81. T. scabra Rost. Collected from decayed wood near Tippecanoe River, August 5.

82. T. persimilis Karst. Single specimen collected July 26. Decayed elm.

83. T. Iowensis McBr. Found growing in rotten wood near Tippecanoe River, August 5.

84. Lycogala exiguum Morg. Not common. Collected only once. June 26.

85. L. flavo fuscum Rost. Several specimens collected from water soaked decaying wood. Turkey Lake, July 14.

86. L. miniatum Pers. Very common on all kinds of decaying trunks. This species was found on almost every collecting trip.

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c. The Plankton of Winona Lake.

Chancey Juday.

Winona Lake is one of the numerous lakelets found in northern Indiana. It is located in Kosciusko County about one mile (1.6 kilometers) southeast of the city of Warsaw. Concerning the physical features of the lake but little need be said as two hydrographic maps showing many of these points, have been published; one by Large in 1896 (Proc. Ind. Acad. Sci., 1896) and another by Norris in 1901 (Proc. Ind. Acad. Sci., 1901). The lake is irregular in outline and has an average length north and south of about one and an eighth miles (1.8 kilometers) and an average width east and west of about seven-tenths of a mile (1.1 kilometers) with a large bay extending westward from the north end. It has an area of about 0.9 of a square mile (2.3 square kilometers) and a maximum depth of eighty-one feet (twenty-five meters). Two small creeks flow into the southeastern portion of the lake and there are several large springs along the east side.

The data for this paper were collected at the Indiana University Biological Station during the summer of 1901. I wish to acknowledge my indebtedness to Dr. C. H. Eigenmann, Director of the Station, for many courtesies shown me. I am also much indebted to Mr. Clarence Kennedy and Mr. Heilman C. Wadsworth for their valuable assistance both in making the observations and in the tedious work of counting the material.

TRANSPARENCY.

The transparency of the water was determined by means of a Seechi's disk, about fifteen centimeters in diameter. The depth at which this disk just disappeared from view varied from 2.1 meters as a minimum to 2.5 meters as a maximum.

TEMPERATURES.

The thermophone and deep sea thermometer were not in working order so that the temperatures had to be taken by means of a pump and hose. This method, of course, is subject to considerable error and the results were found to be of comparatively little value except to determine the location and extent of the thermocline, so that the distribution of the plankton with regard to this region, might be studied.

The temperature observations were made in the deepest part of the lake, and they consisted of eight sets in July and ten sets in August. During July there was very little wind so that the upper stratum of water was not disturbed to any great extent. As a result this stratum accumulated considerable heat during this period. The surface temperature, taken at a depth of eight or ten centimeters, averaged 28.0° C. for the eight sets of observations, with 31.2° C. as a maximum.

During August, however, the wind was much stronger and the upper stratum of water was much more thoroughly stirred up. As a result, the average surface temperature for the ten sets of observations was 25.0° with a maximum of 26.0.°

The thermocline consisted of a stratum of water three meters in thickness. The difference in temperature between the top of this stratum and the bottom of it varied between 9.0° and 12.0°. In July it extended from four meters to seven meters, and in August from five meters to eight meters. The downward movement was doubtless due to the stronger winds prevailing in August.

The change in bottom temperature during the two months was very slight, 7.5° being the minimum and 8.0° the maximum.

METHODS.

The plankton observations as well as the temperature observations were made in the deepest part of the lake and by the pump method. An ordinary pitcher pump, 1-inch garden hose, and a plankton net whose

straining part was made of Dufour's No. 20 bolting cloth, were used. The quantity of water strained for a catch was the amount produced by forty strokes of the pump, which averaged 22.5 liters.

The counting method was used to determine the relative abundance of the various plankton forms. In most cases 20 per cent. of the material obtained in a catch was counted, and the results thus obtained for the various forms were multiplied by five in order to determine the number of individuals in a whole catch. Whenever a catch contained a comparatively small number of individuals, for example, the catches near the surface in day time, the whole catch was counted. Also, all the individuals of the larger forms, such as Epischura and Leptodora, which are readily recognizable with the naked eye, were counted.

The sets of observations may be divided into five groups:

1. Twenty sets of day catches which were made not earlier than 9 a. m., nor later than 4 p. m.

2. Six sets of night catches which, with one exception, were made between 9 p. m. and midnight. On September 2, a series was made as early as 8 p. m., but this, however, was an hour and a half after sunset.

3. Four sets of evening catches were made. These were begun shortly before sunset and continued at half hour intervals an hour or more after sunset.

4. The morning observations were begun one and a half to two hours before sunrise and were continued at thirty minute intervals until after sunrise. Six sets of these were made.

5. In August there were two sets of observations in which catches were made at the surface at regular intervals during the entire night. Both series were begun before sunset and continued until after sunrise. Catches were made at half hour intervals until 8 and 9 p. m., respectively, then every hour until 3 and 4 a. m., respectively, and again at half hour intervals until after sunrise. The results of these observations are shown in Figs. 1 to 4.

The first and second groups covered the entire depth of the lake (twenty-five meters), while the catches of the third and fourth groups were confined to the upper four meters. The fifth group consisted of surface catches.

THE PLANKTON FORMS.

PHYTOPLANKTON.

The phytoplankton was made up of three forms, Clathrocystis, Coelosphaerium and Oscillaria. Clathrocystis was much more abundant than the other two forms as it made up about 75 per cent. of the total quantity of phytoplankton.

CRUSTACEA.

Copepoda.—My thanks are due Prof. C. Dwight Marsh for his determination of the following copepods:

Epischura lacustris Forbes.
Diaptomus oregonensis Lillj.
Diaptomus birgei Marsh.
Cyclops pulchellus Koch.
Cyclops brevispinosus Herrick.
Cyclops leuckarti Sars.
Cyclops albidus Jurine.
Cyclops prasinus Fischer.
Cyclops serrulatus Fischer.
Ergasilus.

The following concerning Diaptomus birgei is quoted from Professor Marsh's letter: "The finding of D. birgei is of great interest to me. I described the species some years ago from a few specimens from New Lisbon, Wisconsin, and have never seen a specimen since. I had begun to fear that I had described a freak form and that the species would not stand; but here comes the creature in the proper proportions. It is a little queer that I should have found it only in two such widely separated localities, but doubtless it lives at some intermediate locations."

Cladocera.—The following linmetic forms were found:

Daphnia hyalina Leyd.
Daphnia pulex De G. var. *pulicaria* Forbes.
Daphnia retrocurva Forbes.
Diaphanosoma brachyurum Sars.
Ceriodaphnia lacustris Birge.
Leptodora hyalina Lillj.
Chydorus.
Bosmina,

Littoral forms:

Pleuroxus procurvatus Birge.

Pleuroxus denticulatus Birge.

Eurycercus lamellatus O. F. M.

Acroperus harpae Baird.

The following genera were represented by at least one species each. *Alona*, *Graptoleberis*, and *Simocephalus*.

Cypris and *Corethra* larvae were found in some of the catches.

ROTIFERA.

Four members of this group were specifically identified, *Triarthra longiseta*, *Anurea cochlearis*, *Anurea aculeata*, and *Notholca longispina*. The other members of the group belonged to the genera *Asplanchna*, *Polyarthra*, and *Mastigocerca*.

CHANGE IN QUANTITY OF PLANKTON.

These observations covered too brief a period, July 10 to September 3, to show much concerning the increase or decrease of the various plankton constitutents. In general, it may be said that there was comparatively little change. There was apparently a slight increase of the phytoplankton, due mainly to an increase of Clathrocystis. Only two forms of the crustacea showed any change. During August, there was a perceptible increase of Diaptomus and Cyclops. They were found to be twice as numerous the first of September as the last of July and first of August.

DIURNAL MOVEMENT.

Epischura lacustris.—This form was not found regularly in the day catches as it was present in only six of the twenty day series. On these six occasions it was confined to the thermocline, that is, between five and seven meters. It was taken, however, in the surface catches of the six night series. The time of its appearance at the surface varied from half an hour to an hour and a half after sunset and it disappeared from the surface about an hour before sunrise. In the all-night series of August 5-6, it was found in only one catch. This was at 9 p. m., five individuals per 100 liters of surface water. In the all-night series of August 27-28, it reached a maximum of 140 per 100 liters at 8 p. m.

Diaptomus.—As noted above, two species were present, but they were not counted separately. For the most part, Diaptomus remained in the upper ten meters of the lake as those found below this depth constituted less than 5 per cent. of the total number of individuals taken in either a day or a night series. They were found at the surface in sixteen of the twenty day series, but, with two exceptions, there was a marked increase in the number of individuals at the surface at night. This increase varied from five to twenty-five fold. The two exceptions were surface catches made on cloudy days. These differed but little from the night surface catches. The increase at the surface usually began about sunset and the greatest decrease occurred half an hour to an hour before sunrise.

Fig. 1 shows the surface conditions for Diaptomus in the two all-night series. The vertical spaces represent the number of individuals per hundred liters of surface water and the horizontal spaces represent the time between 6 p. m. and 6 a. m. The curves show a striking similarity of conditions although the observations were separated by a time interval of three weeks. They show that the maximum number was found at the surface at 7:30 p. m. on both occasions. Both also show a decided decrease during the next half hour, a second but smaller rise at midnight, a third near morning, and a fourth is indicated for the period immediately following sunrise. Diaptomus was not found in the surface catch on August 5 at 11 a. m. and there were 160 per 100 liters on August 27 at 9 a. m.

Cyclops.—Several species were present but no attempt was made to count them separately. They were distributed through the entire depth of the lake. They were found at the surface in all the day catches. In general, the night increase was comparatively small as it did not exceed five fold. There was little or no difference between the surface catches made on cloudy days and those made at night.

The curves of Fig. 2 represent the status of Cyclops in the two all-night series. The early evening conditions differ a great deal as there is no maximum in the curve for August 27-28 corresponding to the 7:30 p. m. maximum of August 5-6. Beyond this, however, the curves are very similar. The surface catch on August 5 at 11 a. m. showed a total of 160 Cyclops per 100 liters and there were 200 on August 27, at 9 a. m.

Nauplii.—They were found throughout the entire depth of the lake and showed no evidence of a movement.

Eryasilus.—This form was irregularly distributed in the upper six meters and showed no movement.

Daphnia hyalina.—In this species, the young and the adults were counted separately. The ratio between them was very variable. The young constituted from 10 per cent. to 78 per cent. of the entire number of individuals of a series. The young predominated near the surface on bright sunny days and the adults predominated in the deeper strata. In all but one set of observations, 70 per cent. to 95 per cent. of the total number of *D. hyalina*, were found in the upper seven meters and in this one instance 60 per cent. were in this region.

Usually a few young were found at the surface in the daytime. Likewise adults were found at the surface on two cloudy days but, on clear days, they were at a depth of one to two meters. In three sets of observations, adults appeared at the surface about half an hour after sunset, and on a fourth occasion about sunset. In five sets of morning observations, the time of their disappearance from the surface varied from nearly two hours before sunrise as a maximum to thirty minutes before sunrise as a minimum.

Figs. 3 and 4 represent both young and adult in the all-night series. It will be noted that the curves for young and adult in each series cross and recross each other, showing that the ratio between them was very variable. The two curves for adults do not show the similarity that the curves for Diaptomus and Cyclops do. In fact, if plotted together, they cross each other several times, one curve showing an increase of individuals at the same hour that the other shows a decrease. In the first series, August 5-6, the adults reached a pronounced maximum at 8 p. m., while in the series of August 27-28, two equal maxima were observed, one at 7:30 p. m. and the other at 10 p. m.

There is the same lack of similarity between the curves representing the young. The first series showed a maximum of young at 8 p. m. and the second at 4:30 a. m.

Daphnia pulicaria.—It occupied the region between the middle of the thermocline and the bottom. It was usually most numerous within one to three meters of the bottom. There was practically no diurnal movement. Adults were found at the surface in one evening catch and at a depth of only one meter in a night catch. These were the only indications of a movement,

Daphnia retrocurva.—It was rarely found at a greater depth than seven meters. Both young and adult were one to three meters below the surface on clear days. Both appeared at the surface in the evening about half an hour after sunset. In the morning, however, the adults left the surface before the young. The young usually disappeared about sunrise while the adults moved down from the surface an hour or more before sunrise. The surface maximum of young and adults combined, was found three-quarters of an hour after sunset in the first all-night series and half an hour later in the second, about 8 p. m. in each case.

Diaphanosoma brachyurum.—A comparatively small number of this species was found. It was rather irregular in its movements but, in general, it appeared at the surface thirty to forty-five minutes after sunset and left the surface an hour or more before sunrise. It was found at a depth of one meter, usually, in the daytime, and rarely occurred in catches below a depth of seven meters.

Ceriodaphnia lacustris.—This form was confined to the upper four meters and was present in very small numbers. There was no diurnal movement shown by it.

Leptodora hyalina.—Only a small number were found. It occurred in only five of the twenty day series. In these five instances, it was confined to the region of the thermocline, that is, between four and eight meters. Both young and adult appeared at the surface in the evening from thirty to forty-five minutes after sunset. The young left the surface about an hour before sunrise and the adults half an hour or more earlier.

Chydorus and *Bosmina* were found in very small numbers. No diurnal movement was noted.

Cypris.—There was, apparently, an extended horizontal migration of Cypris as it was found in a third of the morning and evening series, and these observations were made in the deepest part of the lake. In the daytime, however, Cypris was never found in the limnetic region of the lake but in the littoral region.

A few *Corethra* larvæ were found in and below the thermocline in the daytime. In a few instances they came to the surface at night.

Rotifera.—The rotifers showed no diurnal movement. With respect to their vertical distribution, they form three groups:

1. *Mastigocerca, Polyarthra,* and *Aspianchna* were confined to the upper five, six and seven meters respectively, or the region in and above the thermocline.

2. *Anurea aculeata* and *Triorthra* occupied the region below a deph of ten meters. They were usually most abundant within two or three meters of the bottom.

3. *Anurea cochlearis* and *Notholca longispina* were found through the entire depth of the lake.

MAXIMUM NUMBER AT SURFACE.

This diurnal migration must not be taken to mean that the individuals of the various species concerned, congregate at the surface at night in such numbers as to form what might be called a "swarm," for no such aggregation was noted. This is shown by the fact that *Diaptomus*, *Cyclops* and *Daphnia hyalina*, in a majority of the night observations, were more numerous at a depth of one or two meters or even deeper, than at the surface. It simply means that the upper stratum, one or two meters in thickness, is sparsely populated on bright, sunny days, but that this region is more or less densely populated at night.

Blanc (1898) and Fordyce (1900) found the greatest number of crustacea at the surface at 4 a. m. My observations do not agree with their results. Figs. 1 to 4 do not show a morning maximum with the exception of young *Daphnia hyalina* in the second series. On the other hand, *Diaptomus* reached a maximum at 7:30 p. m., adult *D. hyalina* at 7:30 and 8 p. m., and *Cyclops* at 7:30 p. m. and midnight. Also, each of the other forms showing a diurnal movement, reached its maximum about 8 p. m.

CAUSES OF DIURNAL MOVEMENT.

Various theories have been advanced to account for this phenomenon. It has been ascribed to various factors such as food, temperature, light, gravity, and in some cases chemical stimuli. Experiments on several of the crustacea which show diurnal movement, seem to show that light is the primary factor. But generally, there are other factors involved which may modify the effect of light to a very considerable degree, thus making the phenomenon complex instead of apparently very simple.

The migrating forms of Winona Lake may be separated into two groups. The first group includes those whose day position bears a more or less direct relation to the intensity of the sunlight. *Daphnia hyalina* and *retrocurva*, *Diaptomus*, and *Cyclops* belong to this group. The Daphnias

desert the upper meter or two on bright, sunny days and the other two members occupy this region in rather limited numbers. But, on cloudy days, all are found in this region in nearly as large numbers as at night. This seems to show that light is the primary factor controlling their movements. They move down to avoid intense light and then move up into this region again as soon as the intensity of the light is sufficiently decreased.

Epischura, *Leptodora*, and *Corethra* larvæ belong to the second group. The depth to which these descend in the daytime did not depend, apparently, upon the intensity of the sunlight as they were found at the same depth on cloudy as on clear days. Besides, it does not seem probable that sunlight alone would cause them to descend to so great a depth, that is, five to seven meters or more, especially since the transparency of the water was so low, 2.1 to 2.5 meters. Therefore, it seems reasonable to suppose that some other factors are very largely responsible for their movements.

Daphnia pulicaria might also be added to this group. While it showed only a very slight tendency toward diurnal movement in Winona Lake, it did show distinct and regular migrations in one of the Wisconsin lakes upon which the writer made observations. In the latter lake the same as in Winona Lake, it remained in and below the thermocline in the daytime and in neither case was its day position affected by the intensity of the sunlight. In general, the diurnal migration of all the members of this group, seems to be much more akin to the "nocturnal habits" of many other animals, than are the movements exhibited by the members of the first group.

Some crustacea upon which experiments have been performed, have shown that they are attracted by diffuse light. If this were true of all crustacea, and if it were to hold true for them in their natural haunts as well as in the laboratory, then one might suppose that there would be morning and evening surface increases of about equal proportions. Furthermore, it would not be unreasonable, perhaps, to expect moonlight to produce an appreciable effect, if the crustacea were attracted by diffuse light. For the most part, however, the truth of this supposition is not confirmed by the crustacea of Winona Lake. With the exception of the young *Daphnia hyalina* in the second all-night series, there was no morning surface increase comparable in every way to that of the evening.

Diaptomus was the only other form that showed any tendency toward a considerable surface increase after midnight, but its morning increases were much smaller than those of the evening. Then, too, moonlight had no appreciable effect upon the diurnal movement of any of the crustacea.

SUMMARY.

1. There was comparatively little change in the quantity of plankton.

2. Diurnal movement was shown by *Epischura*, *Diaptomus*, *Cyclops*, *Daphnia hyalina* and *retrocurva* *Diaphanosoma*, *Leptodora*, and *Corethra* larvæ.

3. These various forms reached a maximum at the surface about 8 p. m.

4. Light is a very important factor in the movement of *Diaptomus*, *Cyclops*, and *Daphnia hyalina* and *retrocurva*. It is, apparently, not so important a factor in the movement of *Epischura*, *Daphnia pulicaria*, *Leptodora*, and *Corethra* larvæ.

5. Diurnal movement was not affected by moonlight.

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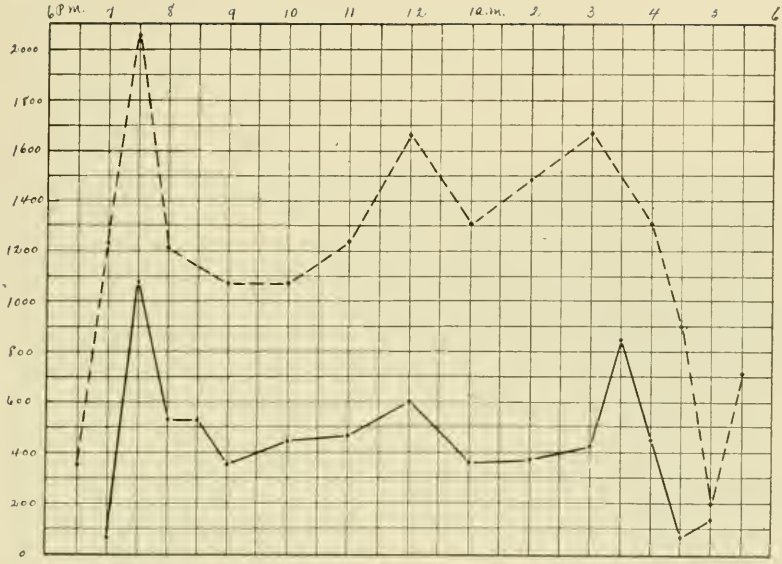
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Fig. 1.

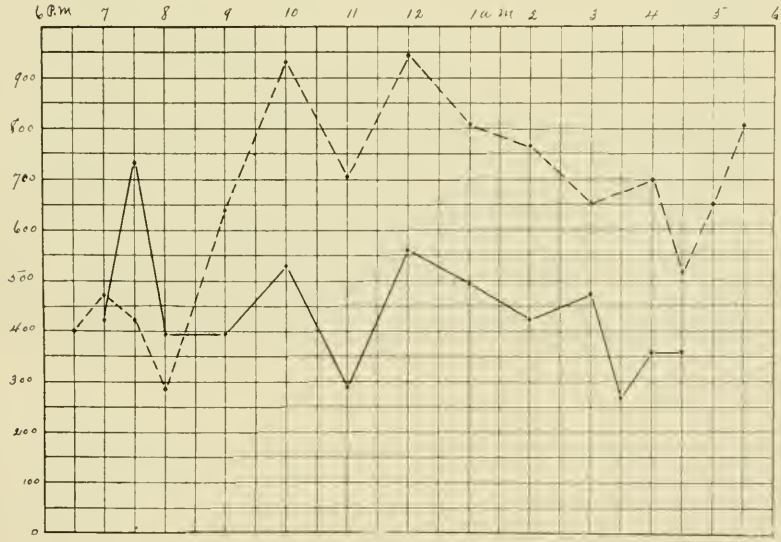
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Fig. 2.

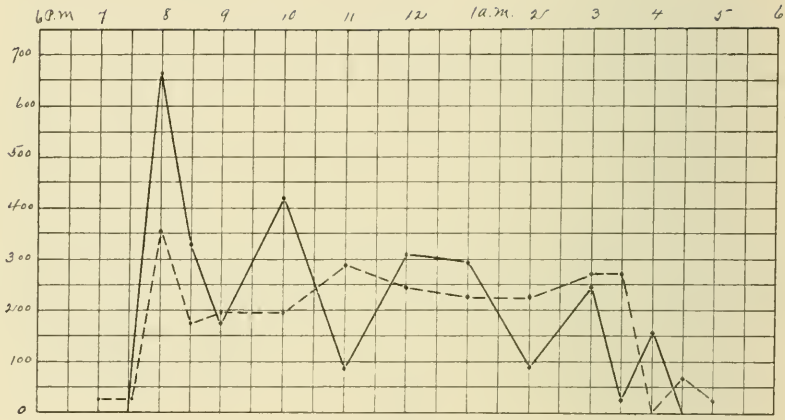
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Fig. 3.

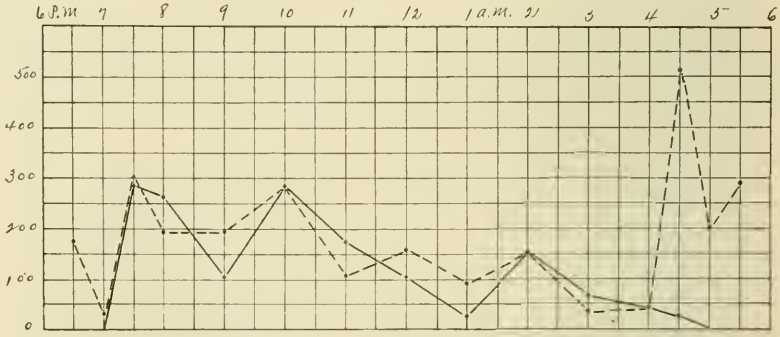
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Fig. 4.

EXPLANATION OF FIGURES.

Fig. 1. *Diaptomus.* Scale, one vertical space equals 100 individuals per hundred liters of surface water.

——————— August 5–6.

..... August 27–28.

Fig. 2. *Cyclops.* Scale, one vertical space equals 50 individuals per hundred liters of surface water.

——————— August 5–6.

- - - - - - - - - - - - August 27–28.

Fig. 3. *Daphnia hyalina.* Scale, one vertical space equals 50 individuals per hundred liters of surface water.

——————— Adult. } August 5–6.

..... Young. }

Fig. 4. *Daphnia hyalina.* Scale, one vertical space equals 50 individuals per hundred liters of surface water.

——————— Adult. } August 27–28.

..... Young. }