A STUDY OF SUMMER ENTOMOSTRACA

IN BOOMER LAKE

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By

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PREFACE

This thesis was written as the result of a study of some limnological conditions on Boomer Lake near Stillwater, Oklahoma. It is among the first of its kind in the state, and the first concerning permanent waters, to be directed by the Zoology Department of the Oklahoma Agricultural and Mechanical College at Stillwater. It is an humble contribution to the rapidly increasing knowledge of ecological changes occurring in fresh-water, and it is hoped that it may stimulate others to further explore this interesting field of investigation.

Grateful acknowledgement is due Dr. John D. Mizelle, of the Department of Zoology of the above-named institution, for his aid in direction of the problem and the organization of this paper.

I am indebted also to Mr. Fred Carson, the lake caretaker, for the use of his boat during the summer of 1938; to Professor Charles E. Sanborn, of the Entomology Department of the College, for the use of his boat during the summer of 1939; to Harold Crowder, my brother and co-worker; and to all persons who contributed literature which aided the production of this thesis.

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HISTORY OF LIMNOLOGY

Although there was some knowledge of marine and fresh-water life as early as three or four hundred years before Christ, limnology as a field of science is comparatively new. The early knowledge of aquatic life, at best, was a mixture of truth and speculation. Except for historical interest, such knowledge is of little or no value. It was perhaps two thousand years later that any work was done which could be relied on by the modern limnologist.

The invention of the microscope probably had as much to do with the emergence of limnology, as it did with many of the other specialized fields of biology. Anton von Leeuwenhoek (1632-1723) was the first to describe minute organisms in water. Otto Friedrich Müller, a Danish biologist, in 1786 first attempted classification of microscopic organisms in his "Animalcula Infusoria Fluviatilia et Marina". Another step that marked this early period was "The Infusion Animalcules as Complete Organisms", by Ehrenberg in 1836.(1)

The discovery of plankton was the second great stimulus for water investigations and there seems to be some question as to just who should receive credit for this. It is believed by Needham and Lloyd that Liljeborg and Sars discovered plankton in their work on the Baltic Sea. They found what they described as a well-adjusted society of organisms including fauna, flora, herbivores, carnivores, parasites, and scavangers.

The work of Johannes Müller in the North Sea near Helgoland and that of Peter Erasmus Müller in certain Swiss lakes did a great deal to

(1) Most of the history concerning limnology is taken from Welch (1935).

dispel the previously held idea that clear lakes were devoid of microscopic life. It was not until later, however, that a definite name was given to this drifting mass of microscopic life. Hensen in 1887 gave the name "plankton" to all minute plants, animals, and debris found floating in open waters. Haeckel used the term to include all pelagic life, but Hensen's definition has become more or less universally accepted. The term "plankton", however, has become restricted to organisms only and the always present detritus is designated by other terms. The organisms included in the more recent use of the term plankton are: (1) plants, which include Algae and fungi and (2) animals, which include Protozoa, Coelenterata, Trochelminthes, Molluscoidea, and Arthropoda. The Entomostraca of the phylum Arthropoda is probably the most prominent and significant of the plankton groups.

Certainly some credit must go to Peter Erasmus Müller and Anton Fritsch for their discoveries on fresh-water plankton, but F. A. Forel (1841-1912) is recognized as the man who foresaw the real biological opportunity in lake investigations. To Forel goes the honor and title of the founder of modern limnology. Some of Forel's principal works are: "Instruction a' l'etude de la fauna profonde du Lac Leman", in 1869; "Materiaux pour servir a' l'etude de la fauna profonde du Leman", in 1874-1879; "Le Leman. Monographie limnologique", in 1892-1901; "La fauna profonde des lacs Swisses", in 1885, for which he was awarded a prize; "Handbuch der Seenkunde. Allegemeine Limnologie", in 1901, which might be termed the first textbook of limnology. In 1910, Chumley listed some 116 papers that were published by Forel. His comprehensive vision of limnology and his anticipation of the future of the subject was not surpassed by even F. Simony, who, about 1850, discovered thermal stratification and who, by some, is believed should be regarded as the founder of limnology.

As an outgrowth of the work of Forel there was established a part of the Swiss Natural History Society, a limnological commission in Switzerland, and later an International Commission of limnology.

The impetus of fresh-water investigations soon began to be felt in both Europe and America. This resulted in the establishment of fresh-water biological stations on both continents.

Two pioneer stations of worth were: one in the Bohemian forest founded by Professor Anton Fritsch in 1888, and another at Plön, Germany, founded by O. Zacharias a little later (1891). Soon after the establishment of these fresh-water stations others were set up in Germany, France, Norway, Sweden, Switzerland, Denmark, Austria, Italy, Scotland, Russia, Finland, Belgium, and in the United States. According to Welch (1935), a few important investigations also had their inception during this period: (1) the work of Zschokke and his associates on the Alpine Lakes of Switzerland; (2) the work of Sir John Murray and his associates which resulted in the publication of the extensive six-volume "Bathymetrical Survey of the Scottish Fresh-water Lochs"; (3) the Plankton Expedition of Victor Hensen to the North Atlantic Ocean in connection with which certain improved plankton methods were used; (4) the work of Apstein on the plankton of the Holstein lakes; (5) the investigations of Wesenburg-Lund and his students on Dannish Lakes; (6) the investigations of Woltereck and his students, first at the Biological Station at Lunz, Austria, and later in connection with the University of Leipzig; (7) the researches of Reighard and Ward and their co-workers on certain portions of the Great Lakes; and (8) the work of Birge and Juday and co-workers on the inland lakes of Wisconsin.

The plankton of American Lakes was little known previous to 1870, except from a taxonomic standpoint. Considerable work was published concerning the Great Lakes in the latter part of the 19th century but it dealt largely with vegetation and fishes. Quoting from Welch: "During the decade of 1890-1900, four fresh-water biological stations were founded, viz., by the University of Minnesota at Gull Lake, Minnesota, 1893; by the University of Illinois on the Illinois river, 1894; by the University of Indiana at Turkey Lake, Indiana, 1895; and by the University of Montana at Flathead Lake, Montana, 1898. Early work was done by Birge and Marsh on Wisconsin lakes, by Whipple in the New England States, by Reighard in Michigan, and by others. In 1893, work was again undertaken on the Great Lakes by a party, maintained by the Michigan Fish Commission and composed of about one-half dozen men, working under the direction of Prof. J. E. Reighard. Lake St. Clair was the seat of the work and a series of reports resulted."

Some limnological information was gleaned from the investigations of certain boards of health on water systems in general. The real foundation of American Limnology was laid by the work of (1) Kofoid, on the Illinois River, (2) Birge and Juday on Wisconsin lakes, and (3) Needham on the lakes of New York. According to Welch (1935), there were in active existence in 1935 the following numbers of biological stations: Europe, about 50; America, about 20; China, 1; Japan, 2; and Russia, 17 stations. Nearly all the fresh-water stations of America are in the United States.

Six meetings of the International Congress of Limnology have already occurred, as follows: (1) Kiel, Germany, 1922; (2) Innsbruck, Austria, 1923; (3) Moscow, U.S.S.R., 1925; (4) Rome, Italy, 1927; (5) Budapest, Hungary, 1930, and (6) Amsterdam, Holland, 1932.

Quoting Welch (1935): "During the last decades of the 19th century, a few formal courses in hydrobiology were given in colleges and universities, but almost entirely of taxonomic-faunistic nature. Of recent years, a few courses, strictly limnological in content have been offered and the number is steadily increasing. In a recent report, Needham (1930) states that eleven American universities offer work in general limnology. Because of the newness of the subject, the content of the various courses is still very diverse. Of the vast array of fresh-water lakes, very few have received any attention from limnologists, and such ones as have been studied are, for the most part, confined to restricted geographical regions. In America the innumerable inland lakes so generously distributed over upper United States, southern Canada, the mountain regions, and elsewhere present a wide open opportunity".

The author is not aware of any limnological study having been previously done on Oklahoma lakes.

MATERIALS AND METHODS

This study was made on Boomer Lake, which is about one and one-half miles north of Stillwater, Oklahoma, in the edge of the Great Plains. The lake normally is about two miles long (north-south) and approximately one-half mile wide with a dam at the south end. It drains 9.13 square miles of surrounding terrain (Eakin, 1939), and is subject to considerable change in size because of seasonal distribution of rainfall. There is a marked increase in volume from March to July, when most of the spring and summer rains occur, according to the U. S. Department of Agriculture, Weather Bureau. In late fall and winter the lake is often reduced to a comparatively narrow channel which marks the site of the creek (Boomer) which was dammed. This body of water is considered permanent since, after its impounding in 1925, it has never gone dry. The banks have gentle slopes and the shoreline is not extensive. Vegetation of the usual type for this region is present around the lake but none normally penetrates into the water. At times some terrestrial vegetation is incorporated in the lake due to rapid rises following heavy rains. Comparative absence of littoral vegetation is due mainly to the fact that this artificial lake is the main water supply for the city of Stillwater and men are hired to remove vegetation which might invade it from the shores.

The first part of this study was made in June and July of 1938. At this time four stations were established as shown in figure 1. These were selected with the idea of sampling the main aquatic habitats which the lake had to offer at the time. Station I was selected near the limestone-lined dam in water about five meters deep. Station II was located in water about the same depth as in Station I and near the center

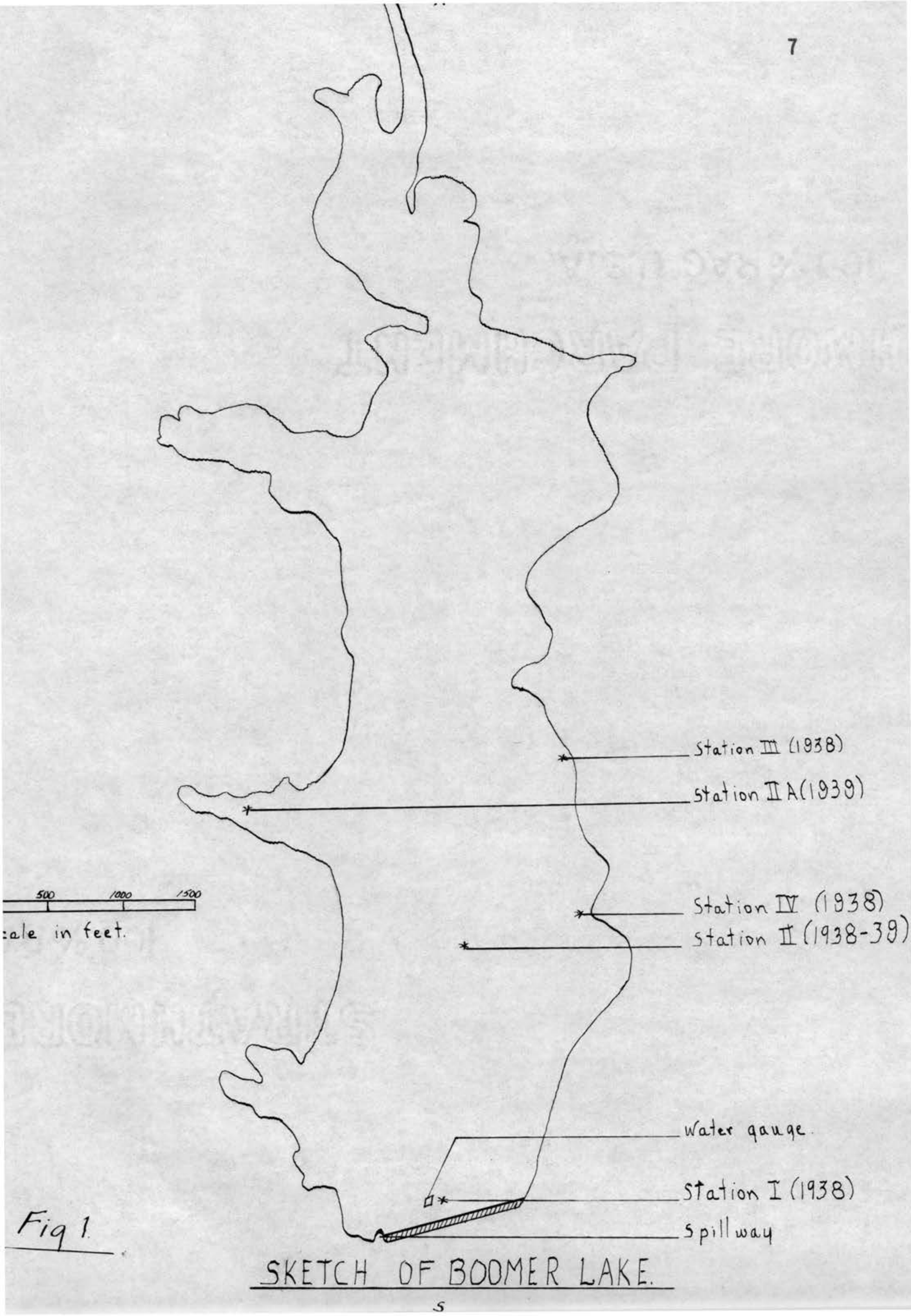


Fig 1.

SKETCH OF BOOMER LAKE.

of the lake which had unobstructed access to wind action. Station III was located near the eastern shore in water about one meter deep. Station IV was selected also on the eastern shore, but in a recently flooded area which contained weeds and grasses of a terrestrial sort. The water here was about the same depth as that in Station III. During the second summer's work (June and July, 1939), the water level had fallen sufficiently to destroy stations III and IV. Since Station I was so manifestly like Station II, it was decided to eliminate the former and establish another station (II-A), in a west arm of the lake where the water was less than one meter deep, to replace Station III. These changes resulted in sampling from only two stations (II and II-A) during the second part of the work (summer of 1939). Stations involved were visited one afternoon per week, approximately between the hours of two and four o'clock, for the duration of the study. Measurements of temperature, turbidity, and pH together with collections of plankton were made from the water surface and also at a point near the bottom for each station. A few drops of 40% formalin were added to the plankton samples. After the organisms were killed and had settled to the bottom, the top part of the fluid was poured off sufficiently to allow addition of enough formalin (40%) to make a 4-5% solution. Each collection was then labelled, stoppered, and placed in a container for conveyance to the laboratory.

Since this work was the first of its kind to be undertaken at Oklahoma Agricultural and Mechanical College, most of the equipment used during the first half of the investigation was of an improvised nature, and somewhat inadequate. During this period, the plankton collections (20 gallons each) were taken with a large-mouth gallon jug, similar in construction to Meyer's bottle (Reighard, 1918). For subsurface samples the container was lowered (closed) by means of weights and sashcord. At the desired depth, the cork stopper was removed by means of a string, the jug filled, and was then hauled to the surface. It is thought that only little mixing of the jug contents and extrinsic lake water occurred during the passage of the jug to the surface. The water was then strained through a muslin plankton net which had a bottle attached for receiving the organisms (fig. 2). Temperature was determined by means of an ordinary centigrade thermometer. Temperature readings for subsurface samples were taken immediately on arrival of the sample at the surface. Turbidity was determined by means of an improvised Sechhi disc. The writer is aware of the fact that turbidity readings by this method are worth very little because of light intensity variations that occur due to obstruction of solar rays, time of day, season of the year, wave action, etc. pH was determined with a Hellige pH set.

During the second summer, the plankton collections (30 liters each) were taken with a Foerst-Improved water sampler (30 liter, fig. 3) and the same net (muslin). The temperature was measured with a deepsea reversing thermometer, manufactured by the H-B Instrument Company of Philadelphia. Turbidity readings were done under standard light conditions with a Jackson candle turbidimeter and interpreted in parts per million of diatomaceous earth. The pH readings were made with LaMotte block comparators. Plankton counts were made with the aid of a wide field binocular microscope and a Sedgewick-Rafter counting chamber (1 cc.). Each concentrated sample was diluted to 30 cc. in a graduated cylinder, agitated thoroughly, and five separate counts (1 cc. each) were made on each sample. An average was then calculated for separate

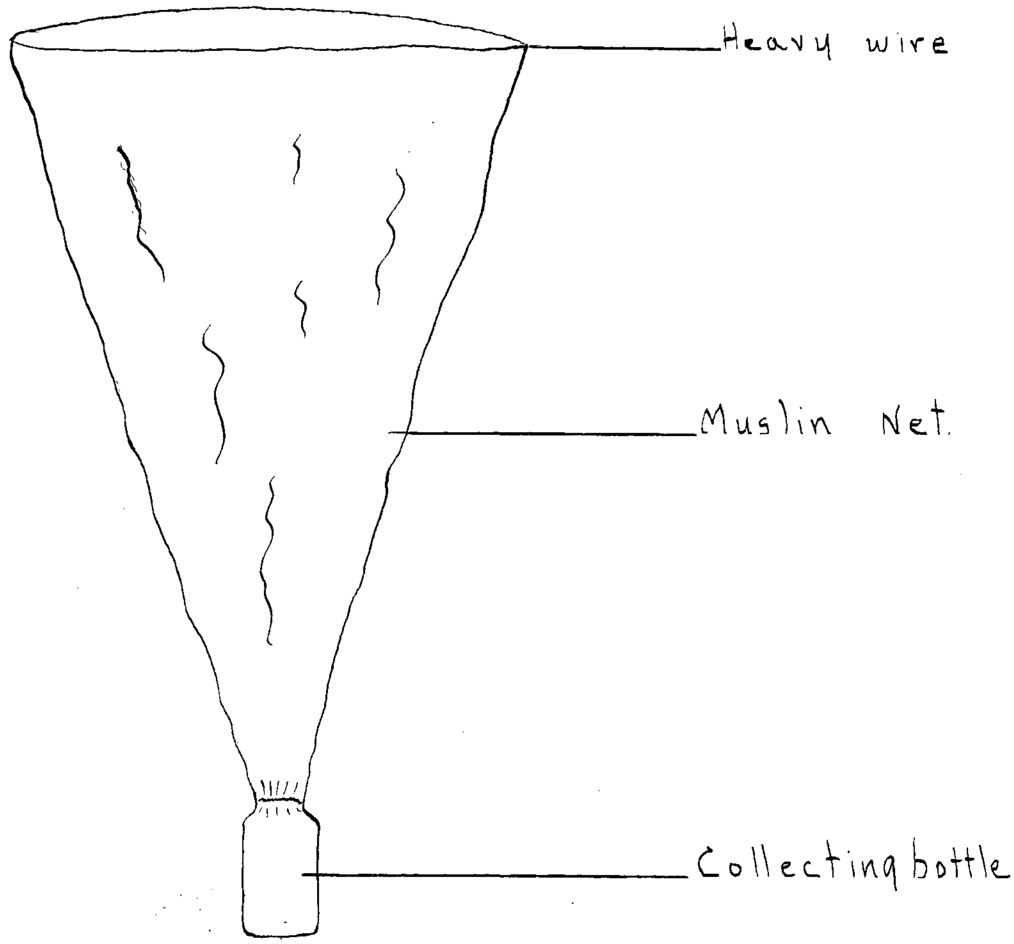


Fig-2. Collecting Net.

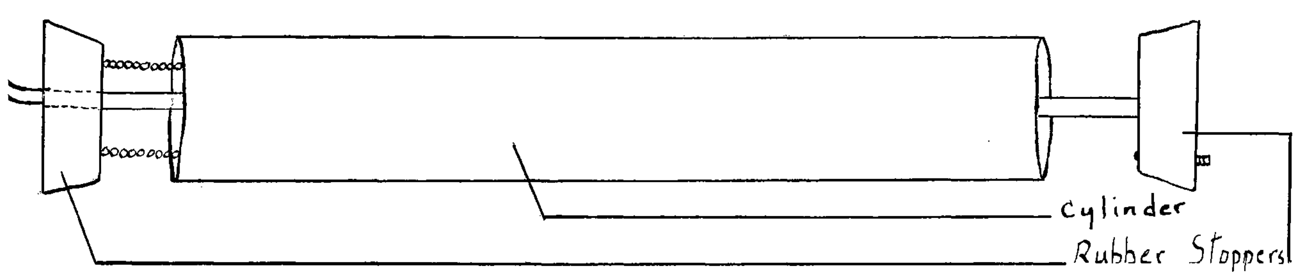


Fig 3. Water Sampler

organisms and multiplied by 30 to get the number of each per 30 liters of water. Twenty-gallon samples taken during June and July of 1938 were calculated on a 30 liter basis.

ENVIRONMENTAL FACTORS AFFECTING PLANKTON

There have been a great many definitions given as to what designates a lake. The terms "pond" and "swamp" are often confused with the term "lake". Forel, in 1892, defined a lake as body of standing water occupying a basin and lacking continuity with the sea. This definition would include the entire standing-water series. Muttkowski, in 1918, set up criteria which would make a lake include only those bodies of standing water which are of considerable expanse and deep enough to stratify thermally. This definition would eliminate all the smaller bodies of water. Perhaps the most satisfactory classification has grown out of that developed by Forel and later modified by Whipple (Welch, 1935). He classified temperate lakes as those whose surface temperatures vary above and below 4° C. into three orders:

"Order I. Temperature of the bottom water at 4° C. throughout the year; two circulation periods possible (one in spring and one in autumn), often none.

Order II. Temperature of the bottom water varies not far from 4° C.; two circulation periods (one in spring and one in autumn).

Order III. Temperature of the bottom water very similar to that of the surface water; circulation is continuous except when frozen."

Boomer Lake would fall into Order III of the above classification.

There are many factors that affect frequency, distribution, and size of plankters in open waters. Among the more common are light, temperature, food, turbidity, wind, pH, water depth, and dissolved gases. According to the literature, lakes of a given type show considerable uniformity in plankton content. None of the above-mentioned factors can be discussed accurately in the absence of the others. The effects of each are qualified by one or more of the other factors.

R. R. Langford (1938) thinks that light intensity is the prime influence upon distribution and points out that in most cases there is evidence that maxima in strata near the surface are held there by a positive phototropism. He further states that an absence of plankton exists at the immediate surface layers and in the deeper layers because of the intensity of light and the lack of light respectively.

A group of experiments carried on by G. L. Clarke (1930) on the reactions of Daphnia to light intensity and to light direction suggests a possible answer to diurnal migration and vertical distribution; however, observations in nature are contrary to the laboratory results. Clarke thinks that diurnal migration may be due to a positive phototropism and a negative geotropism produced by the rising of the sun in the morning and to a reversal of these tropisms when the sun sets at night. He has shown by his experiments that Daphnia exhibits complete power of adaptation to light in the laboratory, but whether it is an active or passive effect on the organism in nature remains a question.

A great deal has been written on the effects of temperature on plankton. According to observations by Langford (1938), temperature has some direct effects on plankton. He found that some species preferred the cool hypolimnion when the upper waters were warmed. Other species were found consistently at the thermocline while still others were near the surface day and night, so it appears that the temperature was possibly the dominant factor so far as light and temperature are concerned. Dissolved gases, turbidity, pH, food or wind may have entered into the results.

Quoting from Langford (1938), "The temperature gradient at the thermocline is an important factor in the vertical distribution of many species. This has not been as noticeable with respect to diurnal movements as is cited in so many instances in the literature, but definite effects have been observed in daylight distribution. In most cases maxima are observed either above or below the thermocline, or, in some cases, in both epilimnion and hypolimnion. Under such circumstances there is usually a definite scarcity of the species in the thermocline region itself. In very few cases were numbers found in this region equal to, or larger than, those observed either above or below. It would appear where a temperature gradient exists, the forms are able to orient themselves and move toward favorable temperatures. In some cases the temperature gradient is observed to be a definite barrier to such selection of habitat."

According to W. L. Tressler, University of Buffalo, and Ruby Bere, University of Wisconsin (1936), the region of temperature change or thermocline is a very important region in a lake. Its position determines the depth to which winds are able to affect the circulation of the lake water. Differences in density, due to temperature differences, prevent any circulation of the water below the thermocline during the summer, and it is a well known fact that this region from the bottom to the region of temperature change is only able to mix with the upper waters during the periods when temperatures are uniform from top to bottom. These periods of uniform vertical temperatures occur in the spring and fall and are vital factors in the economy of a lake. Oxygen is restored to the depths at these periods and decomposition products are mixed with the upper waters and in this way are partially eliminated from the bottom waters, thus preventing stagnation and making life possible.

A "first class" lake, according to Birge, is one that has sufficient size and depth to enable it to acquire the maximum amount of heat possible under existing weather conditions. The amount of heat which a body of water can absorb is a vital factor in the productivity of a lake.

R. E. Coker of the University of North Carolina (1934) carried on some interesting experiments with copepods and their relation to temperature. He writes that, in spite of much diversity of size within the class, the largest copepods reared at 29° C. would rarely be as large as the smallest of the same sex reared at 19° C., while few, if any, reared at 19° C. were equal in size to the smallest reared at about 9° C. Change in size with successive generations, independently of the temperature at which the particular copepods were reared, was not noted. At any given temperature level the males, always smaller than the females, were relatively more uniform in size than were the females. Differences in size between temperature classes were also notably less for males than for females. Development is greatly retarded both by low temperature and by shortage of food; but semi-starvation, carried so far as to prolong the period of development to six times the normal period for the temperature, seemed to have no marked effect, as compared with temperature, on size attained when development could be completed. There was no clear indication of an optimum temperature for size, above and below which the copepods were smaller. Suggestions of an optimum temperature reflected in size and abundance of copepods receive no support from our experiments, since the optima for size and rate of development, respectively, would be near opposite ends of the range of tolerable temperatures.

Rate of development is a function of temperature and of food supply, and doubtless of inheritance, while, if our experiments are properly indicative, size of copepods is a function of temperature and of inheritance, and, only very slightly, if at all, of food supply (as far as quantity of food is concerned).

Coker also found other changes, due to temperature, such as variations in the relative lengths and widths of the furcal rami, some variations in the swimming feet and even to some physiological changes.

Plankton organisms, like other forms of life, must have sufficient food to maintain optimum growth and reproduction or the population will suffer. Very little has been done to determine the actual source of food of plankton. Langford (1938) states, "The importance of the utilization of particulate organic material other than phytoplankton is not known." Naumann has shown that fresh-water Daphnia rapidly filter out detritus with attached bacteria. Woltereck decided that pelagic Daphnia cannot make use of detritus, although pond forms do so. The utilization of bacteria by plankton organisms is little known, but may be of some considerable importance. Bond and Stewart, McPherson, and Cooper have shown that certain bacteria are utilized as food by various plankton organisms.

It is realized that many of the plankton crustacea feed upon phytoplankton forms which are more or less restricted to the upper strata, but abundance or scarcity of phytoplankters should not be confused with abundance or scarcity of food, since other particulate organic material may be utilized. Plankton crustacea are not always numerous where algae and protozoans are most abundant, and, until our knowledge of the food relationships is more detailed, no absolute correlation can be expected.

It is, of course, realized that other modifying factors may be more influential than the relation between food and feeder in determining the vertical distribution of a population.

An increase in phytoplankton with its decomposition products causes an increase in turbidity, thus cutting off the sun's rays and limiting the growth of phytoplankton to the upper waters. The turbidity of a given body of water depends a great deal on the nature of its bottom and the surrounding terrain. Bottoms of sand, gravel, or rock show a low degree of turbidity. If the bottom is clay, turbidity is usually high. Swimming life keeps matter suspended in water and inflowing sediment causes variations in turbidity. Turbid waters might be favorable or unfavorable. If the light intensity was lessened by suspended matter it would permit some forms to feed nearer to the surface where food might be more plentiful.

The direct effect of wind on distribution of plankton has been definitely identified in only one instance, according to Langford (1938). Distribution in nearly all cases is the same in quiet or windy weather so far as the direct wave action is concerned. Indirectly, however, the cooling effect of the wind lowers the thermocline and consequently scatters the inhabitants of the epilimnion and concentrates those of the hypolimnion.

The hydrogen-ion concentration or pH of lake waters is known to possess a sufficient importance to require attention, but definite knowledge is often quite fragmentary, often incoherent, and none too certain. Some lakes have shown a uniform change daily and seasonably, others show a progressive change daily or over a season. Wesenburg-Lund found in some lakes of Denmark a variation of from 4.4 to 9.4. Changes of 9.2 to 6.6 have been known to occur in a day. Rain, vegetation, and a great many other factors probably contributes to pH change.

Probably none of the above-mentioned factors cause any great degree of variation of plankters in Boomer Lake. It is not of sufficient depth to prevent light penetration, or to have a great degree of temperature variation from top to bottom. It is not large enough to permit excessive wave action, and the food is probably uniformly distributed. According to the classification as given by Forel and Whipple, there is very little if any true thermal stratification and consequently the turbidity is relatively uniform and without apparent effect.

DISCUSSION

It is generally recognized that Entomostraca in thermally stratified waters tend to occupy the aerated regions (Welch, 1935). Thus the hypolimnion contains these forms in fewer and fewer numbers as the stagnation period proceeds after the spring overturn. In ponds and shallow lakes where no true thermal stratification exists there is little or no forthcoming explanation on the basis of physical factors for the periodic increases, decreases, and vertical population shifts in microcrustacean fauna. This has been recently concluded by Ward (1939) who examined a number of ponds, over periods ranging from one to two years, in the vicinity of Cincinnati, Ohio, and by Crowder (unpublished thesis) for a temporary pond located near Stillwater, Oklahoma. Since few general conclusions can be drawn other than that there are periodic population peaks which may be due to increase in numbers and/or vertical shifts of the forms involved, the findings in this thesis will be presented according to (1) collecting periods, and (2) the collecting stations involved.

The seven collections of 1938 from Station I show peaks at the surface on June 27th and July 18th for all the Copepoda involved. On June 27th, the Cyclops peak was lower than those for the other two (developmental forms and Diaptomus) by some 250 organisms per sample. The July 18th highs show a considerable variation in numbers though they still represent peaks for each of the forms. Cyclops shows approximately 50, developmental forms 200, and Diaptomus 600 individuals per sample of 30 liters. The deep samples presented peaks for developmental copepods (450 per sample) on July 5th, for Diaptomus (150 per sample) on June 27th, and for Cyclops (50 per sample) on June 20th. Diaphanosoma and very young Cladocera showed slight increases which culminated on June 20th, and the former showed a comparatively high peak on July 18th, whereas the young Cladocera and Bosmina steadily decreased in the rest of the surface collections. The only noticeable peak for Cladocera (Diaphanosoma) in deep samples was on June 20th (250 per sample). The unmentioned dates of collection show relatively low numbers of plankters. In general when increases, as marked by peaks, occur in the upper waters there are also peaks in the deep samples, but the latter are of smaller magnitude.

In the 1938 collections for Station II, the developmental Copepoda and Cyclops show surface population peaks (150 per sample) with corresponding lows in deep samples on alternate dates throughout the summer. Intervening collections show a reversal of these conditions. Each surface population is accompanied by an increase in temperature, whereas population peaks in deep waters are marked by temperature decreases. Surface population peaks for Diaptomus occurred on June 27th (one week later than that of the first peak for the above forms), and on July 18th, which coincided with the third date for same with reference to nauplii, metanauplii, and Cyclops. Diaphanosoma showed a definite high on June 20th and on July 18th at the surface, while the other forms of Cladocera remained comparatively scarce for the other surface readings and all deep readings.

In Station III the developmental forms at the surface showed fluctuations in numbers similar to those in Station II. Surface population peaks for Diaptomus occurred on June 20th and July 18th. These in height approached those for the developmental copepods. Cyclops showed only one low surface peak on June 27th. In marked contrast to the picture for deep and surface samples for developmental copepods in Station II, these forms in Station III showed only one, but very high, peak for deep samples (July 5th). Highs for Cyclops and Diaptomus in deep water were one each for the summer and occurred on June 27th and July 13th, respectively. Diaphanosoma, the dominant cladoceran for this station throughout the summer of 1938, showed one significant peak at the surface on June 26th and one at the bottom on July 13th. For the other Cladocera (Pleuroxus, Daphnia, Bosmina, and young forms) there were comparatively low readings.

The developmental Copepoda in Station IV were present in enormous numbers (974 per sample) in the surface water on June 20th and very scarce in all other readings. In the deep samples a moderately high population (475 per sample) was present on July 5th, but these forms were very scarce in all other samples during the summer. Diaptomus showed similar behavior for the surface samples but with a lower peak (175 per sample). This genus, for the deep samples, showed a comparatively low peak (160 per sample) on June 20th, which indicated little preference for conditions in different depths of this station. Another peak was presented by these forms on July 5th indicating a migration to the lower waters. On June 20th the behavior of Cyclops was reversed with reference to Diaptomus and developmental forms. They moved to the upper waters one week later, then practically disappeared from both regions for the rest of the collecting period. This probably means that they migrated to deep water farther out in the lake. Cladocera were present in small numbers during the first of the collections, showing little preference for particular horizontal layers of water and like the Copepoda declined toward the end of the collecting period.

In Station II for 1939, the behavior of the different forms involved showed little or no consistency in their behavior with reference to 1938. In general the copepods were scarce from June 19th to July 10th and were found in both top and bottom waters. An increase in Diaptomus occurred in deep samples on July 20th and August 19th and Diaptomus and developmental forms showed increases on July 26th in surface waters. These phenomena indicate that the wind may have been responsible for their scarcity during the first part of the summer. Similar behavior was noted for Diaphanosoma. The other Cladocera were present in small numbers and only in the surface samples for the entire collecting period.

Station II-A (1939) was established to replace Station III (1938). Due to a shallow depth, only surface samples were taken. Developmental copepods, Cyclops, Diaptomus, and Diaphanosoma showed similar behavior with increases manifest on June 19th, July 10th and July 26th. Daphnia were absent from all collections until July 26th after which they rose sharply (240 per sample) on August 19th.

In summing up the results of the two summers study, the population peaks for all Entomostraca concerned have occurred most consistently for June on the 20th and 27th, and for July on the 5th and 18th. The outstanding factors for the June peaks at the surface were clear skies, high turbidities, and high temperatures for June 20th. The July collections were taken in clearer waters than those of June. The temperatures were also higher and the wind was stronger. However, the above-mentioned peaks never occurred on dates when the wind was very strong. The forms seemed to be well distributed with reference to depth. According to Welch (1935): "Wind effect of any significant amount varies with the season. During the summer, it can influence directly only the epilimnion in which during hard blows it may make changes in the vertical distribution of the plankton. However, it is probable that such changes are not so extensive as has been supposed, since active forms, particularly the Crustacea, are to a considerable degree independent of such vertical currents as may be temporarily produced and, in fact, may respond negatively to them. Furthermore, some of the non-motile, floating phytoplankton show surprising resistance to such mechanical influences working toward changing their normal levels."

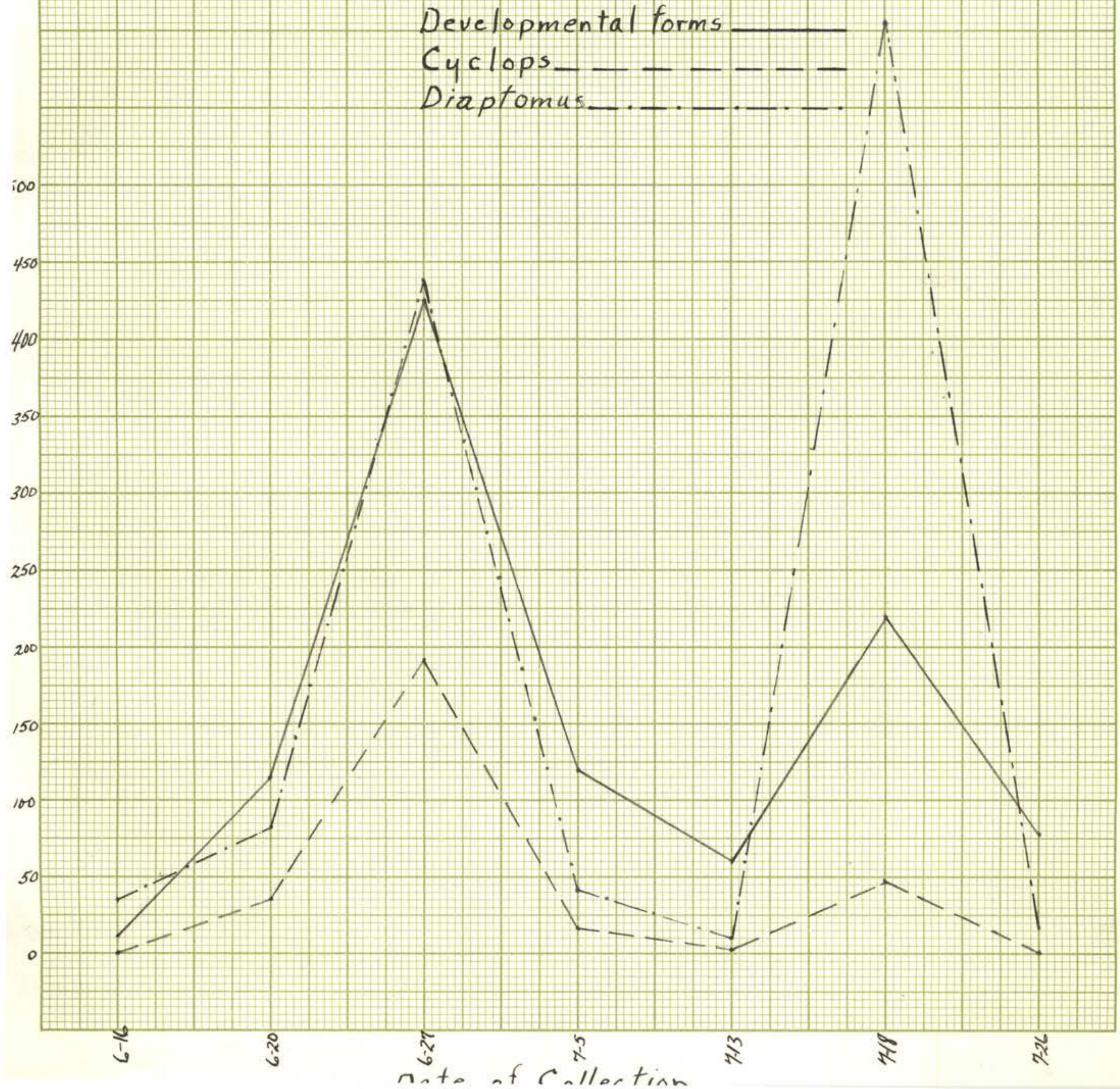
"Temperature acts both directly and indirectly in influencing vertical distribution of plankton. Direct effects are usually manifested through either (1) selection by some motile plankters of certain favorable temperatures or (2) inability of some non-motile forms to exist in levels having certain temperatures.

"Temperature acts indirectly in causing changes in the density and viscosity of water, such changes altering the flotation levels of those plankters which are delicately adjusted to flotation. It is also said to act indirectly in changing the sensitiveness to light of the limnetic crustacea; higher temperature increases while lower temperature decreases this sensitivity, thus leading to different degrees of response."

As has been suggested before in this thesis, it is difficult to say what factors exert the most influence when they are all present and acting at once. If one factor could be applied to plankton in the absence of the others, one could reach definite conclusions as to that factor's effects, but when it is modified by a great many others those effects are quite uncertain. For relative heights of peaks as well as for accompanying conditions the reader should consult the graphs.

Station I. 1938. Copepoda. Surface.

Date	Secchi Disk	Temp.	pH	wind	light.
6-16	4 cm	26°C	6.8	slight	Cloudy
6-20	3.5 "	33°	6.8	"	Clear
6-27	4 "	27°	7.0	"	"
7-5	3 "	28.5°	7.2	Moderate	Cloudy
7-13	6.5 "	30°	7.2	gale	Clear
7-18	9 "	33°	7.0	slight	Cloudy
7-26	7 "	28°	7.2	gale	clear



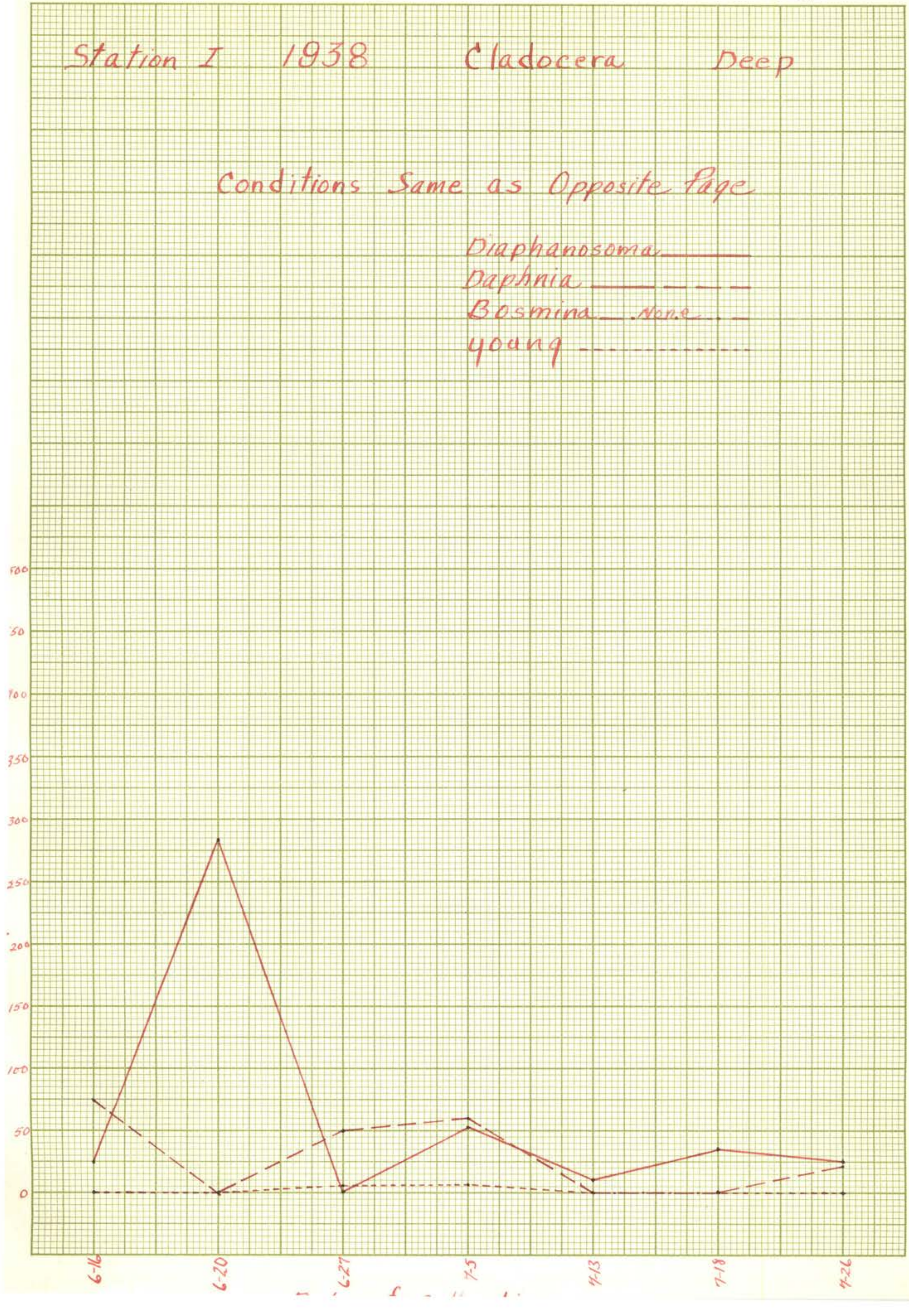
Station I 1938 Cladocera Surface

Conditions Same as Opposite Page

Station I. 1938. Copepoda. Deep.

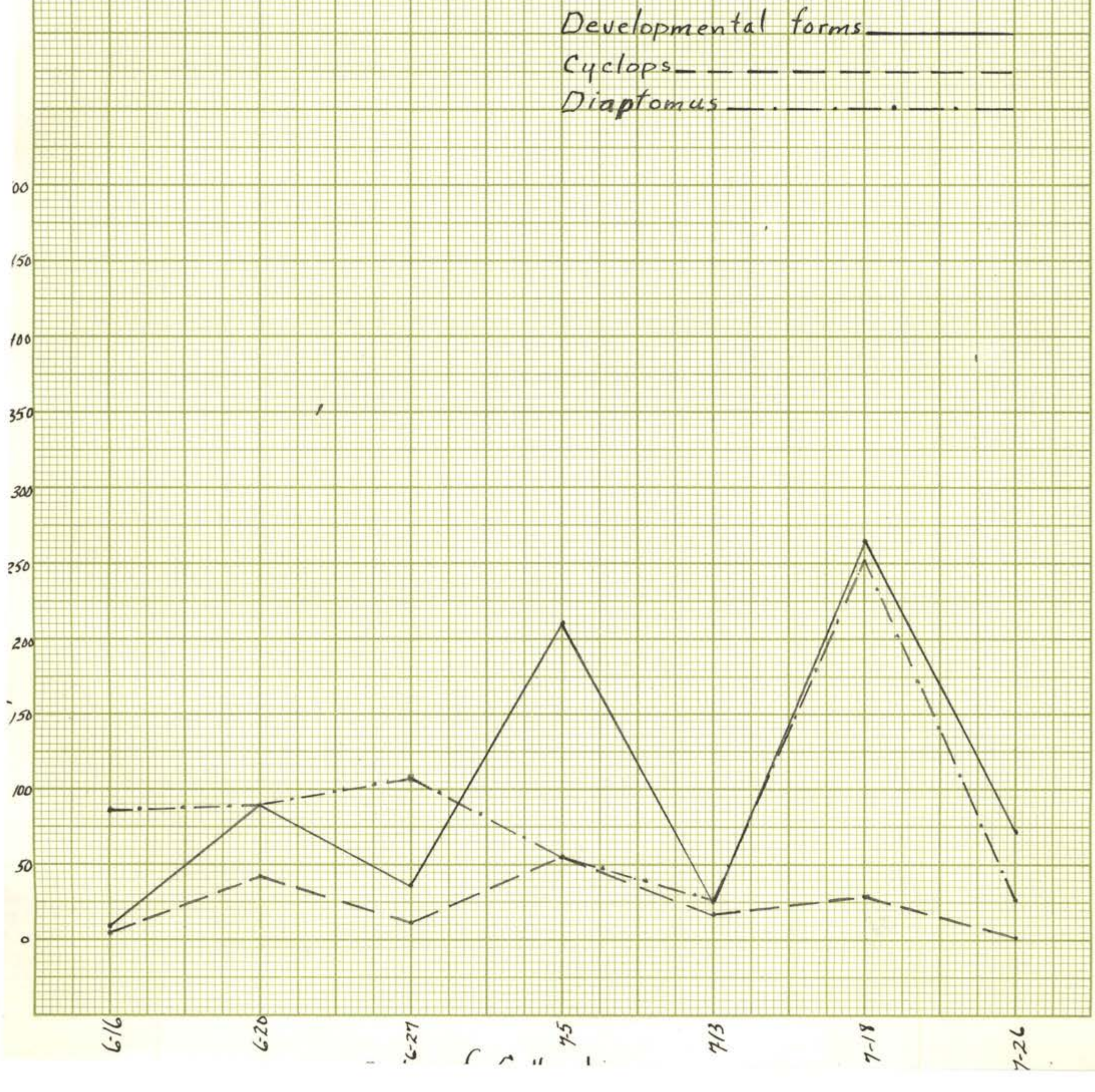
Date	Secchi Disk	Temp.	pH	Wind	Light
6-16	4 cm	25°C	6.8	Slight	Cloudy
6-20	3.5 "	27°	6.8	"	Clear
6-27	4 "	25°	7.0	"	"
7-5	3 "	26.5°	7.2	Moderate	Cloudy
7-13	6.5"	26.5°	7.2	"	Clear
7-18	9 "	27°	7.0	Slight	Cloudy
7-26	4 "	26.2°	7.2	gale	Clear

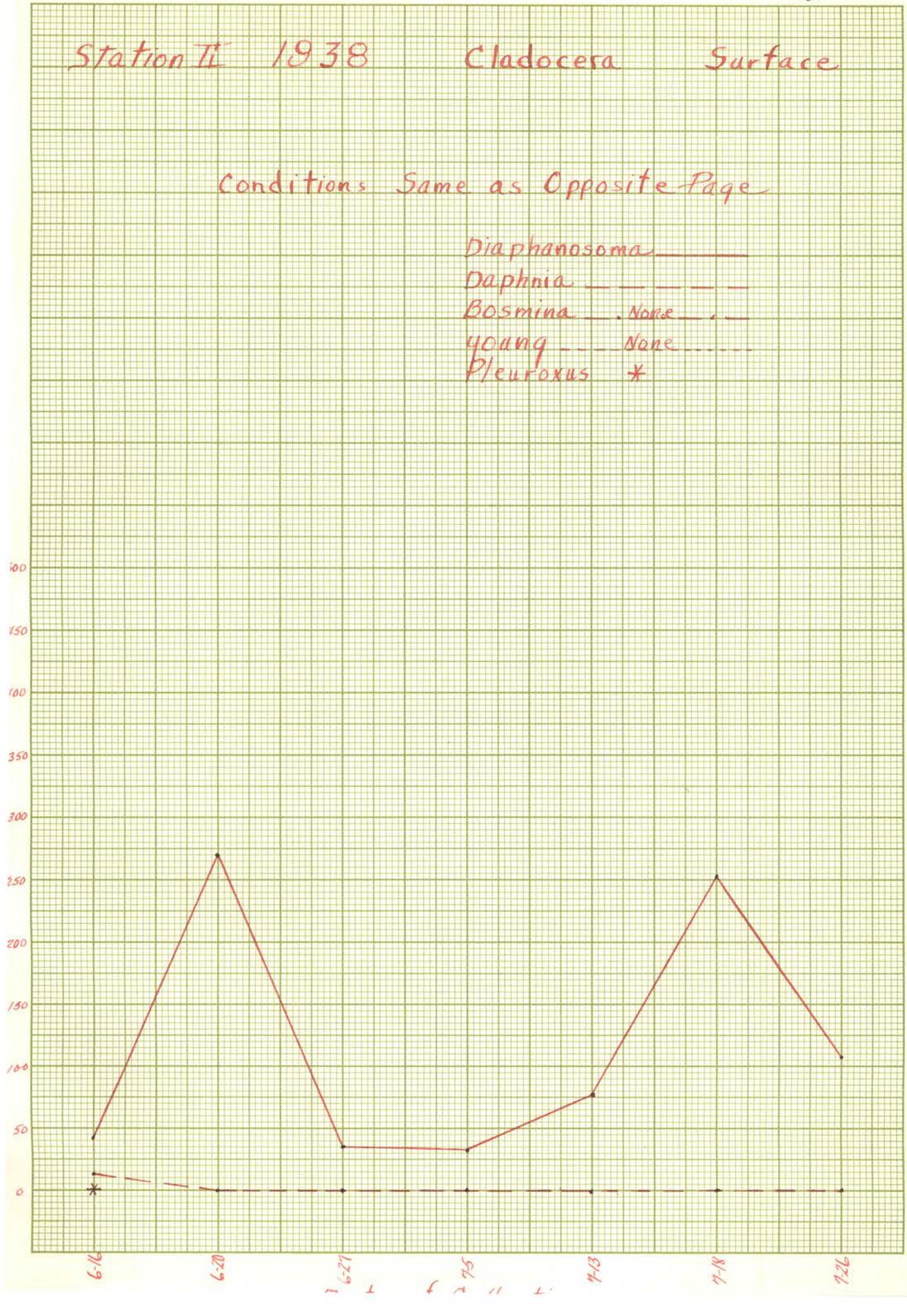
Developmental forms ————
Cyclops — — — — — —
Diaptomus —.—.—.—.—


Station I 1938 Cladocera Deep
Conditions Same as Opposite Page
Diaphanosoma
Daphnia
Bosmina None
young
500
450
400
350
300
250
200
150
100
50
0
6-16
6-20
6-27
7-5
7-13
7-18
7-26

Station II 1938 Copepoda Surface

Date	Secchi Disk	Temp	pH	Wind	Light
6-16	4 cm	26°C	6.8	slight	Cloudy
6-20	4 cm	31°	6.8	"	clear
6-27	4 cm	27°	7.2	"	"
7-5	3.5cm	29°	7.0	Moderate	cloudy
7-13	6 cm	30°	7.2	Slight	clear
7-18	6 cm	33°	7.2	"	Cloudy
7-26	6 cm	28°	7.2	gale	Clear





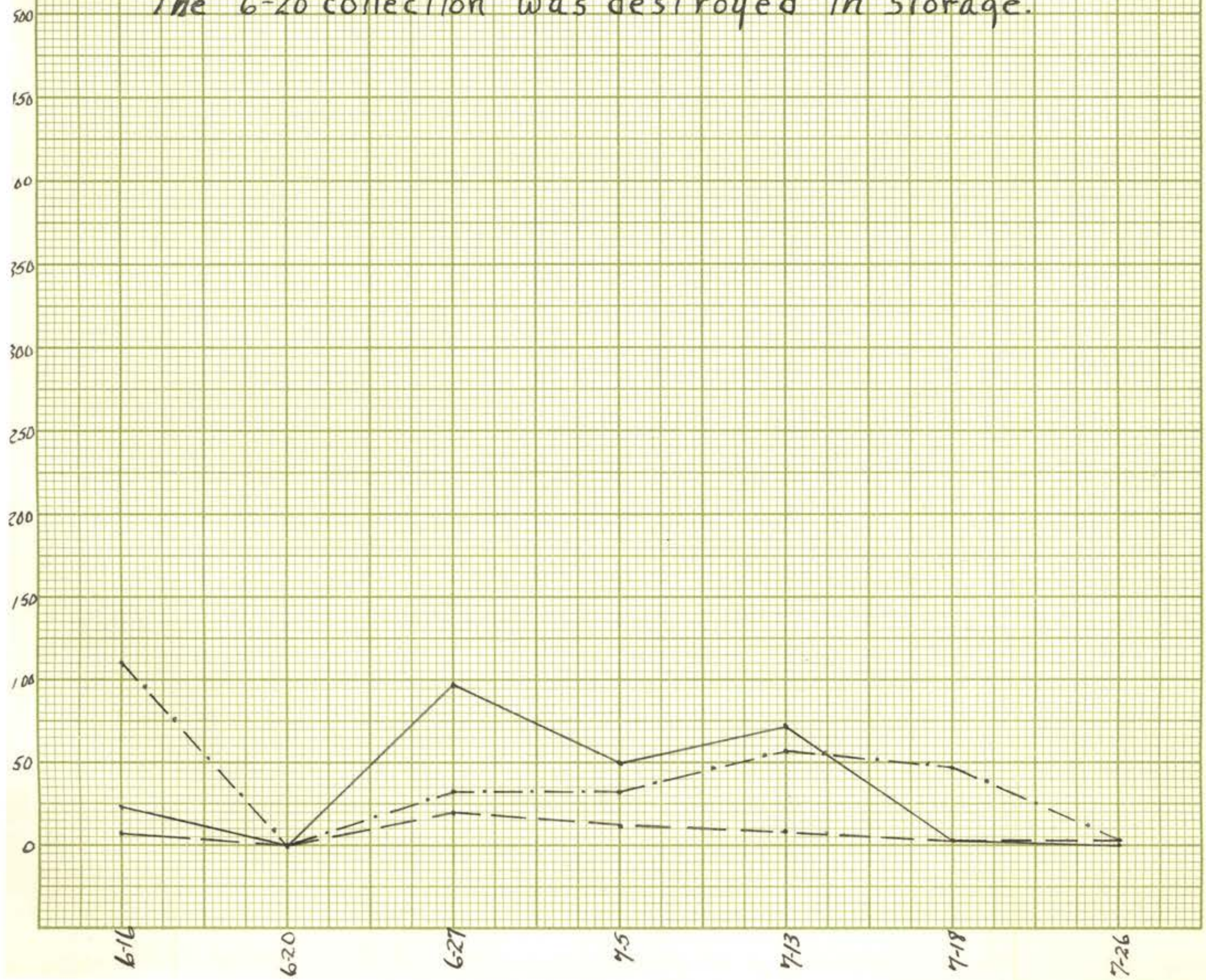
Station II 1938 Cladocera Surface
Conditions Same as Opposite Page
Diaphanosoma
Daphnia
Bosmina None
young None
Pleuroxus *
350
300
250
200
150
100
50
0
6-16
6-20
6-27
7-5
7-13
7-18
7-26

Station II. 1938. Copepoda. Deep.

Date	Secchi Disk	Temp.	pH	Wind	Light.
6-16	4 cm	20°C	6.8	slight	cloudy
6-20	4 cm	22°	6.8	"	Clear
6-27	4 cm	23°	7.2	"	"
7-5	3.5cm	26°	7.0	Moderate	Cloudy
7-13	6 cm	29°	7.2	slight	clear
7-18	6 cm	27°	7.2	"	cloudy
7-26	6 cm	25°	7.2	gale	clear

Developmental forms ———
Cyclops — — —
Diaptomus —.—.—

The 6-20 collection was destroyed in storage.

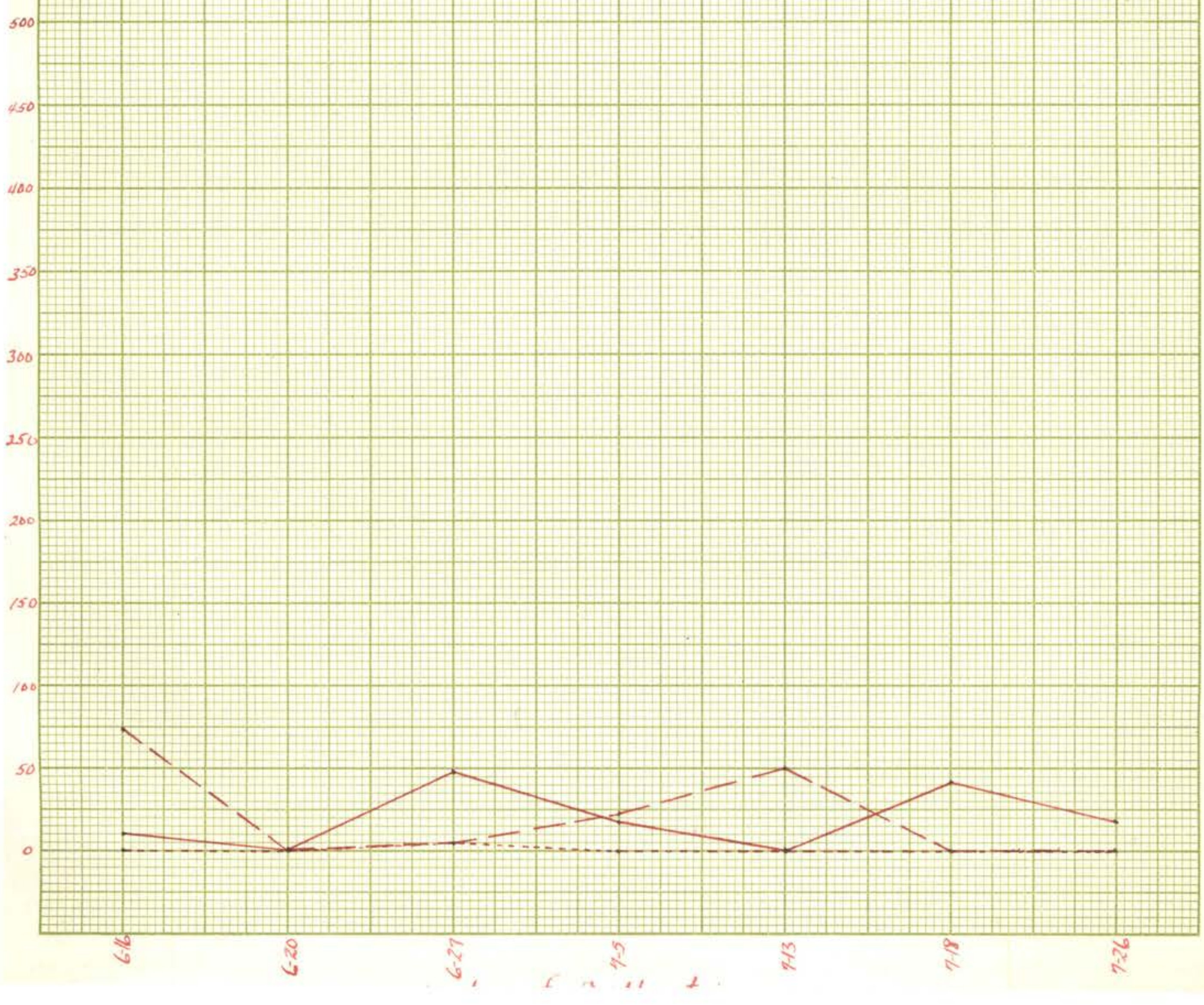


Station II 1938 Cladocera Deep

Conditions Same as Opposite Page.

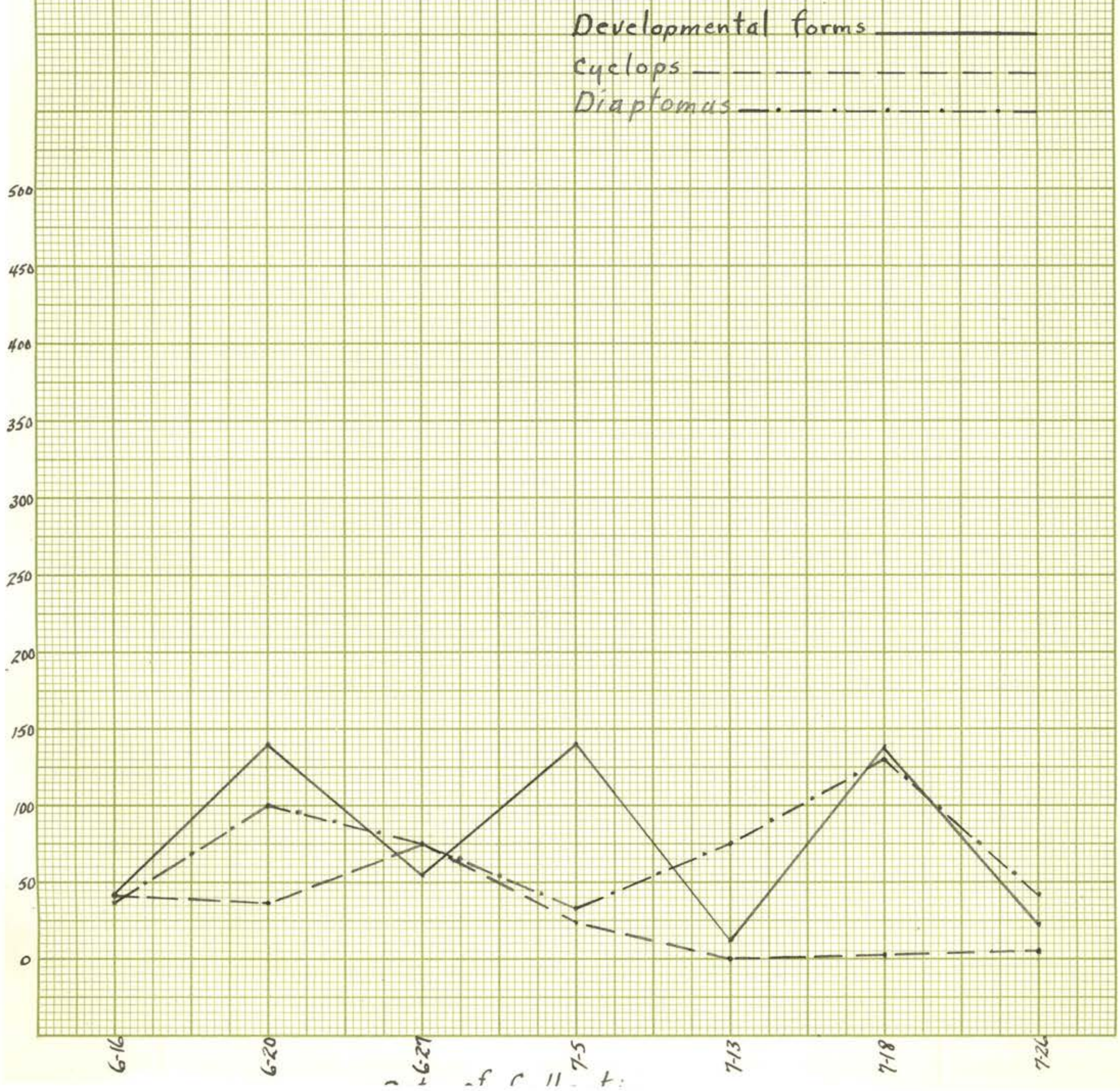
Diaphanosoma ———
Daphnia — — — — —
Bosmina — . None .
Young ....

The 6-20 Collection was Destroyed in Storage



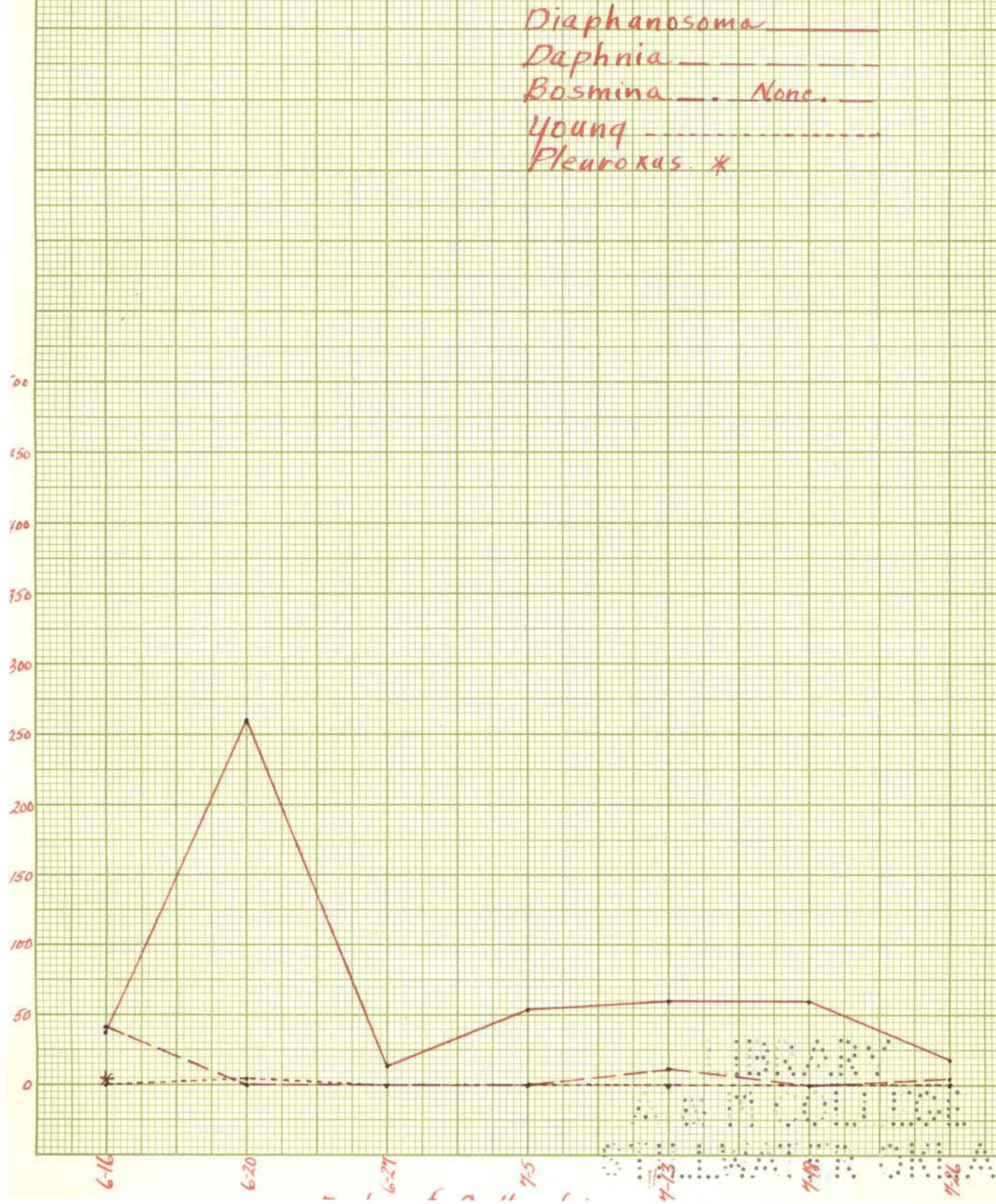
Station III. 1938. Copepoda. Surface.

Date	Secchi Disk	Temp.	pH	Wind.	Light
6-16	4 cm	26.3°c	6.6	Slight	Cloudy
6-20	4 cm	31°	6.6	"	Clear
6-27	6 cm	26°	7.3	"	"
7-5	3 cm	28.5°	7.1	Moderate	Cloudy
7-13	5.5 cm	31°	7.2	slight	clear
7-18	6 cm	32°	7.2	"	Cloudy
7-26	5 cm	30°	7.2	gale	clear



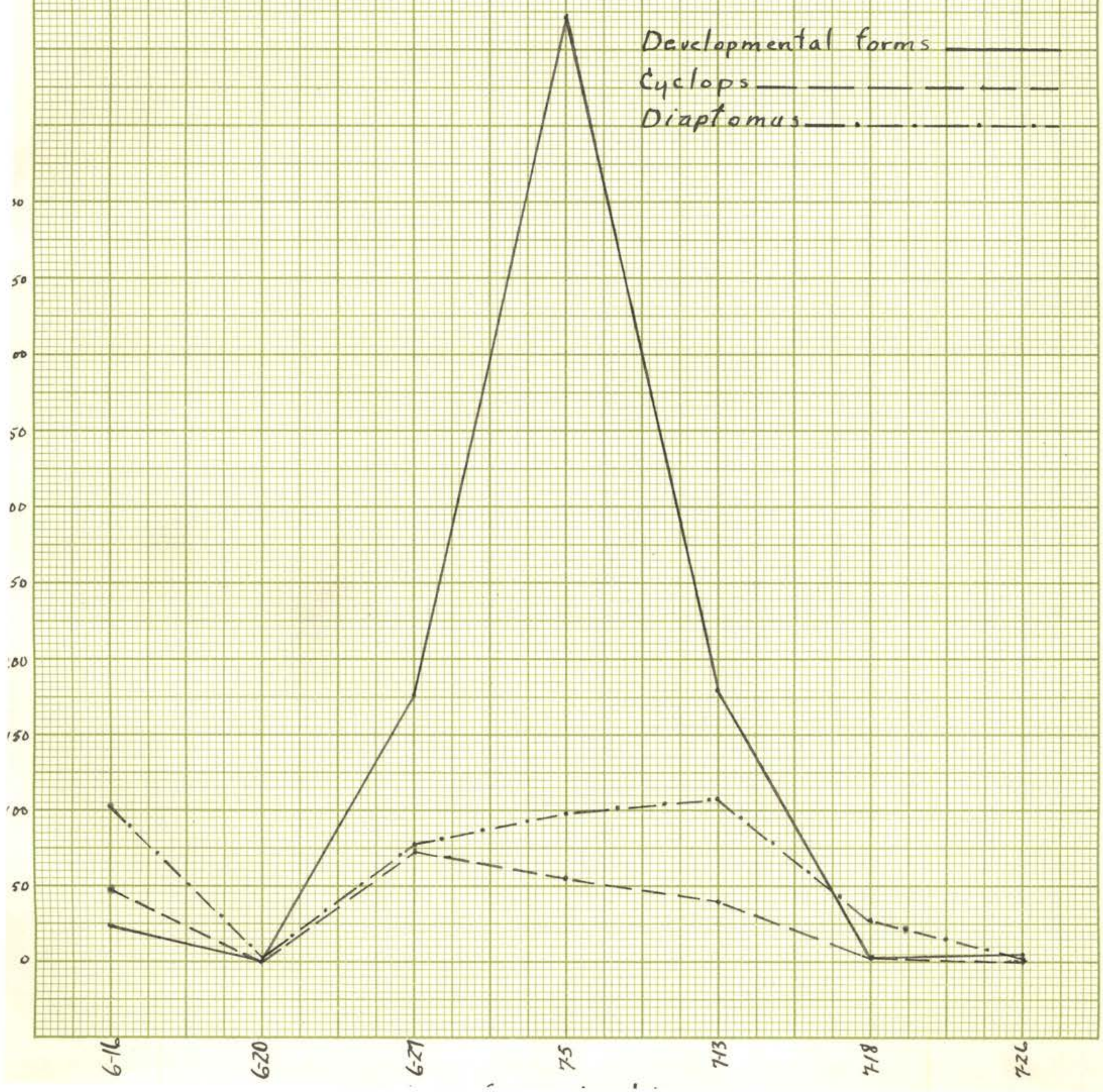
Station III 1938 Cladocera Surface

Conditions Same as Opposite Page



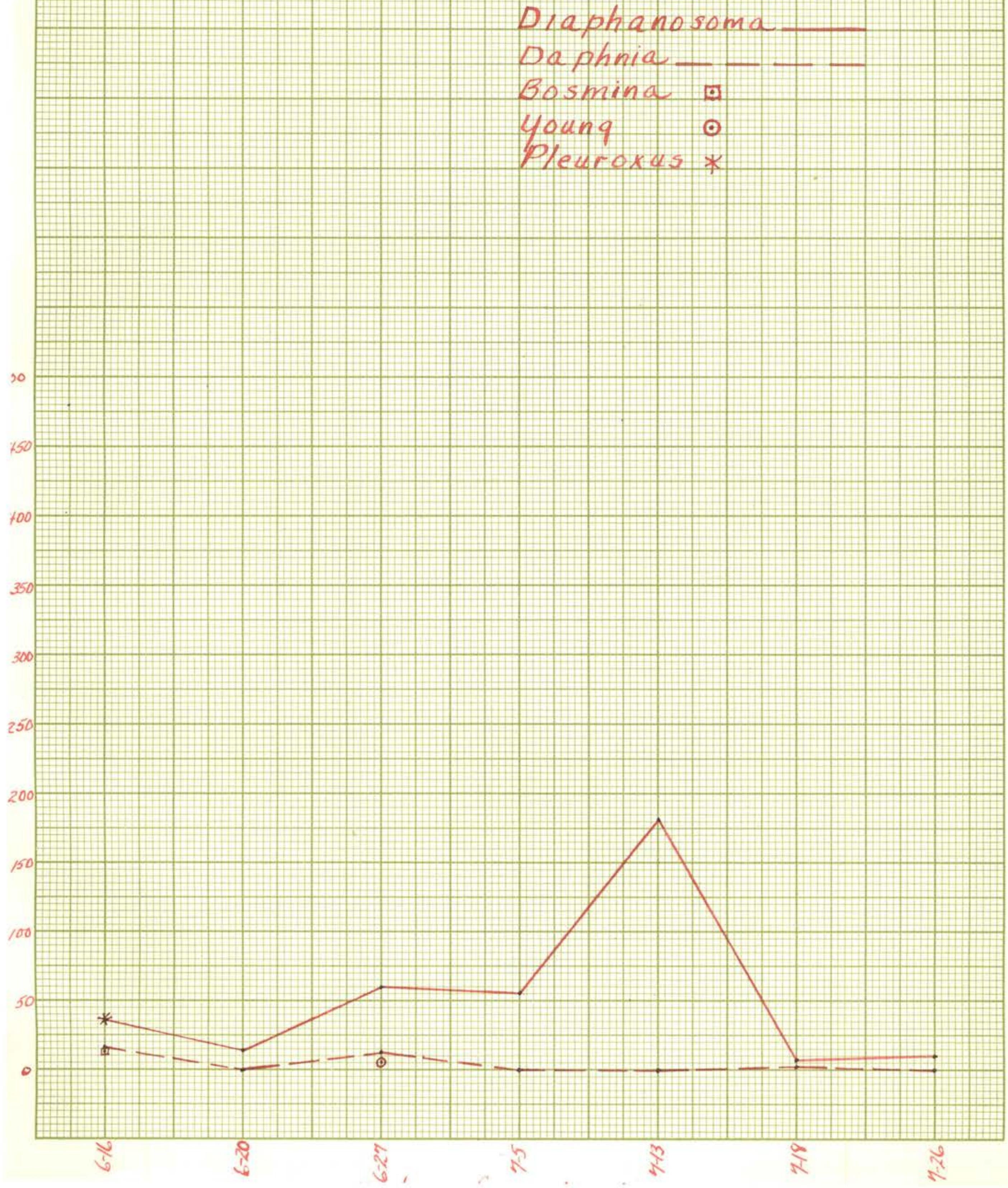
Station III. 1938. Copepoda. Deep.

Date	Secchi Disk	Temp.	pH	Wind	Light
6-16	4 cm	26°C	6.6	Slight	Cloudy
6-20	4 cm	30°	6.6	"	Clear
6-27	6 cm	25.5°	7.3	"	"
7-5	3 cm	28°	7.1	Moderate	Cloudy
7-13	5.5 cm	30°	7.2	Slight	Clear
7-18	6 cm	30°	7.2	"	Cloudy
7-26	5 cm	30°	7.2	gale	Clear



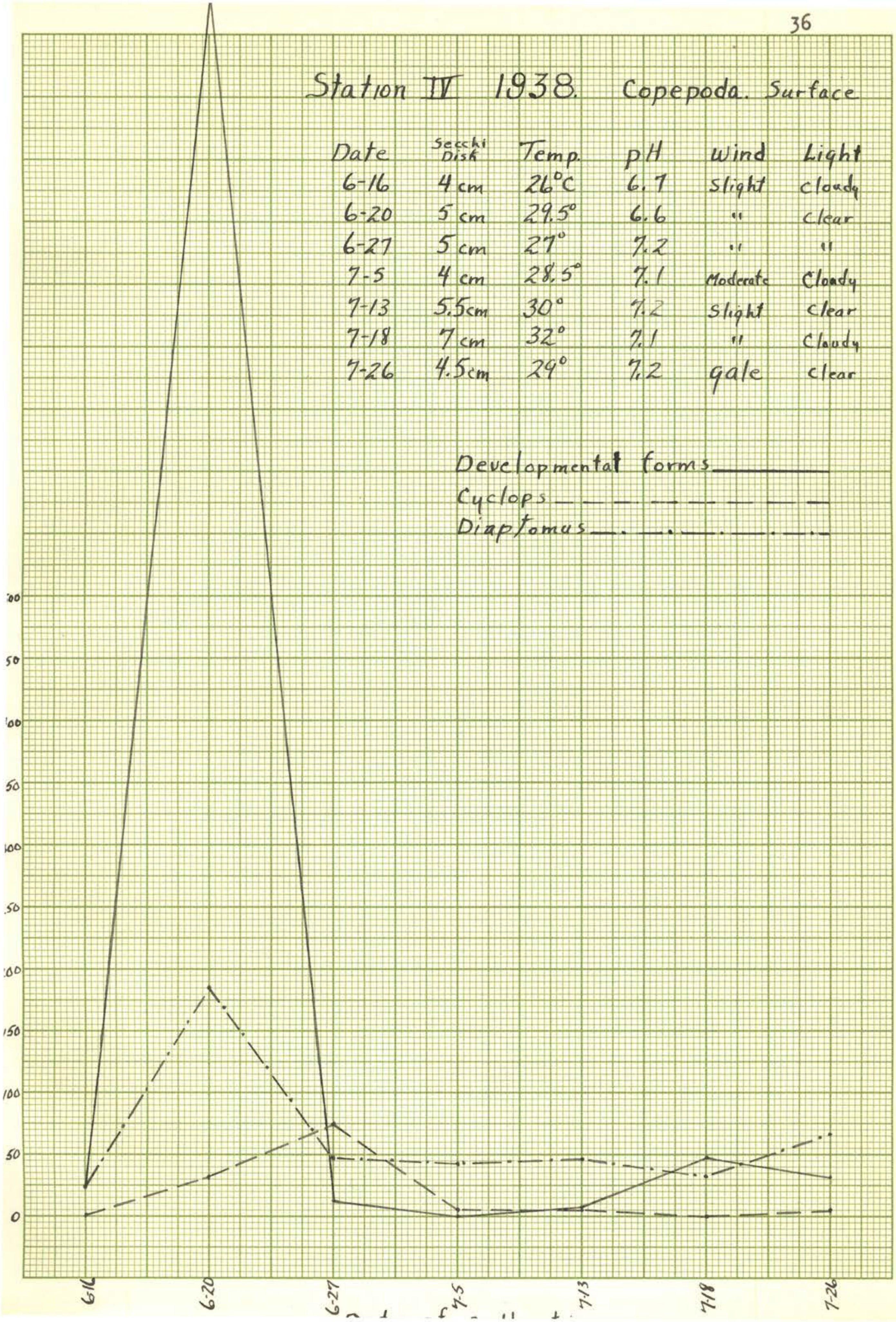
Station III 1938 Cladocera Deep

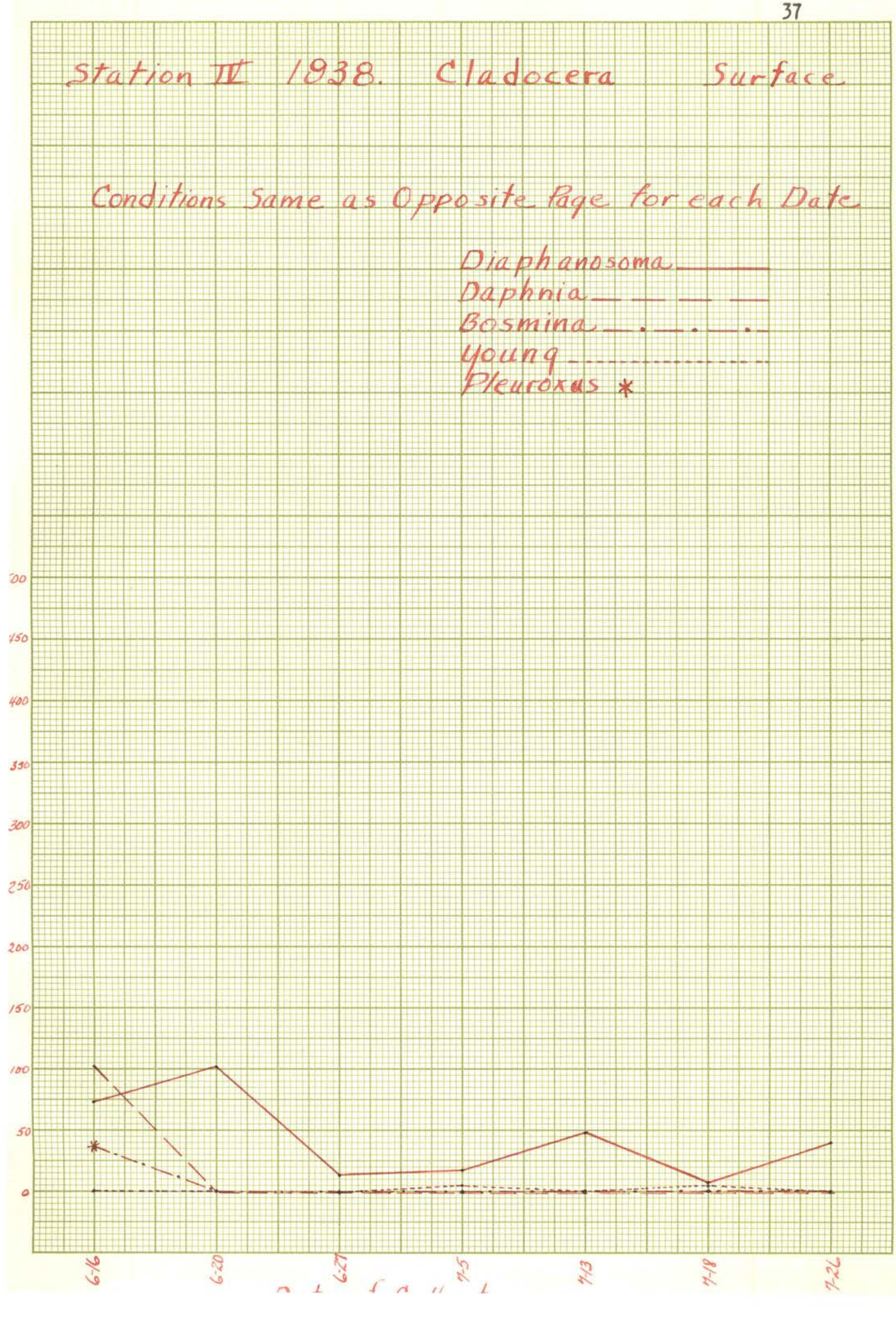
Conditions Same as Opposite Page for each Date.



Station IV 1938. Copepoda. Surface

Date	Secchi Disk	Temp.	pH	Wind	Light
6-16	4 cm	26°C	6.7	Slight	Cloudy
6-20	5 cm	29.5°	6.6	"	Clear
6-27	5 cm	27°	7.2	"	"
7-5	4 cm	28.5°	7.1	Moderate	Cloudy
7-13	5.5 cm	30°	7.2	Slight	Clear
7-18	7 cm	32°	7.1	"	Cloudy
7-26	4.5 cm	29°	7.2	gale	clear

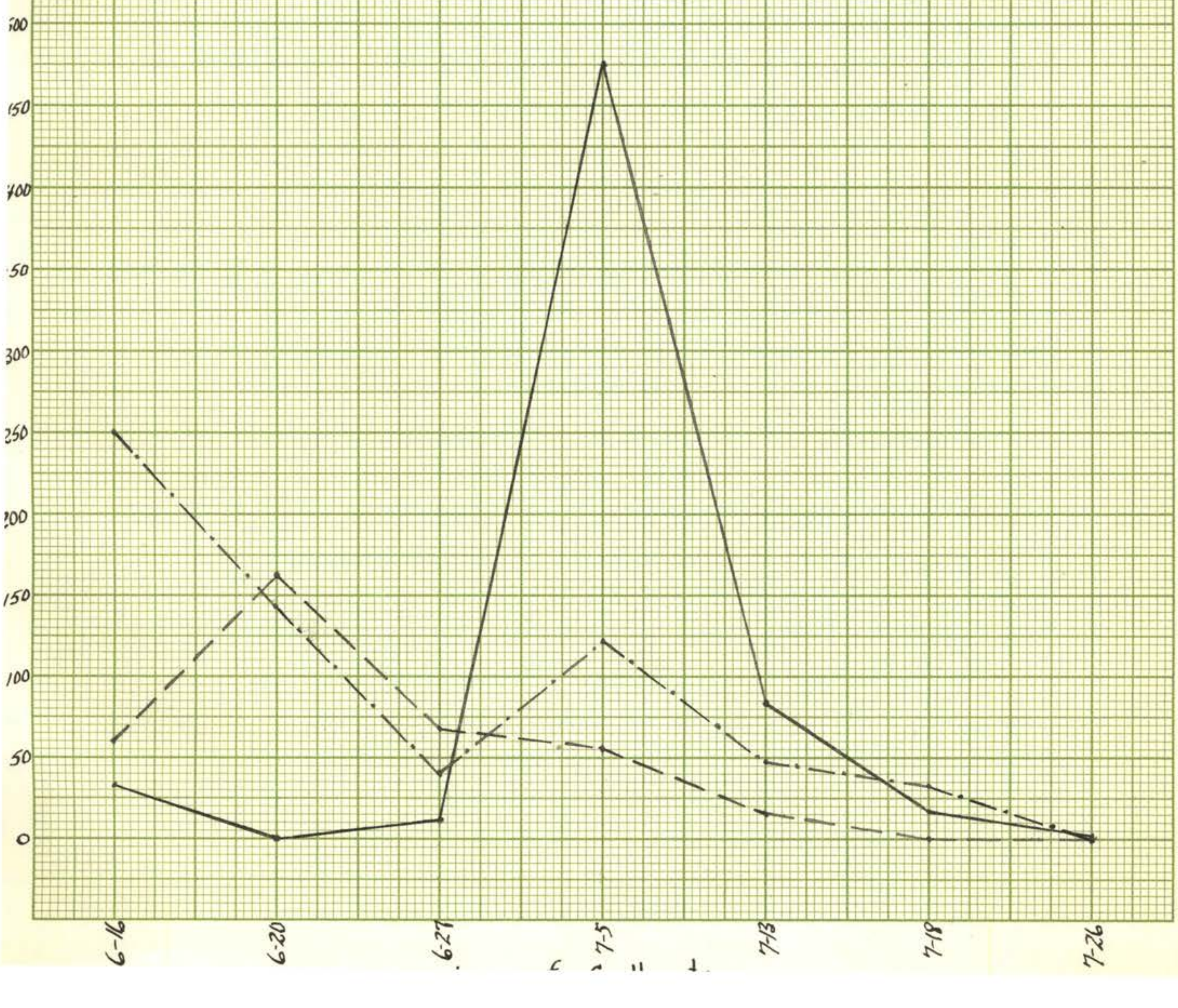



Station IV 1938. Cladocera Surface
Conditions Same as Opposite Page for each Date
Diaphanosoma
Daphnia
Bosmina
Young
Pleuroxus *
500
450
400
350
300
250
200
150
100
50
0
6-16
6-20
6-27
7-5
7-13
7-18
7-26

Station IV. 1938 Copepoda. Deep.

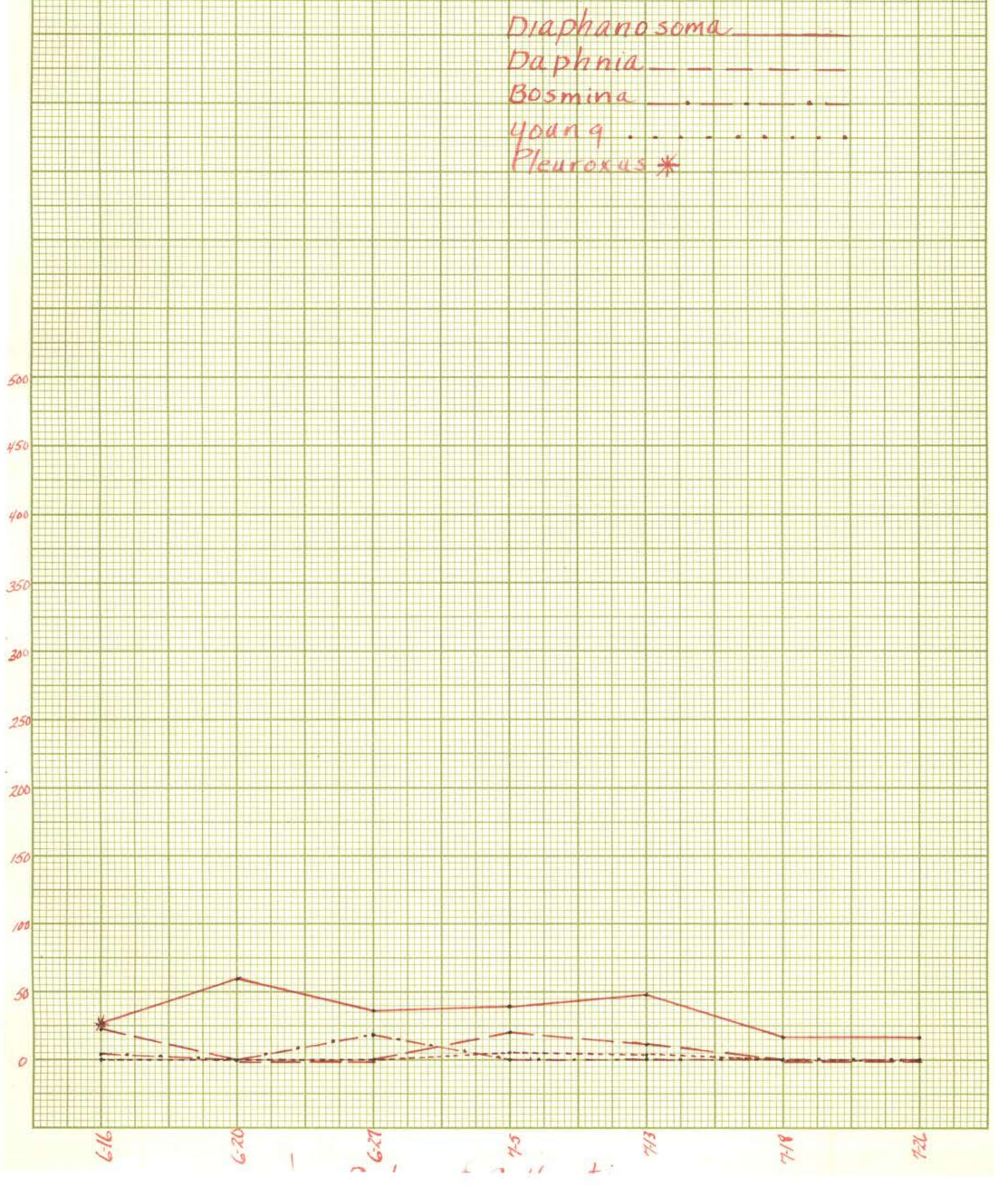
Date	Secchi Disk	Temp.	pH	Wind	Light
6-16	4 cm	24.5°c	6.7	Slight	Cloudy
6-20	5 cm	28°	6.6	"	Clear
6-27	5 cm	26.5°	7.2	"	"
7-5	4 cm	28°	7.1	"	Cloudy
7-13	5.5 cm	30°	7.2	"	Clear
7-18	7 cm	30°	7.1	"	Cloudy
7-26	4.5 cm	29°	7.2	full	Clear

Developmental forms ————
Cyclops — — — — —
Diaptomus —·—·—·—



Station IV 1938 Cladocera Deep

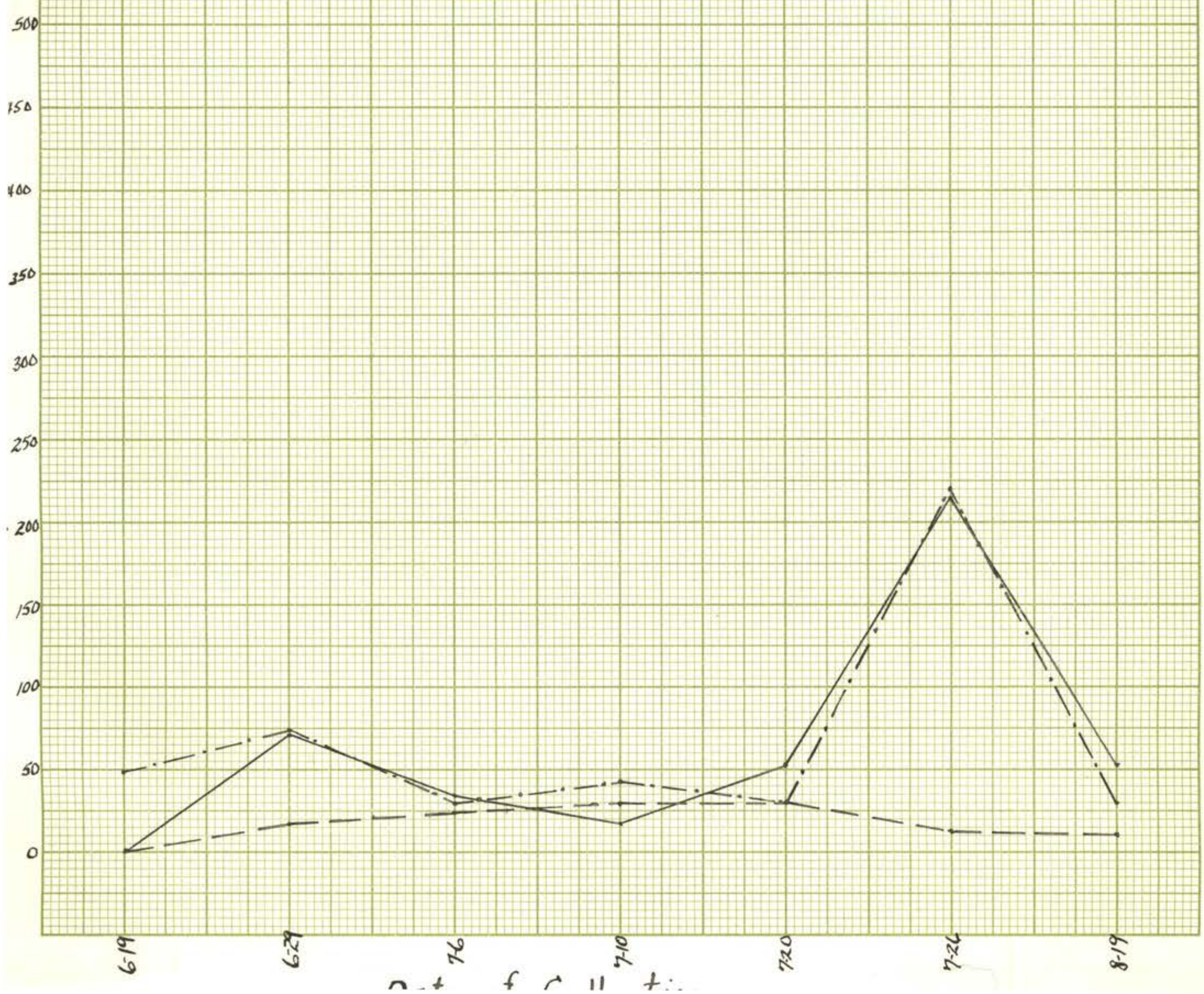
Conditions Same as Opposite Page for each Date



Station II. 1939. Copepoda. Surface.

Date	Turbidity	Temp.	pH	Wind	Light.
6-19	114 ppm.	27°c	8	gale	Cloudy
6-29	135 "	25.8°	7.4	Moderate	"
7-6	120 "	29°	7.5	gale	Clear
7-10	105 "	29.2	7.5	Moderate	"
7-20	90 "	32.4°	8	Slight	"
7-26	93 "	33.8°	7.8	"	"
8-19	77 "	26.6°	7.7	"	"

Developmental forms ————
Cyclops — — — — — —
Diaptomus —.—.—.—.—



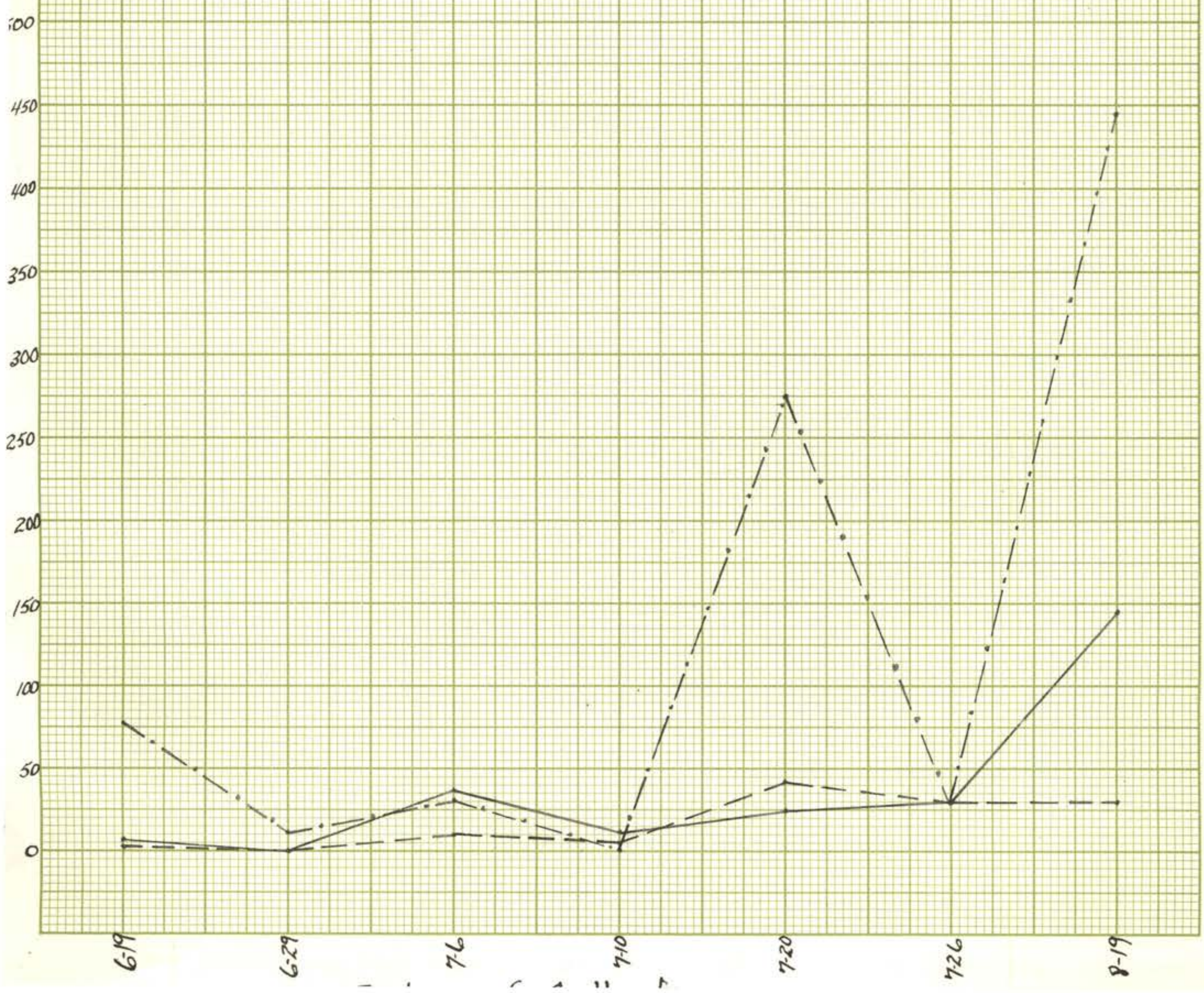
Station II 1939 Cladocera. Surface

Conditions Same as Opposite page for each Date.

Station II. 1939. Copepoda. Deep.

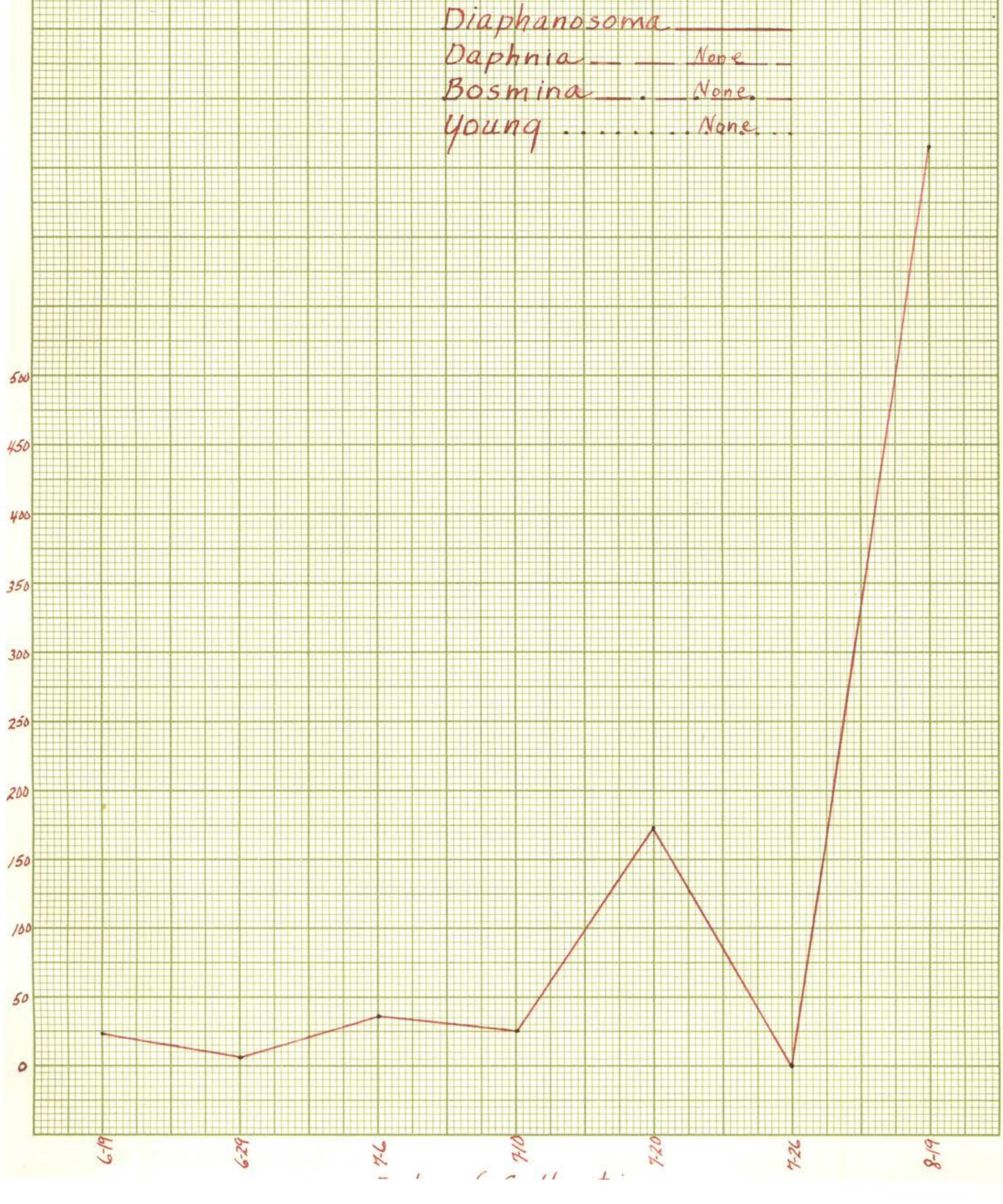
Date	Turbidity	Temp.	pH	Wind	Light.
6-19	130 ppm.	26.4°	7.8	gale	Cloudy
6-29	104 "	25.8°	7.6	Moderate	"
7-6	150 "	27.4°	7.4	gale	Clear
7-10	160 "	27.8°	7.6	Moderate	"
7-20	88 "	28.5°	8	Slight	"
7-26	88 "	28.2°	8	"	"
8-19	82 "	26.4°	7.8	"	"

Developmental forms ————
Cyclops — — — —
Diaptomus —.—.—.—



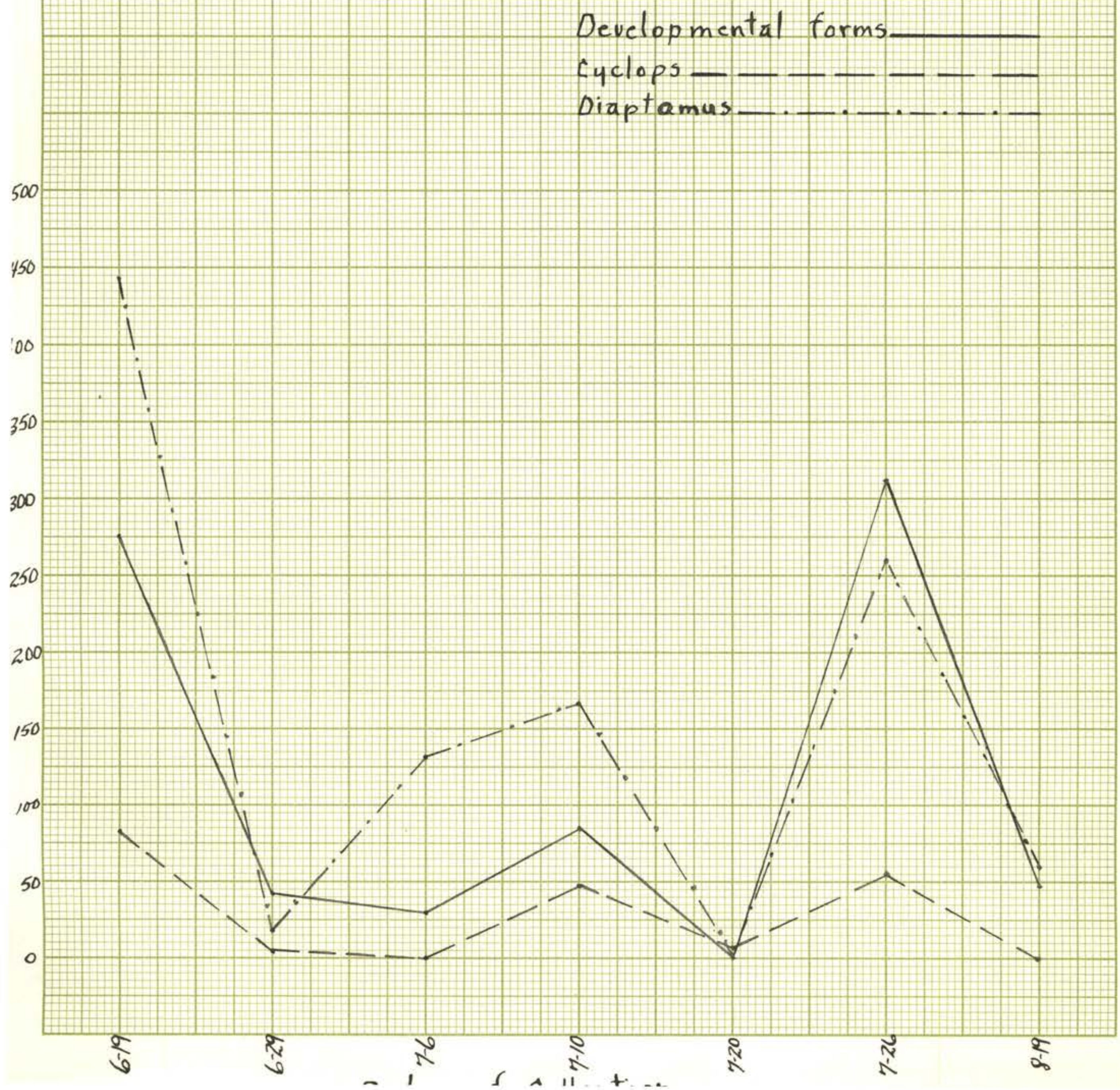
Station II 1939. Cladocera. Deep.

Conditions Same as Opposite page for each Date.



Station IIA. 1939. Copepoda. Surface.

Date	Turbidity	Temp.	pH	Wind	Light
6-19	120 p.p.m.	27°c	8	gale	Cloudy
6-29	134 "	25.4°	7.6	Moderate	"
7-6	110 "	29°	7.6	gale	Clear
7-10	102 "	29.2°	7.7	Moderate	"
7-20	75 "	32.4°	8	Slight	"
7-26	80 "	33.8°	7.8	"	"
8-19	77 "	26.6°	7.8	"	"



Station II A 1939. Cladocera. Surface

Conditions same as Opposite Page for each Date

SUMMARY

This paper is an attempt to discover crustacean plankton phenomena occurring in Boomer Lake which is located near Stillwater, Oklahoma. Data were taken during the summers of 1938 and 1939. The material is organized according to the stations collected from and twenty-two graphs depict the population phenomena.

The results show no definite relationships of plankton populations with temperature, light, turbidity, pH, or wind. [Results indicate that nauplii and metanauplii tend to congregate or develop very favorably in areas of flooded vegetation] and that wind may affect the horizontal distribution of Copepoda and Cladocera. *

The only Copepoda that were found were members of the genus *Cyclops*, *Diaptomus*, and developmental forms of these genera. The genera of Cladocera collected were *Diaphanosoma*, *Daphnia*, *Bosmina*, and *Pleuroxus*. *

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