On the Vertical Distribution of the Plankton in Winona Lake.

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During the summer of 1912, while studying at the Biological Station of Indiana University, I undertook to make a quantitative determination of the vertical distribution of the plankton in Winona Lake. A study was also made of the significant physical and chemical conditions associated with it. The lake was mapped by A. A. Norris ('02), and some of its physical features were considered by Juday ('03).

Winona Lake is a small temperate lake of the deeper type. Its maximum length is 1.4 miles. Its maximum width is 1.2 miles and its maximum depth is 81 feet. It is large enough to present all of the usual plankton problems and small enough to make their study at critical times easily possible. All forms taken were determined, at least generically, and their abundance estimated. The exact quantitative work was limited to the eleven genera and groups, *Ceratium*, *Tribonema*, *Anabaena*, *Diaptomus*, *Fragilaria*, *Microcystis*, *Lyngbya*, *Cyclops*, *Nauplii*, *Cladocera*, and *Rotifera*. The *Cladocera* were represented by the following forms: *Daphnia hyalina*, *Daphnia pulex*, *Daphnia retrocurva*, *Chydorus*, *Bosmina*, *Pleuroxus procurvatus*. The following *Rotifera* were identified: *Anuræa cochlearis*, *Anuræa aculeata*, *Notholca longispina*, *Brachionus pala*, and *Hexarthra polyptera*. Weekly catches, July 11th to August 13th, were taken of the eleven forms at ten levels, ranging from surface to 23 meters. The temperature, also the amount of dissolved oxygen, carbon dioxide, and carbonates were determined for the different depths.

I desire to express my thanks to Dr. Will Scott, acting director of the Station, for the many courtesies and helpful suggestions extended to me in the collection of the data for this paper. Scott Edwards made the temperature observation and G. N. Hoffer determined the dissolved gases. To these gentlemen I am under obligation for permission to use these data.

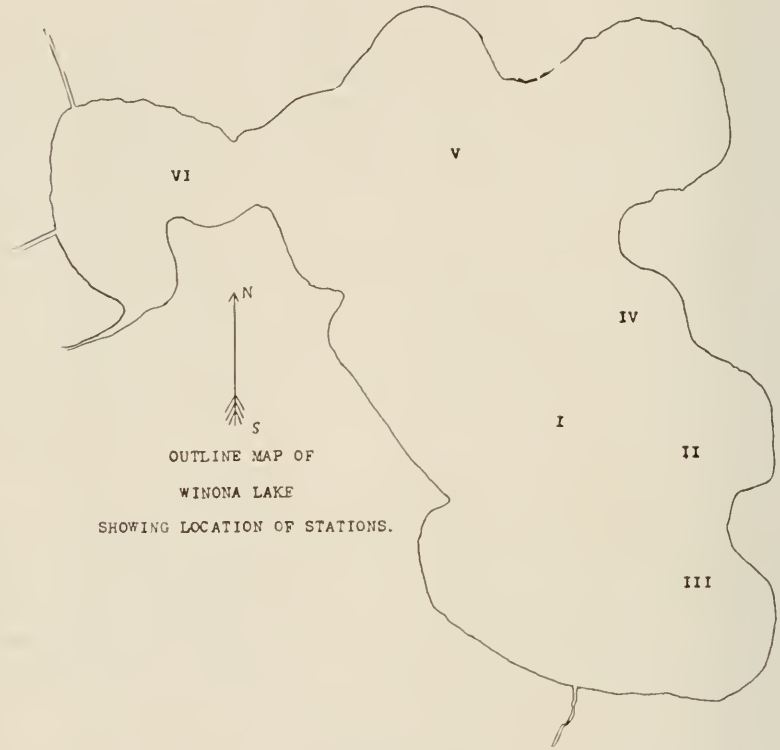
PHYSICAL CONDITIONS.

Turbidity.

The turbidity of the lake was determined by means of a Secchi's disk. The water was clearest on July 24th, when the disk disappeared at 4 m. The minimum depth, 2.7 m., occurred several times during the summer.

Temperature.

Temperature readings were made by means of a thermophone, and were taken simultaneously with the plankton catches. The temperature of the surface water, during the summer, varied from 21° to 26° C. At the bottom of the lake, only a slight variation ranging from 8.3° C. to 9° C. occurred. The thermocline was about 6 or 7 m. in thickness. The epilimnion was 5.5 m. thick on July 1st; by the middle of August it had descended to 14.5 m. This descent of the thermocline was associated with the high wind and cloudy days of the latter part of August. The average vertical readings are given in the accompanying temperature graph. They were taken in the deepest part of the lake at various times during the day.



OUTLINE MAP OF
WINONA LAKE
SHOWING LOCATION OF STATIONS.

Weather.

The summer of 1912 exhibited very unsettled weather conditions in the vicinity of the lake. Strong winds prevailed much of the time, especially

during the month of August, and heavy rains often raised the surface of the lake several inches above its normal level. The winds, which were generally accompanied by cloudy weather, blew the surface of the water into waves of considerable magnitude for a small lake, and caused a piling up of the surface water on the leeward side. Detailed records cannot be given because the only anemometer available was adapted to winds of low velocity only, which rendered it useless during the high winds which prevailed.

Dissolved Gases.

A study of the dissolved gases revealed the fact that there was sufficient carbon dioxide present for photosynthesis, and that oxygen was present in sufficient quantities to support animal life at all depths. At the surface of the lake there were 5 c. c. of dissolved oxygen per liter; in the upper layer of the epilimnion there were 4.25 c. c. present; in the middle of the thermocline 2.35 c. c., and at the bottom of the lake there was 1.5 c. c. of dissolved oxygen per liter of water.

The carbon dioxide increased from .8 c. c. at the surface to 8.75 c. c. at the bottom. It increased from 2.5 c. c. to 5.5 c. c. from the top to the bottom of the thermocline.

METHOD USED IN PLANKTON CATCHES.

Six stations, position of which are indicated on the outline map, were established. They were located in positions which best showed the effect of the wind upon the plankton. The depths of the staions varied from 7.5 to 23 m. The catches for this report were mostly made at Station 1, depth 23 m., the other stations being used as a check upon the results obtained at that station. Weekly catches were made by the use of a brass pump, known in the trade as "The Barnes Hydroject Pump," a three-fourths inch garden hose, and a plankton net, the straining part of which was made of No. 20 Dufour bolting cloth. These weekly catches were taken respectively at the surface, 1 m., 2 m., 4 m., 6 m., 8 m., 10 m., 14 m., 20 m., and 23 m. The quantity of water, 10.4 liters, strained for each catch, was the amount produced by 50 strokes of the pump. The ordinary counting method was used to determine the number of organisms. In most cases 20 per cent. of the material was counted, but all individuals of forms readily recognized by the naked eye were counted.

PLANKTON DISTRIBUTION IN REFERENCE TO THE EPILIMNION, THERMOCLINE, AND HYPOLIMNION.

Seventy-four and six-tenths per cent. of the plankton inhabited the epilimnion. The per cent. of the eleven forms studied quantitatively are: *Rotifera* 87.4, *Lyngbya* 80.7, *Ceratium* 88.6, *Microcystis* 76.5, *Anabaena* 84.8, *Tribonema* 64.3, *Nauplii* 60.5, *Diaptomus* 71.2, *Fragilaria* 76.7, *Cyclops* 38.8, *Cladocera* 31.6.

Seventy-three and three-tenths per cent. of the phytoplankton and 83.3 per cent. of the zooplankton inhabited the epilimnion.

The thermocline contained 21.8 per cent. of the plankton of the lake. The following synopsis gives the per cent. of each of the eleven forms: *Diaptomus* 23.8, *Fragilaria* 19.5, *Cyclops* 34.4, *Cladocera* 40.7, *Tribonema* 26.6, *Nauplii* 18.7, *Microcystis* 20.3, *Anabaena* 14.4, *Ceratium* 10.3, *Lyngbya* 18, *Rotifera* 10.8. Of the zooplankton 12.3 per cent., and of the phytoplankton 22.6 per cent. lived in the thermocline.

The hypolimnion contained 3.5 per cent. of the plankton, 4.3 per cent. of the zooplankton, and 3.4 per cent. of the phytoplankton. The per cent. of each form in the hypolimnion was: *Cladocera* 27.7, *Cyclops* 26.7, *Fragilaria* 3.5, *Nauplii* 20.8, *Diaptomus* 5, *Anabaena* .8, *Tribonema* 9.1, *Microcystis* 3.2, *Lyngbya* 1.1, *Rotifera* 1.7, *Ceratium* 1.1.

At 23 m. there were more forms per liter than at 20 m. This was probably due to the presence of some dead organisms that by the loss of activity had sunk to the bottom. The end of the hose at 23 m. was very close to the bottom.

THE EFFECTS OF PHYSICAL FACTORS UPON DISTRIBUTION.

The large per cent. of plankton in the epilimnion was due to the presence of sunlight and plenty of food. In the upper half (best lighted part) of this stratum, there was sufficient carbon dioxide to permit rapid photosynthesis. Apstein ('96) found light to be the most important factor in explaining the presence of fifty-six times as much plankton from 0-2 m. as in the remainder of the water. That direct sunlight has a repelling effect upon some plankton, was demonstrated by the fact that 53 per cent. inhabited the first two meters, while only 12 per cent. lived at the surface, *i. e.*, in the surface meter. Other factors enter into the explanation of the prolific life in the epilimnion. Many organisms were too heavy to sink into the cold heavy waters of the thermocline. Juday in his work on the Wisconsin

Lakes, determined that the vast amount of algæ collecting at the top of the thermocline, at certain times, so increased the process of photosynthesis, that 300 per cent. oxygen saturation occurred. It is also to be remembered that the lowering of the thermocline in August increased the depth of the epilimnion one meter.

Four factors must be taken into consideration in accounting for the rapid decrease of organisms below the epilimnion: First, the lower temperature (20° C. at the top of the thermocline and 9.6° C. at the bottom during July, 21.1° C. and 10.7° C. respectively being the average temperatures for August); second, the decrease in the amount of oxygen from 4.25 c. c. per liter of water at six meters to 2.50 c. c. at the bottom of the thermocline; third, the decrease in the amount of food; and, fourth, the limited amount of sunlight.

In the hypolimnion the physical conditions were so uniform that the plankton was very evenly distributed in this stratum.

SEASONAL DISTRIBUTION OF THE PLANKTON.

Six weeks is too short a time to obtain results of much value concerning seasonal distribution. However, the data collected indicate the following facts: The plankton, as a whole, increased in amount in August. *Ceratium*, *Fragilaria*, *Microcystis*, and *Lyngbya* increased gradually to August 13th, the date of the last observation. *Diaptomus* reached its maximum August 1st; *Nauplii* and *Anabaena* on August 8th. The *Cladocera* and *Rotifera* increased rather suddenly in August and were most numerous on the date of the last collection.

THE EFFECTS OF WIND UPON DISTRIBUTION.

As mentioned earlier in this paper, six stations were established to determine whether or not the plankton of the whole lake at a given level was homogeneous at all times. Repeated catches at different stations under ordinary conditions indicate that the plankton at the different levels was uniform.

SUMMARY.

Oxygen sufficient for respiration occurs at all levels of the lake, and probably is not a limiting factor.

Carbon dioxide was present in sufficient quantities for photosynthesis.

The epilimnion contained 74.6 per cent. of the plankton, the thermocline 21.8 per cent. and the hypolimnion 3.5 per cent.

Plankton was more abundant in August than in July.

So far as these observations go, wind has no appreciable effect upon the distribution of the plankton.

EXPLANATION OF FIGURES.

Figures 1 to 15, inclusive, indicate the distribution of the organisms. The numbers at the bottom indicate the date.

Figure 16 shows graphically the amount of dissolved gases at different depths.

Figure 17 indicates the maximum, minimum, and average temperatures.

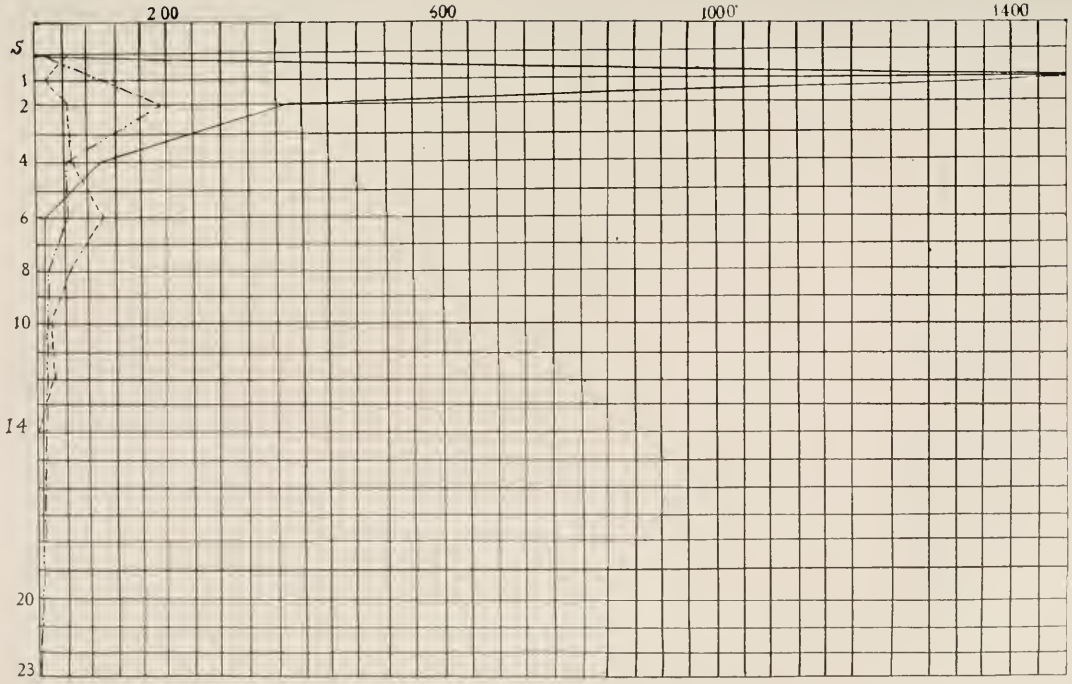


Fig.1.--- Ceratium.
7-11. – – – – – – –
8-1. —··—··—··—
8-13. ————————

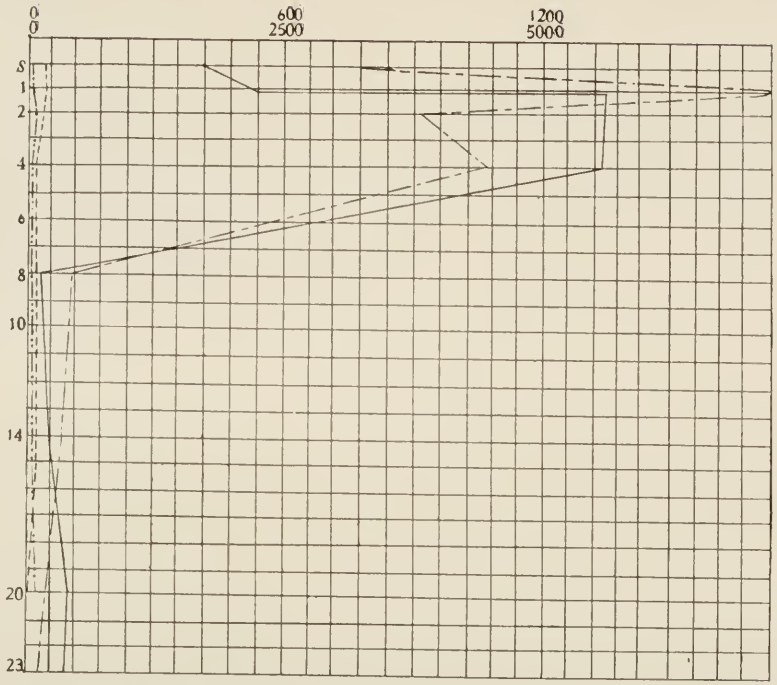


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Fig.2.--- Fragilaria and Microcystis.
Fragilaria. 7-11.
Fragilaria. 8-13.
Microcystis.7-11.
Microcystis.8-13.

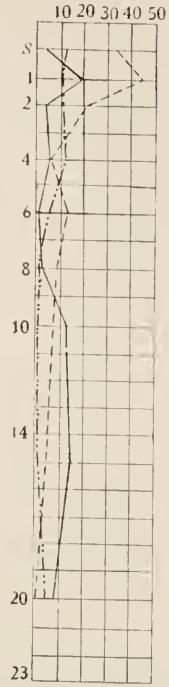

Fig.3.--Nauplii.
7-11.
8-1.
8-13.

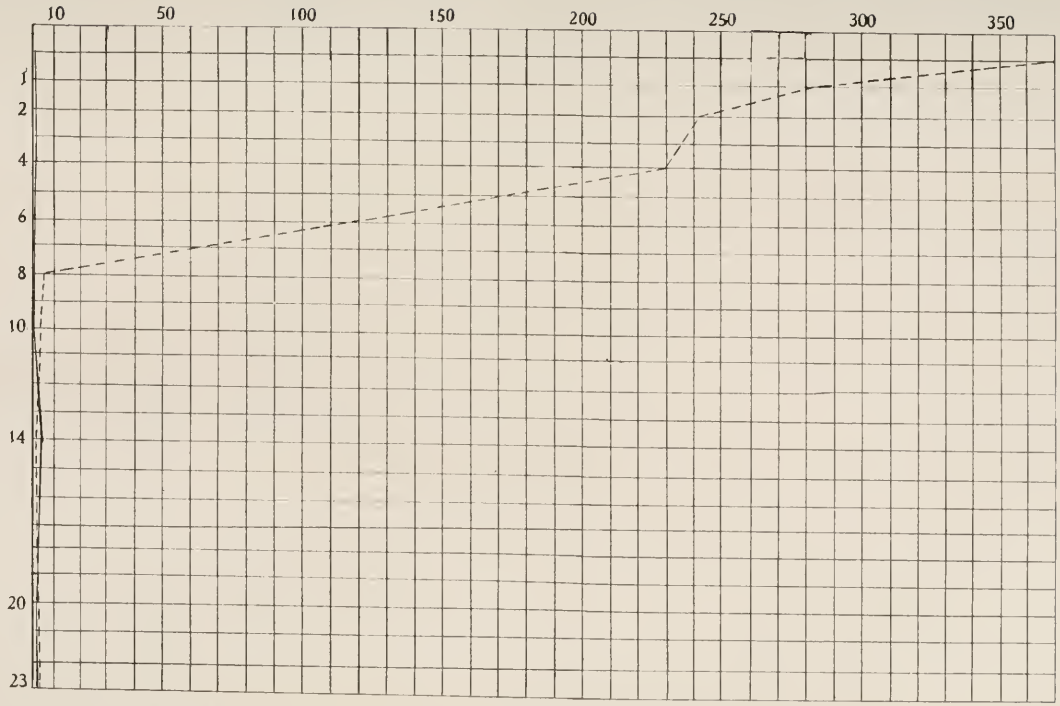

Fig.4.--- Anabaena.
7-11. ————————
8-8. — — — — — —

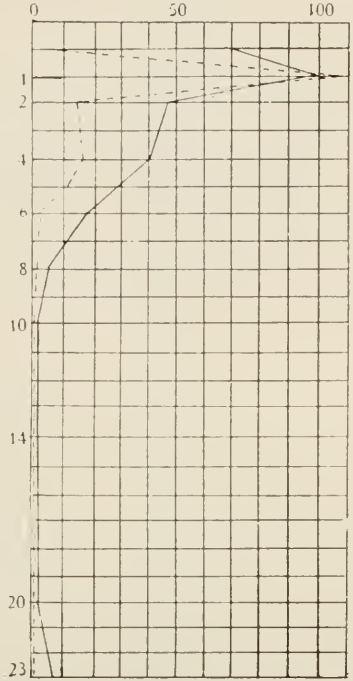

Fig.5.--- Lyngbya.
7-11. — — — — —
8-13. ————————

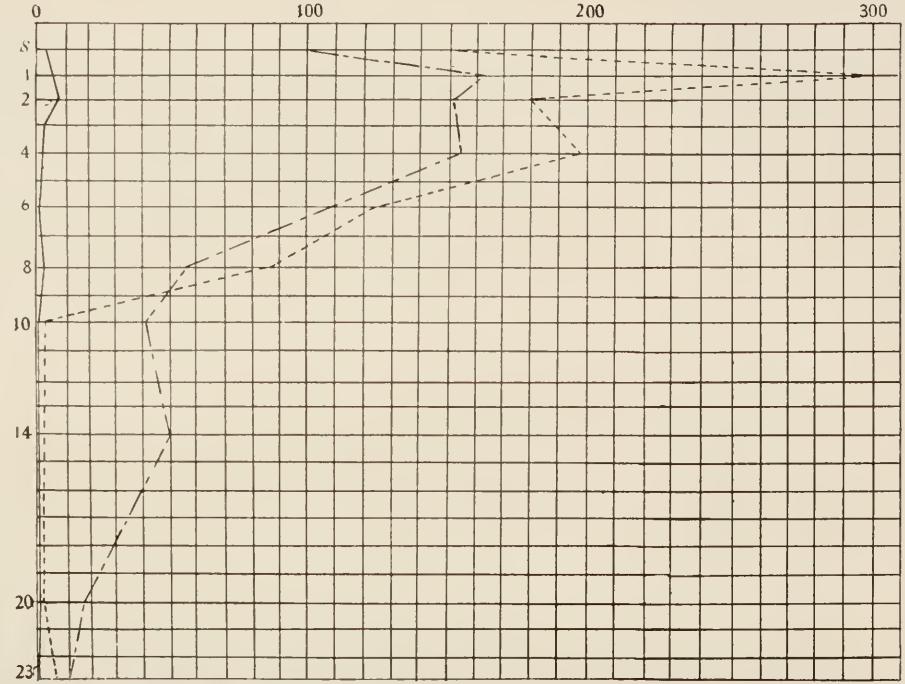

Fig.6.---Tribonema.
7-11. ————————
6-8. — — — — —
8-13. — — — — — —

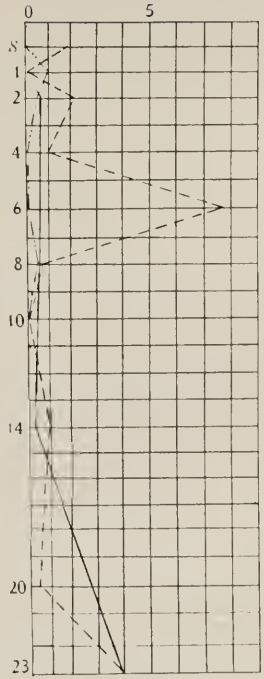

Fig.7.--- Cladocera.
7-11.—·· —·· —·· —
8-8. — — — — — —
8-13.————————

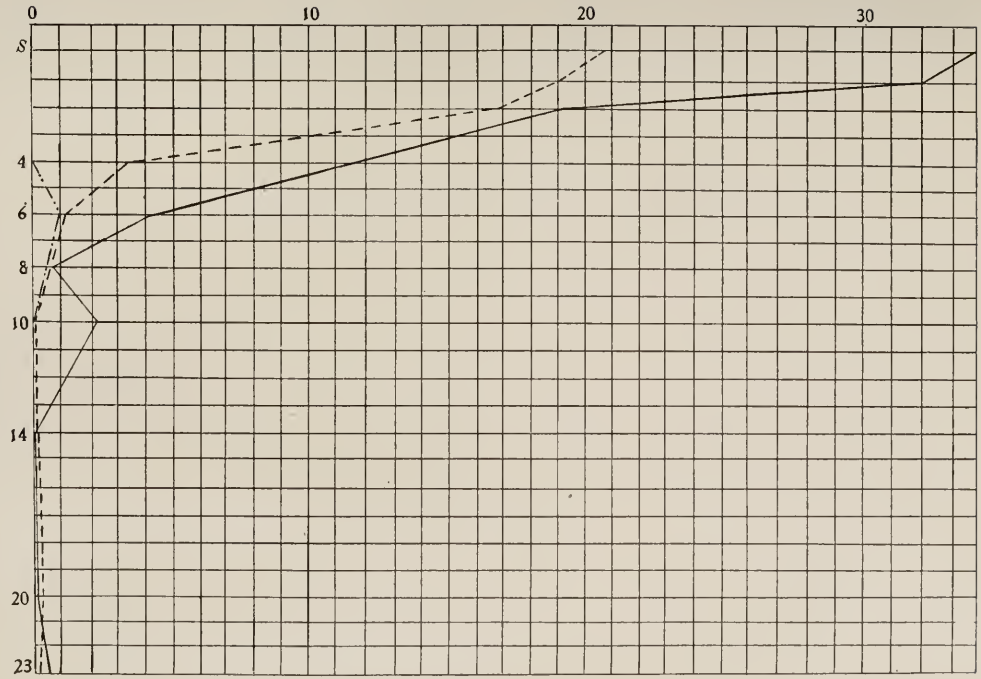

Fig.8.--- Rotifera.
7-11. —·· —·· —·· —
8-8. — — — — — —
8-13.————————

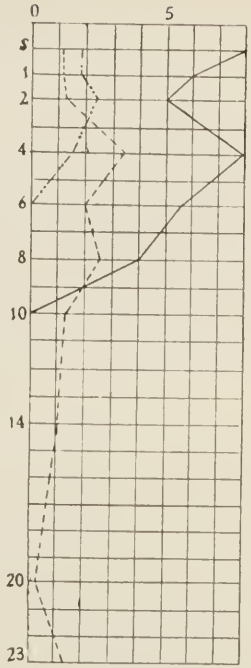

Fig.9.--- Diaptomus.
7-11.— — —
8-8. — — — — — —
8-13.————————

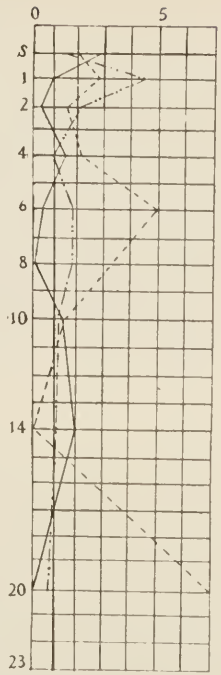

Fig.10.--- Cyclops.
7-11.— — — —
8-8. — — — — — —
7-18.————————

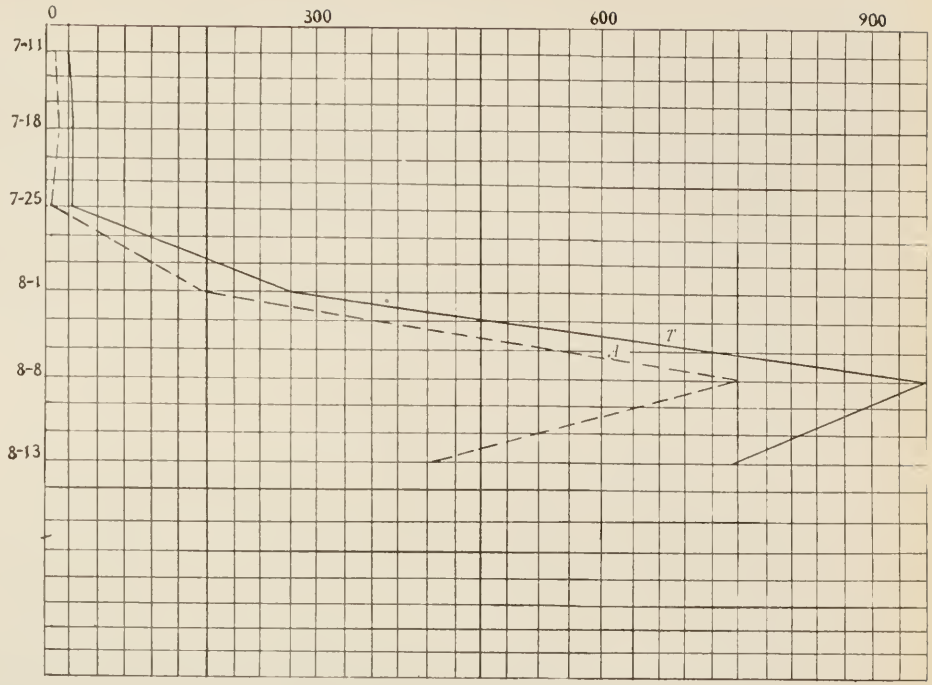

Fig.11.---Tribonema and Anabaena.
Tribonema.————Anabaena. — — — — —

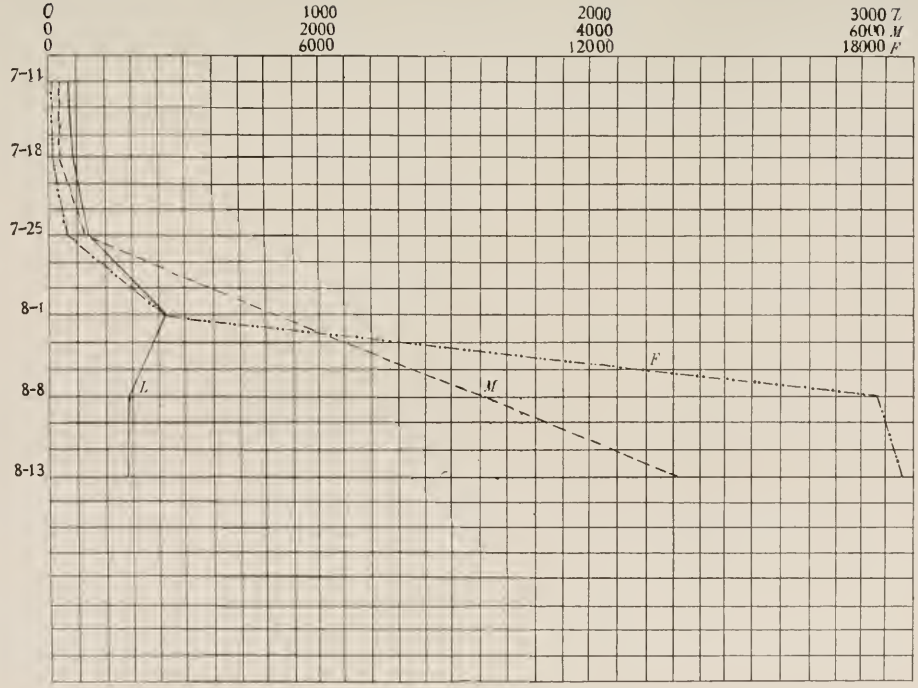

Fig.12.---Fragilaria,Microcystis,and Lyngbya.
Fragilaria —·—Microcystis----Lyngbya———

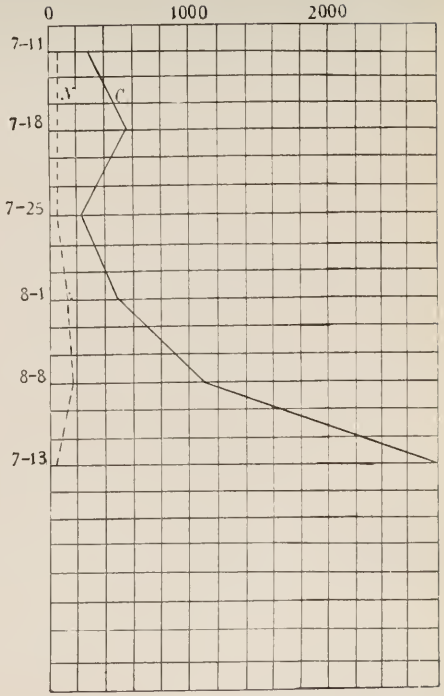

Fig.13.--- Ceratium and Nauplii.
Ceratium.——— Nauplii.------

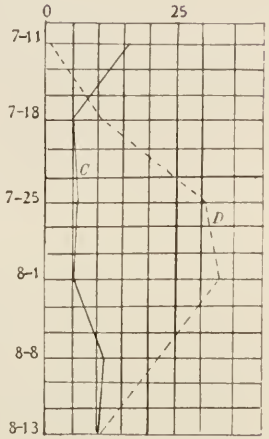

Fig.14.-Diaptomus--Cyclops
Diaptomus.----Cyclops.——

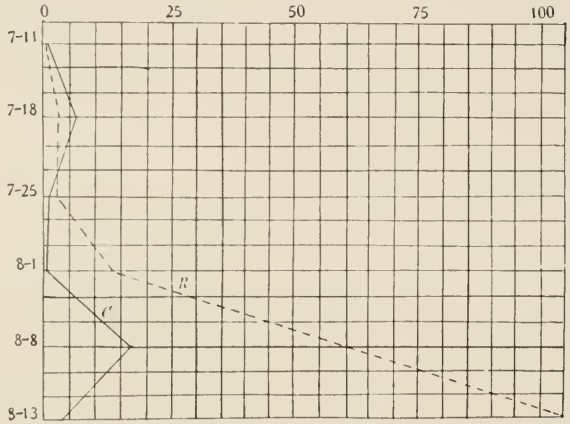

Fig.15.--- Cladocera and Rotifera.
Cladocera.———Rotifera.- - - - -

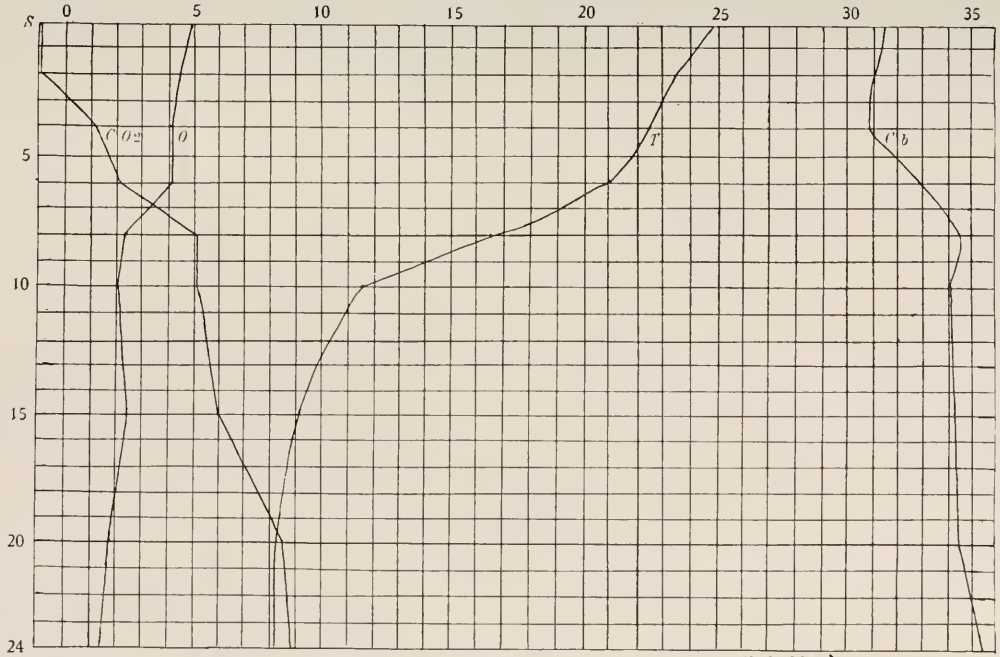

Fig. 16. Chemical chart of Winona Lake, Aug. 21, 12. (By George N. Hoffer)
Scale, 1 Vertical space=1 meter. CO
CO. = read in cc per liter.
O = " " " "
T = " " Centigrade
Cb = " " grams per liter.

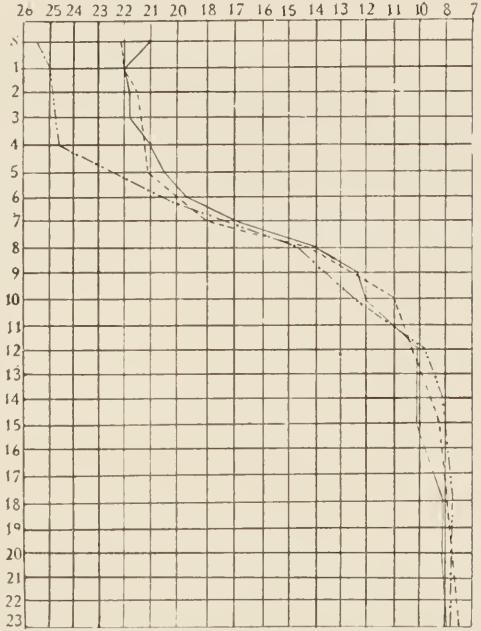

Fig 17 Seasonal Temperature Graph.
Horizontal spaces=degrees of temperature C
Vertical spaces=depth in meters.
Average temperature ————————
Maximum temperature — — — — — —
Minimum temperature —.. —.. —