter.

The work of dredging is done from a row boat which is fitted with a sail. The mast is unshipped, and in the mast hole is inserted an upright about six feet long, to which is attached a cross piece extending over the side of the boat. From this cross piece the dredge is suspended by a pulley block, and upon the cross piece is a hook from which the messenger is suspended. The dredge is lowered vertically, and after being raised to the required point, is "set off" by the messenger. When the messenger strikes the releasing apparatus the top of the dredge falls over, and it remains suspended by the middle. At the same time the weight of the lead causes the cord around the middle of the dredge to tighten, so that there is a double safeguard against the entrance of any other organisms — the inverted top and the stricture of the suspending cord.

There is one source of inaccuracy in this dredge, and that is the loss of material, when it is released, between the top and the cord passing around the center. My hauls, however, were made through five meter distances, and I do not think that in this distance, the loss would have much effect on the results, and, of course, for comparative work it need not be considered at all.

For winter work, the apparatus is hung from a tripod placed over a hole in the ice. (Plate XIV.)

The tube at the bottom of the bucket was made of a size to fit in the top of an eight drachm homeopathic bottle, and in order to preserve material, I simply washed it with strong alcohol immediately from the bucket into the bottle.

A buoy was anchored in from forty to forty-five meters of water, and all collections were made from that point. In successive years the buoy was located in very nearly the same place, and when collections were made through the ice, it was intended that they should be taken at nearly the location of the buoy.

Collections were made in all kinds of weather, but more were made in comparatively pleasant weather, as naturally one would prefer to visit the lake under such conditions.

The record of observations was kept in a book arranged for the purpose. A sample page of this book appears on the next page.

The temperatures were taken by a Miller-Casella deep-sea maximum and minimum thermometer, which was loaned to me by the United States Fish Commission for the purpose. As those who have used this form of thermometer know, it is very slow in its action, it being necessary to allow at least twenty minutes for each observation. This made it impossible for me to get a record of temperatures at intermediate depths, although such a record is very important in determining the laws governing the vertical distribution.

The temperature curves of the two years, 1895 and 1896, are shown in plates V and VI, with the exception that no observations were made in July and August, 1895. It will be noticed that the maximum range of bottom temperature observed was from 35 to 45 degrees, thus indicating great uniformity of conditions of temperature at the bottom.

SERIAL COLLECTION. No. 13.96.

Made at Green Lake,.................. Aug. 3,...................... 1896, 6-6:40 p. m., with .... closing dredge .... at permanent station............... 4; .... depth 43.5 m. ;............ water, .·.... small waves; .....wind.......... s w.; .... sky .... clear;........ temperature, air ...83;... temperature, surface,.. 75; ... temperature, bottom... 43; ... ‘ Observed *Diaptomi, D. minutus, C. fluviatilis* egg-bearing. Much fine sand in collection: is explained perhaps by the high wind earlier in the day.

Names.	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	Total
Diaptomus sicilis...	760	1,192	272	40	140	14	11	75	4	.....	.....	.....	2,508
" Ashlandi	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
" minutus	....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....	....	......
" oregonensis	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
Epischura lacustris.	16	4	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	30
Limnocalanus macrurus	....	.....	1	4	8	1	2	13	.....	.....	.....	.....	29
Cyclops brevispinosus.....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
" pulchellus..	....	... .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
" Leuckarti....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
" albidus......	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
" fluviatilis. ..	72	72	32	6	.....	.....	.....	.....	.....	.....	.....	.....	182
" serrulatus...	....	.....	.....	.....	.....	.....	. ...	.....	.....	.....	.....	.....	......
....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
Cyclops larvæ.......	160	8	.....	6	4	.....	2	.....	.....	.....	.....	.....	180
Leptodora hyalina.	4	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	5
Daphnia kahlbergiensis.............	12	16	40	8	8	.....	.....	.....	.....	.....	.....	.....	84
Bosmina	56	.....	2	3	6	.....	.....	.....	.....	.....	.....	.....	67
Daphnella	12	24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	36
....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
Mysis relicta........	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
Pontoporeia Hoyi..	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
Notholca	Nos	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
Ceratium	"	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......
....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......

The surface temperature varied from the freezing point of water in winter to eighty degrees in August, 1896. In general the rise of surface temperature in the spring, and the fall in autumn, were both uniform and rapid, but there were some exceptions. Very noticeable is the jog in the curve in May, 1895. In this month there was a period of unusually warm weather, followed by severe frosts.

There was a curious rise in the bottom temperature in the fall of both 1894 and 1895. On November 11, 1894, I found the bottom temperature 45, while the highest point reached previous to that time was 42½.

On October 24, and November 3, 1894, I found the bottom temperature 44, while the highest point reached previous to that time was 43. On November 11, 1895, the bottom temperature was 45, while the highest previously recorded was 42½. My first impression on seeing these temperatures was that there must have been a mistake in the observation. I felt the more certain of this probability in one case, as the observation had been made by my assistant without my direct supervision. But a repetition of the work showed that there was no mistake.

A similar rise in bottom temperature in November has been noticed in Lake Cochituate (Whipple, '95, p. 205, and Fitzgerald, '95, p. 74), and these authors have also noticed a fall in bottom temperature in the spring. These apparent abnormalities in temperature have been explained by the above mentioned authors on the supposition that as the top and bottom temperatures approached each other, the water, being of nearly equal density from top to bottom, would be in a state of unstable equilibrium, and currents would be set in motion, which would effect the whole depth, especially under the influence of high winds. Whipple has shown ('95, p. 208), that under some circumstances an overturning and mingling of the whole mass of water in a lake may take place with almost incredible suddenness.

Although no attempt was made to keep a systematic record of other organisms than crustacea, some notes were kept of the appearance of other animals and of plants.

Of plants, the only one besides diatoms, which occurred in any abundance was the *Anabaena* already mentioned. In 1896 this appeared in the latter part of June, and continued well through August. In other years, I have found it present only during a very short time. I have notes also of a red alga that was found in considerable abundance about the middle of August. In one of the March collections there was also an undetermined green alga.

Rotifera were of course present in large numbers, but no attempt was made to keep any record of them. *Notholca longispina* was found throughout the year, sometimes in great abundance.

Ceratium occurred quite constantly in the collections from June to the latter part of October, and in 1896, until the middle of November.

From May through the year, *Diptera* are occasionally found in the collections. This is what one would expect, for the larvae are found in the bottom fauna.

METHOD OF COUNTING.

The method used in counting was somewhat different from that used by other authors, and a method that perhaps could not be used so successfully in collections containing a large amount of vegetable material. The alcohol in the bottles was largely replaced by glycerine in order to have the material in a medium that would not evaporate rapidly. I had prepared for me a glass plate sixteen centimeters in diameter, ruled with concentric circles a centimeter apart. The circles were divided by diameters into eight segments. The plate was mounted on a tripod such as is used in leveling gelatine plates in bacteriological work, and carefully leveled. The collection was then poured as nearly as possible upon the exact center of the plate. Ordinarily it would spread with great uniformity upon the plate. The fractional part of the whole counted depended upon the numbers of the species under consideration. Commonly I counted only one-eighth of the *Diaptomi*. Of the species present in smaller numbers, I would ordinarily count all on the plate. In any case all parts of the plate were examined in order to detect the presence of any unusual form. This work was done with the aid of a dissecting lens such as is furnished with a Reichert dissecting microscope. This lens answered every purpose so far as determining the species of the crustacea, except that I could not distinguish with certainty *D. minutus* from *D. sicilis.* As the object of the counting was mainly to determine distribution, the fact that I did not distinguish between these species was of little importance, as their habits are the same. In every case, however, a test of the collection was carefully examined under the compound microscope, and in this way a fairly accurate idea was obtained of the seasonal distribution of these species, and notes were made also in regard to the occurrence of other smaller organisms. No attempt, however, was made to keep any record of diatoms.

The accuracy of this method of counting was carefully tested, and the amount of error was found very small,—so small that I do not think the general results would be appreciably affected. As stated before, it is very doubtful if the method could be applied so successfully to plankton rich lakes.

These results were afterwards reduced to percentages in order to show the relative abundance in vertical distribution.

In the following table I have tabulated the conditions under which the various collections were made. The table is, in the main, self-explanatory. To indicate the condition of the surface I have used four terms, "smooth, ripples, waves, and rough."

In the tables given for the various species the "total" column indicates the actual number obtained in my dredge. These numbers might easily be reduced to give the actual number per square meter by multiplying by the coefficient of the dredge, but my object was simply to get comparative results, and, as indicated later in this paper, I myself have only limited confidence in the value of plankton determinations. In the columns following "total" are given the percentages found for every five meters of depth.

No.	Date.	Time.	Temp. Air.	Temp. Sur.	Temp. Bot.	Wind.	Water.	Sky.
1.94	Sept. 27....	6:30-7:30 p. m.	70	....	....	S. W.	Waves	Clear.
4.94	Oct. 6....	10:45-11:45 a. m.	57	60	43	S. W.	Ripples	Clear.
5.94	Oct. 6....	2:30-3:30 p. m.	59	59	43	S. W.	Waves	Clear.
6.94	Oct. 6....	4:50-5:45 p. m.	....	....	....	S.	Waves	Clear.
7.94	Oct. 6....	10-11 p. m.	53	....	....	S.	Waves	Clouds.
8.94	Oct. 9....	6-7 p. m.	....	....	....	S.	Waves	Clear.
10.94	Oct. 10....	6-7 a. m.	45	56	..	S. W.	Rough	Clouds.
11.94	Oct. 10....	9-10 a. m.	....	....	....	N. W.	Rough	Clouds.
12.94	Oct. 16....	6-7 p. m.	....	....	....	S. W.	Waves	Clear.
13.94	Oct. 16....	10:30-11:30 p. m.	54	53	43	S. W.	Waves	Clear.
14.94	Oct. 17....	6-7 a. m.	49	53	....	W.	Waves	Clear.
15.94	Oct. 17....	8:45-9:30 a. m.	51	....	....	W.	Waves	Clear.
16.94	Oct. 20....	11:15-12 a. m.	57	53	43	S. E.	Ripples	Clouds, fog.
17.94	Oct. 20....	2:15-3:15 p. m.	64	54	....	S. E.	Ripples	Clear.
18.94	Oct. 20....	4:40-5:20 p. m.	58	....	....	S. E.	Ripples	Clear.
20.94	Oct. 24....	10-11 p. m.	48	54	44	S.	Waves	Clouds.
21.94	Oct. 25....	6-6:50 a. m.	48	....	....	S.	Waves	Clouds.
22.94	Oct. 25....	8:45-9:30 a. m.	....	....	....	S. W.	Rough	Clouds.
24.94	Nov. 3....	2:45-3:30 p. m.	45	52	44	S.	Waves	Clouds.
25.94	Nov. 3....	4:30-5:20 p. m.	45	....	....	S. W.	Rough	Clouds.
26.94	Nov. 8....	5:30-6:15 p. m.	....	....	....	S.	Ripples	Clear.
27.94	Nov. 8....	10-11 p. m.	35	49	....	S.	Waves	Clouds.
29.94	Nov. 21....	....	38	39	43	W.	Ripples	Clear.
1.95	Feb. 14....	11:30-12:30 m.	29	33	38	N. W.	Ice	Clear.
2.95	Mar. 9....	11:30-12:30 m.	45½	36	37½	S. W.	Ice	Cloudy, and rain.
3.95	Mar. 27....	10:45-12 m.	51	36½	37	W.	Ice	Clear.
4.95	Apr. 27....	1:15-2:30 p. m.	58	42	40½	N. E.	Waves	Clear.
5.95	May 3....	4:30-5:15 p. m.	68½	47	40½	S. W.	Change	Cloudy.
6.95	May 3....	7:20-8 p. m.	53½	....	....	E.	Waves	Clear.
7.95	May 9....	4:30-5.30 p. m.	80½	55½	40½	S. W.	Rough	Clear.
8.95	May 18....	1:25-2:05 p. m.	81	51	41	N. E.	Waves	Clouds.
9.95	May 24....	4:30-5:30 p. m.	74	54	41½	S. W.	Rough	Clear.
10.95	June 1....	10:50-11:35 a. m.	81	63	41½	S. W.	Rough	Clear.
11.95	June 6....	....	70	65	42	S. E.	Waves	Clear.
12.95	June 15....	4:30-5:30 p. m.	78	68	42	E.	Waves	Clear.
13.95	June 22....	12:10-1:15 p. m.	90½	72	42¼	N. W.	Waves	Clear.
14.95	June 28....	3:30-4:30 p. m.	75	72	42	N W-N E	Waves	Clear.
15.95	Sept. 21....	2-3 p. m.	84½	71½	42½	S. W.	Rough	Clear.
16.95	Oct. 2....	4:45-5:45 p. m.	70	60	42½	S W-S E	Ripples	Clear.
17.95	Oct. 5....	4-5 p. m.	70	61	42½	S. W.	Smooth	Clear.
18.95	Oct. 24....	10-11 a. m.	40	50	42½	S. W.	Rough	Clear.
19.95	Nov. 11....	1:30-2:30 p. m.	48	46	45	S. W.	Waves	Clear.
20.95	Dec. 5....	12:15-1 m.	22	42	43	S. W.	Waves	Gray.
1.96	Jan. 28....	1-2 p. m.	32	34	35	S. W.	Ice	Cloudy.
2.96	Feb. 22....	12:30-1:30 p. m.	40	34½	35½	S. W.	Ice	Clear.
3.96	Mar. 21....	11:45-12:30 m.	45	36	36	S. W.	Ice	Overcast.
5.96	May 4....	3:25-4:10 p. m.	86	52	41	N. W.	Smooth	Clear.
6.96	May 18....	3:45-4:30 p. m.	74	55	42	N. W.	Waves	Clouds in west.
7.96	June 1....	3:15-4 p. m.	73	60	43	E.	Waves	Clear.
8.96	June 15....	3:40-4:20 p. m.	88	69	43½	E.	Waves	Clear.
9.96	June 29....	12:05-12:40 m.	101	74	43	N.	Smooth	Clear.
10.96	July 9....	11:45-12:30 a. m.	78	75	43	N. E.	Waves	Clouds.
11.96	July 20....	10:20-11:15 a. m.	78	74	43¾	S. W.	Rough	Clouds.
12.96	July 27....	3:30-4:15 p. m.	88½	75	43	S. W.	Waves	Clouds.
13.96	Aug. 3....	6-6:40 p. m.	83	75	43	S. W.	Waves	Clear.
14.96	Aug. 10....	3:35-4:10 p. m.	....	80	43½	S. W.	Waves	Clear.
15.96	Aug. 17....	12-12:45 m.	72	76½	44	N. W.	Waves	Clear.
16.96	Aug. 24....	3:25-4:05 p. m.	76	74	44	W.	Waves	Clear.
17.96	Aug. 31....	9:50-10:35 a. m.	68	70	44	N. W.	Waves	Clouds.
18.96	Sept. 7....	9:25-10:15 a. m.	78½	66	44	S. W.	Rough	Clear.
19.96	Sept. 15....	3.20-4:05 p. m.	62½	65	44½	N. E.	Waves	Clear.
20.96	Sept. 21....	2:45-3:30 p. m.	70	63	44	N. E.	Waves	Clouds.
21.96	Sept. 28....	2.55-3.40 p. m.	70	61	43½	E.	Ripples	Clear.
22.96	Oct. 6....	11-11:35 a. m.	59	58	44	N. W.	Waves	Clouds.
23.96	Oct. 15....	12:45-1:20 p. m.	67	56	43½	N.	Waves	Clouds.
24.96	Oct. 24....	11:30-12:15 m.	50	51½	43½	N. W.	Waves	Clear.
25.96	Nov. 14....	3.50-4:40 p. m.	49	45	43	S. W.	Waves	Clear.
26.96	Nov. 14....	7:20-8:45 p. m.	....	45	....	S. W.	Waves	Clear, moonlight.
27.96	Dec. 3....	11:15-12 a. m.	41	41½	39½	S.	Waves	Hazy.

DIAPTOMUS.

No. of Coll.	Total No.	Per cent.								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
1.94..	3,912	58.64	11.63	12.48	7.16	1.23	5.11	1.43	1.02	1.23
4.94..	5,630	60.25	24.58	7.18	2.34	3.81	.85	.78	.78	.43
5.94..	4,171	72.50	14.67	3.93	4.22	.57	2.22	.86	.77	.26
6.94..	4,382	73.80	16.00	4.	3.40	.73	.32	1.40	.29	......
7.94..	2,023	46.27	20.56	11.86	12.46	2.37	1.98	1.19	.34	2.97
8.94..	4,585	68.57	20.54	4.62	2.62	.26	.59	1.22	.87	.70
10.94..	4,040	28.61	26.93	31.78	7.82	2.77	.74	.79	.37	.17
11.94..	3,991	54.92	14.88	17.24	3.66	1.05	7.02	.45	.50	.28
12.94..	6,439	36.77	19.32	17.52	6.21	13.36	5.60	.77	.25	.20
13.94..	4,611	57.73	13.54	16.39	5.12	5.29	1.34	.15	.24	.19
14.94..	4,347	45.73	19.05	23.92	7.72	1.84	1.14	.11	.25	.18
15.94..	3,466	46.39	27.81	14.19	9.81	.52	......	.38	.69	.20
16.94..	1,763	59.44	17.92	13.16	4.36	3.18	.28	.17	.11	.79
17.94..	1,542	71.92	17.38	4.60	3.76	.58	.39	.52	.26	.39
18.94..	1,386	80.81	4.97	10.39	1.44	.58	.36	1.01	.01	.43
19.94..	1,464	......	......	......	......	......	......	......	......	......
20.94..	2,197	59.17	18.02	15.66	1.86	2.82	1.91	.04	.36	.13
21.94..	1,917	35.89	27.33	25.45	4.23	2.87	2.39	1.15	.58	.11
22.94..	3,823	60.27	24.48	9.52	3.19	.71	1.59	.18	......	.05
24.94..	1,972	65.72	12.99	10.34	6.23	1.17	2.13	.56	.61	.25
25.94..	1,695	63.30	28.	2.53	1.35	2.80	.70	.18	.10	.10
26.94..	884	77.83	12.22	1.81	1.47	1.36	2.37	1.36	.90	.68
27.94..	6,447	28.29	21.98	25.56	13.57	9.06	.85	.39	.16	.12
29.94..	1,192	40.60	10.73	11.41	6.03	7.06	10.73	4.03	6.72	2.69
1.95..	1,374	27.80	7.57	22.13	7.57	2.04	5.53	7.57	13.68	6.11
2.95..	1,947	28.35	9.86	2.67	18.02	27.94	4.11	2.92	4.71	1.43
3.95..	2,742	68.27	4.67	4.52	2.77	4.82	3.50	5.11	3.87	2.47
4.95..	676	14.20	17.75	22.49	13.02	8.88	7.69	12.42	3.55	......
5.95..	686	35.27	9.91	14.58	6.99	5.25	11.67	9.04	5.25	2.04
6.95..	694	29.39	18.44	23.05	8.07	4.61	6.48	.14	5.76	4.03
7.95..	286	.69	15.39	14.69	5.59	15.39	24.48	16.08	3.50	4.19
8.95..	295	1.36	10.85	23.73	10.51	11.19	16.27	7.46	11.51	7.11
9.95..	576	44.44	22.22	4.16	10.41	6.08	4.51	2.60	2.79	2.79
10.95..	1,845	66.88	22.98	6.08	.16	1.30	.38	1.30	.65	.27
11.95..	1,250	......	......	......	......	......	......	......	......	......
12.95..	2,950	40.68	29.29	14.10	10.31	1.62	3.12	.47	.14	.27
13.95..	2,612	21.44	18.07	19.91	14.70	7.66	5.51	4.90	4.59	3.22
14.95..	3,039	54.72	22.51	5.79	7.63	4.21	1.71	.66	1.45	1.32
15.95..	2,605	37.77	24.57	12.59	6.45	9.52	1.84	2.46	4.15	.65
16.95..	1,748	34.32	35.69	18.31	4.12	1.83	1.38	1.14	2.75	.46
17.95..	1,813	10.59	43.35	33.54	4.85	4.86	1.27	.88	.67	......
18.95..	1,667	51.35	10.32	11.52	18.23	7.32	.72	.36	.18	......
19.95..	647	42.04	3.71	1.24	21.02	17.93	8.65	3.71	1.70	......
20.95..	520	33.85	17.69	5.38	9.23	6.92	10.77	12.31	3.85	......
1.96..	485	......	19.79	4.95	3.30	36.28	13.20	17.53	1.65	3.30
2.96..	1,324	25.98	11.48	10.88	12.08	23.56	7.25	1.81	3.33	3.63
3.96..	892	35.43	23.32	11.88	9.42	6.28	5.38	5.38	2.24	.67
5.96..	1,712	74.77	5.61	5.84	2.57	.82	2.10	4.91	1.87	1.52
6.96..	297	33.67	10.77	33.67	5.39	2.70	4.04	4.71	3.37	1.68
7.96..	2,712	36.87	50.44	9.44	1.62	.89	.30	.29	.11	.04
8.96..	3,044	27.59	47.83	13.14	3.68	3.71	.65	1.70	.78	.92

DIAPTOMUS — continued.

No. of Coll.	Total No.	Per cent.								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
9.96..	2,392	56.52	25.09	10.70	5.02	.75	.50	.25	.12	1.05
10.96..	2,354	39.50	33.30	8.84	6.12	.25	.69	1.44	4.76	5.10
11.96..	2,793	36.17	24.63	28.07	2.72	.46	1.25	.68	4.80	1.22
12.96..	3,612	47.84	37.65	9.74	2.99	.30	.17	.75	.17	.39
13.96..	2,508	30.30	47.53	10.84	1.60	5.58	.56	.44	2.99	.16
14.96..	3,803	64.16	19.99	6.42	3.10	......	2.84	2.52	.26	.71
15.96..	1,563	98.91	.13	......	......	.06	.19	.13	.19	.39
16.96..	4,785	62.90	9.01	18.06	1.25	2.01	2.67	1.33	2.17	.60
17.96..	4,933	41.60	28.81	19.62	1.87	2.59	.57	.89	2.27	1.78
18.96..	5,646	70.86	.42	15.02	4.85	.49	.98	4.83	.78	1.77
19.96..	4,766	46.37	33.02	6.73	3.35	2.35	3.02	3.86	1.09	.21
20.96..	5,248	59.18	21.80	6.25	1.22	2.04	3.43	4.08	.69	.91
21.96..	3,772	54.72	26.73	14.21	1.06	.95	1.01	.64	.13	.50
22.96..	4,229	45.40	19.11	23.22	9.27	2.46	.11	.31	.07	.05
23.96..	4,736	78.21	7.43	8.96	4.39	.46	.25	.13	.13	.04
24.96..	1,527	54.49	16.76	23.58	4.19	.26	.20	.13	.26	.13
25.96..	746	18.23	7.51	6.43	15.55	16.09	23.59	7.50	3.76	1.34
26.96..	490	in 0–20	meter	s.						
27.96..	762	42.	7.35	9.98	6.30	4.20	5.77	6.29	15.75	2.36

A glance at Pl. VII will show that *Diaptomus* has a strongly marked minimum of occurrence in December and in January. There is an increase in February and March, but in both 1895 and 1896, the number in May was very small. *Diaptomus* appears to reach its maximum in the latter part of September and October. In the fall months, the collections consist mostly of mature forms. In the winter months most of them are immature. From the latter part of March to the latter part of May, nearly all are mature, and the females egg-bearing. In June there is a great preponderance of larvæ.

Apstein ('96, 179 and following) states that the maximum period of *D. graciloides* differs in different German lakes. The time of the maximum occurrence of Green Lake *Diaptomi* as recorded above, does not agree with any of his observations. Birge (Birge '95 p. 448) states that the maximum time of *Diaptomus* in Lake Mendota is in July. Inasmuch as *Diaptomus* is very little affected by differences of temperature, as will be shown later, I think these differences in maximum periods are probably caused by some differences in the development of food supply.

There are only two species of *Diaptomus* found in Green Lake, — *D. minutus* and *D. sicilis*. In the counting no distinction was made in regard to these species, but a slide was prepared from each collection and examined under the compound microscope and thus a rough idea obtained of the relative abundance of the two forms. During Sept. and Oct. *D. minutus* was much more abundant. In Sept. very few of *D. sicilis* were found. During October and November the relative number of *D. sicilis* increases, and in the winter months the collections were almost entirely of *D. sicilis*.

In 1894 I first found *D. sicilis* in the collection of Sept. 28. In 1895 it first appeared Oct. 5, and 1896 on Oct. 6. Although I did not find this species in the summer months while I was making my serial collections, I do not think that it was probably entirely absent from the lake; for in 1890 and 1891 I found it in summer collections, although I did not find it in 1892. (Marsh, '93 p. 198.) I find, on looking over my notes of 1890 and 1891 that it was not numerous in those years, and I presume that it occurs in the summer months, but only in very small numbers. A reexamination of my notes on the Michigan copepods shows that the same thing holds true there. In the collections made by Professor Reighard in April, in Lake Michigan, *D. sicilis* was always present, while in the summer collections in the Great Lakes and Lake Michigan, *D. minutus* was the more common form, as I have already noted in my paper on Michigan copepods, and *D. sicilis* occurs rather infrequently. In April and May *D. minutus* is entirely lacking in Green Lake, but appears again in June.

Inasmuch as it is claimed by some that some copepods show a seasonal dimorphism, one might raise the question whether we did not here have a case of that kind. I do not think that this is so, although I have not now material to fortify my belief.

The *Diaptomi* are found at all depths, but in the deeper strata only in small numbers. There were very few hauls in which I did not find some representatives of this genus in every five meter stratum, and yet from sixty to seventy-five per cent. were commonly in the upper ten meters.

In order to find out whether there was any difference in the vertical distribution in summer and in winter I took the averages in the upper three levels of collections 7.96 to 17.96 inclusive, and 24.94 to 3.95 inclusive. I took these years because in 1894–5 I made a large number of collections in cold weather, and in 1896 I made the largest number of collections in warm weather.

The following table indicates the results:

	0–5	5–10	10–15
Summer, 7.96–17.96	49.31	24.49	12.26
Winter, 24.94–3.95	50.02	13.50	10.12

It appears from these averages that the seasons make no difference in the vertical distribution of *Diaptomus*, but that it is uniform throughout the year.

Apstein comes to the same conclusion. ('96, p. 180.)

The day and night collections of October, 1894, compared as follows:

	0–5	5–10
Day	59.44	18.42
Night	53.70	18.40

Here is no evidence of diurnal migration.

I think, then, that I am safe in saying that the vertical distribution of *Diaptomus* varies but little from one end of the year to the other and is not appreciably affected by changes in the amount of light.

Birge finds the same thing to be true of *D. oregonensis.* (Birge, '95, 450.)

EPISCHURA LACUSTRIS.

No. of Coll.	Total. No.	Per cent. 0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
1.94..	155	77.42	20.65	1.23	......	......	......	......	......	......
4.94..	121	59.50	33.06	6.61	.83	......	......	......	......	......
5.94..	100	56.	24.	16.	4.	......	......	......	......	......
6.94..	180	87.	8.30	4.44	......	.55	......	......	......	......
7.94.	149	34.90	32.21	18.79	10.74	2.69	......	......	......	.67
8.94..	390	41.54	33.82	16.41	5.13	.51	.26	1.56	.51	.26
10.94..	220	50.90	21.82	23.63	2.72	.99	......	......	......	......
11.94..	191	54.45	15.71	25.13	2.09	......	2.09	......	.52	......
12.94..	104	19.23	7.69	9.61	38.46	11.54	11.54	.96	.96	......
13.94..	141	28.37	11.35	45.39	8.51	2.84	3.54	......	......	......
14.94..	126	38.09	19.05	22.22	9.52	9.52	.79	......	.79	......
15.94..	214	56.08	18.69	20.56	......	2.80	......	.93	.47	.47
16.94..	96	75.	14.79	8.33	1.04	......	......	1.04	......	......
17.94..	50	64.	28.	6.	......	......	......	......	2.	......
18.94..	183	81.43	3.27	8.74	......	......	......	......	.55	......
20.94..	95	23.16	25.26	47.37	......	1.05	3.16	......	......	......
21.94..	65	49.23	24.61	21.54	3.08	......	1.54	......	......	......
22.94..	32	62.50	21.88	9.38	3.12	3.12	......	......	......	......
24.94..	41	50.	......	25.	......	......	......	......	25.	......
25.94..	22	31.82	45.45	......	9.09	9.09	4.55	......	......	......
26.94..	118	74.57	14.41	4.24	5.93	......	......	.85	......	......
27.94..	330	53.33	5.45	31.52	8.49	.91	.30	......	......	......
29.94..	8	......	......	......	......	100.	......	......	......	......
1.95..	60	33.33	40.	26.67	......	......	......	......	......	......
2.95..	395	50.63	8.10	8.10	16.46	14.17	2.04	......	.50	......
3.95..	24	66.67	......	......	......	......	......	......	33.33	......
4.95..	......	......	......	......	......	......	......	......	......	......
5.95..	......	......	......	......	......	......	......	......	......	......
6.95..	......	......	......	......	......	......	......	......	......	......
7.95..	......	......	......	......	......	......	......	......	......	......
8.95..	......	......	......	......	......	......	......	......	......	......
9.95..	......	......	......	......	......	......	......	......	......	......
10.95..	93	98.72	......	1.28	......	......	......	......	......	......
11.95..	96	33.33	58.33	......	8.34	......	......	......	......	......
12.95..	41	19.51	78.05	2.44	......	......	......	......	......	......
13.95..	64	37.50	37.50	12.50	12.50	......	......	......	......	......
14.95..	196	24.49	69.39	4.08	2.04	......	......	......	......	......
15.95..	24	50.	12.50	25.	4.17	4.17	......	......	4.16	......
16.95..	65	73.84	18.46	4.62	......	1.54	......	......	1.54	......
17.95..	37	8.11	64.86	21.62	5.41	......	......	......	......	......
18.95..	100	48.	20.	8.	16.	8.	......	......	......	......
19.95..	4	50.	50.	......	......	......	......	......	......	......
20.95..	......	......	......	......	......	......	......	......	......	......
1.96..	223	7.79	......	32.29	3.59	......	......	22.87	39.46	......
2.96..	96	58.33	33.33	......	8.34	......	......	......	......	......
3.96..	......	......	......	......	......	......	......	......	......	......
5.96..	......	......	......	......	......	......	......	......	......	......
6.96..	......	......	......	......	......	......	......	......	......	......
7.96..	10	10.	80.	10.	......	......	......	......	......	......
8.96..	41	98.	2.	......	......	......	......	......	......	......
9.96..	32	50.	50.	......	......	......	......	......	......	......

EPISCHURA LACUSTRIS—continued.

No. of Coll.	Total. No.	*Per cent.*								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
10.96..	140	61.43	34.29	1.43	.71	......	......	.71	......	1.43
11.96..	131	61.07	7.63	30.54	.76	......	......	......	......	......
12.96..	54	44.44	44.45	11.11	......	......	......	......	......	......
13.96..	30	53.33	13.33	33.34	......	......	......	......	......	......
14.96..	29	27.59	48.28	20.68	3.45	......	......	......	......	......
15.96..	203	99.01	.99	......	......	......	......	......	......	......
16.96..	397	84.63	11.34	4.03	......	......	......	......	......	......
17.96..	333	76.58	21.32	1.80	.30	......	......	......	......	......
18.96..	270	91.48	......	5.93	2.22	......	.37	......	......	......
19.26..	107	61.68	37.38	......	.94	......	......	......	......	......
20.96..	100	28.	72.	......	......	......	......	......	......	......
21.96..	120	46.66	40.	13.34	......	......	......	......	......	......
22.96..	46	34.79	34.78	26.09	2.17	2.17	......	......	......	......
23.96..	150	69.33	21.34	5.34	2.67	......	......	.66	.66	......
24.96..	46	69.56	15.22	15.22	......	......	......	......	......	......
25.96..	98	93.88	......	......	3.06	1.02	2.04	......	......	......
26.96..	9	in 0.20	met'rs	......	......	......	......	......	......	......
27.96..	4	100.	......	......	......	......	......	......	......	......

From the table it appears that *Epischura* occurs in the summer and fall months, with no very well defined time of maximum numbers. (See Pl. VIII.) The largest numbers obtained at single hauls were 390 in the evening of October 9, 1894, 395 from a haul made through the ice on March 9, 1895, and 397 on August 24, 1896. In the March haul a large proportion were larval forms. *Epischura* disappears entirely in the latter part of March and does not appear again until June.

The number of my winter collections was, unfortunately, very small, so that one must be very careful about drawing inferences from them. But I think we may consider it fairly certain that *Epischura* is hatched from the egg in the winter,—probably in February or the early part of March. This in itself is a matter of some interest, as, so far as I know, there is no previous record of the occurrence of any considerable number of larval forms of *Epischura*.

It is a curious fact that so soon after the appearance of the larval forms, *Epischura* entirely disappears for several months. I will not in this paper hazard a conjecture as to the explanation of this, as I hope in a later paper to treat more fully upon its life history after further researches.

So far as I know there have been no preceding observations on the seasonal distribution of *Epischura*. Its nearest European relative is *Heterocope*, and this is stated by Apstein to occur from the latter part of July into November, its maximum period being in the summer. He does not record any time of the appearance of the larval forms.

In its vertical distribution, *Epischura* is largely confined to the upper regions. While laboratory experiments would seem to indicate that it avoids bright light, the averages of my collections apparently show that it is more largely controlled by the conditions of temperature. In my collections of August, 1893, I found 81 per cent. in the upper ten meters. The average of the collections of 1894, extending from the latter part of September to the last of November was 53.11 per cent. in the upper five meters and 19.52 per cent. from five to ten meters, thus making 72.63 per cent in the upper ten meters. In order to compare the distribution at different seasons, I computed the average percentages in the collections from the surface to five meters, and from five meters to ten meters for June, July and August, 1896, and from November, 1894 to April, 1895, with the following results:

	0–5	5–10	0–10
Winter, 24.94–3.95	42.53	14.18	56.71
Summer, 7.96-17.96.............	60.55	28.51	89.06

This would seem to indicate that *Epischura* prefers the warmer water, although it is by no means absent from the cold water of the surface in the cold season. It occurred to me that if *Epischura* were, to a large extent, controlled in its vertical distribution by conditions of temperature, there might be a diurnal migration caused by the cooling of the surface water at night, for the surface responds quickly to changes in atmospheric temperature. To determine whether any such effect would be produced, I compared the night and day collections of October, 1894. From Oct. 6 to Oct. 24, I made five collections between six p. m. and six a. m. Four of these were made between ten and twelve o'clock. In these collections between six p. m. and six a. m., 29.44 per cent. were between the surface and five meters, and 22.06 per cent. between five and ten, making 51.50 per cent. in the upper ten meters.

In ten collections made during the same period between six a. m. and six p. m., 62.24 per cent. were between the surface and five meters, and 18.67 per cent. between five and ten meters, or 80.91 per cent in the upper ten meters. The average of all the collections made during this time was 51.31 per cent. from the surface to five meters, and 19.80 per cent. from five to ten meters, making 71.11 per cent. in the upper ten meters.

These results are contrary to my expectations, for I had supposed that *Epischura* came to the surface at night. On the contrary, it appears that in October nights it migrates to greater depths. It appears to me probable that temperature is the controlling cause of both its diurnal and seasonal migrations.

The fact that surface tows in summer evenings are sometimes rich in *Eprischau* is, I think, in harmony with the statements above. For while, as has been stated, *Epischura* prefers warm water, it also avoids bright light. In the daytime during the hot months, it is most abundant in the upper layers, but not at the immediate surface. In the darkness of the evening, however, it is no longer repelled from the surface by the light, and the change of temperature may not be sufficient to affect it.

In the 1893 collections, made in warm weather in the latter part of August, three of the hauls were made between six at night and six in the morning. In these three night hauls, there was an average of 82 per cent. in the 0-5 stratum, while the average in the day hauls in the same stratum was 33.32 per cent.

The fact that *Epischura* comes to the surface in such large numbers on warm summer nights may be accounted for by the fact that it is a large species and a strong swimmer, and moves toward the surface because of the greater amount of food material there.

LIMNOCALANUS MACRURUS.

No. of Coll.	Total No.	Per cent.								
		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-
1.94..	72	......	......	......	44.44	27.77	5.55	13.88	1.39	6.95
4.94..	133	......	......	......	2.26	1.50	1.50	11.28	38.35	45.11
5.94..	87	1.15	2.30	......	1.15	1.15	3.45	9.20	31.03	50.57
6.94..	96	......	1.04	......	1.04	11.44	8.33	24.90	53.12	......
7.94..	113	.88	.88	......	6.19	38.94	20.35	13.27	7.08	12.39
8.94..	81	......	1.23	4.93	9.87	9.87	7.40	27.16	27.16	12.35
10.94..	59	......	1.69	1.69	1.69	23.73	28.81	13.56	18.66	10.17
11.94..	33	......	......	......	......	6.06	9.09	6.06	54.54	24.24
12.94..	79	......	1.27	5.06	10.13	20.25	15.19	12.66	22.78	12.66
13.94..	38	21.05	7.90	2.63	......	7.90	13.16	5.26	21.05	21.05
14.94..	43	......	......	......	2.32	13.95	16.28	9.30	25.58	32.56
15.94..	8	12.50	......	......	......	......	......	12.50	25.	50.
16.94..	16	......	......	......	6.25	12.50	......	6.25	6.25	68.75
17.94..	10	......	......	10.	......	......	10.	......	80.	......
18.94..	56	......	......	1.79	1.79	......	7.14	32.14	37.50	19.64
20.94..	30	3.33	3.33	40.	......	3.33	43.33	......	6.66	......
21.94..	19	......	......	......	......	......	26.32	15.79	31.58	26.32
22.94..	8	......	25.	......	......	......	12.50	12.50	......	50.
24.94..	20	......	......	......	......	......	10.	10.	20.	60.
25.94..	16	25.	......	......	......	12.50	25.	25.	6.	6.
26.94..	51	5.88	3.92	17.65	17.65	5.88	23.53	7.84	15.69	1.96
27.94..	113	23.01	4.42	14.16	16.81	8.85	6.20	19.47	2.66	4.42
29.94..	101	2.97	3.96	1.98	5.94	27.72	14.85	6.93	7.92	27.72
1.95..	25	16.	48.	8.	4.	......	......	8.	12.	4.
2.95..	64	37.50	1.56	3.13	1.56	4.69	1.56	6.24	21.88	21.88
3.95..	34	2.94	......	2.94	......	8.82	8.83	17.65	11.76	47.06
4.95..	140	8.57	22.87	25.71	7.14	14.28	10.	7.86	3.57	......
5.95..	90	11.11	3.33	4.44	4.44	5.56	22.22	27.78	15.56	5.56
6.95..	104	11.54	7.69	9.62	15.38	19.24	18.27	2.88	13.46	1.92
7.95..	85	......	......	3.53	2.35	17.65	35.30	30.59	8.23	2.35
8.95..	20	......	......	15.	10.	5.	10.	10.	25.	25.
9.95..	26	......	......	......	......	3.85	7.69	26.92	26.92	34.62
10.95..	6	98.72	......	1.28	......	......	......	......	......	......
11.95..	5	......	......	......	20.	......	20.	60.	......	......
12.95..	60	......	......	......	3.33	......	35.	40.	10.	11.67
13.95..	27	......	......	......	11.11	......	14.81	14.82	44.44	14.81
14.95..	7	......	......	......	......	......	14.28	......	71.43	14.29
15.95..	6	......	......	......	......	16.66	......	16.67	......	66.67
16.95..	15	......	......	......	6.66	6.66	26.67	......	46.67	13.34
17.95..	16	......	......	......	......	12.50	......	56.25	36.25	......
18.95..	1	......	......	100.	......	......	......	......	......	......
19.95..	22	13.64	13.64	4.55	13.64	......	13.63	27.27	13.63	......
20.95..	12	8.33	33.34	......	16.66	8.34	33.33	......	......	......
1.96..	8	......	......	......	......	......	12.50	25.	50.	12.50
2.96..	43	9.30	......	27.91	......	18.60	18.60	6.98	18.61	......
3.96..	76	15.79	10.52	3.95	......	......	15.79	21.05	31.58	1.32
5.96..	203	29.56	1.97	13.79	13.79	4.43	5.42	23.64	5.91	1.48
6.96..	52	1.92	23.08	11.54	19.23	15.38	......	19.23	1.92	7.70
7.96..	20	5.	......	......	15.	30.	40.	......	10.	......
8.96..	41	......	......	......	......	......	4.54	27.28	27.27	40.91
9.96..	4	......	......	......	......	......	......	25.	......	75.

LIMNOCALANUS MACRURUS — Continued.

No. of Coll.	Total No.	Per cent.								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
10.96..	32	......	......	......	6.25	......	......	6.25	43.75	43.75
11.96..	17	......	......	23.53	5.88	5.88	......	5.88	17.65	41.18
12.96..	9	......	......	11.11	11.11	......	......	11.12	22.22	44.44
13.96..	29	......	......	3.45	13.79	27.58	3.45	6.90	44.83	......
14.96..	15	......	......	6.66	13.34	......	19.98	6.66	26.68	26.68
15.96..	......	......	......	......	......	......	......	......	......	......
16.96..	42	......	......	16.66	....	......	......	......	66.68	16.66
17.96..	21	......	......	......	28.57	9.52	14.29	23.81	9.52	14.29
18.96..	34	......	......	2.94	17.65	2.94	11.76	14.71	29.41	20.59
19.96..	35	......	......	......	28.57	22.86	5.71	11.43	25.71	5.72
20.96..	51	......	1.96	......	......	11.76	11.76	33.34	25.49	15.69
21.96..	37	......	......	......	8.11	......	5.41	2.70	16.21	67.57
22.96..	7	......	......	......	14.29	28.57	......	......	28.57	28.57
23.96..	34	......	......	5.88	2.94	11.76	11.76	14.71	17.65	35.30
24.96..	26	3.85	3.85	26.92	3.85	11.53	3.85	11.54	7.69	26.92
25.96..	56	1.78	5.36	3.57	25.	28.57	30.36	5.36	......	......
26.96..	200	from	0-2½	met'rs	106	from	0-20	met'rs		
27.96..	43	......	6.98	6.98	4.65	11.63	16.28	9.30	34.88	9.30

Limnocalanus macrurus (see Pl. IX) occurs in collections at all times of the year, but never in very large numbers. The largest single collection that I made was May 8, 1896. While the numbers were very variable, I think I can say that it was most abundant in the months of May and November, thus having two maximum periods,—the spring period showing greater numbers.

In February, March, and April most of the *Limnocalani* are immature.

In its vertical distribution *Limnocalanus* is very interesting. From May to November it is seldom found in the day time in the upper five meters, and only in small numbers in the upper ten. In the winter months it is found at all depths. Thus its vertical distribution would seem to be controlled, in part, at least, by temperature. It also seems to be somewhat sensitive to light, for the night collections in 1894 show a greater number near the surface. As these night collections were not extended through the year, it would perhaps be unsafe to say that *Limnocalanus* comes to the surface in the night, but it is certainly very significant that most of the evening collections show more or less of this species in the 0–5 and 5–10 hauls.

The collections of November 14, 1896, seem to show quite conclusively the effect of light on the vertical distribution of *Limnocalanus.* On this date, the temperature of the surface was 45, and that of the bottom 43, so that the temperature was practically uniform through the whole depth of the water. In the collection made at about four o'clock in the afternoon, *Limnocalanus* was absent in the upper two and one-half meters, there was one in the upper five meters, three in the layer from five to ten, two in ten to fifteen, and an increasing number in the deeper layers. In the evening, at about eight o'clock, there were two hundred in the upper two and one-half meters, and a rapidly decreasing number in the deeper layers. A surface tow taken in the evening consisted very largely of *Limnocalanus.*

I think we can state with positiveness from these observations that *Limnocalanus* is repelled by the higher temperature of the surface waters in summer, and is also repelled by light. There is a further question, however, which it is not so easy to answer, and that is the positive reason of the vertical migration. Why do they approach the surface when there is neither a high temperature or light to repel them. It occurred to me that possibly, while they are repelled by bright light, they may be attracted by a faint light, like that of the moon. A comparison of the collections of cloudy and moonlight nights, however, shows no essential difference.

It is possible that the more highly aerated surface waters may attract them; this is not probable, however, for the fact that during such a large portion of the year they are found in deeper water would seem to imply that they are adapted to the somewhat stagnant conditions of those waters. It seems to me most probable that the larger food supply of the surface waters is the main cause of the vertical migration.

The relation of *Limnocalanus* to the "sprungschicht" is interesting. Unfortunately I have been able to make temperature determinations for only the surface and bottom, so that I do not know the position of the "sprungschicht" in Green Lake at different periods of the year. By the kindness of Prof. E. A.

Birge a set of serial temperatures was taken with the thermophone September 3, 1896, which seemed to show that at that time the "sprungschicht" was located at about fourteen meters below the surface. Probably its location does not change materially during the summer months. In looking over the collection of *Limnocalanus*, I find that during the summer months it is found mostly below the fifteen meter level, its distribution becoming gradually more general in the fall, and continuing so until the late spring. This leads me to infer that the vertical distribution of the *Linnocalanus* varies nearly as the "sprungschicht" varies.

C. brevispinosus did not occur in large numbers in any of the serial collections. The largest number obtained at one time was 291, on June 6, 1895. In both 1895 and 1896 its occurrence was confined almost entirely to the month of June. It was found in both May and July, but only in small numbers. At other times I have found it in Green Lake in August, but it must be comparatively rare at that time, for in my serial collections in 1893 I did not find a single individual. I have found it in the Michigan lakes, too, in July and August.

In regard to its vertical distribution, it appears to be most abundant from five to twenty meters in depth. In the upper five meters only a few are found, and they do not go below 20 to 25 meters to any extent.

CYCLOPS BREVISPINOSUS.

C. brevispinosus not present in collections from 1.94 to 6.95.

No. of Coll.	Total No.	Per cent.								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
7.95..	1	......	......	......	100.	......	......	......	......	......
8.95..	......	......	......	......	......	......	......	......	......	......
9.95..	......	......	......	......	......	......	......	......	......	......
10.95..	246	......	......	87.80	4.47	4.88	1.22	.81	.41	.41
11.95..	291	8.25	54.98	10.99	16.84	......	8.25	......	.69	......
12.95..	79	......	50.63	10.13	10.13	6.32	20.25	1.27	1.27	......
13.95..	166	......	......	19.28	62.65	14.46	3.61	......	......	......
14.95..	13	......	......	61.54	15.38	15.39	7.69	......	......	......
15.95..	......	......	......	......	......	......	......	......	......	......
16.95..	......	......	......	......	......	......	......	......	......	......
17.95..	......	......	......	......	......	......	......	......	......	......
18.95..	......	......	......	......	......	......	......	......	......	......
19.95..	......	......	......	......	......	......	......	......	......	......
20.95..	7	......	......	57.15	......	......	......	42.85	......	......
1.96..	6	16.66	50.	......	33.34	......	......	......	......	......
2.96..	......	......	......	......	......	......	......	......	......	......
3.96..	......	......	......	......	......	......	......	......	......	......
5.96..	......	......	......	......	......	......	......	......	......	......
6.96..	1	100.	......	......	......	......	......	......	......	......
7.96..	33	......	72.73	3.03	12.12	......	12.12	......	......	......
8.96..	52	15.38	46.15	30.77	3.85	3.85	......	......	......	......
9.96..	36	......	......	44.45	44.44	11.11	......	......	......	......
10.96..	7	14.28	......	14.29	57.14	......	......	14.29	......	......
11.96..	3	......	......	......	33.33	66.67	......	......	......	......
12.96..	......	......	......	......	......	......	......	......	......	......
13.96..	......	......	......	......	......	......	......	......	......	......
14.96..	......	......	......	......	......	......	......	......	......	......
15.96..	......	......	......	......	......	......	......	......	......	......
16.96..	1	......	......	100.	......	......	......	......	......	......
17.96..	......	......	......	......	......	......	......	......	......	......
18.96..	......	......	......	......	......	......	......	......	......	......
19.96..	......	......	......	......	......	......	......	......	......	......
20.96..	......	......	......	......	......	......	......	......	......	......
21.96..	2	......	100.	......	......	......	......	......	......	......
22.96..	......	......	......	......	......	......	......	......	......	......
23.96..	......	......	......	......	......	......	......	......	......	......
24.96..	......	......	......	......	......	......	......	......	......	......
25.96..	......	......	......	......	......	......	......	......	......	......
26.96..	......	......	......	......	......	......	......	......	......	......
27.96..	25	100.	......	......	......	......	......	......	......	......

CYCLOPS FLUVIATILIS.

No. of Coll.	Total No.	Per cent.								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
1.94..	336	30.95	2.38	26.19	33.33	......	7.15	......	......	......
4.94..	530	24.15	23.39	21.89	23.77	6.04	.76	......	......	......
5.94..	740	16.22	41.62	14.46	23.78	1.76	.54	.27	1.35	......
6.94..	707	33.94	16.97	24.33	5.76	2.12	.42	.14	......	......
7.94..	968	23.97	3.72	10.74	47.52	9.50	1.26	.42	......	2.94
8.94..	823	14.58	18.97	33.53	26.24	4.13	1.10	.97	.12	.36
10.94..	791	25.79	15.67	11.63	31.86	8.09	3.16	3.54	.12	.12
11.94..	783	33.72	8.43	23.50	25.29	3.58	.38	1.02	.51	......
12.94..	881	21.34	16.34	13.62	9.53	17.71	19.52	1.36	.34	.23
13.94..	378	42.33	22.22	17.99	3.70	9.53	2.12	.79	......	1.32
14.94..	525	54.63	16.76	8.38	12.95	6.10	......	.95	......	......
15.94..	535	27.66	20.93	9.72	36.64	4.86	......	......	......	.19
16.94..	452	17.48	21.24	27.43	22.78	7.30	1.10	.44	1.33	.66
17.94..	378	22.22	16.93	21.43	34.66	3.17	.27	......	......	1.32
18.94..	262	36.87	16.87	24.42	18.32	3.05	......	.38	......	.38
20.94..	1,241	20.63	5.16	58.34	11.60	3.38	.64	......	.08	.16
21.94..	618	26.54	22.01	20.06	25.89	4.53	......	.81	.16	......
22.94..	625	38.40	14.08	9.60	30.40	6.55	.96	......	......	......
24.94..	865	55.49	14.80	9.94	11.79	6.59	.81	.23	.35	......
25.94..	1,043	45.60	24.35	12.20	8.40	7.70	1.10	.20	.30	.10
26.94..	1,912	42.67	33.47	13.39	4.55	3.76	.84	.89	.16	.32
27.94..	564	44.68	17.38	12.77	17.73	5.85	.53	.53	.53	......
29.94..	1,036	40.15	9.26	16.21	8.49	5.02	6.18	3.47	6.18	5.02
1.95..	134	......	......	17.91	47.76	23.88	4.48	2.98	2.24	.75
2.95..	322	24.84	7.45	2.48	14.91	22.36	9.94	12.42	5.59	......
3.95..	324	54.32	6.17	6.17	2.47	6.17	4.94	7.41	4.94	7.41
4.95..	114	14.03	6.14	5.26	10.53	21.93	28.07	10.53	3.51	......
5.95..	138	20.29	23.19	31.88	2.17	......	17.39	4.35	.73	......
6.95..	154	20.78	23.38	16.88	18.18	9.09	11.04	......	.65	......
7.95..	93	81.72	16.13	......	......	......	......	......	......	2.15
8.95..	116	91.38	6.89	......	.86	......	......	......	.86	......
9.95..	58	75.87	20.69	......	......	1.72	......	......	......	1.72
10.95..	415	86.75	9.64	1.93	......	......	1.44	......	......	.24
11.95..	357	71.71	8.96	.28	13.73	......	4.48	.28	.56	......
12.95..	68	29.41	11.77	47.05	11.77	......	......	......	......	......
13.95..	85	67.07	18.82	9.41	......	......	......	......	......	4.70
14.95..	400	73.75	14.	12.	......	......	.25	......	......	......
15.95..	397	8.06	2.02	65.49	14.11	10.07	.25	......	......	......
16.95..	340	56.47	25.88	9.41	5.89	1.76	.59	......	......	......
17.95..	385	6.23	14.55	47.79	22.86	8.31	.26	......	......	......
18.95..	610	45.25	11.80	18.36	14.43	3.93	3.93	1.64	.66	......
19.95..	403	23.82	11.91	......	36.24	19.85	3.97	3.47	.74	......
20.95..	280	14.29	14.29	8.57	14.29	8.57	5.71	14.28	20.	......
1.96..	91	......	......	26.38	13.19	52.75	2.19	1.09	......	4.40
2.96..	389	......	4.11	8.22	49.36	32.90	3.09	2.06	......	.26
3.96..	89	2.25	31.46	3.37	8.99	22.47	26.96	3.37	......	1.13
5.96..	23	69.57	17.39	13.04	......	......	......	......	......	......
6.96..	77	72.72	10.40	15.58	......	......	1.30	......	......	......
7.96..	124	77.42	12.90	6.45	......	3.23	......	......	......	......
8.96 .	136	100.	......	......	......	......	......	......	......	......
9.96..	328	82.92	4.88	12.20	......	......	......	......	......	......

CYCLOPS FLUVIATILIS—continued.

No. of Coll.	Total No.	Per cent.								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
10.96..	423	92.67	1.18	2.83	2.84	.24	......	......	.24	......
11.96..	607	96.21	2.63	......	......	.49	.17	.16	.34	......
12.96..	546	85.35	13.19	.73	......	.19	.18	.18	......	.18
13.96..	182	39.56	39.56	17.58	3.30	......	......	......	......	......
14.96..	153	31.37	31.37	33.99	3.27	......	......	......	......	......
15.96..	331	99.10	......	.60	......	.30	......	......	......	......
16.96..	230	55.65	5.22	24.35	3.48	......	8.69	1.30	......	1.31
17.96..	474	18.57	8.44	60.76	10.97	.84	.42	......	......	......
18.96..	368	32.61	.54	34.78	30.44	.54	.27	......	......	.82
19.96..	525	50.29	4.57	13.71	16.76	3.81	3.05	7.62	.19	......
20.96..	619	51.70	11.63	28.43	3.23	......	3.23	1.62	......	.16
21.96..	369	23.85	19.52	32.52	18.43	2.17	.27	1.64	.55	1.09
22.96..	489	29.45	11.45	8.18	32.72	16.36	.82	.61	.41	......
23.96..	396	51.01	12.12	14.14	22.48	.25	......	......	......	......
24.96..	253	28.46	17.39	22.13	25.30	2.77	.39	......	3.56	......
25.96..	342	25.73	12.86	4.68	8.19	7.02	4.68	18.72	7.60	10.52
26.96..	312	in	0–20	mete	rs.					
27.96..	400	10.	8.	8.	14.	42.	2.	6.	2.	......

C. fluviatilis (see Pl. X) occurs in the collections during the whole year, and generally in considerable numbers. The maximum seems to be reached in the months of October and November, although in 1896 quite large collections were made in July, and the smallest collections were made in the months of May and June.

C. fluviatilis is found in greater or smaller numbers at all depths, but is far the most abundant near the surface, the greater part of the collection being ordinarily within ten meters of the surface, and below twenty-five meters very few are found. In many cases more than fifty per cent. were in the upper five meters. In the winter collections, however, the numbers at the surface were smaller, and the bulk of the collection was frequently in the intermediate regions, between ten and thirty meters. There are apparent exceptions to this, however, as in 3.95, where 54 per cent. were in the upper five meters. But in this case the remaining fifty per cent. was distributed pretty evenly through the deeper regions.

In order to determine with some degree of exactness the difference in vertical distribution in cold weather as compared with that in warm weather I averaged the percentages in the upper five divisions from June until September, 1896, —7.96 to 17.96 inclusive,—and from November to April, 1895,—24.94 to 3.95 inclusive,— with the following results:

	0–5	5–10	10–15	15–20	20–25
7.96 to 17.96—warm weather..........	70.80	10.85	14.50	2.17	.48
24.94 to 3.95—cold weather...........	38.47	14.11	11.38	14.51	10.17

It is evident from these figures that there is a marked difference in the vertical distribution in warm and in cold weather. Nearly 71 per cent. in warm weather are in the upper five meters, while the upper fifteen include 96.15 per cent. In cold weather, on the other hand, only 38.47 per cent. are in the upper five meters, and below that they are somewhat evenly distributed.

To determine the difference between day and night I averaged the five hauls in October, 1894, which were taken between six p. m. and six a m., and compared them with ten hauls taken in the same month between six a. m. and six p. m. The following was the result:

	0–5	5–10	10–15	15–20
Night hauls................................	24.57	13.28	26.84	19.72
Day hauls..................................	29.27	19.88	18.72	23.58

It will be seen that the percentages are very similar, and I infer that there is no appreciable diurnal migration. I conclude from this that they are not very sensitive to changes in the amount of light. I take it, too, that while they are affected by changes of temperature, they are not very sensitive to such changes, or a larger proportion would be found in the warmer deep water in the winter. *C. fluviatilis*, in this respect, differs very markedly from *Epischura lacustris*, which not only has a more pronounced seasonal migration, but moves vertically in accordance with diurnal changes of temperature in the surface water

LEPTODORA HYALINA.

No. of Coll.	Total No.	Per cent. 0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
4.94..	3	33.33	33.33	33.34	......	......	......	......	......	......
5.94..	1	......	100.	......	......	......	......	......	......	......
6.94..	12	100.	......	......	......	......	......	......	......	......
7.94..	5	80.	20.	......	......	......	......	......	......	......
8.94..	4	100.	......	......	......	......	......	......	......	......
10.94..	5	......	80.	......	20.	......	......	......	......	......
11.94..	11	18.18	9.09	54.54	9.09	......	9.09	......	......	......
12.94..	5	20.	60.	......	......	......	20.	......	......	......
13.94..	1	......	100.	......	......	......	......	......	......	......
14.94..	1	......	......	100.	......	......	......	......	......	......
15.94..	2	......	100.	......	......	......	......	......	......	......
16.94..	......	......	......	......	......	......	......	......	......	......
17.94..	......	......	......	......	......	......	......	......	......	......
18.94..	......	......	......	......	......	......	......	......	......	......
20.94..	1	......	100.	......	......	......	......	......	......	......
21.94..	2	......	100.	......	......	......	......	......	......	......
22.94..	1	......	......	100.	......	......	......	......	......	......
					No *Leptodora* from 23.94 to 2.95.					
3.95..	3	100.	......	......	......	......	......	......	......	......
					No *Leptodora* from 4.95 to 12.95.					
13.95..	6	......	......	83.33	16.67	......	......	......	......	......
14.95..	12	100.	......	......	......	......	......	......	......	......
15.95..	2	......	......	50.	......	50.	......	......	......	......
16.95..	......	......	......	......	......	......	......	......	......	......
17.95..	......	......	......	......	......	......	......	......	......	......
18.95..	1	100.	......	......	......	......	......	......	......	......
19.95..	......	......	......	......	......	......	......	......	......	......
20.95..	......	......	......	......	......	......	......	......	......	......
1.96..	......	......	......	......	......	......	......	......	......	......
2.96..	......	......	......	......	......	......	......	......	......	......
3.96..	......	......	......	......	......	......	......	......	......	......
5.96..	......	......	......	......	......	......	......	......	......	......
6.96..	......	......	......	......	......	......	......	......	......	......
7.96..	......	......	......	......	......	......	......	......	......	......
8.96..	2	50.	50.	......	......	......	......	......	......	......
9.96..	16	37.50	18.75	12.50	31.35	......	......	......	......	......
10.96..	2	50.	50.	......	......	......	......	......	......	......
11.96..	24	100.	......	......	......	......	......	......	......	......
12.96..	8	75.	25.	......	......	......	......	......	......	......
13.96..	5	80.	......	......	......	20.	......	......	......	......
14.96..	6	33.33	66.67	......	......	......	......	......	......	......
15.96..	5	100.	......	......	......	......	......	......	......	......
16.96..	22	63.63	3.82	......	4.55	......	......	......	......	......
17.96..	15	53.34	13.33	26.67	......	......	......	......	6.66	......
18.96..	21	90.48	......	4.76	4.76	......	......	......	......	......
19.96..	1	......	......	......	100.	......	......	......	......	......
20.96..	4	25.	25.	50.	......	......	......	......	......	......
21.96..	8	37.50	37.50	......	12.50	12.50	......	......	......	......
22.96..	1	......	......	......	......	100.	......	......	......	......
23.96..	2	......	......	100.	......	......	......	......	......	......
24.96..	1	......	......	......	100.	......	......	......	......	......
25.96..	......	......	......	......	......	......	......	......	......	......
26.96..	......	......	......	......	......	......	......	......	......	......
27.96..	......	......	......	......	......	......	......	......	......	......

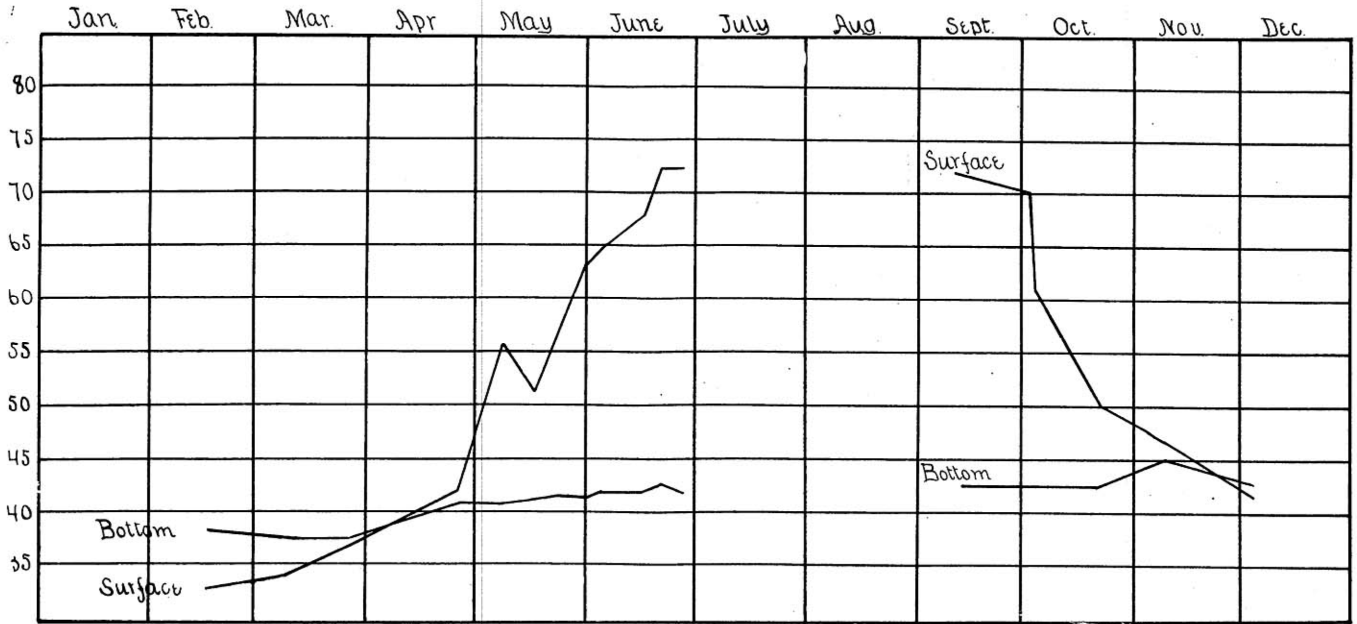
With the exception of three individuals in the collection of March 27, 1895, I found no *Leptodora* from the latter part of October to the middle of June. It was present pretty generally in the summer collections, but never in very large numbers. The largest number that I obtained in any collection was twenty-four.

In its vertical distribution, *Leptodora* is commonly within ten meters of the surface. I have found individuals at a depth of between twenty-five and thirty meters, but it is not a common occurrence.

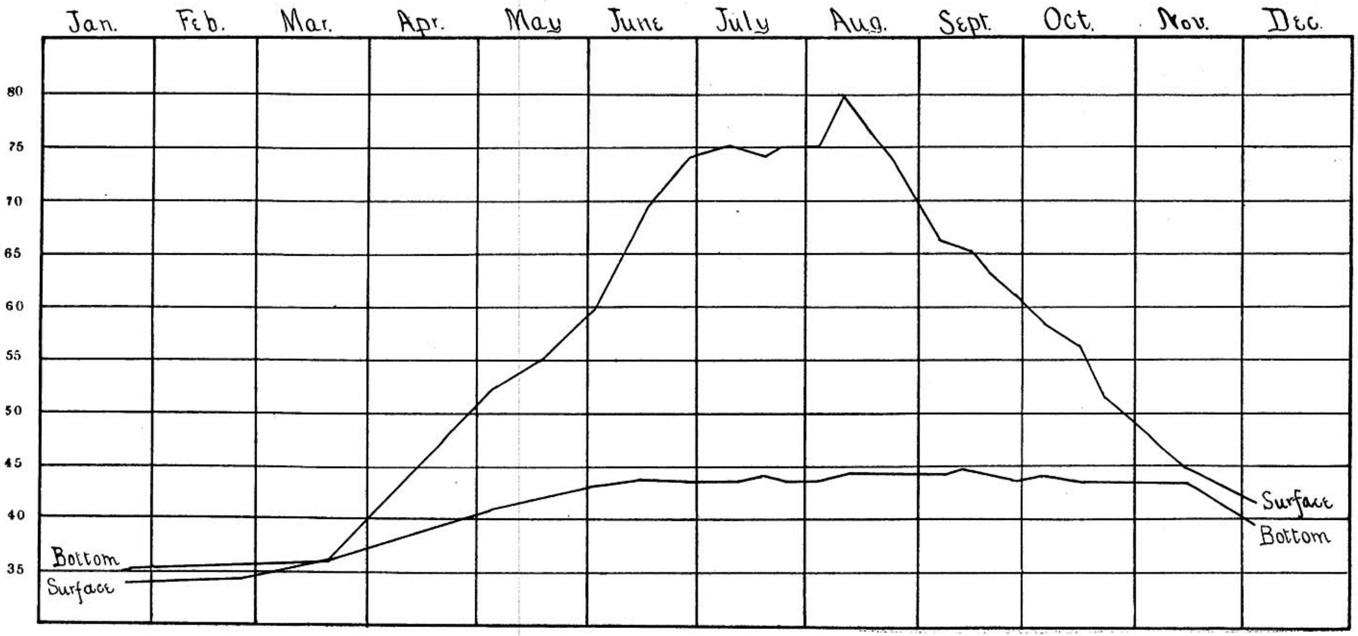
Leptodora was never present in sufficient numbers in my collections so that I could draw any inferences in regard to the effect changes of temperature would have on its vertical distribution.

It will be noticed that my observations in regard to the seasonal distribution of *Leptodora* correspond very closely with what Zacharias says of *Leptodora* in Ploener See, for he states that it disappears in the course of the month of October, and appears again towards the end of May. (Zacharias, '94, p. 100. Also, Apstein '96, p. 175. Friç and Vávra, '94, pp. 55, 108.)

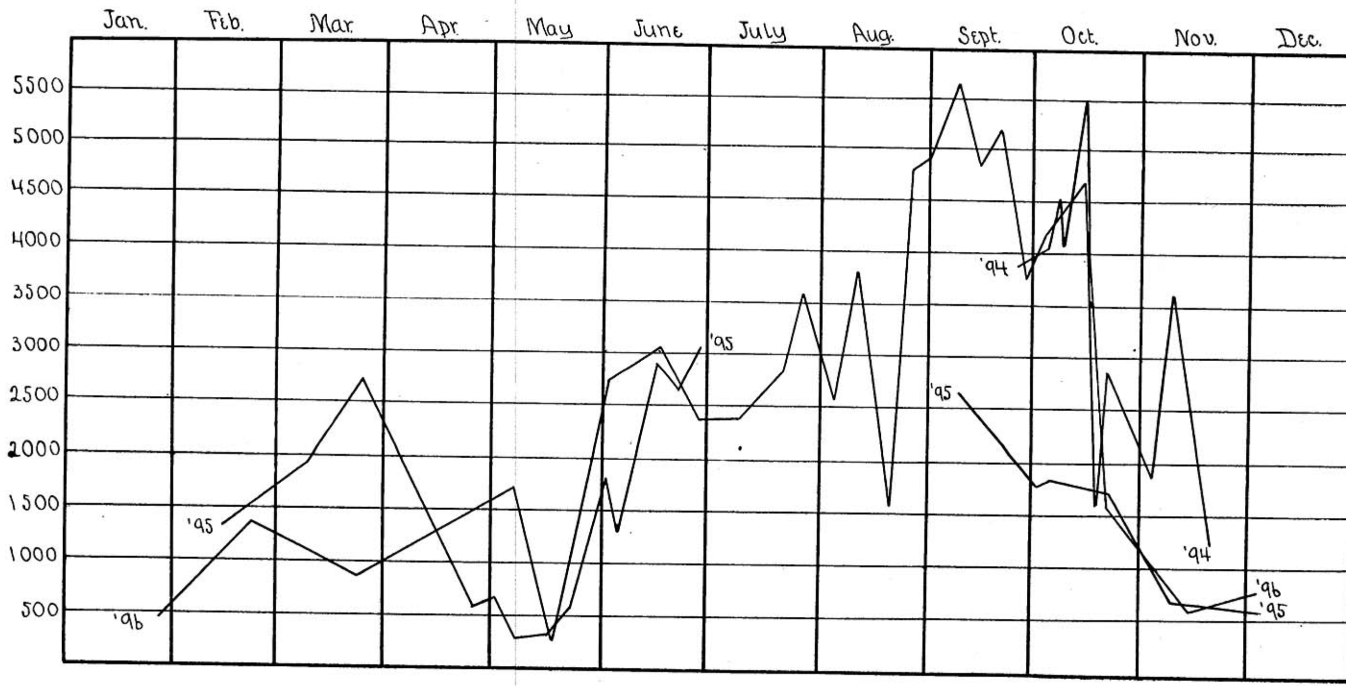
Apstein ('96, p. 80) states that *Leptodora* is found most abundantly in the deep water. This is certainly not according to my observations, as they would indicate that it should rather be considered a surface form, although it is by no means confined to the immediate surface. As Apstein does not state what he means by deep water in this case, the seeming contradiction in our observations may be more apparent than real.



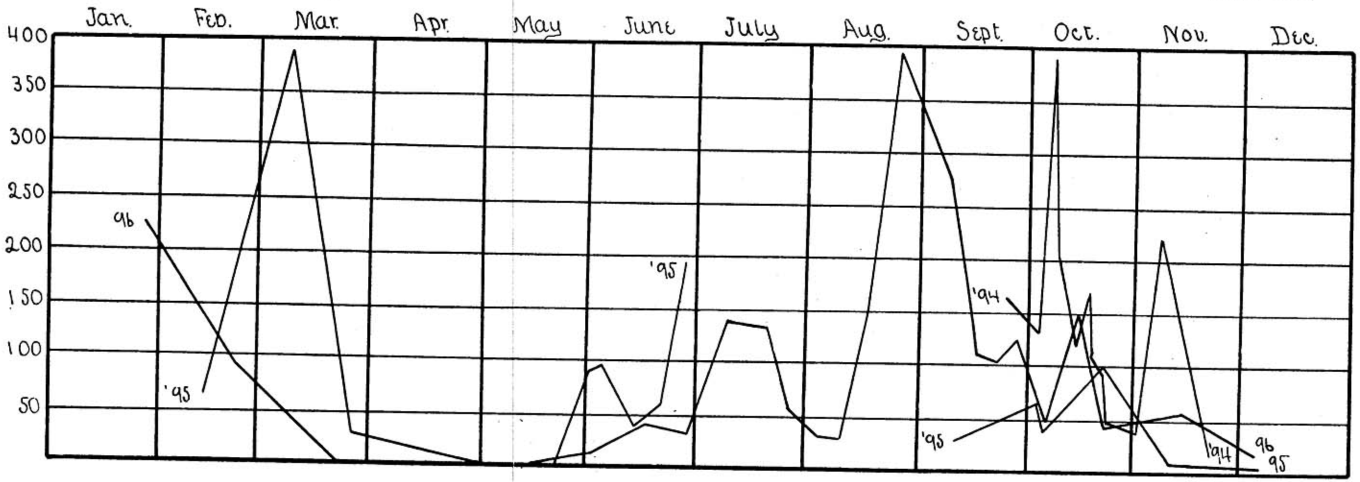
TEMPERATURE CURVES, 1895.



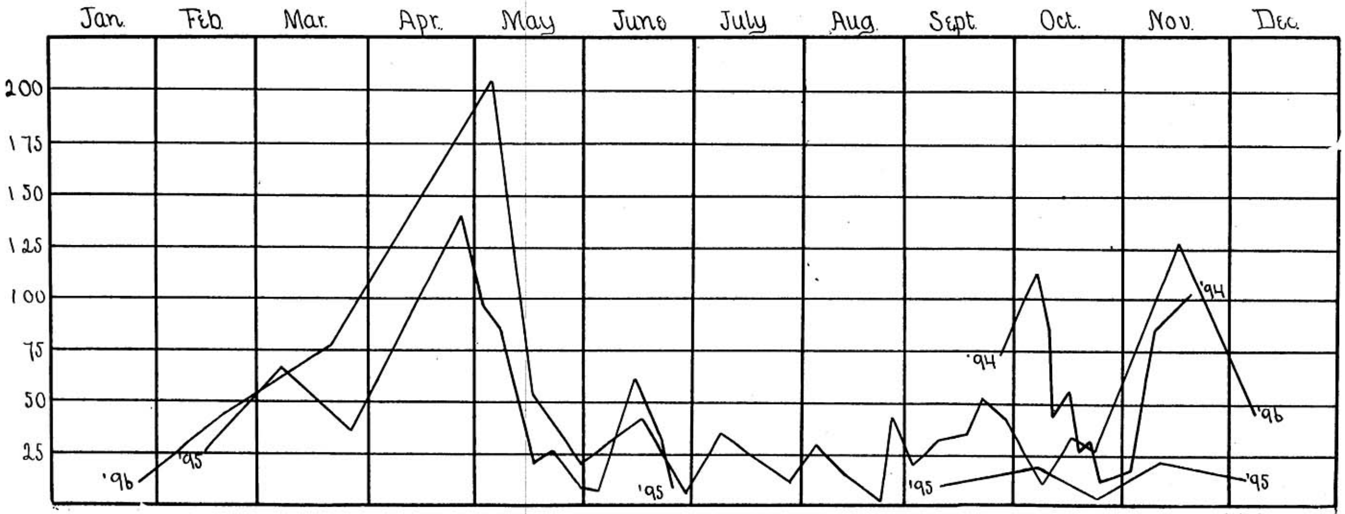
TEMPERATURE CURVES, 1896,



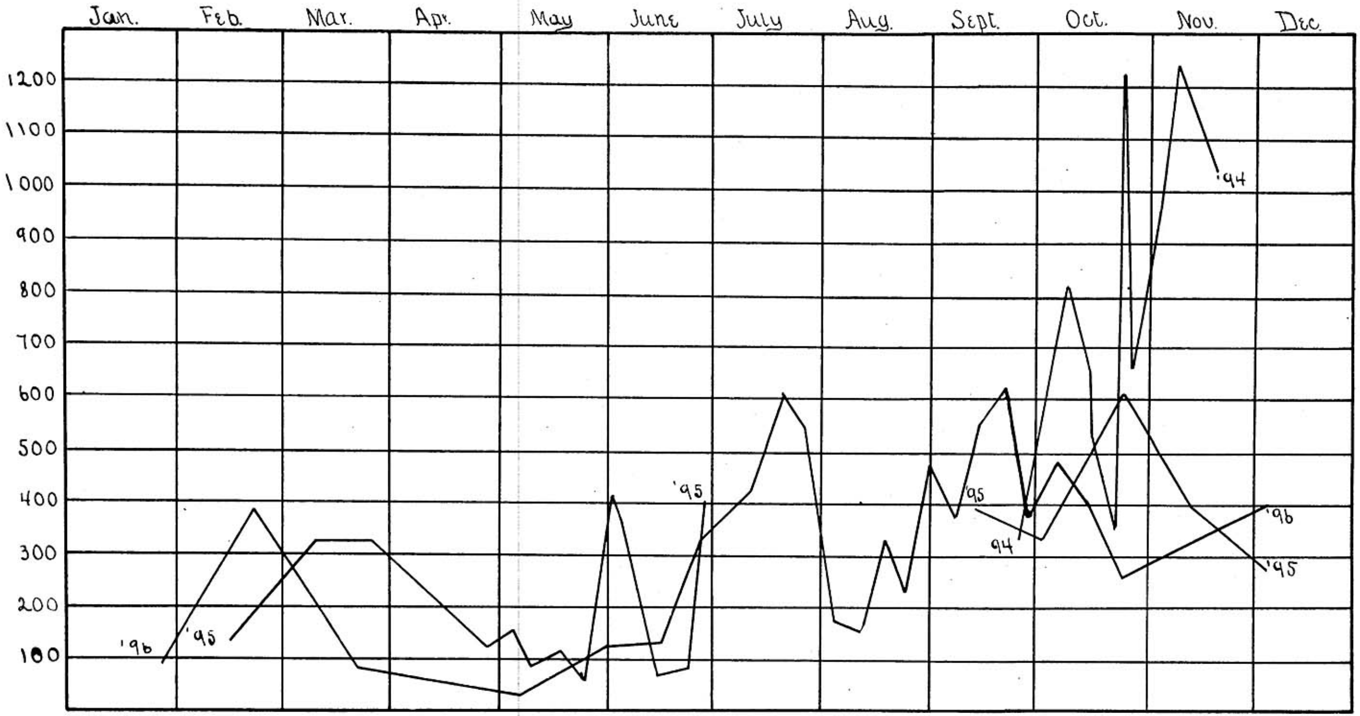
ANNUAL DISTRIBUTION OF DIAPTOMUS.



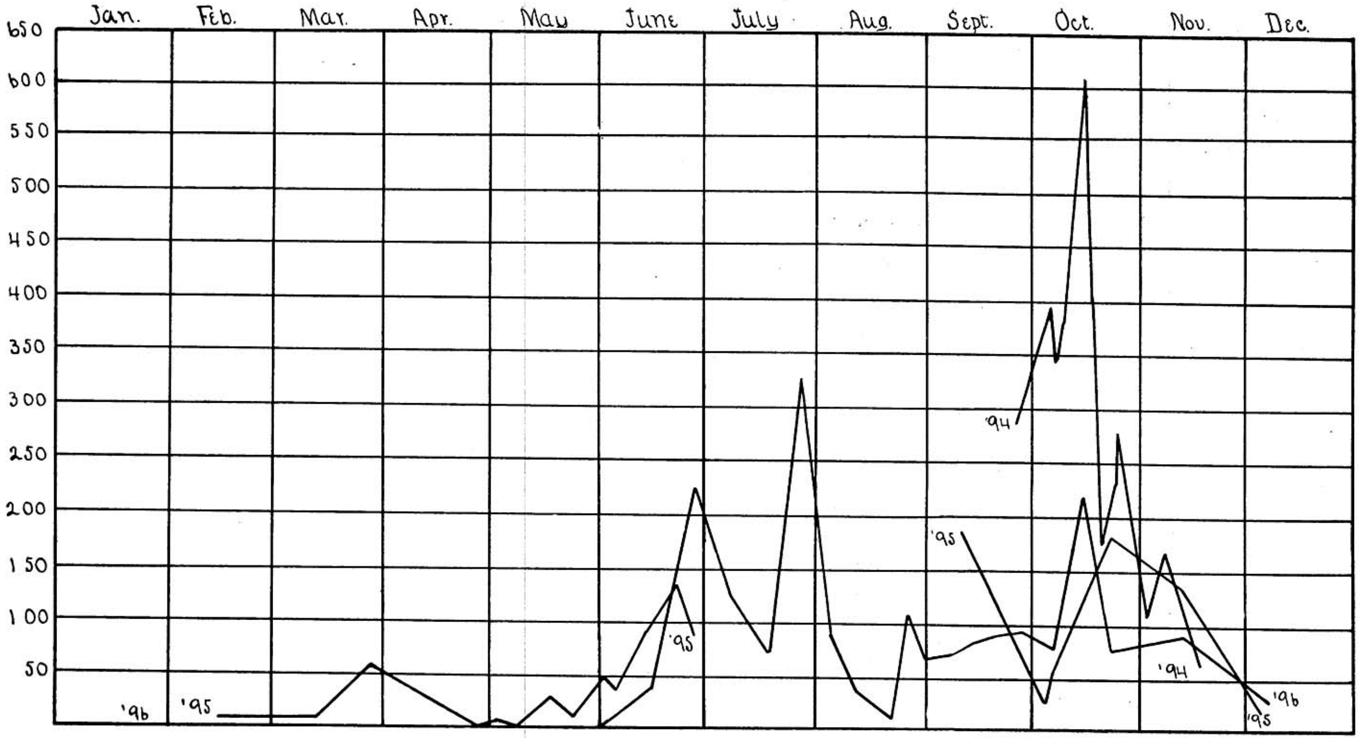
ANNUAL DISTRIBUTION OF EPISCHURA LACUSTRIS.



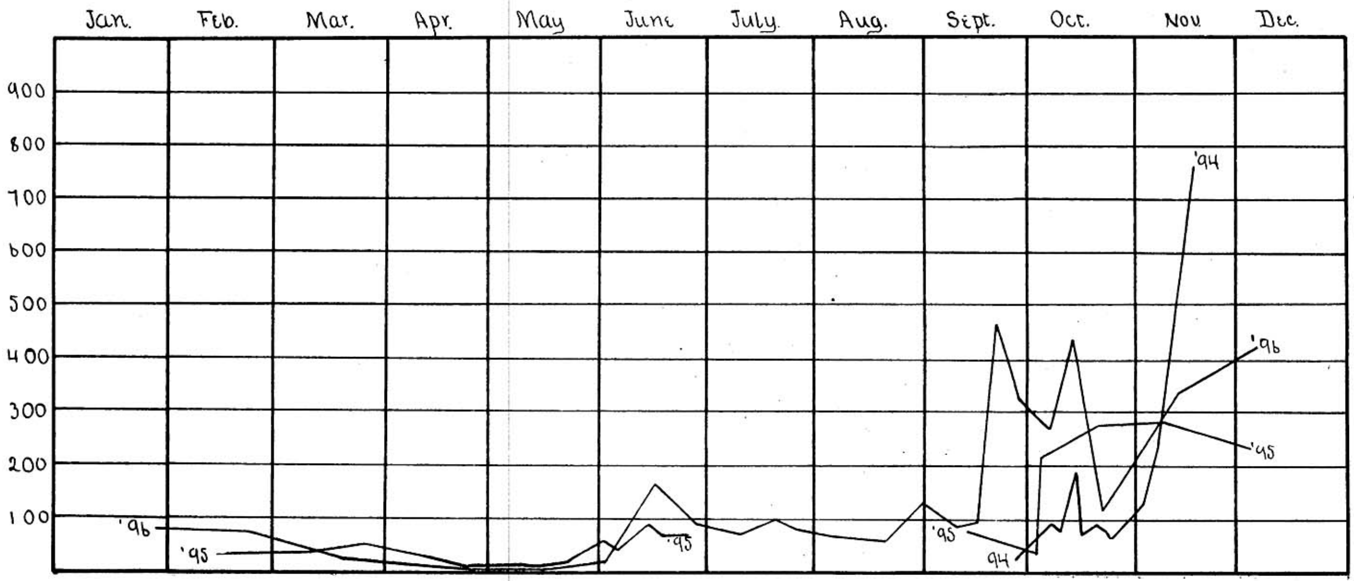
ANNUAL DISTRIBUTION OF LIMNOCALANUS MACRURUS.



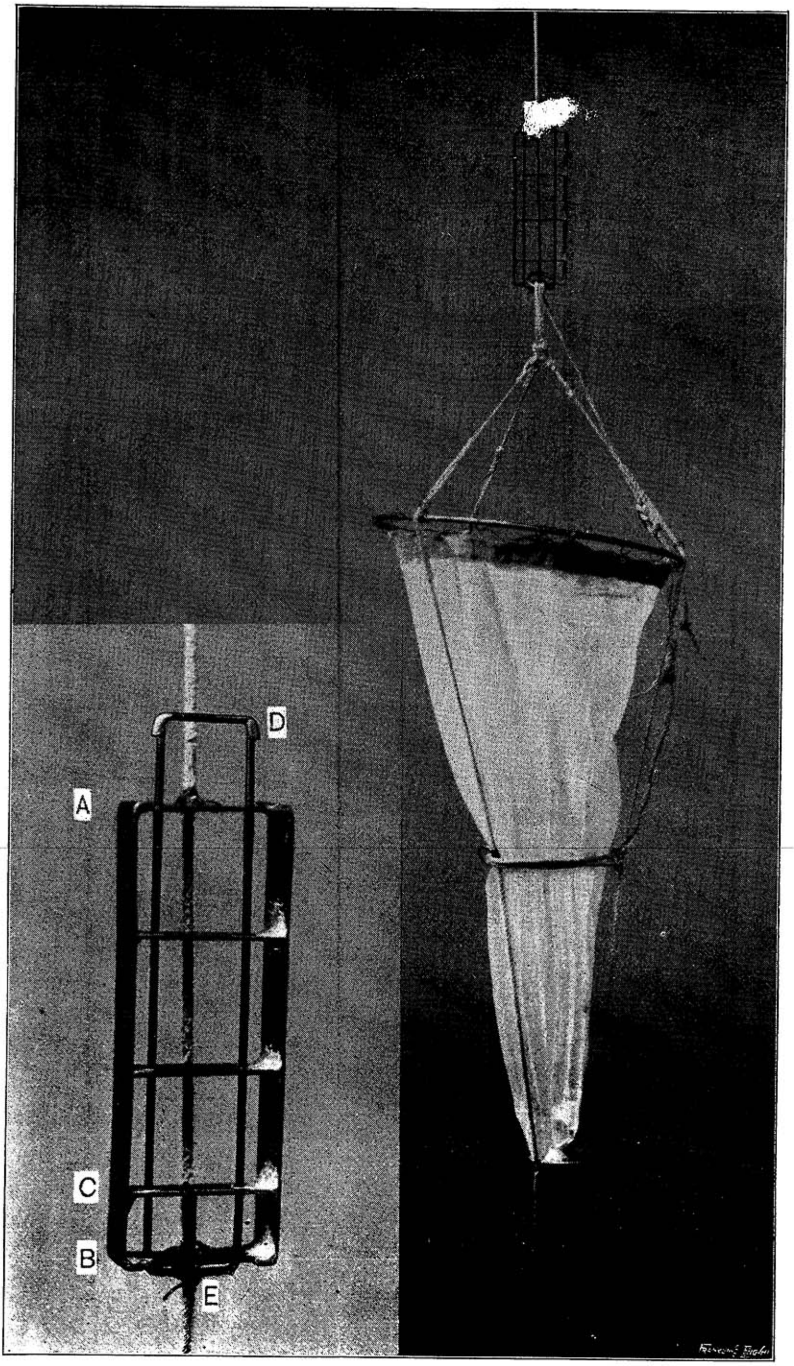
ANNUAL DISTRIBUTION OF CYCLOPS FLUVIATILIS.



ANNUAL DISTRIBUTION OF DAPHNIA KAHLBERGIENSIS.



ANNUAL DISTRIBUTION OF BOSMINA.



CLOSING DREDGE AND RELEASING APPARATUS.

Dredge as Mounted for Use on Ice.

DAPHNIA KAHLBERGIENSIS.

No. of Coll.	Total No.	*Per cent.*								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
1.94..	292	60.27	24.66	13.70	......	1.03	......	.34	......	......
4.94..	372	6.45	23.66	22.58	11.83	12.90	6.45	5.91	8.60	1.61
5.94..	377	25.47	21.22	20.16	16.97	3.18	6.37	4.24	2.12	.27
6.94..	419	39.14	21.95	10.50	15.28	9.55	3.34	.24	......	......
7.94..	419	43.91	30.55	16.23	1.91	3.82	......	.24	......	3.34
8.94..	345	46.38	32.47	14.49	2.90	.58	......	2.31	.58	.29
10.94..	353	31.76	37.39	14.73	6.79	3.40	1.98	1.70	1.70	.59
11.94..	414	46.37	13.53	27.06	7.24	1.93	1.93	.25	1.50	.25
12.94..	571	39.23	23.12	16.81	6.30	2.80	10.51	.70	.52	......
13.94..	641	77.38	16.85	2.49	1.23	.62	.31	.16	......	.96
14.94..	495	29.09	22.63	21.82	18.59	7.27	.20	.20	.20	......
15.94..	303	40.59	36.96	13.20	5.21	1.32	......	.33	1.66	.33
16.94..	140	62.85	21.43	10.	3.57	.71	1.42	......	......	......
17.94..	97	24.74	47.42	4.12	21.65	......	......	......	1.01	1.01
18.94..	248	77.41	8.07	9.84	1.61	1.61	......	1.61	......	......
20.94..	232	65.52	12.07	17.24	5.17	......	......	......	......	......
21.94..	236	28.81	35.59	22.03	10.13	.42	......	2.54	.42	......
22.94..	320	48.75	37.50	6.25	5.62	.94	.62	.31	......	......
24.94..	105	51.43	22.86	11.43	7.62	5.71	......	.95	......	......
25.94..	106	56.60	18.90	2.80	.90	20.	.90	......	......	......
26.94..	90	80.01	7.78	4.44	3.33	1.11	......	2.22	1.11	......
27.94..	242	52.07	6.65	23.14	12.81	4.54	.41	.41	......	......
29.94..	58	62.07	5.17	12.07	3.45	......	1.72	1.73	13.79	......
1.95..	3	66.	......	......	......	......	......	......	34.	......
2.95..	2	......	......	......	......	......	......	......	......	100.
3.95..	56	100.	......	......	......	......	......	......	......	......
4.95..	......	......	......	......	......	......	......	......	......	......
5.95..	1	100.	......	......	......	......	......	......	......	......
6.95..	2	......	......	50.	......	50.	......	......	......	......
7.95..	......	......	......	......	......	......	......	......	......	......
8.95..	25	......	32.	64.	4.	......	......	......	......	......
9.95..	9	......	89.	......	......	......	......	11.	......	......
10.95..	49	81.63	16.33	......	2.04	......	......	......	......	......
11.95..	33	3.03	48.49	......	48.48	......	......	......	......	......
12.95..	91	8.79	70.33	3.30	17.58	......	......	......	......	......
13.95..	137	......	29.20	52.57	8.76	2.92	5.84	.73	......	......
14.95..	89	......	35.95	35.96	8.99	3.37	13.48	......	2.25	......
15.95..	182	......	4.39	35.16	6.59	26.37	13.19	13.19	1.10	......
16.95..	28	28.57	57.14	7.15	7.14	......	......	......	......	......
17.95..	57	5.26	70.18	7.02	7.02	10.52	......	......	......	......
18.95..	170	42.35	9.41	9.41	32.94	4.71	1.18	......	......	......
19.95..	131	48.85	12.21	3.05	24.43	......	6.12	4.58	.76	......
20.95..	7	57.14	......	......	......	14.28	......	......	28.58	......

DAPHNIA KAHLBERGIENSIS.

D. kahlbergiensis did not occur in the collections from 1.96 to 7.96.

No. of Coll.	Total No.	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
8.96..	40	7.50	60.	20.	10.	2.50	......	......	......	......
9.96..	225	42.67	17.78	21.34	17.77	.44	......	......	......	......
10.96..	129	37.21	18.60	15.50	24.81	.78	......	1.55	......	1.55
11.96..	71	11.27	56.34	16.90	7.04	1.41	4.22	......	2.82	......
12.96..	325	39.38	29.54	24.62	6.15	......	......	......	.30	......
13.96..	84	14.29	19.05	47.62	9.52	9.52	......	......	......	......
14.96..	32	......	62.50	37.50	......	......	......	......	......	......
15.96..	5	20.	......	......	......	......	......	20.	20.	40.
16.96..	108	......	3.70	81.48	11.12	.93	2.77	......	......	......
17.96..	68	......	5.88	35.30	35.29	22.06	......	......	1.47	......
18.96..	73	21.92	......	32.88	35.62	6.85	1.37	1.36	......	......
19.96..	86	37.21	27.91	......	9.30	10.46	13.96	1.16	......	......
20.96..	92	60.87	8.70	6.52	4.35	13.04	3.26	2.17	1.09	......
21.96..	94	34.04	42.55	8.51	8.51	1.07	4.26	1.06	......	......
22.96..	78	10.26	30.77	35.89	12.82	3.85	2.57	2.56	1.28	......
23.96..	223	46.19	17.94	17.94	10.76	5.38	.89	.45	......	.45
24.96..	72	13.88	22.23	33.34	27.78	......	2.77	......	......	......
25.96..	61	59.02	26.23	6.56	6.55	1.64	......	......	......	......
26.96..	102	in	0–20	met'rs						
27.96..	16	18.75	25.	12.50	6.25	12.50	25.	......	......	......

During the fall of 1894 (see Pl. XI) the collections of *Daphnia kahlbergiensis* were quite uniform in amount, reaching a maximum in the latter part of October. During the winter the number was very small, and they did not become numerous again until June. There is a fall maximum again in 1895 in the latter part of October, but, curiously, the total numbers collected during the fall of 1895 are much smaller than in 1894. During the winter and spring of 1896 *Daphnia* was entirely absent from the collections. They appear again about the middle of May, and the largest collections of the year were made from June 29 to July 27. In August and September the collections were rather small, but the number became larger the latter part of October as in the preceding years.

Apstein ('96, p. 170) states that the species of *Daphnia* reach their maximum in August, but that *D. cederstroemi* is somewhat later, so that it would appear that my results in regard to the seasonal distribution of *Daphnia* do not agree very closely with his. It is probable that the various species of *Daphnia* may differ considerable in their periods of maximum occurrence.

Daphnia may be found at all depths, but is most numerous in the upper ten meters. In some cases, however, more than fifty per cent. of the catch is below the twenty meter line.

Very few *Daphnias* occur in winter, and I could not distinguish any effect of season on distribution.

The averages of the day and night hauls of '94 were as follows:

	0–5	5–10	10–15
Day, Oct. '94....................	38.39	24.43	15.40
Night, Oct. '94..................	54.48	23.01	13.46

These averages would seem to indicate a movement towards the surface at night. I am not sure that this inference is warranted, however, for the averages are of numbers with wide limits of variation, and I accept the conclusion with considerable doubt.

BOSMINA.

No. of Coll.	Total No.	*Per cent.*								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
1.94..	9	89.	11.	......	......	......	......	......	......	......
4.94..	57	56.14	14.04	21.05	7.02	1.75	......	......	......	......
5.94..	112	71.43	17.86	7.14	3.57	......	......	......	......	......
6.94..	98	65.31	16.33	4.08	12.24	......	1.02	1.02	......	......
7.94..	26	11.54	61.54	7.69	3.85	......	......	......	......	15.38
8.94..	95	42.12	29.47	22.15	4.21	......	1.05	......	......	......
10.94..	57	42.10	28.08	3.51	21.06	......	5.27	......	......	......
11.94..	106	75.47	7.55	.94	......	15.09	......	......	......	......
12.94..	280	31.43	10.	34.29	5.71	10.	8.57	......	......	......
13.94..	64	37.50	6.25	18.75	9.37	25.	......	......	......	3.13
14.94..	40	20.	50.	20.	10.	......	......	......	......	......
15.94..	85	47.06	28.24	9.41	14.12	......	......	1.17	......	......
16.94..	51	78.43	3.92	5.88	3.92	......	5.88	......	......	1.96
17.94..	7	77.92	6.49	6.49	5.19	1.29	......	......	......	2.59
18.94..	212	75.47	11.32	13.11	......	......	......	......	......	......
20.94..	64	56.25	6.25	28.12	6.25	3.13	......	......	......	......
21.94..	37	13.51	43.24	43.24	......	......	......	......	......	......
22.94..	72	38.88	50.	5.55	2.78	1.39	1.39	......	......	......
24.94..	151	70.20	13.25	10.59	3.31	2.65	......	......	......	......
25.94..	115	70.	15.	6.10	5.20	1.70	1.70	1.	......	......
26.94..	257	80.93	12.45	1.55	1.95	1.56	.39	......	.39	.78

BOSMINA.

No. of Coll.	Total. No.	Per cent. 0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45
27.94..	191	56.54	8.38	8.38	14.66	11.52	......	.52	......	......
29.94..	772	56.48	14.51	9.33	3.11	4.14	4.14	3.63	4.14	.52
1.95..	26	46.15	15.38	15.38	3.85	3.85	7.70	......	3.85	3.84
2.95..	30	26.67	......	13.33	26.67	3.33	3.33	20.	3.33	3.34
3.95..	49	81.63	8.16	......	2.04	8.17	......	......	......	......
4.95..	......	......	......	......	......	......	......	......	......	......
5.95..	5	40.	20.	40.	......	......	......	......	......	......
6.95..	1	100.	......	......	......	......	......	......	......	......
7.95..	3	100.	......	......	......	......	......	......	......	......
8.95..	4	50.	50.	......	......	......	......	......	......	......
9.95..	10	80.	......	10.	......	10.	......	......	......	......
10.95..	48	83.34	2.08	12.50	......	......	......	2.08	......	......
11.95..	40	60.	40.	......	......	......	......	......	......	......
12.95..	91	52.75	8.79	35.16	......	......	1.10	2.20	......	......
13.95..	61	52.46	13.11	4.92	......	3.28	26.23	......	......	......
14.95..	64	25.	37.50	3.12	......	10.94	9.38	......	1.56	12.50
15.95..	75	42.67	10.66	21.33	10.67	10.67	4.	......	......	......
16.95..	42	57.14	4.76	19.05	19.05	......	......	......	......	......
17.95..	205	85.85	7.81	1.95	......	3.90	.49	......	......	......
18.95..	288	58.33	8.34	5.56	11.12	16.65	......	......	......	......
19.95..	279	51.61	11.47	1.44	10.75	17.20	5.73	1.08	.72	......
20.95..	232	24.13	6.90	20.69	6.90	6.90	1.73	25.86	6.89	......
1.96..	75	16.	32.	8.	2.66	16.	13.34	8.	4.	......
2.96..	66	6.06	36.36	7.58	18.18	25.75	3.03	1.52	1.52	......
3.96..	12	......	8.33	8.34	33.33	33.33	8.33	8.34	......	......
5.96..	......	......	......	......	......	......	......	......	......	......
6.96..	2	100.	......	......	......	......	......	......	......	......
7.96..	8	100.	......	......	......	......	......	......	......	......
8.96..	165	82.42	14.55	1.21	......	......	......	1.82	......	......
9.96..	94	51.06	8.51	17.02	17.02	4.26	2.13	......	......	......
10.96..	71	67.60	2.82	1.40	22.53	4.25	......	......	1.40	......
11.96..	99	72.72	20.20	4.04	1.01	......	2.02	......	......	......
12.96..	79	81.01	5.06	5.06	6.33	1.27	......	1.27	......	......
13.96..	67	83.58	......	2.98	4.48	8.96	......	......	......	......
14.96..	2	50.	......	......	50.	......	......	......	......	......
15.96..	57	98.25	1.75	......	......	......	......	......	......	......
16.96..	86	83.72	1.16	......	4.65	8.14	1.16	1.17	......	......
17.96..	134	89.55	1.49	1.49	2.99	4.48	......	......	......	......
18.96..	82	87.80	......	9.75	......	1.22	......	......	......	1.23
19.96..	92	47.83	52.17	......	......	......	......	......	......	......
20.96..	479	67.64	16.70	10.02	2.09	2.50	.21	.84	......	......
21.96..	322	84.47	3.11	4.97	.31	6.21	......	.62	......	.31
22.96..	247	68.02	25.91	.41	.40	4.86	.40	......	......	......
23.96..	435	95.63	2.53	1.84	......	......	......	......	......	......
24.96..	109	88.07	7.34	1.84	1.83	......	.....	......	......	.92
25.96..	280	59.02	26.23	6.56	6.55	1.64	......	......	......	......
26.96..	438	in 0-	20 met	ers.						
27.96..	420	30.48	9.53	11.43	13.33	9.52	19.04	2.86	2.86	.95

Bosmina (see Pl. XII) was present at all times of the year. In only one collection during something over two years,— that of May 4th, 1896,— did I fail to find some individuals of this genus. Its time of maximum occurrence is in November. The numbers found in successive collections vary within very wide limits. For instance, Oct. 20, 1894, in a collection made between 2:15 and 3:15 p. m., I found only seven individuals, while in a collection made about two hours later, I found 212; and yet the conditions were apparently precisely the same.

In regard to its vertical distribution, its home is in the upper layers, although it is found occasionally at all depths.

In order to determine whether there was any difference in the vertical distribution at different seasons, I averaged the summer collections of 1896, from June to September,— 7.96 to 17.96 inclusive,— and the winter collections of 1894–5 from November to April,— 24.94 to 3.95 inclusive, with results as follows:

	0-5	5-10	10-15	15-20
Winter, 24.94 to 3.95................	61.07	10.89	8.08	7.60
Summer, 7.96 to 17.96...............	78.18	5.05	3.02	9.91

While this would indicate a somewhat larger percentage in the 0–5 layer in summer, the difference is not very marked, and we may say that the vertical distribution is very little affected by the changes of season.

The averages of the night collections of 1894 compare with those of the day collections as follows:

	0-5	5-10	10-15	15-20
Night	35.77	22.70	22.20	5.88
Day..................................	60.93	18.38	9.16	7.71

These figures would indicate that there is a distinctly larger number in the 0–5 layer in the day time than in the night, and I infer that is attracted, to some extent, at least, by the light.

DAPHNELLA.

No. of Coll.	Total No.	Per cent.								
		0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–
1.94..	29	55.17	20.69	3.45	......	3.45	13.79	3.45	......	......
4.94..	31	51.61	9.68	38.71	......	......	......	......	......	......
5.94..	27	88.88	7.41	......	3.71	......	......	......	......	......
6.94..	62	77.42	1.61	1.61	19.36	......	......	......	......	......
7.94..	24	66.66	16.67	8.33	......	......	......	......	......	8.34
8.94..	46	52.18	26.09	13.04	4.35	......	2.17	......	2.17	......
10.94..	25	80.	12.	4.	4.	......	......	......	......	......
11.94..	35	45.71	34.29	2.86	11.43	......	5.71	......	......	......
12.94..	47	59.57	4.26	4.26	17.02	12.77	2.13	......	......	......
13.94..	46	86.96	2.17	2.17	8.70	......	......	......	......	......
14.94..	11	9.09	36.36	18.18	27.27	......	......	9.09	......	......
15.94..	19	15.79	63.15	......	21.05	......	......	......	......	......
16.94..	......	......	......	......	......	......	......	......	......	......
17.94..	7	14.29	14.29	......	71.43	......	......	......	......	......
18.94..	1	......	......	100.	......	......	......	......	......	......
19.94..	2	......	......	......	......	......	......	......	......	......
20.94..	15	80.	......	13.33	......	......	......	......	6.66	......
21.94..	17	35.29	47.06	11.76	5.88	......	......	......	......	......
22.94..	16	25.	37.50	12.50	25.	......	......	......	......	......
24.94..	1	......	......	......	......	100.	......	......	......	......
25.94..	1	......	100.	......	......	......	......	......	......	......
26.94..	......	......	......	......	......	......	......	......	......	......
27.94..	......	......	......	......	......	......	......	......	......	......
28.94..	1	......	100.	......	......	......	......	......	......	......
29.94..	......	......	......	......	......	......	......	......	......	......
1.95..	......	......	......	......	......	......	......	......	......	......
2.95..	......	......	......	......	......	......	......	......	......	......
3.95..	16	100.	......	......	......	......	......	......	......	......
4.95..	......	......	......	......	......	......	......	......	......	......
5.95..	......	......	......	......	......	......	......	......	......	......
6.95..	......	......	......	......	......	......	......	......	......	......
7.95..	......	......	......	......	......	......	......	......	......	......
8.85..	......	......	......	......	......	......	......	......	......	......
9.95..	......	......	......	......	......	......	......	......	......	......
10.95..	1	100.	......	......	......	......	......	......	......	......
11.95..	......	......	......	......	......	......	......	......	......	......
12.95..	......	......	......	......	......	......	......	......	......	......
13.95..	......	......	......	......	......	......	......	......	......	......
14.95..	1	100.	......	......	......	......	......	......	......	......
15.95..	5	60.	......	40.	......	......	......	......	......	......
16.95..	26	66.54	30.77	7.69	......	......	......	......	......	......
17.95..	3	33.33	......	33.34	33.33	......	......	......	......	......
18.95..	8	12.50	12.50	37.50	12.50	25.	......	......	......	......
19.95..	......	......	......	......	......	......	......	......	......	......
20.95..	No	*Daph*	*nella*	from	1.96	to 8.96				
9.96..	8	88.88	......	......	11.12	......	......	......	......	......
10.96..	40	100.	......	......	......	......	......	......	......	......
11.96..	33	48.48	48.48	3.04	......	......	......	......	......	......
12.96..	18	88.88	11.12	......	......	......	......	......	......	......
13.96..	36	33.33	66.67	......	......	......	......	......	......	......
14.96..	50	4.	96.	......	......	......	......	......	......	......

DAPHNELLA—continued.

No. of Coll.	Total No.	Per cent.								
		0–5	5–10	10–15	15 20	20–25	25–30	30–35	35–40	40–
15.96..	201	99.50	......	......	......	......	.50	......	......	......
16.96..	141	56.74	31.21	8.51	......	......	2.12	1.42	......	......
17.96..	143	2.80	5.59	89.51	1.40	......	.70	......	......	......
18.96..	65	73.85	24.61	......	......	1.54	......	......	......	......
19.96..	211	15.16	51.87	26.54	.95	......	.48	......	......	......
20.96..	88	54.55	36.36	9.09	......	......	......	......	......	......
21.96..	22	18.18	45.45	36.37	......	......	......	......	......	......
22.96..	12	66.67	8.33	25.	......	......	......	......	......	......
23.96..	12	8.34	16.67	8.34	66.65	......	......	......	......	......
24.96..	2	......	......	50.	50.	......	......	......	......	......
25.96..	......	......	......	......	......	......	......	......	......	......
26.96..	......	......	......	......	......	......	......	......	......	......
27.96..	......	......	......	......	......	......	......	......	......	......

Daphnella is at its maximum in point of numbers from about the middle of August to the middle of September. From the last of October to the last of June, very few are found. Only in one collection made during the winter months did I find any *Daphnella*,—that of March 27, 1895. Friç and Vávra ('94, p. 103) state that *Daphnella* occurs from April to October. The observations of Apstein ('96, p. 166) very nearly agree with mine.

In regard to its vertical distribution, *Daphnella* may be found at any depth. By far the larger number, however, occur in the upper layers, ordinarily from seventy to eighty per cent. being found within ten or fifteen meters of the surface.

In order to get at the facts in regard to its vertical distribution, and possible migrations, I computed the average percentages in the upper four or five levels for the day and night collections of October, 1894, for the August collections,—all taken in the daytime,—of 1896, for the September and October collections of 1894, and for the collections of 1893, about twenty in number, made within two or three days in the latter part of August, with the following results:

	0–5	5–10	10–15	15–20
August, 1893	48.30	30.60	......	......
August, 1896	39.27	39.89	19.60	......
September–October, 1894	52.01	16.28	15.46	......
October, 1894, day	38.28	17.89	16.54	15.82
October, 1894, night	69.07	9.84	8.23	6.01

I do not think that the number of collections is large enough to draw inferences final in character in regard to the vertical distribution of *Daphnella*, especially since the total number in any collection is small. It would appear, however, that the upper five meters are more densely populated in September and October than in August and that the number is also greater in the upper five meters in the night time than in the day time. I do not feel like speaking in any dogmatic way in regard to the interpretation of these facts, but I venture to suggest that *Daphnella* is, in its vertical distribution, controlled rather by light and darkness than by changes of temperature. If it were very sensitive to changes of temperature the fact that it is found in greater numbers near the surface at night than in the day time, and also in greater numbers in September and October than in August would indicate a liking for cool water: but if this liking were very pronounced, it would seem that it would migrate deeper in August. If we suppose light to be the controlling factor, we would explain the greater number near the surface in September and October by the greater number of cloudy days in those months. Very likely the solution of this problem is not so simple as my speculations would indicate, and a satisfactory result can only be reached by a carefully conducted investigation in the laboratory of the behavior of the animal under different conditions of light and temperature. It may be noticed that Apstein ('96, p. 79) states that the time when the larger numbers are found at the surface, coincides with the time of total maximum numbers, a conclusion quite the opposite of what my observations would indicate. It does not appear, however, that his conclusions were based on any large number of exact observations.

GENERAL CONCLUSIONS IN REGARD TO VERTICAL DISTRIBUTION.

I had supposed that there was a general movement of the whole body of crustacea in such vertical migrations as existed. It is evident that this is not the case, for the different kinds have their individual peculiarities of distribution.

In the case of *Diaptomus* there is little or no vertical migration from any cause.

Epischura avoids bright light, and has a preference for warm water, and shows both seasonal and diurnal migrations.

Limnocalanus is repelled by bright light and by a high temperature, hence its diurnal migration is more pronounced in cold weather.

Cyclops brevispinosus occurs most abundantly between five and twenty meters in depth. I have no evidence in regard to its diurnal migrations.

Cyclops fluviatilis has no diurnal migration, but in its seasonal distribution shows a preference for the warmer water.

Leptodora is a surface form. I have no conclusive evidence in regard to its diurnal migrations.

Daphnia kahlbergienses apparently moves towards the surface at night.

There is no appreciable difference in the seasonal distribution of *Bosmina.* There is a distinct diurnal migration due to its attraction to light.

Daphnella has a diurnal migration due to the fact that it is repelled by light.

I cannot make out from my collections that the winds have any effect on the vertical distribution of entomostraca. The distribution when the surface is roughened by waves seems to be practically the same as when it is smooth. Neither is there any marked difference between dark and moonlight nights.

It must be remembered, however, that all my collections were at five meter intervals, and that there may be migrations within these limits of which I have no indication. I know for instance from surface tows that the immediate surface is almost entirely devoid of entomostraca in the day time, but is populated in enormous numbers in the night. There is evidently a very marked diurnal migration of most of the forms at the immediate surface, but it would take a series of collections at very short intervals to determine the limits of this general movement. These conclusions in regard to the surface phenomena are in harmony with the observations of Francé ('94, p. 35) and Birge ('95, p. 477).

THE HORIZONTAL DISTRIBUTION OF THE LIMNETIC CRUSTACEA.

The results of quantitative plankton determinations are entirely dependent on the assumption that the horizontal distribution of the plankton material is uniform. The laborious methods formulated by Hensen and his co-workers are founded on the assumption that over wide stretches of the ocean there is a practical uniformity in the distribution of the plankton. They believe that their investigations prove this assumption to be a fact. Their theory, however, has not gained universal assent. Haeckel (Haeckel, '90), among others, opposes it strongly. The same question has arisen in regard to lakes, and here it has a great practical importance, for if we can assume the horizontal uniformity of the plankton, then collections made in different lakes under similar conditions would furnish us accurate means of comparing the lakes in regard to the richness of the fauna and flora.

If this could be done, it would have a practical value in relation to the cultivation of fish, as we would expect that the lake rich in plankton would be especially adapted to nourish large numbers of fish. The question of horizontal uniformity of distribution in lakes has been actively discussed by many authors, and thus far with no uniformity of conclusions. Apstein ('92, p. 491) expressed his conviction from the measurements of plankton hauls and the counting of three comparative collections, that the distribution of the plankton in fresh water was practically uniform.

Friç and Vávra ('94, p. 118) come to a similar conclusion from their researches on the Unter Poçernitzer Teich.

Francé ('94, p. 34 ff.) from his investigations on Balaton See comes to directly opposite conclusions, and says that the plankton is very unequally distributed, and that the organisms occur in swarms.

Imhof (Imhof, '92) states that many of the organisms of the plankton occur in swarms.

Zacharias ('94, p. 129 ff.) enters into the subject in considerable detail, and gives his reasons for believing that the plankton is not uniformly distributed, one of his arguments being the very different character of the plankton at two distant points in Lake Plön, as determined by him.

Apstein again ('96, p. 51 ff.) takes up the question, and argues it at length, maintaining his original position.

Reighard ('94, p. 38) concludes that the plankton in Lake St. Clair and Lake Erie is distributed with great uniformity, and finds no positive evidence of swarms.

Ward in his report on Lake Michigan ('96, p. 62), concludes from his study of the plankton of that lake that there is no evidence whatever for the existence of swarms.

In my preliminary report on vertical distribution in Green Lake (Marsh, '94, p. 809) I stated that apparently the crustacea were not uniformly distributed. The figures of my collections of the past two years have served to confirm the opinion I expressed in 1894. It seems to me clear, that, so far as the crustacea are concerned, the horizontal distribution is far from uniform, and inasmuch as the crustacea ordinarily form the larger part of any plankton collection, it would follow that the distribution of the plankton is not uniform.

It must be remembered that all my collections were made from a buoy kept in one spot during the whole season, and in successive seasons, an attempt was made to drop the anchor as nearly as possible in the same spot. All collections, then, were made from the same depth of water in any season, and in very nearly the same depth in all the seasons. Now, if the distribution of the crustacea were uniform, collections made for the whole depth of water on the same day, or on successive days, should show nearly the same numbers of each species. Of course, if a species were rare, the fact that two or three individuals were found in one collection, and none in the next would not invalidate the assumption of uniformity. Nor even in cases where the numbers of a species were very large, would the fact that a considerably larger number were found in one collection than in another be any conclusive argument against the practical uniformity of distribution. Nor, on the other hand should it be assumed, because two or three successive hauls show the same, or nearly the same numbers, that the distribution is therefore uniform, because this could be easily explained by supposing that the swarm was of considerable extent or remained stationary for a considerable period.

My collections made in 1893, which were reported in the former paper, were made almost continuously in the course of two days. Now if the plankton is uniformly distributed, those collections should show a practical uniformity of numbers, and the more numerous a species was, the less should be the proportional variation. Yet the collections of *Diaptomus*, the most abundant genus, varied from 291 to 2,966. In many of the collections made in the fall of 1894 on the same day, or successive days, there was a marked uniformity in the numbers of *Diaptomus*, as for example, nos. 4.94, 5.94 and 6.94 show a range of numbers only from 4,171 to 5,630. If one were to base his conclusions on a small number of observations, he might well say that here was clear evidence of uniformity. Yet a few hours later in the same place I found only 2,023; with a difference as great as this, we certainly cannot speak of the *Diaptomi* as being uniformly distributed. In hauls 21.94 and 22.94, made in the forenoon of October 25, there was in one case 1,917 and in the other 3,823 — twice as many. Still more marked was the difference in two collections, one made at about six p. m., and the other between ten and eleven p. m., November 8. In the six o'clock collection there were 884, while in the evening collection there were 6,447. Such an enormous difference as this is certainly not consistent with any theory of uniformity of distribution. In these same two collections of November 8, *Cyclops fluviatilis* showed a similar wide variation,— the numbers in the six o'clock collection being 1,912, and in the evening collection being 564. October 24 I found between ten and eleven o'clock in the evening 1,241 *C. fluviatilis*, and yet the next morning between six and seven o'clock, I found only 618.

Limnocalanus is not a very good genus to consider in connection with this discussion, because it does not often occur in any large numbers. It is significant, however, that in successive hauls there were sometimes differences of from two to five hundred per cent. On November 14, 1896, I found in a collection made in the afternoon 56. In a collection made at about eight o'clock the same evening, I found 200 in the upper two and one half meters. In this case, curiously, the total number obtained in the other hauls from the surface to twenty meters was only 106.

An examination of the numbers of the other species as collected at similar times shows the same variations. None of them, however, seem to me to furnish such conclusive evidence as we get from *Diaptomus* and *C. fluviatilis*, because of the smaller number involved.

Thus my results are in harmony with those obtained by Zacharias and Francé. Inasmuch as one certainly would not question the accuracy of the work of the observers who have come to different conclusions, the question arises whether there is any way of explaining such differences I think a critical examination of their work and the inferences derived from it will show that such an explanation is possible.

In the first place I would state my entire agreement with the school of Hensen, that *only by an enumeration of individuals can we get at exact results in plankton work.* Volumetric determinations have a value in a general way, and may be used even in comparing different bodies of water, but only with a large allowance for the possibilities of error. Many of the difficulties in this method of work have been well pointed out by Ward himself. (Ward, '95a, p. 256 ff.). Most important is the difference in the time of subsidence due to the differences in the character of the plankton at different times and places. Some kinds of material will remain suspended for an almost indefinite period. Consequently, the volumetric method would rarely be sufficiently accurate to indicate even very considerable differences in horizontal distribution. There are, also, questions in regard to the accuracy of any gravimetric method that has yet been devised, although the amount of error by this method must be much less than by the volumetric method.

As a second principle I would say that *only a long continued series of observations on the same body of water will furnish sufficient evidence of the uniformity or lack of uniformity in distribution.* Two or three, or even several parallel, or successive collections do not furnish sufficient evidence.

Now, in criticising other observers, Friç and Vávra apparently determined the amount of plankton entirely by the method of weighing. Reighard and Ward made their comparisons entirely by the volumetric method, but in the results of both, there were certain discrepancies which could be most easily explained on the assumption that some of the organisms occurred in swarms. (Reighard, '94, p. 37, Ward, '96, p. 63.)

Apstein bases his opinion largely on volumetric determinations. He also furnishes an enumeration of individuals in three parallel hauls in the Dobersdorfer See, and two sets of two each in the Great Plöner See. These counts show a remarkable uniformity in the smaller organisms, but there is a considerable variation in the numbers of the crustacea, the difference being in many cases over 200 per cent. The only criticism one can make of Apstein's work is that the enumerations do not include a sufficient number of collections. While apparent uniformity in a few collections would be presumptive proof of a general uniformity, a single well authenticated case of unequal distribution would overthrow any conclusions founded on such collections.

Both Apstein and Ward raise the question as to the definition of the term "swarm." Now, it seems to me, the determination of the fact that limnetic organisms are or are not uniformly distributed is of first importance, and it makes very little difference just what meaning shall be attached to the word "swarm," until this question is decided. Without doubt the term has been used without any very exact meaning, as simply indicating a greater or less local aggregation of organisms, with very little thought of the cause of that aggregation, or of the exact or even approximate density of population that should be designated by the term.

Of course, as the result of my investigations I can speak only of the crustacea, and not of the plankton as a whole, except as the plankton, in many cases, is very largely composed of crustacea.

It seems to me that my collections clearly show that so far as the crustacea are concerned, while parallel or successive collections may show great similarity in numbers, they may, in other cases vary within such wide limits as to make plankton determinations unreliable, unless they are made from the average of a very large number of collections. Inasmuch as it is practically impossible to take a sufficiently large number of collections, it follows that plankton collections largely made of crustacea, cannot be taken as giving the exact measure of the productiveness of different bodies of water that some authors would have us think. We may say, indeed, with reasonable certainty, that one lake is much richer than another, but it seems to me very doubtful if we can express their relative productiveness by any definite numerical ratio.

LIST OF PAPERS QUOTED.

Apstein, Carl. '92. Quantitative Plankton Studien in Susswasser. Biol. Centralbl. Bd. 12 pp. 484–512, 608.

—— '96. Das Susswasserplankton: Methode und Resultate der quantitativen Untersuchungen. Kiel und Leipzig.

Birge, E. A. '95. Plankton Studies on Lake Mendota. I. The vertical distribution of the pelagic crustacea during July, 1894. Trans. Wis. Acad., Vol. X, pp. 421–484.

Fitzgerald, Desmond. '95. The temperature of lakes. Trans. Amer. Soc. of Civil Engineers, Vol. XXXIV., pp. 67–114.

Francé, R. H. '94. Zur Biologie des Planktons. Biolog. Centralbl. XIV., Band, pp. 34–38.

Friç, Ant., und Vávra, V. '94. Untersuchungen über die Fauna der Gewässer, Böhmens, IV. die Thierwelt des Unterpočernitzer und Gatterschlager Teiches als Resultat der Arbeiten an der übertragbaren zoologischen Station. Prag.

Haeckel, Ernst. '90. Planktonic Studien. Jenaische Zeitschrift, Vol. XXV. Trans. in Report U. S. Fish Commission, 1889–91, pp. 565–641.

Imhof, O. E. '92. Die Zusammensetzung der pelagischen Fauna der Susswasserbecken. Biol. Centralbl. Bd. 12.

Marsh, C. Dwight. '93. On the cyclopidae and calanidae of Central Wisconsin. Trans. Wis. Acad., Vol. IX., pp. 189–224.

—— '94. On the vertical distribution of pelagic crustacea in Green Lake, Wis. Amer. Nat., Vol. XVIII., pp. 807–809.

—— '95. On the cyclopidae and calanidae of Lake St. Clair. Lake Michigan, and certain of the inland lakes of Michigan Bull. of the Michigan Fish Commission. No. 5.

Reighard, J. E. '94. A biological examination of Lake St. Clair. Bull. of the Mich. Fish Com. No. 4.

Ward, H. B. '95a. A new method for the quantitative determination of plankton hauls. Proc. Amer. Micr. Soc., Vol. XVII., pp. 256–260.

—— '96. A biological examination of Lake Michigan in the Traverse Bay region. Bull. Mich. Fish Com. No. 6.

Whipple, Geo. C. '95. Some observations of the temperature of surface waters: and the effect of temperatures on the growth of micro-organisms. Jour. N. E. Water Works Assoc. Vol. IX., pp. 202–222.

Zacharias, Otto. '94. Beobachtungen am Plankton des Gr. Plöner See's- Forschungsberichte aus der Biologischen Station zu Plön. Theil 2, pp. 91–137.